IN THE UNITED STATES DISTRICT COURT
FOR THE EASTERN DISTRICT OF TEXAS
MARSHALL DIVISION

CYWEE GROUP LTD., Plaintiff v. SAMSUNG ELECTRONICS CO., LTD. AND SAMSUNG ELECTRONICS AMERICA, INC., Defendants.	§ § § § § § § § § § §	NO. 2:17-CV-00140-WCB-RSP

EXPERT REPORT OF DR. M. RAY MERCER REGARDING INVALIDITY

TABLE OF CONTENTS

I. INTRODUCTION 1

II. BACKGROUND AND QUALIFICATIONS 1

III. RETENTION AND COMPENSATION 6

IV. SUMMARY OF MY OPINIONS 6

V. MATERIALS CONSIDERED 7

VI. LEGAL STANDARDS 7

A. Anticipation 8
B. Obviousness 8
C. Written Description 9
D. Enablement 9
E. Priority Date 10

VII. LEVEL OF ORDINARY SKILL IN THE ART 10

VIII. CLAIM CONSTRUCTION 11

IX. THE PATENTS-IN-SUIT 12

A. U.S. Patent No. 8,441,438 12
1. Summary 12
2. The ’438 Patent File History 15
3. The Asserted Claims 18
B. U.S. Patent No. 8,552,978 21
1. Summary 21
2. The ’978 Patent File History 23
3. The Asserted Claims 24

X. CYWEE’S CLAIMED PRIORITY DATE OF THE ’438 PATENT 25

A. The ’438 Patent is not entitled to a priority date of January 6, 2010 based on Provisional Application No. 61/292,558 25
1. “a predicted measurement obtained based on the first signal set without using any derivatives of the first signal set” (Claim 1)/“calculating predicted axial accelerations Ax′, Ay′, Az′ based on the measured angular velocities ω_x, ω_y, ω_z of the current state of the six-axis motion sensor module without using any derivatives of the measured angular velocities ω_x, ω_y, ω_z” (Claims 14 and 19) 26
2. “quaternions” (Claims 14, 16, and 19) 28

3. "utilizing a comparison to compare the first signal set with the second signal set" (Claim 1)/"comparing the second quaternion in relation to the measured angular velocities ω_x, ω_y, ω_z of the current state at current time T with the measured axial accelerations Ax, Ay, Az and the predicted axial accelerations Ax′, Ay′, Az′ also at current time T" (Claims 14 and 19) 29
4. "obtaining an updated state of the six-axis motion sensor module by comparing the current state with the measured state of the six-axis motion sensor module" (Claims 14 and 19) 31
B. The '978 Patent is not entitled to a priority date of January 6, 2010 based on Provisional Application No. 61/292,558 33
1. "generating the orientation output based on the first signal set, the second signal set and the rotation output or based on the first signal set and the second signal set" (Claim 10) 34
2. "using the orientation output and the rotation output to generate a transformed output associated with a fixed reference frame associated with a display device" (Claim 12) 36
3. "obtaining one or more resultant deviation including a plurality of deviation angles using a plurality of measured magnetisms Mx, My, Mz and a plurality of predicted magnetism Mx′, My′ and Mz′ for the second signal set" (Claim 10) 38
4. "quaternions" (Claim 12) 39
C. The '978 Patent is not entitled to a priority date of November 11, 2010 based on Continuation-in-Part Application No. 12/943,934 40
1. "generating the orientation output based on the first signal set, the second signal set and the rotation output or based on the first signal set and the second signal set" ('978 Patent, Claim 10) 40
2. "using the orientation output and the rotation output to generate a transformed output associated with a fixed reference frame associated with a display device, wherein the orientation output and the rotation output is generated by a nine-axis motion sensor module" ('978 Patent Claim 10) 41
3. "obtaining one or more resultant deviation including a plurality of deviation angles using a plurality of measured magnetisms Mx, My, Mz and a plurality of predicted magnetism Mx′, My′ and Mz′ for the second signal set" ('978 Patent, Claim 10) 42
D. The '978 Patent is not entitled to a priority date of March 28, 2011 based on Continuation-in-Part Application No. 13/072,794 42
1. "generating the orientation output based on the first signal set, the second signal set and the rotation output or based on the first signal set and the second signal set" ('978 Patent, Claim 10) 43
2. "using the orientation output and the rotation output to generate a transformed output associated with a fixed reference frame associated with a display device, wherein the orientation output and the rotation output is generated by a nine-axis motion sensor module" ('978 Patent Claim 10) 45

3. "obtaining one or more resultant deviation including a plurality of deviation angles using a plurality of measured magnetisms Mx, My, Mz and a plurality of predicted magnetism Mx′, My′ and Mz′ for the second signal set" ('978 Patent, Claim 10) 46

XI. TECHNOLOGY OVERVIEW 48

A. Basics of Movement 48
B. Measuring Movement: Velocity and Acceleration 48
C. Rigid and Non-Rigid Bodies/Simple and Complex Motions 50
D. Orientation/Reference Frames 51
E. Representing Orientation 52
F. Sensors 53
G. Sensor Fusion 54

XII. SUMMARY OF PRIOR ART REFERENCES 55

A. "An Attitude Compensation Technique for a MEMS Motion Sensor Based Digital Writing Instrument" by Luo, et al. 55
B. "Development of a MEMS-based Wearable Motion Capture System" by Abbate, et al. 56
C. U.S. Patent Pub. No. 2005/0240347 to Yang, et al. 58
D. CH Robotics CHR-6dm System 60
E. U.S. Patent No. 8,515,707 to Joseph 63

XIII. THE ASSERTED CLAIMS OF THE '438 PATENT ARE RENDERED OBVIOUS BY THE PRIOR ART 64

A. *Luo* in view of *Abbate* render obvious Claims 1, 3, 4, 5, 14, 15, 16, 17, and 19 of the '438 Patent 64
1. Claim 1 64
2. Claim 3 77
3. Claim 4 78
4. Claim 5 79
5. Claim 14 80
6. Claim 15 93
7. Claim 16 95
8. Claim 17 96
9. Claim 19 96

B. *Luo* in view of *Yang* render obvious Claims 1, 3, 4, 5, 14, 15, 16, 17, and 19 of the '438 Patent 96
1. Claim 1 96
2. Claim 3 104
3. Claim 4 104
4. Claim 5 105
5. Claim 14 105
6. Claim 15 117
7. Claim 16 120
8. Claim 17 120

9. Claim 19 120
C. The CHR-6dm in view of *Abbate* renders obvious Claims 1, 3, 4, 5, 14, 15, 16, 17, and 19 of the '438 Patent 121
1. Claim 1 121
2. Claim 3 135
3. Claim 4 136
4. Claim 5 137
5. Claim 14 137
6. Claim 15 157
7. Claim 16 160
8. Claim 17 161
9. Claim 19 161
D. The CHR-6dm n view of *Yang* renders obvious Claims 1, 3, 4, 5, 14, 15, 16, 17, and 19 of the '438 Patent 161
1. Claim 1 161
2. Claim 3 172
3. Claim 4 172
4. Claim 5 172
5. Claim 14 173
6. Claim 15 193
7. Claim 16 196
8. Claim 17 197
9. Claim 19 197

XIV. THE ASSERTED CLAIMS OF THE '978 PATENT ARE RENDERED OBVIOUS BY THE PRIOR ART 197

A. *Joseph* in view of *Abbate* and *Yang* renders obvious Claims 10 and 12 of the '978 Patent 197
1. Claim 10 197
2. Claim 12 212
B. The CHR-6dm in view of *Abbate* and *Yang* renders obvious Claims 10 and 12 of the '978 Patent 212
1. Claim 10 212
2. Claim 12 228

XV. INVALIDITY UNDER 35 U.S.C. §112 229

A. The '438 Patent 229
1. "3D pointing device" where the display is incorporated into the device ('438 Patent, Claims 1, 3, 4, 5, 14, 15, 16, 17, 19) 229
2. "utilizing a comparison to compare the first signal set with the second signal set" ('438 Patent, Claim 1) 231
3. "comparing the second quaternion in relation to the measured angular velocities ω_x, ω_y, ω_z of the current state at current time T with the measured axial accelerations Ax, Ay, Az and the predicted axial accelerations Ax′, Ay′, Az′ also at current time T" 238

4. "obtaining an updated state of the six-axis motion sensor module by comparing the current state with the measured state of the six axis motion sensor module" ('438 Patent, Claims 14 and 19)..... 239
5. "a predicted measurement obtained based on the first signal set without using any derivatives of the first signal set" ('438 Patent, Claim 1) 241
6. "calculating predicted axial accelerations Ax′, Ay′, Az′ based on the measured angular velocities ω_x, ω_y, ω_z of the current state of the six-axis motion sensor module without using any derivatives of the measured angular velocities ω_x, ω_y, ω_z" ('438 Patent, Claims 14 and 19) 245

B. The '978 Patent 246
1. "3D pointing device" where the display is incorporated into the device ('978 Patent, Claim 10) 246
2. "generating the orientation output based on the first signal set, the second signal set and the rotation output or based on the first signal set and the second signal set" ('978 Patent, Claim 10)..... 246
3. "obtaining one or more resultant deviation including a plurality of deviation angles using a plurality of measured magnetisms Mx, My, Mz and a plurality of predicted magnetism Mx′, My′ and Mz′ for the second signal set" ('978 Patent, Claim 10) 251

XVI. SECONDARY CONSIDERATIONS 254

XVII. SIGNATURE..... 255

I. INTRODUCTION

1. My name is Dr. M. Ray Mercer. I have been retained by Paul Hastings LLP, counsel to Defendants Samsung Electronics Co., Ltd. ("SEC") and Samsung Electronics America, Inc. ("SEA") (collectively, "Samsung" and/or "Defendants"), as an independent expert witness in this litigation initiated by Plaintiff CyWee Group Ltd. ("Plaintiff" or "CyWee").

2. This report provides my opinions regarding the invalidity of the asserted patent claims of U.S. Patent Nos. 8,441,438 ("'438 Patent") and 8,552,978 ("'978 Patent") (collectively, "patents-in-suit").

3. I reserve the right, within the Court's guidelines, to supplement or amend my opinions, as well as the basis for my opinions, if additional data or information that affects my opinions becomes available, including any evidence that CyWee or its experts may present.

4. I expect to testify at trial regarding the matters expressed in this report and any supplemental reports or declarations that I may prepare for this litigation. I also expect to testify at trial with respect to any matters addressed by any expert testifying on behalf of CyWee, if asked.

II. BACKGROUND AND QUALIFICATIONS

5. I have summarized in this section my educational background, career details, and other relevant qualifications. Additional details appear in my curriculum vitae, attached as Exhibit A to this declaration.

6. I have more than forty-seven years of dual industrial and academic experience in Electrical Engineering and Computer Engineering. I received a B.S. in Electrical Engineering from Texas Tech University in 1968, a Master of Science in Electrical Engineering from Stanford University in 1971, and a Doctor of Philosophy in Electrical Engineering from The University of Texas at Austin in 1980. Further, I have authored dozens of published technical

papers and delivered many lectures addressing various aspects of Electrical and Computer Engineering.

7. From 1968 to 1973, I was a Research/Development Engineer at General Telephone and Electronics Sylvania in Mountain View, California. I completed my M.S. in Electrical Engineering from Stanford University in 1971. At Stanford, I worked on techniques that were unique in that they involved adaptive linear optimizations for monitoring non-stationary signals. This work involved the application of filtering and estimation techniques using data gathered from sensors. For example, I worked on a project involving in vitro detection of signals generated by a fetal heartbeat in the presence of multiple noise sources from the pregnant mother. During this period, much of my work related to communications, computer control of data collection, and analysis systems used by organizations in the United States government. Leading-edge sensing techniques were a key aspect of much of this work.

8. From 1973 to 1977, I was a Member of Technical Staff at Hewlett-Packard's Santa Clara Division and subsequently at Hewlett-Packard Laboratories in Palo Alto, California. During that time, I continued to develop application programs. I also designed interface hardware to interact with computer software and accomplish various tasks. One major project I was responsible for was the real-time control of environmental test systems for satellites and satellite components. Applications for these analysis and control tools required filtering of noise components to isolate data collected by sensors from noise inherent in the system using a previously unknown set of filtering techniques designed and implemented by my team and utilized Fourier Transforms for tasks best performed in the frequency domain. For example, these tools allowed automated analysis of communication systems. Key concepts in this work are related to this case because they involved digital data communications, motion control, motion

analysis, and data collection based upon sensors including accelerometers. During this period, I also used variations of these tools to monitor and analyze motions of rigid and semi-rigid objects—particularly with respect to vibration mode analysis. The same tools also found application in the automated diagnosis of communication systems such as telephone systems.

9. At HP Laboratories, among other projects, I developed hardware and software to provide real-time control of manufacturing systems for solid state devices. This work related directly to the issues in this case because the tools I developed involved sensor systems and control systems for displacement, rotation, temperature control, etc. I also did some of the earliest research on the dominant sources for the degradation of liquid crystal displays.

10. From 1977 to 1980, I was a Lecturer in the Division of Mathematics, Statistics, and Computer Science at the University of Texas at San Antonio. As the director of a laboratory for teaching students to program and build hardware interfaces and control systems using small computers, my students and I purchased, built, and operated some of the earliest personal computers. Additionally, I taught courses in the design of digital systems. During this period, I also completed my Ph.D. in Electrical Engineering at the University of Texas at Austin in 1980. I also did my first consulting work at this time involving the control, sensing, and evaluation of human motion control capabilities under adverse environmental conditions.

11. From 1980 to 1983, I was a Member of Technical Staff at Bell Laboratories in Murray Hill, New Jersey. My work involved the programming of computers and the design of hardware components for communication systems. I was part of a three-person team that designed, tested, and directed the manufacture of an integrated circuit that was a key component in a digital telephone modem. I also actively worked with designers of large scale digital telephone switching systems. This work relates generally to the topics in this case because

modems obviously sense and produce sound. The manufacture testing of this product involved extensive investigation of the external sensing aspects of this product and associated conclusions about aspects of the device that were only indirectly determinable.

12. In 1983, I was appointed Assistant Professor of Electrical and Computer Engineering at the University of Texas at Austin. In 1987, I was promoted to Associate Professor. In 1991, I was promoted to Professor. During this period, I taught Computer Engineering courses at the undergraduate and graduate level, directed the research of graduate students, and consulted with numerous organizations. One consulting project I did at this time involved the study of early printed circuit board surface mount techniques where component placement was automated using pick-and-robotic systems. As part of this work I interfaced with more than a dozen of the largest printed circuit manufacturers in the United States at that time. Aspects of this work relate to issues in this case since the manufacturing systems made extensive use of sensors and controllers.

13. In 1995, I was appointed Professor of Electrical and Computer Engineering, Leader of the Computer Engineering Group, and Holder of the Computer Engineering Chair in Electrical Engineering at Texas A&M University in College Station, Texas. My teaching, my research, my technical publications, and my supervision of graduate students during that period included the areas of the modeling, design, and fabrication of digital hardware and software systems. As with my previous work (at The University of Texas at Austin), during this period, I taught courses at the undergraduate and graduate level, directed the research of graduate students, and consulted with numerous organizations on a variety of topics. I was also responsible for monitoring controlled experiments to optimize and quantify the use of tester time to detect defects in electrical products, and I was part of a team that used analytical techniques to

predict the expected growth of quiescent currents in MOS transistors as a function of the reduction in integrated circuit feature sizes.

14. In September 2005, I retired from my teaching position, and the Regents of the Texas A&M University System appointed me as Professor Emeritus of Electrical and Computer Engineering at Texas A&M University.

15. In 1984, I formed Mercer and Associates, an independent consulting firm that I have owned and directed to this day. Since 1979, I have provided private consultation and advice in Electrical and Computer Engineering to numerous entities, including IBM Corp., Rockwell International, Motorola Semiconductor, AT&T, Inc., and SigmaTel.

16. I first served as an expert witness at the request of the Office of the State Attorney General of Texas in 1984. Since then, I have been hired by numerous law firms to provide them and their clients with expert consultation and expert testimony, often in the areas of patent infringement litigation related to electrical and computer engineering. Among other topics, I have opined with respect to communications systems including telephony, cell phone networks and devices, and particular characteristics of private and public network communications networks, including the Internet. I have testified regarding standalone and Internet-based online gaming systems. I have testified regarding home entertainment systems that use wireless communications. I have testified with respect to online educational institutions and technical aspects of their media distribution systems. I have testified with respect to media and entertainment systems for mobile vehicles as well as special aspects of display equipment similar to the equipment at issue in the current case. I have testified in a case involving delta-sigma modulation for high performance analog-to-digital and digital-to-analog converters—such as those commonly utilized in personal computers. Many of the technical issues and topics in this

work relate directly to the key technical issues in this current case.

17. Throughout my career, I have been actively involved in numerous professional organizations, including the Institute of Electrical and Electronics Engineers ("IEEE") and was recognized as an IEEE Fellow in 1994. I was the Program Chairman for the 1989 International Test Conference, which is an IEEE sponsored annual conference with (at that time) more than one thousand attendees and over one hundred presented papers. I won the Best Paper Award at the 1982 International Test Conference.

18. I also won a Best Paper Award at the 1991 Design Automation Conference, an annual conference with (at that time) more than ten thousand attendees and five hundred submitted papers, many of which related to the design of integrated circuit-based systems.

19. I also won a Best Paper Award at the 1999 VLSI Test Symposium. This paper was focused on manufacturing techniques to optimize the quality of manufactured digital systems. I am the inventor of two United States patents that relate to the design of integrated circuits and digital systems. I was selected as a National Science Foundation Presidential Young Investigator in 1986. This award included $500,000 for support of my research.

III. RETENTION AND COMPENSATION

20. I am being compensated at my normal consulting rate of $650 per hour. I am being separately reimbursed for any out-of-pocket expenses. My compensation does not depend in any way on the outcome of this case, my particular testimony, or the opinions that I express.

IV. SUMMARY OF MY OPINIONS

21. Based on my investigation and analysis in connection with this matter, I have reached the conclusion that, in my opinion, the prior art renders obvious the asserted claims of the patents-in-suit. I have also reached the conclusion that the asserted claims are invalid for inadequate written description and/or lack of enablement. The bases for my conclusions are

provided in the remainder of this report.

V. MATERIALS CONSIDERED

22. In rendering my opinions, I considered the items listed in Exhibit B and the items discussed or listed herein. I have also relied on my professional and educational experiences in the field.

23. I have also attached as Exhibit C the asserted claims and a table of the asserted claims as well as any constructions as agreed to by the parties or provided by the Court. Each element of each claim is numbered, and I will refer to these elements by those numbers in this report.

VI. LEGAL STANDARDS

24. I am not an attorney. However, the law of invalidity has been explained to me, and my understanding is as follows.

25. I have been advised that the claims of issued U.S. patents are presumed to be valid, and invalidity of a particular patent claim must be proven by clear and convincing evidence, which is a higher burden than proof by preponderance of the evidence.

26. I have been advised that a patent validity analysis can involve comparing the prior art to each patent claim. This analysis involves determining the meaning of the terms recited in the patent claims.

27. I have been advised that claims of the patents-in-suit have been construed in this case. For purposes of forming my opinions in this report, I evaluated and applied the construction for the disputed terms, as shown in Judge Payne's Claim Construction Opinion and Judge Bryson's Order, and the agreed constructions set forth in the Parties' Joint Claim Construction Chart. *See* Section VIII. Overall, I evaluated and applied the plain and ordinary meaning of each claim term as it would be understood by one of ordinary skill in the art at the

time of the alleged invention.

A. Anticipation

28. I have been advised that a patent claim is invalid as anticipated only if a single prior art reference describes every element of the claimed invention, either expressly or inherently.

29. I have been advised that express disclosure means that the subject matter is clearly described in the prior art reference.

30. I have been advised that for a claimed element to be inherently within a prior art document, it must be necessarily present. That is, the prior art must necessarily function in accordance with or include the claimed element. I further understand that, to establish inherency, the extrinsic evidence must make clear that the missing descriptive matter is necessarily present in the thing described in the reference, and that it would be so recognized by persons of ordinary skill. Inherency, however, may not be established by probabilities or possibilities. The mere fact that a certain thing may result from a given set of circumstances is not sufficient.

B. Obviousness

31. I have been advised that a patent claim may be found to be obvious when the differences between the claim and the prior art reference or references would have been obvious at the time the invention to a person having ordinary skill in the art to which the patent pertains.

32. I have been further advised that a determination of obviousness requires inquiries into: (i) the scope and contents of the art when the invention was made; (ii) the differences between the art and the claims at issue; (iii) the level of ordinary skill in the pertinent art when the invention was made; and, to the extent they exist; (iv) secondary indicia of obviousness.

33. I have been advised that for objective evidence of secondary considerations to be considered, its proponent should establish a nexus between the evidence and the merits of the

claimed invention.

34. I have been advised that when comparing the claims with the prior art to show obviousness, it is generally necessary to combine the teachings of multiple prior art references to show all claimed features. However, obviousness is not proven simply by showing that all of the claimed elements are present in the combination. One must also show that a person of ordinary skill in the relevant field had a reason, suggestion, or motivation to combine the elements in the manner claimed. In addition to showing a reason, suggestion, or motivation for combination, one must also show that there is a reasonable expectation of success when creating the proposed combination. One must also consider any teaching in the prior art references that the proposed combination should not be made.

35. I have been advised that in a patent obviousness analysis, a fact finder must be aware of the distortion caused by hindsight bias. Thus, a conclusion of obviousness must be firmly based on knowledge and skill of a person of ordinary skill in the art at the time the invention was made without the use of post-filing knowledge.

C. Written Description

36. I have been advised that a claim is invalid if it lacks sufficient written description. I have been advised that to satisfy the written description requirement, the patent specification must describe the claimed subject matter in sufficient detail that one skilled in the art at the time of filing can reasonably conclude that the inventor had possession of the claimed invention

D. Enablement

37. I have been advised that a claim is invalid if it is not enabled. Any analysis of whether a particular claim is enabled by the disclosure in the patent specification requires a determination of whether that disclosure, when filed, contained sufficient information regarding the subject matter of the claims as to enable one skilled in the pertinent art at the time of filing to

make and use the claimed invention without undue experimentation.

38. I have been advised that a patented claim that is found to be impossible or inoperable fails to satisfy the enablement requirement.

E. Priority Date

39. I have been advised that a claim in a United States Patent can be entitled to a priority date of an earlier filed application, but only if the claims in the later filed application are described and enabled by the earlier filed application.

40. I have been advised that this means that both the written description and enablement requirements must be met in the earlier filed application.

VII. LEVEL OF ORDINARY SKILL IN THE ART

41. I have been asked to provide an opinion as to a person of ordinary skill in the art ("POSA") at the time of the purported invention of the '438 and '978 Patents, which I have been asked to assume is: (i) November 11, 2010 for the '438 Patent (the filing date of the '438 Patent Application) and (ii) July 6, 2011 for the '978 Patent (the filing date of the '978 Patent Application). My opinions below would not change if the time of the invention was July 29, 2009, September 25, 2009, January 6, 2010, or March 28, 2011.

42. It is my opinion that one of ordinary skill in the art relevant to the technology of the '438 and '978 Patents is someone who has a computer science, electrical engineering, mechanical engineering, or other related technical degree at the undergraduate level, and knowledge of sensor systems. Superior experience in one of these areas could compensate for lesser experience in the other.

43. I understand that CyWee has asserted that a POSA typically would have had at least a Bachelor's Degree in Computer Science, Electrical Engineering, Mechanical Engineering, or Physics, or equivalent work experience, along with knowledge of sensors (such as

accelerometers, gyroscopes, and magnetometers) and mobile computing technologies.

44. My opinions below would not substantively change if the level of a person of ordinary skill in the art were based on CyWee's assertion of a POSA. I reserve my right to consider and respond to any other opinions or findings as to such a level.

VIII. CLAIM CONSTRUCTION

45. I have reviewed Magistrate Judge Payne's Claim Construction Opinion and Judge Bryson's Order on Defendants' Objections to Magistrate Judge Payne's Claim Construction Opinion. I have applied Judge Payne's Opinion and Judge Bryson's Order in my analysis. A chart summarizing the terms construed by the Court is below:

Term	Court's Construction
"three-dimensional (3D) pointing device"/ "3D pointing device" ('438 Patent, Claims 1, 3, 4, 5, 14, 15, 16, 17, 19) ('978 Patent, Claim 1)	Plain and ordinary meaning
"six-axis motion sensor"/"six-axis motion sensor module" ('438 Patent, Claims 1, 5, 14, 15, 16, 17, 19)	Plain and ordinary meaning
"global reference frame associated with Earth" ('978 Patent, Claim 10)	"reference frame with axes defined with respect to the Earth"
"using the orientation output and the rotation output to generate a transformed output associated with a fixed reference frame associated with a display device" ('978 Patent, Claim 10)	"using the orientation output and rotation output to generate a transformed output representing a movement in a fixed reference frame that is parallel to the screen of the display device"

46. I have also reviewed the Parties' Joint Claim Construction Chart and applied the constructions agreed upon by the Parties in my analysis. A chart summarizing these terms is below:

Term	Agreed Constructions
"calculating predicted axial accelerations Ax′, Ay′, Az′ based on the measured angular velocities ω_x, ω_y, ω_z of the current state of the six-axis motion sensor module without using	Plain and ordinary meaning

any derivatives of the measured angular velocities ω_x, ω_y, ω_z" ('438 Patent, Claims 14, 19)	
"detecting and generating a first signal set" ('438 Patent, Claim 1)	Plain and ordinary meaning
"detecting and generating a second signal set" ('438 Patent, Claim 1)	Plain and ordinary meaning
"resulting deviation comprising resultant angles in said spatial pointer reference frame"/ "resulting deviation comprising said resultant angles in said spatial pointer reference frame of the 3D pointing device" ('438 Patent, Claims 1, 14, 19)	Plain and ordinary meaning
"the measured state includes a measurement of said second signal set and a predicted measurement obtained based on the first signal set without using any derivatives of the first signal set" ('438 Patent, Claim 1)	"the measured state includes a measurement of axial accelerations and predicted axial accelerations calculated using the angular velocities without computing derivatives of said angular velocities (i.e. angular accelerations)"
"spatial pointer reference frame"/ "spatial pointer reference frame of a three-dimensional (3D) pointing device"/"spatial reference frame of the 3D pointing device"/"spatial reference frame associated with the 3D pointing device" ('438 Patent, Claims 1, 4, 14, 15, 19; '978 Patent Claim 10)	"frame of reference associated with the 3D pointing device, which always has its origin at the same point in the device and in which the axes are always fixed with respect to the device"

47. I have included these terms and their constructions in Exhibit C to my report.

48. I understand that other terms in the patent claims should be interpreted to have their plain and ordinary meaning as would have been understood by one of ordinary skill in the art at the time of the invention.

IX. THE PATENTS-IN-SUIT

A. U.S. Patent No. 8,441,438

1. Summary

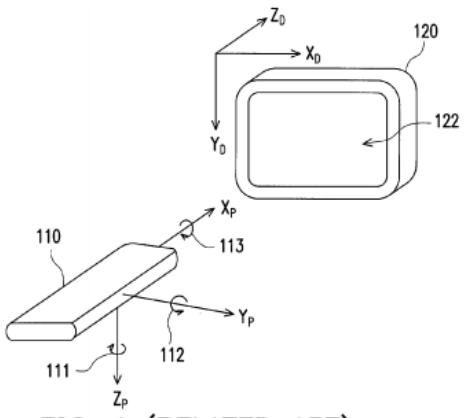
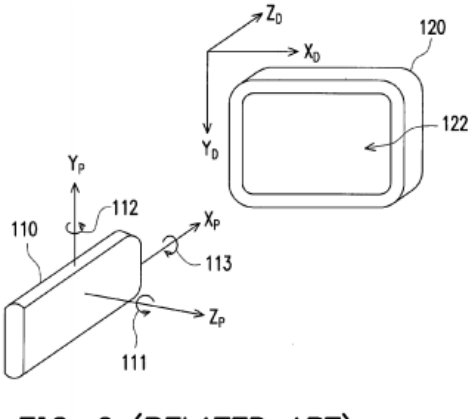
49. U.S. Patent No. 8,441,438 is entitled "3D pointing device and method for compensating movement thereof." The named inventors are Zhou Ye, Chin-Lung Li, and Shun-

Nan Liou.

50. The ’438 Patent is directed to a 3D pointing device and a method of calculating the orientation of the 3D pointing device in relation to the reference frame of a display device. ’438 Patent at Abstract, 1:53–57, 3:52–4:2.

51. More specifically, the ’438 Patent claims an improvement over other 3D pointing devices equipped with orientation sensors, which the ’438 Patent admits were known in the prior art. *Id.* at 2:38–3:15.

52. The ’438 Patent depicts 3D pointing devices in Figures 1 and 2 (reproduced below).

Figure 1 of the ’438 Patent	**Figure 2 of the ’438 Patent**
 FIG. 1 (RELATED ART)	 FIG. 2 (RELATED ART)

53. As shown in Figures 1 and 2 of the ’438 Patent, when the user moves the 3D pointing device (110), a cursor on the screen (122) moves relative to the device. *Id.* at 1:29–2:40.

54. As shown in Figure 4 of the ’438 Patent (reproduced here), the 3D pointing device includes a six-axis motion sensor module, which contains a rotation sensor (342) and accelerometer (344). *Id.* at 7:59–61. The six-axis sensor module is connected to a processing and transmitting module containing a data transmitting unit (346) and a computing processor (348). *Id.*

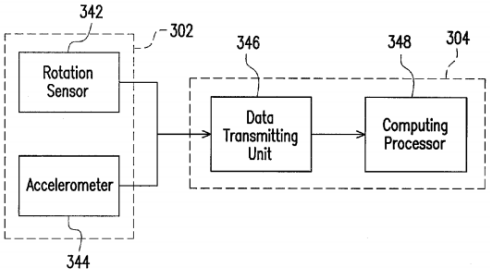


FIG. 4

55. The ’438 Patent admits that “comparison” methods using accelerometers and gyroscopes to calculate orientation were known in the prior art. Instead of claiming all sensor fusion algorithms and/or all 3D pointing devices, the ’438 Patent claims an “enhanced comparison method” that allegedly overcomes problems with prior art 3D pointing devices. *Id.* at 2:38–3:15; 3:51–4:2.

56. Specifically, the ’438 Patent states that prior art 3D pointing devices did not accurately calculate movements when the device was subject to unexpected dynamic movements—“in particular, during unexpected drifting movements and/or accelerations along with the direction of gravity.” *Id.* at 2:38–3:15.

57. To overcome the alleged problems with prior art 3D pointing devices, the ’438 Patent teaches a method of calculating the orientation of the 3D pointing device in relation to the reference frame of a display using “predicted axial accelerations” that are calculated without taking the derivatives of the angular velocities.

58. Specifically, the ’438 Patent recites an algorithm by which:

- A “current state” of the device at current time *t* is calculated using the measured angular velocities obtained from the rotation sensor. *Id.* at 11:5–8.

- A "measured state" of the device at current time *t* is calculated using measured axial accelerations and predicted axial accelerations. These predicted axial accelerations are obtained without taking the derivatives of the angular velocities. *Id.* at 11:9–15.
- An "updated state" of the device at current time *t* is obtained by comparing the "current state" with the "measured state." *Id.* at 11:9–15.
- The "updated state" is used to calculate the deviation of the 3D pointing device and this deviation is mapped to the display reference frame. *Id.* at 11:18–21; 15:26–30.

59. As disclosed in the '438 Patent File History (summarized below), the '438 Patent narrowly claims a specific "enhanced comparison method" that is different from other "comparison methods" because it uses predicted axial accelerations that are calculated without taking the derivatives of the measured angular velocities.

60. Although the '438 Patent does not disclose how exactly the above algorithm operates, I understand that CyWee and its experts have stated that the '438 Patent discloses an Extended Kalman filter or something similar to an Extended Kalman filter. *See* CyWee's Opening Claim Construction Brief, Dkt. No. 66 at 9; February 23, 2018 Declaration of Joseph J. LaViola, Jr. ("LaViola Decl."), Dkt. No. 66-6 ¶¶ 22, 29, 39, 41–42.

2. The '438 Patent File History

61. The '438 Patent issued from U.S. Patent Application No. 12/943,934 ("'934 Application"), which was filed on November 11, 2010.

62. The '934 Application was filed with twenty original claims. In an August 16, 2012 Office Action, the Examiner rejected all twenty pending claims as obvious over a

combination of one or more of U.S. Patent No. 7,817,134 ("*Huang*"), U.S. Patent No. 8,138,938 ("*Troy*"), U.S. Patent No. 7,924,264 ("*Ohta*"), and U.S. Patent No. 6,061,611 ("*Whitmore*"). '438 Patent File History at 131–143.

63. In rejecting all twenty pending claims, the Examiner stated that *Huang* discloses a three-dimensional pointing device. *Troy* discloses "the concept of including a six-axis inertial measurement unit (IMU)" which "has accelerometers and gyros for measurement of linear acceleration and angular velocity, respectively[.]" *Id.* at 131–32. *Ohta* discloses "the concept of wirelessly transmitting the data obtained by the acceleration sensor . . . in order to compute the orientation of the handheld apparatus[.]" *Id.* at 137. Finally, *Whitmore* discloses "an update program used to obtain an updated state based on a previous state" using quaternion vectors. *Id.* at 138.

64. In an October 15, 2012 Office Action Response, the Patent Applicant argued that *Whitmore* and *Troy* do not teach obtaining a "predicted measurement" because: (i) *Whitmore* relied on "time averaging past measurements to arrive at a correction strategy" and therefore was not based on "separating and distinguishing between rotation sensor data and the accelerometer data usage" and (ii) *Troy* only teaches that "acceleration data must be transformed into a stationary coordinate system" and as such, the acceleration data in *Troy* already existed and "is not being predicted, but being transformed from one coordinate system to another[.]" *Id.* at 120.

65. In an December 14, 2012 Office Action, the Examiner again rejected all twenty pending claims as obvious, this time over a combination of one or more of U.S. Patent Publication No. 2009/0262074 ("*Nasiri*") and "Improving Static and Dynamic Registration in a See-through HMD" by Ronald Azuma and Gary Bishop (1994) ("*Azuma*").

66. In particular, the Examiner stated that *Nasiri* teaches both a 3D pointing device

and an Inertial Measuring Unit (IMU) which may include three gyroscopes and three accelerometers. *Id.* at 65. In addition, *Azuma* discloses utilizing a comparison to obtain an updated state and using an "inertial-based predictor." *Id.* at 76–77.

67. In a March 3, 2013 Office Action Response, the Patent Applicant argued that a POSA would not have combined *Nasiri* and *Azuma* because: (i) *Nasiri* teaches moving an object in "the coordinate system in which a specific 3D object is defined" while (ii) *Azuma* teaches formulas under "world space." *Id.* at 53.

68. The Patent Applicant also added new Claim 21, which included the limitation of:

> obtaining a measured state of the six-axis motion sensor module by obtaining measured axial accelerations A_x, A_y, A_z gained from the motion sensor signals of the six-axis motion sensor module at the current time T and calculating predicted axial accelerations $A_{x'}$, $A_{y'}$, $A_{z'}$ based on the measured angular velocities ω_x, ω_y, ω_z of the current state of the six-axis motion sensor module without using any derivatives of the measured angular velocities ω_x, ω_y, ω_z; said current state of the six-axis motion sensor module is a second quaternion with respect to said current time T; comparing the second quaternion in relation to the measured angular velocities ω_x, ω_y, ω_z of the current state at current time T with the measured axial accelerations Ax, Ay, Az and the predicted axial accelerations Ax', Ay', Az' also at current time T;

Id. at at 50–51 (highlighted).

69. The Patent Applicant argued that *Azuma* failed to teach calculating predicted axial accelerations based on the measured angular velocities without using the derivatives of the measured angular velocities because *Azuma* teaches removing unwanted angular acceleration components by subtracting out the derivative of the angular velocity. *Id.* at 54.

70. In a subsequent March 28, 2013 telephonic interview, the Examiner and Patent Applicant agreed that the independent claims would be placed in condition for allowance if the limitation "without using any derivatives of the measured angular velocities ω_x, ω_y, ω_z" was inserted into each of the independent claims. *Id.* at 25.

71. This Examiner amendment was entered into each of the independent claims and the claims were subsequently allowed under this narrow limitation. *Id.* at 26–27.

3. The Asserted Claims

72. I understand that CyWee has asserted Claims 1, 3, 4, 5, 14, 15, 16, 17, and 19 of the ’438 Patent against Samsung.

73. The asserted claims of the ’438 Patent are set forth below.

> 1. A three-dimensional (3D) pointing device subject to movements and rotations in dynamic environments, comprising:
>
> a housing associated with said movements and rotations of the 3D pointing device in a spatial pointer reference frame;
>
> a printed circuit board (PCB) enclosed by the housing;
>
> a six-axis motion sensor module attached to the PCB, comprising a rotation sensor for detecting and generating a first signal set comprising angular velocities ω_x, ω_y, ω_z associated with said movements and rotations of the 3D pointing device in the spatial pointer reference frame, an accelerometer for detecting and generating a second signal set comprising axial accelerations Ax, Ay, Az associated with said movements and rotations of the 3D pointing device in the spatial pointer reference frame; and
>
> a processing and transmitting module, comprising a data transmitting unit electrically connected to the six-axis motion sensor module for transmitting said first and second signal sets thereof and a computing processor for receiving and calculating said first and second signal sets from the data transmitting unit, communicating with the six-axis motion sensor module to calculate a resulting deviation comprising resultant angles in said spatial pointer reference frame by utilizing a comparison to compare the first signal set with the second signal set whereby said resultant angles in the spatial pointer reference frame of the resulting deviation of the six-axis motion sensor module of the 3D pointing device are obtained under said dynamic environments, wherein the comparison utilized by the processing and transmitting module further comprises an update program to obtain an updated state based on a previous state associated with said first signal set and a measured state associated with said second signal set; wherein the measured state includes a measurement of said second

signal set and a predicted measurement obtained based on the first signal set without using any derivatives of the first signal set.

3. The 3D pointing device of claim 1, wherein the PCB enclosed by the housing comprises at least one substrate having a first longitudinal side configured to be substantially parallel to a longitudinal surface of the housing.

4. The 3D pointing device of claim 1, wherein the spatial pointer reference frame is a reference frame in three dimensions; and wherein said resultant angles of the resulting deviation includes yaw, pitch and roll angles about each of three orthogonal coordinate axes of the spatial pointer reference frame.

5. The 3D pointing device of claim 1, wherein the data transmitting unit of the processing and transmitting module is attached to the PCB enclosed by the housing and transmits said first and second signal of the six-axis motion sensor module to the computing processor via electronic connections on the PCB.

14. A method for obtaining a resulting deviation including resultant angles in a spatial pointer reference frame of a three-dimensional (3D) pointing device utilizing a six-axis motion sensor module therein and subject to movements and rotations in dynamic environments in said spatial pointer reference frame, comprising the steps of:

obtaining a previous state of the six-axis motion sensor module; wherein the previous state includes an initial-value set associated with previous angular velocities gained from the motion sensor signals of the six-axis motion sensor module at a previous time T−1;

obtaining a current state of the six-axis motion sensor module by obtaining measured angular velocities ω_x, ω_y, ω_z gained from the motion sensor signals of the six-axis motion sensor module at a current time T;

obtaining a measured state of the six-axis motion sensor module by obtaining measured axial accelerations Ax, Ay, Az gained from the motion sensor signals of the six-axis motion sensor module at the current time T and calculating predicted axial accelerations Ax′, Ay′, Az′ based on the measured angular velocities ω_x, ω_y, ω_z of the current state of the six-axis motion sensor module without using any derivatives of the measured angular velocities ω_x, ω_y, ω_z; said current state of the six-axis motion sensor module is a second

quaternion with respect to said current time T; comparing the second quaternion in relation to the measured angular velocities ω_x, ω_y, ω_z of the current state at current time T with the measured axial accelerations Ax, Ay, Az and the predicted axial accelerations Ax′, Ay′, Az′ also at current time T;

obtaining an updated state of the six-axis motion sensor module by comparing the current state with the measured state of the six-axis motion sensor module; and

calculating and converting the updated state of the six axis motion sensor module to said resulting deviation comprising said resultant angles in said spatial pointer reference frame of the 3D pointing device.

15. The method for obtaining a resulting deviation of a 3D pointing device of claim 14, further comprises the step of outputting the updated state of the six-axis motion sensor module to the previous state of the six-axis motion sensor module; and wherein said resultant angles of the resulting deviation includes yaw, pitch and roll angles about each of three orthogonal coordinate axes of the spatial pointer reference frame.

16. The method for obtaining a resulting deviation of a 3D pointing device of claim 14, wherein said previous state of the six-axis motion sensor module is a first quaternion with respect to said previous time T−1; and said updated state of the six-axis motion sensor module is a third quaternion with respect to said current time T.

17. The method for obtaining a resulting deviation of 3D pointing device of claim 14, wherein the obtaining of said previous state of the six-axis motion sensor module further comprises initializing said initial-value set.

19. A method for obtaining a resulting deviation including resultant angles in a spatial pointer reference frame of a three-dimensional (3D) pointing device utilizing a six-axis motion sensor module therein and subject to movements and rotations in dynamic environments in said spatial pointer reference frame, comprising the steps of:

obtaining a previous state of the six-axis motion sensor module; wherein the previous state includes an initial-value set associated with previous angular velocities gained from the motion sensor

signals of the six-axis motion sensor module at a previous time T−1;

obtaining a current state of the six-axis motion sensor module by obtaining measured angular velocities ω_x, ω_y, ω_z gained from the motion sensor signals of the six-axis motion sensor module at a current time T;

obtaining a measured state of the six-axis motion sensor module by obtaining measured axial accelerations Ax, Ay, Az gained from the motion sensor signals of the six-axis motion sensor module at the current time T and calculating predicted axial accelerations Ax′, Ay′, Az′ based on the measured angular velocities ω_x, ω_y, ω_z of the current state of the six-axis motion sensor module without using any derivatives of the measured angular velocities ω_x, ω_y, ω_z; said current state of the six-axis motion sensor module is a second quaternion with respect to said current time T; comparing the second quaternion in relation to the measured angular velocities ω_x, ω_y, ω_z of the current state at current time T with the measured axial accelerations Ax, Ay, Az and the predicted axial accelerations Ax′, Ay′, Az′ also at current time T;

obtaining an updated state of the six-axis motion sensor module by comparing the current state with the measured state of the six-axis motion sensor module; and

calculating and converting the updated state of the six axis motion sensor module to said resulting deviation comprising said resultant angles in said spatial pointer reference frame of the 3D pointing device.

B. U.S. Patent No. 8,552,978

1. Summary

74. The ’978 Patent is a continuation-in-part of U.S. Patent Publication No. 13/072,794, which is a continuation of the ’438 Patent. The ’978 Patent is entitled “3D pointing device and method for compensating rotations of the 3D pointing device thereof.” The named inventors are Zhou Ye, Chin-Lung Li, and Shun-Nan Liou.

75. Like the ’438 Patent, the ’978 Patent discloses a method of calculating the orientation of the 3D Pointing device in relation to a display’s reference frame. ’978 Patent at

Abstract.

76. The ’978 Patent is also directed to an improvement over prior art 3D pointing devices to provide an “enhanced comparison method” to reduce the “errors and/or noises associated with such signals or fusion of signals from the motion sensors.” *Id.* at 3:53–4:11.

77. As shown in Figure 4 of the ’978 Patent (reproduced here), the ’978 Patent discloses a nine-axis sensor module (versus the six-axis motion sensor module disclosed in the ’438 Patent) containing a: (i) rotation sensor (342); (ii) accelerometer (344); and (iii) magnetometer (345). *Id.* at 9:65–10:1.

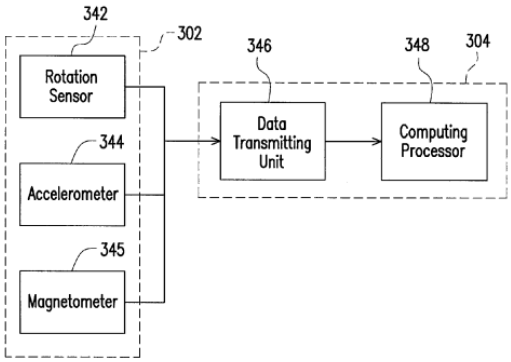


FIG. 4

78. To overcome the alleged problems with prior art 3D pointing devices, the ‘978 Patent teaches a method of obtaining deviation angles using measured and predicted magnetisms. *Id.* at 22:34–23:34.

79. Specifically, the ’978 Patent recites an algorithm by which:

- The rotation sensor generates a rotation output. *Id.* at 33:29–50. The accelerometer generates a first signal set of axial accelerations. *Id.* The magnetometer generates a second signal set of magnetisms. *Id.*
- The orientation output is generated based on: (i) the rotation output, the first signal set, and the second signal set; or (ii) the first and second signal sets. *Id.* The patent discloses that this orientation output may be in the form of a rotation matrix, quaternion, rotation vector, or the three orientation angles: yaw, pitch and roll. *Id.* at 33:53–64.

- The orientation output and rotation output are used to generate a transformed output associated with the fixed reference frame of a display device. The ’978 Patent discloses that these movements may constitute a “movement pattern in the display plane and the display device may be controlled to move a virtual object or a cursor along the movement pattern.” *Id.* at 31:50–55.
- The deviation of the device is calculated using measured and predicted magnetisms to generate an updated state. *Id.* at 22:34–32:34.

80. Like the ’438 Patent, the ’978 Patent does not disclose how exactly the above algorithm operates. I understand however that CyWee and its experts have stated that the ’978 Patent also discloses an Extended Kalman Filter or something similar to an Extended Kalman Filter. *See* CyWee’s Opening Claim Construction Brief, Dkt. No. 66 at 22; March 7, 2018 Deposition Transcript of Joseph J. LaViola, Jr. (“LaViola Dep. Tr.”) at 160:21–162:24.

2. The ’978 Patent File History

81. The ’978 Patent issued from U.S. Patent Application No. 13/176,771 (“’771 Application”), which was filed on July 6, 2011.

82. The ’771 Application was filed with twenty-two original claims.

83. In a January 28, 2013 Office Action, the Examiner rejected all twenty-two pending claims for double-patenting over Application No. 12/943,934 (which eventually became the ’438 Patent). ’978 Patent File History at 68. The Examiner instructed the Patent Applicant to “maintain a clear line of demarcation between the applications.” *Id.*

84. The Examiner further rejected all twenty-two original claims as obvious over *Nasiri*. Specifically, the Examiner found that *Nasiri* discloses a 3D pointing device comprising an orientation sensor that generates an orientation output associated with a global reference

frame. *Id.* at 70–73.

85. In a April 17, 2013 Office Action Response, the Applicant amended the independent claims (1 and 12) to include new limitations for a: (i) "nine-axis motion sensor module" and (ii) to make clear that the 3D pointing device is configured to obtain a resultant deviation using a plurality of measured and predicted magnetisms. *Id.* at 36–37, 39–40.

86. To provide a clear line of demarcation between the '438 and '978 Patents, the Patent Applicant stated that:

> Applicant submits that Application No. 12/943,034 includes the claimed subject matter of a six-axis motion sensor module without having and using measured magnetisms and predicted magnetisms.

Id. at 44 (highlighted).

87. The Patent Applicant further argued that *Nasiri* only briefly described magnetometers and that *Nasiri* therefore failed to disclose or teach "obtaining resultant deviation including deviation angles using a plurality of measured magnetisms Mx, My, Mz, and a plurality of predicted magnetism Mx′, My′ and Mz′." *Id.* at 44, 47–48.

88. The claims were allowed afterwards without further comment. *Id.* at 24.

3. The Asserted Claims

89. I understand that CyWee has asserted Claims 10 and 12 of the '978 Patent against Samsung.

90. The asserted claims of the '978 Patent are set forth below.

> 10. A method for compensating rotations of a 3D pointing device, comprising:
>
> generating an orientation output associated with an orientation of the 3D pointing device associated with three coordinate axes of a global reference frame associated with Earth;

generating a first signal set comprising axial accelerations associated with movements and rotations of the 3D pointing device in the spatial reference frame;

generating a second signal set associated with Earth's magnetism; generating the orientation output based on the first signal set, the second signal set and the rotation output or based on the first signal set and the second signal set;

generating a rotation output associated with a rotation of the 3D pointing device associated with three coordinate axes of a spatial reference frame associated with the 3D pointing device; and

using the orientation output and the rotation output to generate a transformed output associated with a fixed reference frame associated with a display device, wherein the orientation output and the rotation output is generated by a nine-axis motion sensor module; obtaining one or more resultant deviation including a plurality of deviation angles using a plurality of measured magnetisms Mx, My, Mz and a plurality of predicted magnetism Mx′, My′ and Mz′ for the second signal set.

12. The method of claim 10, wherein the orientation output is a rotation matrix, a quaternion, a rotation vector, or comprises three orientation angles.

X. CYWEE'S CLAIMED PRIORITY DATE OF THE '438 PATENT

A. The '438 Patent is not entitled to a priority date of January 6, 2010 based on Provisional Application No. 61/292,558

91. I have been informed that CyWee contends the asserted claims of the '438 Patent are entitled to a priority date of January 6, 2010, which is the filing date of Provisional Application No. 61/292,558 ("'558 Provisional Application").

92. In my opinion, the asserted claims of the '438 Patent should not be entitled to a priority date of January 6, 2010, because: (i) a POSA would not have reasonably concluded from the '558 Provisional Application that the inventors had possession of the claimed invention; and/or (ii) the disclosures of the '558 Provisional Application are insufficient to enable a POSA to make or use the claimed inventions without undue experimentation. The bases of my opinions

are set forth in detail below. I also incorporate my analysis in Section XV.A.

1. "a predicted measurement obtained based on the first signal set without using any derivatives of the first signal set" (Claim 1)/"calculating predicted axial accelerations Ax′, Ay′, Az′ based on the measured angular velocities ω_x, ω_y, ω_z of the current state of the six-axis motion sensor module without using any derivatives of the measured angular velocities ω_x, ω_y, ω_z" (Claims 14 and 19)

93. Claim 1 of the '438 Patent recites an "update program" that obtains an "updated state" based on a "previous state" and a "measured state" where the measured state "includes a measurement of said second signal set and a predicted measurement obtained based on the first signal set without using any derivatives of the first signal set."

94. I understand that the parties have agreed that this predicted measurement comprises "predicted axial accelerations calculated using the angular velocities without computing derivatives of said angular velocities (i.e. angular accelerations)." *See* Section VIII.

95. Similarly, Claims 14 and 19 of the '438 Patent recite obtaining a "measured state" in part by "calculating predicted axial accelerations Ax′, Ay′, Az′ based on the measured angular velocities ω_x, ω_y, ω_z of the current state of the six-axis motion sensor module without using any derivatives of the measured angular velocities ω_x, ω_y, ω_z."

96. There is no disclosure in the '558 Provisional Application of calculating predicted axial accelerations without taking the derivatives of the measured angular velocities. In fact, the terms "predict" and "axial accelerations" and the variables "Ax′, Ay′, Az′" appear nowhere in the '558 Provisional Application. Instead, the '558 Provisional Application only discloses the variables Ax, Ay, and Az which are always referred to as the measured accelerations.

97. I understand that CyWee claims that these limitations are met in the '558 Provisional Application because the Provisional Application discloses representing the "dynamic analysis on rotation effect on the accelerometer(s)" as:

$$\begin{bmatrix} A_{xc} \\ A_{yc} \\ A_{zc} \end{bmatrix} = \begin{bmatrix} \ddot{P}_{mx} \\ \ddot{P}_{my} \\ \ddot{P}_{mz} \end{bmatrix} + \begin{bmatrix} R\,\dot{W}_z + g\sin(\theta_y) \\ -R(W_x^2 + W_z^2) + g\cos(\theta_y)\sin(\theta_x) \\ R\,\dot{W}_x - g\cos(\theta_x)\cos(\theta_y) \end{bmatrix}$$

CyWee's First Supplemental and/or Amended Objections and Responses to Apple's First Set of Interrogatories (CYWEE_SAMSUNG011630–CYWEEE_SAMSUNG011719), Ex. A at 17, 29, 44.

98. Contrary to CyWee's claims however, the '558 Provisional Application does not describe the variables (A_{xc}, A_{yc}, and A_{zc}) as "predicted axial accelerations." Even if they were the predicted axial accelerations, obtaining the values of A_{xc} and A_{zc} clearly requires taking the derivatives of the angular velocities (as shown by the overdot symbols over W_x and W_z).

99. Even more confusingly, this equation uses a single constant variable "R" which the '558 Provisional Application defines as "the distance between the user's wrist and the accelerometer sensing the Ay value." '558 Provisional Application at 6.

100. A POSA would understand that for the simple case of rotation in a perfect circle with a radius R, the centrifugal acceleration is calculated as $R * \omega^2$.

101. However, defining the distance between the user's wrist and the accelerometer as a constant variable R would not match real world situations. When a 3D pointing device is moving in the real world, this motion does not result solely from wrist motion. Therefore, the radius of rotation is not a constant—instead it varies in time based on numerous other sources not considered or described in the '558 Provisional Application.

102. For example, the user's wrist is not a solid body and thus does not induce motion with a fixed value of R (which would also be different based on the user). Similarly, rotation with a different radius of rotation than the wrist can result in compound rotation involving the

forearm. Additional examples of other rotation sources are the fingers of the hand holding the pointer, the upper arm, the shoulder, and general body movements. The equation used in the cited mathematical expressions simply can never apply to compound motion—which always results for human-controlled motion. These values would also differ depending on the user. Accordingly, the use of the single constant variable "R" (and the resulting mathematical expression relying on its use) is far too simple to model actual pointer motion. In addition the mathematical model identified fails to take into account linear motion of the pointer in addition to the rotational motion.

103. Thus, the above disclosure does not describe how to obtain predicted axial accelerations without taking the derivatives of the angular velocities.

104. For at least these reasons, a POSA would not have reasonably concluded from the above disclosure that the inventors had possession of the claimed invention. The above disclosures are also insufficient to enable a POSA to make or use the claimed invention without undue experimentation.

2. "quaternions" (Claims 14, 16, and 19)

105. Claims 14 and 19 of the '438 Patent recite that the current state of the six-axis sensor module is a "second quaternion" with respect to current time T. Claim 16 of the '438 Patent recites that the "previous state" is a "first quaternion" with respect to previous time T-1.

106. There is no disclosure in the '558 Provisional Application of using quaternions. In fact, the term quaternion and all commonly-used methods of expressing quaternions appear nowhere in the '558 Provisional Application.

107. I understand that CyWee claims that "[w]ithin the meaning of the Provisional Application, an object's orientation/attitude in 3D space can be represented by deviation angles,

rotation matrix, and/or a quaternion." CyWee's First Supplemental and/or Amended Objections and Responses to Apple's First Set of Interrogatories (CYWEE_SAMSUNG011630–CYWEEE_SAMSUNG011719), Ex. A at 15. CyWee provides no support for this bare assertion.

108. Indeed, the Provisional Application describes representing orientation solely using angles or a rotation matrix. '558 Provisional Application ¶¶ 28–31, 37. Although deviation angles and rotation matrices are also methods of expressing orientation, they are not quaternions. Thus, the above disclosure does not describe expressing orientation in quaternion format.

109. For at least these reasons, a POSA would not have reasonably concluded from the above disclosure that the inventors had possession of the claimed invention.

3. "utilizing a comparison to compare the first signal set with the second signal set" (Claim 1)/"comparing the second quaternion in relation to the measured angular velocities ω_x, ω_y, ω_z of the current state at current time T with the measured axial accelerations Ax, Ay, Az and the predicted axial accelerations Ax′, Ay′, Az′ also at current time T" (Claims 14 and 19)

110. Claim 1 of the '438 Patent recites "utilizing a comparison to compare the first signal set with the second signal set."

111. Claim 1 further recites that the "first signal set" comprises "angular velocities ω_x, ω_y, ω_z associated with said movements and rotations of the 3D pointing device in the spatial pointer reference frame." Claim 1 recites that this first signal set is detected and generated by a rotation sensor. Claim 1 recites that the "second signal set" comprises "axial accelerations Ax, Ay, Az associated with said movements and rotations of the 3D pointing device in the spatial pointer reference frame." Claim 1 recites that this second signal set is detected and generated by an accelerometer.

112. Similarly, Claims 14 and 19 recite "comparing the second quaternion in relation to the measured angular velocities ω_x, ω_y, ω_z of the current state at current time T with the

measured axial accelerations Ax, Ay, Az and the predicted axial accelerations Ax′, Ay′, Az′, also at current time T."

113. There is no disclosure in the '558 Provisional Application for how this comparison is done.

114. Claim 1 further recites that the comparison is used to calculate resultant "deviation angles." However, the Provisional Application nowhere describes how the comparison between angular velocities and axial accelerations somehow results in an output of deviation angles.

115. First, as I described in Section X.A.2, the '558 Provisional Application does not describe representing orientation in quaternion format (or using quaternions at all).

116. Second, I understand that CyWee claims that the '558 Provisional Application meets these limitations because Fig. 5A of the Provisional Application shows the "current state" (Θx and Θz) being compared with the "measured state" (Tiltx) in "Alg1()" and "Alg2()" to calculate the resultant angles Θxc and Θzc. CyWee's First Supplemental and/or Amended Objections and Responses to Apple's First Set of Interrogatories (CYWEE_SAMSUNG011630–CYWEEE_SAMSUNG011719), Ex. A at 13, 29, 44.

117. Figure 5A (reproduced below) depicts inputting what the Provisional Application states are "rotation angles" into "Pointing Algorithms" (labeled "Alg1" and "Alg2.") '558 Provisional Application ¶ 40. These algorithms are entirely undefined and there is no disclosure of how they actually operate.

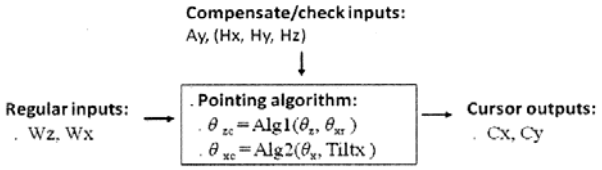


FIG. 5A

118. Indeed, the Provisional Application states only that the "pointing algorithm" may include algorithms 1 and 2 (Alg1 and Alg2) of which "compensated angles" may be calculated, without any other explanation. *Id.*

119. Thus, the above disclosure does not describe how to compare angular velocities with axial accelerations or how to compare a second quaternion in relation to measured angular velocities with measured axial accelerations and predicted axial accelerations.

120. For at least these reasons, a POSA would not have reasonably concluded from the above disclosure that the inventors had possession of the claimed invention. The above disclosures are also insufficient to enable a POSA to make or use the claimed invention without undue experimentation.

4. "obtaining an updated state of the six-axis motion sensor module by comparing the current state with the measured state of the six-axis motion sensor module" (Claims 14 and 19)

121. Claims 14 and 19 of the '438 Patent recite obtaining an "updated state" of the six-axis motion sensor module by comparing the "current state" with the "measured state."

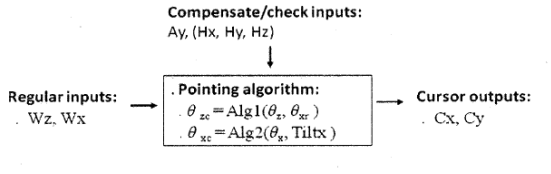
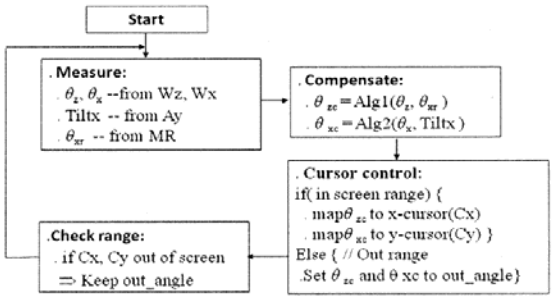
122. The claims recite that: (i) the "current state" is obtained by "obtaining measured angular velocities ω_x, ω_y, ω_z" at current time T; and (ii) the "measured state" is obtained by "obtaining measured axial accelerations Ax, Ay, Az" at current time T and calculating "predicted axial accelerations" also at current time T.

123. Based on the claim language, the "updated state" is therefore obtained by

comparing: (i) a current state obtained from measured angular velocities with (ii) a measured state obtained from measured axial accelerations and predicted axial accelerations.

124. There is no disclosure in the '558 Provisional Application for how this comparison is done.

125. I understand that CyWee claims that the '558 Provisional Application meets these limitations because Figures 5A and 5B of the Provisional Application (reproduced below) show taking the "difference between the current state angle Θx and Θz (which include gyro drift and is calculated from gyroscope measurements Wx and Wz) and the compensated angles Θxc and Θzc (calculated based on the measured state Tiltx)." CyWee's First Supplemental and/or Amended Objections and Responses to Apple's First Set of Interrogatories (CYWEE_SAMSUNG011630–CYWEEE_SAMSUNG011719), Ex. A at 30, 45.

Figure 5A of the '558 Provisional Application	**Figure 5B of the '558 Provisional Application**
 FIG. 5A	 FIG. 5B

126. I disagree. Figure 5B shows angles Θx and Θz being measured from the angular velocities and Tilt angle x being measured from axial acceleration Ay. Figure 5A then separately shows angles (Θx and Θz) being used in a generic "pointing algorithm" to produce angles Θxc and Θzc.

127. It is unclear from this disclosure what the "updated state" is. I understand that

CyWee contends that the updated state in the ’558 Provisional Application is the difference between the current state angle (Θx and Θz) and compensated angles (Θxc and Θzc), but the ’558 Provisional Application does not disclose any algorithm to calculate this difference.

128. Indeed, in the algorithm that CyWee points to, the Provisional Application states only that the “pointing algorithm” may include algorithms 1 and 2 (Alg1 and Alg2) of which “compensated angles” may be calculated, without any other explanation. *Id.*

129. Thus, the above disclosure does not describe how to perform the step of “obtaining an updated state of the six-axis motion sensor module by comparing the current state with the measured state of the six-axis motion sensor module.”

130. For at least these reasons, a POSA would not have reasonably concluded from the above disclosure that the inventors had possession of the claimed invention. The above disclosures are also insufficient to enable a POSA to make or use the claimed invention without undue experimentation.

B. The ’978 Patent is not entitled to a priority date of January 6, 2010 based on Provisional Application No. 61/292,558

131. I understand that CyWee has alleged that the asserted claims of the ’978 Patent are entitled to a priority date of January 6, 2010, based on the date of Provisional Application No. 61/292,558.

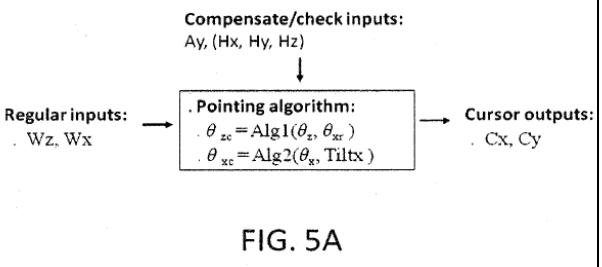
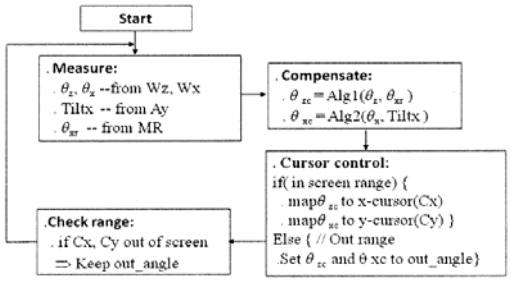
132. In my opinion, the asserted claims of the ’978 Patent should not be entitled to a priority date of January 6, 2010, because: (i) a POSA would not have reasonably concluded from the ’558 Provisional Application that the inventors had possession of the claimed invention; and/or (ii) the disclosures of the ’558 Provisional Application are insufficient to enable a POSA to make or use the claimed inventions without undue experimentation. The bases of my opinions are set forth in detail below. I also incorporate my analysis in Section XV.B.

1. "generating the orientation output based on the first signal set, the second signal set and the rotation output or based on the first signal set and the second signal set" (Claim 10)

133. Claim 10 of the '978 Patent recites "generating the orientation output based on the first signal set, the second signal set and the rotation output or based on the first signal set and the second signal set." Claim 10 recites that the "first signal set" comprises "axial accelerations associated with movements and rotations of the 3D pointing device in the spatial reference frame." Claim 10 recites that the "second signal set" is "associated with [the] Earth's magnetism."

134. There is no disclosure in the '558 Provisional Application of how this "orientation output" is generated.

135. I understand that CyWee claims that the '558 Provisional Application meets these limitations because Figures 5A and 5B of the Provisional Application (reproduced below) disclose an "algorithm 2" which "may use tilt measured by the accelerometer to compensate x-gyro drift and monitor cursor vertical range." CyWee's First Supplemental and/or Amended Objections and Responses to Apple's First Set of Interrogatories (CYWEE_SAMSUNG011630–CYWEEE_SAMSUNG011719), Ex. B at 9.

Figure 5A of '558 Provisional Application	Figure 5B of '558 Provisional Application
	
FIG. 5A	FIG. 5B

136. I disagree. At most, the '558 Provisional Application states that Figure 5A shows that "regular inputs Wz and Wx generated from a gyroscope may be compensated by Ax sensed

by an accelerometer and calibrated data (Hx, Hy, Hz) generated from an MR sensor based on a pointing algorithm." '558 Provisional Application ¶ 40. The pointing algorithm is defined as including algorithms 1 and 2—"Alg1" and "Alg2." However, these algorithms are otherwise entirely undefined and there is no disclosure of how they actually operate.

137. Further, the '558 Provisional Application provides no explanation of what the "calibrated data" (Hx, Hy, and Hz) from the magnetometer actually is or how to obtain it. Instead, it states only that the "calibrated data" may be represented as:

$$\begin{bmatrix} Hx \\ Hy \\ Hz \end{bmatrix} = \begin{bmatrix} a1 & a2 & a3 \\ a4 & a5 & a6 \\ a7 & a8 & a9 \end{bmatrix} \begin{bmatrix} Sx \\ Sy \\ Sz \end{bmatrix}$$

where a1–a9 are undefined "calibration parameters" and Sx, Sy, and Sz represent "compensations" defined only as a set of equations:

$$Sx = Rx - CxT$$
$$Sy1 = Ry1 - Cy1T$$
$$Sy2 = Ry2 - Cy2T$$
$$Sy = Sy2 - Sy1$$
$$Sz = Sy1 + Sy2$$

where Cx, Cy1, and Cy2 are some undefined variables for "temperature compensation." *Id.* ¶ 36.

138. The '558 Provisional Application provides even less explanation for Figure 5B, stating only that it is a "detailed flowchart of a method of a 3D pointing device according to still another example of the present invention." *Id.* ¶ 40.

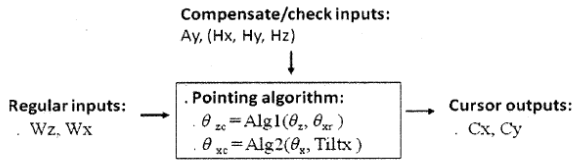
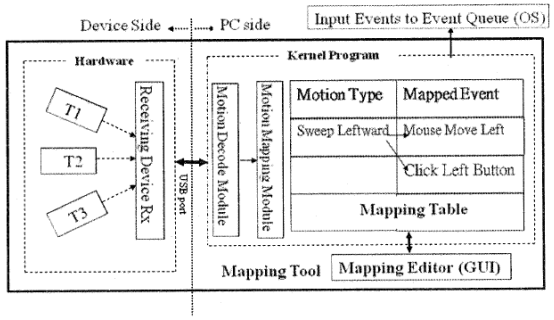
139. Thus, Figures 5A or 5B of the '558 Provisional Application (or any portion of the '558 Provisional Application) do not describe how to generate the orientation output based on the first signal set, the second signal set and the rotation output or based on the first signal set and the second signal set.

140. For at least these reasons, a POSA would not have reasonably concluded from the above disclosure that the inventors had possession of the claimed invention. The above disclosures are also insufficient to enable a POSA to make or use the claimed invention without undue experimentation.

2. "using the orientation output and the rotation output to generate a transformed output associated with a fixed reference frame associated with a display device" (Claim 12)

141. Claim 12 requires "using the orientation output and the rotation output to generate a transformed output associated with a fixed reference frame associated with a display device."

142. I understand that CyWee points to disclosures in Figures 5A and 7A of the '558 Provisional Application (reproduced below) as meeting these limitations. CyWee's First Supplemental and/or Amended Objections and Responses to Apple's First Set of Interrogatories (CYWEE_SAMSUNG011630–CYWEEE_SAMSUNG011719), Ex. B at 12.

Figure 5A of the '558 Provisional Application	**Figure 7A of the '558 Provisional Application**
 FIG. 5A	 FIG. 7A

143. Figure 5A shows inputs from a gyroscope, calibrated data from an magnetometer and readings from an accelerometer being used as inputs to a "pointing algorithm." '558 Provisional Application at Fig. 5A, ¶ 40. The pointing algorithm includes two algorithms ("Alg1") and ("Alg2"), but these algorithms are otherwise entirely undefined and there is no

disclosure of how they actually operate. *Id.*

144. Instead, the '558 Provisional Application merely states that "algorithm 1" somehow uses "magnetic direction to compensate z-gyro drift and a horizontal range of the cursor" while "algorithm 2" somehow uses "tilt measured by the accelerometer to compensate x-gyro drift and monitor cursor vertical range." These inputs exit the "pointing algorithm" black box as "cursor outputs" (Cx and Cy). *Id.*

145. Figure 7A is even sparser, showing only a black box which CyWee argues shows a "Motion Decode Module" that uses orientation output and rotation output to map to a transformed output. CyWee's First Supplemental and/or Amended Objections and Responses to Apple's First Set of Interrogatories (CYWEE_SAMSUNG011630–CYWEEE_SAMSUNG011719), Ex. B at 12.

146. CyWee does not (and cannot) point to any disclosure in the '558 Provisional Application of how this module works. Indeed, the '558 Provisional Application's only reference to Figure 7A is a bare assertion that "[m]otion signals" are "passed to a motion decode module for deciding its motion information." '558 Provisional Application ¶ 42. This provides no information about how this module works.

147. Thus, the above disclosure does not describe how to use the orientation output and the rotation output to generate a transformed output associated with a fixed reference frame associated with a display device.

148. For at least these reasons, a POSA would not have reasonably concluded from the above disclosure that the inventors had possession of the claimed invention. The above disclosures are insufficient to enable a POSA to make or use the claimed invention without undue experimentation.

3. "obtaining one or more resultant deviation including a plurality of deviation angles using a plurality of measured magnetisms Mx, My, Mz and a plurality of predicted magnetism Mx′, My′ and Mz′ for the second signal set" (Claim 10)

149. Claim 10 of the '978 Patent recites "obtaining one or more resultant deviation including a plurality of deviation angles using a plurality of measured magnetisms Mx, My, Mz and a plurality of predicted magnetism Mx′, My′ and Mz′ for the second signal set."

150. There is no disclosure in the '558 Provisional Application of this limitation. In fact, the terms "predict" and the variables "Mx′, My′, Mz′" appear nowhere in the '558 Provisional Application.

151. I understand that CyWee argues this limitation is met because the '558 Provisional Application discloses the variables Sx, Sy1, and Sy2 (shown below) which are defined by the variables Rx, Ry1, and Ry2, which the Provisional Application defines as "raw data read out from the MR sensor." CyWee's First Supplemental and/or Amended Objections and Responses to Apple's First Set of Interrogatories (CYWEE_SAMSUNG011630–CYWEEE_SAMSUNG011719), Ex. B at 14; '558 Provisional Application ¶ 36.

$$Sx = Rx - CxT$$
$$Sy1 = Ry1 - Cy1T$$
$$Sy2 = Ry2 - Cy2T$$
$$Sy = Sy2 - Sy1$$
$$Sz = Sy1 + Sy2$$

152. However, the Provisional Application states only that Sx, Sy, and Sz represent "compensations." The variables are otherwise entirely undefined. Further, the Provisional Application provides no explanation of what the variables Sy1 and Sy2 are, despite CyWee's assertion that these are the predicted magnetisms.

153. The '558 Provisional Application discloses that these "compensations" are

calculated using Cx, Cy1, and Cy2, which are also undefined except by stating that they are a "temperature compensation." There is no other disclosure of what the variables Cx, Cy1, and Cy2 are or how to obtain them.

154. Thus, the above disclosure does not describe how to obtain a plurality of predicted magnetism Mx′, My′ and Mz′ for the second signal set.

155. For at least these reasons, a POSA would not have reasonably concluded from the above disclosure that the inventors had possession of the claimed invention. The above disclosures are also insufficient to enable a POSA to make or use the claimed invention without undue experimentation.

4. "quaternions" (Claim 12)

156. Claim 12 of the '978 Patent recites: "[t]he method of claim 10, wherein the orientation output is a rotation matrix, a quaternion, a rotation vector, or comprises three orientation angles."

157. As I described in Section X.A.2, there is no disclosure in the '558 Provisional Application of quaternions. Indeed, I understand that CyWee points only to the disclosure of a "rotation matrix" and "deviation angle" as disclosing quaternions. CyWee's First Supplemental and/or Amended Objections and Responses to Apple's First Set of Interrogatories (CYWEE_SAMSUNG011630–CYWEEE_SAMSUNG011719), Ex. B at 15. Although rotation matrices and deviation angles are methods of expressing orientation, they are not quaternions.

158. Thus, a POSA would not view the '558 Provisional Application as describing the use of quaternions.

159. For at least these reasons, a POSA would not have reasonably concluded from the above disclosure that the inventors had possession of the claimed invention.

C. The ’978 Patent is not entitled to a priority date of November 11, 2010 based on Continuation-in-Part Application No. 12/943,934

160. The ’978 Patent claims priority to Application No. 13/072,794 (filed on March 28, 2011), which is a continuation-in-part of Application No. 12/943,934 (filed on November 11, 2010). ’978 Patent at 1:8–17.

161. In my opinion, the ’978 Patent is not entitled to a priority date of November 11, 2010 based on Application No. 12/943,934 (“the ’934 Application”), because: (i) a POSA would not have reasonably concluded from the ’934 Application that the inventors had possession of the claimed invention; and (ii) the disclosures of the ’934 Application are insufficient to enable a POSA to make or use the claimed inventions without undue experimentation. The bases of my opinions are set forth in detail below. I also incorporate my analysis in Section XV.B.

1. “generating the orientation output based on the first signal set, the second signal set and the rotation output or based on the first signal set and the second signal set” (’978 Patent, Claim 10)

162. In my opinion, the ’934 Application does not describe the limitation of “generating the orientation output based on the first signal set, the second signal set and the rotation output or based on the first signal set and the second signal set.”

163. Specifically, although Claim 10 of the ’978 Patent recites that the “second signal set” in this claim is a “signal set associated with the Earth’s magnetism,” the ’934 Application does not disclose the use of magnetisms and/or a magnetometer. Accordingly, a POSA would not view the ’934 Application as disclosing the limitation of “generating the orientation output based on the first signal set, the second signal set and the rotation output or based on the first signal set and the second signal set.”

164. To the extent that CyWee argues that the ’934 Application discloses these limitations because the ’934 Application incorporates the ’558 Provisional Application, this

argument is deficient for the same reasons I describe above in Section X.B.1.

165. For at least these reasons, a POSA would not have reasonably concluded from the '934 Application that the inventors had possession of the claimed invention. The '934 Application is also insufficient to enable a POSA to make or use the claimed invention without undue experimentation.

2. "using the orientation output and the rotation output to generate a transformed output associated with a fixed reference frame associated with a display device, wherein the orientation output and the rotation output is generated by a nine-axis motion sensor module" ('978 Patent Claim 10)

166. In my opinion, the '934 Application does not describe "using the orientation output and the rotation output to generate a transformed output associated with a fixed reference frame associated with a display device, wherein the orientation output and the rotation output is generated by a nine-axis motion sensor module."

167. The '934 Application does not use the term "transformed output" and there is no reference to a "transformed output" anywhere in the '934 Application. Accordingly, a POSA would not view the '934 Application as describing the limitation of "using the orientation output and the rotation output to generate a transformed output associated with a fixed reference frame associated with a display device, wherein the orientation output and the rotation output is generated by a nine-axis motion sensor module."

168. To the extent that CyWee argues that the '934 Application discloses these limitations because the '934 Application incorporates the '558 Provisional Application, this argument is deficient for the same reasons I describe above in Section X.B.2.

169. For at least these reasons, a POSA would not have reasonably concluded from the '934 Application that the inventors had possession of the claimed invention. The '934 Application is also insufficient to enable a POSA to make or use the claimed invention without

undue experimentation.

3. "obtaining one or more resultant deviation including a plurality of deviation angles using a plurality of measured magnetisms Mx, My, Mz and a plurality of predicted magnetism Mx′, My′ and Mz′ for the second signal set" ('978 Patent, Claim 10)

170. In my opinion, the '934 Application does not describe "obtaining one or more resultant deviation including a plurality of deviation angles using a plurality of measured magnetisms Mx, My, Mz and a plurality of predicted magnetism Mx′, My′ and Mz′ for the second signal set."

171. The '934 Application does not even recite the terms "magnetism" and "predicted magnetism" or use the variables "Mx′, My′, and Mz′." Accordingly, a POSA would not view the '934 Application as disclosing the limitation of "a plurality of predicted magnetism Mx′, My′ and Mz′ for the second signal set."

172. To the extent that CyWee argues that the '934 Application discloses these limitations because the '934 Application incorporates the '558 Provisional Application, this argument is deficient for the same reasons I describe above in Section X.B.3.

173. For at least these reasons, a POSA would not have reasonably concluded from the '934 Application that the inventors had possession of the claimed invention. The '934 Application is also insufficient to enable a POSA to make or use the claimed invention without undue experimentation.

D. The '978 Patent is not entitled to a priority date of March 28, 2011 based on Continuation-in-Part Application No. 13/072,794

174. As noted above, the '978 Patent claims priority to Application No. 13/072,794 (filed on March 28, 2011), which is a continuation-in-part of Application No. 12/943,934 (filed on November 11, 2010). '978 Patent at 1:8–17.

175. In my opinion, the '978 Patent is not entitled to a priority date of March 28, 2011

based on Application No. 13/072,794 ("the '794 Application"), because: (i) a POSA would not have reasonably concluded from the '794 Application that the inventors had possession of the claimed invention; and (ii) the disclosures of the '794 Application are insufficient to enable a POSA to make or use the claimed inventions without undue experimentation. The bases of my opinions are set forth in detail below. I also incorporate my analysis in Section XV.B.

1. "generating the orientation output based on the first signal set, the second signal set and the rotation output or based on the first signal set and the second signal set" ('978 Patent, Claim 10)

176. In my opinion, the '794 Application does not describe the limitation of "generating the orientation output based on the first signal set, the second signal set and the rotation output or based on the first signal set and the second signal set" for the same reasons that the '978 Patent does not. *See* Section XV.B.2.

177. Specifically, the '794 Application does not describe how to generate the orientation output using just the first signal set ("axial accelerations") and second signal sets ("magnetic readings").

178. A POSA would have understood that it is only mathematically possible to generate an orientation output based on "axial accelerations" and magnetism readings if the axial accelerations are interpreted to be based exclusively on the gravitational accelerations. Otherwise, a POSA would have understood that it is mathematically impossible to determine the direction to the center of the Earth.

179. A POSA would further understand this is only possible when the device was completely stationary, so that the only acceleration would be the gravitational acceleration. Otherwise, this limitation would claim an impossible calculation.

180. Unlike the '978 Patent, under CyWee's interpretation, the '794 Application does not even disclose how to perform this calculation when the device is stationary. Specifically, I

understand that CyWee contends Equations 26–28 of the ’978 Patent disclose how to generate an orientation output based on axial accelerations and magnetism readings if a device is stationary. However, these equations appear nowhere in the ’794 Application.

181. A POSA would understand if the device is moving, it is clear that the orientation output must be based on the first signal set, the second signal set, and the rotation output.

182. However, even assuming that this is true, the ’794 Application does not describe how to generate the “orientation output” based on the “first signal set, the second signal set and the rotation output.” There is no explanation in the ’794 Application of how this is done.

183. To the extent that CyWee argues that Equations 5–11 of the ’794 Application disclose these limitations, this argument is deficient for the reasons I describe in Section XV.B.2.

184. Accordingly, a POSA would not view the ’794 Application as describing the limitation of “generating the orientation output based on the first signal set, the second signal set and the rotation output or based on the first signal set and the second signal set.”

185. To the extent that CyWee argues that the ’794 Application discloses these limitations because the ’794 Application incorporates the ’934 Application and/or the ’558 Provisional Application, this argument is deficient for the same reasons I describe above in Sections X.B.1 and X.C.1.

186. For at least these reasons, a POSA would not have reasonably concluded from the ’794 Application that the inventors had possession of the claimed invention. The ’794 Application is also insufficient to enable a POSA to make or use the claimed invention without undue experimentation.

2. "using the orientation output and the rotation output to generate a transformed output associated with a fixed reference frame associated with a display device, wherein the orientation output and the rotation output is generated by a nine-axis motion sensor module" ('978 Patent Claim 10)

187. In my opinion, the '794 Application does not describe "using the orientation output and the rotation output to generate a transformed output associated with a fixed reference frame associated with a display device, wherein the orientation output and the rotation output is generated by a nine-axis motion sensor module."

188. The '794 Application does not use the term "transformed output" and there is no other reference to a "transformed output" anywhere in the '794 Application. Accordingly, a POSA would not view the '794 Application as disclosing the limitation of "using the orientation output and the rotation output to generate a transformed output associated with a fixed reference frame associated with a display device, wherein the orientation output and the rotation output is generated by a nine-axis motion sensor module."

189. To the extent that CyWee argues that the '794 Application discloses these limitations because the '794 Application incorporates the '934 Application and/or the '558 Provisional Application, this argument is deficient for the same reasons I describe above in Sections X.B.2 and X.C.2.

190. For at least these reasons, a POSA would not have reasonably concluded from the '794 Application that the inventors had possession of the claimed invention. The '794 Application is also insufficient to enable a POSA to make or use the claimed invention without undue experimentation.

3. "obtaining one or more resultant deviation including a plurality of deviation angles using a plurality of measured magnetisms Mx, My, Mz and a plurality of predicted magnetism Mx′, My′ and Mz′ for the second signal set" ('978 Patent, Claim 10)

191. In my opinion, the '794 Application does not describe "obtaining one or more resultant deviation including a plurality of deviation angles using a plurality of measured magnetisms Mx, My, Mz and a plurality of predicted magnetism Mx′, My′ and Mz′ for the second signal set" for the same reasons that the '978 Patent does not. *See* Section XV.B.3.

192. Specifically, the '794 Application describes the "deviation angles" as the "three resultant angles preferably about each of the three axes of the spatial pointer reference frame" including the yaw, pitch, and roll angles. '794 Application ¶ 39.

193. The '794 Application states that the "predicted magnetisms" are calculated using Equations 18–20 (reproduced below) by multiplying the second quaternion representing the "current state" (i.e., a quaternion representation of the device's current orientation) with the dip angle. *Id.* ¶ 67.

Equation 18	$(q_0^{\ 2} + q_1^{\ 2} - q_2^{\ 2} - q_3^{\ 2})\cos\lambda + 2(q_1q_3 - q_0q_2)\sin\lambda = Mx'$ ..... (18)
Equation 19	$2(q_1q_2 - q_0q_3)\cos\lambda + 2(q_2q_3 + q_0q_1)\sin\lambda = My'$ ..... (19)
Equation 20	$2(q_1q_3 + q_0q_2)\cos\lambda + (q_0^2 - q_1^2 - q_2^2 + q_3^2)\sin\lambda = Mz'$ ..... (20)

194. My understanding is that Equations 18-20 are intended to correct the orientation of the user's Earth frame so that this frame's x-axis points exactly to the North horizon. Even if this correction could be construed as a "predicted" magnetism, the concept of correcting the actual magnetometer measurements for the dip angle was well known in the art since the 1500s. Further, the equations by themselves are inadequate to remove this error. In order to use these

equations, a POSA would need details including the appropriate value of ƛ for the particular location of the pointer on the Earth. As the pointer approaches the North Pole, this activity is problematic since there the value of ƛ would approach 90 degrees (directly toward the center of the Earth. The ’978 Patent does not provide any guidance on how to obtain the appropriate value for the dip angle.

195. A “comparison” model is then used that compares “the second quaternion in relation to the measured angular velocities of the current state at present time T with the measured axial accelerations Ax, Ay, Az, the predicted axial accelerations Ax′, Ay′, Az′, the measured magnetism Mx, My, Mz and the predicted magnetism Mx′, My′, Mz′ also at present time T” to output at “updated state.” *Id.* ¶ 68. This result is then further utilized to obtain resultant deviation angles. *Id.* ¶ 69. The ’794 Application does not disclose adequate details so as to communicate the method for obtaining these deviation angles.

196. In my opinion, this cursory description of using a “comparison model” does not does not describe: (i) how to perform this comparison between a second quaternion in relation to measured angular velocities with measured axial accelerations, predicted axial accelerations, measured magnetisms, and predicted magnetisms; and (ii) how the output of this comparison is then used to obtain deviation angles.

197. For the reasons I discuss in Section XV.B.3, a POSA would not have understood how to perform this “comparison model” and would have further understood that any such comparison (at best) would produce a meaningless result.

198. To the extent that CyWee argues that the ’794 Application discloses these limitations because the ’794 Application incorporates the ’934 Application and/or the ’558 Provisional Application, this argument is deficient for the same reasons I describe above in

Sections X.B.3 and X.C.3.

199. For at least these reasons, a POSA would not have reasonably concluded from the above disclosure that the inventors had possession of the claimed invention. The above disclosures are insufficient to enable a POSA to make or use the claimed invention without undue experimentation.

XI. TECHNOLOGY OVERVIEW

200. Below is a brief technology background to aid in the understanding of my analysis in this report.

A. Basics of Movement

201. In mechanical systems, there are four basic types of motion: (i) linear motion; (ii) rotational motion; (iii) reciprocating motion; and (iv) oscillating motion.

202. Linear motion is the movement of an object along a straight line.

203. Rotational motion is the movement of an object along a circle. For example, a spinning wheel.

204. Reciprocating motion is movement backwards and forwards along a straight line.

205. Oscillating motion is movement from side to side, like a pendulum in a clock.

B. Measuring Movement: Velocity and Acceleration

206. In physics, certain measurements are used to describe an object's motion. Two key measurements are velocity and acceleration.

207. Velocity can be understood as the rate of change in the position of an object with respect to time. Velocity can be represented as a vector with both a magnitude and a direction. The magnitude represents the speed at which the object is moving. The direction represents the direction of movement. Velocity is often measured in meters per second.

208. Angular velocity can be understood as the rate of change in the angular position

of an object relative to a center of rotation with respect to time. Angular velocity can also be represented as a vector with a magnitude and direction. Angular velocity is often measured in radians per second.

209. Acceleration can be understood as the rate of change of velocity with respect to time. Like velocity and angular velocity, acceleration can be represented as a vector with both a magnitude and direction. The magnitude is a measurement of how much speed the object is gaining. The direction reflects the direction in which the gain in speed is occurring. Acceleration is often measured in meters per second squared.

210. Under the laws of physics, an object can experience at least one or more of three types of acceleration: (i) gravitational acceleration due to the gravity of the Earth; (ii) linear acceleration due to an externally applied force; and (iii) centrifugal acceleration due to an externally applied rotational force.

211. Gravitational acceleration measures the acceleration of an object experienced as a result of a gravitational force (the force of attraction between two bodies—each with a corresponding mass). When objects on the Earth are supported by some structure, the force of gravity will be counter balanced by an exactly opposite force provided by the supporting structure. An accelerometer in this situation will report the acceleration of gravity as one component of its readings.

212. For example, when two spheres of different weight fall from the same height, both are accelerated by gravity at the same rate and hit the ground at the same time.

213. Similarly, when a person steps onto a bathroom scale, the acceleration of gravity deforms a structure similar to a spring, and the amount of the deformation is read as the person's weight.

214. Although the magnitude of acceleration due to gravity is almost constant everywhere on the Earth's surface (9.8 m/s^2), its direction with respect to an object's frame of reference changes depending on the object's position and orientation, because gravitational acceleration is always directed towards the center of the Earth.

215. Linear acceleration measures the rate of change of linear velocity with respect to time. Linear velocity is the rate of change of the position of an object traveling along a straight path.

216. Centrifugal acceleration results when a rotating body (such as a weight held by a string) rotates about a point (such as the center of the circle of motion).

C. Rigid and Non-Rigid Bodies/Simple and Complex Motions

217. Motions can be described with respect to rigid and non-rigid bodies and simple and complex motions.

218. A rigid body is an idealized model of a solid object in which any changes in the shape or size of an object are assumed to be zero. In this way, the distance between any two given points on the object remain constant in time regardless of external forces, i.e., the body does not deform as it moves.

219. In non-rigid bodies, external forces may change the shape and/or size of the body as it moves.

220. Motions can be simple or compound. For example, humans may produce simple linear acceleration. For example, when a person throws a dart toward a dart board, his arm attempts to linearly accelerate the dart from an initial velocity of zero to the correct velocity so that, after its release, the trajectory of the dart terminates within the bull's eye of the dart board. Machines can also produce simple linear acceleration. A gun linearly accelerates a bullet from an initial velocity (normally zero) to the very high velocity at which it leaves the gun barrel.

221. Rotational motion induced by a single rigid body motion is simple because the radius of rotation remains constant. Rotational motion induced by multiple rigid bodies and/or non-rigid bodies may produce more complex motions, and the radius of rotation changes with time.

222. In this way, centrifugal accelerations can be either simple or compound (if the motions are not induced by a single rigid object.).

223. As one example, the centrifugal force experienced by a baseball when it is thrown by a mechanical pitching machine is in simple rotational motion because there is a fixed radius of rotation and a fixed center of rotation. In the case of this motion, both of these values are constant.

224. In contrast, when the ball is thrown by a human, the centrifugal force experienced by the baseball is compound. This is because the angle of the pitcher's arm at his elbow changes during the pitch, and therefore, the radius of curvature changes when the pitcher moves. Further, the pitcher's shoulder and wrist also move so that many complex motions are combined—and each of these anatomical parts induces different radial motions, each with a different radius that may be a constant or variable value.

D. Orientation/Reference Frames

225. The orientation (or "attitude") of an object is a description of how it is placed in space. If an object is rotating, its orientation changes over time.

226. Conventionally, the orientation of a device is defined with respect to two reference frames.

227. A reference frame provides an origin and axes from which the orientation of an object may be descripted.

228. In defining orientation, the first reference frame is described relative to the body

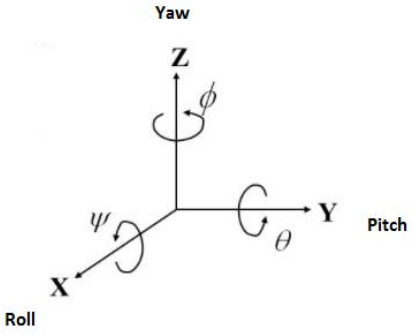
of the object.

229. A second reference frame (such as the Earth) has a different origin and/or axes that are not the same as and not necessarily fixed in time with respect to the origin and axes of the first reference frame. The orientation of the object can be then determined described relative to this second reference frame.

E. Representing Orientation

230. In physics, there are a number of different ways of mathematically representing an object's orientation. One common method is known as Euler angles, introduced by the Swiss mathematician, Leonhard Euler, in the 1700s.

231. In Euler angles, the orientation of an object is broken down into three rotations—the roll, pitch, and yaw rotations (as shown below).



232. Another common method of expressing the rotation of an object is by using quaternions. Quaternions were first described by William Rowan Hamilton, an Irish mathematician, in the 1800s.

233. A quaternion is a hyper-complex number in the form of $q = W + Xi + Yj + Zk$ where:

- W is the scalar part of the quaternion;
- *i*, *j*, and *k* are mutually orthogonal unit basis vectors along the three imaginary

axes (i, j, and k); and

- X, Y, and Z are the magnitudes of the vectors along the three imaginary axes respectively.

234. The direction of a vector with unitary basis components in R_3 can be represented by the pure quaternion (where the value of $q_0 = 0$), shown below.

$$\mathbf{q} = (q_0, q_1, q_2, q_3)$$

235. The right hand side of the above expression is an n-tuple where q_1, q_2, and q_3 specify the length of a vector along each of directions (as specified by the unit vectors i, j, and k).

236. Quaternions, Euler angles, and other methods can be used to describe rotations and calculate the results of rotations.

F. <u>Sensors</u>

237. A gyroscope is a device that can measure the rate of rotation around a particular axis. In other words, a gyroscope measures angular velocities. A triple-axis gyroscope measures the rate of rotation, or the angular velocities, around three axes: *x*, *y*, and *z*.

238. Gyroscopes have existed since at least the 1800s.

239. An accelerometer is a device that measures the accelerations that are acting on a body. Accordingly, an accelerometer measures the sum of linear, centrifugal and gravitational accelerations. An accelerometer cannot partition or decompose these three components of acceleration. Instead, it can only report the total acceleration experienced due to the above three sources.

240. Accelerometers have existed since at least the 1700s.

241. A magnetometer is a device that detects the Earth's magnetic field along the three perpendicular axes.

242. Magnetometers have existed since at least the 1800s.

G. Sensor Fusion

243. Gyroscopes, accelerometers, and magnetometers each have their own specific deficiencies.

244. Gyroscopes are sensitive to outside conditions, like temperature. Gyroscopes are also prone to sensor drift, which results in increasing amounts of errors over time, unless the sensor is recalibrated.

245. Accelerometers are sensitive to electronic noise, such as thermal noise from the internal circuitry of the accelerometers.

246. Magnetometers are sensitive to similar error sources—as well as those errors created by spurious magnetic fields close to the magnetometer. All of these distort the readings of the magnetometer.

247. The process of sensor fusion attempts to combine data from two or more sensors with the objective of reducing at least some of the erroneous components from individual sensors in order to produce potentially more accurate results.

248. Kalman filters and Extended Kalman filters are well-known algorithms for performing filtering and sensor fusion.

249. A Kalman filter is a set of mathematical calculations that starts with a set of initial assumptions and measurements that have some element of noise. The noise is filtered to obtain an estimated value. An Extended Kalman filter is the non-linear version of a Kalman filter.

250. Kalman filters and Extended Kalman filters have been known since the 1960s and were used for inertial navigation in NASA's Apollo Moon Project.

XII. SUMMARY OF PRIOR ART REFERENCES

A. "An Attitude Compensation Technique for a MEMS Motion Sensor Based Digital Writing Instrument" by Luo, et al.

251. I have reviewed "An Attitude Compensation Technique for a MEMS Motion Sensor Based Digital Writing Instrument" by Yilun Luo, Chi Chiu Tsang, Guanglie Zhang, Zhuxin Dong, Guangyi Shi, Sze Yin Kwok, Wen J. Lil, Philip H. W. Leong, and Ming YiuWong (IEEE 2006) ("*Luo*.").

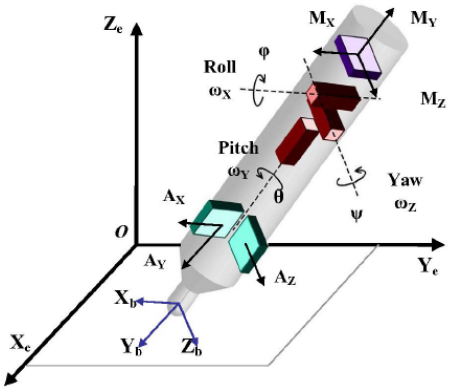


Figure 3. The MAG-µIMU System Structure for a wireless digital writing instrument.

252. As shown in Figure 3 of *Luo* (reproduced here), *Luo* discloses a digital writing instrument that captures and records handwriting and drawing motions in real-time using a MEMS µIMU. *Luo* at 909.

253. Specifically, *Luo* discloses a wireless µIMU system (MAG-µIMU) that integrates accelerometers and gyroscopes using strapdown installation. *Id.* at 910. Magnetometers are added and used in the system to measure the Earth's magnetic field. *Id.* The sensor unit is affixed to a writing instrument to measure the inertial and magnetic information resulting from movements in the instrument's body frame. *Id.* An Extended Kalman filter is incorporated into the MAG-µIMU system to track the real-time position and orientation of the pen. *Id.* at 911–912.

254. As shown in Figure 4 of *Luo* (reproduced here), *Luo* discloses that the Extended Kalman filter is a quaternion-based, recursive algorithm that consists of two stages. In the first stage ("time-update"), the orientation of the device (in quaternion format) is estimated based on the measurements from the gyroscope. *Id.* at Fig. 4, 911. In the second stage ("measurement update"), the difference between the estimated and measured Earth magnetic vector is implemented as feedback to correct the errors from the gyroscope readings. *Id.*

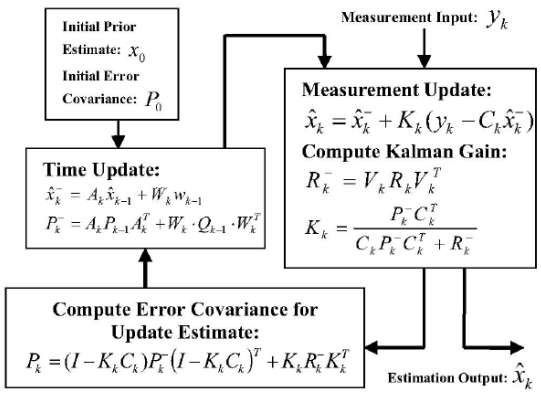


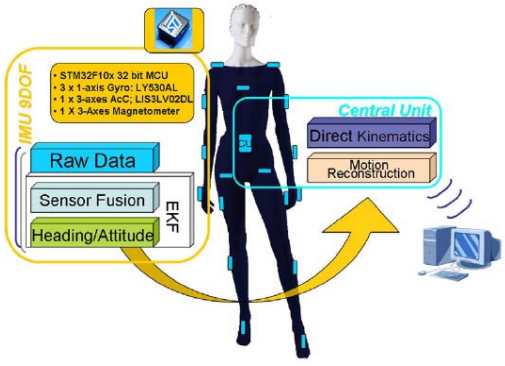
Figure 4. Extended Kalman Filter Algorithm

255. Although *Luo* discloses an Extended Kalman filter specifically using gyroscopes and magnetometers, it also discloses that any reference field sensor, including accelerometers, can be applied to its process model. *Id.* at 912.

B. "Development of a MEMS-based Wearable Motion Capture System" by Abbate, et al.

256. I have reviewed "Development of a MEMS Based Wearable Motion capture System" by Nunzio Abbate, Adriano Basile, Carmen Brigante, and Alessandro Faulisi (May 2009) ("*Abbate*").

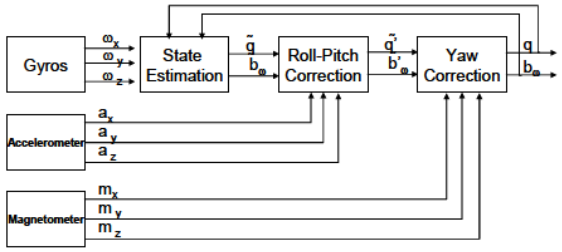
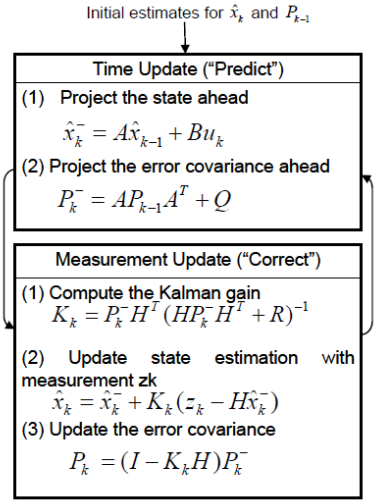
257. As shown in Figure 1 of *Abbate* (reproduced here), *Abbate* discloses a real-time inertial motion capture system that uses IMU units comprising MEMS sensors and a custom Extended Kalman filter to determine the orientation of bodily limbs. *Abbate* at 255, 259.



258. Each IMU consists of: (i) three single-axis angular rate gyroscopes; (ii) one three-axis accelerometer; and (iii) one three-axis magnetometer. The IMUs are placed in fixed key points on the human body and the collected data is used in an Extended Kalman filter. *Id.* at 255–256.

259. As *Abbate* discloses, "the sensor configuration makes a complete nine degree-of-freedom (9 DOF) inertial measurement system" where a microcontroller collects data from the sensors "to perform the EKF algorithm." *Id.* at 256. The Extended Kalman filter is used as a sensor fusion algorithm so that the system is able to use "several kinds of sensors." *Id.* In this way, the "characteristics of one type of sensor avoid overcoming the limitations of other sensors." *Id.* at 257.

260. Specifically, as shown in Figures 6 and 8 of *Abbate* (reproduced below), *Abbate* discloses performing sensor fusion using a recursive, quaternion-based Extended Kalman filter.

Figure 6 of *Abbate*	**Figure 8 of *Abbate***
 Fig.6. Flow diagram of the implemented quaternion based EKF.	

261. The Extended Kalman filter comprises two steps. As shown in Figures 6 and 8, in the first stage, a current state estimation is calculated using the angular velocities measured from the gyroscopes. *Id.* at Fig. 8, 258.

262. In the second stage, the Extended Kalman filter implements a two-step correction process in which: (i) acceleration data is used to correct the roll and pitch of the estimated orientation and (ii) magnetic field data is used to correct the yaw of the estimated orientation. *Id.* These "measurement update" equations are used to get an improved estimated orientation. *Id.* at 257.

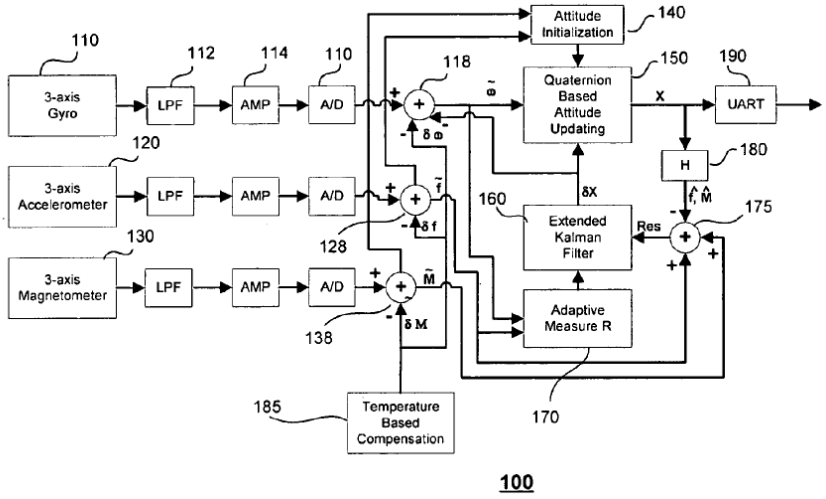
263. Although *Abbate* discloses that quaternions "are used to represent space orientation in order to avoid computational efficiency and avoid singularities," it explicitly states that after the Extended Kalman filter has run, the "computed quaternions could be translated into Roll, Pitch, and Yaw angles" by using transformation equations. *Id.* at 258.

C. U.S. Patent Pub. No. 2005/0240347 to Yang, et al.

264. I have reviewed U.S. Patent Application Publication No. 2005/0240347, entitled "Method and Apparatus for Adaptive Filter Based Attitude Updating" ("*Yang*"). The *Yang* Patent Application Publication was published on October 27, 2005.

265. *Yang* discloses a system that provides an error estimate for an initial attitude (i.e., orientation) using an Extended Kalman filter. The Extended Kalman filter is adaptable based on whether the device is undergoing acceleration. *Yang* at Abstract. The estimated error obtained by the Extended Kalman filter may be used to update the initial orientation calculation. *Id.* ¶¶ 18–19, 39, 107, 112. The basic mechanisms of the system are based on the principles of a Strapdown Inertial Navigation System. *Id.* ¶¶ 13, 30.

266. As shown in Figure 1 of *Yang* (reproduced below), *Yang* discloses a device composed of (among other components): (i) a three-axis gyroscope (110); (ii) a three-axis accelerometer (120); (iii) a three-axis magnetometer (130); and (iv) an Extended Kalman filter (160).



267. *Yang* discloses that when a system is not accelerating, the pitch and roll angles of the body frame of an IMU may be calculated based on the gravity vector. *Id.* ¶ 14. However, as *Yang* further discloses, this method results in errors when the system is accelerating. *Id.* To compensate for this problem, *Yang* discloses an attitude determination device with an Extended Kalman filter that accounts for the "acceleration mode" of the device (i.e., whether the system is or is not accelerating). *Id.* The Extended Kalman filter is provided with an adaptive filter to estimate the errors and sensor bias of the orientation obtained by the device. *Id.* ¶¶ 14, 46.

268. Specifically, as shown in Figure 4 of *Yang* (reproduced below), *Yang* discloses a method by which data from the sensors (gyroscopes, accelerometers, and magnetometers) is measured and then filtered. *Id.* at Fig. 4, ¶¶ 116–117. The Extended Kalman filter is then adapted based on the current acceleration mode. *Id.* at Fig. 4, ¶ 117. Once the Kalman filter is adapted based on the current acceleration mode, it estimates "attitude error and gyro bias" as shown in step 440 of Figure 4. *Id.* ¶ 117. A correction is applied using this error and the corrected orientation is then output. *Id.* ¶ 118.

269. Figure 5 of *Yang* (also reproduced below) depicts the Kalman filtering step disclosed in step 440 of Figure 4 in more detail. The Extended Kalman filter is first initialized

with an initial error estimate. *Id.* at Fig. 5, ¶ 119. The attitude update module is used to generate an updated attitude. *Id.* at Fig. 5, ¶ 120. The updated attitude is then used to "produce a predicted acceleration and heading (f and M) and determine a residual (Res)." *Id. Yang* discloses that this attitude update is performed using quaternions for calculation efficiency. *Id.* at Figs. 4, 5, 6, ¶¶ 19, 26, 39–45, 107, 112, 118, 120, 122–124.

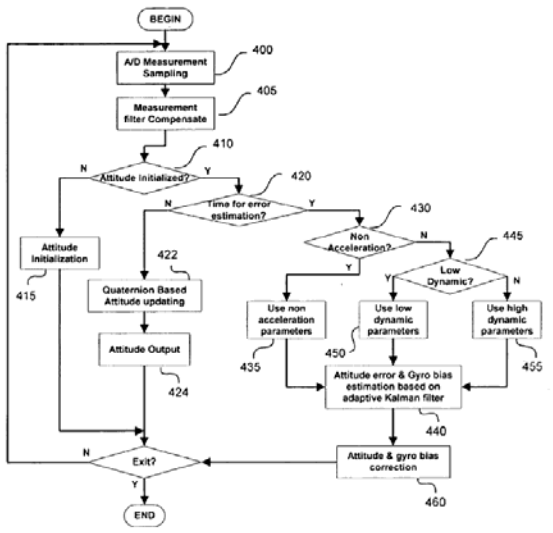
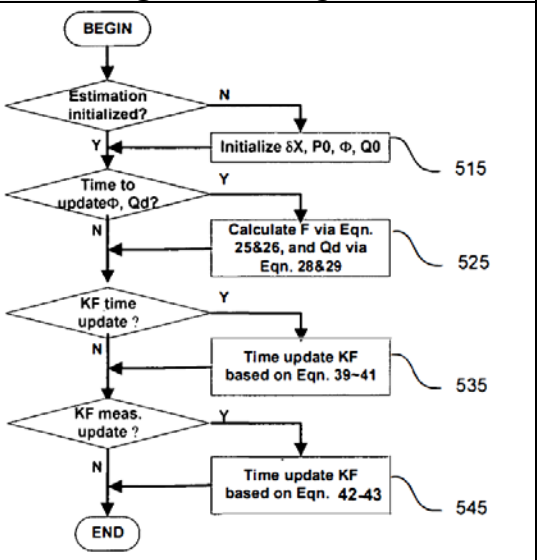
Figure 4 of *Yang*	Figure 5 of *Yang*
	

FIG. 4

270. The residual value (Res) consists of the differences between a measured and a predicted acceleration and a measured and a predicted heading and is used to determine the Kalman filter's error estimates. *Id.* at Fig. 5, ¶¶ 111, 119–121. The measured and predicted axial accelerations are used to update the Kalman filter's error estimate. This error estimate can be used as a correction value to generate a more accurate orientation. *Id.* at Figs. 4, 5, 6, ¶¶ 116–130. The updated attitude can then be recursively fed back into the algorithm. *Id.* at Fig. 4.

D. CH Robotics CHR-6dm System

271. I have reviewed a number of materials relating to the CH Robotics CHR-6dm ("CHR-6dm").

272. These materials include:

- CH Robotics CHR-6dm Attitude and Heading Reference System Product Datasheet (Revision 1.0);
- "CHR6dm Orientation Sensor from CH Robotics" Video (published March 10, 2010), *available at* https://www.youtube.com/watch?v=SUErVK7ix68; and
- Excerpts from the CHR-6dm AHRS firmware v1.0, produced as SAM_CYWEE_PA00002436.

273. I understand that CH Robotics offered the CHR-6dm for sale for the first time in January of 2010.

274. The CHR-6dm is an orientation sensor that uses an Extended Kalman filter to combine data from onboard accelerometers, gyroscopes, and magnetic sensors to produce yaw, pitch and roll angle estimates. CHR-6dm Datasheet at 1. The CHR-6dm utilizes a continuous two-step Extended Kalman filter, where "rate gyro measurements are used to drive the prediction step, and the accelerometer and magnetometer are used for drift correction in the update step." *Id.* at 8. In the drift correction, "[o]n average, the accelerometers measure the gravity vector. The EKF 'knows' which way is down by observing the direction of the gravity vector." *Id.* at 9.

275. The basic steps used in the Extended Kalman filter are detailed in the CHR-6dm firmware code. Specifically, in the chr6dm_states.c file, the Extended Kalman filter is executed in the EKF_EstimateStates function (reproduced below):

EKF_EstimateStates Function from CHR-6dm Firmware

```
void EKF_EstimateStates( AHRS_states* estimated_states, RawSensorData* sensor_data)
{
        static int initialized = 0;

        if( !initialized )
        {
//              EKF_InitFromSensors ( estimated_states, sensor_data );
                EKF_Init( estimated_states );
```

```
                initialized = 1;
        }

        // Run EKF prediction step
        EKF_Predict( estimated_states, sensor_data );

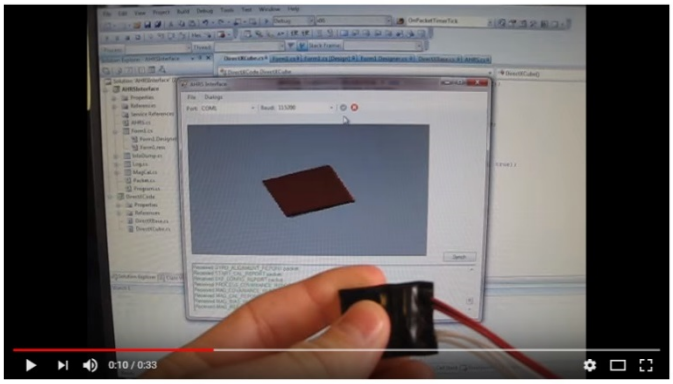
        // Run EKF update step
        EKF_Update( estimated_states, sensor_data );
}
```

In the above code:

- The EKF_InitFromSensors function uses sensor data to fill an initial state estimate structure;
- The EKF_Predict function uses rate gyros to make a new orientation estimate; and
- The EKF_Update function uses the accelerometers to correct pitch and roll errors and magnetic sensors to correct yaw errors.

276. The CHR-6dm can be configured to transmit both raw sensor data and angle estimates over a microcontroller known as a TTL ("transistor-transistor logic") UART ("universal asynchronous receiver and transmitter.").

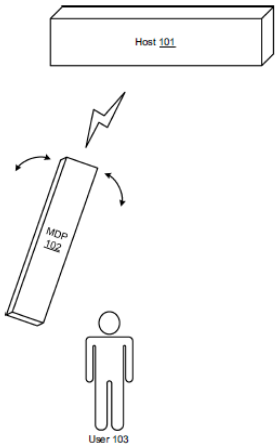
277. As shown in a screenshot from the "CHR6dm Orientation Sensor from CH Robotics" video (reproduced below), the calculated orientation of the device can be translated directly onto a display.



E. U.S. Patent No. 8,515,707 to Joseph

278. I have reviewed U.S. Patent No. 8,515,707 to Joseph ("*Joseph*"). The *Joseph* Patent was issued on August 20, 2013. It was filed on May 6, 2009, and claims priority to Provisional Application No. 61/143,133 filed on January 7, 2009.

279. I have reviewed Provisional Application No. 61/143,133, which is substantively identical to the *Joseph* specification. Accordingly, in my opinion, *Joseph* is entitled to a priority date of January 7, 2009.



280. *Joseph* discloses a "multi-dimensional pointing device," which is described as "a device that may be freely moved in space (e.g., in one, two, or three dimensions) to position a cursor in a user interface of a computer system or other electronic devices." *Joseph* at 1:39–43. The pointing device is "sensitive to six degrees of freedom: x, y, z, yaw, pitch and roll." *Id.* at 4:1–2.

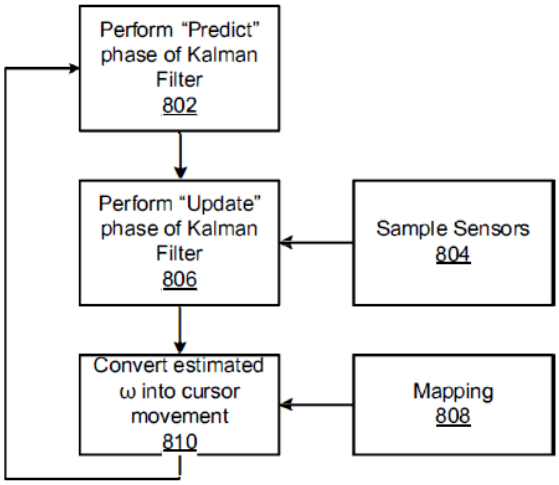
281. As shown in Figure 1 of *Joseph* (reproduced here), "a user 103 can use the multi-dimensional pointing device 102 to issue commands to the host system 101, control objects in the user interface of the host system 101, and/or position objects in the user interface of the host system 101." *Id.* at Fig. 1, 3:62–66.

282. The 3D pointing device contains two or more accelerometers (each of which may either be a two-axis accelerometer or a 3-axis accelerometer) and one or more magnetometers (each of which may either be a two-axis magnetometer or a three-axis magnetometer). *Id.* at Fig. 2, 5:33–36; 5:39–42.

283. Specifically, *Joseph* states that measurements from the multi-dimensional pointing device's accelerometers and magnetometers are used in an Extended Kalman filter algorithm to determine the orientation of the multi-dimensional pointing device. *Id.* at Fig. 8,

12:48–13:15.

284. Figure 8 of *Joseph* (reproduced here) is a process flow diagram showing how *Joseph*'s Extended Kalman filter operates. *Joseph* describes that "[i]n the predict phase (802), an estimated state of the Kalman filter (which can also be considered to be a state of the device) from the previous timestep [(i.e., iteration of the Kalman filter)] is used to produce a predicted estimate of the state (e.g., a 'predicted state') at a current timestep." *Id.* at 12:60–64. In the "update phase" (806), the acceleration and magnetic readings are used to correct the predicted state at current time T to produce an "updated state. This updated state is them used as the estimated state in the next timestep. *Id.* at 12:65–13:15.



XIII. THE ASSERTED CLAIMS OF THE '438 PATENT ARE RENDERED OBVIOUS BY THE PRIOR ART

A. *Luo* in view of *Abbate* render obvious Claims 1, 3, 4, 5, 14, 15, 16, 17, and 19 of the '438 Patent

1. Claim 1

a. [Element 438.1.0] "A three-dimensional (3D) pointing device subject to movements and rotations in dynamic environments, comprising:"

285. I understand that neither Samsung nor CyWee has argued that the preamble of Claim 1 is limiting. However, to the extent that the preamble is considered limiting, in my opinion, *Luo* in view of *Abbate* discloses a 3D pointing device having the features recited in the remaining elements of this claim.

286. The specification of the '438 Patent describes a "three-dimensional (3D) pointing

device" as a device "for detecting motions of the device and translating the detected motions to a cursor display such as a cursor pointing on the screen 122 of a 2D display device 120." '438 Patent at 1:29–33; 53–62.

287. Consistent with its plain and ordinary meaning, *Luo* discloses a "three-dimensional (3D) pointing device" that is "subject to movements and rotations in dynamic environments." Specifically, *Luo* disclose a digital writing instrument that is used to "capture and record human handwriting or drawing motions in real-time based on a MEMS Micro Inertial Measurement Unit (μIMU)[.]" *Luo* at Fig. 3, 909.

288. In my opinion, *Luo*'s digital writing instrument is a "3D pointing device" as claimed in the '438 Patent because it is a device that detects the motions of the device and translates the detected motions to perform a pointing function.

289. Specifically, *Luo* discloses that each digital writing instrument is affixed with a μIMU "sensing system" (MAG-μIMU) containing accelerometers, gyroscopes and magnetometers that are used "to measure the inertial and magnetic information in the instrument's body frame." *Id.* The readings from these sensors are input into an Extended Kalman filter that calculates the orientation of the instrument, while accounting for sensor bias and minimizing noise. *Id.* at Figs. 1, 4, 911–912.

290. *Luo* discloses that during hand motions, the "filter tracks the real-time attitude of the pen with sensor bias separation and sensor random noise minimization." *Id.* at 910. In this way, "any 2D human handwriting is recorded in real time if the pen touches the white board plane." *Id.*

b. [Element 438.1.1] "a housing associated with said movements and rotations of the 3D pointing device in a spatial pointer reference frame"

291. In my opinion, *Luo* discloses these features. As shown in Figure 3 of *Luo* (reproduced here), *Luo* discloses that the digital writing instrument is enclosed entirely in a housing. This housing is "associated with said movements and rotations of the 3D pointing device in a spatial pointer reference frame."

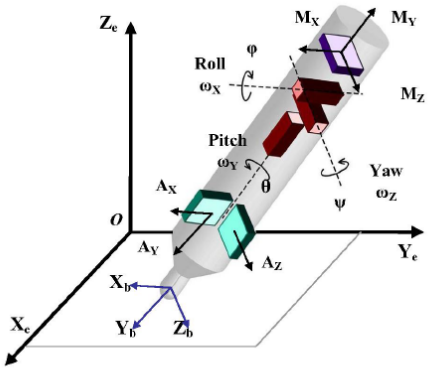


Figure 3. The MAG-μIMU System Structure for a wireless digital writing instrument.

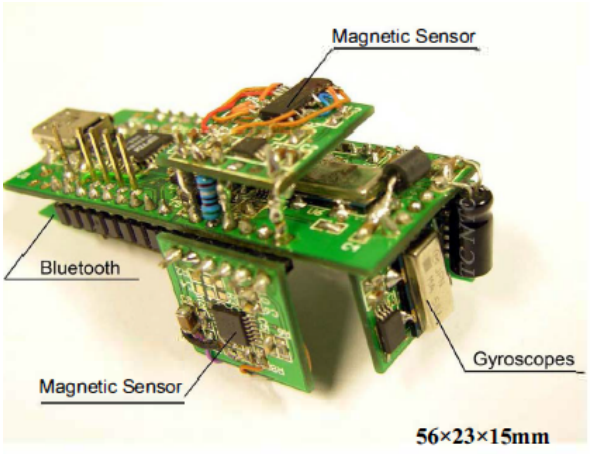
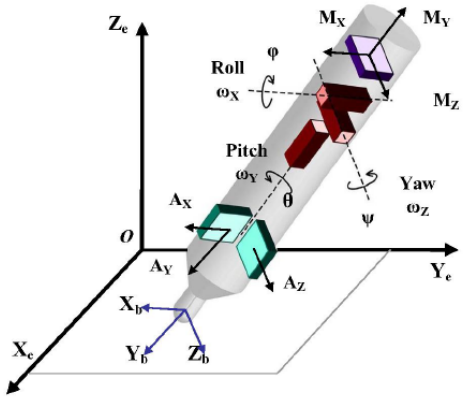
292. As I discussed in Section VIII, I understand that the parties have agreed that the term "spatial pointer reference frame" should be construed as a "frame of reference associated with the 3D pointing device, which always has its origin at the same point in the device and in which the axes are always fixed with respect to the device."

293. Consistent with this description, *Luo* discloses that the digital writing instrument ("3D pointing device") is associated with the movements and rotations of the instrument in the "body reference frame." *Id.* at Fig. 3, 910.

294. A POSA would understand *Luo*'s "body reference frame" to be a spatial pointer reference frame as construed by both parties. Specifically, both *Luo*'s body reference frame and the spatial pointer reference frame are frames of reference defined by an origin within or on the surface of body of the device with fixed axes extending from that origin around which the device rotates. This is further confirmed in Figure 3 of *Luo*, which depicts the roll, pitch, and yaw angles being defined as rotations of the housing about these axes.

c. [Element 438.1.2] "a printed circuit board (PCB) enclosed by the housing;"

295. In my opinion, *Luo* discloses these features. As shown in Figures 2 and 3 of *Luo* (reproduced below), *Luo*'s digital writing instrument comprises a printed circuit board affixed with sensors that are enclosed by a physical housing.

Figure 2 of *Luo*	**Figure 3 of *Luo***
	 Figure 3. The MAG-µIMU System Structure for a wireless digital writing instrument.

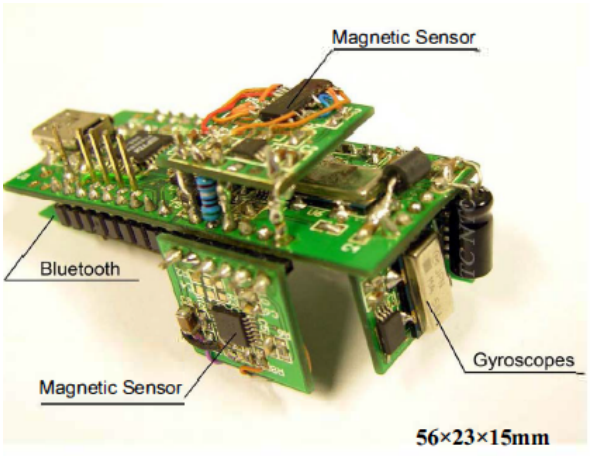
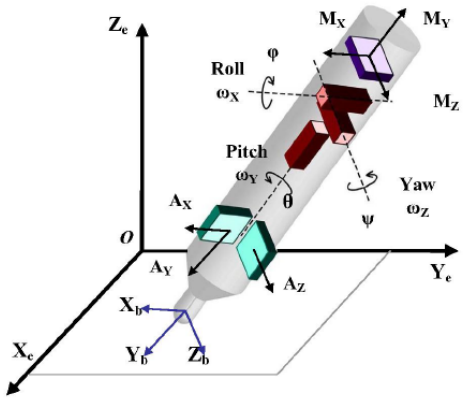
296. Specifically, Figure 2 of *Luo* depicts the system implemented on a PCB using "four-layer printed circuit board techniques." *Id.* at 910. As shown in Figure 3 of *Luo*, the PCB is then incorporated into the digital writing instrument by affixing it into the interior of the instrument and then enclosing it in the instrument's housing.

d. [Element 438.1.3] "a six-axis motion sensor module attached to the PCB,"

297. In my opinion, *Luo* discloses these features. Specifically, *Luo* discloses a MAG-µIMU sensing system that integrates "3D accelerometers and 3D gyroscopes with strapdown installation." *Id.* at 910.

298. *Luo* discloses that the sensors of the MAG-µIMU sensing system are physically attached to a PCB. As shown in Figures 2 and 3 of *Luo* (reproduced below), the sensors are directly attached to the PCB and the MAG-µIMU is then physically incorporated into the digital

writing instrument.

Figure 2 of *Luo*	Figure 3 of *Luo*
	 Figure 3. The MAG-µIMU System Structure for a wireless digital writing instrument.

299. While *Luo* does not explicitly show the accelerometers being physically attached to the PCB in Figure 2, it would have been obvious to a POSA at the time of the alleged invention to modify *Luo*'s system/process to implement such features in the view of the teachings of *Luo* and the knowledge of a POSA.

300. Specifically, *Luo* discloses that the µIMU integrates both the accelerometers and gyroscopes with strapdown installation. *Id.* at 910. A POSA would have recognized that the accelerometer would be attached to the PCB in the same way and for the same reasons that the gyroscopes and magnetometers would be attached to the PCB—in order to couple them onto a circuit board and incorporate them into the digital writing instrument.

e. [Element 438.1.4] "comprising a rotation sensor for detecting and generating a first signal set comprising angular velocities ω_x, ω_y, ω_z associated with said movements and rotations of the 3D pointing device in the spatial pointer reference frame,"

301. In my opinion, *Luo* discloses these features. *Luo* discloses that the MAG-µIMU sensing system ("six-axis sensor module") contains a rotation sensor ("gyroscope"). *Id.* at Fig. 2, 910. *Luo* further discloses that the "[t]he output signals of . . . the gyroscopes [ω_x, ω_y, ω_z] . . . are

the roll, pitch, [and] yaw angular rates . . . ." *Id.* at 910. As shown in Figure 3 of *Luo*, these angular rates are associated with the movements and rotations of the digital writing instrument ("3D pointing device") around the axes of the body frame of reference ("spatial pointer reference frame."). *See* Section XIII.A.1.b.

f. [Element 438.1.5] "an accelerometer for detecting and generating a second signal set comprising axial accelerations A_x, A_y, A_z associated with said movements and rotations of the 3D pointing device in the spatial pointer reference frame; and"

302. In my opinion, *Luo* discloses these features. *Luo* discloses that the MAG-μIMU sensing system ("six-axis sensor module") contains an accelerometer. *Id.* at 910. *Luo* further discloses that "[t]he output signals of the accelerometers [A_x, A_y, A_z] . . . are the body frame accelerations . . . ." *Id.* As shown in Figure 3 of *Luo*, these accelerations are associated with the movements and rotations of the digital writing instrument ("3D pointing device") around the axes of the body frame of reference ("spatial pointer reference frame."). *See* Section XIII.A.1.b.

g. "a processing and transmitting module, comprising a data transmitting unit electrically connected to the six-axis motion sensor module for transmitting said first and second signal sets thereof and a computing processor for receiving and calculating said first and second signal sets from the data transmitting unit, communicating with the six-axis motion sensor module to calculate a resulting deviation comprising resultant angles in said spatial pointer reference frame by utilizing a comparison to compare the first signal set with the second signal set whereby said resultant angles in the spatial pointer reference frame of the resulting deviation of the six-axis motion sensor module of the 3D pointing device are obtained under said dynamic environments, wherein the comparison utilized by the processing and transmitting module further comprises an update program to obtain an updated state based on a previous state associated with said first signal set and a measured state associated with said second signal set; wherein the measured state includes a measurement of said second signal set and a predicted measurement obtained based on the first signal set without using any derivatives of the first signal set."

303. I will discuss the features of this element below in two parts.

(1) [Element 438.1.6] "a processing and transmitting module, comprising a data transmitting unit electrically connected to the six-axis motion sensor module for transmitting said first and second signal sets thereof and a computing processor for receiving and calculating said first and second signal sets from the data transmitting unit,"

304. In my opinion, the claim language of the '438 Patent does not provide guidance on the meaning of the terms "processing and transmitting module," "data transmitting module," or "computing processor" beyond the functions they perform. The '438 Patent specification similarly broadly describes a module comprising a "data transmitting unit" and "processor," whereby the signals from the six-axis sensor module are transmitted via the data transmitting unit to the processor. '438 Patent at 9:42–49.

305. In my opinion, *Luo* discloses components that perform the same functions as the claimed "processing and transmitting module." Specifically, *Luo* discloses that in the MAG-μIMU, "[t]he output signals of the accelerometers [A_x, A_y, A_z] and the gyroscopes [ω_x, ω_y, ω_z] . . . are measured directly" with the "microcontroller." *Luo* at 910.

306. Specifically, *Luo* discloses a "serial Bluetooth transceiver" that is connected to the microcontroller. *Id.* at 910. The digitized sensor measurement readings are read from the microcontroller to the Bluetooth transceiver and then transmitted via the Bluetooth transceiver to a computer, PDA, or cell-phone. The computer, PDA, or cell phone receives the digitized angular velocity and acceleration data from the Bluetooth module and processes the data using an Extended Kalman filter that calculates the 3D pointing device's attitude taking into account sensor biases. *Id.* at 909–911; 913–914.

307. Accordingly, *Luo* discloses the claimed "processing and transmitting module," whereby: (i) the Bluetooth transceiver ("data transmitting unit") is electrically connected to the sensors of the six-axis sensor module; (ii) the Bluetooth transceiver transmits the angular

velocity and acceleration data to a computer processor; which then (iii) receives these signals to calculate an orientation.

308. *Luo*'s description of a Bluetooth transceiver that transmits sensor signals to a processor is also consistent with how the "processing and transmitting module" is described in the '438 Patent. '438 Patent at 9:42–46 ("[T]he signals from the six-axis motion sensor module 502 may then be transmitted via the data transmitting units 546, 552 to the computing processor 554 via wired or wireless communication including for example IEEE 802.11 standards or Bluetooth.").)

(2) [Element 438.1.7] "communicating with the six-axis motion sensor module to calculate a resulting deviation comprising resultant angles in said spatial pointer reference frame by utilizing a comparison to compare the first signal set with the second signal set whereby said resultant angles in the spatial pointer reference frame of the resulting deviation of the six-axis motion sensor module of the 3D pointing device are obtained under said dynamic environments, wherein the comparison utilized by the processing and transmitting module further comprises an update program to obtain an updated state based on a previous state associated with said first signal set and a measured state associated with said second signal set; wherein the measured state includes a measurement of said second signal set and a predicted measurement obtained based on the first signal set without using any derivatives of the first signal set."

309. In my opinion, *Luo* in view of *Abbate* discloses these features.

310. As I explain in Section XV.A.2, the '438 Patent does not describe the limitation of "utilizing a comparison to compare the first signal set with the second signal set."

311. Even more ambiguously, the '438 Patent goes on to recite that the "comparison" that is utilized comprises an "update program" that is used to obtain an "updated state" that is based on: (i) a "previous state" associated with said first signal set and (ii) a "measured state" associated with said second signal set.

312. The "measured state" is defined to include both the measurement of the second signal set and "a predicted measurement obtained based on the first signal set without using any derivatives of the first signal set."

313. I understand that the parties have agreed that this predicted measurement comprises "predicted axial accelerations calculated using the angular velocities without computing derivatives of said angular velocities (i.e. angular accelerations)." *See* Section VIII.

314. I further understand that CyWee has alleged that the "state" of the "3D pointing device" is generally some value used to describe the device at a specific point in time. *See e.g.*, CyWee's Opening Claim Construction Brief, Dkt. No. 66 at 9; Plaintiff's Markman Slides at 30.

315. As I explain in Sections XV.A.2 and XV.A.5, the '438 Patent does not describe how to: (i) obtain predicted axial accelerations or (ii) perform a comparison between angular velocities, axial accelerations and predicted axial accelerations. As I explain in Sections XV.A.2 and XV.A.5, any such comparison is mathematically impossible and would at best produce a meaningless result.

316. I understand that CyWee and its experts have claimed that this limitation is met by an Extended Kalman filter or something like an Extended Kalman filter and an "indirect" comparison between angular velocities and axial accelerations is possible by using an Extended Kalman filter and representing the orientation in quaternion format, as allegedly shown in Equations 5–11 of the '438 Patent.

317. I understand that CyWee and its experts have claimed that the "predicted measurement" is the direction of gravity obtained from a second quaternion representing orientation, as allegedly disclosed in Equations 2–4 of the '438 Patent. Plaintiff's Markman Slides at 30. However, because of the lack of guidance in the '438 Patent regarding the precise

meaning of a "predicted acceleration," in my opinion, it is unclear what the scope of the claim term is beyond that it is some predicted acceleration value.

318. I do not agree with CyWee's claims above. However, taking CyWee's own representations as true, this limitation covers a quaternion-based Extended Kalman filter that uses angular velocities to predict an object's orientation that is then corrected using gravitational accelerations (or some "predicted" acceleration value). Accordingly, if taken as true, in my opinion, *Luo* in view of *Abbate* disclose these features.

319. In particular, *Luo* states that its Extended Kalman filter receives measurements from the gyroscopes and magnetometers and calculates the orientation of the digital writing instrument while minimizing the noise and bias error from each of the sensors. *Luo* at 912. The Extended Kalman filter uses a two-stage process. In the first stage, the attitude (i.e., orientation) of the device is estimated based on the gyroscope readings (i.e., the "current state"). *Id.* at Fig. 4, 911. In the second stage, the difference between an estimated and measured Earth magnetic vector is implemented as feedback to correct the errors from the gyroscope readings. *Id. Luo* discloses that these attitude calculations are "based on a quaternion." *Id.* at 912.

320. *Luo* does not expressly disclose that its quaternion-based Extended Kalman filter corrects its orientation estimation using measured and "predicted" accelerations. However, it would have been obvious to a POSA at the time of the alleged invention to modify *Luo*'s system/process to implement such features in view of the teachings of *Abbate*.

321. *Abbate* discloses a real-time inertial motion capture system using inertial measurement units (IMUs) that are used to record and reconstruct human motion. *Abbate* at 255. The IMUs contain: (i) three single-axis angular rate gyroscopes; (ii) one three-axis accelerometer; and (iii) one three-axis magnetometer. *Id.* at 256. The IMUs are placed on fixed

key points on the human body. *Id.* The readings from these IMUs are fed into a centralized collection point and the orientations of the key points are calculated using a quaternion-based Extended Kalman filter. *Id.* at 255–256. In this way, the system is able to use "several kinds of sensors" so that the "characteristics of one type of sensor avoid overcoming the limitations of other sensors." *Id.* at 257.

322. Figure 6 of *Abbate* (reproduced below) depicts the sensor-fusion process disclosed in *Abbate*'s quaternion-based Extended Kalman filter. As shown in Figure 6, the Extended Kalman filter weighs the three sources of information from the gyroscopes, accelerometers and magnetometers appropriately in order to provide an accurate estimate of orientation and eliminate noise. *Id.* at Fig. 6, 258. In the Extended Kalman filter, the orientation is first estimated using angular rate velocities. The Extended Kalman filter then implements a two-step correction process in which: (i) acceleration data is used to correct roll and pitch angles and (ii) magnetic field data is used to correct the yaw angle. *Id.*

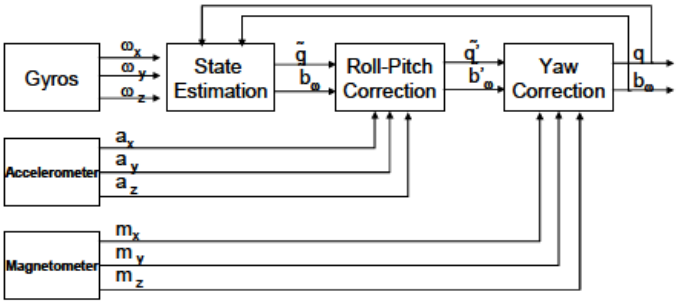


Fig.6. Flow diagram of the implemented quaternion based EKF.

323. Specifically, in *Abbate*, the Kalman filter is initialized with an initial state (i.e., orientation) estimate, and that initial state estimate is combined with the state estimation updated in the prior iteration of the Kalman-filter loop (i.e., the "update[d] state estimation with measurement zk" shown in that figure). *Id.* at Fig. 8. This combined value is depicted as the "state estimation" in Figure 6.

324. As shown in Figure 6, the "state estimation" is modified by angular velocity measurements from the gyroscopes, which generates a quaternion representing the current state

of the device. The roll and pitch components of the quaternion representing the device's current state are then further corrected by the measured accelerations (or the "measured state" as shown in the "roll-pitch correction" step in Figure 6) to update the state estimation used in that iteration of the Kalman-filter loop (i.e., the "updated state"). *Id.* at Fig. 6, 258. Those corrections are based on acceleration measurements from the accelerometers in combination with an error estimate associated with the "state estimation" (i.e., the "predicted measurement"). *Id.* The "updated state" is then fed recursively back into the Extended Kalman filter and used in the next time iteration so that it becomes the "previous state." *Id.* at Figs. 6, 8, 257–258.

325. *Abbate* further discloses the use of a non-linear function that mirrors Equations 2–4 of the '438 Patent (which CyWee discloses meets the "predicted axial accelerations" limitation). *Id.* at 258. Consistent with CyWee's allegation that the acceleration being derived is the gravitational acceleration, "*g*" is defined in *Abbate*'s non-linear function as the gravitational acceleration.

Equations 2–4 in '438 Patent	**Non-Linear Function h(x) in *Abbate***
$Ax=2(q_1q_3-q_0q_2)$ $Ay=2(q_2q_3+q_0q_1)$ $Az=q_0^2-q_1^2-q_2^2+q_3^2$	$h(x)=\begin{bmatrix} 2g(q_1q_3-q_0q_2) \\ 2g(q_2q_3-q_0q_1) \\ g(q_0^2-q_1^2-q_2^2+q_3^2) \\ \arctan\left(\frac{2(q_1q_2+q_0q_3)}{q_0^2-q_1^2-q_2^2+q_3^2}\right) \end{bmatrix}$

326. Consistent with CyWee's allegations, *Abbate*'s non-linear function would obtain "predicted axial accelerations" without taking the derivatives of the angular velocities in the same way that Equations 2–4 in the '438 Patent would.

327. Although *Abbate* discloses the use of measurements from a magnetometer, which are used to correct the yaw component of the state estimation, a POSA would have understood that the algorithm disclosed in *Abbate* could be modified to exclude correction of the yaw

component. If correction of the yaw component is not performed, measurements from the magnetometer are not necessary for the algorithm to function.

328. In view of these teachings of *Abbate*, a POSA would have been motivated to configure *Luo*'s system/process so that *Luo*'s Extended Kalman filter utilizes accelerometer data and the techniques disclosed in *Abbate*'s Extended Kalman filter in order to provide a more accurate estimate of orientation. For example, *Luo* specifically discloses that its Extended Kalman filter can be modified to use other sensors for feedback, including accelerometers. *Luo* at 909, 914. Indeed, *Luo* specifically contemplates this combination stating that for "future work" the "Kalman filter will be expanded by the accelerometers in the measurement update" and that this implementation will be "similar to the magnetometer feedback" which will help in "eliminating magnetic interference." *Id.* at 914.

329. In addition, *Abbate* explicitly discloses the advantages of using an accelerometer, noting that the accelerometer (and magnetometer) provides "a noisy and disturbed but drift-free measurement of orientation." *Abbate* at 257.

330. A POSA would have recognized that such a modification would have been a straightforward combination of known technologies by known methods without changing their respective functions to achieve a predictable result, and would have been well within the capabilities of such a person.

331. Indeed, *Luo* already discloses integrating gyroscopes and accelerometers together using strapdown installation. *Luo* at 910. *Luo* further discloses that in prior work, the Extended Kalman filter was implemented using accelerometers for feedback. *Id.* at 912. A POSA would have recognized that configuring *Luo*'s system/process to include an accelerometer reading as an input to an Extended Kalman filter and to use the sensor fusion techniques disclosed in *Abbate*,

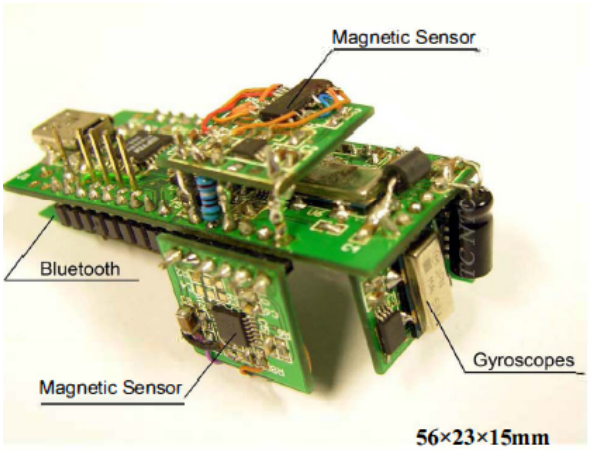
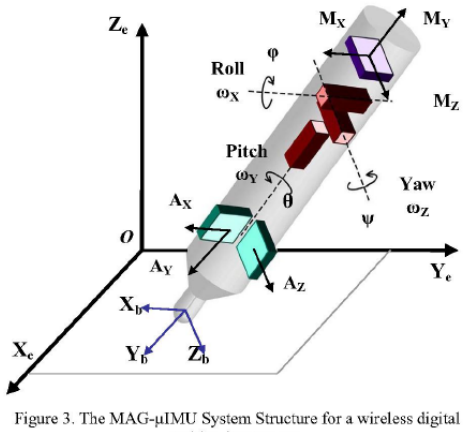
would merely have been an obvious extension of *Luo*'s system and well within the capabilities of such a person.

332. Furthermore, a POSA would have been encouraged to look to *Abbate* to complement the teachings of the *Luo* because these references are all directed to the same technical field and describe solutions to similar problems in the field. For example, each reference describes systems to calculate orientation using a combination of gyroscopes, accelerometers and magnetometers by using a quaternion-based Extended Kalman filter. *Luo* at 909–912; *Abbate* at 255–258.

2. Claim 3

a. [Element 438.3] "The 3D pointing device of claim 1, wherein the PCB enclosed by the housing comprises at least one substrate having a first longitudinal side configured to be substantially parallel to a longitudinal surface of the housing."

333. In my opinion, *Luo* in view of *Abbate* discloses these features. As shown in Figures 2 and 3 of *Luo* (reproduced below), *Luo* discloses a printed circuit board enclosed by a housing. As shown in Figure 3, the printed circuit board can be configured in such a way that one of the substrates has a first longitudinal side that is substantially parallel to the housing.

Figure 2 of *Luo*	**Figure 3 of *Luo***
	 Figure 3. The MAG-μIMU System Structure for a wireless digital writing instrument.

3. Claim 4

a. [Element 438.4] "The 3D pointing device of claim 1, wherein the spatial pointer reference frame is a reference frame in three dimensions; and wherein said resultant angles of the resulting deviation includes yaw, pitch and roll angles about each of three orthogonal coordinate axes of the spatial pointer reference frame."

334. In my opinion, *Luo* in view of *Abbate* discloses these features. As shown in Figure 3 of *Luo* (reproduced below), *Luo* discloses that the "body frame" of its writing instrument is a reference frame that is defined in three dimensions. Specifically, as shown in Figure 3, the *x*-axis and *y*-axis represent the first two dimensions, and the *z*-axis defines the third dimension.

335. *Luo* further discloses that the resulting deviation of the device can be represented using Euler angles (as shown in Figure 3's depiction of the yaw, pitch and roll angles). As disclosed in *Luo*, "Euler angles define one orientation motion in three successive rotations: roll, pitch and yaw about the X, Y, and Z axis respectively." *Id.* at 910.

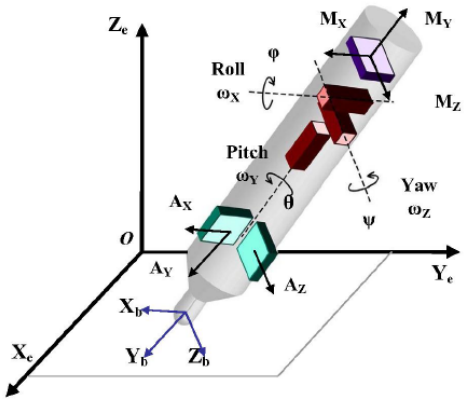


Figure 3. The MAG-μIMU System Structure for a wireless digital writing instrument.

336. Similarly, *Abbate* discloses that while its Extended Kalman filter uses quaternion representations of orientation in order to "improve computational efficiency and avoid singularities," after the EKF is running, "the computed quaternions could be translated into Roll, Pitch, and Yaw angles" through transformation equations. *Abbate* at 258.

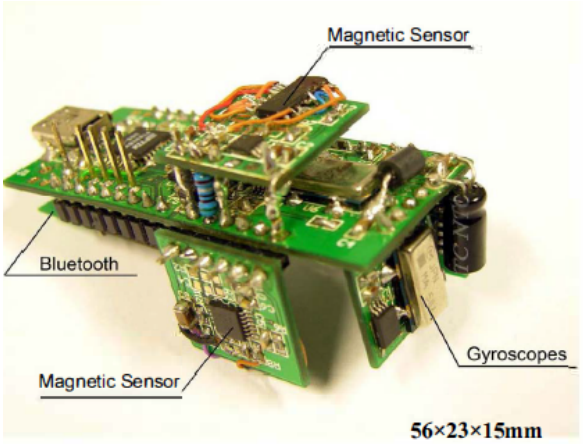
337. In addition, a POSA would have known that the orientation quaternion calculated by *Luo* and *Abbate* would be mathematically equivalent to an Euler angle representation.

4. Claim 5

a. [Element 438.5] "The 3D pointing device of claim 1, wherein the data transmitting unit of the processing and transmitting module is attached to the PCB enclosed by the housing and transmits said first and second signal of the six-axis motion sensor module to the computing processor via electronic connections on the PCB."

338. In my opinion, *Luo* in view of *Abbate* discloses these features. *Luo* discloses that the sensor readings from the accelerometers and gyroscopes are measured with the microcontroller. The microcontroller is connected to a "serial Bluetooth transceiver." The digitized sensor measurement readings are read from the microcontroller to the Bluetooth transceiver and then transmitted via the Bluetooth transceiver to a computer, PDA, or cell-phone. The computer, PDA, or cell phone receives the digitized angular velocity and axial acceleration data from the Bluetooth module and processes the data using an Extended Kalman filter that calculates the 3D pointing device's attitude taking into account sensor biases. *Id.* at 909–911; 913–914.

339. Accordingly, *Luo* discloses the claimed data transmitting unit in the Bluetooth transceiver that is electrically connected to the sensors of the six-axis sensor module. As shown in Figure 2 of *Luo* (reproduced here), the Bluetooth transceiver is coupled to the PCB. The Bluetooth transceiver transmits the angular velocity and axial acceleration data to a computer processor which then receives these signals to calculate an orientation. *Id.* at 909–911; 913–914.



5. Claim 14

a. [Element 438.14.0] "A method for obtaining a resulting deviation including resultant angles in a spatial pointer reference frame of a three-dimensional (3D) pointing device utilizing a six-axis motion sensor module therein and subject to movements and rotations in dynamic environments in said spatial pointer reference frame, comprising the steps of:"

340. I understand that neither Samsung nor CyWee has argued that the preamble of Claim 14 is limiting. However, to the extent that the preamble is considered limiting, in my opinion, *Luo* in view of *Abbate* discloses a method with the recited features.

341. For the reasons I set forth in Section XIII.A.1.a, *Luo* discloses a "three-dimensional (3D) pointing device," consistent with the plain and ordinary meaning of this term. Specifically, *Luo* discloses a digital writing instrument that is used to "capture and record human handwriting or drawing motions in real-time based on a MEMS Micro Inertial Measurement Unit (μIMU)[.]" *Luo* at Fig. 3, 909.

342. For the reasons I set forth in Section XIII.A.1.d, *Luo* further discloses a "six-axis motion sensor module." Specifically, *Luo* discloses a MAG-μIMU sensing system that integrates "3D accelerometers and 3D gyroscopes with strapdown installation." *Id.* at 910.

343. For the reasons I set forth in Section XIII.A.1.g, *Luo* discloses a method for obtaining the deviation of the digital writing instrument ("3D pointing device") in the "spatial pointer reference frame" of the digital writing instrument. Specifically, as I discussed in Section XIII.A.1.g, I understand that CyWee and its experts have claimed that this limitation is met by an Extended Kalman filter or something like an Extended Kalman filter, as allegedly shown in Equations 5–11 of the '438 Patent.

344. I do not agree. However, taking CyWee's own representations as true, Claim 14's method covers a quaternion-based Extended Kalman filter that uses angular velocities to predict

an object's orientation that is then corrected using gravitational accelerations (or some predicted acceleration value).

345. If taken as true, in my opinion, *Luo* in view of *Abbate* disclose these features, as: (i) both *Luo* and *Abbate* disclose the use of quaternion-based Extended Kalman filters for calculating the change in a device's orientation; and (ii) *Abbate* discloses correcting the initial orientation estimation using acceleration data. *See* Section XIII.A.1.g.

b. [Element 438.14.1] "obtaining a previous state of the six-axis motion sensor module; wherein the previous state includes an initial-value set associated with previous angular velocities gained from the motion sensor signals of the six-axis motion sensor module at a previous time T−1;"

346. In my opinion, *Luo* discloses these features. *Luo* discloses a MAG-μIMU sensing system ("six-axis motion sensor module") that integrates "3D accelerometers and 3D gyroscopes with strapdown installation." *Id.* at 910. *Luo* discloses that the output signals of the gyroscope (ω_x, ω_y, ω_z) are read and then used in a recursive Extended Kalman filter.

347. As shown in Figure 4 of *Luo* (reproduced here), the Extended Kalman filter consists of two stages. In the first stage, the attitude of the device is estimated based on the gyroscope readings. *Id.* at Fig. 4, 911. In the second stage, the difference between an estimated and measured Earth magnetic vector is implemented as feedback to correct the errors from the gyroscope readings. *Id.*

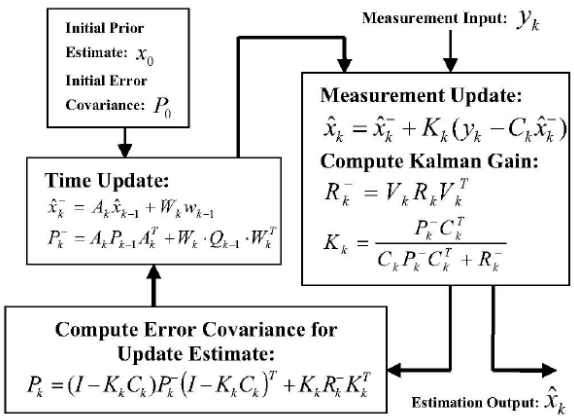


Figure 4. Extended Kalman Filter Algorithm

348. As shown in Figure 4, this updated quaternion is recursively fed back in as the input to the Extended Kalman filter in the next "time update" step.

349. A POSA would have understood the updated quaternion being fed back into the

Extended Kalman filter in *Luo* to be the "previous state" of the six-axis motion sensor module at previous time T-1.

350. A POSA would have understood that *Luo*'s updated quaternion ("previous state") would include "an initial-value set associated with previous angular velocities" as it is composed of the estimated orientation of the digital writing instrument based on the gyroscope readings that is then corrected using the difference between the estimated and measured Earth magnetic vector. *Id.* at Fig. 4, 911.

c. [Element 438.14.2] "obtaining a current state of the six-axis motion sensor module by obtaining measured angular velocities ω_x, ω_y, ω_z gained from the motion sensor signals of the six-axis motion sensor module at a current time T;"

351. In my opinion, *Luo* discloses these features. *Luo* further discloses a MAG-μIMU sensing system ("six-axis motion sensor module") that integrates "3D accelerometers and 3D gyroscopes with strapdown installation." *Id.* at 910.

352. *Luo* discloses that the output signals of the gyroscope (ω_x, ω_y, ω_z) are read and then used in a recursive Extended Kalman filter. A POSA would understand that the output signals of the gyroscope are the "measured angular velocities" at "current time T" as recited in the claim.

353. As shown in Figure 4 of *Luo* (reproduced here), *Luo* discloses an Extended Kalman filter in which at a first stage, the attitude of the device is estimated based on the gyroscope readings. *Id.* at Fig. 4, 911.

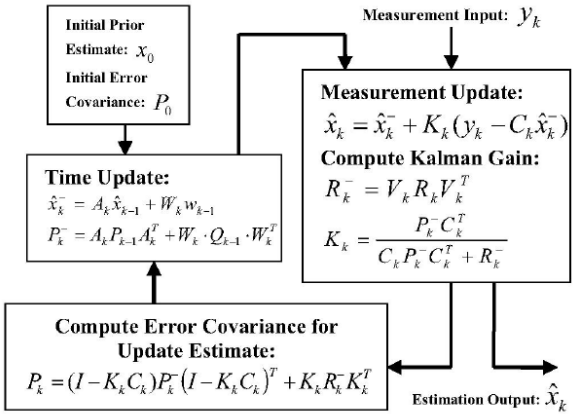


Figure 4. Extended Kalman Filter Algorithm

354. A POSA would understand *Luo*'s initial estimate of the device's attitude to be the

"current state" of the device. As *Luo* discloses, this attitude calculation is based on a quaternion. *Id.* at 34. A POSA would understand that this initial estimate is "obtained" by the "measured angular velocities" because it is estimated based on the readings from the gyroscopes.

d. "obtaining a measured state of the six-axis motion sensor module by obtaining measured axial accelerations Ax, Ay, Az gained from the motion sensor signals of the six-axis motion sensor module at the current time T and calculating predicted axial accelerations Ax′, Ay′, Az′ based on the measured angular velocities ω_x, ω_y, ω_z of the current state of the six-axis motion sensor module without using any derivatives of the measured angular velocities ω_x, ω_y, ω_z; said current state of the six-axis motion sensor module is a second quaternion with respect to said current time T;"

355. I will discuss the features of this element below in three parts.

(1) [Element 438.1.3] "obtaining a measured state of the six-axis motion sensor module by obtaining measured axial accelerations Ax, Ay, Az gained from the motion sensor signals of the six-axis motion sensor module at the current time T and"

356. In my opinion, *Luo* in view of *Abbate* discloses these features. For the reasons I set forth in Section XIII.A.1.d, *Luo* discloses a MAG-μIMU sensing system ("six-axis motion sensor module") that integrates "3D accelerometers and 3D gyroscopes with strapdown installation." *Id.* at 910.

357. *Luo* further discloses reading the output signals from the accelerometers. *Id.* at 910. Although *Luo* does not explicitly disclose using the accelerometer readings in its Extended Kalman filter, it discloses that using accelerometers as feedback was known in the prior art. *Id.* at 912 ("In pervious [sic] work, the attitude extended Kalman filter is implemented using accelerometers for feedback.") It further states that "[f]or future work, the Kalman filter will be expanded by the accelerometers in the measurement update." *Id.* at 914.

358. *Abbate* discloses obtaining the measured accelerometer readings to calculate the orientation of a device. *Abbate* discloses a real-time inertial motion capture system using inertial

measurement units (IMUs) that are used to record and reconstruct human motion. *Abbate* at 255. The IMUs contain: (i) three single-axis angular rate gyroscopes; (ii) one three-axis accelerometer; and (iii) one three-axis magnetometer. *Id.* at 256. The IMUs are placed on fixed key points on the human body. *Id.* The readings from these IMUs are fed into a centralized collection point and the orientations of the key points are calculated using a quaternion-based Extended Kalman filter. *Id.* at 255–256.

359. Figure 6 of *Abbate* (reproduced here) depicts the sensor-fusion process disclosed in *Abbate*'s quaternion-based Extended Kalman filter. As shown in Figure 6, the Extended Kalman filter weighs the three sources of information from the gyroscopes, accelerometers and magnetometers appropriately in order to provide an accurate estimate of orientation and eliminate noise. *Id.* at Fig. 6, 258.

360. In the Extended Kalman filter, the orientation is first estimated using angular rate velocities. The Extended Kalman filter then implements a two-step correction process in which: (i) acceleration data is used to correct roll and pitch angles and (ii) magnetic field data is used to correct the yaw angle. *Id.*

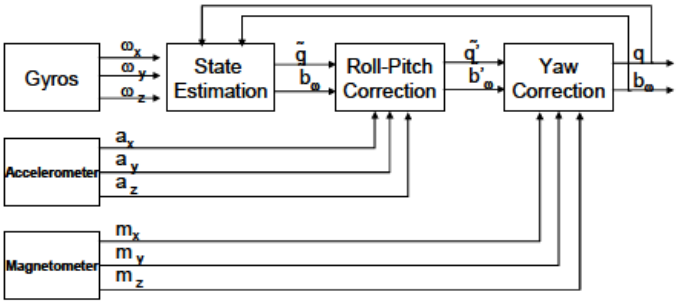


Fig.6. Flow diagram of the implemented quaternion based EKF.

361. Based on CyWee's interpretation of a "measured state," a POSA would understand the measured acceleration readings to be the "measured state." *See* CyWee's Opening Claim Construction Brief, Dkt. No. 66 at 9 ("The second quaternion is used to generate predicted axial accelerations (predicted state), which are compared to the measured accelerations (measured state or second signal set).").

(2) [Element 438.1.4] "calculating predicted axial accelerations Ax′, Ay′, Az′ based on the measured angular velocities ω_x, ω_y, ω_z of the current state of the six-axis motion sensor module without using any derivatives of the measured angular velocities ω_x, ω_y, ω_z;"

362. As I explain in Section XV.A.6, the '438 Patent does not describe how to calculate "predicted axial accelerations Ax′, Ay′, Az′ based on the measured angular velocities ω_x, ω_y, ω_z of the current state of the six-axis motion sensor module without using any derivatives of the measured angular velocities ω_x, ω_y, ω_z."

363. I understand that CyWee and its experts have claimed that the "predicted measurement" is the direction of gravity obtained from a second quaternion representing orientation, as allegedly disclosed in Equations 2–4 of the '438 Patent. Plaintiff's Markman Slides at 30. However, because of the lack of guidance in the '438 Patent regarding the precise meaning of a "predicted acceleration," in my opinion, it is unclear what the scope of the claim term is beyond that it is some predicted acceleration value.

364. As I explain in Section XV.A.6, I do not agree with CyWee's claims. However, taking CyWee's claims as true, *Abbate* discloses the use of a non-linear function that mirrors Equations 2–4 of the '438 Patent which CyWee discloses meets the "predicted axial accelerations" limitation. Consistent with CyWee's allegation that the acceleration being derived is the gravitational acceleration, "*g*" is defined in *Abbate*'s non-linear function as the gravitational acceleration.

Equations 2–4 in '438 Patent	Non-Linear Function h(x) in *Abbate*
$Ax=2(q_1q_3-q_0q_2)$ $Ay=2(q_2q_3+q_0q_1)$ $Az=q_0^2-q_1^2-q_2^2+q_3^2$	$h(x)=\begin{bmatrix} 2g(q_1q_3-q_0q_2) \\ 2g(q_2q_3-q_0q_1) \\ g(q_0^2-q_1^2-q_2^2+q_3^2) \\ \arctan\left(\frac{2(q_1q_2+q_0q_3)}{q_0^2-q_1^2-q_2^2+q_3^2}\right) \end{bmatrix}$

365. Consistent with CyWee's allegations, *Abbate*'s non-linear function would obtain "predicted axial accelerations" without taking the derivatives of the angular velocities in the same way that Equations 2–4 in the '438 Patent would.

366. A POSA would have been motivated to configure *Luo*'s system/process so that *Luo*'s Extended Kalman filter uses the accelerometer data and techniques disclosed in *Abbate*'s Extended Kalman filter for the same reasons described below. *See* Section XIII.A.1.g.

(3) [Element 438.1.5] "said current state of the six-axis motion sensor module is a second quaternion with respect to said current time T;"

367. In my opinion, *Luo* discloses these features. *See* Section XIII.A.5.c.

e. [Element 438.14.6] "comparing the second quaternion in relation to the measured angular velocities ω_x, ω_y, ω_z of the current state at current time T with the measured axial accelerations Ax, Ay, Az and the predicted axial accelerations Ax′, Ay′, Az′ also at current time T;"

368. As I explain in Sections XV.A.3 and XV.A.6, the '438 Patent does not describe how to: (i) obtain predicted axial accelerations or (ii) perform a comparison between angular velocities, axial accelerations and predicted axial accelerations. As I explain in Sections XV.A.3 and XV.A.6, any such comparison is mathematically impossible and would at best produce a meaningless result.

369. I understand that CyWee and its experts have claimed that this limitation is met by an Extended Kalman filter or something like an Extended Kalman filter and an "indirect"

comparison between angular velocities and axial accelerations is possible by using an Extended Kalman filter and representing the orientation in quaternion format, as shown in Equations 5–11 of the ’438 Patent.

370. I understand that CyWee and its experts have claimed that the “predicted measurement” is the direction of gravity obtained from a second quaternion representing orientation, as allegedly disclosed in Equations 2–4 of the ’438 Patent. Plaintiff’s Markman Slides at 30. However, because of the lack of guidance in the ’438 Patent regarding the precise meaning of a “predicted acceleration,” in my opinion, it is unclear what the scope of the claim term is beyond that it is some predicted acceleration value.

371. I do not agree with CyWee’s claims. However, taking CyWee’s own representations as true, this limitation covers a quaternion-based Extended Kalman filter that uses angular velocities to predict an object’s orientation that is then corrected using gravitational accelerations (or some “predicted” acceleration value). Accordingly, if taken as true, in my opinion, *Luo* in view of *Abbate* disclose these features.

372. In particular, *Luo* states that its Extended Kalman filter receives measurements from the gyroscopes and magnetometers and calculates the orientation of the digital writing instrument while minimizing the noise and bias error from each of the sensors. *Luo* at 912. The Extended Kalman filter uses a two-stage process. In the first stage, the attitude (i.e., orientation) of the device is estimated based on the gyroscope readings (i.e., the “current state”). *Id.* at Fig. 4, 911. In the second stage, the difference between an estimated and measured Earth magnetic vector is implemented as feedback to correct the errors from the gyroscope readings. *Id. Luo* discloses that these attitude calculations are “based on a quaternion.” *Id.* at 912.

373. *Luo* does not expressly disclose that its quaternion-based Extended Kalman filter

corrects its orientation estimation using measured and predicted accelerations. However, it would have been obvious to a POSA at the time of the alleged invention to modify *Luo*'s system/process to implement such features in view of the teachings of *Abbate*.

374. *Abbate* discloses a real-time inertial motion capture system using inertial measurement units (IMUs) that are used to record and reconstruct human motion. *Abbate* at 255. The IMUs contain: (i) three single-axis angular rate gyroscopes; (ii) one three-axis accelerometer; and (iii) one three-axis magnetometer. *Id.* at 256. The IMUs are placed on fixed key points on the human body. *Id.* The readings from these IMUs are fed into a centralized collection point and the orientations of the key points are calculated using a quaternion-based Extended Kalman filter. *Id.* at 255–256. In this way, the system is able to use "several kinds of sensors" so that the "characteristics of one type of sensor avoid overcoming the limitations of other sensors." *Id.* at 257.

375. Figure 6 of *Abbate* (reproduced here) depicts the sensor-fusion process disclosed in *Abbate*'s quaternion-based Extended Kalman filter. As shown in Figure 6, the Extended Kalman filter weighs the three sources of information from the gyroscopes, accelerometers and magnetometers appropriately in order to provide an accurate estimate of orientation and eliminate noise. *Id.* at Fig. 6, 258. In the Extended Kalman filter, the orientation is first estimated using angular rate velocities. The Extended Kalman filter then implements a two-step correction process in which: (i) acceleration data is used to correct roll and pitch angles and (ii) magnetic field data is used to correct the yaw angle. *Id.*

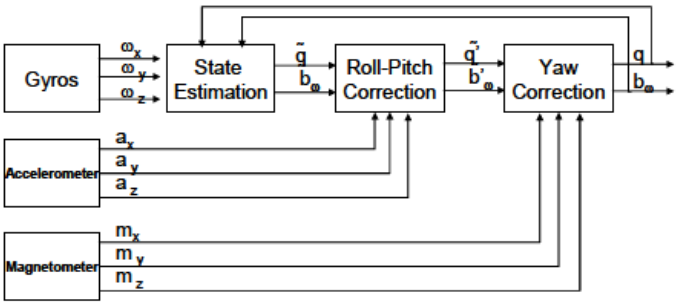


Fig.6. Flow diagram of the implemented quaternion based EKF.

376. Specifically, in *Abbate*, the Kalman filter is initialized with an initial state (i.e., orientation) estimate, and that initial state estimate is combined with the state estimation updated in the prior iteration of the Kalman-filter loop (i.e., the "update[d] state estimation with measurement zk" shown in that figure). *Id.* at Fig. 8. This combined value is depicted as the "state estimation" in Figure 6.

377. As shown in Figure 6, the "state estimation" is modified by angular velocity measurements from the gyroscopes, which generates a quaternion representing the current state of the device. The roll and pitch components of the quaternion representing the device's current state are then further corrected by the measured accelerations (or the "measured state" as shown in the "roll-pitch correction" step in Figure 6) to update the state estimation used in that iteration of the Kalman-filter loop (i.e., the "updated state"). *Id.* at Fig. 6, 258. Those corrections are based on acceleration measurements from the accelerometers in combination with an error estimate associated with the "state estimation" (i.e., the "predicted measurement"). *Id.* The "updated state" is then fed recursively back into the Extended Kalman filter and used in the next time iteration so that it becomes the "previous state." *Id.* at Figs. 6, 8, 257–258.

378. *Abbate* further discloses the use of a non-linear function that mirrors Equations 2–4 of the '438 Patent (which CyWee discloses meets the "predicted axial accelerations" limitation). *Id.* at 258. Consistent with CyWee's allegation that the acceleration being derived is the gravitational acceleration, "*g*" is defined in *Abbate*'s non-linear function as the gravitational acceleration.

Equations 2–4 in '438 Patent	Non-Linear Function h(x) in *Abbate*
$Ax=2(q_1q_3-q_0q_2)$ $Ay=2(q_2q_3+q_0q_1)$ $Az=q_0^2-q_1^2-q_2^2+q_3^2$	$h(x)=\begin{bmatrix} 2g(q_1q_3-q_0q_2) \\ 2g(q_2q_3-q_0q_1) \\ g(q_0^2-q_1^2-q_2^2+q_3^2) \\ \arctan\left(\frac{2(q_1q_2+q_0q_3)}{q_0^2-q_1^2-q_2^2+q_3^2}\right) \end{bmatrix}$

379. Consistent with CyWee's allegations, *Abbate*'s non-linear function would obtain "predicted axial accelerations" without taking the derivatives of the angular velocities in the same way that Equations 2–4 in the '438 Patent would.

380. Although *Abbate* discloses the use of measurements from a magnetometer, which are used to correct the yaw component of the state estimation, a POSA would have understood that the algorithm disclosed in *Abbate* could be modified to exclude correction of the yaw component. If correction of the yaw component is not performed, measurements from the magnetometer are not necessary for the algorithm to function.

381. In view of these teachings of *Abbate*, a POSA would have been motivated to configure *Luo*'s system/process so that the Extended Kalman filter utilizes accelerometer data along with gyroscope data in order to provide a more accurate estimate of orientation. For example, *Luo* specifically discloses that its Extended Kalman filter can be modified to use other sensors for feedback, including accelerometers. *Luo* at 909, 914. Indeed, *Luo* specifically contemplates this combination stating that for "future work" the "Kalman filter will be expanded by the accelerometers in the measurement update" and that this implementation will be "similar to the magnetometer feedback" which will help in "eliminating magnetic interference." *Id.* at 914.

382. In addition, *Abbate* explicitly discloses the advantages of using an accelerometer, noting that the accelerometer (and magnetometer) provides "a noisy and disturbed but drift-free

measurement of orientation." *Abbate* at 257.

383. A POSA would have recognized that such a modification would have been a straightforward combination of known technologies by known methods without changing their respective functions to achieve a predictable result, and would have been well within the capabilities of such a person. Indeed, *Luo* already discloses integrating gyroscopes and accelerometers together using strapdown installation. *Luo* at 910. *Luo* further discloses that in prior work, the Extended Kalman filter was implemented using accelerometers for feedback. *Id.* at 912. A POSA would have recognized that configuring *Luo*'s system/process to include an accelerometer reading as an input to an Extended Kalman filter and to use the sensor fusion techniques disclosed in *Abbate*, would merely have been an obvious extension of *Luo*'s system and well within the capabilities of such a person.

384. Furthermore, a POSA would have been encouraged to look to *Abbate* to complement the teachings of the *Luo* because these references are all directed to the same technical field and describe solutions to similar problems in the field. For example, each reference describes systems to calculate orientation using a combination of gyroscopes, accelerometers and magnetometers by using a quaternion-based Extended Kalman filter. *Luo* at 909–912; *Abbate* at 255–258.

f. [Element 438.14.7] "obtaining an updated state of the six-axis motion sensor module by comparing the current state with the measured state of the six-axis motion sensor module; and"

385. In my opinion, *Luo* in view of *Abbate* discloses these features for the same reasons I described in Section XIII.A.5.e for the "comparing the second quaternion" limitation. Under CyWee's interpretation, both limitations recite obtaining an "updated state" (representing the device's orientation) by taking the "current state" in the form of a second quaternion representing the device's orientation and correcting the orientation using the direction of gravity

(or some predicted acceleration value).

g. [Element 438.14.8] "calculating and converting the updated state of the six axis motion sensor module to said resulting deviation comprising said resultant angles in said spatial pointer reference frame of the 3D pointing device."

386. In my opinion, *Luo* in view of *Abbate* discloses these features. As discussed above, under CyWee's interpretation, *Luo* in view of *Abbate* discloses calculating an "updated state." *See* Section XIII.A.5.f.

387. *Luo* discloses that its quaternion-based Extended Kalman filter uses the orientation calculation to "track the real-time attitude" of its digital writing instrument. *Luo* at 909. In this way, "any 2D human handwriting is recorded in real time if the pen touches the white board plane." *Id.* at 910.

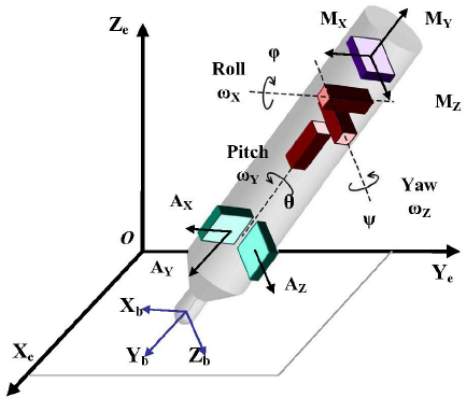


Figure 3. The MAG-μIMU System Structure for a wireless digital writing instrument.

388. As shown in Figure 3 of *Luo* (reproduced here), *Luo* discloses that the deviation of the 3D pointing device can be represented in resultant "angles" or deviation angles (yaw, pitch, roll). *See also id.* at 910. A POSA would understand that the quaternion representing orientation in *Luo* would be mathematically the same as representing the angles as Euler angles (yaw, pitch, and roll).

389. However, to the extent that the claims require that this quaternion be converted into deviation angles, *Abbate* discloses this feature. Specifically, *Abbate* discloses that while its Extended Kalman filter uses quaternion representations of orientation in order to "improve computational efficiency and avoid singularities," after the EKF is running, "the computed quaternions could be translated into Roll, Pitch, and Yaw angles" through transformation

equations. *Abbate* at 258.

390. For the same reasons I described above in Section XIII.A.5.e, a POSA would have been motivated to configure *Luo*'s system/process so that the Extended Kalman filter in *Luo* utilizes accelerometer data and the techniques as disclosed in *Abbate* to obtain the "updated state."

391. To the extent that the claim recites that the quaternion be converted into deviation angles, a POSA would have been motivated to configure *Luo*'s system/process to convert the computed quaternions into deviation angles (yaw, pitch, and roll) as disclosed in *Abbate*. Indeed, this conversion is contemplated in *Luo*, which discloses, there are "many methods to represent[] angular position from one reference to another reference frame" and each has "advantages and disadvantages." *Luo* at 910.

6. Claim 15

a. [Element 438.15] "The method for obtaining a resulting deviation of a 3D pointing device of claim 14, further comprises the step of outputting the updated state of the six-axis motion sensor module to the previous state of the six-axis motion sensor module; and wherein said resultant angles of the resulting deviation includes yaw, pitch and roll angles about each of three orthogonal coordinate axes of the spatial pointer reference frame."

392. In my opinion, *Luo* in view of *Abbate* discloses these features. As discussed above, under CyWee's interpretation, *Luo* in view of *Abbate* discloses calculating an "updated state." *See* Section XIII.A.5.f.

393. As shown in Figure 4 of *Luo* and Figure 8 of *Abbate* (reproduced below), both *Luo* and *Abbate* disclose recursive Extended Kalman filters where the updated quaternion is read back into the next loop of the filter. Specifically: *Luo* discloses that the updated quaternion is read back into the Extended Kalman filter in the next "time update" step. *Luo* at Fig. 4, 911. Similarly, *Abbate* discloses that the result of the "measurement update" stage in its Extended

Kalman filter is fed back into the "time update" stage. *Abbate* at Figs. 6, 8, 257–258.

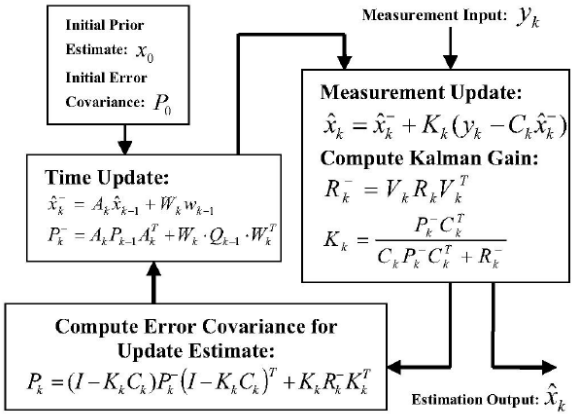
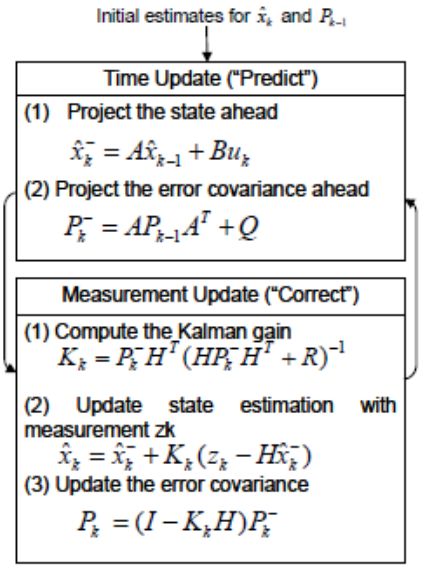
Figure 4 of *Luo*	Figure 8 of *Abbate*
	

Figure 4. Extended Kalman Filter Algorithm

394. Therefore, in both *Luo* and *Abbate*, the updated quaternion is input as the "previous state" of the device at the next time interval.

395. *Luo* discloses that its quaternion-based Extended Kalman filter uses the orientation calculation to "track the real-time attitude" of its digital writing instrument. *Luo* at 909. In this way, "any 2D human handwriting is recorded in real time if the pen touches the white board plane." *Id.* at 910.

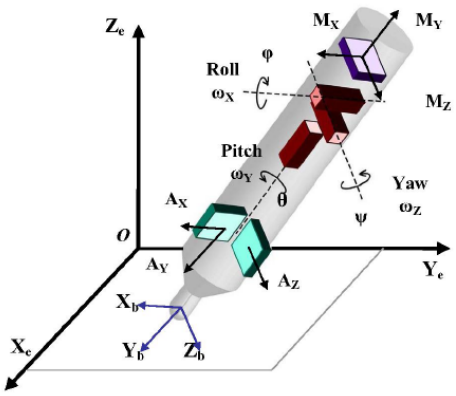


Figure 3. The MAG-μIMU System Structure for a wireless digital writing instrument.

396. As shown in Figure 3 of *Luo* (reproduced here), *Luo* discloses that the deviation of the 3D pointing device can be represented in resultant "angles" or deviation angles (yaw, pitch, roll). *See also id.* at 910.

397. A POSA would understand that the quaternion representing orientation in *Luo* would be mathematically the same as representing the angles as Euler angles (yaw, pitch, and

roll).

398. However, to the extent that the claims require that this quaternion be converted into deviation angles, *Abbate* discloses this feature. Specifically, *Abbate* discloses that while its Extended Kalman filter is quaternion-based in order to "improve computational efficiency and avoid singularities," after the EKF is running, "the computed quaternions could be translated into Roll, Pitch, and Yaw angles" through transformation equations. *Abbate* at 258.

399. A POSA would have been motivated to configure *Luo*'s system/process so that *Luo*'s Extended Kalman filter utilizes accelerometer data and the techniques disclosed in *Abbate*'s Extended Kalman filter in order to obtain the "updated state" and convert this "updated state" into resultant angles in order to provide a more accurate estimate of orientation, for the same reasons described above in Section XIII.A.5.e.

400. To the extent that the claim recites that the quaternion be converted into deviation angles, a POSA would have been motivated to configure *Luo*'s system/process to convert the computed quaternions into deviation angles (yaw, pitch, and roll) as disclosed in *Abbate*. Indeed, this conversion is contemplated in *Luo*, which discloses, there are "many methods to represent[] angular position from one reference to another reference frame" and each has "advantages and disadvantages." *Luo* at 910.

7. Claim 16

a. [Element 438.16] "The method for obtaining a resulting deviation of a 3D pointing device of claim 14, wherein said previous state of the six-axis motion sensor module is a first quaternion with respect to said previous time T−1; and said updated state of the six-axis motion sensor module is a third quaternion with respect to said current time T."

401. In my opinion, *Luo* in view of *Abbate* discloses these features. As discussed above, under CyWee's interpretation, *Luo* in view of *Abbate* discloses calculating an updated

quaternion which is then re-input into the algorithm as the "previous state" at the next time stage of the Extended Kalman filter. *See* Sections XIII.A.5.e and XIII.A.5.f. *Luo* discloses that each of the attitude calculations is based "on a quaternion." *Luo* at 912. Similarly, *Abbate* discloses that its Extended Kalman filter is quaternion based in order to "improve computational efficiency and avoid singularities." *Abbate* at 258.

8. Claim 17

a. [Element 438.17] "The method for obtaining a resulting deviation of 3D pointing device of claim 14, wherein the obtaining of said previous state of the six-axis motion sensor module further comprises initializing said initial-value set."

402. In my opinion, *Luo* in view of *Abbate* discloses these features. *Luo* discloses that a method of initializing the system state where the "attitude quaternion and gyro biases are set to zero." *Luo* at 913.

9. Claim 19

403. From my review, Claims 14 and 19 recite identical claim language. Accordingly, in my opinion, the combination of *Luo* and *Abbate* render obvious Claim 19 for the same reasons that they render obvious Claim 14, as I describe in Section XIII.A.5.

B. *Luo* in view of *Yang* render obvious Claims 1, 3, 4, 5, 14, 15, 16, 17, and 19 of the '438 Patent

1. Claim 1

a. [Element 438.1.0] "A three-dimensional (3D) pointing device subject to movements and rotations in dynamic environments, comprising:"

404. I understand that neither Samsung nor CyWee has argued that the preamble of Claim 1 is limiting. However, to the extent that the preamble is considered limiting, in my opinion, *Luo* in view of *Yang* discloses a 3D pointing device having the features recited in the remaining elements of this claim. *Luo* discloses a "three-dimensional (3D) pointing device" that

is "subject to movements and rotations in dynamic environments." *See* Section XIII.A.1.a.

b. [Element 438.1.1] "a housing associated with said movements and rotations of the 3D pointing device in a spatial pointer reference frame"

405. In my opinion, *Luo* discloses these features. *See* Section XIII.A.1.b.

c. [Element 438.1.2] "a printed circuit board (PCB) enclosed by the housing;"

406. In my opinion, *Luo* discloses these features. *See* Section XIII.A.1.c.

d. [Element 438.1.3] "a six-axis motion sensor module attached to the PCB,"

407. In my opinion, *Luo* discloses these features. *See* Section XIII.A.1.d.

e. [Element 438.1.4] "comprising a rotation sensor for detecting and generating a first signal set comprising angular velocities ω_x, ω_y, ω_z associated with said movements and rotations of the 3D pointing device in the spatial pointer reference frame,"

408. In my opinion, *Luo* discloses these features. *See* Section XIII.A.1.e.

f. [Element 438.1.5] "an accelerometer for detecting and generating a second signal set comprising axial accelerations A_x, A_y, A_z associated with said movements and rotations of the 3D pointing device in the spatial pointer reference frame; and"

409. In my opinion, *Luo* discloses these features. *See* Section XIII.A.1.f.

g. "a processing and transmitting module, comprising a data transmitting unit electrically connected to the six-axis motion sensor module for transmitting said first and second signal sets thereof and a computing processor for receiving and calculating said first and second signal sets from the data transmitting unit, communicating with the six-axis motion sensor module to calculate a resulting deviation comprising resultant angles in said spatial pointer reference frame by utilizing a comparison to compare the first signal set with the second signal set whereby said resultant angles in the spatial pointer reference frame of the resulting deviation of the six-axis motion sensor module of the 3D pointing device are obtained under said dynamic environments, wherein the comparison utilized by the processing and transmitting module further comprises an update program to obtain an updated state based on a previous state associated with said first signal set

and a measured state associated with said second signal set; wherein the measured state includes a measurement of said second signal set and a predicted measurement obtained based on the first signal set without using any derivatives of the first signal set."

410. I will discuss the features of this element below in two parts.

(1) [Element 438.1.6] "a processing and transmitting module, comprising a data transmitting unit electrically connected to the six-axis motion sensor module for transmitting said first and second signal sets thereof and a computing processor for receiving and calculating said first and second signal sets from the data transmitting unit,"

411. In my opinion, *Luo* discloses components that perform the same functions as the claimed "processing and transmitting module." *See* Section XIII.A.1.g.(1).

(2) [Element 438.1.7] "communicating with the six-axis motion sensor module to calculate a resulting deviation comprising resultant angles in said spatial pointer reference frame by utilizing a comparison to compare the first signal set with the second signal set whereby said resultant angles in the spatial pointer reference frame of the resulting deviation of the six-axis motion sensor module of the 3D pointing device are obtained under said dynamic environments, wherein the comparison utilized by the processing and transmitting module further comprises an update program to obtain an updated state based on a previous state associated with said first signal set and a measured state associated with said second signal set; wherein the measured state includes a measurement of said second signal set and a predicted measurement obtained based on the first signal set without using any derivatives of the first signal set."

412. In my opinion, *Luo* in view of *Yang* discloses these features. As I explained in Section XIII.A.1.g.(2), the '438 Patent does not describe how to perform the limitations of: (i) "utilizing a comparison to compare the first signal set with the second signal set"; (ii) obtaining "an updated state based on a previous state associated with said first signal set and a measured state associated with said second signal set"; and/or how to calculate a "predicted measurement obtained based on the first signal set without using any derivatives of the first signal set."

413. As I explained in Section XIII.A.1.g.(2), I understand that CyWee and its experts have claimed that this limitation is met by an Extended Kalman filter or something like an Extended Kalman filter and an "indirect" comparison between angular velocities and axial accelerations is possible by using an Extended Kalman filter and representing the orientation in quaternion format, as allegedly shown in Equations 5–11 of the '438 Patent.

414. I understand that CyWee and its experts have claimed that the "predicted measurement" is the direction of gravity obtained from a second quaternion representing orientation, as allegedly disclosed in Equations 2–4 of the '438 Patent. Plaintiff's Markman Slides at 30. However, because of the lack of guidance in the '438 Patent regarding the precise meaning of a "predicted acceleration," in my opinion, it is unclear what the scope of the claim term is beyond that it is some predicted acceleration value.

415. As I explained in Section XIII.A.1.g.(2), I do not agree with CyWee's claims. However, taking CyWee's own representations as true, this limitation covers a quaternion-based Extended Kalman filter that uses angular velocities to predict an object's orientation that is then corrected using gravitational accelerations (or some predicted acceleration value). Accordingly, if taken as true, in my opinion, *Luo* in view of *Yang* disclose these features.

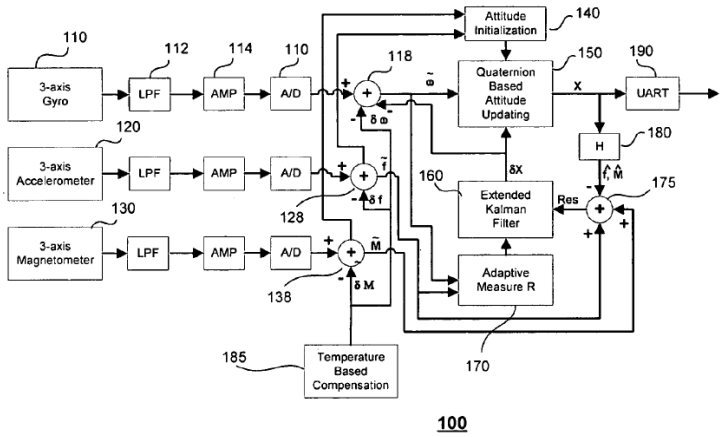
416. In particular, *Luo* states that its Extended Kalman filter receives measurements from the gyroscopes and magnetometers and calculates the orientation of the digital writing instrument while minimizing the noise and bias error from each of the sensors. *Luo* at 912. The Extended Kalman filter uses a two-stage process. In the first stage, the attitude of the device is estimated based on the gyroscope readings (i.e., the "current state"). *Id.* at Fig. 4, 911. In the second stage, the difference between an estimated and measured Earth magnetic vector is implemented as feedback to correct the errors from the gyroscope readings. *Id. Luo* discloses that

these attitude calculations are "based on a quaternion." *Id.* at 912.

417. *Luo* does not expressly disclose that its quaternion-based Extended Kalman filter corrects its orientation estimation using measured and predicted accelerations. However, it would have been obvious to a POSA at the time of the alleged invention to modify *Luo*'s system/process to implement such features in view of the teachings of *Yang*.

418. *Yang* discloses a system that provides an error estimate for an initial attitude (i.e., orientation) using an Extended Kalman filter. The Extended Kalman filter is adaptable based on whether the device is undergoing acceleration. *Yang* at Abstract. The estimated error obtained by the Extended Kalman filter may be used to update the initial orientation calculation. *Id.* ¶¶ 18–19, 39, 107, 112. Specifically, the estimated error, which *Yang* discloses as the residual value, consists of the differences between a measured acceleration (i.e., the "measured state") and predicted acceleration (i.e., the "predicted measurement") and a measured and predicted heading. *Id.* at Fig. 5, ¶¶ 111, 119–121. The basic mechanisms of the system are based on the principles of a Strapdown Inertial Navigation System. *Id.* ¶¶ 13, 30.

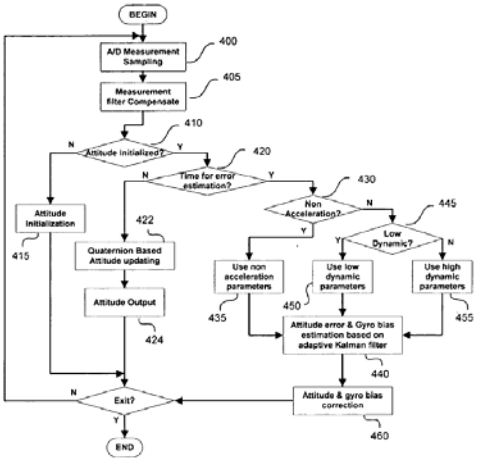
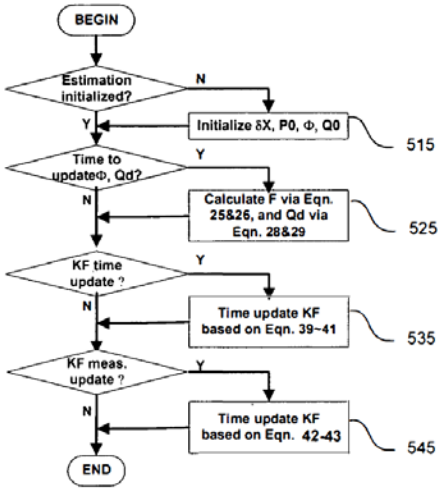
419. As shown in Figure 1 of *Yang* (reproduced here), *Yang* discloses a device composed of (among other components): (i) a three-axis gyroscope (110); (ii) a three-axis accelerometer (120); (iii) a three-axis magnetometer (130); and (iv) an Extended Kalman filter (160).



420. As shown in Figure 4 of *Yang* (reproduced below), *Yang* discloses a method by

which data from the sensors (gyroscopes, accelerometers, and magnetometers) is measured and then filtered. *Id.* at Fig. 4, ¶¶ 116–117. The Extended Kalman filter is then adapted based on the current acceleration mode. *Id.* at Fig. 4, ¶ 117. Once the Kalman filter is adapted based on the current acceleration mode, it estimates "attitude error and gyro bias" as shown in step 440 of Figure 4. *Id.* ¶ 117. A correction is applied using this error and the corrected orientation is then output (i.e., the "updated state"). *Id.* ¶ 118.

421. Figure 5 of *Yang* (also reproduced below) depicts the Kalman filtering step disclosed in step 440 of Figure 4 in more detail. The Extended Kalman filter is first initialized with an initial error estimate. *Id.* at Fig. 5, ¶ 119. The attitude update module is used to generate an updated attitude. *Id.* at Fig. 5, ¶ 120. The updated attitude is then used to "produce a predicted acceleration and heading (f and M) and determine a residual (Res)." *Id. Yang* discloses that this attitude update is performed using quaternions for calculation efficiency. *Id.* at Figs. 4, 5, 6, ¶¶ 19, 26, 39–45, 107, 112, 118, 120, 122–124.

Figure 4 of *Yang*	**Figure 5 of *Yang***
	

422. The residual value (Res) consists of the differences between a measured and a predicted acceleration and a measured and a predicted heading and is used to determine the Kalman filter's error estimates. *Id.* at Fig. 5, ¶¶ 111, 119–121. The measured and predicted axial

accelerations are used to update the Kalman filter's error estimate. This error estimate can be used as a correction value to update the orientation. *Id.* at Figs. 4, 5, 6, ¶¶ 116–130.

423. *Yang* explicitly discloses the use of a predicted acceleration value. Specifically, *Yang* discloses:

> The Kalman Filter 160 operates on a residual value (Res) that is a difference between a measured f^ and M^ and a predicted f^ and M^. The measured f^ and M^ are the measured acceleration (e.g., accelerometer reading) and measured heading (e.g., magnetometer reading) respectively. The predicted f^ and M^ comprise the **predicted acceleration f^** and the predicted heading M^ are predictions based on, for example, a model (H) of a current updated attitude X. **The model H, for example, looks at current accelerations, current attitude and heading, etc., and determines the predicted values.**

Yang ¶ 111 (emphasis added); Equation 31.

424. Further, Equation 31, which *Yang* describes as "one embodiment of a calculation" for the predicted acceleration, does not use the derivatives of the measured angular velocities. *Id.* at Equation 31.

425. Accordingly, in my opinion, *Yang* discloses using "predicted" and "measured" accelerations as inputs into an Extended Kalman filter to calculate an error value that is used to update an initial orientation. Both *Yang* and *Luo* discloses that updated orientation values can be recursively input into the next time iteration of their respective algorithms to become the "previous state." *Luo* at Fig. 4, 911; *Yang* at Fig. 4, ¶ 107.

426. Although *Yang* discloses the use of measurements from a magnetometer as part of its residual value, a POSA would have understood that the algorithm disclosed in *Yang* could be modified to exclude the use of the magnetometer. Under this modification, the residual value would be composed of only the measured and predicted accelerations.

427. In view of these teachings of *Yang*, a POSA would have been motivated to

configure *Luo*'s system/process so that *Luo*'s Extended Kalman filter utilizes accelerometer data and the techniques disclosed in *Yang*'s Extended Kalman filter in order to provide a more accurate estimate of orientation. For example, *Luo* specifically discloses that its Extended Kalman filter can be modified to use other sensors for feedback, including accelerometers. *Luo* at 909, 914. Indeed, *Luo* specifically contemplates this combination, stating that for "future work" the "Kalman filter will be expanded by the accelerometers in the measurement update" and that this implementation will be "similar to the magnetometer feedback" which will help in "eliminating magnetic interference." *Id.* at 914.

428. In addition, *Yang* explicitly discloses the benefit of using acceleration values and its specific fusion techniques, noting that its data fusion method provides a more "optimal attitude estimate" in cases when the device is non-stationary. *Yang* at Abstract, ¶¶ 13, 14.

429. A POSA would have recognized that such a modification would have been a straightforward combination of known technologies by known methods without changing their respective functions to achieve a predictable result, and would have been well within the capabilities of such a person. Indeed, *Luo* already discloses integrating gyroscopes and accelerometers together using strapdown installation. *Luo* at 910. *Luo* further discloses that in prior work, the Extended Kalman filter was implemented using accelerometers for feedback. *Id.* at 912. A POSA would have recognized that configuring *Luo*'s system/process to include an accelerometer reading as an input to an Extended Kalman filter and to use the sensor fusion techniques disclosed in *Yang*, would merely have been an obvious extension of *Luo*'s system and well within the capabilities of such a person.

430. Furthermore, a POSA would have been encouraged to look to *Yang* to complement the teachings of the *Luo* because these references are all directed to the same

technical field and describe solutions to similar problems in the field. For example, each reference describes systems to calculate orientation using a combination of gyroscopes, accelerometers and magnetometers by using a quaternion-based Extended Kalman filter. *Luo* at 909–912; *Yang* ¶¶ 108–129.

2. Claim 3

a. [Element 438.3] "The 3D pointing device of claim 1, wherein the PCB enclosed by the housing comprises at least one substrate having a first longitudinal side configured to be substantially parallel to a longitudinal surface of the housing."

431. In my opinion, *Luo* in view of *Yang* discloses these features. As I discussed in Section XIII.A.2, *Luo* discloses a printed circuit board enclosed by a housing. A POSA would understand that printed circuit board is or can be configured in such a way that one of the substrates has a first longitudinal side that is substantially parallel to the housing.

3. Claim 4

a. [Element 438.4] "The 3D pointing device of claim 1, wherein the spatial pointer reference frame is a reference frame in three dimensions; and wherein said resultant angles of the resulting deviation includes yaw, pitch and roll angles about each of three orthogonal coordinate axes of the spatial pointer reference frame."

432. In my opinion, *Luo* in view of *Yang* discloses these features. As I discussed in Section XIII.A.3, *Luo* discloses that the "body frame" of its writing instrument is a reference frame that is defined in three dimensions. *Luo* further discloses that the resulting deviation of the device can be represented using Euler angles. *Yang* similarly discloses the use of Euler angles, including their benefits. Specifically, *Yang* discloses that while quaternion are "best for attitude determination related to inertial navigation systems due to its excellent mathematical properties, dynamic equations, and calculation efficiency," nevertheless, "Euler angles have clear physical insights for analysis." *Yang* ¶ 12.

433. In addition, a POSA would have known that the orientation quaternion calculated by *Luo* and *Yang* would be mathematically equivalent to an Euler angle representation.

4. Claim 5

a. [Element 438.5] "The 3D pointing device of claim 1, wherein the data transmitting unit of the processing and transmitting module is attached to the PCB enclosed by the housing and transmits said first and second signal of the six-axis motion sensor module to the computing processor via electronic connections on the PCB."

434. In my opinion, *Luo* in view of *Yang* discloses these features. As I discussed in Section XIII.A.4, *Luo* discloses the claimed data transmitting unit in the form of the *Luo*'s Bluetooth transceiver.

5. Claim 14

a. [Element 438.14.0] "A method for obtaining a resulting deviation including resultant angles in a spatial pointer reference frame of a three-dimensional (3D) pointing device utilizing a six-axis motion sensor module therein and subject to movements and rotations in dynamic environments in said spatial pointer reference frame, comprising the steps of:"

435. I understand that neither Samsung nor CyWee has argued that the preamble of Claim 14 is limiting. However, to the extent that the preamble is considered limiting, in my opinion, *Luo* in view of *Yang* discloses a method with the recited features.

436. For the reasons I set forth in Section XIII.A.1.a, *Luo* discloses a "three-dimensional (3D) pointing device," consistent with the plain and ordinary meaning of this term. Specifically, *Luo* discloses a digital writing instrument that is used to "capture and record human handwriting or drawing motions in real-time based on a MEMS Micro Inertial Measurement Unit (μIMU)[.]" *Luo* at Fig. 3, 909.

437. For the reasons I set forth in Section XIII.A.1.d, *Luo* further discloses a "six-axis motion sensor module." Specifically, *Luo* discloses a MAG-μIMU sensing system that integrates

"3D accelerometers and 3D gyroscopes with strapdown installation." *Id.* at 910.

438. For the reasons I set forth in Section XIII.A.1.g, *Luo* discloses a method for obtaining the deviation of the digital writing instrument ("3D pointing device") in the "spatial pointer reference frame" of the digital writing instrument. Specifically, as I discussed in Section XIII.A.1.g, I understand that CyWee and its experts have claimed that this limitation is met by an Extended Kalman filter or something like an Extended Kalman filter, as allegedly shown in Equations 5–11 of the '438 Patent.

439. I do not agree. However, taking CyWee's own representations as true, Claim 14's method covers a quaternion-based Extended Kalman filter that uses angular velocities to predict an object's orientation that is then corrected using gravitational accelerations (or some predicted acceleration value).

440. If taken as true, in my opinion, *Luo* in view of *Yang* disclose these features, as: (i) both *Luo* and *Yang* disclose the use of quaternion-based Extended Kalman filters for calculating the change in a device's orientation and (ii) *Yang* discloses correcting the initial orientation estimation obtained by a gyroscope reading using measured and predicted accelerations. *Luo* at Fig. 4, 911–912; *Yang* at Figs. 4, 5, ¶¶ 117–130.

b. [Element 438.14.1] "obtaining a previous state of the six-axis motion sensor module; wherein the previous state includes an initial-value set associated with previous angular velocities gained from the motion sensor signals of the six-axis motion sensor module at a previous time T−1;"

441. In my opinion, *Luo* discloses these features. *See* Section XIII.A.5.a.

c. [Element 438.14.2] "obtaining a current state of the six-axis motion sensor module by obtaining measured angular velocities ω_x, ω_y, ω_z gained from the motion sensor signals of the six-axis motion sensor module at a current time T;"

442. In my opinion, *Luo* discloses these features. *See* Section XIII.A.5.b.

d. "obtaining a measured state of the six-axis motion sensor module by obtaining measured axial accelerations Ax, Ay, Az gained from the motion sensor signals of the six-axis motion sensor module at the current time T and calculating predicted axial accelerations Ax′, Ay′, Az′ based on the measured angular velocities ω_x, ω_y, ω_z of the current state of the six-axis motion sensor module without using any derivatives of the measured angular velocities ω_x, ω_y, ω_z; said current state of the six-axis motion sensor module is a second quaternion with respect to said current time T;"

443. I will discuss the features of this element below in three parts.

(1) [Element 438.14.3] "obtaining a measured state of the six-axis motion sensor module by obtaining measured axial accelerations Ax, Ay, Az gained from the motion sensor signals of the six-axis motion sensor module at the current time T and"

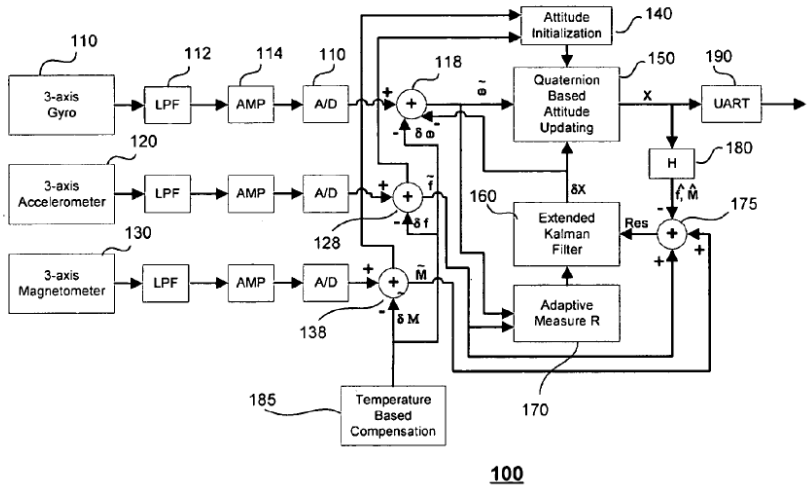
444. In my opinion, *Luo* in view of *Yang* discloses these features. For the reasons I set forth in Section XIII.B.1.d, *Luo* discloses a MAG-μIMU sensing system ("six-axis motion sensor module") that integrates "3D accelerometers and 3D gyroscopes with strapdown installation." *Id.* at 910.

445. *Luo* further discloses reading the output signals from the accelerometers. *Id.* at 910. Although *Luo* does not explicitly disclose using the accelerometer readings in its Extended Kalman filter, it discloses that using accelerometers as feedback was known in the prior art. *Luo* at 912 ("In pervious [sic] work, the attitude extended Kalman filter is implemented using accelerometers for feedback.") It further states that "[f]or future work, the Kalman filter will be expanded by the accelerometers in the measurement update." *Id.* at 914.

446. *Yang* discloses obtaining measured and predicted accelerations. Specifically, *Yang* discloses obtaining a residual value by taking the difference between the measured accelerations (i.e., the "measured state") and predicted accelerations (i.e., the predicted measurement"). *Yang* at Fig. 5, ¶¶ 111, 119–121.

447. Specifically, as shown in Figure 1 of *Yang* (reproduced below), *Yang* discloses a

device composed of (among other components) a three-axis accelerometer (120). Once the Kalman filter is adapted based on the current acceleration mode, it estimates "attitude error and gyro bias." *Id.* ¶ 117. A correction is applied using this error and the corrected orientation is then output (i.e., the "updated state"). *Id.* ¶ 118.



448. The Extended Kalman filter uses a residual value to update its error estimate. As *Yang* discloses, this residual value consists of the difference between a measured acceleration ("measured state") and a predicted acceleration ("predicted measurement"). *Id.* at Fig. 5, ¶¶ 111, 119–121. This error estimate can be used as a correction value to update the orientation ("updated state"). *Id.* at Figs. 4, 5, 6, ¶¶ 116–130.

449. A POSA would have been motivated to configure *Luo*'s system/process so that *Luo*'s Extended Kalman filter uses the accelerometer data and techniques disclosed in *Yang*'s Extended Kalman filter for the same reasons described below. *See* Section XIII.B.1.g.(2).

450. Based on CyWee's interpretation of a "measured state," a POSA would understand the measured acceleration readings to be the "measured state." *See* CyWee's Opening Claim Construction Brief, Dkt. No. 66 at 9 ("The second quaternion is used to generate predicted axial accelerations (predicted state), which are compared to the measured accelerations

(measured state or second signal set).").

(2) [Element 438.14.4] "calculating predicted axial accelerations Ax′, Ay′, Az′ based on the measured angular velocities ω_x, ω_y, ω_z of the current state of the six-axis motion sensor module without using any derivatives of the measured angular velocities ω_x, ω_y, ω_z;"

451. As I explain in Section XV.A.6, the '438 Patent does not describe how to calculate "predicted axial accelerations Ax′, Ay′, Az′ based on the measured angular velocities ω_x, ω_y, ω_z of the current state of the six-axis motion sensor module without using any derivatives of the measured angular velocities ω_x, ω_y, ω_z." Because of the lack of guidance in the '438 Patent regarding the precise meaning of a "predicted acceleration," in my opinion, it is unclear what the scope of the claim term is beyond that it is some predicted acceleration value.

452. Based on the above, *Yang* explicitly discloses the use of a "predicted acceleration" value. Specifically, *Yang* discloses:

> The Kalman Filter 160 operates on a residual value (Res) that is a difference between a measured f^ and M^ and a predicted f^ and M^. The measured f^ and M^ are the measured acceleration (e.g., accelerometer reading) and measured heading (e.g., magnetometer reading) respectively. The predicted f^ and M^ comprise the **predicted acceleration f^** and the predicted heading M^ are predictions based on, for example, a model (H) of a current updated attitude X. **The model H, for example, looks at current accelerations, current attitude and heading, etc., and determines the predicted values.**

Yang ¶ 111 (emphasis added); Equation 31.

453. A POSA would have been motivated to configure *Luo*'s system/process so that *Luo*'s Extended Kalman filter uses the accelerometer data and techniques disclosed in *Yang*'s Extended Kalman filter for the same reasons described below. *See* Section XIII.B.5.e.

(1) [Element 438.14.5] "said current state of the six-axis motion sensor module is a second quaternion with respect to said current time T;"

454. In my opinion, *Luo* discloses these features. *See* Section XIII.B.5.c.

e. [Element 438.14.6] "comparing the second quaternion in relation to the measured angular velocities ω_x, ω_y, ω_z of the current state at current time T with the measured axial accelerations Ax, Ay, Az and the predicted axial accelerations Ax′, Ay′, Az′ also at current time T;"

455. As I explain in Sections XV.A.3 and XV.A.6, the '438 Patent does not describe how to: (i) obtain predicted axial accelerations or (ii) perform a comparison between angular velocities, axial accelerations and predicted axial accelerations. As I explain in Sections XV.A.3 and XV.A.6, any such comparison is mathematically impossible and would at best produce a meaningless result.

456. I understand that CyWee and its experts have claimed that this limitation is met by an Extended Kalman filter or something like an Extended Kalman filter and an "indirect" comparison between angular velocities and axial accelerations is possible by using an Extended Kalman filter and representing the orientation in quaternion format, as shown in Equations 5–11 of the '438 Patent.

457. I understand that CyWee and its experts have claimed that the "predicted measurement" is the direction of gravity obtained from a second quaternion representing orientation, as allegedly disclosed in Equations 2–4 of the '438 Patent. Plaintiff's Markman Slides at 30. However, because of the lack of guidance in the '438 Patent regarding the precise meaning of a "predicted acceleration," in my opinion, it is unclear what the scope of the claim term is beyond that it is some predicted acceleration value.

458. I do not agree with CyWee's claims. However, taking CyWee's own representations as true, this limitation covers a quaternion-based Extended Kalman filter that

uses angular velocities to predict an object's orientation that is then corrected using gravitational accelerations (or some predicted acceleration value). Accordingly, if taken as true, in my opinion, *Luo* in view of *Yang* disclose these features.

459. In particular, *Luo* states that its Extended Kalman filter receives measurements from the gyroscopes and magnetometers and calculates the orientation of the digital writing instrument while minimizing the noise and bias error from each of the sensors. *Luo* at 912. The Extended Kalman filter uses a two-stage process. In the first stage, the attitude of the device is estimated based on the gyroscope readings (i.e., the "current state"). *Id.* at Fig. 4, 911. In the second stage, the difference between an estimated and measured Earth magnetic vector is implemented as feedback to correct the errors from the gyroscope readings. *Id. Luo* discloses that these attitude calculations are "based on a quaternion." *Id.* at 912.

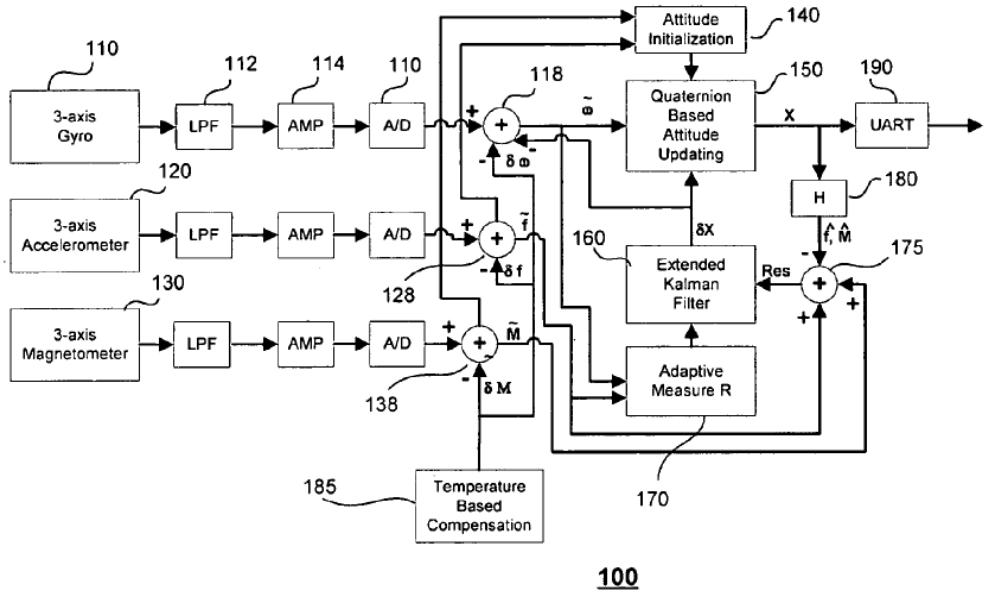
460. *Luo* discloses that updated orientation values can be recursively input into the next time iteration of the Extended Kalman filter to become the "previous state." *Luo* at Fig. 4, 911.

461. *Luo* does not expressly disclose that its quaternion-based Extended Kalman filter corrects its orientation estimation using measured and predicted accelerations. However, it would have been obvious to a POSA at the time of the alleged invention to modify *Luo*'s system/process to implement such features in view of the teachings of *Yang*.

462. *Yang* discloses a system that provides an error estimate for an initial attitude (i.e., orientation) using an Extended Kalman filter. The Extended Kalman filter is adaptable based on whether the device is undergoing acceleration. *Yang* at Abstract. The estimated error obtained by the Extended Kalman filter may be used to update the initial orientation calculation. *Id.* ¶¶ 18–19, 39, 107, 112. Specifically, the estimated error, which *Yang* discloses as the residual value,

consists of the differences between a measured acceleration (i.e., the "measured state") and predicted acceleration (i.e., the "predicted measurement") and a measured and predicted heading. *Id.* at Fig. 5, ¶¶ 111, 119–121. The basic mechanisms of the system are based on the principles of a Strapdown Inertial Navigation System. *Id.* ¶¶ 13, 30.

463. As shown in Figure 1 of *Yang* (reproduced below), *Yang* discloses a device composed of (among other components): (i) a three-axis gyroscope (110); (ii) a three-axis accelerometer (120); (iii) a three-axis magnetometer (130); and (iv) an Extended Kalman filter (160).



464. As shown in Figure 4 of *Yang* (reproduced below), *Yang* discloses a method by which data from the sensors (gyroscopes, accelerometers, and magnetometers) is measured and then filtered. *Id.* at Fig. 4, ¶¶ 116–117. The Extended Kalman filter is then adapted based on the current acceleration mode. *Id.* at Fig. 4, ¶ 117. Once the Kalman filter is adapted based on the current acceleration mode, it estimates "attitude error and gyro bias" as shown in step 440 of Figure 4. *Id.* ¶ 117. A correction is applied using this error and the corrected orientation is then output (i.e., the "updated state"). *Id.* ¶ 118.

465. Figure 5 of *Yang* (also reproduced below) depicts the Kalman filtering step disclosed in step 440 of Figure 4 in more detail. The Extended Kalman filter is first initialized with an initial error estimate. *Id.* at Fig. 5, ¶ 119. The attitude update module is used to generate an updated attitude. *Id.* at Fig. 5, ¶ 120. The updated attitude is then used to "produce a predicted acceleration and heading (f and M) and determine a residual (Res)." *Id. Yang* discloses that this attitude update is performed using quaternions for calculation efficiency. *Id.* at Figs. 4, 5, 6, ¶¶ 19, 26, 39–45, 107, 112, 118, 120, 122–124.

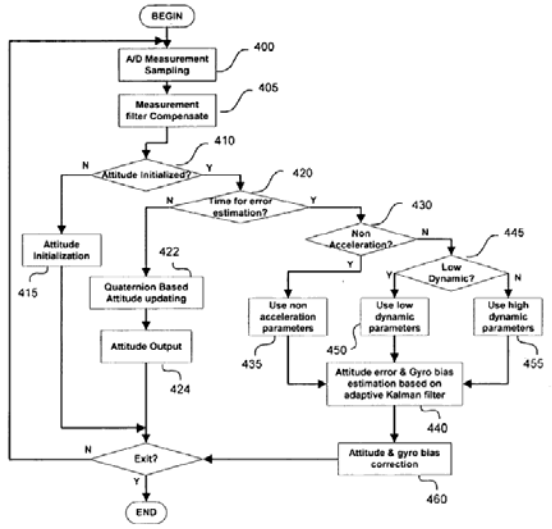
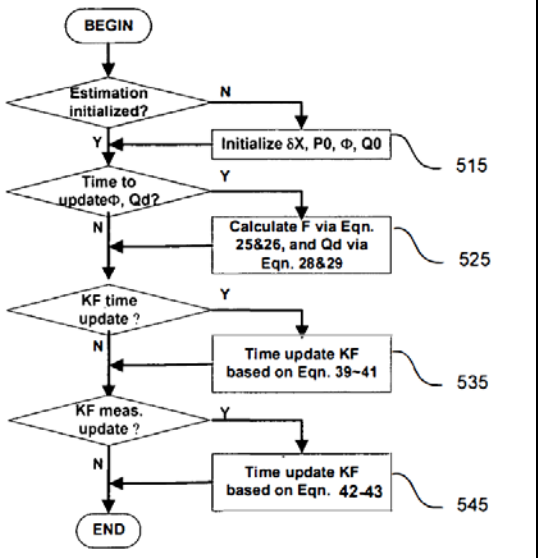
Figure 4 of *Yang*	**Figure 5 of *Yang***
	

FIG. 4

466. The residual value (Res) consists of the differences between a measured and a predicted acceleration and a measured and a predicted heading and is used to determine the Kalman filter's error estimates. *Id.* at Fig. 5, ¶¶ 111, 119–121. The measured and predicted axial accelerations are used to update the Kalman filter's error estimate. This error estimate can be used as a correction value to update the orientation. *Id.* at Figs. 4, 5, 6, ¶¶ 116–130.

467. *Yang* explicitly discloses the use of a predicted acceleration value. Specifically, *Yang* discloses:

> The Kalman Filter 160 operates on a residual value (Res) that is a difference between a measured f^ and M^ and a predicted f^ and M^. The measured f^ and M^ are the measured acceleration (e.g., accelerometer reading) and measured heading (e.g., magnetometer reading) respectively. The predicted f^ and M^ comprise the **predicted acceleration f^** and the predicted heading M^ are predictions based on, for example, a model (H) of a current updated attitude X. **The model H, for example, looks at current accelerations, current attitude and heading, etc., and determines the predicted values.**

Id. ¶ 111 (emphasis added); Equation 31.

468. Accordingly, in my opinion, *Yang* discloses using "predicted" and "measured" accelerations as inputs into an Extended Kalman filter to calculate an error value that is used to update an initial orientation.

469. Although *Yang* discloses the use of measurements from a magnetometer as part of its residual value, a POSA would have understood that the algorithm disclosed in *Yang* could be modified to exclude the use of the magnetometer. Under this modification, the residual value would be composed of only the measured and predicted accelerations.

470. In view of these teachings of *Yang*, a POSA would have been motivated to configure *Luo*'s system/process so that *Luo*'s Extended Kalman filter utilizes accelerometer data and the techniques disclosed in *Yang*'s Extended Kalman filter in order to provide a more accurate estimate of orientation. For example, *Luo* specifically discloses that its Extended Kalman filter can be modified to use other sensors for feedback, including accelerometers. *Luo* at 909, 914. Indeed, *Luo* specifically contemplates this combination, stating that for "future work" the "Kalman filter will be expanded by the accelerometers in the measurement update" and that this implementation will be "similar to the magnetometer feedback" which will help in "eliminating magnetic interference." *Id.* at 914.

471. In addition, *Yang* explicitly discloses the benefit of using acceleration values and

its specific fusion techniques, noting that its data fusion method provides a more "optimal attitude estimate" in cases when the device is non-stationary. *Yang* at Abstract, ¶¶ 13, 14.

472. A POSA would have recognized that such a modification would have been a straightforward combination of known technologies by known methods without changing their respective functions to achieve a predictable result, and would have been well within the capabilities of such a person. Indeed, *Luo* already discloses integrating gyroscopes and accelerometers together using strapdown installation. *Luo* at 910. *Luo* further discloses that in prior work, the Extended Kalman filter was implemented using accelerometers for feedback. *Id.* at 912. A POSA would have recognized that configuring *Luo*'s system/process to include an accelerometer reading as an input to an Extended Kalman filter and to use the sensor fusion techniques disclosed in *Yang*, would merely have been an obvious extension of *Luo*'s system and well within the capabilities of such a person.

473. Furthermore, a POSA would have been encouraged to look to *Yang* to complement the teachings of the *Luo* because these references are all directed to the same technical field and describe solutions to similar problems in the field. For example, each reference describes systems to calculate orientation using a combination of gyroscopes, accelerometers and magnetometers by using a quaternion-based Extended Kalman filter. *Luo* at 909–912; *Yang* ¶¶ 108–129.

f. [Element 438.14.7] "obtaining an updated state of the six-axis motion sensor module by comparing the current state with the measured state of the six-axis motion sensor module; and"

474. In my opinion, *Luo* in view of *Yang* discloses these features for the same reasons I described in Section XIII.B.5.e for the "comparing the second quaternion" limitation.

475. Under CyWee's interpretation, both limitations recite obtaining an "updated state" (representing the device's orientation) by taking the "current state" in the form of a second

quaternion representing the device's orientation and correcting the orientation using the direction of gravity (or some predicted acceleration value).

g. [Element 438.14.8] "calculating and converting the updated state of the six axis motion sensor module to said resulting deviation comprising said resultant angles in said spatial pointer reference frame of the 3D pointing device."

476. In my opinion, *Luo* in view of *Yang* discloses these features. As discussed above, under CyWee's interpretation, *Luo* in view of *Yang* discloses calculating an "updated state." *See* Section XIII.B.5.f.

477. *Luo* discloses that its quaternion-based Extended Kalman filter uses the orientation calculation to "track the real-time attitude" of its digital writing instrument. *Luo* at 909. In this way, "any 2D human handwriting is recorded in real time if the pen touches the white board plane." *Id.* at 910.

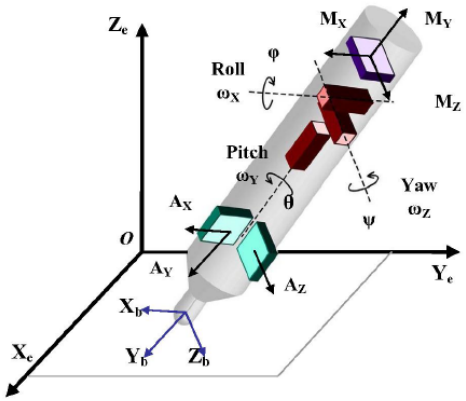


Figure 3. The MAG-μIMU System Structure for a wireless digital writing instrument.

478. As shown in Figure 3 of *Luo* (reproduced here), *Luo* discloses that the deviation of the 3D pointing device can be represented in resultant "angles" or deviation angles (yaw, pitch, roll). *See also id.* at 910. A POSA would understand that the quaternion representing orientation in *Luo* would be mathematically the same as representing the angles as Euler angles (yaw, pitch and roll).

479. *Yang* similarly discloses the use of Euler angles, including their benefits. Specifically, *Yang* discloses that while quaternion are "best for attitude determination related to inertial navigation systems due to its excellent mathematical properties, dynamic equations, and calculation efficiency," nevertheless, "Euler angles have clear physical insights for analysis."

Yang ¶ 12.

480. A POSA would have been motivated to configure *Luo*'s system/process so that the Extended Kalman filter in *Luo* utilizes accelerometer data and the techniques disclosed in *Yang* to obtain the "updated state" and convert this "updated state" into resultant angles in order to provide a more accurate estimate of orientation, for the same reasons described above in Section XIII.B.5.e.

481. To the extent that the claim recites that the quaternion be converted into deviation angles, a POSA would have been motivated to configure *Luo*'s system/process to convert the computed quaternions into deviation angles (yaw, pitch and roll) for the reasons discussed in both *Luo* and *Yang*.

482. Indeed, this conversion is contemplated in both *Luo* and *Yang*. *Luo* discloses, there are "many methods to represent[] angular position from one reference to another reference frame" and each has "advantages and disadvantages." *Luo* at 910. *Yang* similarly discloses that "[d]ifferent applications and situations have different attitude representations that are most convenient to implement." *Yang* ¶ 11.

6. Claim 15

a. [Element 438.15] "The method for obtaining a resulting deviation of a 3D pointing device of claim 14, further comprises the step of outputting the updated state of the six-axis motion sensor module to the previous state of the six-axis motion sensor module; and wherein said resultant angles of the resulting deviation includes yaw, pitch and roll angles about each of three orthogonal coordinate axes of the spatial pointer reference frame."

483. In my opinion, *Luo* in view of *Yang* discloses these features. As discussed above, under CyWee's interpretation, *Luo* in view of *Yang* discloses calculating an "updated state." *See* Section XIII.B.5.f.

484. As shown in Figures 4 of *Luo* and *Yang*, both *Luo* and *Yang* disclose recursive

algorithms where the updated quaternion is used in the next loop. Specifically: *Luo* discloses that the updated quaternion is read back into the Extended Kalman filter in the next "time update" step. *Luo* at Fig. 4, 911. Similarly, *Yang* discloses that the outputted orientation is fed back into the algorithm in a process where the orientation is continually being updated. *Yang* at Fig. 4, ¶ 107.

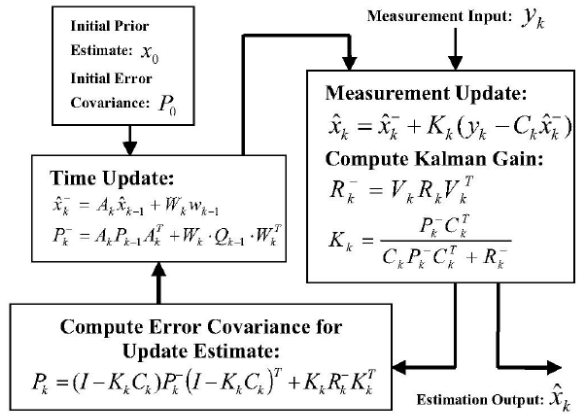
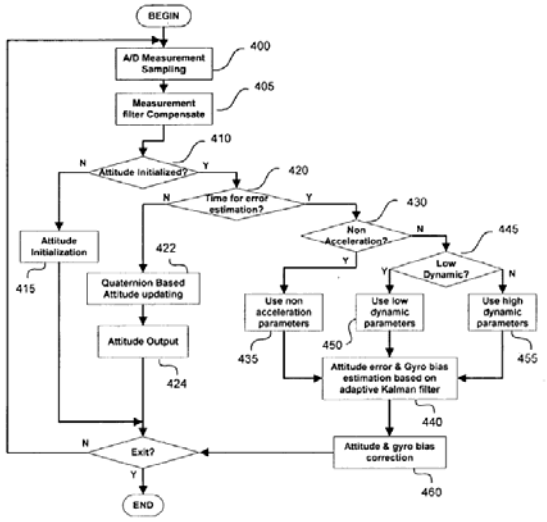
Figure 4 of *Luo*	Figure 4 of *Yang*
	

Figure 4. Extended Kalman Filter Algorithm

FIG. 4

485. Therefore, in both *Luo* and *Yang* the updated orientation is input as the "previous state" of the device at the next time interval.

486. *Luo* discloses that its quaternion-based Extended Kalman filter uses the orientation calculation to "track the real-time attitude" of its digital writing instrument. *Luo* at 909. In this way, "any 2D human handwriting is recorded in real time if the pen touches the white board plane." *Id.* at 910.

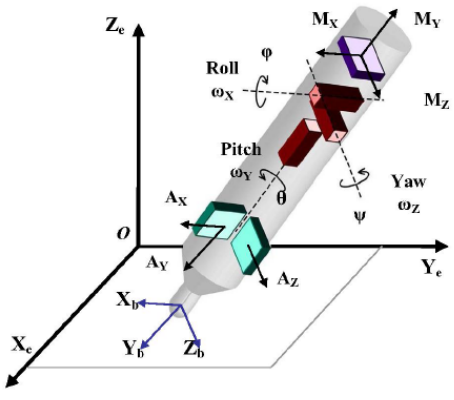


Figure 3. The MAG-μIMU System Structure for a wireless digital writing instrument.

487. As shown in Figure 3 of *Luo* (reproduced here), *Luo* discloses that the deviation of the 3D pointing device can be represented

in resultant "angles" or deviation angles (yaw, pitch, roll). *See also id.* at 910.

488. A POSA would understand that the quaternion representing orientation in *Luo* would be mathematically the same as representing the angles as Euler angles (yaw, pitch, and roll).

489. *Yang* similarly discloses the use of Euler angles, including their benefits. Specifically, *Yang* discloses that while quaternion are "best for attitude determination related to inertial navigation systems due to its excellent mathematical properties, dynamic equations, and calculation efficiency," nevertheless, "Euler angles have clear physical insights for analysis." *Yang* ¶ 12.

490. A POSA would have been motivated to configure *Luo*'s system/process so that the Extended Kalman filter in *Luo* utilizes accelerometer data and the techniques disclosed in *Yang* to obtain the "updated state" and convert this "updated state" into resultant angles in order to provide a more accurate estimate of orientation, for the same reasons described above in Section XIII.B.5.e.

491. To the extent that the claim recites that the quaternion be converted into deviation angles, a POSA would have been motivated to configure *Luo*'s system/process to convert the computed quaternions into deviation angles (yaw, pitch, and roll) for the reasons discussed in both *Luo* and *Yang*. Indeed, this conversion is contemplated in both *Luo* and *Yang*. *Luo* discloses, there are "many methods to represent[] angular position from one reference to another reference frame" and each has "advantages and disadvantages." *Luo* at 910. *Yang* similarly discloses that "[d]ifferent applications and situations have different attitude representations that are most convenient to implement." *Yang* ¶ 11.

7. Claim 16

a. [Element 438.16] "The method for obtaining a resulting deviation of a 3D pointing device of claim 14, wherein said previous state of the six-axis motion sensor module is a first quaternion with respect to said previous time T−1; and said updated state of the six-axis motion sensor module is a third quaternion with respect to said current time T."

492. In my opinion, *Luo* in view of *Yang* discloses these features. As discussed above, under CyWee's interpretation, *Luo* in view of *Yang* discloses calculating an updated quaternion which is then re-input into the algorithm as the "previous state" at the next time stage of the Extended Kalman filter. *See* Sections XIII.B.5.e and XIII.B.5.f. *Luo* discloses that each of the attitude calculations is based "on a quaternion." *Luo* at 912. Similarly, *Yang* discloses that quaternions are used in its orientation updates due to "its good mathematical properties, dynamic equations, and calculation efficiency." *Yang* ¶ 39.

8. Claim 17

a. [Element 438.17] "The method for obtaining a resulting deviation of 3D pointing device of claim 14, wherein the obtaining of said previous state of the six-axis motion sensor module further comprises initializing said initial-value set."

493. In my opinion, *Luo* in view of *Yang* discloses these features. *Luo* discloses that a method of initializing the system state where the "attitude quaternion and gyro biases are set to zero." *Luo* at 913.

9. Claim 19

494. From my review, Claims 14 and 19 recite identical claim language. Accordingly, in my opinion, the combination of *Luo* and *Yang* render obvious Claim 19 for the same reasons that they render obvious Claim 14, as I describe in Section XIII.B.5.

C. The CHR-6dm in view of *Abbate* renders obvious Claims 1, 3, 4, 5, 14, 15, 16, 17, and 19 of the '438 Patent

1. Claim 1

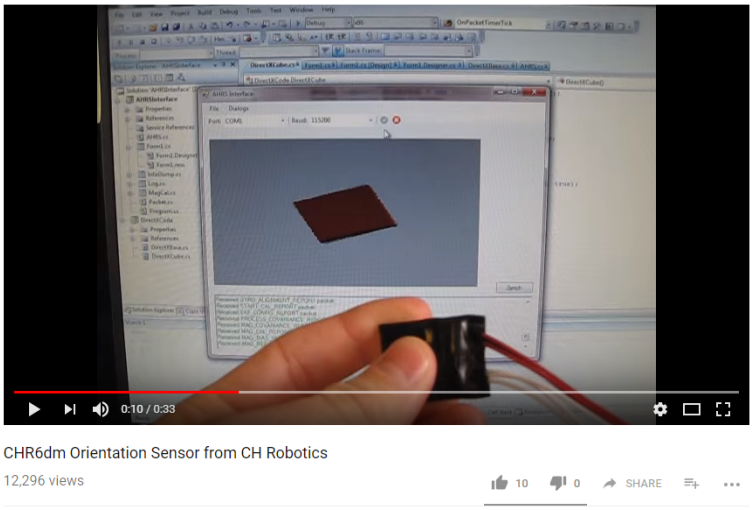
a. [Element 438.1.0] "A three-dimensional (3D) pointing device subject to movements and rotations in dynamic environments, comprising:"

495. I understand that neither Samsung nor CyWee has argued that the preamble of Claim 1 is limiting. However, to the extent that the preamble is considered limiting, in my opinion, the CHR-6dm in view of *Abbate* discloses a 3D pointing device having the features recited in the remaining elements of this claim.

496. I understand that CyWee has interpreted a 3D pointing device to be "a handheld device that uses at least a rotation sensor comprising one or more gyroscopes, and one or more accelerometers to determine deviation angles or the orientation of a device." CyWee's Opening Claim Construction Brief, Dkt. No. 66 at 13–14.

497. Although I do not agree with this interpretation, consistent with CyWee's own definition, the CHR-6dm is a 3D pointing device that is "subject to movements and rotations in dynamic environments." Specifically, the CHR-6dm is an orientation sensor with one or more onboard accelerometers and gyroscopes. The CHR-6dm uses an Extended Kalman filter to produce yaw, pitch and roll angle estimates. *See* CHR-6dm Datasheet at 1.

498. As shown in a screenshot from the "CHR6dm Orientation Sensor from CH Robotics" video (reproduced below), the sensor can be implemented as a handheld device that calculates its own orientation which is translated directly onto a display.

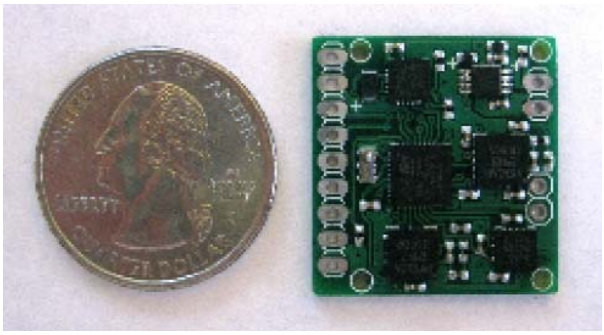
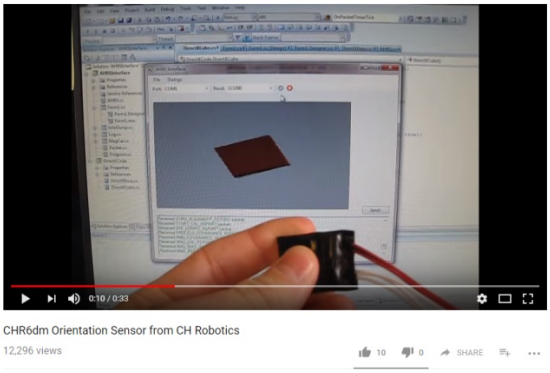


499. If a 3D pointing device is instead interpreted under its proper plain and ordinary meaning, it would have been obvious to a POSA to incorporate the CHR-6dm sensor into any existing prior art 3D pointing device to calculate orientation and facilitate the pointing function.

500. Indeed, as discussed above, the ’438 Patent admits that 3D pointing devices equipped with orientation sensors were well known in the prior art. ’438 Patent at 2:38–3:15. A POSA would have recognized that such a configuration would have been a straightforward combination of known technologies by known methods without changing their respective functions to achieve a predictable result, and would have been well within the capabilities of such a person.

b. [Element 438.1.1] “a housing associated with said movements and rotations of the 3D pointing device in a spatial pointer reference frame;”

501. In my opinion, the CHR-6dm discloses these features. As shown in the figures below, the CHR-6dm is an orientation sensor implemented on a printed circuit board. A POSA would understand that this printed circuit board could be enclosed by a housing.

CHR-6dm System Printed Circuit Board	CHR-6dm System Printed Circuit Board
	

502. As I discussed in Section VIII, I understand that the parties have agreed that the term "spatial pointer reference frame" should be construed as a "frame of reference associated with the 3D pointing device, which always has its origin at the same point in the device and in which the axes are always fixed with respect to the device."

503. Consistent with this description, the CHR-6dm discloses that the orientation sensor is associated with the movements and rotations of the sensor within its own body. Specifically, the CHR-6dm defines two frames of reference. The first is the body frame of the sensor. CHR-6dm Datasheet at 12, 36. The second is the North-East-Down inertial frame, where the "x-axis is aligned with the magnetic north, the y-axis is aligned with magnetic east, and the z-axis points down toward the center of the Earth." *Id.* at 9.

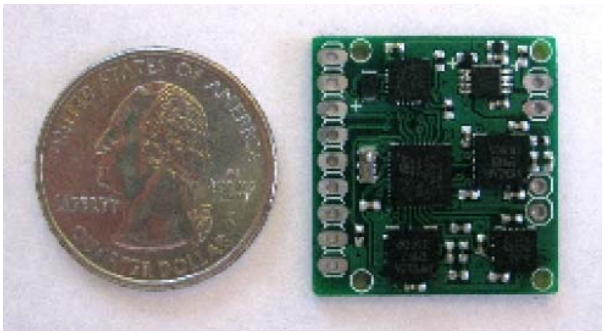
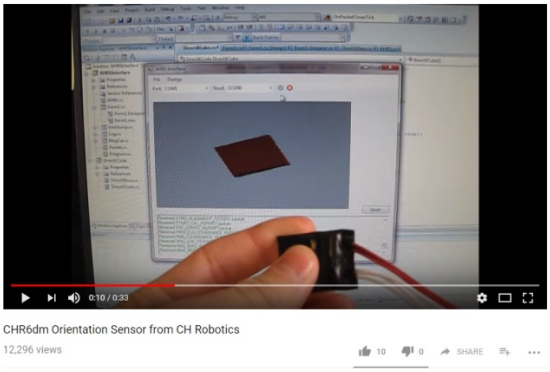
504. As shown in the "CHR6dm Orientation Sensor from CH Robotics" video, a POSA would understand that the CHR-6dm sensor calculates the orientation of the CHR-6dm sensor based on the sensor's orientation in the body frame relative to a known reference frame and then translates this orientation to the display.

505. A POSA would further understand the CHR-6dm's body frame to be a "spatial pointer reference frame" as construed by both parties. Specifically, a POSA would understand that both the CHR-6dm's body frame and the spatial pointer reference frame are frames of

reference defined by an origin within or on the surface of body of the device with fixed axes extending from that origin around which the device rotates.

c. [Element 438.1.2] "a printed circuit board (PCB) enclosed by the housing;"

506. In my opinion, the CHR-6dm discloses these features. As shown in the figures below, the CHR-6dm is an orientation sensor implemented on a printed circuit board. A POSA would understand that this printed circuit board could be enclosed by a housing.

CHR-6dm System Printed Circuit Board	CHR-6dm System Printed Circuit Board
	

d. [Element 438.1.3] "a six-axis motion sensor module attached to the PCB,"

507. In my opinion, the CHR-6dm discloses these features. The CHR-6dm is an orientation sensor implemented on a printed circuit board. The CHR-6dm sensor is composed of on-board gyroscopes and accelerometers that are physically attached to the printed circuit board. CHR-6dm Datasheet at 1.

e. [Element 438.1.4] "comprising a rotation sensor for detecting and generating a first signal set comprising angular velocities ω_x, ω_y, ω_z associated with said movements and rotations of the 3D pointing device in the spatial pointer reference frame,"

508. In my opinion, the CHR-6dm discloses these features. Specifically, the CHR-6dm includes one or more on-board gyroscopes. CHR-6dm Datasheet at 1. The gyroscopes measure the angular velocities associated with the movements and rotations of the orientation sensor. *Id.*

at 1, 7–8, 28, 35–36. These angular velocities are "associated with said movements and rotations" of the CHR-6dm sensor ("3D pointing device") in the "spatial pointer reference frame." Specifically, the gyroscopes measure "rotation rates in the body frame" (i.e., the "spatial pointer reference frame"). *Id.* at 36.

f. [Element 438.1.5] "an accelerometer for detecting and generating a second signal set comprising axial accelerations A_x, A_y, A_z associated with said movements and rotations of the 3D pointing device in the spatial pointer reference frame; and"

509. In my opinion, the CHR-6dm discloses these features. Specifically, the CHR-6dm includes an on-board accelerometer. CHR-6dm Datasheet at 1. The accelerometers measure the accelerations associated with the movements and rotations of the orientation sensor. *Id.* at 1, 7–8, 13, 35–36. These accelerations are "associated with said movements and rotations" of the CHR-6dm sensor ("3D pointing device") in the "spatial pointer reference frame." Specifically, the accelerometers are "aligned to the body frame of the device." A POSA would understand that the accelerometers measure accelerations in this body frame (i.e., the "spatial pointer reference frame"). *Id.* at 13.

g. "a processing and transmitting module, comprising a data transmitting unit electrically connected to the six-axis motion sensor module for transmitting said first and second signal sets thereof and a computing processor for receiving and calculating said first and second signal sets from the data transmitting unit, communicating with the six-axis motion sensor module to calculate a resulting deviation comprising resultant angles in said spatial pointer reference frame by utilizing a comparison to compare the first signal set with the second signal set whereby said resultant angles in the spatial pointer reference frame of the resulting deviation of the six-axis motion sensor module of the 3D pointing device are obtained under said dynamic environments, wherein the comparison utilized by the processing and transmitting module further comprises an update program to obtain an updated state based on a previous state associated with said first signal set and a measured state associated with said second signal set; wherein the measured state includes a measurement of said second signal set and a predicted measurement obtained based on the first

signal set without using any derivatives of the first signal set."

510. I will discuss the features of this element below in two parts.

(1) [Element 438.1.6] "a processing and transmitting module, comprising a data transmitting unit electrically connected to the six-axis motion sensor module for transmitting said first and second signal sets thereof and a computing processor for receiving and calculating said first and second signal sets from the data transmitting unit,"

511. In my opinion, the claim language of the '438 Patent does not provide guidance on the meaning of the terms "processing and transmitting module," "data transmitting module," or "computing processor" beyond the functions they perform. The '438 Patent specification similarly broadly describes a module comprising a "data transmitting unit" and "processor," whereby the signals from the six-axis sensor module are transmitted via the data transmitting unit to the processor.'438 Patent at 9:42–49.

512. In my opinion, the CHR-6dm system discloses components that perform the same functions as the claimed "processing and transmitting module." Specifically, the CHR-6dm discloses that it can be configured to transmit both raw sensor data and angle estimates over a microcontroller known as a TTL ("transistor-transistor logic") UART ("universal asynchronous receiver and transmitter."). CHR-6dm Datasheet at 1. This sensor data is passed to the on-board Extended Kalman filter. *Id.* at 8–9. A POSA would have understood that a processor would be necessary to run the code implementing this Extended Kalman filter.

513. Accordingly, the CHR-6dm discloses the claimed "processing and transmitting module" whereby: (i) the sensors are electrically connected and transmit data via a TTL UART ("data transmitting unit") to (ii) an on-board Extended Kalman filter which would necessarily include a processor ("computing processor") which receives and calculations an estimated orientation based on these measured values.

(2) [Element 438.1.7] "communicating with the six-axis motion sensor module to calculate a resulting deviation comprising resultant angles in said spatial pointer reference frame by utilizing a comparison to compare the first signal set with the second signal set whereby said resultant angles in the spatial pointer reference frame of the resulting deviation of the six-axis motion sensor module of the 3D pointing device are obtained under said dynamic environments, wherein the comparison utilized by the processing and transmitting module further comprises an update program to obtain an updated state based on a previous state associated with said first signal set and a measured state associated with said second signal set; wherein the measured state includes a measurement of said second signal set and a predicted measurement obtained based on the first signal set without using any derivatives of the first signal set."

514. In my opinion, the CHR-6dm in view of *Abbate* discloses these features.

515. As I explain in Section XV.A.2, the '438 Patent does not describe the limitation of "utilizing a comparison to compare the first signal set with the second signal signal set."

516. Even more ambiguously, the '438 Patent goes on to recite that the "comparison" that is utilized further comprises an "update program" that is used to obtain an "updated state" that is based on: (i) a "previous state" associated with said first signal set and (ii) a "measured state" associated with said second signal set.

517. The "measured state" is defined to include both the measurement of the second signal set and "a predicted measurement obtained based on the first signal set without using any derivatives of the first signal set."

518. I understand that the parties have agreed that this predicted measurement comprises "predicted axial accelerations calculated using the angular velocities without computing derivatives of said angular velocities (i.e. angular accelerations)." *See* Section VIII.

519. I further understand that CyWee has alleged that the "state" of the "3D pointing device" is generally some value used to describe the device at a specific point in time. *See e.g.*,

CyWee's Opening Claim Construction Brief, Dkt. No. 66 at 9; Plaintiff's Markman Slides at 30.

520. As I explain in Sections XV.A.2 and XV.A.5, the '438 Patent does not describe how to: (i) obtain predicted axial accelerations or (ii) perform a comparison between angular velocities, axial accelerations and predicted axial accelerations. As I explain in Sections XV.A.2 and XV.A.5, any such comparison is mathematically impossible and would at best produce a meaningless result.

521. I understand that CyWee and its experts have claimed that this limitation is met by an Extended Kalman filter or something like an Extended Kalman filter and an "indirect" comparison between angular velocities and axial accelerations is possible by using an Extended Kalman filter and representing the orientation in quaternion format, as allegedly shown in Equations 5–11 of the '438 Patent.

522. I understand that CyWee and its experts have claimed that the "predicted measurement" is the direction of gravity obtained from a second quaternion representing orientation, as allegedly disclosed in Equations 2–4 of the '438 Patent. Plaintiff's Markman Slides at 30. However, because of the lack of guidance in the '438 Patent regarding the precise meaning of a "predicted acceleration," in my opinion, it is unclear what the scope of the claim term is beyond that it is some predicted acceleration value.

523. I do not agree with CyWee's claims above. However, taking CyWee's own representations as true, this limitation covers a quaternion-based Extended Kalman filter that uses angular velocities to predict an object's orientation that is then corrected using gravitational accelerations (or some "predicted" acceleration value). Accordingly, if taken as true, in my opinion, the CHR-6dm in view of *Abbate* discloses these features.

524. Specifically, the CHR-6dm is an orientation sensor that uses an Extended Kalman

filter to combine data from onboard accelerometers, gyroscopes, and magnetic sensors to produce yaw, pitch, and roll angle estimates. CHR-6dm Datasheet at 1.

525. The CHR-6dm utilizes a continuous two-step Extended Kalman filter, where "rate gyro measurements are used to drive the prediction step, and the accelerometer and magnetometer are used for drift correction in the update step." *Id.* at 8. In the drift correction, "[o]n average, the accelerometers measure the gravity vector. The EKF 'knows' which way is down by observing the direction of the gravity vector." *Id.* at 9.

526. The basic steps used in the Extended Kalman filter are detailed in the CHR-6dm firmware code. Specifically, in the chr6dm_states.c file, the Extended Kalman filter is executed in the EKF_EstimateStates function (reproduced below):

EKF_EstimateStates Function from CHR-6dm Firmware

```
void EKF_EstimateStates( AHRS_states* estimated_states, RawSensorData* sensor_data)
{
        static int initialized = 0;

        if( !initialized )
        {
//              EKF_InitFromSensors ( estimated_states, sensor_data );
                EKF_Init( estimated_states );
                initialized = 1;
        }

        // Run EKF prediction step
        EKF_Predict( estimated_states, sensor_data );

        // Run EKF update step
        EKF_Update( estimated_states, sensor_data );
}
```

In the above code:

- The EKF_InitFromSensors function uses sensor data to fill an initial state estimate structure;

- The EKF_Predict function uses rate gyros to make a new orientation estimate; and
- The EKF_Update function uses the accelerometers to correct pitch and roll errors and magnetic sensors to correct yaw errors.

527. This Extended Kalman filter uses both measured accelerations and predicted accelerations.

528. Specifically, the EKF_Update function initializes variables for pitch, roll and yaw.

EKF_Update Function from CHR-6dm Firmware (Initializing theta, phi, psi)

float theta = estimated_states->theta;
float phi = estimated_states->phi;
float psi = estimated_states->psi;

529. A rotation matrix (R) from the inertial frame to the body frame is created for computing expected sensor outputs.

EKF_Update Function from CHR-6dm Firmware (Building Rotation Matrix)
R.data[0][0] = cos_psi*cos_theta; R.data[0][1] = cos_theta*sin_psi; R.data[0][2] = -sin_theta; R.data[1][0] = cos_psi*sin_phi*sin_theta - cos_phi*sin_psi; R.data[1][1] = cos_phi*cos_psi + sin_phi*sin_psi*sin_theta; R.data[1][2] = cos_theta*sin_phi; R.data[2][0] = sin_phi*sin_psi + cos_phi*cos_psi*sin_theta; R.data[2][1] = cos_phi*sin_psi*sin_theta - cos_psi*sin_phi; R.data[2][2] = cos_phi*cos_theta;

530. An expected accelerometer output is computed.

EKF_Update Function from CHR-6dm Firmware (Compute "Expected" Accelerometer Output)
MatVectMult3(&R, &accel_ref, &acc_hat);

531. The covariance matrix for the Kalman filter is computed. After that, the measured

accelerations are input into a data array.

EKF_Update Function from CHR-6dm Firmware (Obtain "Measured" Accelerations)

acc_vect.data[0] = sensor_data->accel_x;
acc_vect.data[1] = sensor_data->accel_y;
acc_vect.data[2] = sensor_data->accel_z;

532. The measured accelerations and the expected accelerometer output are then used to correct pitch and roll errors.

EKF_Update Function from CHR-6dm Firmware (Using "Measured" and "Expected" Accelerations to Correct Pitch and Roll Errors)

// Subtract accel bias
acc_vect.data[0] = acc_vect.data[0] - (float)gConfig.x_accel_bias;
acc_vect.data[1] = acc_vect.data[1] - (float)gConfig.y_accel_bias;
acc_vect.data[2] = acc_vect.data[2] - (float)gConfig.z_accel_bias;
 	
// Apply alignment correction
MatVectMult3(&gConfig.accel_alignment, &acc_vect, &acc_vect);
 	
// Now subtract the reference vector
acc_vect.data[0] = acc_vect.data[0] - acc_hat.data[0];
acc_vect.data[1] = acc_vect.data[1] - acc_hat.data[1];
acc_vect.data[2] = acc_vect.data[2] - acc_hat.data[2];
 	
// Multiply by Kalman gain
MatVectMult3(&L, &acc_vect, &correction);
 	
// Apply correction
estimated_states->phi = estimated_states->phi + correction.data[0];
estimated_states->theta = estimated_states->theta + correction.data[1];
estimated_states->psi = estimated_states->psi + correction.data[2];

533. Consistent with CyWee's interpretation of the "predicted measurement" the CHR-6dm operates under the assumption that accelerometers measure the "gravity vector" and that the EKF therefore knows "which way is down by observing the direction of the gravity vector." CHR-6dm Datasheet at 8–9.

534. Accordingly, the EKF uses the measured accelerometers (i.e., the "measured

state") and expected accelerations (i.e., the "predicted measurement") to correct an orientation estimate (i.e., "the updated state."). A POSA would understand that this "updated state" could be fed back into the Extended Kalman filter as the "previous state."

535. To the extent that CyWee claims that the CHR-6dm does not meet this limitation because it does not use quaternion representations of orientation or because the "expected acceleration" in the CHR-6dm is not a "predicted acceleration," it would have been obvious to a POSA at the time of the alleged invention to modify the CHR-6dm to use quaternions and/or "predict accelerations" in view of the teachings of *Abbate*.

536. *Abbate* discloses a real-time inertial motion capture system using inertial measurement units (IMUs) that are used to record and reconstruct human motion. *Abbate* at 255. The IMUs contain: (i) three single-axis angular rate gyroscopes; (ii) one three-axis accelerometer; and (iii) one three-axis magnetometer. *Id.* at 256. The IMUs are placed on fixed key points on the human body. *Id.* The readings from these IMUs are fed into a centralized collection point and the orientations of the key points are calculated using a quaternion-based Extended Kalman filter. *Id.* at 255–256. In this way, the system is able to use "several kinds of sensors" so that the "characteristics of one type of sensor avoid overcoming the limitations of other sensors." *Id.* at 257.

537. Figure 6 of *Abbate* (reproduced here) depicts the sensor-fusion process disclosed in *Abbate*'s quaternion-based Extended Kalman filter. As shown in Figure 6, the Extended Kalman filter weighs the three sources of information from the gyroscopes, accelerometers

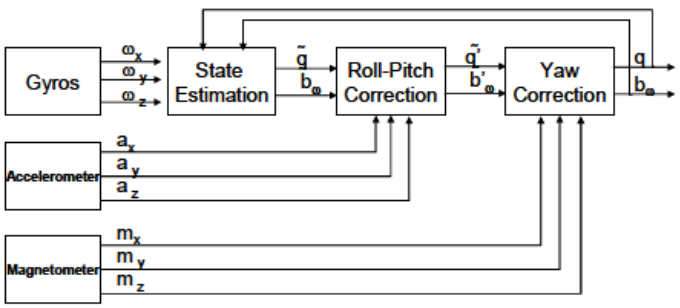


Fig.6. Flow diagram of the implemented quaternion based EKF.

and magnetometers appropriately in order to provide an accurate estimate of orientation and eliminate noise. *Id.* at Fig. 6, 258. In the Extended Kalman filter, the orientation is first estimated using angular rate velocities. The Extended Kalman filter then implements a two-step correction process in which: (i) acceleration data is used to correct roll and pitch angles and (ii) magnetic field data is used to correct the yaw angle. *Id.*

538. Specifically, in *Abbate*, the Kalman filter is initialized with an initial state (i.e., orientation) estimate, and that initial state estimate is combined with the state estimation updated in the prior iteration of the Kalman-filter loop (i.e., the "update[d] state estimation with measurement zk" shown in that figure). *Id.* at Fig. 8. This combined value is depicted as the "state estimation" in Figure 6.

539. As shown in Figure 6, the "state estimation" is modified by angular velocity measurements from the gyroscopes, which generates a quaternion representing the current state of the device. The roll and pitch components of the quaternion representing the device's current state are then further corrected by the measured accelerations (or the "measured state" as shown in the "roll-pitch correction" step in Figure 6) to update the state estimation used in that iteration of the Kalman-filter loop (i.e., the "updated state"). *Id.* at Fig. 6, 258. Those corrections are based on acceleration measurements from the accelerometers in combination with an error estimate associated with the "state estimation" (i.e., the "predicted measurement"). *Id.* The "updated state" is then fed recursively back into the Extended Kalman filter and used in the next time iteration so that it becomes the "previous state." *Id.* at Figs. 6, 8, 257–58.

540. *Abbate* further discloses the use of a non-linear function that mirrors Equations 2–4 of the '438 Patent (which CyWee discloses meets the "predicted axial accelerations" limitation). *Id.* at 258. Consistent with CyWee's allegation that the acceleration being derived is

the gravitational acceleration, "*g*" is defined in *Abbate*'s non-linear function as the gravitational acceleration.

Equations 2–4 in '438 Patent	Non-Linear Function h(x) in *Abbate*
$Ax=2(q_1q_3-q_0q_2)$ $Ay=2(q_2q_3+q_0q_1)$ $Az=q_0^2-q_1^2-q_2^2+q_3^2$	$h(x)=\begin{bmatrix} 2g(q_1q_3-q_0q_2) \\ 2g(q_2q_3-q_0q_1) \\ g(q_0^2-q_1^2-q_2^2+q_3^2) \\ \arctan\left(\frac{2(q_1q_2+q_0q_3)}{q_0^2-q_1^2-q_2^2+q_3^2}\right) \end{bmatrix}$

541. Consistent with CyWee's allegations, *Abbate*'s non-linear function would obtain "predicted axial accelerations" without taking the derivatives of the angular velocities in the same way that Equations 2–4 in the '438 Patent would.

542. Although *Abbate* and the CHR-6dm both disclose the use of measurements from a magnetometer, which are used to correct the yaw component of the state estimation, a POSA would have understood that the algorithm disclosed in *Abbate* and used by the CHR-6dm could be modified to exclude correction of the yaw component. If correction of the yaw component is not performed, measurements from the magnetometer are not necessary for the algorithm to function.

543. In view of these teachings of *Abbate*, a POSA would have been motivated to configure the CHR-6dm so that the Extended Kalman filter uses quaternions as disclosed in *Abbate* for computational efficiency and to eliminate the singularity when the pitch is at +/- 90 degrees.

544. As the CHR-6dm Datasheet acknowledges, by using Euler angles, the CHR-6dm "cannot be used to measure orientation if it is expected to approach a pitch angle of +/- 90 degrees. To fix this problem, a quaternion representation must be used instead of Euler Angles." CHR-6dm Datasheet at 9. This same advantage of using quaternions is disclosed in *Abbate*. As

Abbate discloses, "[q]uaternions are used to represent space orientation in order to improve computational efficiency and avoid singularities [4]." *Abbate* at 258.

545. In addition, to the extent that CyWee contends the CHR-6dm does not disclose "predicted accelerations," a POSA would have been further motivated to configure the CHR-6dm to use the techniques disclosed in *Abbate*, for the same reasons that CyWee contends any POSA would have been motivated to use "predicted accelerations."

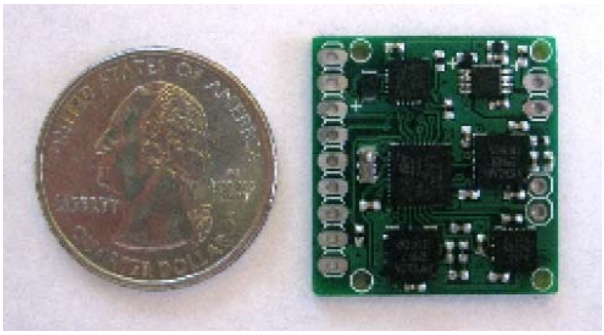
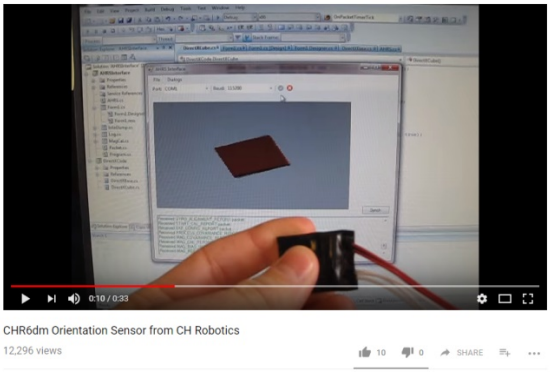
546. A POSA would have recognized that such a modification would have been a straightforward combination of known technologies by known methods without changing their respective functions to achieve a predictable result, and would have been well within the capabilities of such a person.

547. Furthermore, a POSA would have been encouraged to look to *Abbate* to complement the teachings of the CHR-6dm because these references are all directed to the same technical field and describe solutions to similar problems in the field. For example, both the CHR-6dm and *Abbate* disclose calculating orientation using a combination of gyroscopes, accelerometers and magnetometers by using Extended Kalman filters. CHR-6dm Datasheet at 8–9; *Abbate* at 255–258.

2. Claim 3

a. [Element 438.3] "The 3D pointing device of claim 1, wherein the PCB enclosed by the housing comprises at least one substrate having a first longitudinal side configured to be substantially parallel to a longitudinal surface of the housing."

548. In my opinion, the CHR-6dm in view of *Abbate* discloses these features. As shown in the figures below, the CHR-6dm is an orientation sensor implemented on a printed circuit board. A POSA would understand that this printed circuit board could be enclosed by a housing.

CHR-6dm System Printed Circuit Board	CHR-6dm System Printed Circuit Board
	

549. A POSA would have understood that the printed circuit board could be configured in such a way that one of the substrates has a first longitudinal side that is substantially parallel to the housing. For example, a POSA would have been motivated to configure the printed circuit board in this way to better conform to the structure of traditional pointing devices and to make a more natural shape for manipulation by a human hand.

3. Claim 4

a. [Element 438.4] "The 3D pointing device of claim 1, wherein the spatial pointer reference frame is a reference frame in three dimensions; and wherein said resultant angles of the resulting deviation includes yaw, pitch and roll angles about each of three orthogonal coordinate axes of the spatial pointer reference frame."

550. In my opinion, the CHR-6dm in view of *Abbate* discloses these features. The CHR-6dm discloses a "body frame" defined in relation to the orientation sensor that is a reference frame defined in three dimensions. CHR-6dm Datasheet at 12, 35. As I describe above in Section XIII.C.1.b, a POSA would understand this "body frame" to be a "spatial pointer reference frame."

551. The CHR-6dm further discloses that the resulting deviation of the device is expressed using yaw, pitch, and roll angles. *Id.* at 1, 7. The "pitch" angle represents "positive rotation about the x-axis," the "roll" angle represents "positive rotation about the y-axis" and the

"yaw" angle represents "positive rotation about the z-axis." *Id.* at 9.

4. Claim 5

a. [Element 438.5] "The 3D pointing device of claim 1, wherein the data transmitting unit of the processing and transmitting module is attached to the PCB enclosed by the housing and transmits said first and second signal of the six-axis motion sensor module to the computing processor via electronic connections on the PCB."

552. In my opinion, the CHR-6dm in view of *Abbate* discloses these features. Specifically, the CHR-6dm discloses that it can be configured to transmit both raw sensor data and angle estimates over a microcontroller known as a TTL ("transistor-transistor logic") UART ("universal asynchronous receiver and transmitter."). CHR-6dm Datasheet at 1. This sensor data is passed to the on-board EKF. *Id.* at 8–9. A POSA would have understood that a processor would be necessary to run the code implementing this EKF.

553. Accordingly, the CHR-6dm in view of *Abbate* discloses the claimed "processing and transmitting module" whereby: (i) the sensors are electrically connected and transmit data via a TTL UART ("data transmitting unit") to (ii) an on-board EKF which would necessarily include a processor ("computing processor), which is executed to calculate orientation.

5. Claim 14

a. [Element 438.14.0] "A method for obtaining a resulting deviation including resultant angles in a spatial pointer reference frame of a three-dimensional (3D) pointing device utilizing a six-axis motion sensor module therein and subject to movements and rotations in dynamic environments in said spatial pointer reference frame, comprising the steps of:"

554. I understand that neither Samsung nor CyWee has argued that the preamble of Claim 14 is limiting. However, to the extent that the preamble is considered limiting, in my opinion, the CHR-6dm in view of *Abbate* discloses a method with the recited features.

555. For the reasons I set forth in Section XIII.C.1.a, the CHR-6dm is a "three-

dimensional (3D) pointing device," consistent with CyWee's proposed construction of this term. Specifically, the CHR-6dm is an orientation sensor implemented on a handheld device that uses onboard gyroscopes and accelerometers to determine the device's orientation. CHR-6dm Datasheet at 1.

556. For the reasons I set forth in Section XIII.C.1.d, the CHR-6dm has a "six-axis motion sensor module." Specifically, the CHR-6dm sensor is composed of on-board gyroscopes and accelerometers that are physically attached to a printed circuit board. CHR-6dm Datasheet at 1.

557. For the reasons I set forth in Section XIII.C.1.g, the CHR-6dm discloses a method for obtaining the deviation of the orientation sensor ("3D pointing device") in the "spatial pointer reference frame" of the orientation sensor. Specifically, as I discussed in Section XIII.C.1.g, I understand that CyWee and its experts have claimed that this limitation is met by an Extended Kalman filter or something like an Extended Kalman filter, as allegedly shown in Equations 5–11 of the '438 Patent.

558. I do not agree. However, taking CyWee's own representations as true, Claim 14's method covers a quaternion-based Extended Kalman filter that uses angular velocities to predict an object's orientation that is then corrected using gravitational accelerations (or some predicted acceleration value).

559. If taken as true, in my opinion, the CHR-6dm in view of *Abbate* disclose these features as: (i) the CHR-6dm discloses the use of Extended Kalman filters for calculating the deviation of a device's orientation; (ii) *Abbate* discloses a quaternion-based Extended Kalman filter for calculating the deviation of a device's orientation; and (iii) both the CHR-6dm and *Abbate* disclose correcting the initial orientation estimation obtained by a gyroscope reading

using acceleration data. *See* Section XIII.C.1.g.

b. [Element 438.14.1] "obtaining a previous state of the six-axis motion sensor module; wherein the previous state includes an initial-value set associated with previous angular velocities gained from the motion sensor signals of the six-axis motion sensor module at a previous time T−1;"

560. In my opinion, the CHR-6dm in view of *Abbate* discloses these features. For the reasons I set forth in Section XIII.C.1.d, the CHR-6dm sensor is composed of on-board gyroscopes and accelerometers that are physically attached to a printed circuit board ("six-axis motion sensor module.").

561. The CHR-6dm uses angular velocity readings in a continuous two-step Extended Kalman filter, where the "rate gyro measurements are used to drive the prediction step, and the accelerometer and magnetometer are used for drift correction in the update step." CHR-6dm Datasheet at 8. In the drift correction step, "[o]n average, the accelerometers measure the gravity vector. The EKF 'knows' which way is down by observing the direction of the gravity vector." *Id.* at 9.

562. The basic steps used in the Extended Kalman filter are detailed in the CHR-6dm firmware code. Specifically, in the chr6dm_states.c file, the Extended Kalman filter is executed in the EKF_EstimateStates function (reproduced below):

EKF_EstimateStates Function from CHR-6dm Firmware

```
void EKF_EstimateStates( AHRS_states* estimated_states, RawSensorData* sensor_data)
{
        static int initialized = 0;

        if( !initialized )
        {
//              EKF_InitFromSensors ( estimated_states, sensor_data );
                EKF_Init( estimated_states );
                initialized = 1;
        }
```

```
        // Run EKF prediction step
        EKF_Predict( estimated_states, sensor_data );

        // Run EKF update step
        EKF_Update( estimated_states, sensor_data );
}
```

In the above code:

- The EKF_InitFromSensors function uses sensor data to fill an initial state estimate structure;
- The EKF_Predict function uses rate gyros to make a new orientation estimate; and
- The EKF_Update function uses the accelerometers to correct pitch and roll errors and magnetic sensors to correct yaw errors.

563. As shown in the EKF_Predict function, the CHR-6dm's EKF is continuous and begins by setting the variables phi, theta and psi with the current state estimates from the last iteration of the algorithm.

EKF_Predict Function from CHR-6dm Firmware

```
// Get current state estimates
 phi = estimated_states->phi;
 theta = estimated_states->theta;
 psi = estimated_states->psi;
```

564. To the extent that the "previous state" is interpreted to require the orientation to be in quaternion format, it would have been obvious to a POSA at the time of the alleged invention to modify the CHR-6dm to use quaternions in view of the teachings of *Abbate*.

565. *Abbate* discloses a real-time inertial motion capture system using inertial measurement units (IMUs) that are used to record and reconstruct human motion. *Abbate* at 255. The IMUs contain: (i) three single-axis angular rate gyroscopes; (ii) one three-axis accelerometer; and (iii) one three-axis magnetometer. *Id.* at 256. The IMUs are placed on fixed

key points on the human body. *Id.* The readings from these IMUs are fed into a centralized collection point and the orientations of the key points are calculated using a quaternion-based Extended Kalman filter. *Id.* at 255–256. In this way, the system is able to use "several kinds of sensors" so that the "characteristics of one type of sensor avoid overcoming the limitations of other sensors." *Id.* at 257.

566. Figure 6 of *Abbate* (reproduced here) depicts the sensor-fusion process disclosed in *Abbate*'s quaternion-based Extended Kalman filter. As shown in Figure 6, the Extended Kalman filter weighs the three sources of information from the gyroscopes, accelerometers and magnetometers appropriately in order to provide an accurate estimate of orientation and eliminate noise. *Id.* at Fig. 6, 258. In the Extended Kalman filter, the orientation is first estimated using angular rate velocities. The Extended Kalman filter then implements a two-step correction process in which: (i) acceleration data is used to correct roll and pitch angles and (ii) magnetic field data is used to correct the yaw angle. *Id.*

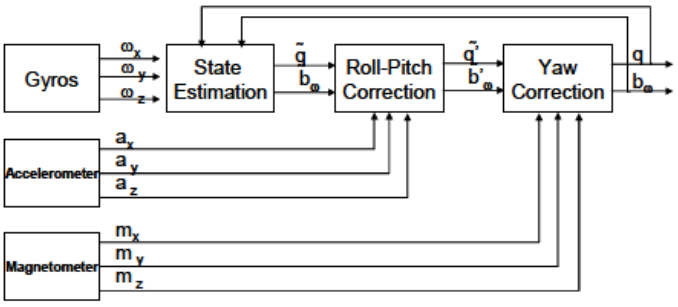


Fig.6. Flow diagram of the implemented quaternion based EKF.

567. Specifically, in *Abbate*, the Kalman filter is initialized with an initial state (i.e., orientation) estimate, and that initial state estimate is combined with the state estimation updated in the prior iteration of the Kalman-filter loop (i.e., the "update[d] state estimation with measurement zk" shown in that figure). *Id.* at Fig. 8. This combined value is depicted as the "state estimation" in Figure 6.

568. As shown in Figure 6, the "state estimation" is modified by angular velocity measurements from the gyroscopes, which generates a quaternion representing the current state

of the device. The roll and pitch components of the quaternion representing the device's current state are then further corrected by the measured accelerations (or the "measured state" as shown in the "roll-pitch correction" step in Figure 6) to update the state estimation used in that iteration of the Kalman-filter loop (i.e., the "updated state"). *Id.* at Fig. 6, 258. Those corrections are based on acceleration measurements from the accelerometers in combination with an error estimate associated with the "state estimation" (i.e., the "predicted measurement"). *Id.* The "updated state" is then fed recursively back into the Extended Kalman filter and used in the next time iteration so that it becomes the "previous state." *Id.* at Figs. 6, 8, 257–58.

569. A POSA would have been motivated to configure the CHR-6dm's Extended Kalman filter to represent the "current state" in quaternion format in light of *Abbate* for the same reasons I described above in Section XIII.C.1.g. Specifically, a POSA would have been motivated to configure the CHR-6dm so that the Extended Kalman filter uses quaternions as disclosed in *Abbate* for computational efficiency and to eliminate singularities.

c. [Element 438.14.2] "obtaining a current state of the six-axis motion sensor module by obtaining measured angular velocities ω_x, ω_y, ω_z gained from the motion sensor signals of the six-axis motion sensor module at a current time T;"

570. In my opinion, the CHR-6dm in view of *Abbate* discloses these features. For the reasons I set forth in Section XIII.C.1, the CHR-6dm sensor is composed of on-board gyroscopes and accelerometers that are physically attached to a printed circuit board ("six-axis motion sensor module").

571. As I described above in Section XIII.C.5.b, the CHR-6dm's Extended Kalman filter calculates current state estimates using measured angular velocities. *See* CHR-6dm Datasheet at 8.

572. To the extent that the "current state" is interpreted to require the orientation to be

in quaternion format, it would have been obvious to a POSA at the time of the alleged invention to modify the CHR-6dm to use quaternions in view of the teachings of *Abbate*.

573. As I described above in Section XIII.C.5.b, *Abbate* discloses a quaternion-based Extended Kalman filter where the orientation is first estimated using angular rate velocities.

574. Specifically, in *Abbate*, the Kalman filter is initialized with an initial state (i.e., orientation) estimate, and that initial state estimate is combined with the state estimation updated in the prior iteration of the Kalman-filter loop (i.e., the "update[d] state estimation with measurement zk" shown in that figure). *Id.* at Fig. 8. This combined value is depicted as the "state estimation" in Figure 6 (reproduced here). As shown in Figure 6, the "state estimation" is modified by angular velocity measurements from the gyroscopes, which generates a quaternion representing the current state of the device.

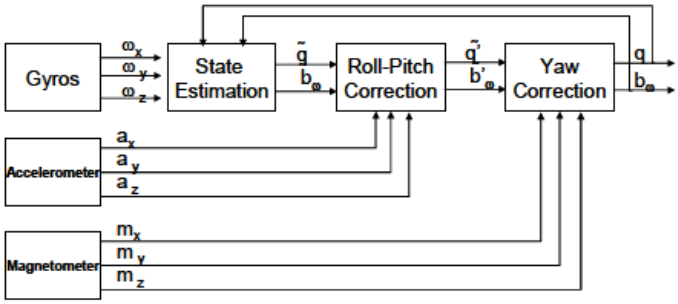


Fig.6. Flow diagram of the implemented quaternion based EKF.

575. A POSA would have been motivated to configure the CHR-6dm's Extended Kalman filter to represent the "current state" in quaternion format in light of *Abbate* for the same reasons I described above in Section XIII.C.1.g. Specifically, a POSA would have been motivated to configure the CHR-6dm so that the Extended Kalman filter uses the quaternions as disclosed in *Abbate* for computational efficiency and to eliminate singularities.

d. "obtaining a measured state of the six-axis motion sensor module by obtaining measured axial accelerations Ax, Ay, Az gained from the motion sensor signals of the six-axis motion sensor module at the current time T and calculating predicted axial accelerations Ax′, Ay′, Az′ based on the measured angular velocities ω_x, ω_y, ω_z of the current state of the six-axis motion sensor module without

using any derivatives of the measured angular velocities ω_x, ω_y, ω_z; said current state of the six-axis motion sensor module is a second quaternion with respect to said current time T; comparing the second quaternion in relation to the measured angular velocities ω_x, ω_y, ω_z of the current state at current time T with the measured axial accelerations Ax, Ay, Az and the predicted axial accelerations Ax′, Ay′, Az′ also at current time T;"

576. I will discuss the features of this element below in three parts.

(1) [Element 438.14.3] "obtaining a measured state of the six-axis motion sensor module by obtaining measured axial accelerations Ax, Ay, Az gained from the motion sensor signals of the six-axis motion sensor module at the current time T and"

577. In my opinion, the CHR-6dm discloses these features. For the reasons I set forth in Section XIII.C.1.d, the CHR-6dm sensor is composed of on-board gyroscopes and accelerometers that are physically attached to a printed circuit board ("six-axis motion sensor module.").

578. The CHR-6dm further discloses taking measured accelerometer values and expected accelerometer values to apply a correction to the estimated state calculated using measured angular velocities.

579. These steps are shown in the chr6dm_states.c file.

580. Specifically, in the chr6dm_states.c file, the Extended Kalman filter is executed in the EKF_EstimateStates function (reproduced below):

EKF_EstimateStates Function from CHR-6dm Firmware

```
void EKF_EstimateStates( AHRS_states* estimated_states, RawSensorData* sensor_data)
{
        static int initialized = 0;

        if( !initialized )
        {
//              EKF_InitFromSensors ( estimated_states, sensor_data );
                EKF_Init( estimated_states );
                initialized = 1;
```

```
        }

        // Run EKF prediction step
        EKF_Predict( estimated_states, sensor_data );

        // Run EKF update step
        EKF_Update( estimated_states, sensor_data );
}
```

In the above code:

- The EKF_InitFromSensors function uses sensor data to fill an initial state estimate structure;
- The EKF_Predict function uses rate gyros to make a new orientation estimate; and
- The EKF_Update function uses the accelerometers to correct pitch and roll errors and magnetic sensors to correct yaw errors.

581. As shown in the EKF_Update function, the measured accelerations are input into a data array.

EKF_Update Function from CHR-6dm Firmware (Obtain "Measured" Accelerations)

```
acc_vect.data[0] = sensor_data->accel_x;
acc_vect.data[1] = sensor_data->accel_y;
acc_vect.data[2] = sensor_data->accel_z;
```

582. The measured accelerations and the expected accelerometer values are then used to correct pitch and roll errors.

EKF_Update Function from CHR-6dm Firmware (Using "Measured" and "Expected" Accelerations to Correct Pitch and Roll Errors)

```
// Subtract accel bias
acc_vect.data[0] = acc_vect.data[0] - (float)gConfig.x_accel_bias;
acc_vect.data[1] = acc_vect.data[1] - (float)gConfig.y_accel_bias;
acc_vect.data[2] = acc_vect.data[2] - (float)gConfig.z_accel_bias;

// Apply alignment correction
MatVectMult3( &gConfig.accel_alignment, &acc_vect, &acc_vect );
```

```
// Now subtract the reference vector
acc_vect.data[0] = acc_vect.data[0] - acc_hat.data[0];
acc_vect.data[1] = acc_vect.data[1] - acc_hat.data[1];
acc_vect.data[2] = acc_vect.data[2] - acc_hat.data[2];

// Multiply by Kalman gain
MatVectMult3( &L, &acc_vect, &correction );

// Apply correction
estimated_states->phi = estimated_states->phi + correction.data[0];
estimated_states->theta = estimated_states->theta + correction.data[1];
estimated_states->psi = estimated_states->psi + correction.data[2];
```

583. Based on CyWee's interpretation of a "measured state," a POSA would understand the measured acceleration readings to be the "measured state." *See* CyWee's Opening Claim Construction Brief, Dkt. No. 66 at 9 ("The second quaternion is used to generate predicted axial accelerations (predicted state), which are compared to the measured accelerations (measured state or second signal set).").

(2) [Element 438.14.4] "calculating predicted axial accelerations Ax′, Ay′, Az′ based on the measured angular velocities ω_x, ω_y, ω_z of the current state of the six-axis motion sensor module without using any derivatives of the measured angular velocities ω_x, ω_y, ω_z"

584. As I explain in Section XV.A.6, the '438 Patent does not describe how to calculate "predicted axial accelerations Ax′, Ay′, Az′ based on the measured angular velocities ω_x, ω_y, ω_z of the current state of the six-axis motion sensor module without using any derivatives of the measured angular velocities ω_x, ω_y, ω_z."

585. I understand that CyWee and its experts have claimed that the "predicted measurement" is the direction of gravity obtained from a second quaternion representing orientation, as allegedly disclosed in Equations 2–4 of the '438 Patent. Plaintiff's Markman Slides at 30. However, because of the lack of guidance in the '438 Patent regarding the precise meaning of a "predicted acceleration," in my opinion, it is unclear what the scope of the claim

term is beyond that it is some predicted acceleration value.

586. In my opinion, the CHR-6dm discloses these features. In particular, the CHR-6dm's Extended Kalman filter computes an "expected accelerometer output" based on the yaw, pitch, and roll angles.

587. The measured accelerations and the expected accelerometer output are then used to correct pitch and roll errors.

EKF_Update Function from CHR-6dm Firmware (Using "Measured" and "Expected" Accelerations to Correct Pitch and Roll Errors)

```
// Subtract accel bias
acc_vect.data[0] = acc_vect.data[0] - (float)gConfig.x_accel_bias;
acc_vect.data[1] = acc_vect.data[1] - (float)gConfig.y_accel_bias;
acc_vect.data[2] = acc_vect.data[2] - (float)gConfig.z_accel_bias;

// Apply alignment correction
MatVectMult3( &gConfig.accel_alignment, &acc_vect, &acc_vect );

// Now subtract the reference vector
acc_vect.data[0] = acc_vect.data[0] - acc_hat.data[0];
acc_vect.data[1] = acc_vect.data[1] - acc_hat.data[1];
acc_vect.data[2] = acc_vect.data[2] - acc_hat.data[2];

// Multiply by Kalman gain
MatVectMult3( &L, &acc_vect, &correction );

// Apply correction
estimated_states->phi = estimated_states->phi + correction.data[0];
estimated_states->theta = estimated_states->theta + correction.data[1];
estimated_states->psi = estimated_states->psi + correction.data[2];
```

588. Consistent with CyWee's interpretation of the "predicted measurement" the CHR-6dm operates under the assumption that accelerometers measure the "gravity vector" and that the EKF therefore knows "which way is down by observing the direction of the gravity vector." CHR-6dm Datasheet at 8–9.

589. To the extent that CyWee argues that the "expected accelerations" in the CHR-

6dm are not "predicted acceleration," *Abbate* discloses these features. *Abbate* discloses the use of a non-linear function that mirrors Equations 2–4 of the '438 Patent which CyWee discloses meets the "predicted axial accelerations" limitation. Consistent with CyWee's allegation that the acceleration being derived is the gravitational acceleration, "*g*" is defined in *Abbate*'s non-linear function as the gravitational acceleration.

Equations 2–4 in '438 Patent	**Non-Linear Function h(x) in *Abbate***
$Ax=2(q_1q_3-q_0q_2)$ $Ay=2(q_2q_3+q_0q_1)$ $Az=q_0^2-q_1^2-q_2^2+q_3^2$	$h(x)=\begin{bmatrix} 2g(q_1q_3-q_0q_2) \\ 2g(q_2q_3-q_0q_1) \\ g(q_0^2-q_1^2-q_2^2+q_3^2) \\ \arctan\left(\frac{2(q_1q_2+q_0q_3)}{q_0^2-q_1^2-q_2^2+q_3^2}\right) \end{bmatrix}$

590. Consistent with CyWee's allegations, *Abbate*'s non-linear function would obtain "predicted axial accelerations" without taking the derivatives of the angular velocities in the same way that Equations 2–4 in the '438 Patent would.

591. To the extent that CyWee contends the CHR-6dm does not disclose "predicted accelerations," a POSA would have been further motivated to configure the CHR-6dm to use the predicted accelerations in *Abbate* for the same reasons that CyWee contends any POSA would have been motivated to use "predicted accelerations."

(3) [Element 438.14.5] "said current state of the six-axis motion sensor module is a second quaternion with respect to said current time T;"

592. In my opinion, the CHR-6dm in view of *Abbate* discloses these features. *See* Section XIII.C.5.c.

e. [Element 438.14.6] "comparing the second quaternion in relation to the measured angular velocities ω_x, ω_y, ω_z of the current state at current time T with the measured axial accelerations Ax, Ay, Az and the predicted axial accelerations Ax′, Ay′, Az′ also at current time T;"

593. As I explain in Sections XV.A.3 and XV.A.6, the '438 Patent does not describe how to: (i) obtain predicted axial accelerations or (ii) perform a comparison between angular velocities, axial accelerations and predicted axial accelerations. As I explain in Sections XV.A.3 and XV.A.6, any such comparison is mathematically impossible and would at best produce a meaningless result.

594. I understand that CyWee and its experts have claimed that this limitation is met by an Extended Kalman filter or something like an Extended Kalman filter and an "indirect" comparison between angular velocities and axial accelerations is possible by using an Extended Kalman filter and representing the orientation in quaternion format, as shown in Equations 5–11 of the '438 Patent.

595. I understand that CyWee and its experts have claimed that the "predicted measurement" is the direction of gravity obtained from a second quaternion representing orientation, as allegedly disclosed in Equations 2–4 of the '438 Patent. Plaintiff's Markman Slides at 30. However, because of the lack of guidance in the '438 Patent regarding the precise meaning of a "predicted acceleration," in my opinion, it is unclear what the scope of the claim term is beyond that it is some predicted acceleration value.

596. I do not agree with CyWee's claims. However, taking CyWee's own representations as true, this limitation covers a quaternion-based Extended Kalman filter that uses angular velocities to predict an object's orientation that is then corrected using gravitational accelerations (or some "predicted" acceleration value). Accordingly, if taken as true, in my opinion, the CHR-6dm in view of *Abbate* discloses these features.

597. Specifically, the CHR-6dm is an orientation sensor that uses an Extended Kalman filter to combine data from onboard accelerometers, gyroscopes, and magnetic sensors to produce yaw, pitch, and roll angle estimates. CHR-6dm Datasheet at 1.

598. The CHR-6dm utilizes a continuous two-step Extended Kalman filter, where "rate gyro measurements are used to drive the prediction step, and the accelerometer and magnetometer are used for drift correction in the update step." *Id.* at 8. In the drift correction, "[o]n average, the accelerometers measure the gravity vector. The EKF 'knows' which way is down by observing the direction of the gravity vector." *Id.* at 9.

599. The basic steps used in the Extended Kalman filter are detailed in the CHR-6dm firmware code. Specifically, in the chr6dm_states.c file, the Extended Kalman filter is executed in the EKF_EstimateStates function (reproduced below):

EKF_EstimateStates Function from CHR-6dm Firmware

```
void EKF_EstimateStates( AHRS_states* estimated_states, RawSensorData* sensor_data)
{
        static int initialized = 0;

        if( !initialized )
        {
//              EKF_InitFromSensors ( estimated_states, sensor_data );
                EKF_Init( estimated_states );
                initialized = 1;
        }

        // Run EKF prediction step
        EKF_Predict( estimated_states, sensor_data );

        // Run EKF update step
        EKF_Update( estimated_states, sensor_data );
}
```

In the above code:

- The EKF_InitFromSensors function uses sensor data to fill an initial state

estimate structure;

- The EKF_Predict function uses rate gyros to make a new orientation estimate; and
- The EKF_Update function uses the accelerometers to correct pitch and roll errors and magnetic sensors to correct yaw errors.

600. This Extended Kalman filter uses both measured accelerations and predicted accelerations.

601. Specifically, the EKF_Update function initializes variables for pitch, roll, and yaw.

EKF_Update Function from CHR-6dm Firmware (Initializing theta, phi, psi)

float theta = estimated_states->theta;
float phi = estimated_states->phi;
float psi = estimated_states->psi;

602. A rotation matrix (R) from the inertial frame to the body frame is created for computing expected sensor outputs.

EKF_Update Function from CHR-6dm Firmware (Building Rotation Matrix)
R.data[0][0] = cos_psi*cos_theta; R.data[0][1] = cos_theta*sin_psi; R.data[0][2] = -sin_theta; R.data[1][0] = cos_psi*sin_phi*sin_theta - cos_phi*sin_psi; R.data[1][1] = cos_phi*cos_psi + sin_phi*sin_psi*sin_theta; R.data[1][2] = cos_theta*sin_phi; R.data[2][0] = sin_phi*sin_psi + cos_phi*cos_psi*sin_theta; R.data[2][1] = cos_phi*sin_psi*sin_theta - cos_psi*sin_phi; R.data[2][2] = cos_phi*cos_theta;

603. An expected accelerometer output is computed.

EKF_Update Function from CHR-6dm Firmware (Compute "Expected" Accelerometer Output)
MatVectMult3(&R, &accel_ref, &acc_hat);

604. The covariance matrix for the Kalman filter is computed. After that, the measured accelerations are input into a data array.

EKF_Update Function from CHR-6dm Firmware (Obtain "Measured" Accelerations)

acc_vect.data[0] = sensor_data->accel_x;
acc_vect.data[1] = sensor_data->accel_y;
acc_vect.data[2] = sensor_data->accel_z;

605. The measured accelerations and the expected accelerometer output are then used to correct pitch and roll errors.

EKF_Update Function from CHR-6dm Firmware (Using "Measured" and "Expected" Accelerations to Correct Pitch and Roll Errors)

// Subtract accel bias
acc_vect.data[0] = acc_vect.data[0] - (float)gConfig.x_accel_bias;
acc_vect.data[1] = acc_vect.data[1] - (float)gConfig.y_accel_bias;
acc_vect.data[2] = acc_vect.data[2] - (float)gConfig.z_accel_bias;
 	
// Apply alignment correction
MatVectMult3(&gConfig.accel_alignment, &acc_vect, &acc_vect);
 	
// Now subtract the reference vector
acc_vect.data[0] = acc_vect.data[0] - acc_hat.data[0];
acc_vect.data[1] = acc_vect.data[1] - acc_hat.data[1];
acc_vect.data[2] = acc_vect.data[2] - acc_hat.data[2];
 	
// Multiply by Kalman gain
MatVectMult3(&L, &acc_vect, &correction);
 	
// Apply correction
estimated_states->phi = estimated_states->phi + correction.data[0];
estimated_states->theta = estimated_states->theta + correction.data[1];
estimated_states->psi = estimated_states->psi + correction.data[2];

606. Consistent with CyWee's interpretation of the "predicted measurement" the CHR-6dm operates under the assumption that accelerometers measure the "gravity vector" and that the EKF therefore knows "which way is down by observing the direction of the gravity vector." CHR-6dm Datasheet at 8–9.

607. Accordingly, the EKF uses the measured accelerometers (i.e., the "measured state") and expected accelerations (i.e., the "predicted measurement") to correct an orientation estimate (i.e., "the updated state."). A POSA would understand that this "updated state" could be fed back into the Extended Kalman filter as the "previous state."

608. To the extent that CyWee claims that the CHR-6dm does not meet this limitation because it does not use quaternion representations of orientation or because the "expected acceleration" in the CHR-6dm is not a "predicted acceleration," it would have been obvious to a POSA at the time of the alleged invention to modify the CHR-6dm to use quaternions and/or "predict accelerations" in view of the teachings of *Abbate*.

609. *Abbate* discloses a real-time inertial motion capture system using inertial measurement units (IMUs) that are used to record and reconstruct human motion. *Abbate* at 255. The IMUs contain: (i) three single-axis angular rate gyroscopes; (ii) one three-axis accelerometer; and (iii) one three-axis magnetometer. *Id.* at 256. The IMUs are placed on fixed key points on the human body. *Id.* The readings from these IMUs are fed into a centralized collection point and the orientations of the key points are calculated using a quaternion-based Extended Kalman filter. *Id.* at 255–256. In this way, the system is able to use "several kinds of sensors" so that the "characteristics of one type of sensor avoid overcoming the limitations of other sensors." *Id.* at 257.

610. Figure 6 of *Abbate* (reproduced here) depicts the sensor-fusion process disclosed in *Abbate*'s quaternion-based Extended Kalman filter. As shown in Figure 6, the Extended Kalman filter weighs the three

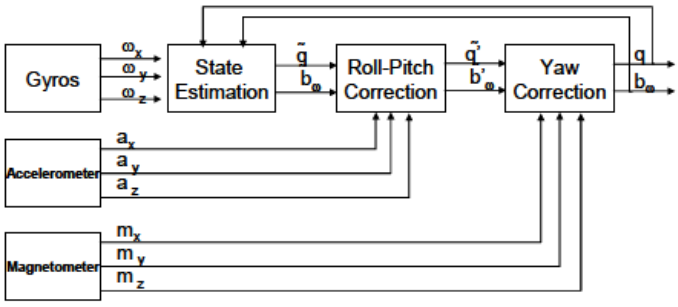


Fig.6. Flow diagram of the implemented quaternion based EKF.

sources of information from the gyroscopes, accelerometers and magnetometers appropriately in order to provide an accurate estimate of orientation and eliminate noise. *Id.* at Fig. 6, 258. In the Extended Kalman filter, the orientation is first estimated using angular rate velocities. The Extended Kalman filter then implements a two-step correction process in which: (i) acceleration data is used to correct roll and pitch angles and (ii) magnetic field data is used to correct the yaw angle. *Id.*

611. Specifically, in *Abbate*, the Kalman filter is initialized with an initial state (i.e., orientation) estimate, and that initial state estimate is combined with the state estimation updated in the prior iteration of the Kalman-filter loop (i.e., the "update[d] state estimation with measurement zk" shown in that figure). *Id.* at Fig. 8. This combined value is depicted as the "state estimation" in Figure 6.

612. As shown in Figure 6, the "state estimation" is modified by angular velocity measurements from the gyroscopes, which generates a quaternion representing the current state of the device. The roll and pitch components of the quaternion representing the device's current state are then further corrected by the measured accelerations (or the "measured state" as shown in the "roll-pitch correction" step in Figure 6) to update the state estimation used in that iteration of the Kalman-filter loop (i.e., the "updated state"). *Id.* at Fig. 6, 258. Those corrections are based on acceleration measurements from the accelerometers in combination with an error estimate associated with the "state estimation" (i.e., the "predicted measurement"). *Id.* The "updated state" is then fed recursively back into the Extended Kalman filter and used in the next time iteration so that it becomes the "previous state." *Id.* at Figs. 6, 8, 257–58.

613. *Abbate* further discloses the use of a non-linear function that mirrors Equations 2–4 of the '438 Patent (which CyWee discloses meets the "predicted axial accelerations"

limitation). *Id.* at 258. Consistent with CyWee's allegation that the acceleration being derived is the gravitational acceleration, "*g*" is defined in *Abbate*'s non-linear function as the gravitational acceleration.

Equations 2–4 in '438 Patent	Non-Linear Function h(x) in *Abbate*
$Ax=2(q_1q_3-q_0q_2)$ $Ay=2(q_2q_3+q_0q_1)$ $Az=q_0^2-q_1^2-q_2^2+q_3^2$	$h(x)=\begin{bmatrix} 2g(q_1q_3-q_0q_2) \\ 2g(q_2q_3-q_0q_1) \\ g(q_0^2-q_1^2-q_2^2+q_3^2) \\ \arctan\left(\frac{2(q_1q_2+q_0q_3)}{q_0^2-q_1^2-q_2^2+q_3^2}\right) \end{bmatrix}$

614. Consistent with CyWee's allegations, *Abbate*'s non-linear function would obtain "predicted axial accelerations" without taking the derivatives of the angular velocities in the same way that Equations 2–4 in the '438 Patent would.

615. Although *Abbate* and the CHR-6dm both disclose the use of measurements from a magnetometer, which are used to correct the yaw component of the state estimation, a POSA would have understood that the algorithm disclosed in *Abbate* and used by the CHR-6dm could be modified to exclude correction of the yaw component. If correction of the yaw component is not performed, measurements from the magnetometer are not necessary for the algorithm to function.

616. In view of these teachings of *Abbate*, a POSA would have been motivated to configure the CHR-6dm so that the Extended Kalman filter uses quaternions as disclosed in *Abbate* for computational efficiency and to eliminate the singularity when the pitch is at +/- 90 degrees.

617. As the CHR-6dm Datasheet acknowledges, by using Euler angles, the CHR-6dm "cannot be used to measure orientation if it is expected to approach a pitch angle of +/- 90 degrees. To fix this problem, a quaternion representation must be used instead of Euler Angles."

CHR-6dm Datasheet at 9. This same advantage is disclosed in *Abbate*. As *Abbate* discloses, "[q]uaternions are used to represent space orientation in order to improve computational efficiency and avoid singularities [4]." *Abbate* at 258.

618. To the extent that CyWee contends the CHR-6dm does not disclose "predicted accelerations," a POSA would have been further motivated to configure the CHR-6dm to use the predicted accelerations in *Abbate* for the same reasons that CyWee contends any POSA would have been motivated to use "predicted accelerations."

619. A POSA would have recognized that such a modification would have been a straightforward combination of known technologies by known methods without changing their respective functions to achieve a predictable result, and would have been well within the capabilities of such a person.

620. Furthermore, a POSA would have been encouraged to look to *Abbate* to complement the teachings of the CHR-6dm because these references are all directed to the same technical field and describe solutions to similar problems in the field. For example, both the CHR-6dm and *Abbate* disclose calculating orientation using a combination of gyroscopes, accelerometers and magnetometers by using Extended Kalman filters. CHR-6dm Datasheet at 8–9; *Abbate* at 255–258.

f. [Element 438.14.7] "obtaining an updated state of the six-axis motion sensor module by comparing the current state with the measured state of the six-axis motion sensor module; and"

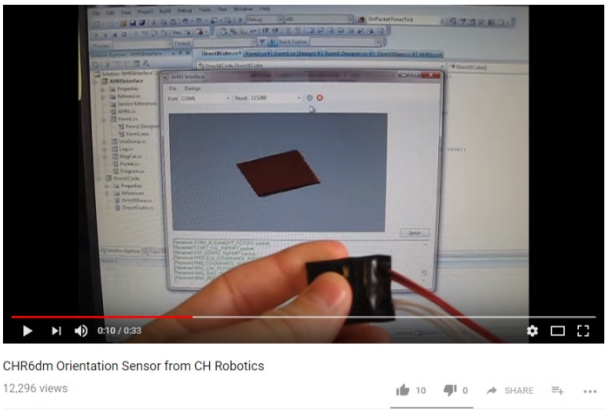
621. In my opinion, the CHR-6dm in view of *Abbate* discloses these features for the same reasons I described in Section XIII.C.5.e for the "comparing the second quaternion" limitation. Under CyWee's interpretation, both limitations recite obtaining an "updated state" (representing the device's orientation) by taking the "current state" in the form of a second quaternion representing the device's orientation and correcting the orientation using the direction

of gravity (or some predicted acceleration value).

g. [Element 438.14.8] "calculating and converting the updated state of the six axis motion sensor module to said resulting deviation comprising said resultant angles in said spatial pointer reference frame of the 3D pointing device."

622. In my opinion, the CHR-6dm in view of *Abbate* discloses these features. As discussed above, under CyWee's interpretation, the CHR-6dm in view of *Abbate* discloses calculating an "updated state." *See* Section XIII.C.5.f.

623. As shown in a screenshot from the "CHR6dm Orientation Sensor from CH Robotics" video (reproduced below), the sensor can be implemented as a handheld device that calculates its own orientation which is translated directly onto a display.



624. The CHR-6dm represents orientation in Euler angles (yaw, pitch, and roll). CHR-6dm Datasheet at 9.

6. Claim 15

a. [Element 438.15] "The method for obtaining a resulting deviation of a 3D pointing device of claim 14, further comprises the step of outputting the updated state of the six-axis motion sensor module to the previous state of the six-axis motion sensor module; and wherein said resultant angles of the resulting deviation includes yaw, pitch and roll angles about each of three orthogonal coordinate axes of the spatial pointer reference frame."

625. In my opinion, the CHR-6dm in view of *Abbate* discloses these features. As

discussed above, under CyWee's interpretation, the CHR-6dm in view of *Abbate* discloses calculating an "updated state." *See* Section XIII.C.5.f.

626. Both the CHR-6dm and *Abbate* disclose recursive Extended Kalman filters where the updated state is read back into the next loop of the filter. Specifically, the CHR-6dm uses angular velocity readings in a continuous two-step Extended Kalman filter. In the first step, the gyroscope measurements are used to predict an initial orientation. CHR-6dm Datasheet at 8. In the second "update" step, the accelerometer and magnetometers are used to correct for drift. *Id*. Specifically, the accelerometers are used to measure the gravity vector. *Id.* at 9.

627. The basic steps used in the Extended Kalman filter are detailed in the CHR-6dm firmware code. Specifically, in the chr6dm_states.c file, the Extended Kalman filter is executed in the EKF_EstimateStates function (reproduced below):

EKF_EstimateStates Function from CHR-6dm Firmware

```
void EKF_EstimateStates( AHRS_states* estimated_states, RawSensorData* sensor_data)
{
        static int initialized = 0;

        if( !initialized )
        {
//              EKF_InitFromSensors ( estimated_states, sensor_data );
                EKF_Init( estimated_states );
                initialized = 1;
        }

        // Run EKF prediction step
        EKF_Predict( estimated_states, sensor_data );

        // Run EKF update step
        EKF_Update( estimated_states, sensor_data );
}
```

In the above code:

- The EKF_InitFromSensors function uses sensor data to fill an initial state

estimate structure;

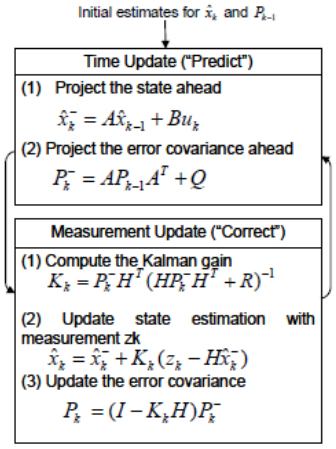
- The EKF_Predict function uses rate gyros to make a new orientation estimate; and
- The EKF_Update function uses the accelerometers to correct pitch and roll errors and magnetic sensors to correct yaw errors.

628. As shown in the EKF_Predict function, the CHR-6dm's EKF is continuous and begins by setting the variables phi, theta and psi with the current state estimates from the last iteration of the algorithm.

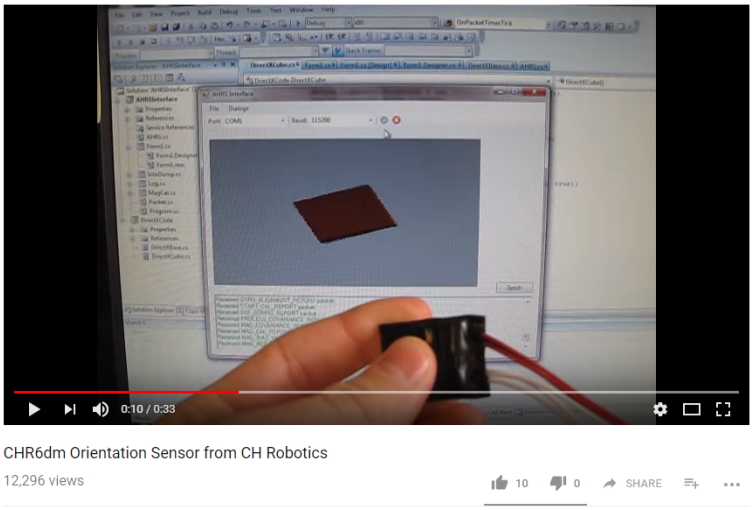
EKF_Predict Function from CHR-6dm Firmware

// Get current state estimates
phi = estimated_states->phi;
theta = estimated_states->theta;
psi = estimated_states->psi;

629. Similarly, as shown in Figure 8 of *Abbate* (reproduced here), *Abbate* discloses that the result of the "measurement update" stage in its Extended Kalman filter is fed back into the "time update" stage. *Abbate* at Figs. 6, 8, 257–258. Therefore, in both the CHR-6dm and *Abbate*, the updated state is input as the "previous state" of the device at the next time interval.



630. As shown in a screenshot from the "CHR6dm Orientation Sensor from CH Robotics" video (reproduced below), the CHR-6dm sensor can be implemented as a handheld device that calculates its own orientation which is translated directly onto a display.



631. The CHR-6dm represents orientation in Euler angles (yaw, pitch, and roll). CHR-6dm Datasheet at 9.

7. Claim 16

a. [Element 438.16] "The method for obtaining a resulting deviation of a 3D pointing device of claim 14, wherein said previous state of the six-axis motion sensor module is a first quaternion with respect to said previous time T−1; and said updated state of the six-axis motion sensor module is a third quaternion with respect to said current time T."

632. In my opinion, the CHR-6dm in view of *Abbate* discloses these features. As discussed above, under CyWee's interpretation, the CHR-6dm discloses calculating an updated state which is then re-input into the algorithm as the "previous state" at the next time stage of the Extended Kalman filter. *See* Sections VIII.C.5.e and XIII.C.5.f. *Abbate* discloses a similar Extended Kalman filter that uses quaternion representations of orientation where the updated quaternion is re-input into the algorithm as the "previous state" at the next time stage. *See id.* A POSA would have been motivated to configure the CHR-6dm's Extended Kalman filter to use quaternion representations of orientation for the reasons I described above. *See* Sections XIII.C.1.g.

8. Claim 17

a. [Element 438.17] "The method for obtaining a resulting deviation of 3D pointing device of claim 14, wherein the obtaining of said previous state of the six-axis motion sensor module further comprises initializing said initial-value set."

633. In my opinion, the CHR-6dm in view of *Abbate* discloses these features. *See* CHR-6dm EKF_InitFromSensors function.

9. Claim 19

634. From my review, Claims 14 and 19 recite identical claim language. Accordingly, in my opinion, the combination of the CHR-6dm and *Abbate* render obvious Claim 19 for the same reasons that they render obvious Claim 14, as I describe in Section XIII.C.5.

D. The CHR-6dm n view of *Yang* renders obvious Claims 1, 3, 4, 5, 14, 15, 16, 17, and 19 of the '438 Patent

1. Claim 1

a. [Element 438.1.0] "A three-dimensional (3D) pointing device subject to movements and rotations in dynamic environments, comprising:"

635. I understand that neither Samsung nor CyWee has argued that the preamble of Claim 1 is limiting. However, to the extent that the preamble is considered limiting, in my opinion, the CHR-6dm in view of *Yang* discloses a 3D pointing device having the features recited in the remaining elements of this claim.

636. Specifically, the CHR-6dm discloses a "three-dimensional (3D) pointing device" that is "subject to movements and rotations in dynamic environments" consistent with both CyWee's interpretation of the term and the proper plain and ordinary construction. *See* Section XIII.C.1.a.

b. [Element 438.1.1] "a housing associated with said movements and rotations of the 3D pointing device in a spatial pointer reference frame"

637. In my opinion, the CHR-6dm discloses these features. *See* Section XIII.C.1.b.

c. [Element 438.1.2] "a printed circuit board (PCB) enclosed by the housing;"

638. In my opinion, the CHR-6dm discloses these features. *See* Section XIII.C.1.c.

d. [Element 438.1.3] "a six-axis motion sensor module attached to the PCB,"

639. In my opinion, the CHR-6dm discloses these features. *See* Section XIII.C.1.d.

e. [Element 438.1.4] "comprising a rotation sensor for detecting and generating a first signal set comprising angular velocities ω_x, ω_y, ω_z associated with said movements and rotations of the 3D pointing device in the spatial pointer reference frame,"

640. In my opinion, the CHR-6dm discloses these features. *See* Section XIII.C.1.e.

f. [Element 438.1.5] "an accelerometer for detecting and generating a second signal set comprising axial accelerations A_x, A_y, A_z associated with said movements and rotations of the 3D pointing device in the spatial pointer reference frame; and"

641. In my opinion, the CHR-6dm discloses these features. *See* Section XIII.C.1.f.

g. "a processing and transmitting module, comprising a data transmitting unit electrically connected to the six-axis motion sensor module for transmitting said first and second signal sets thereof and a computing processor for receiving and calculating said first and second signal sets from the data transmitting unit, communicating with the six-axis motion sensor module to calculate a resulting deviation comprising resultant angles in said spatial pointer reference frame by utilizing a comparison to compare the first signal set with the second signal set whereby said resultant angles in the spatial pointer reference frame of the resulting deviation of the six-axis motion sensor module of the 3D pointing device are obtained under said dynamic environments, wherein the comparison utilized by the processing and transmitting module further comprises an update program to obtain an updated state based on a previous state associated with said first signal set and a measured state associated with said second signal set; wherein the measured state includes a measurement of said second

signal set and a predicted measurement obtained based on the first signal set without using any derivatives of the first signal set."

642. I will discuss the features of this element below in two parts.

(1) [Element 438.1.6] "a processing and transmitting module, comprising a data transmitting unit electrically connected to the six-axis motion sensor module for transmitting said first and second signal sets thereof and a computing processor for receiving and calculating said first and second signal sets from the data transmitting unit,"

643. In my opinion, the CHR-6dm discloses components that perform the same functions as the claimed "processing and transmitting module." *See* Section XIII.C.1.g.(1).

(2) [Element 438.1.7] "communicating with the six-axis motion sensor module to calculate a resulting deviation comprising resultant angles in said spatial pointer reference frame by utilizing a comparison to compare the first signal set with the second signal set whereby said resultant angles in the spatial pointer reference frame of the resulting deviation of the six-axis motion sensor module of the 3D pointing device are obtained under said dynamic environments, wherein the comparison utilized by the processing and transmitting module further comprises an update program to obtain an updated state based on a previous state associated with said first signal set and a measured state associated with said second signal set; wherein the measured state includes a measurement of said second signal set and a predicted measurement obtained based on the first signal set without using any derivatives of the first signal set."

644. In my opinion, the CHR-6dm in view of *Yang* discloses these features. As I explained in Section XIII.C.1.g.(2), the '438 Patent does describe the limitations of: (i) "utilizing a comparison to compare the first signal set with the second signal set"; (ii) obtaining "an updated state based on a previous state associated with said first signal set and a measured state associated with said second signal set"; and/or how to calculate a "predicted measurement obtained based on the first signal set without using any derivatives of the first signal set."

645. As I explained in Section XIII.C.1.g.(2), I understand that CyWee and its experts

have claimed that this limitation is met by an Extended Kalman filter or something like an Extended Kalman filter and an "indirect" comparison between angular velocities and axial accelerations is possible by using an Extended Kalman filter and representing the orientation in quaternion format, as allegedly shown in Equations 5–11 of the '438 Patent.

646. I understand that CyWee and its experts have claimed that the "predicted measurement" is the direction of gravity obtained from a second quaternion representing orientation, as allegedly disclosed in Equations 2–4 of the '438 Patent. Plaintiff's Markman Slides at 30. However, because of the lack of guidance in the '438 Patent regarding the precise meaning of a "predicted acceleration," in my opinion, it is unclear what the scope of the claim term is beyond that it is some predicted acceleration value.

647. As I explained in Section XIII.C.1.g.(2), I do not agree with CyWee's claims. However, taking CyWee's own representations as true, this limitation covers a quaternion-based Extended Kalman filter that uses angular velocities to predict an object's orientation that is then corrected using gravitational accelerations (or some predicted acceleration value). Accordingly, if taken as true, in my opinion, the CHR-6dm in view of *Yang* discloses these features.

648. The CHR-6dm is an orientation sensor that uses an Extended Kalman filter to combine data from onboard accelerometers, gyroscopes, and magnetic sensors to produce yaw, pitch, and roll angle estimates. CHR-6dm Datasheet at 1.

649. The CHR-6dm utilizes a continuous two-step Extended Kalman filter, where "rate gyro measurements are used to drive the prediction step, and the accelerometer and magnetometer are used for drift correction in the update step." *Id.* at 8. In the drift correction, "[o]n average, the accelerometers measure the gravity vector. The EKF 'knows' which way is down by observing the direction of the gravity vector." *Id.* at 9.

650. The basic steps used in the Extended Kalman filter are detailed in the CHR-6dm firmware code. Specifically, in the chr6dm_states.c file, the Extended Kalman filter is executed in the EKF_EstimateStates function (reproduced below):

EKF_EstimateStates Function from CHR-6dm Firmware

```
void EKF_EstimateStates( AHRS_states* estimated_states, RawSensorData* sensor_data)
{
        static int initialized = 0;

        if( !initialized )
        {
//              EKF_InitFromSensors ( estimated_states, sensor_data );
                EKF_Init( estimated_states );
                initialized = 1;
        }

        // Run EKF prediction step
        EKF_Predict( estimated_states, sensor_data );

        // Run EKF update step
        EKF_Update( estimated_states, sensor_data );
}
```

In the above code:

- The EKF_InitFromSensors function uses sensor data to fill an initial state estimate structure;
- The EKF_Predict function uses rate gyros to make a new orientation estimate; and
- The EKF_Update function uses the accelerometers to correct pitch and roll errors and magnetic sensors to correct yaw errors.

651. This Extended Kalman filter uses both measured accelerations and predicted accelerations.

652. Specifically, the EKF_Update function initializes variables for pitch, roll, and yaw.

EKF_Update Function from CHR-6dm Firmware (Initializing theta, phi, psi)

float theta = estimated_states->theta;
float phi = estimated_states->phi;
float psi = estimated_states->psi;

653. A rotation matrix (R) from the inertial frame to the body frame is created for computing expected sensor outputs.

EKF_Update Function from CHR-6dm Firmware (Building Rotation Matrix)
R.data[0][0] = cos_psi*cos_theta; R.data[0][1] = cos_theta*sin_psi; R.data[0][2] = -sin_theta; R.data[1][0] = cos_psi*sin_phi*sin_theta - cos_phi*sin_psi; R.data[1][1] = cos_phi*cos_psi + sin_phi*sin_psi*sin_theta; R.data[1][2] = cos_theta*sin_phi; R.data[2][0] = sin_phi*sin_psi + cos_phi*cos_psi*sin_theta; R.data[2][1] = cos_phi*sin_psi*sin_theta - cos_psi*sin_phi; R.data[2][2] = cos_phi*cos_theta;

654. An expected accelerometer output is computed.

EKF_Update Function from CHR-6dm Firmware (Compute "Expected" Accelerometer Output)
MatVectMult3(&R, &accel_ref, &acc_hat);

655. The covariance matrix for the Kalman filter is computed. After that, the measured accelerations are input into a data array.

EKF_Update Function from CHR-6dm Firmware (Obtain "Measured" Accelerations)

acc_vect.data[0] = sensor_data->accel_x;
acc_vect.data[1] = sensor_data->accel_y;
acc_vect.data[2] = sensor_data->accel_z;

656. The measured accelerations and the expected accelerometer output are then used to correct pitch and roll errors.

EKF_Update Function from CHR-6dm Firmware (Using "Measured" and "Expected" Accelerations to Correct Pitch and Roll Errors)

// Subtract accel bias
acc_vect.data[0] = acc_vect.data[0] - (float)gConfig.x_accel_bias;
acc_vect.data[1] = acc_vect.data[1] - (float)gConfig.y_accel_bias;
acc_vect.data[2] = acc_vect.data[2] - (float)gConfig.z_accel_bias;
 	
// Apply alignment correction
MatVectMult3(&gConfig.accel_alignment, &acc_vect, &acc_vect);
 	
// Now subtract the reference vector
acc_vect.data[0] = acc_vect.data[0] - acc_hat.data[0];
acc_vect.data[1] = acc_vect.data[1] - acc_hat.data[1];
acc_vect.data[2] = acc_vect.data[2] - acc_hat.data[2];
 	
// Multiply by Kalman gain
MatVectMult3(&L, &acc_vect, &correction);
 	
// Apply correction
estimated_states->phi = estimated_states->phi + correction.data[0];
estimated_states->theta = estimated_states->theta + correction.data[1];
estimated_states->psi = estimated_states->psi + correction.data[2];

657. Consistent with CyWee's interpretation of the "predicted measurement" the CHR-6dm operates under the assumption that accelerometers measure the "gravity vector" and that the EKF therefore knows "which way is down by observing the direction of the gravity vector." CHR-6dm Datasheet at 8–9.

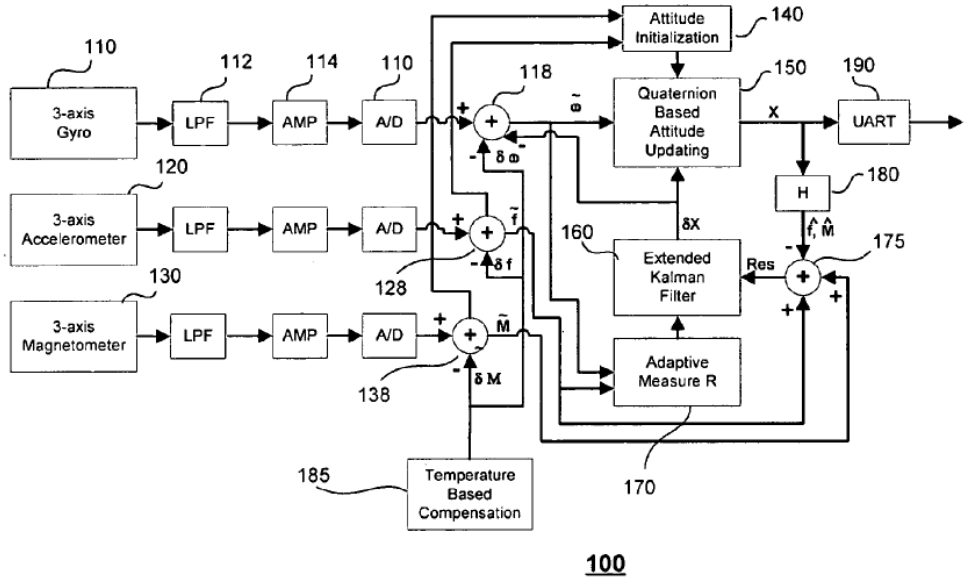
658. Accordingly, the EKF uses the measured accelerometers (i.e., the "measured state") and expected accelerations (i.e., the "predicted measurement") to correct an orientation estimate (i.e., "the updated state."). A POSA would understand that this "updated state" could be fed back into the Extended Kalman filter as the "previous state."

659. To the extent that CyWee claims that the CHR-6dm does not meet this limitation because it does not use quaternion representations of orientation or because the "expected acceleration" in the CHR-6dm is not a "predicted acceleration," it would have been obvious to a

POSA at the time of the alleged invention to modify the CHR-6dm to use quaternions and/or "predict accelerations" in view of the teachings of *Yang*.

660. *Yang* discloses a system that provides an error estimate for an initial attitude (i.e., orientation) using an Extended Kalman filter. The Extended Kalman filter is adaptable based on whether the device is undergoing acceleration. *Yang* at Abstract. The estimated error obtained by the Extended Kalman filter may be used to update the initial orientation calculation. *Id.* ¶¶ 18–19, 39, 107, 112. Specifically, the estimated error, which *Yang* discloses as the residual value, consists of the differences between a measured acceleration (i.e., the "measured state") and predicted acceleration (i.e., the "predicted measurement") and a measured and predicted heading. *Id.* at Fig. 5, ¶¶ 111, 119–121. The basic mechanisms of the system are based on the principles of a Strapdown Inertial Navigation System. *Id.* ¶¶ 13, 30.

661. As shown in Figure 1 of *Yang* (reproduced below), *Yang* discloses a device composed of (among other components): (i) a three-axis gyroscope (110); (ii) a three-axis accelerometer (120); (iii) a three-axis magnetometer (130); and (iv) an Extended Kalman filter (160).



662. As shown in Figure 4 of *Yang* (reproduced below), *Yang* discloses a method by which data from the sensors (gyroscopes, accelerometers, and magnetometers) is measured and then filtered. *Id.* at Fig. 4, ¶¶ 116–117. The Extended Kalman filter is then adapted based on the current acceleration mode. *Id.* at Fig. 4, ¶ 117. Once the Kalman filter is adapted based on the current acceleration mode, it estimates "attitude error and gyro bias" as shown in step 440 of Figure 4. *Id.* ¶ 117. A correction is applied using this error and the corrected orientation is then output (i.e., the "updated state"). *Id.* ¶ 118.

663. Figure 5 of *Yang* (also reproduced below) depicts the Kalman filtering step disclosed in step 440 of Figure 4 in more detail. The Extended Kalman filter is first initialized with an initial error estimate. *Id.* at Fig. 5, ¶ 119. The attitude update module is used to generate an updated attitude. *Id.* at Fig. 5, ¶ 120. The updated attitude is then used to "produce a predicted acceleration and heading (f and M) and determine a residual (Res)." *Id. Yang* discloses that this attitude update is performed using quaternions for calculation efficiency. *Id.* at Figs. 4, 5, 6, ¶¶ 19, 26, 39–45, 107, 112, 118, 120, 122–124.

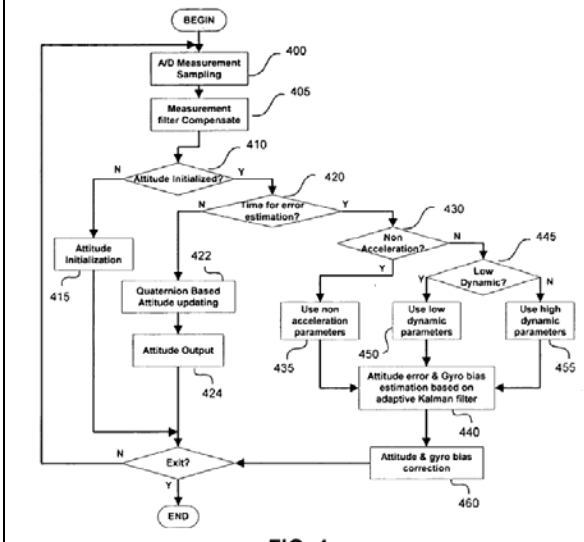
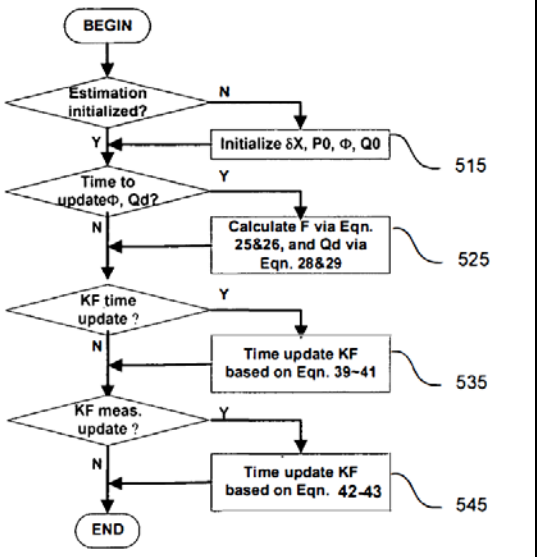
Figure 4 of *Yang*	**Figure 5 of *Yang***
	

FIG. 4

664. The residual value (Res) consists of the differences between a measured and a predicted acceleration and a measured and a predicted heading and is used to determine the Kalman filter's error estimates. *Id.* at Fig. 5, ¶¶ 111, 119–121. The measured and predicted axial accelerations are used to update the Kalman filter's error estimate. This error estimate can be used as a correction value to update the orientation. *Id.* at Figs. 4, 5, 6, ¶¶ 116–130.

665. *Yang* explicitly discloses the use of a predicted acceleration value. Specifically, *Yang* discloses:

> The Kalman Filter 160 operates on a residual value (Res) that is a difference between a measured f^ and M^ and a predicted f^ and M^. The measured f^ and M^ are the measured acceleration (e.g., accelerometer reading) and measured heading (e.g., magnetometer reading) respectively. The predicted f^ and M^ comprise the **predicted acceleration f^** and the predicted heading M^ are predictions based on, for example, a model (H) of a current updated attitude X. **The model H, for example, looks at current accelerations, current attitude and heading, etc., and determines the predicted values.**

Yang ¶ 111 (emphasis added); Equation 31.

666. Further, Equation 31, which *Yang* describes as "one embodiment of a calculation" for the predicted acceleration, does not use the derivatives of the measured angular velocities. *Id.* at Equation 31.

667. Accordingly, in my opinion, *Yang* discloses using "predicted" and "measured" accelerations as inputs into an Extended Kalman filter to calculate an error value that is used to update an initial orientation. Both *Yang* and the CHR-6dm discloses that updated orientation values can be recursively input into the next time iteration of their respective algorithms to become the "previous state." CHR-6dm Datasheet at 7–8; *Yang* at Fig. 4, ¶ 107.

668. Although *Yang* and the CHR-6dm both disclose the use of measurements from a magnetometer, a POSA would have understood that the algorithm disclosed in *Yang* and used by

the CHR-6dm could be modified to exclude the use of a magnetometer.

669. In view of these teachings of *Yang*, a POSA would have been motivated to configure the CHR-6dm so that the Extended Kalman filter uses the quaternions as disclosed in *Yang* for computational efficiency and to eliminate the singularity when the pitch is at +/- 90 degrees.

670. As the CHR-6dm Datasheet acknowledges, by using Euler angles, the CHR-6dm "cannot be used to measure orientation if it is expected to approach a pitch angle of +/- 90 degrees. To fix this problem, a quaternion representation must be used instead of Euler Angles." CHR-6dm Datasheet at 9. This same advantage is disclosed in *Yang*. As *Yang* discloses, the quaternion "is useful due to its good mathematical properties, dynamic equations and calculation efficiency."

671. In addition, to the extent that CyWee contends the CHR-6dm does not disclose "predicted accelerations," a POSA would have been further motivated to configure the CHR-6dm to use the predicted accelerations in *Yang* for the same reasons that CyWee contends any POSA would have been motivated to use "predicted accelerations."

672. A POSA would have recognized that such a modification would have been a straightforward combination of known technologies by known methods without changing their respective functions to achieve a predictable result, and would have been well within the capabilities of such a person. Both Euler angle and quaternion representations of orientation are well known in the art.

673. Furthermore, a POSA would have been encouraged to look to *Yang* to complement the teachings of the CHR-6dm because these references are all directed to the same technical field and describe solutions to similar problems in the field. For example, both the

CHR-6dm and *Yang* disclose calculating orientation using a combination of gyroscopes, accelerometers and magnetometers by using Extended Kalman filters. CHR-6dm Datasheet at 8–9; *Yang* ¶¶ 108–129.

2. Claim 3

a. [Element 438.3] "The 3D pointing device of claim 1, wherein the PCB enclosed by the housing comprises at least one substrate having a first longitudinal side configured to be substantially parallel to a longitudinal surface of the housing."

674. In my opinion, the CHR-6dm in view of *Yang* discloses these features. As I discussed in Section XIII.C.2, the CHR-6dm discloses that its orientation sensor is implemented on a printed circuit board. A POSA would understand that this printed circuit board could be enclosed by a housing.

3. Claim 4

a. [Element 438.4] "The 3D pointing device of claim 1, wherein the spatial pointer reference frame is a reference frame in three dimensions; and wherein said resultant angles of the resulting deviation includes yaw, pitch and roll angles about each of three orthogonal coordinate axes of the spatial pointer reference frame."

675. In my opinion, the CHR-6dm in view of *Yang* discloses these features. As I discussed in Section XIII.C.3, the CHR-6dm discloses a "body frame" defined in relation to the orientation sensor that is a reference frame defined in three dimensions. *Id.* at 12, 35. The CHR-6dm further discloses that the resulting deviation of the device is expressed using yaw, pitch, and roll angles. *Id.* at 1, 7.

4. Claim 5

a. [Element 438.5] "The 3D pointing device of claim 1, wherein the data transmitting unit of the processing and transmitting module is attached to the PCB enclosed by the housing and transmits said first and second signal of the six-axis motion sensor module to the computing processor via electronic connections on the PCB."

676. In my opinion, the CHR-6dm in view of *Yang* discloses these features. As I discussed in Section XIII.C.4, the CHR-6dm discloses that it can be configured to transmit both raw sensor data and angle estimates over a microcontroller known as a TTL ("transistor-transistor logic") UART ("universal asynchronous receiver and transmitter.").

5. Claim 14

a. [Element 438.14.0] "A method for obtaining a resulting deviation including resultant angles in a spatial pointer reference frame of a three-dimensional (3D) pointing device utilizing a six-axis motion sensor module therein and subject to movements and rotations in dynamic environments in said spatial pointer reference frame, comprising the steps of:"

677. I understand that neither Samsung nor CyWee has argued that the preamble of Claim 14 is limiting. However, to the extent that the preamble is considered limiting, in my opinion, the CHR-6dm in view of *Yang* discloses a method with the recited features.

678. For the reasons I set forth in Section XIII.C.1.a, the CHR-6dm discloses a "three-dimensional (3D) pointing device," consistent with CyWee's interpretation of this term. Specifically, the CHR-6dm is an orientation sensor with one or more onboard accelerometers and gyroscopes. The CHR-6dm uses an Extended Kalman filter to produce yaw, pitch, and roll angle estimates. CHR-6dm Datasheet at 1.

679. For the reasons I set forth in Section XIII.C.1.d, the CHR-6dm further discloses a "six-axis motion sensor module." Specifically, the CHR-6dm is an orientation sensor implemented onto a printed circuit board. The CHR-6dm sensor is composed of on-board gyroscopes and accelerometers that are physically attached to the printed circuit board. *Id.* at 1.

680. For the reasons I set forth in Section XIII.C.1.g, the CHR-6dm discloses a method for obtaining the deviation of the orientation sensor ("3D pointing device") in the "spatial pointer reference frame" of the orientation sensor. Specifically, as I discussed in Section XIII.C.1.g, I

understand that CyWee and its experts have claimed that this limitation is met by an Extended Kalman filter or something like an Extended Kalman filter, as allegedly shown in Equations 5–11 of the '438 Patent.

681. I do not agree. However, taking CyWee's own representations as true, Claim 14's method covers a quaternion-based Extended Kalman filter that uses angular velocities to predict an object's orientation that is then corrected using gravitational accelerations (or some predicted acceleration value).

682. If taken as true, in my opinion, the CHR-6dm in view of *Yang* disclose these features, as: (i) the CHR-6dm discloses the use of Extended Kalman filters for calculating the deviation of a device's orientation; (ii) *Yang* discloses a quaternion-based Extended Kalman filter for calculating the deviation of a device's orientation; and (iii) both the CHR-6dm and *Yang* disclose correcting the initial orientation estimation obtained by a gyroscope reading using acceleration data. *See* Section XIII.C.1.g.

b. [Element 438.14.1] "obtaining a previous state of the six-axis motion sensor module; wherein the previous state includes an initial-value set associated with previous angular velocities gained from the motion sensor signals of the six-axis motion sensor module at a previous time T−1;"

683. In my opinion, the CHR-6dm in view of *Yang* discloses these features. *See* Section XIII.C.5.a. For the reasons I set forth in Section XIII.C.5.d, the CHR-6dm sensor is composed of on-board gyroscopes and accelerometers that are physically attached to a printed circuit board ("six-axis motion sensor module.").

684. The CHR-6dm uses angular velocity readings in a continuous two-step Extended Kalman filter. In the first step, the gyroscope measurements are used to predict an initial orientation. CHR-6dm Datasheet at 8. In the second "update" step, the accelerometer and magnetometers are used to correct for drift. *Id*. Specifically, the accelerometers are used to

measure the gravity vector. *Id.* at 9.

685. The basic steps used in the Extended Kalman filter are detailed in the CHR-6dm firmware code. Specifically, in the chr6dm_states.c file, the Extended Kalman filter is executed in the EKF_EstimateStates function (reproduced below):

EKF_EstimateStates Function from CHR-6dm Firmware

```
void EKF_EstimateStates( AHRS_states* estimated_states, RawSensorData* sensor_data)
{
        static int initialized = 0;

        if( !initialized )
        {
//              EKF_InitFromSensors ( estimated_states, sensor_data );
                EKF_Init( estimated_states );
                initialized = 1;
        }

        // Run EKF prediction step
        EKF_Predict( estimated_states, sensor_data );

        // Run EKF update step
        EKF_Update( estimated_states, sensor_data );
}
```

In the above code:

- The EKF_InitFromSensors function uses sensor data to fill an initial state estimate structure;
- The EKF_Predict function uses rate gyros to make a new orientation estimate; and
- The EKF_Update function uses the accelerometers to correct pitch and roll errors and magnetic sensors to correct yaw errors.

686. As shown in the EKF_Predict function, the CHR-6dm's EKF is continuous and begins by setting the variables phi, theta, and psi with the current state estimates from the last iteration of the algorithm.

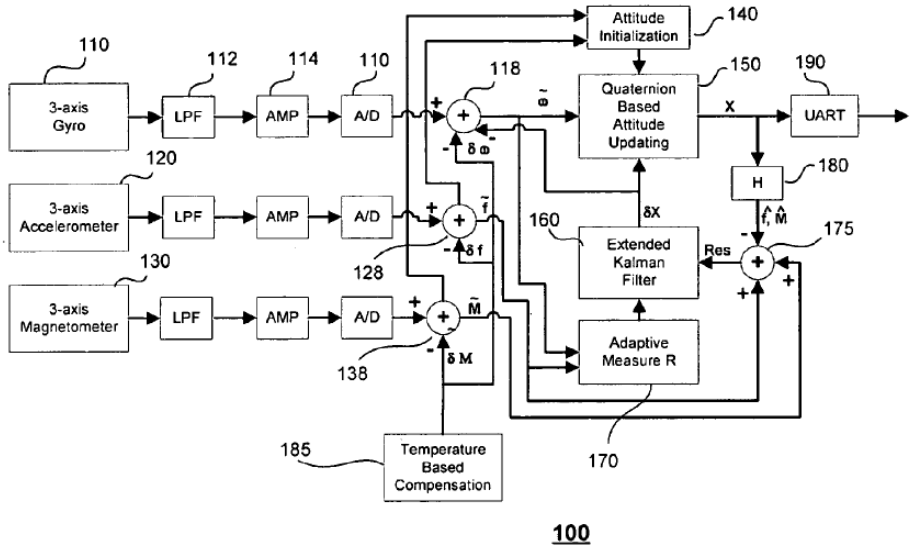
EKF_Predict Function from CHR-6dm Firmware

// Get current state estimates
phi = estimated_states->phi;
theta = estimated_states->theta;
psi = estimated_states->psi;

687. To the extent that the "previous state" is interpreted to require the orientation to be in quaternion format, it would have been obvious to a POSA at the time of the alleged invention to modify the CHR-6dm to use quaternions in view of the teachings of *Yang.*

688. *Yang* discloses a system that provides an error estimate for an initial attitude (i.e., orientation) using an Extended Kalman filter. The Extended Kalman filter is adaptable based on whether the device is undergoing acceleration. *Yang* at Abstract. The estimated error obtained by the Extended Kalman filter may be used to update the initial orientation calculation. *Id.* ¶¶ 18–19, 39, 107, 112. Specifically, the estimated error, which *Yang* discloses as the residual value, consists of the differences between a measured acceleration (i.e., the "measured state") and predicted acceleration (i.e., the "predicted measurement") and a measured and predicted heading. *Id.* at Fig. 5, ¶¶ 111, 119–121. The basic mechanisms of the system are based on the principles of a Strapdown Inertial Navigation System. *Id.* ¶¶ 13, 30.

689. As shown in Figure 1 of *Yang* (reproduced below), *Yang* discloses a device composed of (among other components): (i) a three-axis gyroscope (110); (ii) a three-axis accelerometer (120); (iii) a three-axis magnetometer (130); and (iv) an Extended Kalman filter (160).



690. As shown in Figure 4 of *Yang* (reproduced below), *Yang* discloses a method by which data from the sensors (gyroscopes, accelerometers, and magnetometers) is measured and then filtered. *Id.* at Fig. 4, ¶¶ 116–117. The Extended Kalman filter is then adapted based on the current acceleration mode. *Id.* at Fig. 4, ¶ 117. Once the Kalman filter is adapted based on the current acceleration mode, it estimates "attitude error and gyro bias" as shown in step 440 of Figure 4. *Id.* ¶ 117. A correction is applied using this error and the corrected orientation is then output (i.e., the "updated state"). *Id.* ¶ 118.

691. Figure 5 of *Yang* (also reproduced below) depicts the Kalman filtering step disclosed in step 440 of Figure 4 in more detail. The Extended Kalman filter is first initialized with an initial error estimate. *Id.* at Fig. 5, ¶ 119. The attitude update module is used to generate an updated attitude. *Id.* at Fig. 5, ¶ 120. The updated attitude is then used to "produce a predicted acceleration and heading (f and M) and determine a residual (Res)." *Id. Yang* discloses that this attitude update is performed using quaternions for calculation efficiency. *Id.* at Figs. 4, 5, 6, ¶¶ 19, 26, 39–45, 107, 112, 118, 120, 122–124.

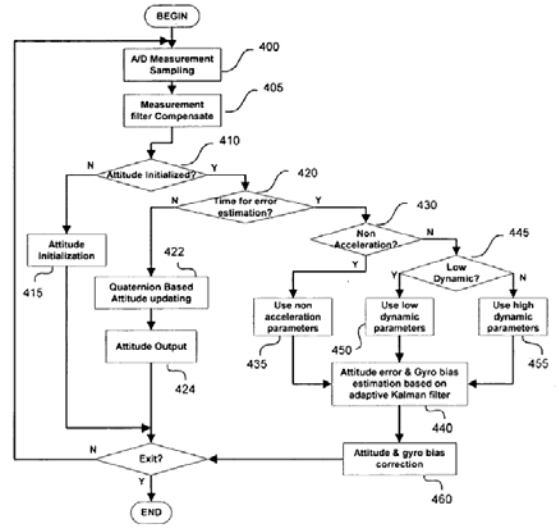
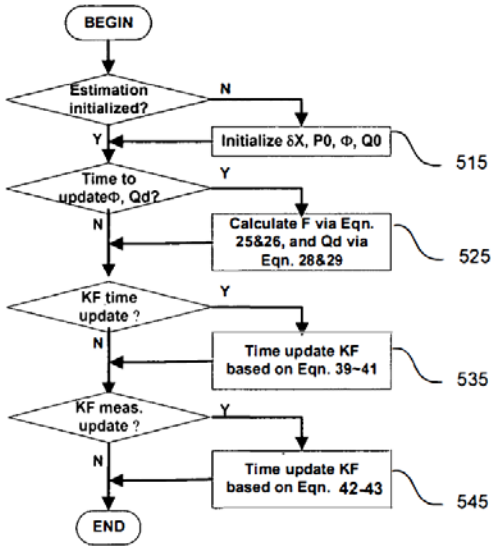
Figure 4 of *Yang*	Figure 5 of *Yang*
	

FIG. 4

692. *Yang* further discloses that the outputted orientation is fed back into the algorithm in a process where the orientation is continually being updated. *Id.* at Fig. 4, ¶ 107.

693. A POSA would have been motivated to configure the CHR-6dm's Extended Kalman filter to represent the "current state" in quaternion format in light of *Yang* for the same reasons I described above in Section XIII.D.1.g. Specifically, a POSA would have been motivated to configure the CHR-6dm so that the Extended Kalman filter uses quaternions as disclosed in *Yang* for computational efficiency and to eliminate singularities.

c. [Element 438.14.2] "obtaining a current state of the six-axis motion sensor module by obtaining measured angular velocities ω_x, ω_y, ω_z gained from the motion sensor signals of the six-axis motion sensor module at a current time T;"

694. In my opinion, the CHR-6dm in view of *Yang* discloses these features. For the reasons I set forth in Section XIII.D.1, the CHR-6dm sensor is composed of on-board gyroscopes and accelerometers that are physically attached to a printed circuit board ("six-axis motion sensor module.").

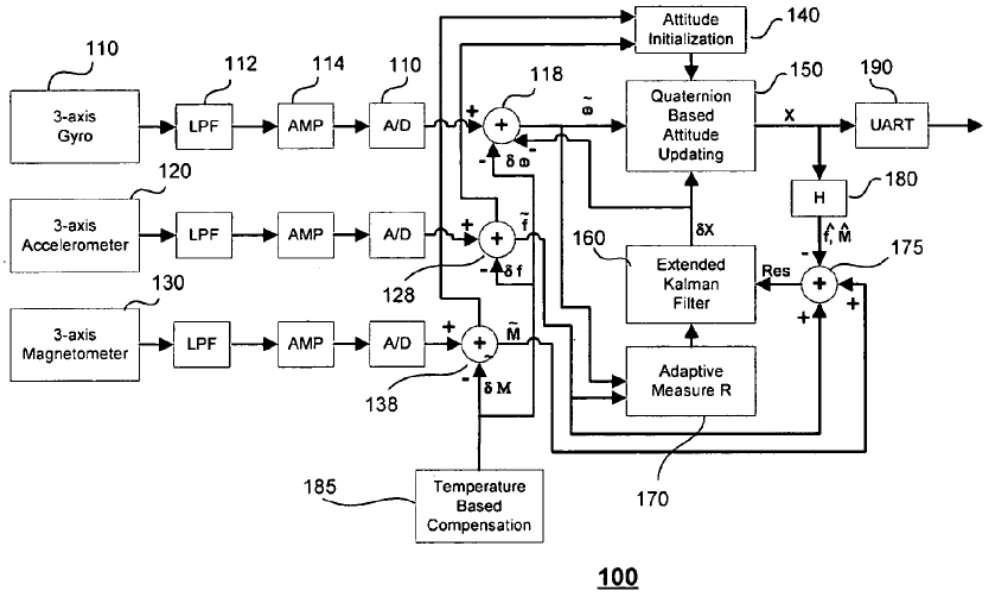
695. As I described above in Section XIII.D.5.b, the CHR-6dm's Extended Kalman

filter calculates current state estimates using measured angular velocities.

696. To the extent that the "current state" is interpreted to require the orientation to be in quaternion format, it would have been obvious to a POSA at the time of the alleged invention to modify the CHR-6dm to use quaternions in view of the teachings of *Yang*.

697. As I described above in Section XIII.D.5.b, *Yang* discloses a system that provides an error estimate for an initial attitude (i.e., orientation) using an Extended Kalman filter. The Extended Kalman filter is adaptable based on whether or the device is undergoing acceleration. *Yang* at Abstract. The estimated error may be used to update an initial orientation calculation. *Id.* ¶¶ 18–19, 39, 107, 112. Specifically, the estimated error, which *Yang* discloses as the residual value, consists of the differences between a measured acceleration (i.e., the "measured state") and predicted acceleration (i.e., the "predicted measurement") and a measured and predicted heading. *Id.* at Fig. 5, ¶¶ 111, 119–121. The basic mechanisms of the system are based on the principles of a Strapdown Inertial Navigation System. *Id.* ¶¶ 13, 30.

698. As shown in Figure 1 of *Yang* (reproduced below), *Yang* discloses a device composed of (among other components): (i) a three-axis gyroscope (110); (ii) a three-axis accelerometer (120); (iii) a three-axis magnetometer (130); and (iv) an Extended Kalman filter (160).



699. As shown in Figure 4 of *Yang* (reproduced below), *Yang* discloses a method by which data from the sensors (gyroscopes, accelerometers, and magnetometers) is measured and then filtered. *Id.* at Fig. 4, ¶¶ 116–117. The Extended Kalman filter is then adapted based on the current acceleration mode. *Id.* at Fig. 4, ¶ 117. Once the Kalman filter is adapted based on the current acceleration mode, it estimates "attitude error and gyro bias" as shown in step 440 of Figure 4. *Id.* ¶ 117. A correction is applied using this error and the corrected orientation is then output (i.e., the "updated state"). *Id.* ¶ 118.

700. Figure 5 of *Yang* (also reproduced below) depicts the Kalman filtering step disclosed in step 440 of Figure 4 in more detail. The Extended Kalman filter is first initialized with an initial error estimate. *Id.* at Fig. 5, ¶ 119. The attitude update module is used to generate an updated attitude. *Id.* at Fig. 5, ¶ 120. The updated attitude is then used to "produce a predicted acceleration and heading (f and M) and determine a residual (Res)." *Id. Yang* discloses that this attitude update is performed using quaternions for calculation efficiency. *Id.* at Figs. 4, 5, 6, ¶¶ 19, 26, 39–45, 107, 112, 118, 120, 122–124.

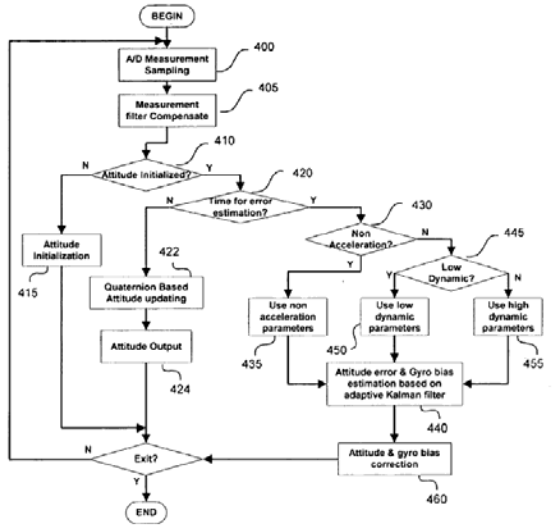
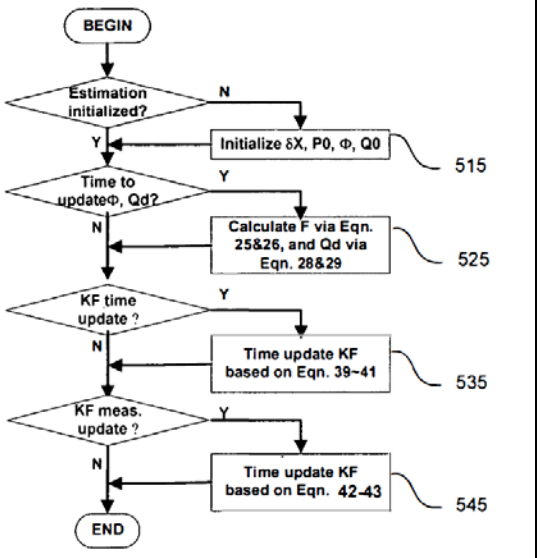
Figure 4 of *Yang*	Figure 5 of *Yang*
	

FIG. 4

701. A POSA would have been motivated to configure the CHR-6dm's Extended Kalman filter to represent the "current state" in quaternion format in light of *Yang* for the same reasons I described above in Section XIII.D.1.g. Specifically, a POSA would have been motivated to configure the CHR-6dm so that the Extended Kalman filter uses the quaternions as disclosed in *Yang* for computational efficiency and to eliminate singularities.

d. "obtaining a measured state of the six-axis motion sensor module by obtaining measured axial accelerations Ax, Ay, Az gained from the motion sensor signals of the six-axis motion sensor module at the current time T and calculating predicted axial accelerations Ax′, Ay′, Az′ based on the measured angular velocities ω_x, ω_y, ω_z of the current state of the six-axis motion sensor module without using any derivatives of the measured angular velocities ω_x, ω_y, ω_z; said current state of the six-axis motion sensor module is a second quaternion with respect to said current time T;"

702. I will discuss the features of this element below in three parts.

(1) [Element 438.14.3] "obtaining a measured state of the six-axis motion sensor module by obtaining measured axial accelerations Ax, Ay, Az gained from the motion sensor signals of the six-axis motion sensor module at the current time T"

703. In my opinion, the CHR-6dm discloses these features. *See* Section XIII.C.5.d.(1).

(2) [Element 438.14.4] "and calculating predicted axial accelerations Ax′, Ay′, Az′ based on the measured angular velocities ω_x, ω_y, ω_z of the current state of the six-axis motion sensor module without using any derivatives of the measured angular velocities ω_x, ω_y, ω_z;"

704. As I explain in Section XV.A.6, the '438 Patent does not describe how to calculate "predicted axial accelerations Ax′, Ay′, Az′ based on the measured angular velocities ω_x, ω_y, ω_z of the current state of the six-axis motion sensor module without using any derivatives of the measured angular velocities ω_x, ω_y, ω_z."

705. I understand that CyWee and its experts have claimed that the "predicted measurement" is the direction of gravity obtained from a second quaternion representing orientation, as allegedly disclosed in Equations 2–4 of the '438 Patent. Plaintiff's Markman Slides at 30. However, because of the lack of guidance in the '438 Patent regarding the precise meaning of a "predicted acceleration," in my opinion, it is unclear what the scope of the claim term is beyond that it is some predicted acceleration value.

706. In my opinion, the CHR-6dm discloses these features. In particular, the CHR-6dm's Extended Kalman filter computes an "expected accelerometer output" based on the yaw, pitch, and roll angles.

707. The measured accelerations and the expected accelerometer output are then used to correct pitch and roll errors.

EKF_Update Function from CHR-6dm Firmware (Using "Measured" and "Expected" Accelerations to Correct Pitch and Roll Errors)

// Subtract accel bias
acc_vect.data[0] = acc_vect.data[0] - (float)gConfig.x_accel_bias;
acc_vect.data[1] = acc_vect.data[1] - (float)gConfig.y_accel_bias;
acc_vect.data[2] = acc_vect.data[2] - (float)gConfig.z_accel_bias;
 	
// Apply alignment correction
MatVectMult3(&gConfig.accel_alignment, &acc_vect, &acc_vect);

```
// Now subtract the reference vector
acc_vect.data[0] = acc_vect.data[0] - acc_hat.data[0];
acc_vect.data[1] = acc_vect.data[1] - acc_hat.data[1];
acc_vect.data[2] = acc_vect.data[2] - acc_hat.data[2];

// Multiply by Kalman gain
MatVectMult3( &L, &acc_vect, &correction );

// Apply correction
estimated_states->phi = estimated_states->phi + correction.data[0];
estimated_states->theta = estimated_states->theta + correction.data[1];
estimated_states->psi = estimated_states->psi + correction.data[2];
```

708. Consistent with CyWee's interpretation of the "predicted measurement" the CHR-6dm operates under the assumption that accelerometers measure the "gravity vector" and that the EKF therefore knows "which way is down by observing the direction of the gravity vector." CHR-6dm Datasheet at 8–9.

709. To the extent that CyWee argues that the "expected accelerations" in the CHR-6dm are not "predicted acceleration," *Yang* discloses these features. *Yang* explicitly discloses the use of a predicted acceleration value. Specifically, *Yang* discloses:

> The Kalman Filter 160 operates on a residual value (Res) that is a difference between a measured f^ and M^ and a predicted f^ and M^. The measured f^ and M^ are the measured acceleration (e.g., accelerometer reading) and measured heading (e.g., magnetometer reading) respectively. The predicted f^ and M^ comprise the **predicted acceleration f^** and the predicted heading M^ are predictions based on, for example, a model (H) of a current updated attitude X. **The model H, for example, looks at current accelerations, current attitude and heading, etc., and determines the predicted values.**

Yang ¶ 111 (emphasis added); Equation 31.

710. To the extent that CyWee contends the CHR-6dm does not disclose "predicted accelerations," a POSA would have been further motivated to configure the CHR-6dm to use the predicted accelerations in *Yang* for the same reasons that CyWee contends any POSA would

have been motivated to use "predicted accelerations."

(3) [Element 438.14.5] "said current state of the six-axis motion sensor module is a second quaternion with respect to said current time T;"

711. In my opinion, the CHR-6dm in view of *Yang* discloses these features. *See* Section XIII.D.1.c.

e. [Element 438.14.6] "comparing the second quaternion in relation to the measured angular velocities ω_x, ω_y, ω_z of the current state at current time T with the measured axial accelerations Ax, Ay, Az and the predicted axial accelerations Ax′, Ay′, Az′ also at current time T;"

712. As I explain in Section XV, the '438 Patent does not describe how to: (i) obtain predicted axial accelerations or (ii) perform a comparison between angular velocities, axial accelerations and predicted axial accelerations. As I explain in Section XV, any such comparison is mathematically impossible and would at best produce a meaningless result.

713. I understand that CyWee and its experts have claimed that this limitation is met by an Extended Kalman filter or something like an Extended Kalman filter and an "indirect" comparison between angular velocities and axial accelerations is possible by using an Extended Kalman filter and representing the orientation in quaternion format, as shown in Equations 5–11 of the '438 Patent.

714. I understand that CyWee and its experts have claimed that the "predicted measurement" is the direction of gravity obtained from a second quaternion representing orientation, as allegedly disclosed in Equations 2–4 of the '438 Patent. Plaintiff's Markman Slides at 30. However, because of the lack of guidance in the '438 Patent regarding the precise meaning of a "predicted acceleration," in my opinion, it is unclear what the scope of the claim term is beyond that it is some predicted acceleration value.

715. As I explained in Section XIII.D.1.g.(2), I do not agree with CyWee's claims.

However, taking CyWee's own representations as true, this limitation covers a quaternion-based Extended Kalman filter that uses angular velocities to predict an object's orientation that is then corrected using gravitational accelerations (or some predicted acceleration value). Accordingly, if taken as true, in my opinion, the CHR-6dm in view of *Yang* discloses these features.

716. Specifically, the CHR-6dm is an orientation sensor that uses an Extended Kalman filter to combine data from onboard accelerometers, gyroscopes, and magnetic sensors to produce yaw, pitch, and roll angle estimates. CHR-6dm Datasheet at 1.

717. The CHR-6dm utilizes a continuous two-step Extended Kalman filter, where "rate gyro measurements are used to drive the prediction step, and the accelerometer and magnetometer are used for drift correction in the update step." *Id.* at 8. In the drift correction, "[o]n average, the accelerometers measure the gravity vector. The EKF 'knows' which way is down by observing the direction of the gravity vector." *Id.* at 9.

718. The basic steps used in the Extended Kalman filter are detailed in the CHR-6dm firmware code. Specifically, in the chr6dm_states.c file, the Extended Kalman filter is executed in the EKF_EstimateStates function (reproduced below):

EKF_EstimateStates Function from CHR-6dm Firmware

```
void EKF_EstimateStates( AHRS_states* estimated_states, RawSensorData* sensor_data)
{
        static int initialized = 0;

        if( !initialized )
        {
//              EKF_InitFromSensors ( estimated_states, sensor_data );
                EKF_Init( estimated_states );
                initialized = 1;
        }

        // Run EKF prediction step
        EKF_Predict( estimated_states, sensor_data );
```

```
        // Run EKF update step
        EKF_Update( estimated_states, sensor_data );
}
```

In the above code:

- The EKF_InitFromSensors function uses sensor data to fill an initial state estimate structure;
- The EKF_Predict function uses rate gyros to make a new orientation estimate; and
- The EKF_Update function uses the accelerometers to correct pitch and roll errors and magnetic sensors to correct yaw errors.

719. This Extended Kalman filter uses both measured accelerations and predicted accelerations.

720. Specifically, the EKF_Update function initializes variables for pitch, roll, and yaw.

EKF_Update Function from CHR-6dm Firmware (Initializing theta, phi, psi)

```
float theta = estimated_states->theta;
float phi = estimated_states->phi;
float psi = estimated_states->psi;
```

721. A rotation matrix (R) from the inertial frame to the body frame is created for computing expected sensor outputs.

EKF_Update Function from CHR-6dm Firmware (Building Rotation Matrix)

```
R.data[0][0] = cos_psi*cos_theta;
R.data[0][1] = cos_theta*sin_psi;
R.data[0][2] = -sin_theta;

R.data[1][0] = cos_psi*sin_phi*sin_theta - cos_phi*sin_psi;
R.data[1][1] = cos_phi*cos_psi + sin_phi*sin_psi*sin_theta;
R.data[1][2] = cos_theta*sin_phi;

R.data[2][0] = sin_phi*sin_psi + cos_phi*cos_psi*sin_theta;
R.data[2][1] = cos_phi*sin_psi*sin_theta - cos_psi*sin_phi;
```

```
R.data[2][2] = cos_phi*cos_theta;
```

722. An expected accelerometer output is computed.

EKF_Update Function from CHR-6dm Firmware (Compute "Expected" Accelerometer Output)

```
MatVectMult3( &R, &accel_ref, &acc_hat );
```

723. The covariance matrix for the Kalman filter is computed. After that, the measured accelerations are input into a data array.

EKF_Update Function from CHR-6dm Firmware (Obtain "Measured" Accelerations)

```
acc_vect.data[0] = sensor_data->accel_x;
acc_vect.data[1] = sensor_data->accel_y;
acc_vect.data[2] = sensor_data->accel_z;
```

724. The measured accelerations and the expected accelerometer output are then used to correct pitch and roll errors.

EKF_Update Function from CHR-6dm Firmware (Using "Measured" and "Expected" Accelerations to Correct Pitch and Roll Errors)

```
// Subtract accel bias
acc_vect.data[0] = acc_vect.data[0] - (float)gConfig.x_accel_bias;
acc_vect.data[1] = acc_vect.data[1] - (float)gConfig.y_accel_bias;
acc_vect.data[2] = acc_vect.data[2] - (float)gConfig.z_accel_bias;

// Apply alignment correction
MatVectMult3( &gConfig.accel_alignment, &acc_vect, &acc_vect );

// Now subtract the reference vector
acc_vect.data[0] = acc_vect.data[0] - acc_hat.data[0];
acc_vect.data[1] = acc_vect.data[1] - acc_hat.data[1];
acc_vect.data[2] = acc_vect.data[2] - acc_hat.data[2];

// Multiply by Kalman gain
MatVectMult3( &L, &acc_vect, &correction );

// Apply correction
estimated_states->phi = estimated_states->phi + correction.data[0];
estimated_states->theta = estimated_states->theta + correction.data[1];
estimated_states->psi = estimated_states->psi + correction.data[2];
```

725. Consistent with CyWee's interpretation of the "predicted measurement" the CHR-6dm operates under the assumption that accelerometers measure the "gravity vector" and that the EKF therefore knows "which way is down by observing the direction of the gravity vector." CHR-6dm Datasheet at 8–9.

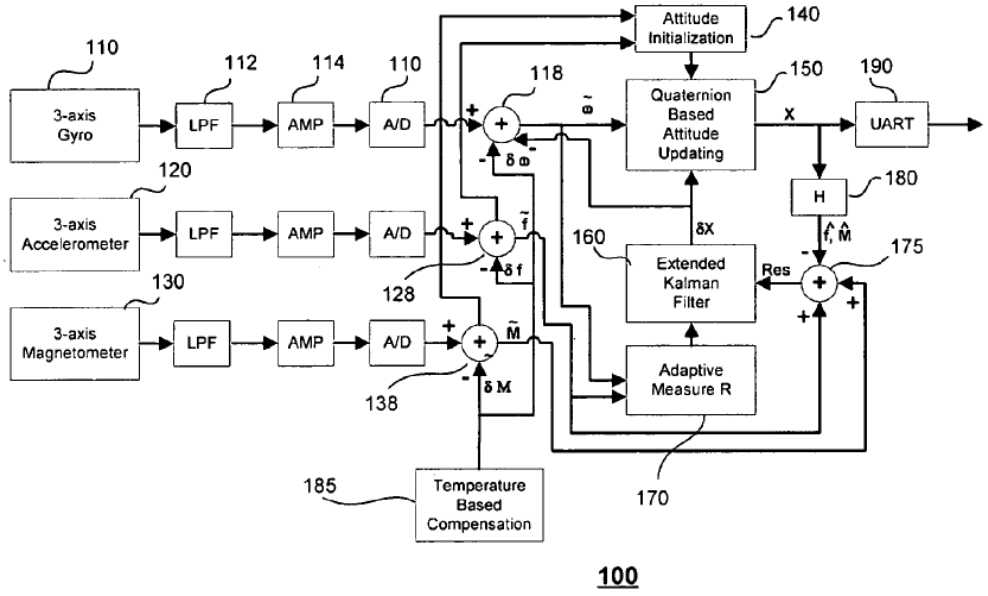
726. Accordingly, the EKF uses the measured accelerometers (i.e., the "measured state") and expected accelerations (i.e., the "predicted measurement") to correct an orientation estimate (i.e., "the updated state."). A POSA would understand that this "updated state" could be fed back into the Extended Kalman filter as the "previous state."

727. To the extent that CyWee claims that the CHR-6dm does not meet this limitation because it does not use quaternion representations of orientation or because the "expected acceleration" in the CHR-6dm is not a "predicted acceleration," it would have been obvious to a POSA at the time of the alleged invention to modify the CHR-6dm to use quaternions and/or "predict accelerations" in view of the teachings of *Yang*.

728. *Yang* discloses a system that provides an error estimate for an initial attitude (i.e., orientation) using an Extended Kalman filter. The Extended Kalman filter is adaptable based on whether the device is undergoing acceleration. *Yang* at Abstract. The estimated error obtained by the Extended Kalman filter may be used to update the initial orientation calculation. *Id.* ¶¶ 18–19, 39, 107, 112. Specifically, the estimated error, which *Yang* discloses as the residual value, consists of the differences between a measured acceleration (i.e., the "measured state") and predicted acceleration (i.e., the "predicted measurement") and a measured and predicted heading. *Id.* at Fig. 5, ¶¶ 111, 119–121. The basic mechanisms of the system are based on the principles of a Strapdown Inertial Navigation System. *Id.* ¶¶ 13, 30.

729. As shown in Figure 1 of *Yang* (reproduced below), *Yang* discloses a device

composed of (among other components): (i) a three-axis gyroscope (110); (ii) a three-axis accelerometer (120); (iii) a three-axis magnetometer (130); and (iv) an Extended Kalman filter (160).



730. As shown in Figure 4 of *Yang* (reproduced below), *Yang* discloses a method by which data from the sensors (gyroscopes, accelerometers, and magnetometers) is measured and then filtered. *Id.* at Fig. 4, ¶¶ 116–117. The Extended Kalman filter is then adapted based on the current acceleration mode. *Id.* at Fig. 4, ¶ 117. Once the Kalman filter is adapted based on the current acceleration mode, it estimates "attitude error and gyro bias" as shown in step 440 of Figure 4. *Id.* ¶ 117. A correction is applied using this error and the corrected orientation is then output (i.e., the "updated state"). *Id.* ¶ 118.

731. Figure 5 of *Yang* (also reproduced below) depicts the Kalman filtering step disclosed in step 440 of Figure 4 in more detail. The Extended Kalman filter is first initialized with an initial error estimate. *Id.* at Fig. 5, ¶ 119. The attitude update module is used to generate an updated attitude. *Id.* at Fig. 5, ¶ 120. The updated attitude is then used to "produce a predicted acceleration and heading (f and M) and determine a residual (Res)." *Id. Yang* discloses that this

attitude update is performed using quaternions for calculation efficiency. *Id.* at Figs. 4, 5, 6, ¶¶ 19, 26, 39–45, 107, 112, 118, 120, 122–124.

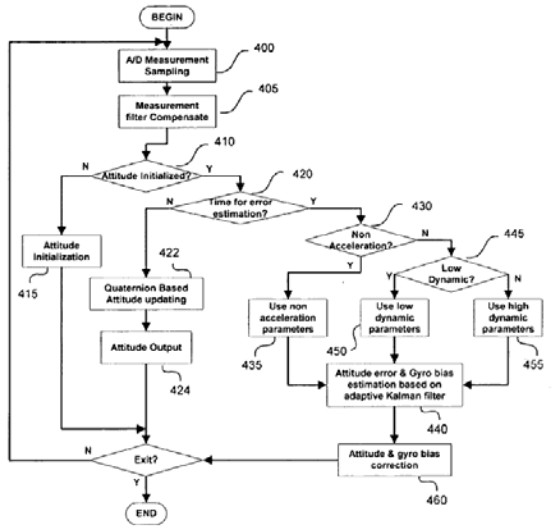
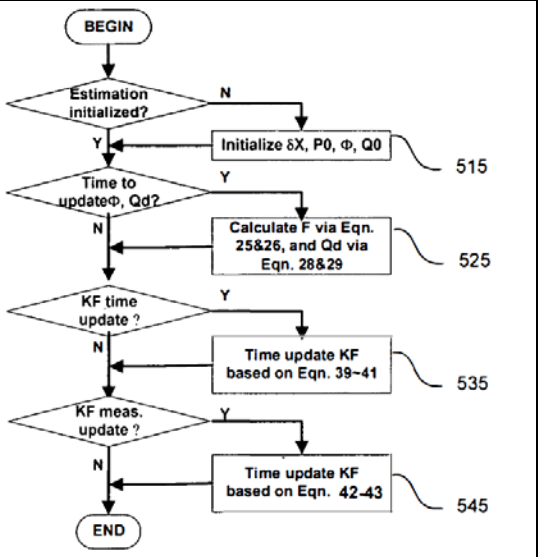
Figure 4 of *Yang*	Figure 5 of *Yang*
	

FIG. 4

732. The residual value (Res) consists of the differences between a measured and a predicted acceleration and a measured and a predicted heading and is used to determine the Kalman filter's error estimates. *Id.* at Fig. 5, ¶¶ 111, 119–121. The measured and predicted axial accelerations are used to update the Kalman filter's error estimate. This error estimate can be used as a correction value to update the orientation. *Id.* at Figs. 4, 5, 6, ¶¶ 116–130.

733. *Yang* explicitly discloses the use of a predicted acceleration value. Specifically, *Yang* discloses:

> The Kalman Filter 160 operates on a residual value (Res) that is a difference between a measured f^ and M^ and a predicted f^ and M^. The measured f^ and M^ are the measured acceleration (e.g., accelerometer reading) and measured heading (e.g., magnetometer reading) respectively. The predicted f^ and M^ comprise the **predicted acceleration f^** and the predicted heading M^ are predictions based on, for example, a model (H) of a current updated attitude X. **The model H, for example, looks at current accelerations, current attitude and heading, etc., and determines the predicted values.**

Yang ¶ 111 (emphasis added); Equation 31.

734. Further, Equation 31, which *Yang* describes as "one embodiment of a calculation" for the predicted acceleration, does not use the derivatives of the measured angular velocities. *Id.* at Equation 31.

735. Accordingly, in my opinion, *Yang* discloses using "predicted" and "measured" accelerations as inputs into an Extended Kalman filter to calculate an error value that is used to update an initial orientation. Both *Yang* and the CHR-6dm discloses that updated orientation values can be recursively input into the next time iteration of their respective algorithms to become the "previous state." CHR-6dm Datasheet at 7–8; *Yang* at Fig. 4, ¶ 107.

736. Although *Yang* and the CHR-6dm both disclose the use of measurements from a magnetometer, a POSA would have understood that the algorithm disclosed in *Yang* and used by the CHR-6dm could be modified to exclude the use of a magnetometer.

737. In view of these teachings of *Yang*, a POSA would have been motivated to configure the CHR-6dm so that the Extended Kalman filter uses the quaternions as disclosed in *Yang* for computational efficiency and to eliminate the singularity when the pitch is at +/- 90 degrees.

738. As the CHR-6dm Datasheet acknowledges, by using Euler angles, the CHR-6dm "cannot be used to measure orientation if it is expected to approach a pitch angle of +/- 90 degrees. To fix this problem, a quaternion representation must be used instead of Euler Angles." CHR-6dm Datasheet at 9. This same advantage is disclosed in *Yang*. As *Yang* discloses, the quaternion "is useful due to its good mathematical properties, dynamic equations and calculation efficiency."

739. In addition, to the extent that CyWee contends the CHR-6dm does not disclose

"predicted accelerations," a POSA would have been further motivated to configure the CHR-6dm to use the predicted accelerations in *Yang* for the same reasons that CyWee contends any POSA would have been motivated to use "predicted accelerations."

740. A POSA would have recognized that such a modification would have been a straightforward combination of known technologies by known methods without changing their respective functions to achieve a predictable result, and would have been well within the capabilities of such a person. Both Euler angle and quaternion representations of orientation are well known in the art.

741. Furthermore, a POSA would have been encouraged to look to *Yang* to complement the teachings of the CHR-6dm because these references are all directed to the same technical field and describe solutions to similar problems in the field. For example, both the CHR-6dm and *Yang* disclose calculating orientation using a combination of gyroscopes, accelerometers and magnetometers by using Extended Kalman filters. CHR-6dm Datasheet at 8–9; *Yang* ¶¶ 108–129.

f. [Element 438.14.7] "obtaining an updated state of the six-axis motion sensor module by comparing the current state with the measured state of the six-axis motion sensor module; and"

742. In my opinion, the CHR-6dm in view of *Yang* discloses these features for the same reasons I described in Section XIII.D.5.e for the "comparing the second quaternion" limitation.

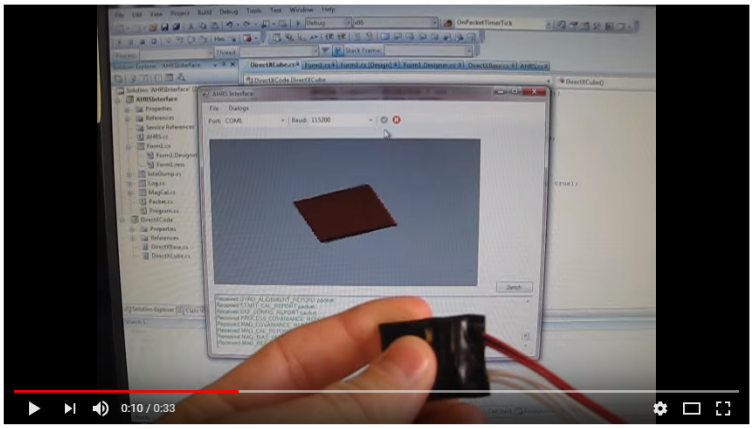
743. Under CyWee's interpretation, both limitations recite obtaining an "updated state" (representing the device's orientation) by taking the "current state" in the form of a second quaternion representing the device's orientation and correcting the orientation using the direction of gravity (or some predicted acceleration value).

g. [Element 438.14.8] "calculating and converting the updated state

of the six axis motion sensor module to said resulting deviation comprising said resultant angles in said spatial pointer reference frame of the 3D pointing device."

744. In my opinion, the CHR-6dm in view of *Yang* discloses these features. As discussed above, under CyWee's interpretation, the CHR-6dm in view of *Yang* discloses calculating an "updated state." *See* Section XIII.D.1.g.

745. As shown in a screenshot from the "CHR6dm Orientation Sensor from CH Robotics" video (reproduced below), the sensor can be implemented as a handheld device that calculates its own orientation which is translated directly onto a display.



746. The CHR-6dm represents orientation in Euler angles (yaw, pitch, and roll). CHR-6dm Datasheet at 9.

6. Claim 15

a. [Element 438.15] "The method for obtaining a resulting deviation of a 3D pointing device of claim 14, further comprises the step of outputting the updated state of the six-axis motion sensor module to the previous state of the six-axis motion sensor module; and wherein said resultant angles of the resulting deviation includes yaw, pitch and roll angles about each of three orthogonal coordinate axes of the spatial pointer reference frame."

747. In my opinion, the CHR-6dm in view of *Yang* discloses these features. As

discussed above, under CyWee's interpretation, the CHR-6dm in view of *Yang* discloses calculating an "updated state." *See* Section XIII.D.5.

748. Both the CHR-6dm and *Yang* disclose recursive Extended Kalman filters where the updated state is read back into the next loop of the filter. Specifically, the CHR-6dm uses angular velocity readings in a continuous two-step Extended Kalman filter. In the first step, the gyroscope measurements are used to predict an initial orientation. CHR-6dm Datasheet at 8. In the second "update" step, the accelerometer and magnetometers are used to correct for drift. *Id*. Specifically, the accelerometers are used to measure the gravity vector. *Id.* at 9.

749. The basic steps used in the Extended Kalman filter are detailed in the CHR-6dm firmware code. Specifically, in the chr6dm_states.c file, the Extended Kalman filter is executed in the EKF_EstimateStates function (reproduced below):

EKF_EstimateStates Function from CHR-6dm Firmware

```
void EKF_EstimateStates( AHRS_states* estimated_states, RawSensorData* sensor_data)
{
        static int initialized = 0;

        if( !initialized )
        {
//              EKF_InitFromSensors ( estimated_states, sensor_data );
                EKF_Init( estimated_states );
                initialized = 1;
        }

        // Run EKF prediction step
        EKF_Predict( estimated_states, sensor_data );

        // Run EKF update step
        EKF_Update( estimated_states, sensor_data );
}
```

In the above code:

- The EKF_InitFromSensors function uses sensor data to fill an initial state

estimate structure;

- The EKF_Predict function uses rate gyros to make a new orientation estimate; and
- The EKF_Update function uses the accelerometers to correct pitch and roll errors and magnetic sensors to correct yaw errors.

750. As shown in the EKF_Predict function, the CHR-6dm's EKF is continuous and begins by setting the variables phi, theta, and psi with the current state estimates from the last iteration of the algorithm.

EKF_Predict Function from CHR-6dm Firmware

// Get current state estimates
phi = estimated_states->phi;
theta = estimated_states->theta;
psi = estimated_states->psi;

751. Similarly, as shown in Figure 4 of *Yang* (reproduced here), *Yang* discloses that the outputted orientation is fed back into the algorithm in a process where the orientation is continually being updated. *Yang* at Fig. 4, ¶ 107.

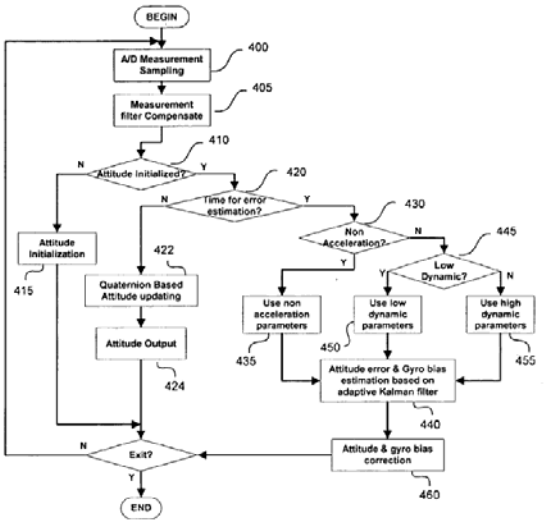
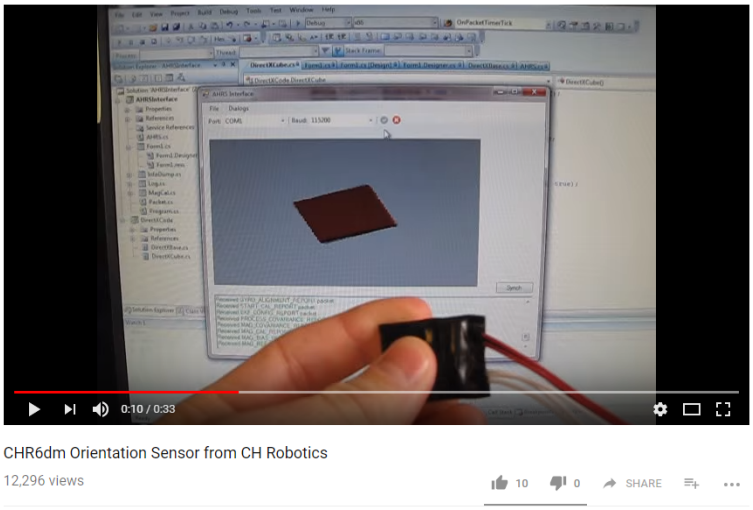


FIG. 4

752. As shown in a screenshot from the "CHR6dm Orientation Sensor from CH Robotics" video (reproduced below), the CHR-6dm sensor can be implemented as a handheld device that calculates its own orientation which is translated directly onto a display.



753. The CHR-6dm represents orientation in Euler angles (yaw, pitch, and roll). CHR-6dm Datasheet at 9.

7. Claim 16

a. [Element 438.16] "The method for obtaining a resulting deviation of a 3D pointing device of claim 14, wherein said previous state of the six-axis motion sensor module is a first quaternion with respect to said previous time T−1; and said updated state of the six-axis motion sensor module is a third quaternion with respect to said current time T."

754. In my opinion, the CHR-6dm in view of *Yang* discloses these features. As discussed above, under CyWee's interpretation, the CHR-6dm discloses calculating an updated state which is then re-input into the algorithm as the "previous state" at the next time stage of the Extended Kalman filter. *See* Section VIII.D.6. *Yang* discloses a similar Extended Kalman filter that uses quaternion representations of orientation where the updated quaternion is re-input into the algorithm as the "previous state" at the next time stage. *See id.* A POSA would have been motivated to configure the CHR-6dm's Extended Kalman filter to use quaternion representations of orientation for the reasons I described above. *See* Sections XIII.D.5.

8. Claim 17

a. [Element 438.17] "The method for obtaining a resulting deviation of 3D pointing device of claim 14, wherein the obtaining of said previous state of the six-axis motion sensor module further comprises initializing said initial-value set."

755. In my opinion, the CHR-6dm in view of *Abbate* discloses these features. *See* EKF_InitFromSensors function.

9. Claim 19

756. From my review, Claims 14 and 19 recite identical claim language. Accordingly, in my opinion, the combination of the CHR-6dm and *Yang* render obvious Claim 19 for the same reasons that they render obvious Claim 14, as I describe in Section XIII.D.5.

XIV. THE ASSERTED CLAIMS OF THE '978 PATENT ARE RENDERED OBVIOUS BY THE PRIOR ART

A. *Joseph* in view of *Abbate* and *Yang* renders obvious Claims 10 and 12 of the '978 Patent

1. Claim 10

a. [Element 978.10.0] "A method for compensating rotations of a 3D pointing device, comprising:"

757. I understand that neither Samsung nor CyWee has argued that the preamble of Claim 10 is limiting. However, to the extent that the preamble is considered limiting, in my opinion, *Joseph* in view of *Abbate* discloses a method with the recited features.

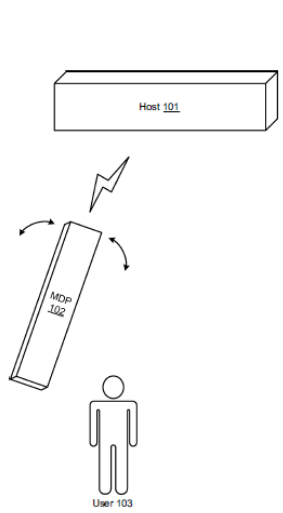
758. The specification of the '978 Patent describes a "three-dimensional (3D) pointing device" as a device "for detecting motions of the device and translating the detected motions to a cursor display such as a cursor pointing on the screen 122 of a 2D display device 120." '978 Patent at 1:29–33; 53–62.

759. Consistent with its plain and ordinary meaning, *Joseph* discloses a "three-dimensional (3D) pointing device" that is "subject to movements and rotations in dynamic

environments."

760. In particular, *Joseph* discloses a "multi-dimensional pointing device," which is described as "a device that may be freely moved in space (e.g., in one, two, or three dimensions) to position a cursor in a user interface of a computer system or other electronic devices." *Joseph* at 1:39–43. The pointing device is "sensitive to six degrees of freedom: x, y, z, yaw, pitch and roll." *Id.* at 4:1–2.

761. As shown in Figure 1 of *Joseph* (reproduced here), "a user 103 can use the multi-dimensional pointing device 102 to issue commands to the host system 101, control objects in the user interface of the host system 101, and/or position objects in the user interface of the host system 101." *Id.* at Fig. 1, 3:62–66.



762. *Joseph* in view of *Abbate* discloses a method for "compensating rotations" of the 3D pointing device. Although the '978 Patent does not explicitly define the meaning of the term "compensating rotations," it notes that "[t]he term compensation [as used in the relevant prior art] refers to the correction and compensation of signals subject to gravity effects or extra rotations about the axis related to 'roll'." '978 Patent at 2:25–29.

763. Consistent with that understading of the "compensating rotations" term, *Joseph* discloses a method by which measurements of the movement of the multi-dimensional pointing device are compensated or corrected to account for measurement errors from the device's accelerometer and magnetometer. Specifically, *Joseph* discloses the use of an Extended Kalman filter—which incorporates measurements from the device's two accelerometers, a magnetic field measurement received from the device's multi-dimensional magnetometer, and a gain factor

based on accelerometer measurements—to determine the orientation of the pointing device. *Joseph* at 1:66–2:6.

764. Similarly, *Abbate* discloses a method of compensating for the measurements of sensors by through an Extended Kalman Filter. The Extended Kalman filter is used so that the system is able to use "several kinds of sensors." *Id.* In this way, the "characteristics of one type of sensor avoid overcoming the limitations of other sensors." *Id.* at 257.

765. Accordingly, in both *Joseph* and *Abbate*, the Extended Kalman filter "compensates" for any errors resulting from an individual sensor.

b. [Element 978.10.1] "generating an orientation output associated with an orientation of the 3D pointing device associated with three coordinate axes of a global reference frame associated with Earth;"

766. In my opinion, *Joseph* discloses this limitation.

767. The '978 Patent defines the term "orientation output" as a value "associated with the orientation of the 3D pointing device associated with the three coordinate axes of the global reference frame associated with the Earth." '978 Patent at 33:29–50; 33:53–64.

768. Claim 10 of the '978 Patent recites in later elements that the "orientation output" is generated based on: (i) the first signal set, the second signal set, and the rotation output; or (ii) the first signal set and the second signal set. *See* '978 Patent, Claim 10, Elements 978.10.4 and 978.10.5.

769. As I describe below in Section XIV.A.1.e, *Joseph* discloses a method for generating an "orientation output" consistent with CyWee's interpretation of these limitations.

770. In my opinion, this orientation output is "associated with an orientation of the 3D pointing device associated with three coordinate axes of a global reference frame associated with Earth," as recited by Claim 10.

771. *Joseph* defines two frames of reference. The first is the body frame of the multi-

dimensional pointing device, which is defined as "[t]he coordinate system in which B [(i.e., Earth's magnetic field)] and G [(i.e., Earth's gravity)] are measured with respect to a fixed point on the multi-dimensional pointing device . . . ." *Joseph* at 10:5–7. The second is the Earth frame, which is defined as a frame of reference in which measurements are taken with respect to a fixed point on the surface of the Earth. *Id.* at 10:14–17.

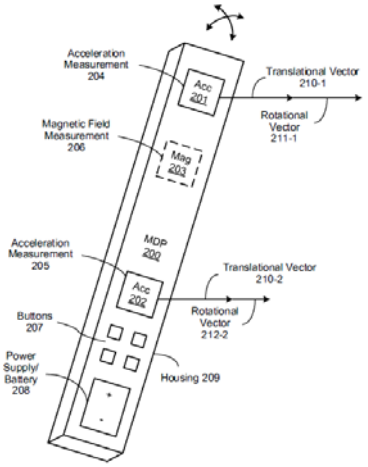
772. I understand that the term "global reference frame" has been construed as a "reference frame with axes defined with respect to the Earth." *See* Section VIII. A POSA would understand *Joseph*'s use of an Earth frame to be a "reference frame with axes defined with respect to the Earth."

773. A POSA would further understand that the orientation of *Joseph*'s pointing device is calculated based on the sensor's orientation in the body frame relative to a known reference frame (the Earth frame). *Joseph* at 10:22–27; *see also* 10:35–12:47.

c. [Element 978.10.2] "generating a first signal set comprising axial accelerations associated with movements and rotations of the 3D pointing device in the spatial reference frame;"

774. In my opinion, *Joseph* discloses this limitation.

775. As shown in Figure 2 of *Joseph* (reproduced here), *Joseph*'s pointing device contains two or more accelerometers 201 and 202 that measure accelerations of the multi-dimensional pointing device. *Joseph* at Fig. 2. Each accelerometer may be either "a 2-axis accelerometer that measures a magnitude and a direction of an acceleration force in two dimensions [or] a 3-axis accelerometer that measures a magnitude and a direction of an acceleration force in three dimensions." *Joseph* at 5:33–36.

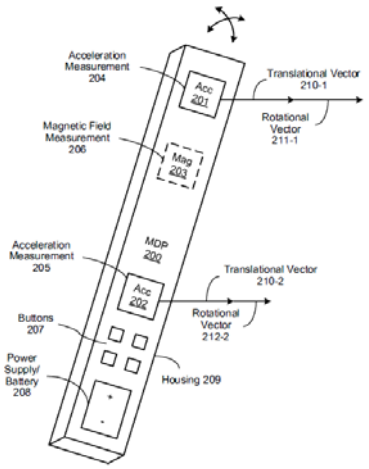


776. *Joseph* further discloses that the accelerometers measure accelerations in the

device's body frame of reference (i.e., the "spatial pointer reference frame"), which is defined as "the coordinate system in which [magnetic field and acceleration measurements] are measured with respect to a fixed point on the multi-dimensional pointing device 102." *Joseph* at 10:4–7. Specifically, acceleration measurements are made by the accelerometers in the body frame of reference and then mapped to the Earth frame of reference. *Joseph* at 10:22–27; *see also* 10:35–11:25.

d. [Element 978.10.3] "generating a second signal set associated with Earth's magnetism;"

777. In my opinion, *Joseph* discloses this limitation. As shown in Figure 2 of *Joseph* (reproduced here), *Joseph*'s 3D pointing device contains a magnetometer (203) that measures the magnetic field surrounding the multi-dimensional pointing device. Each magnetometer in *Joseph*'s 3D pointing device may either be a "a 2-axis magnetometer that measures a magnitude and a direction of a magnetic field in two dimensions [or] a 3-axis magnetometer that measures a magnitude and a direction of a magnetic field in three dimensions." *Joseph* at 5:39–42.



778. A POSA would understand that a magntometer provides data regarding the position of a device with which it is associated based on measurements of the Earth' magnetic field. Accordingly, a POSA would understand the signal set generated by the magnetometer to be "associated with the Earth's magnetism."

e. [Element 978.10.4] "generating the orientation output based on the first signal set, the second signal set and the rotation output or based on the first signal set and the second signal set;"

779. In my opinion, *Joseph* in view of *Abbate* discloses this feature. As I explained in

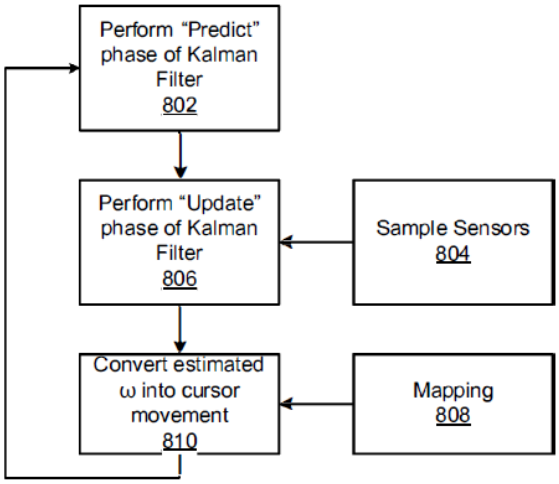
Section XV.B.2, the '978 Patent does not describe the limitation of "generating the orientation output based on the first signal set, the second signal set and the rotation output or based on the first signal set and the second signal set."

780. As I also explained in Section XV.B.2, I understand that CyWee and its experts have claimed that this limitation is met by an Extended Kalman filter or something like an Extended Kalman filter, as allegedly shown in Equations 5–11 of the '978 Patent.

781. I do not agree with CyWee's claims above. However, taking CyWee's own representations as true, this limitation covers an Extended Kalman filter that either combines: (i) accelerations ("first signal set"), magnetic readings ("second signal set") and angular velocities ("rotation output"); or (ii) accelerations ("first signal set"); and (iii) magnetic readings ("second signal set") to obtain an estimated orientation.

782. Accordingly, if taken as true, *Joseph* in view of *Abbate* discloses these features.

783. Specifically, *Joseph* states that measurements from the multi-dimensional pointing device's accelerometers and magnetometers are used in an Extended Kalman filter algorithm to determine the orientation of the multi-dimensional pointing device. *Joseph* at Fig. 8, 12:48–13:15.



784. Figure 8 of *Joseph* (reproduced here) is a process flow diagram showing how *Joseph*'s Extended Kalman filter operates. *Joseph* describes that "[i]n the predict phase (802), an estimated state of the Kalman filter (which can also be considered to be a state of the device) from the previous timestep [(i.e., iteration of the

Kalman filter)] is used to produce a predicted estimate of the state (e.g., a 'predicted state') at a current timestep." *Id.* at 12:60–64. In the "update phase" (806), the acceleration and magnetic readings are used to correct the predicted state at current time T to produce an "updated state. This updated state is them used as the estimated state in the next timestep. *Id.* at 12:65–13:15.

785. Although *Joseph* does not expressly disclose using a rotation output (i.e., angular velocity measurements) in its Kalman filter, it would have been obvious to a POSA to modify *Joseph*'s Kalman filter to also use angular velocity measurements in view of the teachings of *Abbate*.

786. *Abbate* discloses a real-time inertial motion capture system using inertial measurement units (IMUs) that are used to record and reconstruct human motion. *Abbate* at 255. The IMUs contain: (i) three single-axis angular rate gyroscopes; (ii) one three-axis accelerometer; and (iii) one three-axis magnetometer. *Id.* at 256. The IMUs are placed on fixed key points on the human body. *Id.* The readings from these IMUs are fed into a centralized collection point and the orientations of the key points are calculated using a quaternion-based Extended Kalman filter. *Id.* at 255–256. In this way, the system is able to use "several kinds of sensors" so that the "characteristics of one type of sensor avoid overcoming the limitations of other sensors." *Id.* at 257.

787. Figure 6 of *Abbate* (reproduced here) depicts the sensor-fusion process disclosed in *Abbate*'s quaternion-based Extended Kalman filter. As shown in Figure 6, the Extended Kalman filter weighs the three sources of information from the gyroscopes,

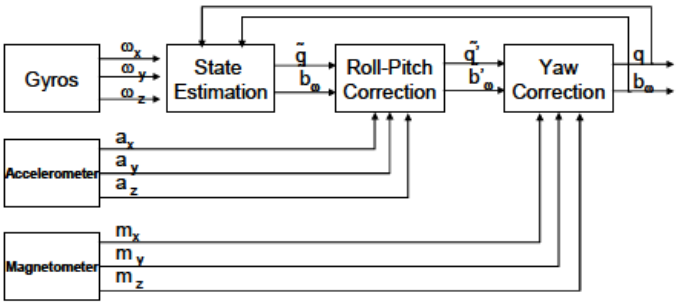


Fig.6. Flow diagram of the implemented quaternion based EKF.

accelerometers and magnetometers appropriately in order to provide an accurate estimate of orientation and eliminate noise. *Id.* at Fig. 6, 258. In the Extended Kalman filter, the orientation is first estimated using angular rate velocities. The Extended Kalman filter then implements a two-step correction process in which: (i) acceleration data is used to correct roll and pitch angles and (ii) magnetic field data is used to correct the yaw angle. *Id.*

788. Specifically, in *Abbate*, the Kalman filter is initialized with an initial state (i.e., orientation) estimate, and that initial state estimate is combined with the state estimation updated in the prior iteration of the Kalman-filter loop (i.e., the "update[d] state estimation with measurement zk" shown in that figure). *Id.* at Fig. 8. This combined value is depicted as the "state estimation" in Figure 6.

789. As shown in Figure 6, the "state estimation" is modified by angular velocity measurements from the gyroscopes, which generates a quaternion representing the current state of the device. The roll and pitch components of the quaternion representing the device's current state are then further corrected by the measured accelerations (as shown in the "roll-pitch correction" step in Figure 6) to update the state estimation used in that iteration of the Kalman-filter loop. *Id.* at Fig. 6, 258. The yaw component of the quaternion representing the device's current state is then corrected by the measured magnetic readings (as shown in the "yaw correction" step in Figure 6) to update the state estimation used in that iteration of the Kalman-filter loop. *Id.* at Fig. 6, 258.

790. In view of these teachings of *Abbate*, a POSA would have been motivated to configure *Joseph*'s pointing device to implement an Extended Kalman filter that utilizes gyroscope data along with accelerometer data and magnetometer data to provide more data for estimating the pointer orientation. Specifically, *Joseph* acknowledges that a gyroscope can be

used with the accelerometer to compensate for measurement errors. *Id.* at 4:51–58.

791. A POSA would have recognized that configuring *Joseph*'s pointing device to use an Extended Kalman filter that uses gyroscope, accelerometer, and magnetometer readings, as disclosed in *Abbate*, would have been an improvement to *Joseph*'s pointing device. Indeed, as noted above, *Joseph* already discloses integrating gyroscopes and accelerometers together for use in a pointing device. A POSA would have recognized that incorporating data from a gyroscope (which was well known in the art at the time) into *Joseph*'s 3D pointing device for use in *Joseph*'s Extended Kalman filter would improve the accuracy of the generated orientation predictions.

792. A POSA would have recognized that such a modification would have been a straightforward combination of known technologies by known methods without changing their respective functions to achieve a predictable result, and would have been well within the capabilities of such a person.

793. Furthermore, a POSA would have been encouraged to look to *Abbate* to complement the teachings of the *Joseph* because these references are all directed to the same technical field and describe solutions to similar problems in the field. For example, both *Joseph* and *Abbate* disclose calculating orientation using a combination of orientation sensors using Extended Kalman filters. *Joseph* at Abstract, 12:48–13:15; *Abbate* at 255–258

f. [Element 978.10.5] "generating a rotation output associated with a rotation of the 3D pointing device associated with three coordinate axes of a spatial reference frame associated with the 3D pointing device; and"

794. In my opinion, *Joseph* in view of *Abbate* discloses this feature. The '978 Patent states that: "the rotation sensor 342 generates a rotation output (ω_x, ω_y, ω_z) associated with the rotation of the 3D pointing device associated with the three coordinate axes of a spatial reference

associated with the 3D pointing device[.]" '978 Patent at 30:57–62. Similarly, it provides that the "rotation output [ω_x, ω_y, ω_z], includes three angular velocities ω_x, ω_y, ω_z respectively associated with the three coordinate axes X_p, Y_p, and Z_p of the spatial reference frame associated with the 3D pointing device." Accordingly, a POSA would understand the "rotation output" to be the measured angular velocities.

795. As I discussed in Section XIV.A.1.e, a POSA would have been motivated to modify the Extended Kalman filter disclosed in *Joseph* to use the measurements from a gyroscope and the techniques disclosed in *Abbate*'s Extended Kalman filter. Specifically, a POSA would have been motivated to incorporate a gyroscope into *Joseph*'s 3D pointing device and use the techniques disclosed in *Abbate*'s Extended Kalman filter to improve the accuracy of the orientation calculation.

g. [Element 978.10.6] "using the orientation output and the rotation output to generate a transformed output associated with a fixed reference frame associated with a display device, wherein the orientation output and the rotation output is generated by a nine-axis motion sensor module;"

796. In my opinion, *Joseph* in view of *Abbate* discloses these features. In my opinion, a POSA would understand that this limitation refers to calculating a change in the orientation of a device and then "mapping" this change onto a display.

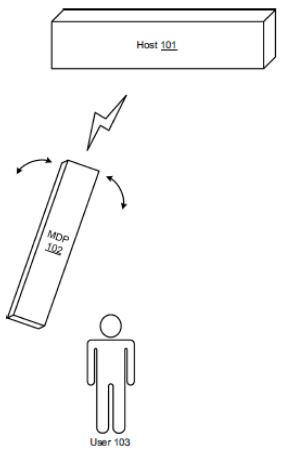
797. As I described in Sections XIV.A.1.b and XIV.A.1.f, *Joseph* in view of *Abbate* discloses generating a rotation output (i.e., measured angular velocities) and an "orientation output."

798. The orientation output and rotation output is "generated by a nine-axis motion sensor module." As I described above, *Joseph* discloses a multi-dimensional 3D pointing device with two or more multi-dimensional accelerometers and one or more multi-dimensional magnetometers. *Joseph* at Fig. 2, 5:13–30; 19:24–20:30.

799. Although *Joseph* does not disclose an on-board gyroscope, *Abbate* discloses a real-time inertial motion capture system using inertial measurement units (IMUs) that are used to record and reconstruct human motion. *Abbate* at 255. The IMUs contain: (i) three single-axis angular rate gyroscopes; (ii) one three-axis accelerometer; and (iii) one three-axis magnetometer. *Id.* at 256.

800. Further, a POSA would have been motivated to configure *Joseph*'s 3D pointing device to include both gyroscopes, accelerometers and magnetometers (i.e., a "nine-axis motion sensor module") as shown in *Abbate* and to use the filtering techniques disclosed in *Abbate* for the reasons I described in Sections XIV.A.1.e.

801. As shown in Figure 1 of *Joseph* (reproduced here), the 3D pointing device (102) is coupled to a host system (101) through a wireless interface. In this embodiment, "a user 103 can use the multi-dimensional pointing device 102 to issue commands to the host system 101, control objects in the user interface of the host system 101, and/or position objects in the user interface of the host system 101." *Joseph* at 3:63–4:2; *see also* 6:10–8:40.



802. *Joseph* discloses that a "mapping (808) is applied to the body rotation rate ω (e.g., obtained from the state vector of the Kalman filter) to convert (810) ω into the cursor motion." *Id.* at 13:5–7.

803. A POSA would further understand that the aforementioned cursor motion occurs in the fixed reference frame of a device's display. The pointing device calculates its own orientation which is translated directly onto a display. Any change in the rotational movement of the sensor is reflected on the screen.

h. [Element 978.10.7] "obtaining one or more resultant deviation including a plurality of deviation angles using a plurality of measured magnetisms M_x, M_y, M_z and a plurality of predicted magnetism M_x', M_y' and M_z' for the second signal set."

804. In my opinion, *Joseph* in view of *Abbate* further in view of *Yang* discloses this limitation. As I described in Section XV.B.3, the '978 Patent does not describe the limitation of "obtaining one or more resultant deviation including a plurality of deviation angles using a plurality of measured magnetisms M_x, M_y, M_z and a plurality of predicted magnetism M_x', M_y' and M_z' for the second signal set."

805. In my opinion, a POSA would understand that this limitation could refer broadly to obtaining the change in a device's orientation using two sets of magnetism values.[1]

806. In my opinion, *Joseph* in view of *Abbate* further in view of *Yang* discloses these features. As I described above, *Joseph* in view of *Abbate* discloses a pointing device that uses an Extended Kalman filter to combine data from onboard gyroscopes, accelerometers, and magnetic sensors to calculate the device's orientation.

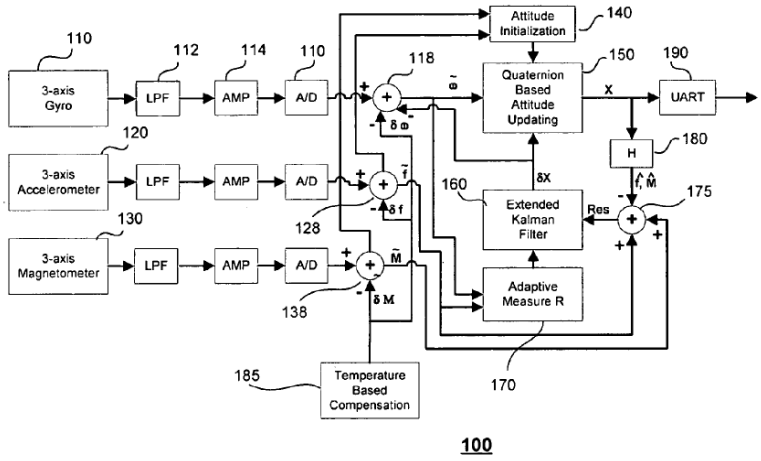
807. In the second step of *Abbate*'s Extended Kalman filter, magnetic field data is used to correct the yaw angle. *Abbate* at Fig. 6, 258. Although *Abbate* does not explicitly disclose the use of "predicted magnetisms," it would have been obvious to a POSA at the time of the alleged invention to modify the Extended Kalman filter used in *Abbate* to implement such a feature in view of the teachings of *Yang*.

808. *Yang* discloses a system that provides an error estimate for an initial attitude (i.e., orientation) using an Extended Kalman filter. The Extended Kalman filter is adaptable based on

[1] I understand that the '978 Patent discloses that a "predicted magnetism" is calculated by Equations 18–20, which I understand is intended are intended to correct the orientation of the user's Earth frame so that this frame's x-axis points exactly to the North horizon. Even if this correction could be construed as a "predicted" magnetism, the concept of correcting the actual magnetometer measurements for the dip angle was well known in the art since the 1500s.

whether the device is undergoing acceleration. *Yang* at Abstract. The estimated error obtained by the Extended Kalman filter may be used to update the initial orientation calculation. *Id.* ¶¶ 18–19, 39, 107, 112. Specifically, the estimated error, which *Yang* discloses as the residual value, consists of the differences between a measured acceleration and predicted acceleration and a measured heading (i.e., measured magnetisms) and predicted heading (i.e., predicted magnetisms). *Id.* at Fig. 5, ¶¶ 111, 119–121. The basic mechanisms of the system are based on the principles of a Strapdown Inertial Navigation System. *Id.* ¶¶ 13, 30.

809. As shown in Figure 1 of *Yang* (reproduced below), *Yang* discloses a device composed of (among other components): (i) a three-axis gyroscope (110); (ii) a three-axis accelerometer (120); (iii) a three-axis magnetometer (130); and (iv) an Extended Kalman filter (160).



810. As shown in Figure 4 of *Yang* (reproduced below), *Yang* discloses a method by which data from the sensors (gyroscopes, accelerometers, and magnetometers) is measured and then filtered. *Id.* at Fig. 4, ¶¶ 116–117. The Extended Kalman filter is then adapted based on the current acceleration mode. *Id.* at Fig. 4, ¶ 117. Once the Kalman filter is adapted based on the current acceleration mode, it estimates "attitude error and gyro bias" as shown in step 440 of Figure 4. *Id.* ¶ 117. A correction is applied using this error and the corrected orientation is then

output. *Id.* ¶ 118.

811. Figure 5 of *Yang* (also reproduced below) depicts the Kalman filtering step disclosed in step 440 of Figure 4 in more detail. The Extended Kalman filter is first initialized with an initial error estimate. *Id.* at Fig. 5, ¶ 119. The attitude update module is used to generate an updated attitude. *Id.* at Fig. 5, ¶ 120. The updated attitude is then used to "produce a predicted acceleration and heading (f and M) and determine a residual (Res)." *Id. Yang* discloses that this attitude update is performed using quaternions for calculation efficiency. *Id.* at Figs. 4, 5, 6, ¶¶ 19, 26, 39–45, 107, 112, 118, 120, 122–124.

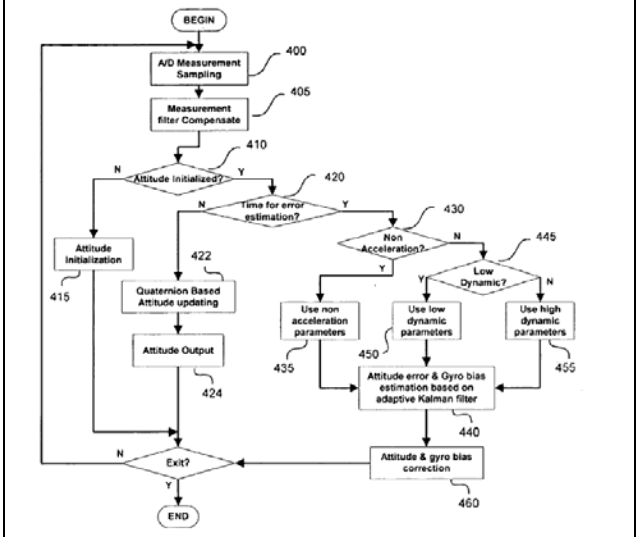
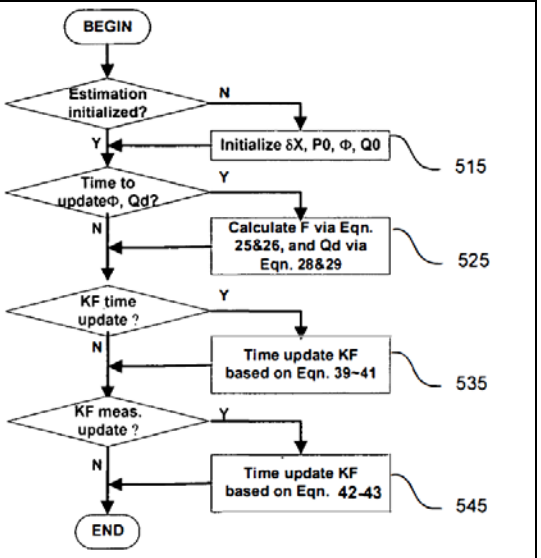
Figure 4 of *Yang*	**Figure 5 of *Yang***
	

FIG. 4

812. The residual value (Res) consists of the differences between a measured and a predicted acceleration and a measured and a predicted heading and is used to determine the Kalman filter's error estimates. *Id.* at Fig. 5, ¶¶ 111, 119–121. The measured and predicted axial accelerations are used to update the Kalman filter's error estimate. This error estimate can be used as a correction value to update the orientation. *Id.* at Figs. 4, 5, 6, ¶¶ 116–130.

813. *Yang* explicitly discloses the use of a predicted magnetism value. Specifically, *Yang* discloses:

> The Kalman Filter 160 operates on a residual value (Res) that is a difference between a measured f^ and M^ and a predicted f^ and M^. The measured f^ and M^ are the measured acceleration (e.g., accelerometer reading) and measured heading (e.g., magnetometer reading) respectively. The predicted f^ and M^ comprise the predicted acceleration f^ and the **predicted heading M^** are predictions based on, for example, a model (H) of a current updated attitude X. **The model H, for example, looks at current accelerations, current attitude and heading, etc., and determines the predicted values.**

Yang ¶ 111 (emphasis added); Equation 35.

814. Accordingly, in my opinion, *Yang* discloses using "predicted" and "measured" magnetisms as inputs into an Extended Kalman filter to calculate an error value that is used to update an initial orientation.

815. In view of these teachings of *Yang*, a POSA would have been motivated to configure *Joseph* so that the Extended Kalman filter uses the techniques in *Yang* to obtain a more accurate estimate of the Extended Kalman filter's error.

816. A POSA would have recognized that such a modification would have been a straightforward combination of known technologies by known methods without changing their respective functions to achieve a predictable result, and would have been well within the capabilities of such a person.

817. Furthermore, a POSA would have been encouraged to look to *Abbate* to complement the teachings of the *Joseph* because these references are all directed to the same technical field and describe solutions to similar problems in the field. For example, both *Joseph* and *Abbate* disclose calculating orientation using a combination of orientation sensors using Extended Kalman filters. *Joseph* at Abstract, 12:48–13:15; *Abbate* at 255–258.

2. Claim 12

a. [Element 978.12] "The method of claim 10, wherein the orientation output is a rotation matrix, a quaternion, a rotation vector, or comprises three orientation angles."

818. In my opinion, *Joseph* in view of *Abbate* and *Yang* discloses this limitation. As I described above, Joseph discloses a pointing device and an Extended Kalman filter that is used to determine the attitude of the pointing device. Joseph states that, in some embodiments, the attitude of the pointing device is "represented using a quaternion" that includes "a unit vector representing a direction and a rotation angle about the unit vector." *Joseph* at 2:33–37.

819. *Abbate* also discloses generating the "orientation output" in quaternion format. *Abbate* at 258. Similarly, *Yang* discloses representing orientation using Euler angles, a rotation matrix, and quaternions. *Yang* ¶¶ 11–12. A POSA would understand that all of these methods are commonly understood ways of representing orientation.

B. The CHR-6dm in view of *Abbate* and *Yang* renders obvious Claims 10 and 12 of the '978 Patent

1. Claim 10

a. [Element 978.10.0] "A method for compensating rotations of a 3D pointing device, comprising:"

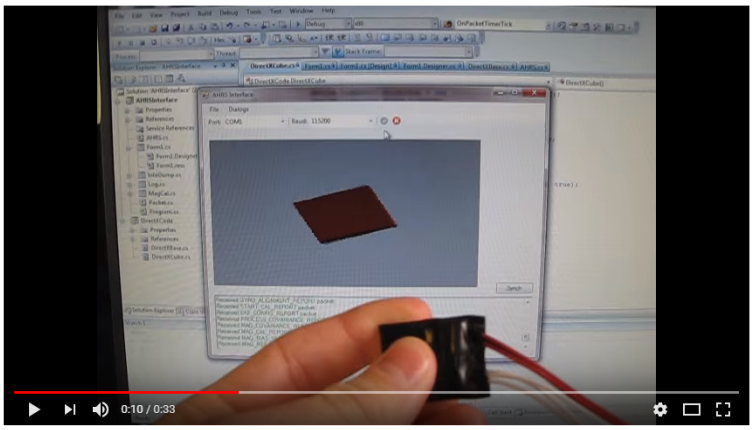
820. I understand that neither Samsung nor CyWee has argued that the preamble of Claim 10 is limiting. However, to the extent that the preamble is considered limiting, in my opinion, the CHR-6dm in view of *Abbate* discloses a method with the recited features.

821. I understand that CyWee has interpreted a 3D pointing device to be "a handheld device that uses at least a rotation sensor comprising one or more gyroscopes, and one or more accelerometers to determine deviation angles or the orientation of a device." CyWee's Opening Claim Construction Brief, Dkt. No. 66 at 13–14.

822. Although I do not agree with this interpretation, consistent with CyWee's own

definition, the CHR-6dm is a 3D pointing device. Specifically, the CHR-6dm is an orientation sensor with one or more onboard accelerometers and gyroscopes. The CHR-6dm uses an Extended Kalman filter to produce yaw, pitch and roll angle estimates. CHR-6dm Datasheet at 1.

823. As shown in a screenshot from the "CHR6dm Orientation Sensor from CH Robotics" video (reproduced below), the sensor can be implemented as a handheld device that calculates its own orientation which is translated directly onto a display.



824. The CHR-6dm in view of *Abbate* discloses a method for "compensating rotations" of the 3D pointing device. Although '978 Patent does not explicitly define what it means to compensate for rotations, it states that "[t]he term compensation [as used in the prior art] refers to the correction and compensation of signals subject to gravity effects or extra rotations about the axis related to 'roll'." '978 Patent at 2:25–29.

825. Consistent with this understanding, the CHR-6dm discloses a method for "compensating" for any sensor errors resulting from moving the CHR-6dm sensor. Specifically, the CHR-6dm uses a sensor fusion algorithm (an Extended Kalman filter) that "combines data from onboard accelerometers, rate gyros, and magnetic sensors to produce yaw, pitch and roll angle estimates." CHR-6dm Datasheet at 1, 8. This combination of sensors "compensates" for

any individual errors resulting from measuring rotations with just one sensor.

826. If a 3D pointing device is instead interpreted under its proper plain and ordinary meaning, it would have been obvious to a POSA to incorporate the CHR-6dm sensor into any existing prior art 3D pointing device to calculate orientation and facilitate the pointing function.

827. Indeed, as discussed above, the '978 Patent admits that 3D pointing devices equipped with orientation sensors were well known in the prior art. *Id.* at 3:53–4:11. A POSA would have recognized that such a configuration would have been a straightforward combination of known technologies by known methods without changing their respective functions to achieve a predictable result, and would have been well within the capabilities of such a person.

b. [Element 978.10.1] "generating an orientation output associated with an orientation of the 3D pointing device associated with three coordinate axes of a global reference frame associated with Earth;"

828. In my opinion, the CHR-6dm discloses these features.

829. The '978 Patent defines the term "orientation output" as a value "associated with the orientation of the 3D pointing device associated with the three coordinate axes of the global reference frame associated with the Earth." '978 Patent, 33:29–50; 33:53–64.

830. Claim 10 of the '978 Patent recites in later elements that the "orientation output" is generated based on: (i) the first signal set, the second signal set, and the rotation output; or (ii) the first signal set and the second signal set. *See* '978 Patent, Claim 10, Elements 978.10.4 and 978.10.5.

831. As I describe below in Section XIV.B.1.e, the CHR-6dm discloses a method for generating an "orientation output" consistent with CyWee's interpretation of these limitations.

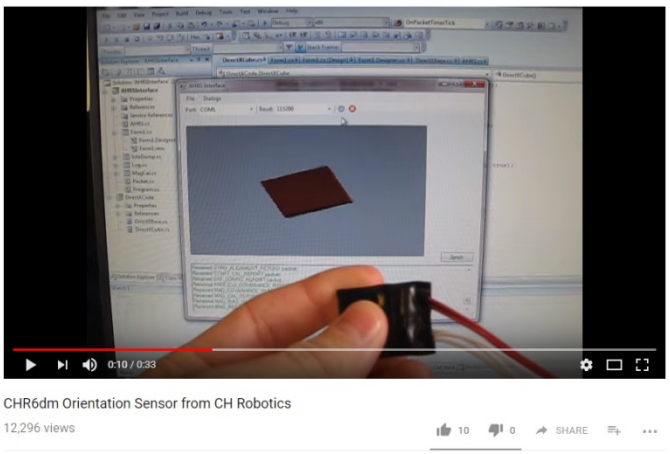
832. In my opinion, this orientation output is "associated with an orientation of the 3D pointing device associated with three coordinate axes of a global reference frame associated with Earth," as recited by Claim 10.

833. The CHR-6dm defines two frames of reference. The first is the body frame of the sensor. CHR-6dm Datasheet at 12, 36. The second is the North-East-Down inertial frame. *Id.* at 9.

834. I understand that the term "global reference frame" has been construed as a "reference frame with axes defined with respect to the Earth." *See* Section VIII. A POSA would understand the CHR-6dm's use of a North-East-Down inertial frame to be a "reference frame with axes defined with respect to the Earth."

835. As described in the CHR-6dm Datasheet, the "inertial frame x-axis is aligned with magnetic north, the y-axis is aligned with magnetic east, and the z-axis points down toward the center of the Earth." CHR-6dm Datasheet at 9.

836. As shown in the "CHR6dm Orientation Sensor from CH Robotics" video (screenshot reproduced below), a POSA would understand that the CHR-6dm sensor calculates the orientation of the CHR-6dm sensor based on the sensor's orientation in the body frame relative to a known reference frame and then translates this orientation to the display.



c. [Element 978.10.2] "generating a first signal set comprising axial accelerations associated with movements and rotations of the 3D pointing device in the spatial reference frame;"

837. In my opinion, the CHR-6dm discloses these features. As I described above, the

CHR-6dm discloses a "3D pointing device." *See* Section XIV.B.1.a. The CHR-6dm sensor ("3D pointing device") includes an on-board accelerometer. CHR-6dm Datasheet at 1. The accelerometers measure the accelerations ("first signal set") associated with the movements and rotations of the orientation sensor. *Id.* at 1, 7–8, 13, 38; chr6dm_states.c.

838. These measured accelerations are "associated with movements and rotations of the 3D pointing device in the spatial reference frame."

839. As I described above, the CHR-6dm defines two frames of reference: (i) the body frame of the sensor; and (ii) the North-East-Down inertial frame. CHR-6dm Datasheet at 9, 12, 36.

840. As I described in Section VIII, I understand that the parties have agreed that the term "spatial pointer reference frame" should be construed as a "frame of reference associated with the 3D pointing device, which always has its origin at the same point in the device and in which the axes are always fixed with respect to the device."

841. A POSA would further understand the CHR-6dm's body frame to be a "spatial pointer reference frame" as construed by both parties. Specifically, a POSA would understand that both the CHR-6dm's body frame and the spatial pointer reference frame are frames of reference defined by an origin within or on the surface of body of the device with fixed axes extending from that origin around which the device rotates.

842. A POSA would understand that the accelerations measured by the CHR-6dm's accelerometer are "associated with said movements and rotations" of the CHR-6dm sensor ("3D pointing device") in the "spatial pointer reference frame." Specifically, the accelerometers are "aligned to the body frame of the device." A POSA would understand that the accelerometers measure accelerations in this body frame (i.e., the "spatial pointer reference frame"). *Id.* at 13.

d. [Element 978.10.3] "generating a second signal set associated with Earth's magnetism;"

843. In my opinion, the CHR-6dm discloses these features. The CHR-6dm includes on-board magnetic sensors. The magnetic sensors take readings associated with Earth. *Id.* at 1, 35; chr6dm_states.c.

844. A POSA would understand that a magnetometer provides data regarding the position of a device with which it is associated based on measurements of the Earth' magnetic field. Accordingly, a POSA would understand the signal set generated by the magnetometer to be "associated with the Earth's magnetism."

e. [Element 978.10.4] "generating the orientation output based on the first signal set, the second signal set and the rotation output or based on the first signal set and the second signal set;"

845. In my opinion, the CHR-6dm in view of *Abbate* discloses this feature. As I explained in Section XV.B.2, the '978 Patent does not describe the limitation of "generating the orientation output based on the first signal set, the second signal set and the rotation output or based on the first signal set and the second signal set."

846. As I also explained in Section XV.B.2, I understand that CyWee and its experts have claimed that this limitation is met by an Extended Kalman filter or something like an Extended Kalman filter, as allegedly shown in Equations 5–11 of the '978 Patent.

847. I do not agree with CyWee's claims above. However, taking CyWee's own representations as true, this limitation covers an Extended Kalman filter that either combines: (i) accelerations ("first signal set"), magnetic readings ("second signal set") and angular velocities ("rotation output"); or (ii) accelerations ("first signal set"); and (iii) magnetic readings ("second signal set") to obtain an estimated orientation.

848. Accordingly, if CyWee's interpretation is taken as true, the CHR-6dm discloses

these features.

849. Specifically, the CHR-6dm is an orientation sensor that uses an Extended Kalman filter to combine data from onboard accelerometers, gyroscopes, and magnetic sensors to produce yaw, pitch, and roll angle estimates. CHR-6dm Datasheet at 1.

850. The CHR-6dm utilizes a continuous two-step Extended Kalman filter, where "rate gyro measurements are used to drive the prediction step, and the accelerometer and magnetometer are used for drift correction in the update step." *Id.* at 8. In the drift correction, "[o]n average, the accelerometers measure the gravity vector. The EKF 'knows' which way is down by observing the direction of the gravity vector." *Id.* at 9.

851. The basic steps used in the Extended Kalman filter are detailed in the CHR-6dm firmware code. Specifically, in the chr6dm_states.c file, the Extended Kalman filter is executed in the EKF_EstimateStates function (reproduced below):

EKF_EstimateStates Function from CHR-6dm Firmware

```
void EKF_EstimateStates( AHRS_states* estimated_states, RawSensorData* sensor_data)
{
        static int initialized = 0;

        if( !initialized )
        {
//              EKF_InitFromSensors ( estimated_states, sensor_data );
                EKF_Init( estimated_states );
                initialized = 1;
        }

        // Run EKF prediction step
        EKF_Predict( estimated_states, sensor_data );

        // Run EKF update step
        EKF_Update( estimated_states, sensor_data );
}
```

In the above code:

- The EKF_InitFromSensors function uses sensor data to fill an initial state estimate structure;
- The EKF_Predict function uses rate gyros to make a new orientation estimate; and
- The EKF_Update function uses the accelerometers to correct pitch and roll errors and magnetic sensors to correct yaw errors.

852. Accordingly, the Extended Kalman filter uses the rotation output (i.e., the angular velocities) in the EKF_Predict function to generate an estimated orientation and corrects this estimated orientation using the readings from the accelerometer ("first signal set") and magnetometer ("second signal set") in the EKF_Update function.

853. Claim 10 does not recite quaternions. However, to the extent that CyWee argues that the CHR-6dm does not meet this limitation because it does not use quaternion representations of orientation, it would have been obvious to a POSA at the time of the alleged invention to modify the CHR-6dm to use quaternions in view of the teachings of *Abbate*.

854. *Abbate* discloses a real-time inertial motion capture system using inertial measurement units (IMUs) that are used to record and reconstruct human motion. *Abbate* at 255. The IMUs contain: (i) three single-axis angular rate gyroscopes; (ii) one three-axis accelerometer; and (iii) one three-axis magnetometer. *Id.* at 256. The IMUs are placed on fixed key points on the human body. *Id.* The readings from these IMUs are fed into a centralized collection point and the orientations of the key points are calculated using a quaternion-based Extended Kalman filter. *Id.* at 255–256. In this way, the system is able to use "several kinds of sensors" so that the "characteristics of one type of sensor avoid overcoming the limitations of other sensors." *Id.* at 257.

855. Figure 6 of *Abbate* (reproduced here) depicts the sensor-fusion process disclosed in *Abbate*'s quaternion-based Extended Kalman filter. As shown in Figure 6, the Extended Kalman filter weighs the three sources of information from the gyroscopes, accelerometers and magnetometers appropriately in order to provide an accurate estimate of orientation and eliminate noise. *Id.* at Fig. 6, 258. In the Extended Kalman filter, the orientation is first estimated using angular rate velocities. The Extended Kalman filter then implements a two-step correction process in which: (i) acceleration data is used to correct roll and pitch angles and (ii) magnetic field data is used to correct the yaw angle. *Id.*

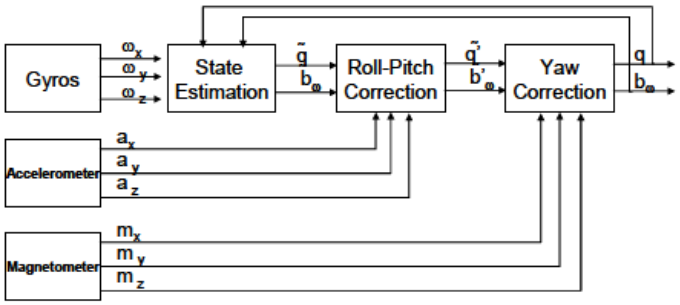


Fig.6. Flow diagram of the implemented quaternion based EKF.

856. Specifically, in *Abbate*, the Kalman filter is initialized with an initial state (i.e., orientation) estimate, and that initial state estimate is combined with the state estimation updated in the prior iteration of the Kalman-filter loop (i.e., the "update[d] state estimation with measurement zk" shown in that figure). *Id.* at Fig. 8. This combined value is depicted as the "state estimation" in Figure 6.

857. As shown in Figure 6, the "state estimation" is modified by angular velocity measurements from the gyroscopes, which generates a quaternion representing the current state of the device. The roll and pitch components of the quaternion representing the device's current state are then further corrected by the measured accelerations (as shown in the "roll-pitch correction" step in Figure 6) to update the state estimation used in that iteration of the Kalman-filter loop. *Id.* at Fig. 6, 258. The yaw component of the quaternion representing the device's current state is then corrected by the measured magnetic readings (as shown in the "yaw

correction" step in Figure 6) to update the state estimation used in that iteration of the Kalman-filter loop. *Id.* at Fig. 6, 258.

858. In view of these teachings of *Abbate*, a POSA would have been motivated to configure the CHR-6dm so that the Extended Kalman filter uses quaternions as disclosed in *Abbate* for computational efficiency and to eliminate the singularity when the pitch is at +/- 90 degrees.

859. As the CHR-6dm Datasheet acknowledges, by using Euler angles, the CHR-6dm "cannot be used to measure orientation if it is expected to approach a pitch angle of +/- 90 degrees. To fix this problem, a quaternion representation must be used instead of Euler Angles." CHR-6dm Datasheet at 9. This same advantage of using quaternions is disclosed in *Abbate*. As *Abbate* discloses, "[q]uaternions are used to represent space orientation in order to improve computational efficiency and avoid singularities [4]." *Abbate* at 258.

860. A POSA would have recognized that such a modification would have been a straightforward combination of known technologies by known methods without changing their respective functions to achieve a predictable result, and would have been well within the capabilities of such a person. Both Euler angle and quaternion representations of orientation are well known in the art.

861. Furthermore, a POSA would have been encouraged to look to *Abbate* to complement the teachings of the CHR-6dm because these references are all directed to the same technical field and describe solutions to similar problems in the field. For example, both the CHR-6dm and *Abbate* disclose calculating orientation using a combination of gyroscopes, accelerometers and magnetometers by using Extended Kalman filters. CHR-6dm Datasheet at 8–9; *Abbate* at 255–258.

f. [Element 978.10.5] "generating a rotation output associated with a rotation of the 3D pointing device associated with three coordinate axes of a spatial reference frame associated with the 3D pointing device; and"

862. In my opinion, the CHR-6dm discloses these features. The '978 Patent states that: "the rotation sensor 342 generates a rotation output (ω_x, ω_y, ω_z) associated with the rotation of the 3D pointing device associated with the three coordinate axes of a spatial reference associated with the 3D pointing device[.]" '978 Patent at 30:57–62. Similarly, it provides that the "rotation output [ω_x, ω_y, ω_z], includes three angular velocities ω_x, ω_y, ω_z respectively associated with the three coordinate axes X_p, Y_p, and Z_p of the spatial reference frame associated with the 3D pointing device." Accordingly, a POSA would understand the "rotation output" to be the measured angular velocities.

863. Consistent with this understanding, the CHR-6dm includes one or more on-board gyroscopes. CHR-6dm Datasheet at 1. The gyroscopes measure the angular velocities associated with the movements and rotations of the orientation sensor. *Id.* at 1, 7–8, 28, 36, 38; chr6dm_states.c.

864. A POSA would understand that these angular velocities are "associated with the three coordinate axes of a spatial reference frame associated with the 3D pointing device." As I described above in Section XIV.B.1.c, a POSA would understand the body frame of the orientation frame to be a "spatial pointer reference frame" as claimed in the '978 Patent. Consistent with this understanding, the CHR-6dm's gyroscope measures "rotation rates in the body frame[.]" *Id.* at 36.

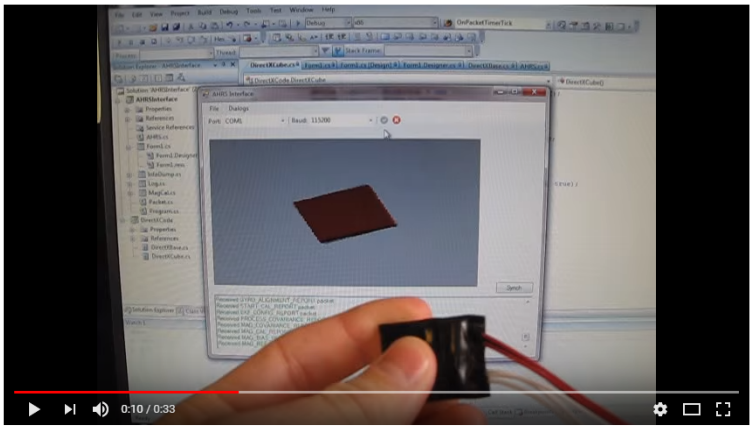
g. [Element 978.10.6] "using the orientation output and the rotation output to generate a transformed output associated with a fixed reference frame associated with a display device, wherein the orientation output and the rotation output is generated by a nine-axis motion sensor module;"

865. In my opinion, the CHR-6dm discloses these features. In my opinion, a POSA would understand that this limitation refers to calculating a change in the orientation of a device and then "mapping" this change onto a display.

866. As I described in Sections XIV.B.1.b and XIV.B.1.f, the CHR-6dm discloses generating a rotation output (i.e., measured angular velocities). The CHR-6dm in view of *Abbate* further discloses generating an orientation output based on the rotation output (under CyWee's interpretation of this limitation).

867. The orientation output and rotation output is "generated by a nine-axis motion sensor module." The CHR-6dm is an orientation sensor implemented on a printed circuit board. The CHR-6dm sensor is composed of on-board gyroscopes, accelerometers and magnetometers that are physically attached to the printed circuit board. CHR-6dm Datasheet at 1.

868. A POSA would understand that the orientation output could be used to generate a transformed output that is "associated with a fixed reference frame associated with a display device." As shown in the "CHR6dm Orientation Sensor from CH Robotics" video (screenshot reproduced below), the sensor can be implemented as a handheld device that calculates its own orientation which is translated directly onto a display. Any changes in the rotational movement of the sensor are reflected on the screen.



h. [Element 978.10.7] "obtaining one or more resultant deviation including a plurality of deviation angles using a plurality of measured magnetisms M_x, M_y, M_z and a plurality of predicted magnetism M_x', M_y' and M_z' for the second signal set."

869. In my opinion, the CHR-6dm in view of *Yang* discloses these features. As I described in Section XV.B.2, the '978 Patent does not describe the limitation of "obtaining one or more resultant deviation including a plurality of deviation angles using a plurality of measured magnetisms M_x, M_y, M_z and a plurality of predicted magnetism M_x', M_y' and M_z' for the second signal set."

870. In my opinion, a POSA would understand that this limitation could refer broadly to obtaining the change in a device's orientation using two sets of magnetism values.[2]

871. In my opinion, the CHR-6dm discloses these features. As I described above, the CHR-6dm is an orientation sensor that uses an Extended Kalman filter to combine data from onboard accelerometers, gyroscopes, and magnetic sensors to calculate deviation angles (i.e.

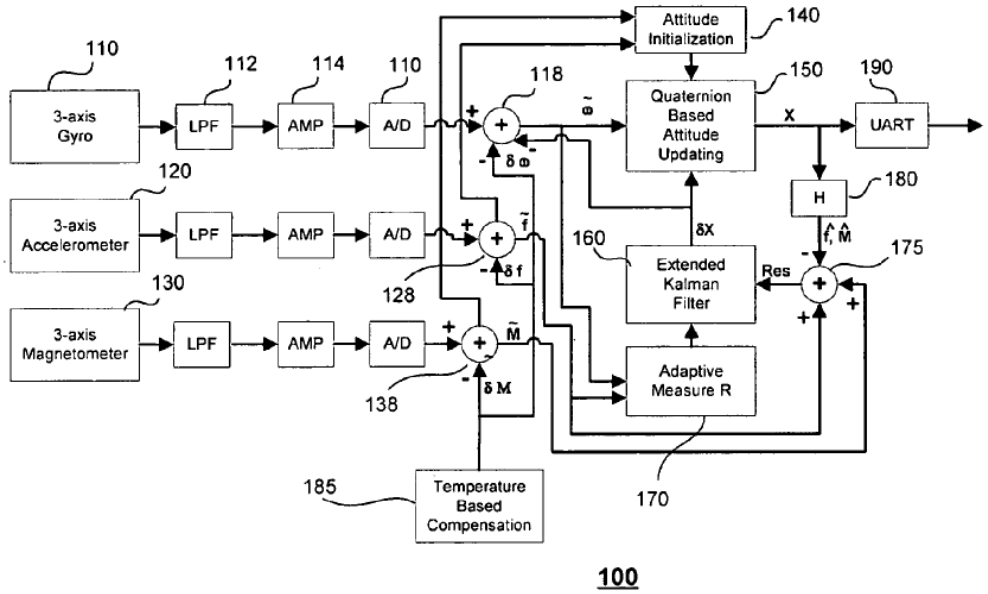
[2] I understand that the '978 Patent discloses that a "predicted magnetism" is calculated by Equations 18-20, which I understand are intended to correct the orientation of the user's Earth frame so that this frame's x-axis points exactly to the North horizon. Even if this correction could be construed as a "predicted" magnetism, the concept of correcting the actual magnetometer measurements for the dip angle was well known in the art since the 1500s.

yaw, pitch, and roll angle estimates). CHR-6dm Datasheet at 1. In the second step, the EKF_Update function uses the magnetic sensors to correct yaw errors.

872. Although the CHR-6dm does not explicitly disclose the use of "predicted magnetisms," it would have been obvious to a POSA at the time of the alleged invention to modify the Extended Kalman filter used the CHR-6dm to implement such a feature in view of the teachings of *Yang*.

873. *Yang* discloses a system that provides an error estimate for an initial attitude (i.e., orientation) using an Extended Kalman filter. The Extended Kalman filter is adaptable based on whether the device is undergoing acceleration. *Yang* at Abstract. The estimated error obtained by the Extended Kalman filter may be used to update the initial orientation calculation. *Id.* ¶¶ 18–19, 39, 107, 112. Specifically, the estimated error, which *Yang* discloses as the residual value, consists of the differences between a measured acceleration and predicted acceleration and a measured heading (i.e., measured magnetisms) and predicted heading (i.e., predicted magnetisms). *Id.* at Fig. 5, ¶¶ 111, 119–121. The basic mechanisms of the system are based on the principles of a Strapdown Inertial Navigation System. *Id.* ¶¶ 13, 30.

874. As shown in Figure 1 of *Yang* (reproduced below), *Yang* discloses a device composed of (among other components): (i) a three-axis gyroscope (110); (ii) a three-axis accelerometer (120); (iii) a three-axis magnetometer (130); and (iv) an Extended Kalman filter (160).



875. As shown in Figure 4 of *Yang* (reproduced below), *Yang* discloses a method by which data from the sensors (gyroscopes, accelerometers, and magnetometers) is measured and then filtered. *Id.* at Fig. 4, ¶¶ 116–117. The Extended Kalman filter is then adapted based on the current acceleration mode. *Id.* at Fig. 4, ¶ 117. Once the Kalman filter is adapted based on the current acceleration mode, it estimates "attitude error and gyro bias" as shown in step 440 of Figure 4. *Id.* ¶ 117. A correction is applied using this error and the corrected orientation is then output. *Id.* ¶ 118.

876. Figure 5 of *Yang* (also reproduced below) depicts the Kalman filtering step disclosed in step 440 of Figure 4 in more detail. The Extended Kalman filter is first initialized with an initial error estimate. *Id.* at Fig. 5, ¶ 119. The attitude update module is used to generate an updated attitude. *Id.* at Fig. 5, ¶ 120. The updated attitude is then used to "produce a predicted acceleration and heading (f and M) and determine a residual (Res)." *Id. Yang* discloses that this attitude update is performed using quaternions for calculation efficiency. *Id.* at Figs. 4, 5, 6, ¶¶ 19, 26, 39–45, 107, 112, 118, 120, 122–124.

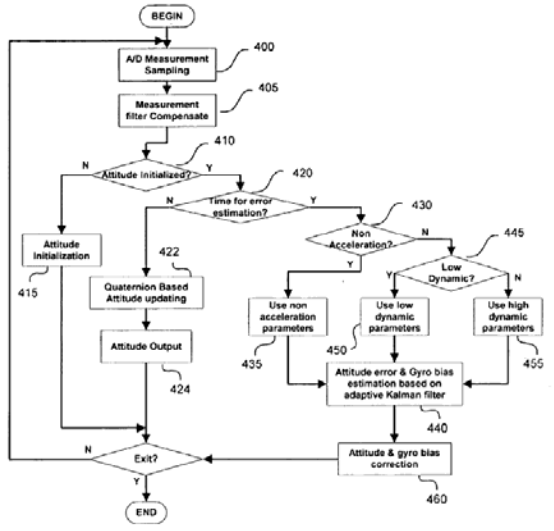
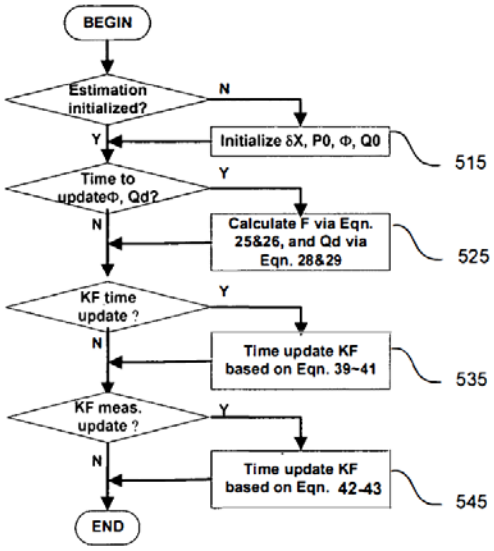
Figure 4 of *Yang*	Figure 5 of *Yang*
	

FIG. 4

877. The residual value (Res) consists of the differences between a measured and a predicted acceleration and a measured and a predicted heading and is used to determine the Kalman filter's error estimates. *Id.* at Fig. 5, ¶¶ 111, 119–121. The measured and predicted axial accelerations are used to update the Kalman filter's error estimate. This error estimate can be used as a correction value to update the orientation. *Id.* at Figs. 4, 5, 6, ¶¶ 116–130.

878. *Yang* explicitly discloses the use of a predicted magnetism value. Specifically, *Yang* discloses:

> The Kalman Filter 160 operates on a residual value (Res) that is a difference between a measured f^ and M^ and a predicted f^ and M^. The measured f^ and M^ are the measured acceleration (e.g., accelerometer reading) and measured heading (e.g., magnetometer reading) respectively. The predicted f^ and M^ comprise the predicted acceleration f^ and the **predicted heading M^** are predictions based on, for example, a model (H) of a current updated attitude X. **The model H, for example, looks at current accelerations, current attitude and heading, etc., and determines the predicted values.**

Yang ¶ 111 (emphasis added); Equation 35.

879. Accordingly, in my opinion, *Yang* discloses using "predicted" and "measured"

magnetisms as inputs into an Extended Kalman filter to calculate an error value that is used to update an initial orientation.

880. In view of these teachings of *Yang*, a POSA would have been motivated to configure the CHR-6dm so that the Extended Kalman filter uses the techniques in *Yang* to obtain a more accurate estimate of the Extended Kalman filter's error.

881. A POSA would have recognized that such a modification would have been a straightforward combination of known technologies by known methods without changing their respective functions to achieve a predictable result, and would have been well within the capabilities of such a person.

882. Furthermore, a POSA would have been encouraged to look to *Yang* to complement the teachings of the CHR-6dm because these references are all directed to the same technical field and describe solutions to similar problems in the field. For example, both the CHR-6dm and *Yang* disclose calculating orientation using a combination of gyroscopes, accelerometers and magnetometers by using Extended Kalman filters. CHR-6dm Datasheet at 8–9; *Yang* ¶¶ 108–129.

2. Claim 12

a. [Element 978.12] "The method of claim 10, wherein the orientation output is a rotation matrix, a quaternion, a rotation vector, or comprises three orientation angles."

883. In my opinion, the CHR-6dm in view of *Abbate* and *Yang* discloses this limitation. As I described above, the CHR-6dm produces an "orientation output" in the form of three orientation angles (i.e., the yaw, pitch, and roll angle estimates). CHR-6dm Datasheet at 1.

884. *Abbate* discloses generating the "orientation output" in quaternion format. *Abbate* at 258. Similarly, *Yang* discloses representing orientation using Euler angles, a rotation matrix, and quaternions. *Yang* ¶ 11–12. A POSA would understand that all of these methods are

commonly understood ways of representing orientation.

XV. INVALIDITY UNDER 35 U.S.C. §112

A. The ’438 Patent

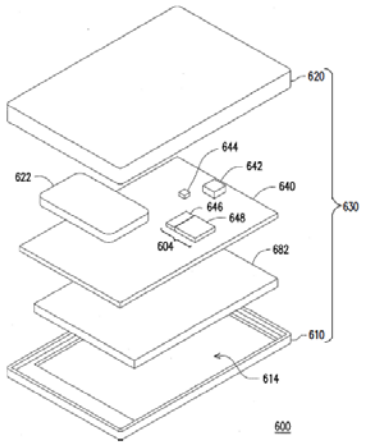
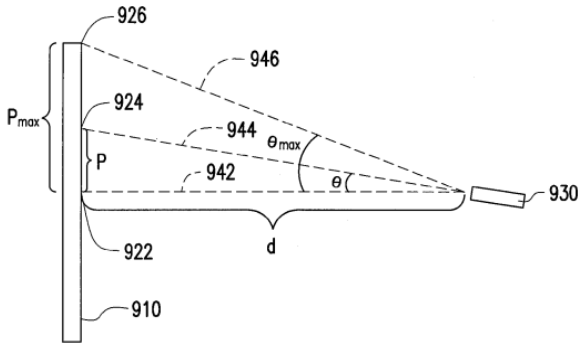
1. “3D pointing device” where the display is incorporated into the device (’438 Patent, Claims 1, 3, 4, 5, 14, 15, 16, 17, 19)

885. Claims 1, 3, 4, 5, 14, 15, 16, 17, and 19 of the ’438 Patent recite a “3D pointing device.” I understand that the term has been construed to have its plain and ordinary meaning. I further understand that based on Judge Bryson’s Order, a 3D pointing device is not required to control a “cursor or pointer on a display,” but may indicate movement of the device on the display in other ways such as displaying “some video effect on the display screen” or exhibiting a “movement pattern on the display screen.” Dkt. No. 153 at 2.

886. The only embodiment disclosed in the ’438 Patent of a 3D pointing device with an integrated display is in Figure 6 (reproduced below). In reference to Figure 6, the ’438 Patent states that: “the 3D pointing device 600 may further comprise a built-in display 682. In other words, the abovementioned display reference frame associated with a display may need not to be external to the spatial pointer reference frame in terms of the hardware configuration of the present invention.”’438 Patent at 10:11–16.

887. However, the ’438 Patent does not describe **how** the 3D pointing device performs a pointing function to indicate the movement of the device on a display when the display itself is integrated on the device. More basically, it is unclear from the ’438 Patent how a 3D pointing device “points” to a display that is on the device itself.

888. This lack of disclosure is further compounded when comparing Figure 6 with the other embodiments disclosed in the ’438 Patent of a 3D pointing device (such as Figure 9 of the ’438 Patent (reproduced below)).

Figure 6 of the ’438 Patent	Figure 9 of the ’438 Patent
 FIG. 6	 FIG. 9

889. Figure 9 also depicts a 3D pointing device (930). In this embodiment, the 3D pointing device points to a target point (924) of a display device. The ’438 Patent discloses that the “target point 924 is the position that the 3D pointing device 930 is pointing to.” *Id.* at Fig. 9, 16:18–44.

890. Despite this explicit disclosure of how “pointing” is done in the embodiment shown in Figure 9, there is no corresponding disclosure in the ’438 Patent as to how pointing is done in a 3D pointing device with an integrated display (such as Figure 6).

891. Instead, the ’438 Patent specification merely states that:

> The computing processor 648 of the processing and transmitting module 604 may too perform the mapping of resultant deviation from or in said spatial reference frame or 3D reference frame to a display reference frame such as a 2D reference frame by translating the resultant angles of the resulting deviation of the 3D pointing device 600 in the spatial pointer reference frame, preferably about each of three orthogonal coordinate axes of the spatial pointer reference frame to a movement pattern in a display reference frame associated with the 3D pointing device 600 itself. The display 682 displays the aforementioned movement pattern. The top cover 610 includes a transparent area 614 for the user to see the display 682.

Id. at 10:29–30.

892. This disclosure fails to answer even basic questions regarding how the mapping is accomplished (or even possible) with an integrated display, how this translates into a "movement pattern", what "movement pattern" is displayed or even what the "movement pattern" is.

893. For at least the above mentioned reasons, in my opinion, a POSA would not have reasonably concluded from the '438 Patent that the inventors had possession of the claimed "3D pointing device" where the display is incorporated into the device and that meets the remaining claim limitations. In addition, the disclosures of the '438 Patent are insufficient to enable a POSA as of the time the patent was filed to make or use a 3D pointing device with a display incorporated into the device and that meets the remaining claim limitations.

2. "utilizing a comparison to compare the first signal set with the second signal set" ('438 Patent, Claim 1)

894. Claim 1 of the '438 Patent recites "utilizing a comparison to compare the first signal set with the second signal set."

895. Claim 1 further recites that the "first signal set" comprises "angular velocities ω_x, ω_y, ω_z associated with said movements and rotations of the 3D pointing device in the spatial pointer reference frame." Claim 1 recites that this first signal set is detected and generated by a rotation sensor.

896. Claim 1 recites that the "second signal set" comprises "axial accelerations Ax, Ay, Az associated with said movements and rotations of the 3D pointing device in the spatial pointer reference frame." Claim 1 recites that this second signal set is detected and generated by an accelerometer.

897. Claim 1 therefore recites a comparison between angular velocities and axial accelerations.

898. The angular velocity of a moving object measures the time rate of change of the

angular position of a rotating body, usually expressed in radians per second.

899. I understand that CyWee has alleged that an "axial acceleration" is the acceleration reading obtained by an accelerometer. An accelerometer reports four possible values: (i) linear accelerations; (ii) gravitational accelerations; (iii) centrifugal accelerations; or (iv) the sum of a combination of any of these accelerations..

900. Accordingly, there are four possible interpretations of this comparison: (i) a comparison between measured angular velocities and linear accelerations; (ii) a comparison between measured angular velocities and gravitational accelerations; (iii) a comparison between measured angular velocities and centrifugal accelerations; and (iv) a comparison between measured angular velocities and some combination of linear, gravitational and centrifugal accelerations.

901. However, the comparison of an object's angular velocity with any of these possible interpretations of an axial acceleration is impossible or would at most result in a meaningless comparison.

902. This is because an object's angular velocity and the accelerations that are read from an accelerometer (the "axial accelerations") either: (i) measure fundamentally different values or (ii) would require additional data that is not known and which the '438 Patent does not disclose how to obtain.

903. First, linear and gravitational accelerations measure fundamentally different values than angular velocities. Linear acceleration measures the rate of change of linear velocity with respect to time. Linear velocity is the rate of change of the position of an object traveling along a straight path. Gravitational acceleration measures the acceleration of an object caused by gravitational force.

904. Accordingly: (i) the angular velocity of an object; (ii) the linear acceleration of that same object; and (iii) gravitational accelerations experienced by that object are mutually independent values. In other words, an object's linear and gravitational accelerations do not provide any independent information about any centrifugal acceleration experienced due to the object's rotation.

905. For example, an accelerometer and gyroscope could be mounted on a ball. If the ball is spun on a string around a center of rotation by a person who is riding on a train in linear motion that is on a non-spherical section of the Earth's surface, there are three independent component accelerations that are combined to produce one value expressed by the accelerometer mounted on the ball.

906. The measurement of the angular velocity of the ball, however, provides no information on the component values of linear acceleration (movement on train) or gravitational acceleration (gravitational force based on position in non-spherical section of the Earth's surface), or vice versa.

907. Second, although the magnitude of the centrifugal acceleration is a function of the object's angular velocity, the centrifugal acceleration also depends on the radius of the motion's curved path.

908. Thus, even in the simplest case of circular rotation, in order to relate an instantaneous centrifugal force to a corresponding instantaneous angular velocity, the instantaneous radius of rotation must be known. The specifications of the patents-in-suit never discuss this problem or propose a solution for it.

909. The '438 Patent neither considers nor discusses the radius of rotation associated with an angular velocity or centrifugal acceleration, how to find it, or how to use it in relating

angular motion to measured centrifugal acceleration.

910. Further, except for rotation induced by a single rigid body, this curvature in general is variable and the rotational motions may be compound—each with a different radius of curvature. For example, as a pitcher delivers a pitch, the change of the angle between his forearm and upper arm (as allowed by his elbow) changes the radius of rotation of the ball being thrown. A second additional rotational motion (and the associated accelerations) will be imparted by the wrist.

911. The ’438 Patent neither considers nor discusses how to deal with such compound rotational movements.

912. Accordingly, a POSA would not have been able to determine the centrifugal acceleration of a device in rotational motion based upon the disclosure in the ’438 Patent.

913. To further compound this deficiency, Claim 1 recites that the comparison is used to calculate resultant “deviation angles.” However, the ’438 Patent specification does not describe how the comparison between angular velocities and axial accelerations somehow results in an output of deviation angles.

914. I understand that CyWee has asserted that the “utilizing a comparison” limitation recites an “indirect comparison” in which quaternions are used to convert the angular velocities and axial accelerations into a “common state.” I understand that CyWee bases this assertion on the ’438 Patent specification’s disclosure that the term “comparison” refers to “calculating and obtaining [] the actual deviation angles of the 3D pointing device 110 with respect to the first reference frame or spatial pointing frame utilizing signals generated by motion sensors while reducing or eliminating noises associated with said motion sensors.” ’438 Patent at 2:26–32.

915. I also understand that CyWee has asserted that a POSA would have understood

this indirect comparison to occur in an Extended Kalman filter (or something like an Extended Kalman filter) which CyWee alleges is set forth in the patents-in-suit in Equations 5–11.

916. In my opinion, a POSA would not have understood the '438 Patent to describe any sort of comparison of angular velocities and axial accelerations, including an "indirect comparison," in Equations 5–11 (or anywhere else in the patents-in-suit).

917. Specifically, the '438 Patent does not provide a disclosure of Equations 5–11 that would have informed a POSA as to what the purpose of the equations are and how they are to be used to accomplish this indirect comparison.

918. As just one problem, Equations 5–11 comprise numerous undefined functions. For example, as shown below, Equations 5–11 recite functions *f* and *h*, which are defined only by the variables that are input into these functions. The patents-in-suit do not explain what these functions are, what their output is, or how they work.

Equation 5	$x(t\|t-1)=f(x_{t-1},u_t)$
Equations 6–7	$P(x_t \mid x_{t-1}, u_t) = F_x P(x_{t-1} \mid x_{t-1}) F_x^T + F_u P(u_{t-1} \mid u_{t-1}) F_u^T + Q_t$ $F_x = \frac{\partial f(x_{t-1}, u_t)}{\partial x_{t-1}} \qquad F_u = \frac{\partial f(x_{t-1}, u_t)}{\partial u_t}$
Equation 8	$z_t(t\|t-1)=h(x(t\|t-1))$
Equation 9–10	$P(z_t \mid x_t) = H_x P(x_t \mid x_{t-1}) H_x^T + R_t$ $H_x = \frac{\partial h(x(t \mid t-1))}{\partial x(t \mid t-1)}$
Equation 11	$D_t=\{[z_t-h(z(t\|t-1))]P(z_t\|x_t)[z_t-h(x(t\|t-1))]^{-1}\}^{1/2}$

919. As shown below, this problem is further compounded because equations *f* and *h* are then inputs as variables into functions *H* and *F*, which are themselves undefined and ambiguous, and then also contain undefined functions *f* and *h* as variables.

Equation 5	$x(t\|t-1)=f(x_{t-1},u_t)$
Equations 6–7	$P(x_t \mid x_{t-1}, u_t) = F_x P(x_{t-1} \mid x_{t-1}) F_x^T + F_u P(u_{t-1} \mid u_{t-1}) F_u^T + Q_t$ $F_x = \frac{\partial f(x_{t-1}, u_t)}{\partial x_{t-1}} \qquad F_u = \frac{\partial f(x_{t-1}, u_t)}{\partial u_t}$
Equation 8	$z_t(t\|t-1)=h(x(t\|t-1))$
Equation 9–10	$P(z_t \mid x_t) = H_x P(x_t \mid x_{t-1}) H_x^T + R_t$ $H_x = \frac{\partial h(x(t \mid t-1))}{\partial x(t \mid t-1)}$
Equation 11	$D_t=\{[z_t-h(z(t\|t-1))]P(z_t\|x_t)[z_t-h(x(t\|t-1))]^{-1}\}^{1/2}$

920. The equations also contain numerous undefined variables, including Q_t, which the '438 Patent describes only as "additional motion noise" ('438 Patent at 13:56, 65) and R_t which the '438 Patent describes only as "measurement noise." '438 Patent at 14:11, 16. The '438 Patent provides no description of how these values are obtained.

Equation 5	$x(t\|t-1)=f(x_{t-1},u_t)$
Equations 6–7	$P(x_t \mid x_{t-1}, u_t) = F_x P(x_{t-1} \mid x_{t-1}) F_x^T + F_u P(u_{t-1} \mid u_{t-1}) F_u^T + Q_t$ $F_x = \frac{\partial f(x_{t-1}, u_t)}{\partial x_{t-1}} \qquad F_u = \frac{\partial f(x_{t-1}, u_t)}{\partial u_t}$
Equation 8	$z_t(t\|t-1)=h(x(t\|t-1))$
Equation 9–10	$P(z_t \mid x_t) = H_x P(x_t \mid x_{t-1}) H_x^T + R_t$ $H_x = \frac{\partial h(x(t \mid t-1))}{\partial x(t \mid t-1)}$
Equation 11	$D_t=\{[z_t-h(z(t\|t-1))]P(z_t\|x_t)[z_t-h(x(t\|t-1))]^{-1}\}^{1/2}$

921. Second, a POSA would have understood (for many of the reasons already described), that conversion into a common state followed by a comparison is not described by the '438 Patent, is not possible, and that any such "conversion" would only result in a meaningless value.

922. For example, if the axial accelerations encompasses linear accelerations (which it

would under CyWee's interpretation), as explained above, converting the linear accelerations into a common state with an angular velocity is mathematically impossible.

923. If the axial accelerations encompass gravitational accelerations (which again they would under CyWee's interpretation), converting the gravitational accelerations into a common state with the angular velocities is also impossible. Gravitational accelerations and angular velocities measure fundamentally different independent physical effects that are experienced by a body in motion (rotation versus gravitational force), but they both are included by summation to produce the single value of acceleration reported by an accelerometer.

924. Finally, if the axial accelerations encompass centrifugal accelerations (which they would under CyWee's interpretation), even for the simple case of rigid body motion, as explained above, converting centrifugal accelerations into a common state with the angular velocities for comparison is impossible without knowing the value of the radius of curvature of the object's motion. Nowhere does the '438 Patent disclose how this would be done.

925. The problems described above are not resolved just by reliance on the use of quaternions or Equations 5–11. A POSA would have understood that a quaternion is simply one of many algebraic systems for performing the required calculations. Accordingly, the fact that any of the above values are in a quaternion-based calculation does not remedy the fact that it is: (i) mathematically impossible to perform the comparison as required by the '438 Patent (i.e., to compare a quaternion representing the object's angular rotation with its linear acceleration); (ii) mathematically impossible to partition out values where their sum is reported by an accelerometer; and (iii) mathematically impossible to process a quaternion representing the object's angular velocity in order to determine the expected corresponding centrifugal acceleration (because determining the radius of rotation is neither taught in the '438 Patent

specification nor realistic in the real-world case of human-induced rotation).

926. For at least the above mentioned reasons, in my opinion, a POSA would not have reasonably concluded from the ’438 Patent that the inventors had possession of an invention which could utilize a comparison to compare axial accelerations with angular velocities. In addition, the disclosures of the ’438 Patent are insufficient to enable a POSA as of the time the patent was filed to utilize a comparison to compare axial accelerations with angular velocities. In my opinion, this is because the claimed comparison is impossible, regardless of whether the comparison is a direct or indirect one. At most, any such comparison would produce a meaningless result, thereby rendering the claimed invention inoperable.

3. “comparing the second quaternion in relation to the measured angular velocities ω_x, ω_y, ω_z of the current state at current time T with the measured axial accelerations Ax, Ay, Az and the predicted axial accelerations Ax′, Ay′, Az′ also at current time T”

927. Claims 14 and 19 of the ’438 Patent recite “comparing the second quaternion in relation to the measured angular velocities ω_x, ω_y, ω_z of the current state at current time T with the measured axial accelerations Ax, Ay, Az and the predicted axial accelerations Ax′, Ay′, Az′ also at current time T.”

928. This limitation in Claims 14 and 19 is substantively identical to the “utilizing a comparison” limitation described above in Claim 1 of the ’438 Patent.

929. As stated above in Section XV.A.2, a POSA would not have reasonably concluded from the ’438 Patent that the inventors had possession of an invention capable of performing this comparison. In addition, the disclosures of the ’438 Patent specification are insufficient to enable a POSA as of the time the patent was filed to perform this comparison, as any such comparison would at most produce a meaningless result.

930. Specifically, a POSA would have understood that this would require the

impossible comparison of: (i) units that measure fundamentally different attributes of an object (i.e., comparing linear or gravitational accelerations with angular velocities); or (ii) units with undefined variables (i.e., comparing a centrifugal acceleration with an undefined radius with angular velocities).

931. The fact that claims 14 and 19 recite a "second **quaternion** in relation to the measured angular velocities" does not change my analysis.

932. As also stated above in Section XV.A.2, a quaternion is just a mathematical notation and does not remedy the fact that it is: (i) mathematically impossible to compare a quaternion representing the object's angular rotation with its linear acceleration; (ii) mathematically impossible to compare a quaternion representing the object's angular rotation with its gravitational acceleration; (iii) mathematically impossible to compare a quaternion representing the object's angular rotation with its centrifugal acceleration; (iv) mathematically impossible to do any of these comparisons while also performing a comparison with the "predicted axial accelerations."

933. I understand that CyWee's assertions as to how this limitation operates is substantively identical to its assertions regarding the "utilizing a comparison" limitation described above, including that this limitation is disclosed in Equations 5–11. I disagree for the same reasons described above in Section XV.A.2.

4. "obtaining an updated state of the six-axis motion sensor module by comparing the current state with the measured state of the six axis motion sensor module" ('438 Patent, Claims 14 and 19)

934. Claims 14 and 19 recite obtaining an "updated state" of the six-axis motion sensor module by comparing the "current state" with the "measured state."

935. The claims recite that: (i) the "current state" is obtained by "obtaining measured angular velocities ω_x, ω_y, ω_z" at current time T; and (ii) the "measured state" is obtained by

"obtaining measured axial accelerations Ax, Ay, Az" at current time T and calculating "predicted axial accelerations" also at current time T.

936. Based on the claim language, the "updated state" is therefore obtained by comparing: (i) a current state obtained from measured angular velocities with (ii) a measured state obtained from measured axial accelerations and predicted axial accelerations.

937. As an initial matter, it is unclear if this step of "obtaining an updated state" by comparing the "current state" with the "measured state" is different from the preceding one of "comparing the second quaternion in relation to the measured angular velocities ωx, ωy, ωz of the current state at current time T with the measured axial accelerations Ax, Ay, Az and the predicted axial accelerations Ax′, Ay′, Az′ also at current time T[.]" If this step is different, it is unclear how it is different.

938. As stated above in Sections XV.A.2 and XV.A.3, the '438 Patent does not describe how to perform this comparison, Further, any such comparison would at most produce a meaningless result. Specifically, a POSA would have understood that this would require the impossible comparison of: (i) units that measure fundamentally different attributes of an object (i.e., comparing linear or gravitational accelerations with angular velocities); or (ii) units with undefined variables (i.e., comparing a centrifugal acceleration with an undefined radius with angular velocities).

939. Indeed, the only disclosure in the '438 Patent specification regarding how to obtain the "current state", "measured state" and "updated state" is in Equations 5–11. Specifically, the '438 Patent states that the current state may be obtained from Equation 5, the "measured state" may be obtained from Equation 8, and the "updated state" may be obtained from Equation 11.'438 Patent at 13:44–51; 13:65–14:8; 14:16–21.

940. As I describe above in Section XV.A.2 however, Equations 5, 8, and 11 (reproduced below) contain numerous undefined functions (as examples, *f* and *h*, highlighted below).

Equation 5	$x(t\|t-1)=f(x_{t-1},u_t)$
Equation 8	$z_t(t\|t-1)=h(x(t\|t-1))$
Equation 11	$D_t=\{[z_t-h(z(t\|t-1))]P(z_t\|x_t)[z_t-h(x(t\|t-1))]^{-1}\}^{1/2}$

941. Additionally, apart from the numerous undefined functions, which makes it impossible to determine how the equations operate, it would also be unclear to a POSA:

- How Equation 5 recites obtaining a "current state" from angular velocities, when the equation does not appear to use angular velocities in anyway;
- How Equation 8 recites obtaining a "measured state" from measured axial accelerations and predicted axial accelerations when the equation does not appear to use either axial accelerations or predicted axial accelerations in anyway; and
- How Equation 11 recites a comparison between the "states" obtained from Equations 5 and 8.

942. Accordingly, in my opinion, a POSA would not have reasonably concluded from the '438 Patent that the inventors had possession of an invention capable of obtaining an updated state by comparing a current state with a measured state. In addition, the disclosures of the '438 Patent specification would have been insufficient to enable a POSA as of the time the patent was filed to obtain an updated state by comparing a current state with a measured state.

5. "a predicted measurement obtained based on the first signal set without using any derivatives of the first signal set" ('438 Patent, Claim 1)

943. Claim 1 of the '438 Patent recites obtaining a "predicted measurement" based on

the "first signal set without using any derivatives of the first signal set."

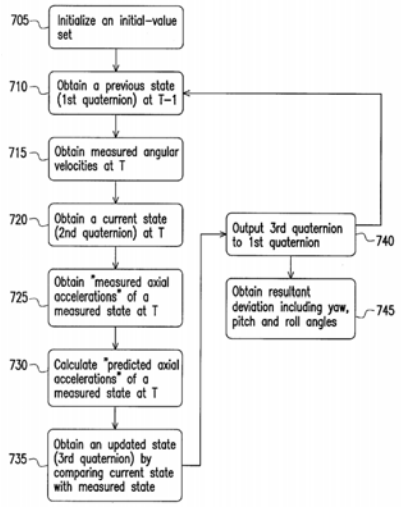
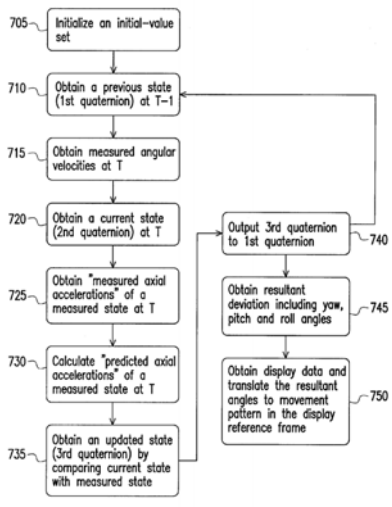
944. As noted above, I understand that the parties have agreed that this predicted measurement comprises "predicted axial accelerations calculated using the angular velocities without computing derivatives of said angular velocities (i.e. angular accelerations)." *See* Section VIII.

945. Claim 1 of the '438 Patent recites a limitation for "predicting" an "axial acceleration" without computing the derivative of an angular velocity. Fundamentally, this is the key concept that the '438 Patent was allowed on during examination. *See* Section IX.A.2.

946. In my opinion however, the '438 Patent does not describe how to predict axial accelerations using any method (including but not limited to a method that is performed without computing the derivatives of an angular velocity).

947. There is no disclosure in the '438 Patent on how to calculate a "predicted" axial acceleration. Instead, the '438 Patent states only that two sets of axial accelerations ore obtained: (i) measured axial accelerations; and (ii) predicted axial accelerations. '438 Patent at 13:5–13 ("In other words, two sets of axial accelerations may be obtained for the measured state of the six-axis motion sensor module; one may be the measured axial accelerations Ax, Ay, As [*sic*] in step 725 and the other may be the predicted axial accelerations Ax′, Ay′, Az′ in step 730 calculated based on the abovementioned current state or second quaternion in relation to the measured angular velocities thereof.")

948. Although the '438 Patent refers to the patent figures, Figures 7 and 8 of the '438 Patent (reproduced below) similarly only discloses the steps of calculating predicted axial accelerations of a measured state at T without any further explanation.

Figure 7 of the ’438 Patent	Figure 8 of the ’438 Patent
 FIG. 7	 FIG. 8

949. Indeed, I understand that CyWee and its experts have taken inconsistent positions on what this limitation has meant at different points in time.

950. First, in its Opening Claim Construction Brief, CyWee alleged that this limitation meant that the “[t]he second quaternion is used to generate predicted axial accelerations (predicted state), which are compared to the measured accelerations (measured state or second signal set),” citing to the declaration of its expert, Dr. LaViola. CyWee’s Opening Claim Construction Brief, Dkt. No. 66 at 9; LaViola Decl. ¶ 21. CyWee provided no other support for this allegation or other explanation for what it means for the “predicted axial accelerations” to be a “predicted state” or how to obtain this “predicted state” without using the derivatives of the measured angular velocities.

951. Second, and even more confusingly, in his deposition, Dr. LaViola testified that Equations 2–4 (reproduced below) disclose calculating predicted axial accelerations. LaViola Dep. Tr. at 15:21–58:12. However, this testimony directly conflicts with the ’438 Patent specification, which states that these equations merely convert the measured axial accelerations

into a quaternion.

952. Specifically, the ’438 Patent states:

> Furthermore, in one embodiment, the computing processor may use a data conversion utility to convert the measured axial accelerations Ax, Ay and Az into a quaternion. This data conversion utility may be a software program represented by the following equations (2), (3) and (4).
>
> $$Ax=2(q_1q_3-q_0q_2)$$
>
> $$Ay=2(q_2q_3+q_0q_1)$$
>
> $$Az=q_0^2-q_1^2-q_2^2+q_3^2$$
>
> The computing processor calculates the solution (q0, q1, q2, q3) of the equations (2), (3) and (4).

’438 Patent at 13:13–25.

953. Indeed, although the ’438 Patent defines the predicted axial accelerations as variables Ax′, Ay′, and Az′, these variables appear nowhere in Equations 2–4 or any other equation in the ’438 Patent. As such, in my opinion, these equations do not disclose how to calculate “predicted axial accelerations” but merely how to convert the measured axial accelerations into a quaternion format. In addition, the method for solving for the values q_0, q_1, q_2, and q_3 is never explained. The only information provided is that a “computing processor calculates the solution.” *Id.* at 13:23–24. The structure, implementation, or code used by the computing processor is not given.

954. To make things even more unclear, CyWee then alleged that the “predicted axial accelerations” are the axial accelerations that stem solely from gravity. Dkt. Nos. 71 at 4, 84-1 at 30. The ’438 Patent does not disclose that the “predicted axial accelerations” are gravitational accelerations. For example, Claim 14 requires “calculating predicted axial accelerations Ax′, Ay′, Az′ based on the measured angular velocities ωx, ωy, ωz of the current state of the six-axis

motion sensor module." Based on CyWee's allegations, it is unclear what the relationship would be between the gravitational accelerations and the measured angular velocities. Further, the '438 Patent does not describe how to obtain gravitational accelerations in any way, including without using the derivatives of the measured angular velocities.

955. In addition, because measured acceleration components are combined to produce the output from an accelerometer, the only method to obtain values for an individual acceleration component (like gravity) is to place the object in a controlled environment which ensures that the accelerometer is experiencing only gravitational acceleration during the gravity measurement. Under such restricted conditions, individual acceleration components may remain constant over time, but the specifications of the patents-in-suit neither teach nor contemplate this restricted situation.

956. fIn my opinion, a POSA would not have reasonably concluded from the '438 Patent that the inventors had possession of an invention where the claimed predicted measurement could be obtained based on the first signal set without using any derivatives of the first signal set. In addition, the disclosures of the '438 Patent are insufficient to enable a POSA as of the time the patent was filed to obtain this predicted measurement based on the first signal set without using any derivatives of the first signal set.

6. "calculating predicted axial accelerations Ax′, Ay′, Az′ based on the measured angular velocities ω_x, ω_y, ω_z of the current state of the six-axis motion sensor module without using any derivatives of the measured angular velocities ω_x, ω_y, ω_z" ('438 Patent, Claims 14 and 19)

957. Claims 14 and 19 recite "calculating predicted axial accelerations Ax′, Ay′, Az′ based on the measured angular velocities ω_x, ω_y, ω_z of the current state of the six-axis motion sensor module without using any derivatives of the measured angular velocities ω_x, ω_y, ω_z."

958. This limitation in Claims 14 and 19 is substantively identical to the "predicted

measurement obtained based on the first signal set without using any derivatives of the first signal set" limitation described above in Claim 1 of the '438 Patent.

959. In my opinion, a POSA would not have reasonably concluded from the '438 Patent that the inventors had possession of an invention capable of performing this limitation for the same reasons described above. In addition, the disclosures of the '438 Patent specification are insufficient to enable a POSA as of the time the patent was filed to make or use this limitation. *See* Section XV.A.5.

B. The '978 Patent

1. "3D pointing device" where the display is incorporated into the device ('978 Patent, Claim 10)

960. Claim 10 recites a "3D pointing device." In my opinion, a POSA would not have reasonably concluded from the '978 Patent that the inventors had possession of the claimed "3D pointing device" where the display is incorporated into the device and that meets the remaining claim limitations. In addition, the disclosures of the '978 Patent are insufficient to enable a POSA as of the time the patent was filed to make or use a 3D pointing device with a display incorporated into the device and that meets the remaining claim limitations for the same reasons I described above with respect to the '438 Patent. *See* Section XV.A.1.

2. "generating the orientation output based on the first signal set, the second signal set and the rotation output or based on the first signal set and the second signal set" ('978 Patent, Claim 10)

961. Claim 10 of the '978 Patent recites generating the orientation output based on the first signal set, the second signal set and the rotation output or based on the first and second signal sets.

962. Claim 10 further recites that the "first signal set" comprises "axial accelerations associated with movements and rotations of the 3D pointing device in the spatial reference

frame" and that the "second signal set" is "associated with [the] Earth's magnetism."

963. The "orientation output" is defined in the '978 Patent as a value "associated with the orientation of the 3D pointing device associated with the three coordinate axes of the global reference frame associated with the Earth." '978 Patent at 33:29–50; 33:53–64.

964. The '978 Patent does not explicitly define the term "rotation output." However, it states that: "the rotation sensor 342 generates a rotation output (ω_x, ω_y, ω_z) associated with the rotation of the 3D pointing device associated with the three coordinate axes of a spatial reference associated with the 3D pointing device[.]" '978 Patent at 30:57–62. Similarly, it provides that the "rotation output [ω_x, ω_y, ω_z], includes three angular velocities ω_x, ω_y, ω_z respectively associated with the three coordinate axes X_p, Y_p, and Z_p of the spatial reference frame associated with the 3D pointing device."

965. Claim 10 therefore recites generating the orientation of a 3D pointing device based on: (i) the axial accelerations, a set of magnetisms, and the angular velocities; or (ii) the axial accelerations and a set of magnetisms.

966. In my opinion, there are two fundamental problems with this limitation.

967. First, the '978 Patent does not describe how to generate the orientation output using just the first signal set ("axial accelerations") and second signal sets ("magnetic readings") if the device is moving.

968. I understand that CyWee's expert, Dr. LaViola, specifically acknowledged this issue. In his February 23, 2018 Declaration, Dr. LaViola stated:

> The '978 patent discloses how to calculate orientation using the axial accelerations (roll and pitch) and the magnetometer measurements (yaw) in Equations 26-28. A person of ordinary skill in the art would understand that the axial accelerations would be based on gravitation in Equations 26-28. **Axial accelerations**

> **would be based solely on gravitational accelerations when the device is stationary.**

LaViola Decl. ¶ 95 (emphasis added).

969. The ’978 Patent also acknowledges this limitation:

> [T]he reading of the accelerometer may be accurate only when the pointing device is static since due to the limitation on known accelerometers that **these sensors may not distinguish the gravitational acceleration from the acceleration of the forces including centrifugal forces or other types of additional accelerations imposed or exerted by the user.**

’978 Patent at 3:14–19 (emphasis added).

970. I understand that CyWee has alleged that Equations 26–28 (as shown below) recite how to obtain orientation angles where g is defined as the gravitational acceleration. ’978 Patent at 34:63–65.

Equation 26	$\theta = \sin^{-1}\left(\frac{Ax}{g}\right)$
Equation 27	$\phi = \sin^{-1}\left(\frac{Ay}{g\cos\theta}\right)$ *or* $\phi = \cos^{-1}\left(\frac{Ax}{g\cos\theta}\right)$
Equation 28	$\psi = \tan^{-1}\left(\frac{-My\cos\phi + Mz\sin\phi}{Mx\cos\theta + My\sin\theta\sin\phi + Mz\sin\theta\cos\phi}\right)$

971. However, Dr. LaViola did not elaborate on the significance of this fact. Claim 10 of the ’978 Patent does not contemplate that an orientation output is generated only when the device is stationary. Instead, Claim 10 states the first signal set which is used to generate the orientation output comprises “axial accelerations **associated with movements and rotations of the 3D pointing** device in the spatial reference frame.” ’978 Patent, Claim 10 (emphasis added). In fact, the plain language of the claim does not even recite gravitational accelerations.

972. In addition, as I discussed above, because measured acceleration components are

combined to produce the output from an accelerometer, the only method to obtain values for an individual acceleration component (like gravity) is to place the object in a controlled environment that ensures that only one type of acceleration is being measured at some given time. Under such restricted conditions, individual acceleration components may remain constant over time, but the specifications of the patents-in-suit neither teach nor contemplate this restricted situation.

973. Indeed, the ’978 Patent specification indirectly refers to this problem when it discloses “undesirable” external forces that result in “undesirable axial accelerations” when trying to obtain an “updated state.” It notes that these “undesirable axial accelerations” should be “preferably excluded.” ’978 Patent at 9:44–55, 24:34–43.

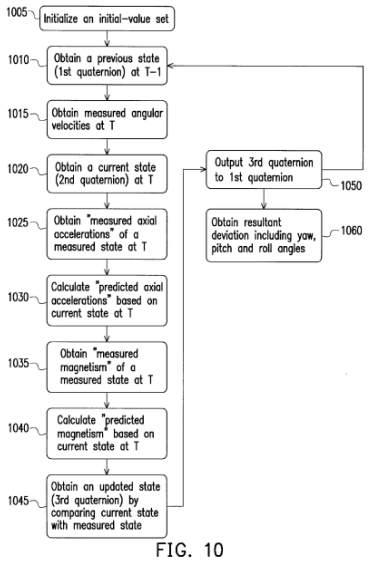
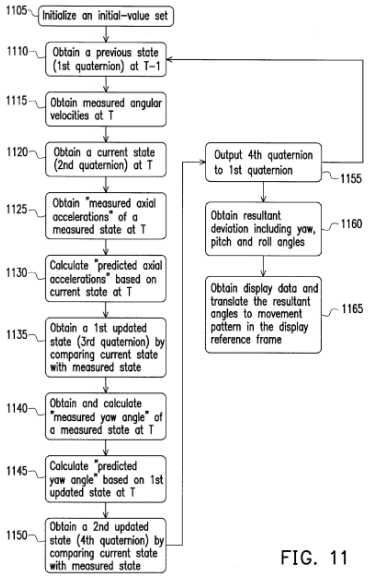
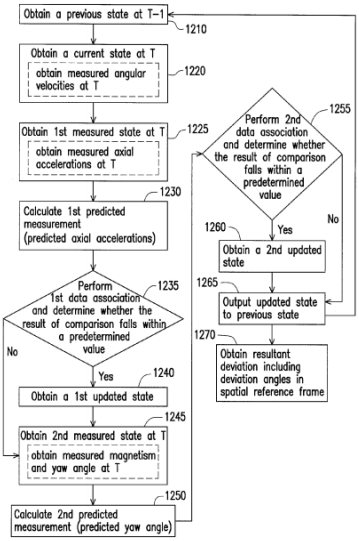
974. The ’978 Patent also does not describe how to generate the “orientation output” based on the “first signal set, the second signal set and the rotation output.”

975. Instead, the ’978 Patent merely states that:

> [T]he orientation sensor 1510 generates an orientation output associated with the orientation of the 3D pointing device associated with the three coordinate axes of the global reference frame associated with the Earth. The computing processor 348 of the orientation sensor 1510 may generate the aforementioned orientation output by **executing steps 1010 to 1060 illustrated in FIG. 10, steps 1110 to 1160 illustrated in FIG. 11, or steps 1210 to 1270 illustrated in FIG. 12.**

’978 Patent at 33:30–35.

976. As shown below, Figures 10, 11 and 12 do not disclose how the orientation output is generated. Instead, the figures show only that angular velocities, axial accelerations, and magnetic readings are read and used to calculate various “states,” perform “comparisons,” and then obtain “updated states.” The figures do not themselves state how the states are obtained or how the comparisons are done.

Figure 10 of the ’978 Patent	Figure 11 of the ’978 Patent	Figure 12 of the ’978 Patent
		

977. The description of these figures in the patent specification also does not explain how the various sensor measurements are used to obtain an orientation output. *See* ’978 Patent at 22:10–23:45 (directed to Figure 10); 22:46–26:39 (directed to Figure 11); and 26:40–29:15 (directed to Figure 12).

978. Indeed, as shown below, each of these portions of the ’978 Patent specification merely describes “comparisons” done to obtain an “updated” state without describing how these comparisons are done. *See id.* at 23:16–34 (directed to Figure 10); 23:62–24:6 (directed to Figure 11); 27:34–28:5 (directed to Figure 12).

979. I understand that CyWee’s expert, Dr. LaViola, has testified that when the object is moving, the ’978 Patent uses Equations 5–11 to calculate the orientation output. LaViola Dep. Tr. at 160:21–162:24.

980. For the reasons I discussed above in Section XV.A.2, in my opinion, Equations 5–11 do not disclose how to calculate an orientation output when an object is moving. As discussed above, Equations 5–11 contain numerous undefined functions and variables and a POSA would

not know how these equations operate.

981. In addition, the ’978 Patent provides no explanation for how these equations, which CyWee states disclose an Extended Kalman filter (or something similar) would deal with linear and rotational accelerations. Kalman filters are designed to handle zero mean uncorrelated white noise with known auto covariance functions. “Fundamentals of Inertial Navigation, Satellite-based Positioning and their Integration,” at Section 7.1.1, p. 228 by Noureldin et. al., (2013). The axial acceleration components due to linear and rotational accelerations are the result of a human hand moving the pointer, and they do not produce “noise” that has these properties.

982. For at least these reasons, in my opinion, a POSA would not have reasonably concluded from the ’978 Patent that the inventors had possession of an invention capable of generating the orientation output based on the first signal set, the second signal set and the rotation output or based on the first signal set and the second signal set. In addition, the disclosures of the ’978 Patent specification would have been insufficient to enable a POSA as of the time the patent was filed to generate the orientation output based on the first signal set, the second signal set and the rotation output or based on the first signal set and the second signal set.

3. “obtaining one or more resultant deviation including a plurality of deviation angles using a plurality of measured magnetisms Mx, My, Mz and a plurality of predicted magnetism Mx′, My′ and Mz′ for the second signal set” (’978 Patent, Claim 10)

983. Claim 10 of the ’978 Patent recites “obtaining one or more resultant deviation including a plurality of deviation angles using a plurality of measured magnetisms Mx, My, Mz and a plurality of predicted magnetism Mx′, My′ and Mz′ for the second signal set.”

984. In my opinion, the ’978 Patent fails to describe how to obtain one or more deviation angles using measured and predicted magnetisms.

985. The ’978 Patent describes the “deviation angles” as the “three resultant angles

preferably about each of the three axes of the spatial pointer reference frame" including the yaw, pitch and roll angles.'978 Patent at 10:61–64.

986. The '978 Patent states that the "predicted magnetisms" are calculated using Equations 18–20 (reproduced below) by multiplying the second quaternion represent the "current state" (i.e., a quaternion representation of the device's current orientation) with the dip angle. *Id.* at 22:40–67.

Equation 18	$(q_0^2+q_1^2-q_2^2-q_3^2)\cos\lambda+2(q_1q_3-q_0q_2)\sin\lambda=Mx'$
Equation 19	$2(q_1q_2-q_0q_3)\cos\lambda+2(q_2q_3+q_0q_1)\sin\lambda=My'$
Equation 20	$2(q_1q_3+q_0q_2)\cos\lambda+(q_0^2-q_1^2-q_2^2+q_3^2)\sin\lambda=Mz'$

987. My understanding is that Equations 18–20 are intended to correct the readings from the magnetometer so that it points perpendicularly to a user's location in the Earth frame. Even if this correction could be construed as a "predicted" magnetism, the concept of correcting the actual magnetometer measurements for the dip angle was well known in the art since the 1500s. Further, the equations themselves are inadequate to remove this error. In order to use these equations, a POSA would need details to perform the quaternion rotation calculations, including the value of dip to be removed and its relation to the angle of rotation λ. These concepts are not taught, disclosed, or suggested in the '978 Patent. Indeed, the '978 Patent specification seems to suggest that the rotation angle in Equations 18–20 is the dip angle.

988. A "comparison" model is then used that compares "the second quaternion in relation to the measured angular velocities of the current state at present time T with the measured axial accelerations Ax, Ay, Az, the predicted axial accelerations Ax′, Ay′, Az′, the

measured magnetism Mx, My, Mz and the predicted magnetism Mx′, My′, Mz′ also at present time T" to output at "updated state." *Id.* at 23:16–22; 35–40. This result is then further utilized to obtain resultant deviation angles. *Id.* at 23:36–41. The '978 Patent does not disclose any additional details about how deviation angles are to be determined.

989. In my opinion, this cursory description of using a "comparison model" does not does not describe: (i) how to perform this comparison between a second quaternion in relation to measured angular velocities with measured axial accelerations, predicted axial accelerations, measured magnetisms, and predicted magnetisms; and (ii) how the output of this comparison is then used to obtain deviation angles.

990. Further, based upon the teachings of the '978 Patent, a POSA would further not have understood how to perform this "comparison model." As I described above in Sections XV.A.2 amd XV.A.3, comparing a second quaternion in relation to measured angular velocities with measured and predicted axial accelerations would result in (at most) a meaningless result. Specifically, a POSA would have understood that this would require the impossible comparison of: (i) units that measure fundamentally different attributes of an object (i.e., comparing linear or gravitational accelerations with angular velocities); or (ii) units with undefined variables (i.e., comparing a centrifugal acceleration with an undefined radius with angular velocities).

991. The fact that the '978 Patent further discloses comparing these values with both measured and predicted magnetisms does not change my analysis.

992. It is unclear for example how a POSA would "compare" a second quaternion in relation to angular velocities with measured and predicted magnetisms. The measurement of the angular velocity of an object provides no information regarding the strength of the Earth's magnetic field on the object along three perpendicular axes (or vice versa).

993. It is also unclear how a POSA would "compare" the "axial accelerations" composed of linear, centrifugal and gravitational accelerations with measured and predicted magnetisms. Again, an object's linear, centrifugal and gravitational acceleration have no relation to the magnitude and direction of the Earth's magnetic field (as read by a magnetometer affixed to the object). Accordingly, any comparison of these values would be meaningless.

994. For at least these reasons, in my opinion, a POSA would not have reasonably concluded from the '978 Patent that the inventors had possession of an invention capable of obtaining one or more resultant deviation angles using a plurality of measured and predicted magnetisms. In addition, the disclosures of the '978 Patent specification would have been insufficient to enable a POSA as of the time the patent was filed to obtain one or more resultant deviation angles using a plurality of measured and predicted magnetisms.

XVI. SECONDARY CONSIDERATIONS

995. I understand that one of the factors used to determine whether a patent claim would have been obvious to one skilled in the art at the time of invention is the presence or absence of "secondary considerations of non-obviousness," including factors such as commercial success, satisfaction of a long-felt need, skepticism and disbelief, and industry praise. I also understand that for such evidence to be relevant, there must be a sufficient nexus with the claimed invention.

996. I understand that it is the patentee's burden to show the presence or absence of these secondary considerations, and that the presence of one or more secondary considerations for a patent claim is not determinative of non-obviousness. I also understand that the presence of certain secondary considerations can weigh in favor of a finding of non-obviousness.

997. I reserve my right to address and rebut any arguments regarding secondary considerations of non-obviousness advanced by CyWee's expert.

XVII. SIGNATURE

This report represents my opinions and conclusions at this time. I reserve the right to supplement my report or offer additional opinions in response to any new opinions disclosed by CyWee.

Dated: October 8, 2018

M. Ray Mercer, Ph.D.

Executed in Dallas, Texas.

MELVIN RAY MERCER

Independent Consultant
and
Professor Emeritus
Department of Electrical and Computer Engineering
Texas A & M University

BUSINESS ADDRESS: 10801 Branch Oaks Circle
Dallas, TX 75230

PHONE: (469) 458-3770
CELL: (979) 676-3109
FAX: (866) 769-1967
EMAIL: ray@rmercer.com

EDUCATION:
The University of Texas at Austin, Ph.D., 1980
Stanford University, MS, 1971
Texas Tech University, BS, 1968

PROFESSIONAL REGISTRATION: Texas #62016

ACADEMIC POSITIONS:

Texas A & M University, Professor Emeritus, 2006
Texas A & M University, Professor and Chair Holder, 1/95-9/2005
University of Texas at Austin, Professor, 9/91-12/94
University of Texas at Austin, Associate Professor, 9/87-8/91
University of Texas at Austin, Assistant Professor, 1/83-8/87
University of Texas at San Antonio, Lecturer, 1977-80

OTHER PROFESSIONAL EXPERIENCE:

Independent Consultant for Mercer and Associates, Inc., Dallas, TX 1984-present
Member of Technical Staff, Bell Laboratories, Murray Hill, NJ, 1980-83
Member of Technical Staff, Hewlett-Packard Laboratories, Palo Alto, CA, 1973-77
Research/Development Engineer, GTE Sylvania, Mountain View, CA, 1968-73
(in 2000, GTE merged with Bell Atlantic to form Verizon)

CONSULTING:

Hale and Dorr, Boston, Massachusetts, Intel, 2001
Fulbright and Jaworski, Houston, TX, Emachines, 1999-2000
Akin, Gump, Strauss, Hauer & Feld, 2000
Harris Corporation, Melbourne, FL, 1999-2001
SigmaTel, Austin, TX, 1999-2000
Martin Gruppen, Denmark, 1999
AT&T, Inc., Murray Hill, NJ, 1995-98
Sematech, Inc., Austin, TX 1994
Teradyne, Inc., Boston, MA, 1993-94
Integri-Test Corp., Commack, NY 1993
Spectrum Information Technologies, Dallas, TX 1993
Motorola Semiconductor, Austin, TX, 1987-88, 1991-99
Rockwell International, Newport Beach, CA, 1991, 1995
Teltech Resource Network, Minneapolis, MN, 1986-93
Cimflex Teknowledge, Pittsburgh, PA, 1989-90
IBM, Inc., Austin, TX, 1984, 1988-90

MCC, Austin, TX, 1989
CBS, New York, NY, 1985-86
Harris Data Communications Inc., Dallas, TX, 1984-86
Cellular Technology, Inc., Lubbock, TX 1985 - 87
Attorney General's Office, State of Texas, Austin, TX, 1984
Lockheed Missiles and Space Company, Austin, TX, 1983
Rothe Development Company, San Antonio, TX, 1979

TECHNOLOGY BASED BUSINESS EXPERIENCE:

Founder, Technical Advisor, and Owner of Conference Management Services, Inc., 1993 – 2013
Technical Advisory Board Member, Test Systems Strategies, Inc., Beaverton, OR, 1988-93
Advisor and Survey Developer, IBM, Inc., Austin, TX, 1988-90
Advisor, Early Cellular Telephone Minority Carriers, Lubbock, Texas, 1983 - 1987

HONORS AND AWARDS:

National and International:

Fellow of the Institute of Electrical and Electronics Engineers, 1994
National Science Foundation -- Presidential Young Investigator, 1986
Best Paper Award, VLSI Test Conference, Dana Point, CA, 1999
Best Paper Award, Design Automation Conference, San Francisco, CA, 1991
Best Paper Award, International Test Conference, Philadelphia, PA, 1982
Best Paper Award, Honorable Mention, Int. Test Conference, Washington, DC, 1988
Texas Tech Electrical Engineering Academy, Lubbock, Texas, 1999
Who's Who in America, 48th, 49th, 50th, 56th, 58th, 59th, 63rd, 67th and 69th Editions, 1994, 1995, 1996, 2000, 2002, 2004, 2005, 2009, 2012, and 2015
Who's Who in American Education, 3rd Edition, 1992-1993
Who's Who in America Finance and Industry, 31st Edition, 1999
Who's Who of Emerging Leaders in America, 7th Edition, 1990 & 1992
Who's Who in Science and Engineering, 3rd, 4th, 7th, 9th & 10th Editions, 2003-2009
Who's Who in the South and Southwest, 21st, 22nd, 23rd, 24th, 37th, 38th , 40th & 41st Editions, 1988, 1990, 1992, 1995, 2011, 2012, 2013, 2014, & 2015
Who's Who in the World, 10th, 11th, 17th, and 21st Editions, 1991, 1992, 2000, 2004, & 2018
Meritorious Service Award, IEEE Computer Society, 1993
Faculty Nominator and Advisor for Jennifer Dworak – Recipient of a National Science Foundation Graduate Research Fellowship 2000 – 2003
Co-Author and Advisor for Jennifer Dworak and Amy Wang – Recipient of the "IEEE Test Technology Technical Council Naveena Nagi Award for 2004" presented in Napa Valley, California

Local:

Computer Engineering Chair in Electrical Engineering, A&M, 1995-2005
Faculty Nominator and Advisor for Jennifer Dworak – Recipient of The Ethel Ashworth-Tsutsui Memorial Award for Graduate Student Research 2002
Texas A&M Outstanding Masters Thesis Award: Jennifer Dworak, 1999-2000
Listed in the Texas A&M Center for Teaching Excellence 2002 Eagle Award Booklet, May 3, 2002
Temple Foundation Endowed Professorship #3 in Engineering, UT, 1991-94
Engineering Foundation Endowed Faculty Fellowship in Engineering, UT, 1990-91
Werner W. Dornberger Centennial Teaching Fellowship in Engineering, UT, 1984-90
Engineering Foundation Faculty Award, UT, 1986
Outstanding Doctoral Dissertation: Honorable Mention, T. E. Kirkland, UT, 1986-87
MCC Sponsored Outstanding Student Paper Award: Bill Underwood, 1991-92
High School Valedictorian

PROFESSIONAL SOCIETIES AND ACTIVITIES:

Government:

National Science Foundation Advisory Committee for Microelectronic Information Processing Systems (MIPS), 1987-88

National Science Foundation Engineering Initiation Awards Evaluation Panel Member —Design, Tools and Test Program, 1987 and 1993

National Science Foundation Advisory Workshops

Future of Testing and Design for Testability, June 30, 1989

Future of VLSI and Computer-Aided Design, October 15-16, 1992

Presentation to the Texas State Board of Registration for Professional Engineers on Computer Engineering and suitable criteria for registration, 1985

Journals and Archival Publications:

Guest Editor, Special Issue on Design for Testability, *IEEE Design and Test of Computers*, October, 1986

Editor, Design for Testability, *IEEE Design and Test of Computers*, 1985-88

Guest Editor, *IEEE Transactions on Computer-Aided Design of Circuits and Systems*, 1988

Guest Editor, Special Issue on 1989 International Test Conference, *IEEE Design and Test of Computers*, April 1990.

Editorial Board Member, *Journal of Electronic Testing: Theory and Applications*, 1990-92

Editorial Advisory Board, *Microelectronics Journal: Circuits and Systems*, 2000 – 2003

Conferences and Workshops:

Finance Chair, Third IEEE Workshop on Microprocessor Test and Verification, (MTV'02), 2002

Program Committee, Ninth IEEE International Test Synthesis Workshop, (ITSW), 2002

Program Committee, Second IEEE Workshop on Microprocessor Test and Verification, (MTV 99), 1999

Exhibits Chairman, Fault-Tolerant Computing Symposium 1994

Planning Chairman, International Test Conference, 1992-93

Marketing Vice-Chairman, International Test Conference, 1990

Program Chairman, International Test Conference, 1989

Program Vice-Chairman, International Test Conference, 1988

Steering Committee, International Test Conference, 1987-93

Program Committee, International Test Conference, 1986-89

Program Committee, IEEE Design for Testability Workshop, 1988-96

Program Committee, International Conference on Computer-Aided Design, 1987

Program Committee, First MCC-University Research Symposium, Austin, TX, 1987

Local Offices:

Vice-Chairman, Central Texas Chapter, IEEE Computer Society, 1983-85

Chairman, Central Texas Chapter, IEEE Computer Society, 1985-86

Memberships:

Institute of Electrical and Electronics Engineers (IEEE), Fellow 1994, Life Member 2012

TEXAS A & M UNIVERSITY COMMITTEE ASSIGNMENTS:

City/County Committees:

Bryan/College Station Economic Development Group

Marketing Committee for the Information Technology Task Force, 1999

University Committees:

Search Committee -- Associate Provost for Information Technology, 1997-99

Research Infrastructure Committee, 1998-99

College of Engineering Committees:

Computer Engineering Committee, Chairman, 2002

Tenure and Promotion Committee, 2000 - 2002

Computer Engineering Committee, Chairman, 1996-1999

Chair Holders Committee, 1995-

Compaq Liaison Committee 1996-

Computer Science Department Head Search Committee, 1996-98

ABET Review Committee, Computer Engineering, 1995

ABET Review Committee, Computer Engineering, Chair, 1998
Ad Hoc Committee to Study the Merger of the CS and EE Departments, 1996
PAM Advisory Committee, 1995-96
Spencer J. Buchanan Professorship Review Committee, 1997

Departmental Committees:

Computer Engineering Area Leader, 1995-present
Faculty Search Committee for the Computer Engineering Group, Chairman, 1995-present
Teaching Assignments for the Computer Engineering Group, 1995-present
Tenure and Promotion Committee, 1996-98, 2000-02, 2003-2005
Graduate Studies Committee, 1996-present
Faculty Advisory Committee, 1997-99
Strategic Planning Committee, 1998
Search Committee for the Eugene Webb Professorship, 1998-99
Search Committee for the Texas Instruments Jack Kilby Chair in Analog Engineering, 1998-99

UNIVERSITY OF TEXAS COMMITTEE ASSIGNMENTS:

University Committees:

Presentation to the MCC Site Selection Committee, the MCC Fact Finding Committee, and the MCC Technology Advisory Board, 1983
Science and Engineering Development Program Review for Dr. Thomas Everhart and Dr. Frank Press, National Academy of Sciences, 1984
Parking and Traffic Panel of the General Faculty, 1983-85
Hearing Officer for Faculty Grievances, 1987-88
University Council Representative, 1992-94
University Faculty Senate, 1992-94
Faculty Governance Committee, 1992-93

College of Engineering Committees:

Scholastic Appeals Committee, 1983-84
Ad Hoc Committee to Prepare a DOD Proposal for a Software Engr. Institute, 1984
State Agency Research Forum Speaker, May 10, 1984
Continuing Engineering Studies Committee, 1984-85
Ad Hoc Committee on Microelectronics and Computer Engineering, 1983-85
Presentation to Heads of State Agencies and Selected Federal Personnel, 1985
Computer Committee, 1985-86
GEC Faculty Meritorious Service Award Committee, 1987
Presentation to Industrial Representatives Research Forum, April 30, 1987
Undergraduate Degree Program Evaluation, 1986-88
Continuing Engineering Studies Committee, 1986-88
Televised Instruction Committee, 1987-91
Briefing for AT&T Visitors, November 21, 1991

Departmental Committees:

Committee on CAD/CAM and Advanced Graphics, 1983
Chairman, MCC Graduate Fellowships Recruiting Poster Committee, 1984
Microelectronics and Computer Engineering Research Support Committee, 1984
Chairman, Computation, Word Processing, and Telecom. Committee, 1984-85
Chairman, Industrial Liaison Committee, 1985-86
Computation, Word Processing, and Telecommunications Committee, 1985-86
Equipment Committee, 1984-86
ABET Accreditation for ECE in Computer Engineering (Site Visit), 1987
VLSI Course Area Committee, 1986-87
Chairman, Local Area Network Committee, 1987-88
Search Committee for New ECE Chairman, 1988-89
ECE Visiting Committee, 1989-90
Chairman, Annual Research Review Committee, 1988-92

Graduate Student Recruitment at Stanford University, January 1992
Alumni Committee 1992-93
Computer Engineering Research Center Executive Committee, 1988-93
Computer Sciences Liaison, 1988-93
Digital Systems Course Area Committee, 1988-93
Chairman, Teaching Effectiveness Committee, 1991-94
Budget Council, 1991-94
Computer Engineering Representative to the ECE Area Committee 1993-94
Junior Faculty Recruiting Committee, Computer Engineering, 1985-94

PUBLICATIONS:
Refereed Conference and Archival Journal Publications:

M. R. Mercer and V. D. Agrawal, "A Novel Clocking Technique for VLSI Circuit Testability," *IEEE Journal of Solid-State Circuits*, Vol. SC-19, April 1984, pp. 207-212.

K. S. Hwang and M. R. Mercer, "Derivation and Refinement of Fanout Constraints to Generate Tests in Combinational Logic Circuits," *IEEE Transactions on Computer-Aided Design of Integrated Circuits and Systems*, October 1986, pp. 564-572.

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E. S. Park and M. R. Mercer, "An Efficient Delay Test Generation System for Combinational Logic Circuits," *IEEE Transactions on Computer-Aided Design of Integrated Circuits and Systems*, vol. 11, no. 7, July 1992, pp. 926-938. {NSF, ONR, TATP}

R. Kapur and M. R. Mercer, "Bounding Signal Probabilities for Testability Measurement Using Conditional Syndromes," *IEEE Transactions on Computers*, vol. 41, no. 12, December 1992, pp. 1580-1588. { NSF, ONR, SRC}

M. Heap and M. R. Mercer, "Least Upper Bounds on OBDD Sizes," *IEEE Transactions on Computers*, accepted for publication, July 1993.

C. Oh and M. R. Mercer, "Efficient Logic-Level Timing Analysis Using Constraint-Guided Critical Path Search," *IEEE Transactions on VLSI*, September 1996. {ONR}

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M. R. Mercer, V. D. Agrawal and C. M. Roman, "Test Generation for Highly Sequential Scan-Testable Circuits through Logic Transformation," *International Test Conference 1981*, Philadelphia, PA, October 1981, pp. 561-565.

V. D. Agrawal and M. R. Mercer, "Testability Measures -- What Do They Tell Us?," *International Test Conference 1982*, Philadelphia, PA, November 1982, pp. 391-396. **(Best Paper of the 1982 ITC)**

M. R. Mercer and B. Underwood, "Correlating Testability with Fault Detection," *International Test Conference 1984*, Philadelphia, PA, October 1984, pp. 697-704.

E. Schell and M. R. Mercer, "CADTOOLS: A CAD Algorithm Development System," *The ACM/IEEE Design Automation Conference (22nd) Proceedings*, Las Vegas, NV, June 23-26, 1985, pp. 658-666.

J. Salick and M. R. Mercer, "Built-In Self Test Input Generator for Programmable Logic Arrays," *International Test Conference 1985*, Philadelphia, PA, November 1985, pp. 115-125.

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K. S. Hwang and M. R. Mercer, "Informed Test Generation Guidance Using Partially Specified Fanout Constraints," *1986 International Test Conference*, Washington, DC, September 8, 1986, pp. 113-119.

R. K. Gaede, M. R. Mercer and B. Underwood, "Calculation of Greatest Lower Bounds Obtainable by the Cutting Algorithm," *1986 International Test Conference*, Washington, DC, September 9, 1986, pp. 498-505.

M. R. Mercer, "Logic Elements for Universally Testable Circuits," *1986 International Test Conference*, Washington, DC, September 9, 1986, pp. 493-497.

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B. Underwood, J. Salick, M. R. Mercer and J. Kuban, "An Automatic Test Pattern Generation Algorithm for PLAs," *IEEE International Conference on Computer-Aided Design*, Santa Clara, CA, November 10-13, 1986, pp. 152-155.

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E. J. Aas and M. R. Mercer, "Algebraic and Structural Computation of Signal Probability and Fault Detectability in Combinational Circuits," *Proceedings of the 17th International Symposium on Fault-Tolerant Computing*, Pittsburgh, PA, July 6-8, 1987, pp. 72-77.

D. E. Ross and M. R. Mercer, "WAVE, A Concurrent Approach to Combinational Test Pattern Generation," *Proceedings of the MCC-University Research Symposium*, Austin, TX, July 14, 1987.

E. S. Park and M. R. Mercer, "Robust and Nonrobust Tests for Path Delay Faults of a Combinational Circuit," *Proc. 1987 International Test Conference*, Washington, DC, September 1-3, 1987, pp. 1027-1034.

S. P. Smith, B. Underwood and M. R. Mercer, "An Analysis of Several Approaches to Circuit Partitioning for Parallel Logic Simulation," *Proc. 1987 IEEE International Conference on Computer Design*, Rye Brook, NY, October 5-8, 1987, pp. 664-667.

C. T. Glover and M. R. Mercer, "A Method of Delay Fault Test Generation," *Proc. 25th ACM/IEEE Design Automation Conference*, Anaheim, CA, June 13-15, 1988, pp. 90-95.

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C. T. Glover and M.R. Mercer, "A Deterministic Approach to Adjacency Testing for Delay Faults," *Proc. 26th ACM/IEEE Design Automation Conference*, Las Vegas, NV, June 25-29, 1989, pp. 351-356.

E. S. Park and M.R. Mercer, "An Efficient Delay Test Generation System for Combinational Logic Circuits," *Proc. 27th ACM/IEEE Design Automation Conference*, Orlando, FL, June 24-28, 1990, pp. 522-528.

K. M. Butler and M.R. Mercer, "The Influences of Fault Type and Topology on Fault Model Performance and the Implications to Test and Testable Design," *Proc. 27th ACM/IEEE Design Automation Conference*, Orlando, FL, June 24-28, 1990, pp. 673-678. {NSF, SRC}

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R. Kapur, J. Park, and M. R. Mercer, "All Tests for a Fault are Not Equally Valuable for Defect Detection," *Proc. 1992 International Test Conference*, Baltimore, MD, September 20-24, 1992, pp. 762-769. {NSF, ONR, SRC}

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M. R. Grimaila, S. Lee, J. Dworak, K. M. Butler, B. Stewart, H. Balachandran, B. Houchins, V. Mathur, J. Park, L-C. Wang, and M. R. Mercer, "REDO -- Random Excitation and Deterministic Observation -- First Commercial Experiment," *Proc. 1999 IEEE VLSI Test Symposium*, Dana Point, Calif., April 25 - 29, 1999, pp. 268-274. **(Best Paper Award at 1999 VLSI Test Symposium)** {TATP}

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J. Dworak, M. R. Grimaila, S. Lee, L-C. Wang, and M. R. Mercer, "Enhanced DO-RE-ME Based Defect Level Prediction Using Defect Site Aggregation – MPG-D," *Proceedings of the 2000 International Test Conference*, Atlantic City, NJ, October 3 - 5, 2000, pp. 930-939. {TATP}

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J. Dworak, J. Wingfield, B. Cobb, S. Lee, Li-C Wang, and M. R. Mercer, "Fortuitous Detection and its Impact on Test Set Sizes Using Stuck-at and Transition Faults," *Proceedings of the 2002 International Symposium on Defect and Fault Tolerance in VLSI Systems (DFT 2002)*, Vancouver, Canada, November 6-8, 2002, pp. 177 - 185.

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J. Wingfield, J. Dworak, and M. R. Mercer, "Function-Based Dynamic Compaction and its Impact on Test Set Sizes," *Proceedings of the 18th IEEE International Symposium on Defect and Fault Tolerance in VLSI Systems*, Boston, MA, November 3 - 5, 2003, pp. 167 - 174.

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K. M. Butler and M. R. Mercer, *Assessing Fault Model and Test Quality*, Kluwer Academic Publishers, 1991, ISBN 0 - 7923 - 9222 - 1.

V. D. Agrawal and M. R. Mercer, "Testability Measures -- What Do They Tell Us?," in *VLSI Testing and Validation Techniques*, IEEE Tutorial, H. Reghbati, editor, 1985, pp. 401-406.

Technical Reports:

M. R. Mercer and V. D. Agrawal, "Use of Clock Signal Redundancy for Testability," Bell Laboratories Technical Memorandum, July 1981.

C. M. Roman, V. D. Agrawal and M. R. Mercer, "An LSI Chip Designed for Testability," *Proceedings of the Bell System Conference on Electronic Testing*, Princeton, NJ, September 1981.

M. R. Mercer and V. D. Agrawal, "Applications for Testability Measures in VLSI Design," *Proceedings of the Bell System Conference on Electronic Testing*, Princeton, NJ, October 1982, pp. 52-58.

M. R. Mercer, "Computer Aided Design of Digital Systems," *Discovery -- Research and Scholarship at The University of Texas at Austin*, Vol. 9, No. 3, 1985, pp 17-21.

M. R. Mercer, "Testing and Design Verification of Electronic Components -- a Perspective of the Last 40 Years," *IEEE Computer*, ***(Invited Publication for the 40th Anniversary Issue)***, September, 1991.

Other publications:

J. Dworak, D. Dorsey, A. Wang, and M. R. Mercer with IBM Technical Contact M. W. Mehalic, "Estimating Mean Time to Failure in Digital Systems Using Manufacturing Defective Part Level," *4th Annual IBM Austin Center for Advanced Studies Conference*, Austin, TX, February 21, 2003.

PROFESSIONAL SOCIETY PRESENTATIONS:

"Testability Strategies for Custom Polycell Designs," Computer Elements Workshop on VLSI Debug and Diagnosis, IEEE Computer Society, New York, NY, May 1982.

"Interpretations of Testability Measures," IEEE Design Automation Workshop, Michigan State University, East Lansing, MI, October 1982.

"Testability Measures -- What Do They Tell Us?," Automatic Testing and Measurement Exhibition, Wiesbaden, West Germany, March 1983 (by invitation as part of the "Best of Cherry Hill" Session).

"Testing Issues at the University of Texas," International Test Conference 1983, Philadelphia, PA, October 1983.

"Refinement of Statistical Evaluation of Testability Algorithms," (with B. Underwood), Seventh Annual IEEE Workshop on Design for Testability, Vail, CO, April 1984.

"SUBTLE -- A New Methodology for Structured Testability," Seventh Annual IEEE Workshop on Design for Testability, Vail, CO, April 1984.

"Why Calculating Observability is More Difficult than Controllability," Eighth Annual IEEE Workshop on Design for Testability, Vail, CO, April 1985.

"Automatic Test Pattern Generation for PLA's," (with J. Salick and B. Underwood), Fifth Annual IEEE West Coast Testing Workshop, Lake Tahoe, CA, April 1986.

"A Method for Empirical Evaluation of the Cutting Algorithm," (with R. Gaede), 9th Annual IEEE Workshop on Design for Testability, Vail, CO, May 1986.

"Exact Calculation of Fault Detection Probabilities in Multi-Output Combinational Circuits," (with E. Aas), Built-In Self-Test Workshop, Kiawah Island, Charleston, SC, March 11-13, 1987.

"Fault Model Comparisons and a Method for Testing with Vector Pairs," (with T. Glover), 10th Annual IEEE Workshop on Design for Testability, Vail, CO, April 23, 1987.

"A Review of Current Methods in Automatic Test Pattern Generation and Design for Testability," Nordic Workshop on Testing, Roros, Norway, March 15, 1988.

"An Empirical Comparison of Random-Pattern Testability under Two Classes of Delay Fault Coverage," (with T. Glover), 11th Annual IEEE Workshop on Design for Testability, Vail, CO, April 21, 1988.

"A Novel Segmentation Scheme for Pseudo-Exhaustive Testing," (with B. Stewart), 12th Annual IEEE Workshop on Design for Testability, Vail, CO, April 20, 1989.

"Distributed Demand-Driven Logic Simulation," (with S.P. Smith), International Workshop on CAD Accelerators, Oxford University, UK, September 21, 1989.

"Syndrome Estimation in Combinational Circuits Using Conditional Probabilities," (with R. Kapur), Built-In Self-Test Workshop, Kiawah Island, Charleston, SC, March 22, 1990.

"On Evaluating Target Fault Models and Non-Target Fault Detection," (with K. Butler), 13th Annual IEEE Workshop on Design for Testability, Vail, CO, April 17, 1990.

"Testing and Design Verification -- a Functional Perspective," **(invited plenary presentation)**, The International Conference on Computer Design, Cambridge, Mass., Sept. 17, 1990.

"Ordered Partial Decision Diagrams and their Applications," (with D. Ross), 14th Annual IEEE Workshop on Design for Testability, Vail, CO, April 17, 1991.

"Delay-Optimization of Synthesized Networks and its Impact on Testing," (with B. Underwood and T. W. Williams), 14th Annual IEEE Workshop on Design for Testability, Vail, CO, April 17, 1991.

"Enhanced Non-Target Defect Detection Based Upon Refined Test Sets for Target Faults," (with R. Kapur and J. Park), 15th Annual IEEE Workshop on Design for Testability, Vail, CO, April 23, 1992.

"A Comparison of Non-Target Defect Levels for Scanned and Non-Scanned Sequential Circuits When the Fault Coverage is 100%," (with J. Park and R. Kapur), 15th Annual IEEE Workshop on Design for Testability, Vail, CO, April 23, 1992.

"Testing and Design Verification -- a Functional Perspective," **(invited presentation)**, The Canadian Workshop on New Directions in Testing, Montreal, Quebec, Canada, May 21, 1992.

"Design for Testability and Built-In Self-Test -- Obstacles and Opportunities," **(invited Keynote)**, IEEE Workshop on Design for Testability and Built-In Self-Test, Vail, CO, April 20, 1994.

"Limitations in Predicting Defect Level Based on Stuck-at-Fault Coverage," (with J. Park, Mark Naiver, T. Williams, and R. Kapur), 15th Annual IEEE Workshop on Design for Testability, Vail, CO, April 20, 1994.

"Enhancing Testing Efficiency by Reducing Testing Biases," (with L-C. Wang, and T. W. Williams), IEEE Workshop on Design for Testability, Vail, CO, April 25, 1996.

"On Bridging Defects which Manifest as Delay Faults but are *NOT* IDDQ Testable," (with D. Ross, and G. Tu), IEEE Workshop on Design for Testability, Vail, CO, April 25, 1996.

"IDDQ Test: Sensitivity Analysis of Scaling," (with T. W. Williams, R. Kapur, R. Dennard, and W. Maly), IEEE Workshop on Design for Testability, Vail, CO, April 25, 1996.

"High Fault Coverage Behavioral Test Generation," (with L-C. Wang, and T. W. Williams), IEEE European Test Workshop, Montpelier, France, June 12 - 14, 1996.

"Failure Prediction Quality for Voltage versus IDDQ Testing Methods," (with R. Kapur and T. W. Williams), IEEE European Test Workshop, Cagliari (Grand Hotel Chia Laguna), Italy, May 28 - 30, 1997.

"Using Commercial ATPG Tools to Accurately Predict and Minimize Defective Part Level," (with J. Dworak, M. R. Grimaila, J. Wicker, K. M. Butler, B. Stewart, L-C. Wang, and T. W. Williams), Eighth International Test Synthesis Workshop, Santa Barbara, CA, March 26 - 28, 2001.

"A Study of Gate-Level Modeling Biases in DFT Methodologies for Testing Custom Designs," (with L-C. Wang, and M. S. Abadir), Eighth International Test Synthesis Workshop, Santa Barbara, CA, March 26 - 28, 2001.

"A Statistical Analysis of the Sensitivity to Defective Part Level Model Parameters during Test Pattern Set Selection (with J. Dworak, M. Grimaila, K. Butler, Jason Wicker and B. Stewart), The Ninth International Test Synthesis Workshop, Santa Barbara, CA, March 25 - 27, 2002. **(Best Student Presentation Award of the Ninth ITSW – student presenting was Jennifer Dworak)**

"The Effect of Uncertainty in the Model Parameter Tau on the Effectiveness of Test Sets Optimized with MPG-D," (with J. Dworak, M.R. Grimaila, J. Wingfield, B. Cobb, S. Lee, J. Wicker, K. Butler, B. Stewart, and B. Underwood), 3rd IEEE International Workshop on Microprocessor Test and Verification, Austin, TX, June 6-7, 2002.

"A New Estimator for Mean Time to First Failure: How Bad Were Those Defective IC's We Missed?" (with J. Dworak, D. Dorsey, and A. Wang," Tenth International Test Synthesis Workshop, Santa Barbara, CA, March 31-April 2, 2003.

“Evaluating a Greedy ATPG Algorithm for Generating Compact Transition Test Sets in Accordance with the Principles of DO-RE-ME,” (with S. Lee, J. Dworak, and B. Cobb), 4th International Workshop on Microprocessor Test and Verification, Austin, TX, May 29-30, 2003.

“Binary Decision Diagrams and their Applications in Manufacture Testing,” (with J. Wingfield, and B. Cobb), Eleventh International Test Synthesis Workshop, Santa Barbara, CA, April 5 - 7, 2004.

“Defect Delectability Classes and Their Effect on Optimal Test Pattern Generation Strategies,” (with J. Dworak), Eleventh International Test Synthesis Workshop, Santa Barbara, CA, April 5 - 7, 2004.

“Reducing Structural Bias: An Initial Look at Observation Diversity,” (with J. Dworak and J. Wingfield), Fifth International Workshop on Microprocessor Test and Verification, Austin, TX, September 8 - 10, 2004.

INVITED LECTURES:

"Computer-Aided Testing and Simulation," First Annual Research Review, Department of Electrical and Computer Engineering, The University of Texas at Austin, May 8, 1984.

"Automatic Test Pattern Generation for Digital Logic Circuits," Second Annual Research Review, Department of Electrical and Computer Engineering, The University of Texas at Austin, May 7, 1985.

"Computer-Aided Testing and Simulation," Texas Instruments, Dallas, TX, June 1985.

"New Directions in Logic Design for Testability," International Business Machines Corporation, Purchase, NY, April 8, 1986.

"New Directions in Logic Design for Testability," Semiconductor Research Corporation, Research Triangle Park, NC, April 11, 1986.

"Research in Logic Testing at the University of Texas at Austin," Weekly Undergraduate Seminar, Mississippi State University, Columbus, MS, November 6, 1986.

"New Issues in Design for Testability," Stanford University, Stanford, CA, November 18, 1986.

"New Issues in Design for Testability," Tektronix Research Laboratories, Beaverton, OR, November 19, 1986.

"Some New Results Using Structured Logic Design Methods," McGill University, Montreal, Quebec, Canada, March 10, 1987.

"A New Design for Testability Method," General Electric Central Research and Development Laboratories, Schenectady, NY, April 9, 1987.

"The Value of Endowed Funds for Research at The University of Texas at Austin," Endowed Donors Dinner, February 26, 1988.

"The Boolean Difference from a New Perspective," The Technical University of Trondheim, Trondheim, Norway, March 17, 1988.

"Automatic Test Pattern Generation for Digital Logic Circuits," IEEE Computer Society, The University of Texas at Austin, April 6, 1988.

"Automatic Test Pattern Generation for Digital Logic Circuits," Schlumberger Austin Systems Center, Austin, Texas, April 7, 1988.

"Automatic Test Pattern Generation for Digital Systems," AT&T, Murray Hill, New Jersey, April 15, 1988.

"An Empirical Comparison of Random-Pattern Testability Under Two Classes of Delay Fault Coverage," NCR Technical Information Exchange Session, MCC, Austin, Texas, May 4, 1988.

"Designing and Testing Integrated Circuits," The Honors Colloquium, The University of Texas at Austin, July 26, 1985, July 26, 1986, July 25, 1987, July 22, 1988, and July 22, 1989.

"Statistical Delay Fault Coverage and Defect Level for Delay Faults," IBM, Austin, Texas, September 22, 1988.

"Statistical Delay Fault Coverage and Defect Level for Delay Faults," Northeastern Univer sity, Boston, MA, March 9, 1989.

"Results from a Survey of Electronic Board Testing Methods," Digital Equipment Corporation, Andover, MA, September 18, 1990.

"Design Verification and Testing -- A Functional Perspective," Massachusetts Institute of Technology VLSI Seminar, Cambridge, MA, November 20, 1990.

"Design Verification and Testing -- A Functional Perspective," MCC, Austin, TX, December 4, 1990.

"Design Verification and Testing -- A Functional Perspective," Philips Research Laboratories, Eindhoven, The Netherlands, March 1, 1991.

"Design Verification and Testing -- A Functional Perspective," University of Virginia, Charlottesville, VA, July 19, 1991.

“All Tests are not Equally Valuable for Non-Target Defect Detection,” Center for Reliable Computing, Stanford University, Stanford, CA, November 13, 1992.

“All Tests are not Equally Valuable for Non-Target Defect Detection,” Center for Reliable Computing, Stanford University, Stanford, CA, November 13, 1992.

"New Testing Methods to Enhance Defect Detection using Existing Fault Models and CAD Tools," Computer Engineering Seminar, University of Illinois at Urbana-Champaign, April 15, 1997.

“The Beginning of the End for Stuck-at-Fault Based Testing,” Computer-Aided Design Seminar, University of California at Berkeley, October 23, 1997.

“A New Model for Defective Part Level Estimation and its Impact on Automatic Test Pattern Generation,” Texas Instruments, Dallas, TX, January 30, 1998.

TUTORIALS:

"Techniques for Designing More Testable Logic Networks," (with T. W. Williams), 27th Design Automation Conference Tutorial, Orlando, FL, June 28, 1990.

"Logic Testing and Design for Testability," Rockwell Testing Conference, Newport Beach, CA, January 17, 1991.

"Techniques for Designing More Testable Logic Networks," (with T. W. Williams), European Test Conference Tutorial, Munich, Germany, April 10-12, 1991.

"Techniques for Designing More Testable Logic Networks," (with T. W. Williams), 5th Annual European Computer Conference Tutorial, Bologna, Italy, May 13-16, 1991.

"Introduction to Integrated Circuit Design" Motorola (William Cannon Site), Austin, Texas, December 3, 5, 9, and 10 1991.

"Techniques for Designing More Testable Logic Networks," (with T. W. Williams), Nordic Workshop on Design Verification and Test, Roros, Norway, March 11, 1992.

"Introduction to Integrated Circuit Design" Motorola (Ed Bluestein Site), Austin, Texas, April 28-May 1, 1992.

"Techniques for Designing More Testable Logic Networks," (with T. W. Williams), 29th Design Automation Conference Tutorial, Anaheim, CA, June 12, 1992.

"Introduction to Integrated Circuit Design" Motorola (Ed Bluestein Site), Austin, Texas, September 1, 3, 8, and 10 1992.

"Techniques for Designing More Testable Logic Networks," (with T. W. Williams), International Test Conference Tutorial, Baltimore, MD, September 20, 1992.

"Introduction to Integrated Circuit Design" Motorola (William Cannon Site), Austin, Texas, December 14-17, 1992.

"Techniques for Designing More Testable Logic Networks," (with T. W. Williams), International Test Conference Tutorial, Baltimore, MD, September 20, 1992.

"Testing Digital Circuits and Design for Test," (with T. W. Williams), IEEE International ASIC Conference Tutorial, Rochester, NY, September 28, 1993.

"Techniques for Designing More Testable Logic Networks," (with T. W. Williams), International Test Conference Tutorial, Baltimore, MD, October 17, 1993.

"Introduction to Integrated Circuit Design" Motorola (Ed Bluestein Site), Austin, Texas, September 21-24, 1993.

"Introduction to Integrated Circuit Design" Motorola (Ed Bluestein Site), Austin, Texas, November 29 - December 2, 1993.

"Introduction to Integrated Circuit Design" Motorola (Ed Bluestein Site), Austin, Texas, March 21 - March 24, 1994.

"Introduction to Integrated Circuit Design" Motorola (William Cannon Site), Austin, Texas, April 5 - April 8, 1994.

"Introduction to Integrated Circuit Design" Motorola (Ed Bluestein Site), Austin, Texas, June 28 - July 1, 1994.

"Introduction to Integrated Circuit Design" Motorola (Ed Bluestein Site), Austin, Texas, September 13-16, 1994.

"Testing Digital Circuits and Design Using Scan and Self-Test," (with T. W. Williams), IEEE International ASIC Conference Tutorial, Rochester, NY, September 19-23, 1994.

PATENTS:

"Scan Testable Integrated Circuit" (with V. D. Agrawal), Patent 4,493,077, United States Patent and Trademark Office, issued January 8, 1985.

"Universally Testable Logic Elements and Method for Structural Testing of Logic Circuits Formed of Such Logic Elements," Patent 4,625,310, United States Patent and Trademark Office, issued November 25, 1986.

GRANTS AND CONTRACTS:

University Research Institute, "A New Automatic Test Generation Algorithm," April-August, 1983, $2,136.

Hewlett-Packard Equipment Grant, 1984, $2,800.

Bureau of Engineering Research, "Generalized Graph Operations for CAD Systems," 1984, $3,000.

Microelectronics and Computer Technology Corporation, "Rule Based Automatic Test Pattern Generation Using Boolean Difference Concepts," January 1 - December 31, 1985, $48,976.

GE Calma, "Software License for the TEGAS Logic Simulator," May, 1983 - August, 1986, $135,000 commercial value.

AT&T Information Systems, "Automatic Testing for Faults in Digital Systems," January 1, 1985 - August 31, 1986, $25,000.

Microelectronics and Computer Technology Corporation, "Test Generation for Faults," January 1 - December 31, 1986, $25,000.

International Test Foundation, "Automatic Test Pattern Generation for Delay Faults in Digital Logic Circuits," September 1, 1986 - August 31, 1987, $14,592.

AT&T Information Systems, "Fault Detection in Digital Systems", May 1, 1986 - December 31, 1987, $30,000.

Microelectronics and Computer Technology Corporation, "Continuation of Testing Research," January 1 - December 31, 1987, $25,000.

AT&T Information Systems, "Continuation of Fault Detection Research," May 1, 1987 - December 31, 1988, $25,000.

International Test Foundation, "Test Technology in the Electrical Engineering Curriculum," January 1, 1988 - July 1, 1989, $30,985. ($10,153 for NSF Matching)

Microelectronics and Computer Technology Corporation, "Continuation of Testing Research," January 1 - December 31, 1988, $25,000.

Microelectronics and Computer Technology Corporation, "Testable System Design of Digital Systems and Knowledge Based Structures," (with Xi-an Zhu) April 1, 1988 - March 31, 1989, $92,750.

Office of Naval Research, "Fault-Tolerant Design Techniques for Advanced Digital Architectures" (with M. Malek), Contract #N00014-86-K-0554, July 1, 1986 - December 31, 1988, $180,000.

National Science Foundation Presidential Young Investigator Award, Grant #MIPS-8552537, June 1, 1986 - May 31, 1991, up to $500,000 (with matching industrial funds).

AT&T Information Systems, "Topological Testing," September 1, 1988 - August 31, 1989, $25,000.

Semiconductor Research Corporation, "The Design of Testable Systems" (with J. Abraham, J. Rahmeh and W. Rogers), SRC Contract, September 1, 1988 - August 31, 1989, $20,000.

Office of Naval Research, "Testing and Fault-Tolerant Design Techniques for Advanced Digital Architectures" (with M. Malek), Contract #N00014-86-K-0554, January 1, 1989 - December 31, 1991, $240,000.

Semiconductor Research Corporation, "The Design of Testable Systems" (with J. Abraham, J. Rahmeh and W. Rogers), SRC Contract #88-DJ-142, January 15, 1989 - January 14, 1990, $250,000.

IBM Corp., "Electronic Testing -- Department Grant" (with J. Abraham), August 1, 1989 - July 31, 1992, $75,000.

Cimflex Teknowledge, "Knowledge Based Design for Testability" (with Xi-an Zhu), June 13 - December 31, 1989, $28,015.

Microelectronics and Computer Technology Corporation, "Continuation of Testing Research," December 7, 1989 - December 31, 1990, $5,000.

Semiconductor Research Corporation, "The Design of Testable Systems" (with J. Abraham, J. Rahmeh, W. Rogers, and L. Pillage), SRC Contract #90-DP-142, January 15, 1990 - January 14, 1991, $350,000.

Texas Advanced Technology Program, "Refined Models of Integrated Circuit Defects Inducing Additional Delays," (with Lawrence T. Pillage), April 24, 1990 - August 31, 1991, $ 137,922.

Semiconductor Research Corporation, "The Design of Testable Systems" (with J. Abraham, J. Rahmeh, W. Rogers, and L. Pillage), SRC Contract #91-DP-142, January 15, 1991 - August 31, 1992, $585,000.

Motorola, Inc., "Timing Analysis for Integrated Circuits," (with Lawrence T. Pillage), November 29, 1991 - December 31, 1992, $10,000.

Office of Naval Research, "Enhanced Timing Analysis for Reliable Wafer Scale Integrated Systems," Contract #N00014-92-J-1723, May 1, 1992 - April 30, 1995, $300,000.

Semiconductor Research Corporation, "The Design of Testable Systems" (with J. Abraham, W. Rogers, and L. Pillage), SRC Contract #92-DP-142, September 1, 1992 - August 31, 1993, $370,000.

Advanced Research Projects Agency (ARPA), "A Unified CAD Tool for Integrated Systems," (with Dean Neikirk and Lawrence T. Pillage) DAAL01-93-K-3317, February 26, 1993 - February 26, 1995, $648,069.

Semiconductor Research Corporation, "The Design of Testable Systems" (with J. Abraham),
SRC Contract #93-DP-142, September 1, 1992 - August 31, 1993, $270,000.

National Science Foundation, "ARI: Development of a Novel Systems Software for Multimedia and High-Performance Computing," Reddy, Mercer, Lu, Cantrell, and Choi, September 15, 1996 - August 31, 1999, $127,450, (Equipment grant).

Texas Advanced Technology Program, "Defect-Directed Test Pattern Generation for Manufacture Testing of Integrated Circuits," January 1, 1998 - December 31, 1999, $139,491.

Semiconductor Research Corporation Custom Research Proposal Sponsored by Texas Instruments, "Automatic Test Pattern Generation for Defect-Directed At-Speed Testing," (with Mike Grimaila) August 1, 2000 - July 31, 2003, $165,000.

U. S. Department of Education, "Meeting the Purposes of Authorizing Statue," (with N. Reddy and K. Watson) August 1, 2001 - July 31, 2004, $ 327,600.

IBM Faculty Partnership Award, "Novel Techniques for Quantifying Confidence during Multi-Processor Verification, Validation, Debug, and Diagnosis," August 1, 2001 - July 31, 2002, $ 25,000.

AMD Research Support Grant, “Integrated Circuit Testing,” November 1, 2001 – October 31, 2002, $ 8,000.

Texas Advanced Technology Program, "Integrating Design Verification Techniques with Defect-Oriented ATPG for Very Deep Submicron Systems," April 18, 2002 - December 31, 2003, $139,720.

IBM Faculty Partnership Award, "A New Approach During Multi-Processor Verification and Validation for Estimating Design Correctness," August 1, 2002 - July 31, 2003, $ 25,000.

IBM Faculty Partnership Award, "Quantifying Design Correctness during Multi-Processor Verification and Validation,” August 1, 2003 - July 31, 2004, $ 25,000.

IBM Faculty Partnership Award, "A Study of AC Timing Defects: Test Pattern Quality and its Relationship to Real-Time System Errors,” August 1, 2004 - July 31, 2005, $ 25,000.

COURSES AT TEXAS A&M UNIVERSITY:

Semester		Course #	Course Title
Fall	2004	EE 680	Testing and Diagnosis of Digital Systems
Fall	2003	EE 652	Switching Theory
Spring	2003	EE 248	Introduction to Digital Logic Design
Spring	2002	EE 248	Introduction to Digital Logic Design
Spring	2001	EE 248	Introduction to Digital Logic Design
Fall	2000	EE 652	Switching Theory
Spring	2000	EE 248	Introduction to Digital Logic Design
Fall	1999	EE 680	Testing and Diagnosis of Digital Systems
Spring	1999	EE 248	Introduction to Digital Logic Design
Fall	1998	EE 652	Switching Theory
Spring	1998	EE 248H	Introduction to Digital Logic Design -- Honors
Fall	1997	EE 680	Testing and Diagnosis of Digital Systems
Spring	1997	EE 248	Introduction to Digital Logic Design
Fall	1996	EE 652	Digital Systems Design
Spring	1996	EE 248	Introduction to Digital Logic Design
Fall	1995	EE 680	Testing and Diagnosis of Digital Systems

COURSES AT THE UNIVERSITY OF TEXAS AT AUSTIN:

Semester		Course #	Course Title
Spring	1995	EE 382M	Topics in Design Verification and Testing
Spring	1994	EE 360M	Digital Systems Engineering II
Fall	1993	EE 382L	Switching Theory
Spring	1993	EE 360M	Digital Systems Engineering II
Fall	1992	EE 382M	Fault Tolerant Computing I
Spring	1992	EE 360M	Digital Systems Engineering II
Fall	1991	EE 382L	Switching Theory
Spring	1991	EE 360M	Digital Systems Engineering II

Fall	1990	EE 382L	Switching Theory
Spring	1990	EE 382M	Fault Tolerant Computing I
Fall	1989	EE 382L	Switching Theory
Spring	1989	EE 382M	Fault Tolerant Computing I
Fall	1988	EE 382L	Switching Theory
Spring	1988	EE 382M	Fault Tolerant Computing I
Fall	1987	EE 382L	Switching Theory
Fall	1987	EE 360M	Digital Systems Engineering II
Spring	1987	EE 382M	Fault Tolerant Computing I
Spring	1986	EE 382M	Fault Tolerant Computing I
Spring	1986	EE 360M	Digital Systems Engineering II
Fall	1985	EE 382L	Switching Theory
Spring	1985	EE 382M	Fault Tolerant Computing I
Fall	1984	EE 382L	Switching Theory
Fall	1984	EE 360M	Digital Systems Engineering II
Spring	1984	EE 382M	Fault Tolerant Computing I
Spring	1984	EE 382M	Fault Tolerant Computing I
Fall	1983	EE 382L	Switching Theory
Summer	1983	EE 382L	Computer Logic Simulation
Spring	1983	EE 360M	Digital Systems Engineering II

PH.D. SUPERVISIONS COMPLETED:

Thomas E. Kirkland	1986	University of Texas at Austin
Ki Soo Hwang	1986	University of Texas at Austin
Rhonda Gaede	1988	University of Texas at Austin
C. T. Glover	1989	University of Texas at Austin
Eun Sei Park	1989	University of Texas at Austin
Kenneth Butler	1990	University of Texas at Austin
Don Ross	1990	University of Texas at Austin
Bret Stewart	1990	University of Texas at Austin
Rohit Kapur	1992	University of Texas at Austin
Mark Heap (with W. A. Rogers)	1993	University of Texas at Austin
Ronn Brashear	1994	University of Texas at Austin
Jaehong Park	1995	University of Texas at Austin
Chanhee Oh	1995	University of Texas at Austin
Li-Chung Wang	1996	University of Texas at Austin
Steve Smith	1996	University of Texas at Austin

Mike Grimaila August 1999 Texas A&M University
Maximizing Non-Target Defect Detection Using Conventional Stuck-at Fault-Based Automated Test Pattern Generation Tools

Sooryong Lee August 2003 Texas A&M University
A New ATPG Algorithm to Generate a Compact Test Sets Which Detect Static and Dynamic Defects in VLSI Circuits

Jennifer Dworak May 2004 Texas A&M University
Modeling Defective Part Level Due to Static and Dynamic Defects Based upon Site Observation and Excitation Balance

M.S. SUPERVISIONS COMPLETED:

Dong Whoan Kim	1984	University of Texas at Austin
Hosung Kim	1984	University of Texas at Austin
Eric J. Schell	1984	University of Texas at Austin
James McKenzie	1985	University of Texas at Austin
Rhonda Gaede	1986	University of Texas at Austin
Ken Butler	1987	University of Texas at Austin
Steve McMahan	1987	University of Texas at Austin
Yi-Feng Lin (Report)	1988	University of Texas at Austin
Tarak M. Parikh	1988	University of Texas at Austin
Wilburn Underwood	1988	University of Texas at Austin
Chih-Teng Hung	1989	University of Texas at Austin
Marvin Denman	1990	University of Texas at Austin
Mark Naiver	1993	University of Texas at Austin
David Carlson	1994	University of Texas at Austin

Mehler, Ronald W. September 1998 Texas A&M University

Koh, T-Pinn Ronnie December 1998 Texas A&M University

Jennifer Dworak May 2000 Texas A&M University
(Texas A&M University Honors Program 1997-1998)

Jason Wicker December 2001 Texas A&M University
An Analysis of Test Effectiveness via Surrogate Simulation of a Commercial IC

Michael Trinka August 2003 Texas A&M University
Defect Site Prediction Based Upon Statistical Analysis of Fault Signatures

Bradley Douglas Cobb December 2003 Texas A&M University
(Texas A&M University Honors Program 2000-2001)
Ordered Partial Decision Diagrams and their use in Manufacture-Test Generation

David Dorsey December 2003 Texas A&M University
(Texas A&M University Honors Program 2001-2002)
Estimating the Expected Latency to Failure Due to Manufacturing Defects

James Wingfield December 2003 Texas A&M University
Approaches to Test Set Generation using Binary Decision Diagrams

TEXAS A&M UNIVERSITY UNDERGRADUATE HONORS RESEARCH PROJECT SPONSOR:

Jennifer Dworak	1998	Best Student Presentation Award
Brad Cobb	2000	Best Student Presentation Award
David Dorsey	2002	Best Paper Award
Jeff Cobb	2003	
Jason Vanfickell	2003	
Nate Davis	2004	

PREVIOUS UNDERGRADUATE RESEARCH STUDENTS:

Theresa Huth	Spring 2003 (Winner of an Undergraduate Student Research Best Oral Presentation Award)
Adam Skelton	(Winner of the Thomas S. Gathright Academic Excellence Award Top Junior in the College of Engineering for 2000 - 2001)
John Lee	Fall 2003 & Spring 2004
Cynthia McReynolds	Summer 2003 & Fall 2003
William Charles Price	Fall 2003 & Spring 2004
Justin Ray	Summer 2003 & Fall 2003
Jason Vanfickell	Summer 2003, Fall 2003 & Spring 2004
Jeff Cobb	Fall 2003 & Spring 2004 & Fall 2004
Nate Davis	Fall 2003 & Spring 2004

POST DOCTORAL RESEARCHERS:

Xian Zhu	1988 -- 1990
Kenneth Butler	1990 (Fall)
Don Ross	1990 -- 1991
Mike Grimaila	1999 – 2001
Jennifer Dworak	2004 (Summer and Fall)

SHORT BIOGRAPHY:

M. Ray Mercer is a Professor Emeritus of Electrical and Computer Engineering at Texas A & M University. In September of 2005 he retired as Professor of Electrical and Computer Engineering, Leader of the Computer Engineering Group, and holder of the Computer Engineering Chair. His research interests are centered in computer engineering and include: the computer-aided design of digital systems, design verification, simulation, design for testability, the modeling of logic networks, automatic test pattern generation, distributed computation, communications, and fault-tolerant computing.

Previously, Dr. Mercer worked at: The University of Texas, Austin, TX; AT&T Bell Laboratories, Murray Hill, NJ; Hewlett-Packard Laboratories, Palo Alto, CA; and General Telephone and Electronics, Mountain View, CA. He holds a B.S.E.E. from Texas Tech University, an M.S.E.E. from Stanford University, and a Ph.D. in Electrical Engineering from The University of Texas at Austin. He was the Program Chairman for the 1989 International Test Conference and holds two patents in design for testability. Mercer became a National Science Foundation Presidential Young Investigator in 1986; he has won Best Paper Awards at the International Test Conference (in 1982), the Design Automation Conference (in 1991), and the VLSI Test Symposium (in 1999); he is a Fellow of the Institute of Electrical and Electronics Engineers.

230318

M. RAY MERCER

PREVIOUS CASES
TESTIMONY IN LAST SIXTEEEN YEARS

Cause:	Inter Partes Review of U.S. Patent No. 8,090,309 B2 to Krampf et al.
Parties:	Apple Inc. Petitioner v. Chestnut Hill Sound Inc., Patent Owner.
Case:	Case IPR2016-00794
Court:	USPTO
Firm:	Fish & Richardson P.C.
Issue:	Invalidity
Testimony:	Deposition on Invalidity 11/11/2016

Cause:	TracBeam, LLC, v T-Mobile US, Inc., and T-Mobile USA, Inc.,
Case:	Case No. 6:14-cv-678-RWS
Court:	U. S. District Court – Eastern District of Texas, Tyler Division
Firm:	Keker & Van Nest, LLP, San Francisco (for T-Mobile), and Perkins Coie LLP, Washington, DC, and San Diego, CA, (for Telecommunication Systems, Inc.)
Issue:	Non-infringement
Testimony:	Deposition on September 9/21/2016

Cause:	LEAM Drilling Systems LLC v. MicroPulse, LLC, Kenneth C. Miller, and Abraham Erdos
Case:	Cause No. 2016-35945
Court:	District Court of Harris County, Texas, 295th Judicial District
Firm:	Morgan, Lewis & Bockius LLP
Issue:	Testing and Selection of Down-Hole Electronic Components for Horizontal Drilling
Testimony:	Deposition on 7/4/2016
Testimony:	Testimony at Hearing on Petition for Continuation of Temporary Restraining Order 7/6 & 7/2016

Cause:	Orange Electronic Co., Ltd. v. Orange Electronic North America, LLC (“OENA”) and Steve Norris
Case:	Case No. 13 CV 84861
Court:	The Court of Common Pleas, Warren County, Ohio, Civil Division
Firm:	Locke Lord LLP
Issue:	Manufacturing Testing and Product Quality
Testimony:	Deposition on 6/10/2016

Cause:	Inter Partes Review of U.S. Patent No. 7,003,357 to Kreikemeier et al.
Parties:	Lindsay Corporation Petitioner v. Valmont Industries, Inc. Patent Owner.
Case:	Case IPR 2015-01039
Court:	USPTO
Firm:	Fish & Richardson P.C.
Issue:	Validity
Testimony:	Deposition on Validity 4/12/2016

Cause:	Inter Partes Review of U.S. Patent No. 8,725,063 to Krampf et al.
Parties:	Apple Inc. Petitioner v. Chestnut Hill Sound Inc., Patent Owner.
Case:	Case IPR2015-01465
Court:	USPTO
Firm:	Fish & Richardson P.C.
Issue:	Invalidity
Testimony:	Deposition on Invalidity 4/5/2016

Cause:	Prism Technologies LLC v. Sprint Spectrum L.P.
Case:	Civil Action No. 8:12-cv-123-LES-TDT
Court:	U. S. District Court – District of Nebraska
Firm:	Shook, Hardy & Bacon LLP
Issue:	Non-Infringement and Invalidity
Testimony:	Deposition on Non-Infringement 1/12/2015
Testimony:	Deposition on Invalidity 2/12/2015
Testimony:	Court testimony on Non-Infringement at Jury Trial (in Omaha, Nebraska) on 6/22/2015

Cause:	ABSTRAX, INC., v. HEWLETT-PACKARD COMPANY
Case:	Civil Action No. 2:14-CV-158
Court:	U. S. District Court – Eastern District of Texas, Marshall Division
Firm:	Fish & Richardson, P. C., Dallas and Houston, TX for HP
Issue:	Invalidity
Testimony:	Deposition on Invalidity 3/20/2015

Cause:	Inter Partes Review of U.S. Patent No. US 5,602,524 to Mock
Parties:	CONTINENTAL AUTOMOTIVE SYSTEMS, INC., Petitioner, v. W ASICA FINANCE GMBH & BLUEARC FINANCE AG, Patent Owner.
Case:	Trial No. IPR2014-00295
Court:	USPTO
Firm:	BRINKS GILSON & LIONE
Issue:	Invalidity
Testimony:	Deposition on Invalidity 9/17/2014 & 1/22/2015

Cause:	Inter Partes Review of U.S. Patent No. US 5,502,689 to Peterson et al.
Parties:	NISSAN NORTH AMERICA, INC. Petitioner v. NORMAN IP HOLDINGS, LLC, Patent Owner.
Case:	Trial No. IPR2014-00563
Court:	USPTO
Firm:	Hartline Dacus Barger Dreyer LLP
Issue:	Invalidity
Testimony:	Deposition on Invalidity 1/3/2015

Cause:	Comcast IP Holdings I, LLC v. Sprint Communications Company, L. P.
Case:	C.A. No.: 1:12-CV-00205-RGA
Court:	U. S. District Court – District of Delaware
Firms:	Shook, Hardy & Bacon L.L.P., Houston, TX for Sprint
Firms:	McGuireWoods, L.L.P., Richmond, VA, for Sprint
Issue:	Invalidity and Non-Infringement
Testimony:	Deposition on Invalidity and Non-Infringement 12/18/2013
Testimony:	Deposition on Invalidity and Non-Infringement 12/20/2013
Testimony:	Court testimony on Non-Infringement at Jury Trial (in Wilmington, Delaware) on 10/8/2014

Cause:	Uniloc USA, Inc. et al. v. Activision Blizzard, Inc.
Case:	Civil Action No. 6:13-cv-00256
Court:	U. S. District Court -- Eastern District of Texas, Tyler Division
Firm:	Shook, Hardy & Bacon LLP
Issue:	Non-Infringement and Marking
Testimony:	Deposition on Non-Infringement 8/30/2014
Testimony:	Deposition on Marking 9/10/2014

Cause:	Inter Partes Review of U.S. Patent Nos. 5,978,791, 6,415,280, 6,928,442, 7,802,310, and 8,099,420 to Farber
Parties:	Rackspace US, Inc. and Rackspace Hosting, Inc. v. PersonalWeb Technologies, LLC. & Level 3 Communications
Case:	Trial No. IPR 2014-00057
Court:	USPTO
Firm:	Haynes and Boone, LLP
Issue:	Invalidity
Testimony:	Deposition on Invalidity 6/24/2014

Cause:	Inter Partes Review of U.S. Patent No 6,978,346 to Baek et al.
Parties:	Dell Inc., Hewlett-Packard Co., and NetApp, Inc. v. Electronics and Telecommunications Research Institute
Case:	Case No. IPR 2013-00635
Court:	USPTO
Firm:	Haynes and Boone, LLP
Issue:	Invalidity
Testimony:	Deposition on Invalidity 6/3/2014

Cause:	GeoTag, Inc. v. Darden Corporation, et al.
Case:	Civil Action No. 2:10-CV-00572
Court:	U. S. District Court -- Eastern District of Texas, Marshall Division
Firm:	Alston & Bird LLP
Issue:	Non-Infringement
Testimony:	Deposition on Non-Infringement 5/28/2014

Cause:	LBS Innovations, LLC v. Sally Beauty Supply, LLC, et al.
Case:	C.A. No. 2:11-cv-00409 (Consolidated C.A. No. 2:11-cv-00407)
Court:	U. S. District Court -- Eastern District of Texas, Marshall Division
Firms:	Alston & Bird LLP, Atlanta, GA for American Express Company, Barnes & Noble, Inc., Bed Bath & Beyond Inc., Home Depot U.S.A., Inc., and SunTrust Banks, Inc.
Issue:	Non-Infringement
Testimony:	Deposition on Non-Infringement 1/9 & 10/2014

Cause:	Schrader Electronics, Inc. v. Continental Automotive Systems US, Inc.
Case:	Case No. 2:12-CV-10715-SJM-MJH
Court:	U. S. District Court -- Eastern District of Michigan, Southern Division
Firms:	King & Spalding LLP, Washington, D. C. for Continental
Issue:	Invalidity and Non-Infringement
Testimony:	Deposition on Invalidity 10/11/2013
Testimony:	Deposition on Non-Infringement 10/14/2013

Cause:	SmartPhone Technologies, LLC v. Research In Motion Corp., et. al.,
Case:	Case No. 6:10-cv-00074-LED
Court:	U. S. District Court -- Eastern District of Texas, Tyler Division
Firms:	Morgan, Lewis & Bockius LLP. Washington, D. C. for LG Electronics.
Issue:	Non-Infringement
Testimony:	Deposition on Non-Infringement 2/6/2013

Cause:	In the Matter of Certain Computers and Computer Peripheral Devices and Components Thereof and Products Containing the Same, Inv. No. 337-TA-841
Court:	International Trade Commission, Washington, D. C.
Firms:	Jones Day, for Canon; Banner & Witcoff, Ltd., for Brother Industries, Ltd.; Kenyon & Kenyon for Hewlett Packard; Eastwind Consultants Company Ltd., for HiTi Digital Inc.; Law Offices of S.J. Christine Yang and Fish & Richardson, PC, for Kingston Technology Co., Inc.; The Webb Law Firm, for Newegg Inc. and Rosewill Inc; Kirkland & Ellis LLP for Seiko Epson Corporation.
Issue:	Noninfringement
Testimony:	Testimony before ALJ on noninfringement on 1/8/2013

Cause:	Abstrax, Inc. v. Sun Microsystems, Inc.
Court 1:	U. S. District Court -- Eastern District of Texas, Marshall Division
Firms 1:	Howrey, LLP, Washington, D. C., for Sun Microsystems
Issue:	Noninfringement
Testimony 1:	Deposition on noninfringement 5/6/2009
Court 2:	U. S. District Court -- Northern District of California -- Oakland Division
Firms 2:	Novak Druce & Quigg, LLP, West Palm Beach, FL for Oracle America, Inc.
Testimony:	Deposition on noninfringement 9/26/2012

Cause:	Prism Technologies, LLC. v. Adobe Systems, Inc., et al.
Court:	U. S. District Court – District of Nebraska
Firms:	Williams Morgan & Amerson, PC, Houston, TX for McAfee, Inc.
Issue:	Noninfringement
Testimony:	Deposition on Noninfringement 8/23/2012

Cause:	St. Clair Intellectual Property Consultants, Inc. v. Acer, Inc., et al.
Court:	U. S. District Court – District of Delaware
Firms:	Perkins Coie Brown & Bain, PA., Phoenix, AZ for Intel
Issue:	Invalidity and Noninfringement
Testimony:	Deposition on invalidity and noninfringement 4/20/2012

Cause:	Cisco Systems, Inc. v. MOSAID Technologies, Inc.
Court:	International Trade Commission, Washington, D. C.
Firms:	Hogan Lovells US LLP, San Francisco, CA for MOSAID
Issue:	Validity
Testimony:	Deposition on validity 1/19 & 20/2012

Cause:	Clear with Computers, LLC v. Hyundai Motor America, Inc.
Court:	U. S. District Court -- Eastern District of Texas, Tyler Division
Firms:	Winston & Strawn, LLP, Washington, DC for Hyundai
Issue:	Noninfringement
Testimony:	Deposition on noninfringement 4/26 & 27/2011
Testimony:	Deposition on Report Preparation 5/21/2011
Testimony:	Court testimony at Jury Trial (in Tyler, TX) on 6/16 & 17/2011

Cause:	Versata, Inc., et al. v. SAP America, Inc. and SAP AG
Court:	U. S. District Court -- Eastern District of Texas, Marshall Division
Firms:	Fish & Richardson, P. C., San Diego, CA for SAP
Issue:	Noninfringement and Damages
Testimony:	Deposition on noninfringement and damages 4/18/2011
Testimony:	Court testimony at Jury Trial (in Marshal, TX) on 5/11 & 12/2011

Cause:	SynQor, Inc. v. Artesyn, et al.
Court:	U. S. District Court -- Eastern District of Texas, Marshall Division
Firms:	Vasquez, Benisek, & Lindgren, LLP, Lafayette, CA for Lineage Power Corporation
Issue:	Invalidity
Testimony:	Deposition on invalidity 11/19/2010
Testimony:	Court testimony at Jury Trial (in Marshal, TX) on 12/20/2010

Cause:	Affinity Labs of Texas, LLC v. BMW North America LLC, et al.
Court:	U. S. District Court -- Eastern District of Texas, Tyler Division
Firms 1:	Crowell & Moring, LLP, Washington, DC for Mercedes, Howrey, LLP, Washington, DC for BMW, Akin, Gump, Strauss, Hauer & Feld, LLP, Washington, DC for Hyundai and Kia Motors
Issue 1:	Invalidity
Testimony 1:	Deposition on invalidity 06/18/2010
Firms 2:	Akin, Gump, Strauss, Hauer & Feld, LLP, Washington, DC for Hyundai and Kia Motors
Issue 2:	Invalidity
Testimony 2:	Court testimony at jury trial (in Lufkin, TX) on 10/27/2010

Cause:	Digital-Vending Services, International, LLC v. The University of Phoenix, Inc., et al.
Court:	U. S. District Court -- Eastern District of Virginia, Norfolk Division
Firms:	Morgan, Lewis, & Bockius, LLP, Houston, TX for The University of Phoenix
Issue:	Noninfringement
Testimony:	Deposition on noninfringement 09/17/2010

Cause:	Network-1 Security Solutions, Inc. v. Cisco Systems, Inc. et al.
Court:	U. S. District Court -- Eastern District of Texas, Tyler Division
Firms:	Simpson Thacher & Bartlett, LLP, Washington, DC for 3COM, Fulbright & Jaworski, LLP, Austin, TX for Adtran, Wilmer Cutler Pickering Hale and Dorr, Palo Alto, CA for Cisco, Vasquez Benisek & Lindgren, LLP, Lafayette, CA for Enterasys Networks, Jones Day, Palo Alto, CA for Extreme Networks, and Howrey, San Francisco, CA for Foundry Networks
Issue:	Invalidity
Testimony:	Deposition on invalidity 03/23/2010

Cause:	PACid Group, LLC, v. Apple Inc. et al.
Court:	U. S. District Court -- Eastern District of Texas, Tyler Division
Firms:	Fish & Richardson, P. C., Washington, DC for Intel
Issue:	Invalidity
Testimony:	Deposition on invalidity 03/12/2010

Cause:	Saxon Innovations, LLC, v. Apple Inc. et al.
Court:	U. S. District Court -- Eastern District of Texas, Tyler Division
Firms:	Perkins, Coie, Brown & Bain, LLP, Phoenix, AZ for Intel
Issue:	Noninfringement
Testimony:	Deposition on claim construction 01/15/2010

Cause:	MHL TEK, LLC, v. Nissan Motor Co. et al.
Court:	U. S. District Court -- Eastern District of Texas, Marshall Division
Firms:	Howrey, LLP, Washington, DC for BMW and Fish & Richardson, P.C. for Porsche
Issue:	Noninfringement
Testimony:	Deposition on noninfringement 11/11/2009

Cause:	O2 Micro International Ltd. v. Monolithic Power Systems, Inc., et al.
Court:	U. S. International Trade Commission, Washington, D. C.
Firms:	Howrey, LLP, San Francisco, CA., for O2 Micro
Issue:	Validity
Testimony:	Deposition on validity 8/27/2009
Testimony:	Testimony at ITC before ALJ on validity on 10/30/2009

Cause:	IBM Corp v. T3 Technologies, Inc.
Court:	U. S. District Court -- Southern District of New York
Firms:	Durie Tangri LLP, San Francisco, CA., for T3 Technologies
Issue:	Noninfringement
Testimony:	Deposition on noninfringement 8/21/2009

Cause:	Quantum World Corp. v. Atmel Corporation, et al.
Court:	U. S. District Court -- Eastern District of Texas, Marshall Division
Firms:	Dechert LLP, Austin, TX, for Lenovo
Issue:	Invalidity
Testimony:	Deposition on invalidity 3/6/2009

Cause:	SanDisk Corp. v. Afa Technologies, Inc. et al
Court:	U. S. International Trade Commission, Washington, D. C.
Firms:	Heller Ehrman, LLP, New York, NY for Afa Technologies, Inc. et al
Issue:	Infringement
Testimony:	Tutorial before ALJ on technology 5/6/2008 (Corsair & PQI)
Testimony:	Deposition on noninfringement 9/12 & 13/2008 (Afa, Chipsbank, & Skymedi)
Testimony:	Deposition on noninfringement and invalidity 9/22/2008 (Corsair & PQI)
Testimony:	Testimony at ITC before ALJ on non-infringement and invalidity on 11/3/2008 (Imation & Skymedi)

Cause:	BIAX Corp. v. Fujitsu Computer Systems Corporation, et. al.
Court:	U. S. District Court -- Eastern District of Texas, Marshall Division
Firms:	Kirkland & Ellis LLP, Palo Alto, CA, for Sun Microsystems, Inc.
Issue:	Invalidity and Noninfringement
Testimony:	Deposition on invalidity and noninfringement 10/20/2008

Cause:	Alcatel USA Resources, Inc. v. Microsoft Corporation
Court:	U. S. District Court -- Eastern District of Texas, Tyler Division
Firms:	Fish and Richardson, Austin, Texas, for Microsoft Corporation
Issue:	Noninfringement
Testimony:	Deposition on noninfringement and invalidity 9/26/2008

Cause:	Blackboard Inc. v. Desire2Learn Inc.
Court:	U. S. District Court -- Eastern District of Texas, Lufkin Division
Firms:	Foley & Lardner, LLP, Chicago, IL for Desire2Learn.
Issue:	Infringement
Testimony:	Deposition re. Motion for Contempt 7/12/2008
Testimony:	Motion for Contempt 7/21/2008

Cause:	Hewlett-Packard Corp. v. Acer Inc. and Acer America Corp.
Court:	U. S. International Trade Commission, Washington, D. C.
Firms:	Orrick, Herrington & Sutcliffe, LLP, Irvine, CA, for Acer Inc.
Issue:	Noninfringement
Testimony:	Deposition on noninfringement, invalidity, and domestic industry on 12/22/2007
Testimony:	Deposition on noninfringement on 2/16/2008
Testimony:	Testimony at ITC before ALJ on noninfringement and invalidity on 2/19/2008

Cause:	Value-Added Communications, Inc. v. T-NETIX, Inc.
Court:	District Court of Dallas County, Texas – 44th Judicial District
Firms:	Jones Day, Dallas, TX, for Value-Added Communications, Inc.
Issue:	Improvements and additions to licensed patents in contract agreement
Testimony:	Deposition on 6/29/2006
Testimony:	Deposition on 12/13/2007
Testimony:	Court testimony at jury trial (State Case) on 1/25/2008 and 1/30/2008

Cause:	Computer Acceleration Corp. v. Microsoft Corp.
Court:	U. S. District Court -- Eastern District of Texas, Lufkin Division
Firms:	Weil, Gotshal & Manges, LLP, Houston, TX, for Microsoft Corp.
Issue:	Noninfringement and invalidity
Testimony:	Deposition on noninfringement and invalidity on 10/11/2007
Testimony:	Court testimony at jury trial (in Beaumont, TX) on 11/13 & 14/2007

Cause:	Mobile Micromedia LLC. v. Nissan North America, Inc.
Court:	U. S. District Court -- Eastern District of Texas, Texarkana Division
Firms:	Steptoe & Johnson, LLP, Washington, DC, for Nissan North America, Inc.
	Hartline, Dacus, Barger, Dreyer & Kern, Dallas, TX, for Nissan North America, Inc.
Issue:	Noninfringement and invalidity
Testimony:	Deposition on noninfringement and invalidity on 10/5/2007

Cause:	Forgent Networks, Inc. v. Echostar Communications, et al
Court:	U. S. District Court -- Eastern District of Texas, Tyler Division
Firms:	Bracewell & Giuliani, Houston, TX, for Forgent Networks Corporation
Issue:	Infringement
Testimony:	Deposition on claim construction on 9/6/2006
Testimony:	Testimony on claim construction at Markman Hearing on 11/9/2006
Testimony:	Deposition on infringement and validity on 3/28-30/2007
Testimony:	Court testimony at jury trial on 5/14 & 18/2007

Cause:	BIAX Corporation v. Intel Corporation, et al
Court:	U. S. District Court -- Eastern District of Texas, Marshall Division
Firms:	Orrick, Herrington & Sutcliffe, LLP, Irvine, CA, for Intel Corporation
Issue:	Noninfringement and invalidity
Testimony:	Deposition on noninfringement and invalidity on 5/2/2007

Cause:	Samsung Electronics Co., Ltd. v. Quanta Computer Inc. and Compal Electronics, Inc.
Court:	U. S. District Court – Northern District of California – San Francisco Division
Firms:	Orrick, Herrington & Sutcliffe, LLP, Menlo Park, CA, for Compal Electronics, Inc.
Issue:	Invalidity
Testimony:	Deposition on invalidity 3/16/2006
Testimony:	Court testimony at jury trial on 11/15/2006

Cause:	Maurice Mitchell Innovations, L.P. v. Intel Corporation
Court:	U. S. District Court -- Eastern District of Texas, Marshall Division
Firms:	Keker & Van Nest, San Francisco, CA, for Intel Corporation
Issues:	Invalidity and Noninfringement
Testimony:	Deposition on patent invalidity and noninfringement on 7/13 and 7/14/2006
Testimony:	Deposition on noninfringement on 10/26/2006

Cause:	Samsung Electronics Co., Ltd. v. Inventec Corporation
	and Inventec Manufacturing (North America Corporation
Court:	U. S. District Court – Southern District of Texas – Houston Division
Firms:	Gibbs and Bruns, L.L.P. and Wong Cabello, Houston, Texas, for Inventec Corporation
Issue:	Invalidity and noninfringement
Testimony:	Deposition on 2/14/2005

Cause:	Antor Media Corporation v. Apple Computer Inc., et al. 2003-2005
Court:	U. S. District Court -- Eastern District of Texas, Marshall Division
Firms:	Fulbright & Jaworski, Dallas and Houston, TX, for Antor Media
Issue:	Infringement and Validity
Testimony:	Deposition on 12/10 & 11/2004

Cause:	Motorola, Inc. v. Analog Devices, Inc.
Court:	U. S. District Court – Eastern District of Texas – Beaumont Division
Firms:	Hale and Dorr, Boston, Massachusetts, for Analog Devices Inc.
Testimony:	Deposition on Proposed Markman construction on 11/17/2003

Cause:	Broadcom Corporation v. Intel Corporation
Court:	U. S. District Court – Eastern District of Texas – Texarkana Division
Firms:	Fish and Richardson, San Diego, California, for Intel Corporation
Testimony:	Deposition on Proposed Markman constructions on 10/16/2002
Testimony:	Deposition on Infringement and Validity (Counter Claims) on 5/21 & 22/2003
Testimony:	Deposition on Noninfringement and Invalidity on 5/23/2003

Cause:	Lynntech, Inc. v. Hydrogenics Corp.
Court:	U. S. District Court – Southern District of Texas – Houston Division
Firms:	Streets and Steele, Houston, Texas, for Lynntech, Inc.
Issue:	Infringement and validity
Testimony:	Deposition on 4/18/2003

Cause:	Samsung Electronics Co., Ltd. v. Arima Computer Corporation
Court:	U. S. District Court – Southern District of Texas – Houston Division
Firms:	Trop, Pruner & Hu, Houston, Texas, for Arima Corporation
Issue:	Noninfringement and Invalidity
Testimony:	Deposition on 9/24 & 25/2002
Testimony:	Testimony at Markman on 11/13/2002

Cause:	Parental Guide of Texas, Inc. v. Funai Corp., et al.
Court:	U. S. District Court – Eastern District of Texas
Firms:	Fulbright and Jaworski, et al., Houston, Texas, for Thomson multimedia Inc., et al.
Issue:	Noninfringement and Invalidity
Testimony:	Deposition on 9/19 & 20/2002

Cause:	Harris Corporation v. Independent Technologies, Inc. 2002
Court:	U. S. District Court – Central District of California, Western Division
Firms:	Holland & Knight, Tampa, Florida, for Harris
Issue:	Noninfringement
Testimony:	Deposition on 4/8/2002
Testimony:	Court testimony at jury trial on 6/12/2002 and 6/18/2002

Cause:	Harris Corporation vs. Sanyo North America Corporation, et al. 1999-2001
Court:	U. S. District Court -- Northern District of Texas, Dallas Division
Firms:	Fulbright & Jaworski, Dallas, TX, for Harris
Issue:	Infringement
Testimony:	Deposition prior to Markman hearing
Testimony:	Markman hearing
Testimony:	Court testimony at jury trial on 8/30/2001

Cause:	Overhead Door Corp. and GMI vs. The Chamberlain Group, Inc., 2000
Court:	U. S. District Court -- Northern District of Texas, Dallas Division
Firms:	Akin, Gump, Strauss, Hauer, & Feld, Dallas, TX, for Overhead Door
Issue:	Nonnfringement and Invalidity
Testimony:	Deposition on patent invalidity 2000

Cause:	Crystal Semiconductor Corp. vs. Sigmatel, Inc., 1999-2000
Court:	U. S. District Court -- Western District of Texas, Austin Division
Firms:	Kirkland & Ellis, Chicago, IL and Taylor & Dunham, Austin, TX, for Sigmatel
Issue:	Noninfringement
Testimony:	Deposition on motion for injunction 2000

Exhibit B – Materials Considered

All materials referenced or cited in this report

U.S. Patent No. 8,441,438

U.S. Patent No. 8,441,438 File History

U.S. Patent No. 8,552,978

U.S. Patent No. 8,552,978 File History

Plaintiff CyWee Group Ltd.'s Opening Claim Construction Brief, dated February 23, 2018 (Dkt. No. 66)

Declaration of Joseph L. LaViola, Jr., Ph.D., dated February 23, 2018 (Dkt. No. 66-6)

Defendants' Responsive Claim Construction Brief, dated March 9, 2018 (Dkt. No. 67)

Plaintiff's Reply Claim Construction Brief, dated March 21, 2018 (Dkt. No. 71)

Patent Rule 4-5(d) Joint Claim Construction Chart, dated March 29, 2018 (Dkt. No. 75)

Plaintiff's April 17, 2018 Claim Construction Hearing Presentation (Dkt. No. 84)

Claim Construction Memorandum and Order, dated July 9, 2018 (Dkt. No. 117)

Order on Defendants' Objections to Magistrate Judge Payne's Claim Construction Memorandum and Order, dated August 14, 2018 (Dkt. No. 153)

CyWee's First Supplemental and/or Amended Objections and Responses to Apple's First Set of Interrogatories, dated October 14, 2016 (CYWEE_SAMSUNG011630–CYWEE_SAMSUNG011719)

CyWee's Infringement Contentions, dated July 12, 2017

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Plaintiff's Objections and Responses to Defendants' First Set of Interrogatories, dated November 22, 2017

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“CHR6dm Orientation Sensor from CH Robotics” Video (published March 10, 2010), available at https://www.youtube.com/watch?v=SUErVK7ix68

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U.S. Patent No. 6,061,611

U.S. Patent No. 7,817,134

U.S. Patent No. 7,924,264

U.S. Patent No. 8,138,938

U.S. Patent No. 8,515,707

EXHIBIT C

Asserted Claims

United States Patent No. 8,441,438

438.1.0 A three-dimensional (3D) pointing device subject to movements and rotations in dynamic environments, comprising:

438.1.1 a housing associated with said movements and rotations of the 3D pointing device in a spatial pointer reference frame;

438.1.2 a printed circuit board (PCB) enclosed by the housing;

438.1.3 a six-axis motion sensor module attached to the PCB,

438.1.4 comprising a rotation sensor for detecting and generating a first signal set comprising angular velocities ωx, ωy, ωz associated with said movements and rotations of the 3D pointing device in the spatial pointer reference frame,

438.1.5 an accelerometer for detecting and generating a second signal set comprising axial accelerations Ax, Ay, Az associated with said movements and rotations of the 3D pointing device in the spatial pointer reference frame; and

438.1.6 a processing and transmitting module, comprising a data transmitting unit electrically connected to the six-axis motion sensor module for transmitting said first and second signal sets thereof and a computing processor for receiving and calculating said first and second signal sets from the data transmitting unit,

438.1.7 communicating with the six-axis motion sensor module to calculate a resulting deviation comprising resultant angles in said spatial pointer reference frame by utilizing a comparison to compare the first signal set with the second signal set whereby said resultant angles in the spatial pointer reference frame of the resulting deviation of the six-axis motion sensor module of the 3D pointing device are obtained under said dynamic environments, wherein the comparison utilized by the processing and transmitting module further comprises an update program to obtain an updated state based on a previous state associated with said first signal set and a measured state associated with said second signal set; wherein the measured state includes a measurement of said second signal set and a predicted measurement obtained based on the first signal set without using any derivatives of the first signal set.

438.3 The 3D pointing device of claim 1, wherein the PCB enclosed by the housing comprises at least one substrate having a first longitudinal side configured to be substantially parallel to a longitudinal surface of the housing.

438.4 The 3D pointing device of claim 1, wherein the spatial pointer reference frame is a reference frame in three dimensions; and wherein said resultant angles of the resulting deviation includes yaw, pitch and roll angles about each of three orthogonal coordinate axes of the spatial pointer reference frame.

438.5 The 3D pointing device of claim 1, wherein the data transmitting unit of the processing and transmitting module is attached to the PCB enclosed by the housing and transmits said first and second signal of the six-axis motion sensor module to the computing processor via electronic connections on the PCB.

438.14.0 A method for obtaining a resulting deviation including resultant angles in a spatial pointer reference frame of a three-dimensional (3D) pointing device utilizing a six-axis motion sensor module therein and subject to movements and rotations in dynamic environments in said spatial pointer reference frame, comprising the steps of:

438.14.1 obtaining a previous state of the six-axis motion sensor module; wherein the previous state includes an initial-value set associated with previous angular velocities gained from the motion sensor signals of the six-axis motion sensor module at a previous time T-1;

438.14.2 obtaining a current state of the six-axis motion sensor module by obtaining measured angular velocities ωx, ωy, ωz gained from the motion sensor signals of the six-axis motion sensor module at a current time T;

438.14.3 obtaining a measured state of the six-axis motion sensor module by obtaining measured axial accelerations Ax, Ay, Az gained from the motion sensor signals of the six-axis motion sensor module at the current time T and

438.14.4 calculating predicted axial accelerations A_x', A_y', A_z' based on the measured angular velocities ω_x, ω_y, ω_z of the current state of the six-axis motion sensor module without using any derivatives of the measured angular velocities ω_x, ω_y, ω_z and

438.14.5 said current state of the six-axis motion sensor module is a second quaternion with respect to said current time T;

438.14.6 comparing the second quaternion in relation to the measured angular velocities ωx, ωy, ωz of the current state at current time T with the measured axial accelerations Ax, Ay, Az and the predicted axial accelerations Ax', Ay', Az' also at current time T;

438.14.7 obtaining an updated state of the six-axis motion sensor module by comparing the current state with the measured state of the six-axis motion sensor module; and

438.14.8 calculating and converting the updated state of the six axis motion sensor module to said resulting deviation comprising said resultant angles in said spatial pointer reference frame of the 3D pointing device.

438.15 The method for obtaining a resulting deviation of a 3D pointing device of claim14, further comprises the step of outputting the updated state of the six-axis motion sensor module to the previous state of the six-axis motion sensor module; and wherein said resultant angles of the resulting deviation includes yaw, pitch and roll angles about each of three orthogonal coordinate axes of the spatial pointer reference frame.

438.16 The method for obtaining a resulting deviation of a 3D pointing device of claim 14, wherein said previous state of the six-axis motion sensor module is a first quaternion with respect to said previous time T-1; and said updated state of the six-axis motion sensor module is a third quaternion with respect to said current time T.

438.17 The method for obtaining a resulting deviation of 3D pointing device of claim 14, wherein the obtaining of said previous state of the six-axis motion sensor module further comprises initializing said initial-value set.

438.19.0 A method for obtaining a resulting deviation including resultant angles in a spatial pointer reference frame of a three-dimensional (3D) pointing device utilizing a six-axis motion sensor module therein and subject to movements and rotations in dynamic environments in said spatial pointer reference frame, comprising the steps of:

438.19.1 obtaining a previous state of the six-axis motion sensor module; wherein the previous state includes an initial-value set associated with previous angular velocities gained from the motion sensor signals of the six-axis motion sensor module at a previous time T-1;

438.19.2 obtaining a current state of the six-axis motion sensor module by obtaining measured angular velocities ωx, ωy, ωz gained from the motion sensor signals of the six-axis motion sensor module at a current time T;

438.19.3 obtaining a measured state of the six-axis motion sensor module by obtaining measured axial accelerations Ax, Ay, Az gained from the motion sensor signals of the six-axis motion sensor module at the current time T and

438.19.4 calculating predicted axial accelerations A_x', A_y', A_z' based on the measured angular velocities ω_x, ω_y, ω_z of the current state of the six-axis motion sensor module without using any derivatives of the measured angular velocities ω_x, ω_y, ω_z;

438.19.5 said current state of the six-axis motion sensor module is a second quaternion with respect to said current time T;

438.19.6 comparing the second quaternion in relation to the measured angular velocities ωx, ωy, ωz of the current state at current time T with the measured axial accelerations Ax, Ay, Az and the predicted axial accelerations Ax', Ay', Az' also at current time T;

438.19.7 obtaining an updated state of the six-axis motion sensor module by comparing the current state with the measured state of the six-axis motion sensor module; and

438.19.8 calculating and converting the updated state of the six axis motion sensor module to said resulting deviation comprising said resultant angles in said spatial pointer reference frame of the 3D pointing device.

978.10.0 A method for compensating rotations of a 3D pointing device, comprising:

978.10.1 generating an orientation output associated with an orientation of the 3D pointing device associated with three coordinate axes of a global reference frame associated with Earth;

978.10.2 generating a first signal set comprising axial accelerations associated with movements and rotations of the 3D pointing device in the spatial reference frame;

978.10.3 generating a second signal set associated with Earth's magnetism;

978.10.4 generating the orientation output based on the first signal set, the second signal set and the rotation output or based on the first signal set and the second signal set;

978.10.5 generating a rotation output associated with a rotation of the 3D pointing device associated with three coordinate axes of a spatial reference frame associated with the 3D pointing device; and

978.10.6 using the orientation output and the rotation output to generate a transformed output associated with a fixed reference frame associated with a display device, wherein the orientation output and the rotation output is generated by a nine-axis motion sensor module;

978.10.7 obtaining one or more resultant deviation including a plurality of deviation angles using a plurality of measured magnetisms Mx, My, Mz and a plurality of predicted magnetism Mx', My' and Mz' for the second signal set.

978.12 The method of claim 10, wherein the orientation output is a rotation matrix, a quaternion, a rotation vector, or comprises three orientation angles.

Court's Claim Constructions (Dkt. Nos. 117, 153)

Term	Court's Construction
"three-dimensional (3D) pointing device"/ "3D pointing device" ('438 Patent, Claims 1, 3, 4, 5, 14, 15, 16, 17, 19) ('978 Patent, Claim 1)	Plain and ordinary meaning
"six-axis motion sensor"/"six-axis motion sensor module" ('438 Patent, Claims 1, 5, 14, 15, 16, 17, 19)	Plain and ordinary meaning
"global reference frame associated with Earth" ('978 Patent, Claim 10)	"reference frame with axes defined with respect to the Earth"
"using the orientation output and the rotation output to generate a transformed output associated with a fixed reference frame associated with a display device" ('978 Patent, Claim 10)	"using the orientation output and rotation output to generate a transformed output representing a movement in a fixed reference frame that is parallel to the screen of the display device"

Parties' Agreed Claim Constructions (Dkt. No. 75)

Term	Agreed Constructions
"calculating predicted axial accelerations Ax′, Ay′, Az′ based on the measured angular velocities ω_x, ω_y, ω_z of the current state of the six-axis motion sensor module without using any derivatives of the measured angular velocities ω_x, ω_y, ω_z" ('438 Patent, Claims 14, 19)	Plain and ordinary meaning
"detecting and generating a first signal set" ('438 Patent, Claim 1)	Plain and ordinary meaning
"detecting and generating a second signal set" ('438 Patent, Claim 1)	Plain and ordinary meaning
"resulting deviation comprising resultant angles in said spatial pointer reference frame"/ "resulting deviation comprising said resultant angles in said spatial pointer reference frame of the 3D pointing device" ('438 Patent, Claims 1, 14, 19)	Plain and ordinary meaning
"the measured state includes a measurement of said second signal set and a predicted measurement obtained based on the first signal set without using any derivatives of the first signal set" ('438 Patent, Claim 1)	"the measured state includes a measurement of axial accelerations and predicted axial accelerations calculated using the angular velocities without computing derivatives of said angular velocities (i.e. angular accelerations)"

Term	Agreed Constructions
"spatial pointer reference frame"/ "spatial pointer reference frame of a three-dimensional (3D) pointing device"/"spatial reference frame of the 3D pointing device"/"spatial reference frame associated with the 3D pointing device" ('438 Patent, Claims 1, 4, 14, 15, 19; '978 Patent Claim 10)	"frame of reference associated with the 3D pointing device, which always has its origin at the same point in the device and in which the axes are always fixed with respect to the device"