

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

Google LLC
Petitioner

v.

Cywee Group Ltd.
(record) Patent Owner

IPR2018-01257
IPR2018-01258

Patent No. 8,552,978
Patent No. 8,441,438

**REBUTTAL DECLARATION OF
PROF. MAJID SARRAFZADEH**

TABLE OF CONTENTS

I.	INTRODUCTION.....	3
II.	OVERVIEW	3
III.	UNDERSTANDING OF THE RELEVANT LAW	4
A.	Written Description	4
B.	Anticipation	5
C.	Obviousness	6
IV.	LEVEL OF ORDINARY SKILL IN THE ART	9
V.	RELEVANT TIMEFRAME FOR DETERMINING OBVIOUSNESS	9
VI.	LACK OF WRITTEN DESCRIPTION SUPPORT FOR THE PROPOSED AMENDED CLAIMS	10
A.	U.S. Provisional Application 61/292,558.....	13
B.	U.S. Application No. 12/943,934	17
VII.	OBVIOUSNESS OF THE PROPOSED AMENDED CLAIMS	18
A.	Overview of Withanawasam.....	19
B.	Overview of Bachmann	22
C.	Overview of the Combination	29
D.	Rationale for the Combination.....	30
E.	Reasonable Expectation of Success.....	38
F.	Analogous Art.....	39
G.	Specific Claim Limitations	39
VIII.	OATH.....	91

I. INTRODUCTION

1. I, Majid Sarrafzadeh, declare as follows.

2. The terms of my engagement and my qualifications are as-stated in my prior declarations, which are Exhibits 1002 in the *inter partes* review proceedings with trial numbers IPR2018-01257 and IPR2018-01258.

II. OVERVIEW

3. I understand that CyWee has filed contingent motions to amend U.S. Pats. Nos. 8,552,978 (“the ’978 patent”) and 8,441,438 (“the ’438 patent”). The motions to amend seek to add claims 19 and 20 to the ’978 patent, and to add claims 20 and 21 to the ’438 patent (“the Proposed Amended Claims”). I understand that CyWee seeks to add these claims to the respective patents, and if they are added, to cancel original claims 10 and 12 of the ’978 patent and claims 1 and 3 of the ’438 patent. The text of the claims is reproduced below, in ¶¶26-25.

4. I understand that CyWee contends that its Proposed Amended Claims are supported by the respective specifications of the ’978 and ’438 patents, and also by the provisional patent application, U.S. Provisional Patent Application 61/292,558, (“the ’558 Provisional”).

5. I am of the opinion that the Proposed Amended Claims are not supported by the ’558 Provisional. I understand that this would have as a consequence that the Proposed Amended Claims are not entitled to rely on the

January 6, 2010 filing date of the '558 Provisional.

6. I am also of the opinion that proposed claim 21 for the '438 and proposed claim 20 for the '978 patent (adding the limitation to a “smartphone”) are not supported by the specification of the '438 patent, including as originally filed (U.S. Application Serial Number 12/943,934) in Ex. 1009. I understand that this should mean that proposed amended claim 21 for the '438 patent would not be patentable, while proposed amended claim 20 for the '978 patent would not enjoy the benefit of the filing date of that application, but only (possibly) of later applications.

7. I am also of the opinion that proposed amended claims 19 and 20 for the '978 patent and proposed amended claim 20 for the '438 patent would be unpatentable as obvious over U.S. Patent Publication US 2010/0312468 A1 (“Withanawasam”)(Ex. 1017) in view of U.S. Pat. No. 7,089,148 (“Bachmann”)(Ex. 1003). Bachmann is the same reference I examined in my first declarations, Exhibits 1002 in the *inter partes* review proceedings with trial numbers IPR2018-01257 and IPR2018-01258.

III. UNDERSTANDING OF THE RELEVANT LAW

8. I have the following understanding of the applicable law:

A. Written Description

I understand that in order to satisfy the “written description” requirement, a

patent specification must describe the claimed invention in sufficient detail that one skilled in the art can reasonably conclude that the inventor had possession of the claimed invention. Possession of the claimed invention can be shown by describing the claimed invention with all of its limitations using such descriptive means as words, structures, figures, diagrams, and formulas that fully set forth the claimed invention. An adequate written description of a claimed genus requires more than a generic statement of an invention's boundaries. A sufficient description of a genus instead requires the disclosure of either a representative number of species falling within the scope of the genus or structural features common to the members of the genus so that one of skill in the art can visualize or recognize the members of the genus.

B. Anticipation

9. I understand that a claim in an issued patent can be unpatentable if it is anticipated. In this case, “anticipation” means that there is a single prior art reference that discloses every element of the claim, arranged in the way required by the claim.

10. I understand that an anticipating prior art reference must disclose each of the claim elements expressly or inherently. I understand that “inherent” disclosure means that the claim element, although not expressly described by the prior art reference, must necessarily be present based on the disclosure. I understand that a mere probability that the element is present is not sufficient to qualify as

“inherent disclosure”.

C. Obviousness

11. I understand that a claim in an issued patent can be unpatentable if it is obvious. Unlike anticipation, obviousness does not require that every element of the claim be in a single prior art reference. Instead, it is possible for claim elements to be described in different prior art references, so long as there is motivation or sufficient reasoning to combine the references.

12. I understand that a claim is unpatentable for obviousness if the differences between the claimed subject matter and the prior art are such that the subject matter as a whole would have been obvious at the time the alleged invention was made to a person having ordinary skill in the art to which said subject matter pertains.

13. I understand, therefore, that when evaluating obviousness, one must consider obviousness of the claim “as a whole”. This consideration must be from the perspective of the person of ordinary skill in the relevant art, and that such perspective must be considered as of the “time the invention was made”.

14. The level of ordinary skill in the art is discussed in ¶22 below.

15. The relevant time frame for obviousness, the “time the invention was made”, is discussed in ¶23, below.

16. I understand that to combine prior art, the prior art must be “analogous”.

I understand that two criteria are relevant in determining whether prior art is analogous: (1) whether the art is from the same field of endeavor, regardless of the problem addressed, and (2) if the reference is not within the field of the inventor's endeavor, whether the reference still is reasonably pertinent to the particular problem with which the inventor is involved.

17. I understand that in considering the obviousness of a claim, one must consider four things. These include the scope and content of the prior art, the level of ordinary skill in the art at the relevant time, the differences between the prior art and the claim, and any "secondary considerations".

18. I understand that "secondary considerations" include real-world evidence that can tend to make a conclusion of obviousness either more probable or less probable. For example, the commercial success of a product embodying a claim of the patent could provide evidence tending to show that the claimed invention is not obvious. In order to understand the strength of the evidence, one would want to know whether the commercial success is traceable to a certain aspect of the claim not disclosed in a single prior art reference (i.e., whether there is a causal "nexus" to the claim language). One would also want to know how the market reacted to disclosure of the invention, and whether commercial success might be traceable to things other than innovation, for example the market power of the seller, an advertising campaign, or the existence of a complex system having many features

beyond the claims that might be desirable to a consumer. One would also want to know how the product compared to similar products not embodying the claim. I understand that commercial success evidence should be reasonably commensurate with the scope of the claim, but that it is not necessary for a commercial product to embody the full scope of the claim.

19. Other kinds of secondary considerations are possible. For example, evidence that the relevant field had a long-established, unsolved problem or need that was later provided by the claimed invention could be indicative of non-obviousness. Evidence that others had tried, but failed to make an aspect of the claim might indicate that the art lacked the requisite skill to do so. Evidence of copying of the patent owner's products before the patent was published might also indicate that its approach to solving a particular problem was not obvious. Evidence that the art recognized the value of products embodying a claim, for example, by praising the named inventors' work, might tend to show that the claim was non-obvious.

20. I further understand that prior art references can be combined where there is an express or implied rationale to do so. Such a rationale might include an expected advantage to be obtained, or might be implied under the circumstances. For example, a claim is likely obvious if design needs or market pressures existing in the prior art make it natural for one or more known components to be combined, where

each component continues to function in the expected manner when combined (i.e., when there are no unpredictable results). A claim is also likely unpatentable where it is the combination of a known base system with a known technique that can be applied to the base system without an unpredictable result. In these cases, the combination must be within the capabilities of a person of ordinary skill in the art.

21. I understand that when considering obviousness, one must not refer to teachings in the specification of the patent itself. One can, however, refer to portions of the specification admitted to being prior art, including the “BACKGROUND” section. Furthermore, a lack of discussion in the patent specification concerning how to implement a disclosed technique can support an inference that the ability to implement the technique was within the ordinary skill in the prior art.

IV. LEVEL OF ORDINARY SKILL IN THE ART

22. In my opinion, the relevant art was that of sensors and sensor data processing. In the relevant timeframe, a person of ordinary skill in the art had an undergraduate degree in computer science, electrical engineering, mechanical engineering, or other related technical field, and knowledge of sensor systems. I believe I would meet this definition, and would have met this definition in the relevant timeframe.

V. RELEVANT TIMEFRAME FOR DETERMINING OBVIOUSNESS

23. I understand that obviousness must be evaluated “at the time of the

invention”. From the cover page of the ’438 and ’978 patents, I can see that the ’558 Provisional was filed in the United States on January 6, 2010. For the purpose of this declaration, I will analyze obviousness in the time frame immediately prior to this date, although my testimony is usually applicable to a longer period of time, even before January 6, 2010. My testimony is directed to this timeframe, even if I do not always use a past tense.

24. As noted above, I do not believe that the Proposed Amended Claims would be entitled to the date of the ’558 Provisional, but only (possibly) to the date of later applications. However, because technology in this present field has been advancing, an invention that is obvious as of just before January 6, 2010 would also be obvious after that date.

VI. LACK OF WRITTEN DESCRIPTION SUPPORT FOR THE PROPOSED AMENDED CLAIMS

25. CyWee’s Proposed Amended Claims for the ’978 patent are reproduced below. I understand that proposed amended claims 19 and 20 have the text of issued claims 10 and 12 of the ’438 patent, but that CyWee has added language that is underlined, and deleted language that has been struck through:

PROPOSED AMENDED CLAIM 19 FOR THE '978 PATENT

[19(a)] A method for compensating rotations of a 3D pointing device, which is handheld, comprising:

[19(b)] 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;

[19(c)] generating a first signal set comprising axial accelerations associated with movements and rotations of the 3D pointing device in [~~the~~] a spatial reference frame;

[19(d)] generating a second signal set associated with Earth's magnetism;

[19(e)] 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;

[19(f)] generating a rotation output associated with a rotation of the 3D pointing device associated with three coordinate axes of [~~a~~] the spatial reference frame associated with the 3D pointing device;

[19(g)] and using the orientation output and the rotation output to generate a transformed output associated with a fixed display reference frame associated with a display device built-in to and integrated with the 3D pointing device, wherein the orientation output and the rotation output is generated by a nine-axis motion sensor module;

[19(h)] 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.

PROPOSED AMENDED CLAIM 20 FOR THE '978 PATENT

[20] The method of claim 10, wherein the 3D pointing device is a smartphone, and wherein the orientation output is a rotation matrix, a quaternion, a rotation vector, or comprises three orientation angles.

26. CyWee's Proposed Amended Claims for the '438 patent are reproduced below. I understand that proposed amended claims 20 and 21 have the text of issued claims 1 and 3 of the '438 patent, but that CyWee has added language that is underlined, and deleted language that has been struck through:

PROPOSED AMENDED CLAIM 20 FOR THE '438 PATENT

[20(a)] A three-dimensional (3D) pointing device, which is handheld, subject to movements and rotations in dynamic environments, comprising:

[20(b)] a housing associated with said movements and rotations of the 3D pointing device in a spatial pointer reference frame;

[20(c)] a printed circuit board (PCB) enclosed by the housing;

[20(d)] 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,

[20(e)] 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;

[20(f)] ~~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,

[20(g)] communicating with the six-axis motion sensor module to calculate a resulting deviation comprising resultant angles in said spatial pointer reference frame

[20(h)] 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;

[20(i)] 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[.];

[20(j)] and a display device built-in to and integrated with the 3D pointing device and associated with a display reference frame, wherein said resultant angles of the resulting deviation in the spatial pointer reference frame are translated to a movement pattern in the display reference frame.

PROPOSED AMENDED CLAIM 21 FOR THE '438 PATENT

[21] The 3D pointing device of claim 1, wherein the 3D pointing device is a smartphone, and 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.

A. U.S. Provisional Application 61/292,558

27. Exhibit 2012 is U.S. Provisional Application 61/292558 (hereinafter “the ’558 Provisional”).

28. Paragraph [0023] of the '558 Provisional mentions three specific types of devices—"a remote controller, a joystick or a cellular phone". (Ex. 2012, ¶[0023]). Each of these three devices may or may not be handheld depending on the device or its context. For example, a remote controller or a joystick can be built into a keyboard, tabletop, or laptop. (The figure below depicts a joystick that is built into a keyboard). Moreover, a cellular phone can be hardwired into a speaker system and controlled using a keypad integrated in a tabletop console. In each of the foregoing scenarios, the device is not handheld. Thus, in my opinion, the disclosure of three specific devices, each of which may or may not be handheld depending on the context, does not demonstrate that the inventors had possession of an entire genus of all "handheld" 3D pointing devices.



Veilux SVK-64 3-Axis Keyboard with Joystick
(<http://www.veilux.net/svk-64.html>)

29. As discussed above, paragraph [0023] of the '558 Provisional mentions "a cellular phone." (Ex. 2012, ¶[0023]). Paragraph [0023] says nothing about this

cellular phone having a “display” of any kind, including whether or not such a display even exists, where it is located, what size it is, or what images are displayed on it. Indeed, even if a cellular phone does have a display, the display could be too small (or otherwise lack the technical capability) to display the output of the claimed invention. For example, a cellular phone might have a display that is capable of displaying only a single line of numbers or letters (as shown below).



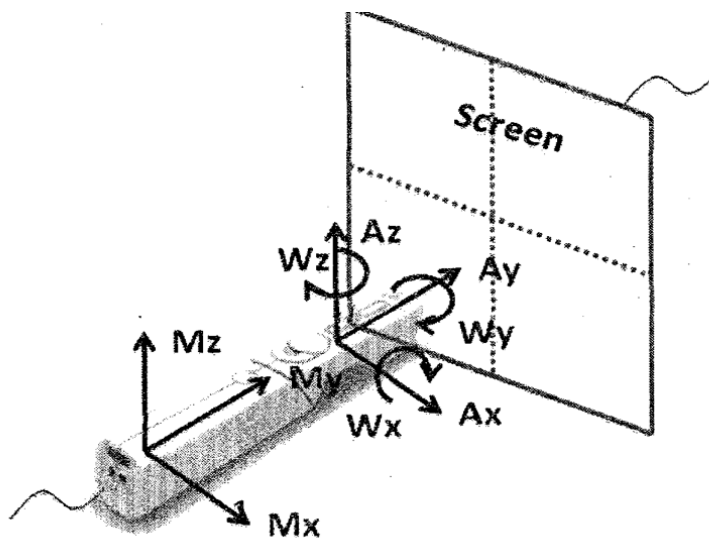
Motorola MicroTAC 9800X

<https://www.pcmag.com/feature/360314/the-golden-age-of-motorola-cell-phones/4>)

30. As previously mentioned, paragraph [0023] of the '553 provisional discloses “a cellular phone.” (Ex. 2012, ¶[0023]). This paragraph does not say that the cellular phone is a smartphone. A smartphone is a specific type of cellular phone that has functionality and features not disclosed in paragraph [0023]. The bare

disclosure of a “cellular phone” in this paragraph does not demonstrate, from the perspective of a person of ordinary skill in the art, that the inventors had possession of a smartphone.

31. Figure 1 of the '558 Provisional is reproduced below. Figure 1 does not contain sufficient information for a person of ordinary skill to know whether the device depicted is or is not handheld. Figure 1 does not show a human hand holding the device, or show how the device is moved in three dimensions—by hand or otherwise. No size scale is



provided in Figure 1 to know whether the device is of a size that can be physically lifted or is ergonomically designed to be lifted comfortably by a user's hand. The size of the device may be too big or too small to be used comfortably and without encumbrance or undue strain. The device might be physically attached to the surface on which it is sitting, which would prevent the device from being lifted. Alternatively, even if the device is not physically attached to the surface, the device may be intended to be used while it rests on the surface. Figure 1 of the '553 provisional simply provides too little information to know whether the device is or

is not handheld.

32. Figure 1 of the '558 Provisional (reproduced above) shows a “Screen” that is separate from the 3D pointing device. Given that this “Screen” is separate from the 3D pointing device, the “Screen” is clearly not built-in to and integrated with the device.

B. U.S. Application No. 12/943,934

33. Exhibit 1009 filed in IPR2018-01258 is U.S. Application No. 12/943,934 (hereinafter “the '934 application”).

34. Paragraph [0037] of the '934 application states that the 3D pointing device may include “a built-in display” which may further be “integrated on the housing.” This statement does not mention a smartphone nor demonstrate that the inventors had possession of a smartphone. Paragraph [0037] does not even mention a telephone. Many types of devices have “a built-in display” that is “integrated on the housing” (*e.g.*, desktop computers, laptop computers, tablets, consoles, televisions, monitors, digital watches). Most of these devices are not telephones, much less smartphones.

35. Figure 6 of the '934 application is reproduced below. According to paragraph [0037] of the '934 application, Figure 6 is an exploded diagram showing a 3D pointing device 600, which has a bottom cover 620, a PCB 640, a battery pack 622, a rotation sensor 642, an accelerometer 644, a data transmitting unit 646, a

computing processor 648, a display 682, and a top cover 610. Nothing in Figure 6 or paragraph [0037] indicates that device 600 is a cellular phone, as opposed to some other kind of device. For example, there are is no speaker or microphone depicted in Figure 6 that would enable voice communication, nor other electronic components necessary for cellular telephony. In short, Figure 6 simply shows solid boxes

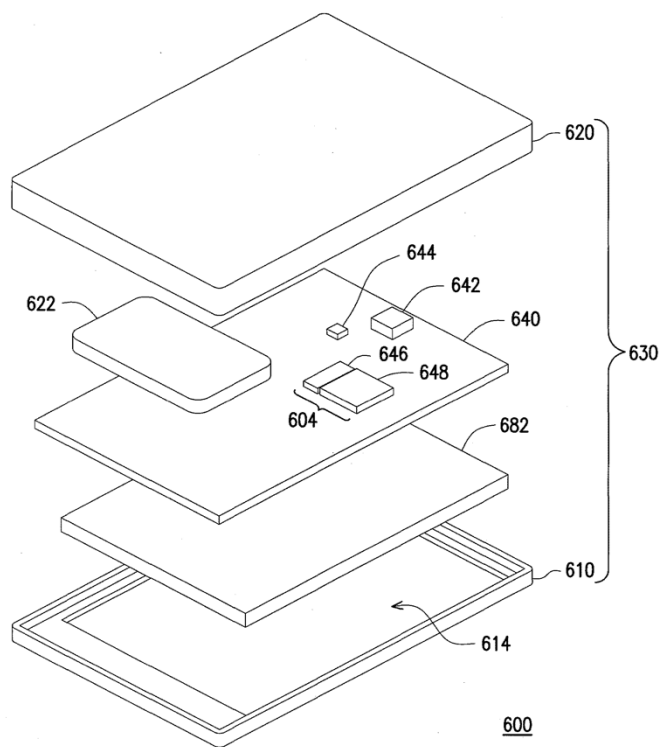


FIG. 6

with no apparent functionality beyond what is set forth in paragraph [0037].

VII. OBVIOUSNESS OF THE PROPOSED AMENDED CLAIMS

36. I am further of the opinion that proposed amended claims 19 and 20 of the '978 patent and proposed amended claim 20 of the '438 patent would have been obvious over the combination of U.S. Patent Publication US 2010/0312468 A1 ("Withanawasam")(Ex. 1017) in view of U.S. Pat. No. 7,089,148 ("Bachmann")(Ex. 1003). Proposed amended claim 21 of the '438 patent would have been obvious over Withanawasam, Bachmann and the knowledge of a person of ordinary skill in the art.

37. I understand that Withanawasam is the publication of a U.S. Patent Application, and was originally filed on June 3, 2009 (shown at the bottom of the left column on the cover page of the Withanawasam publication).

38. Bachmann is the same reference I analyzed in my prior declarations.

A. Overview of Withanawasam

39. Withanawasam concerns portable navigation devices, including smartphones that include a navigation or orientation application. Withanawasam states:

“Mobile devices such as personal navigation devices (PND) and **smart phones** typically have some form of navigation and map orientation application. These mobile devices often utilize a magnetic compass that have to work even when the device is not held level, which requires a micro-electro-mechanical systems (MEMS) accelerometer or a gyroscope to be integrated with the magnetic sensors.”

(Ex. 1017, ¶0001)(Emphasis added). As noted in this passage, it was desirable to have a compass indication that would work even when the device is held level. A person of ordinary skill in the art in the relevant timeframe would understand this to mean that the device should be able to calculate the full three-dimensional orientation of itself.

40. Withanawasam further teaches a device 100 (which can be a smartphone), as shown in Fig. 1, below:

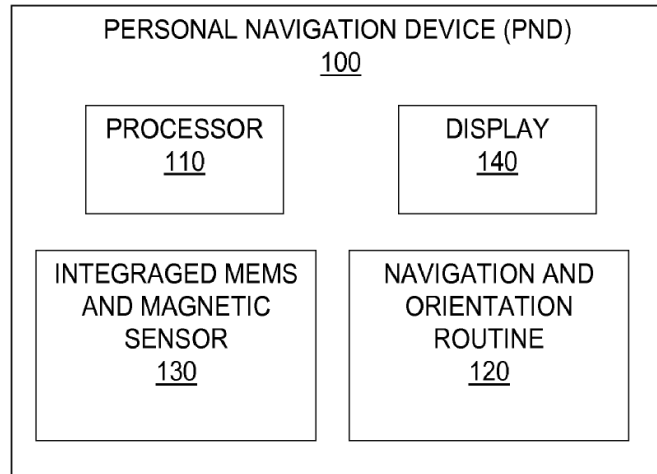


FIG. 1

41. Regarding Fig. 1, Withanawasam states:

“FIG. 1 is one embodiment of a personal navigation device (PND) 100 comprising an integrated MEMS and magnetic sensor 130. The PND 100 can be a mobile (hand-held) navigation device, a **smart phone**, or any similar mobile device configured to aid a user in navigation and applications requiring orientation information. For example, a user can be a professional first responder or a member of the public. The PND 100 includes a processor 110 configured to run a navigation and orientation routine module 120. A **display** 140 presents navigation information to the user, and can comprise a liquid crystal display (LCD), a digital display, or the like. **Navigation information that can be displayed** includes **positional information, orientation information**, maps, compass directions, a predetermined path, or **any other information useful in navigation.**”

(Ex. 1017, ¶0011)(Emphasis added).

42. Withanawasam also explains “orientation information”, and that it can be obtained from integrated sensors:

“Orientation information is information relating to the present orientation of the PND 100, and can be determined using the integrated MEMS and magnetic sensor 130 (also referred to herein as the integrated MEMS sensor). The integrated MEMS and magnetic sensor 130 provides information to the processor 110 relating to acceleration, roll, and directional data (that is, relating to a compass direction). The PND 100 can use three axes of sensing for acceleration and gyroscope data in one single integrated MEMS sensor 130. In alternative embodiments, the PND 100 comprises a plurality of integrated MEMS sensors 130, each for a different axis of acceleration or gyroscope data. The components of the PND 100 are communicatively coupled to one another as needed using suitable interfaces and interconnects.”

(Ex. 1017, ¶0012)(Emphasis added).

43. An example of Withanawasam’s arrangement is found in claims 15-18 of Withanawasam, which are listed here:

“15. A navigation device, comprising: an integrated sensor device, comprising: a first substrate including a surface portion; a second substrate coupled to the surface portion of the first substrate in a

stacked configuration, wherein a cavity is defined between the first substrate and the second substrate; one or more micro-electro-mechanical systems (MEMS) sensors located at least partially in the first substrate, wherein the one or more MEMS sensors communicates with the cavity; and one or more additional sensors; a processor operatively coupled to the integrated sensor device; and a navigation module run by the processor, wherein the navigation module is configured to determine orientation information based on data from the integrated sensor device.

16. The navigation device of claim 15, further comprising a display configured to present the positional information to a user.

17. The navigation device of claim 15, wherein the navigation device comprises a personal navigation device (PND) or a smart phone.

18. The navigation device of claim 15, wherein the one or more MEMS sensors comprise an accelerometer, a gyroscope, a flow sensor, a gas detector, or combinations thereof.

19. The navigation device of claim 15, wherein the one or more additional sensors comprise a magnetic sensor, a pressure sensor, or combinations thereof.”

B. Overview of Bachmann

44. Bachmann discloses determining the orientation of a rigid body, such

as a hand-held device, with magnetometers, accelerometers, and angular rate detectors. (Ex. 1004, Abstract, 7:34-40, 13:43-48). The combination of magnetometers, accelerometers, and angular rate detectors is called a MARG sensor:

“In another sensor embodiment, the **magnetometers** and **accelerometers** are supplemented with **angular rate detectors** configured to detect the angular velocity of the sensor (comprising so-called Magnetic, Angular Rate, Gravity (MARG) sensors). **Each MARG sensor contains angular rate detectors, accelerometers, and magnetometers.**”

(Ex. 1004, 7:34-40)(Emphasis added).

45. At least one of Bachmann’s MARG sensors is a nine-axis sensor because it includes three three-axis sensors: “a three-axis accelerometer (h_1, h_2, h_3) 31, a three-axis magnetometer (b_1, b_2, b_3) 32, and a three-axis angular rate sensor.” (Ex. 1004, 10:10-14). Miniaturized nine-axis MARG sensors were commercially available as of at least 2001 (Bachmann’s priority date)—about ten years before the earliest possible filing dates of the ’978 and ’438 patents. (Ex. 1004, 14:37-59).

46. Bachmann uses a filter to generate a representation of the object’s orientation. This representation is a quaternion generated from the outputs of the accelerometer, magnetometer, and angular rate sensor in the MARG sensor. Bachmann states:

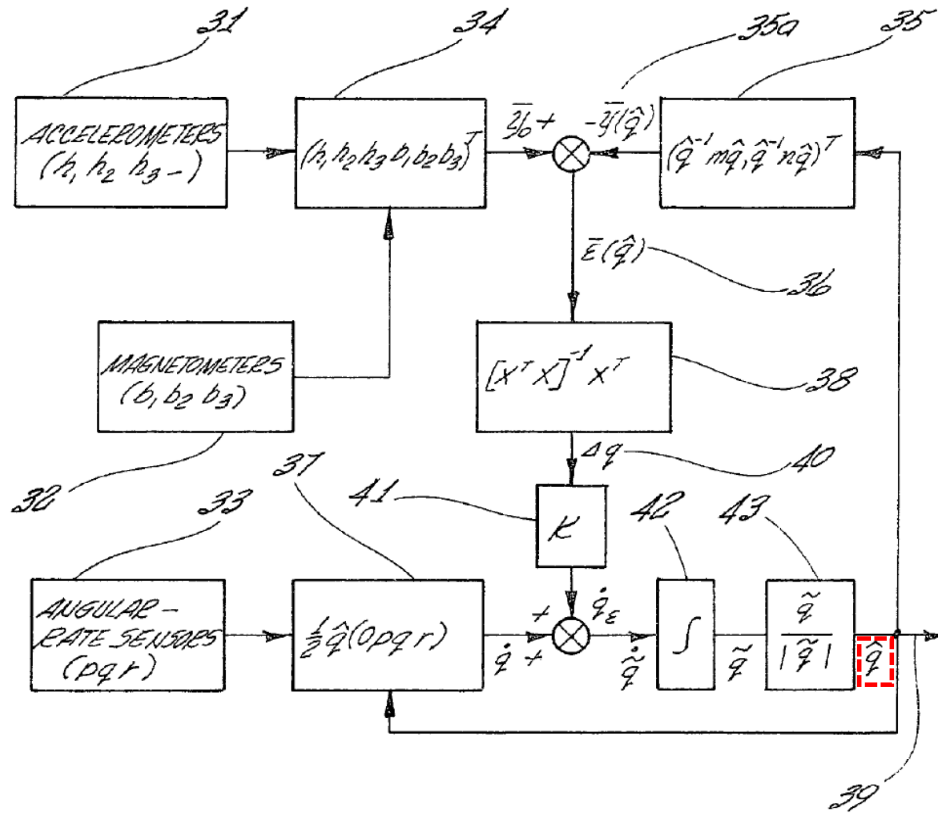
“[T]he filter inputs are from a **three-axis accelerometer** ($h_1 h_2 h_3$) 31, a **three-axis magnetometer** ($b_1 b_2 b_3$) 32, and a **three-**

axis angular rate sensor (p, q, r) 33. Its output is a quaternion representation of the **orientation of the tracked object $\hat{q}$ 39.**”

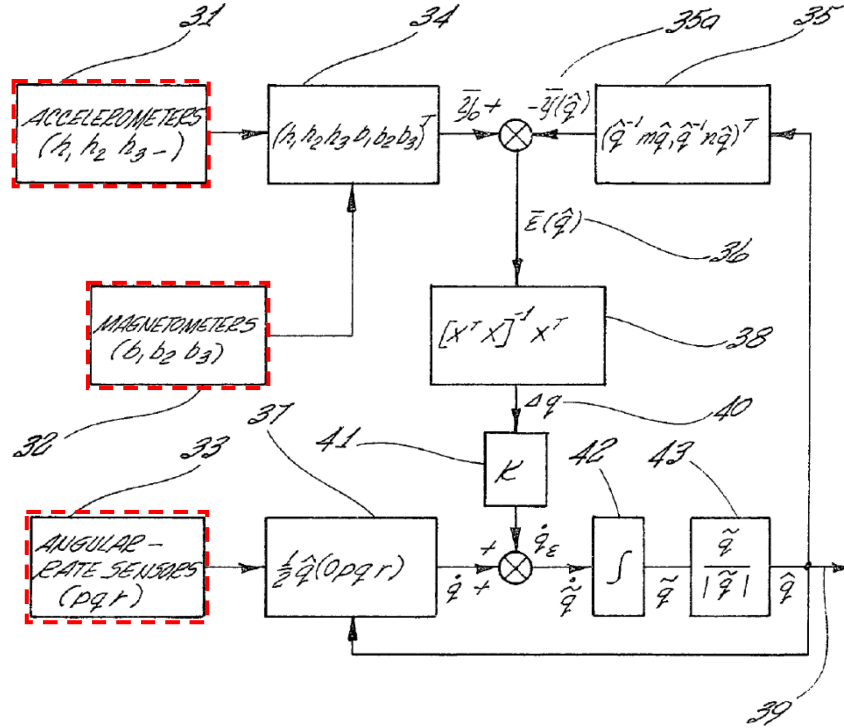
(Ex. 1004, 10:10-14)(Emphasis added).

47. In other words, Bachmann uses the nine outputs from a three-axis accelerometer, three-axis magnetometer, and three-axis angular rate sensor to calculate the orientation of a hand-held device or other object.

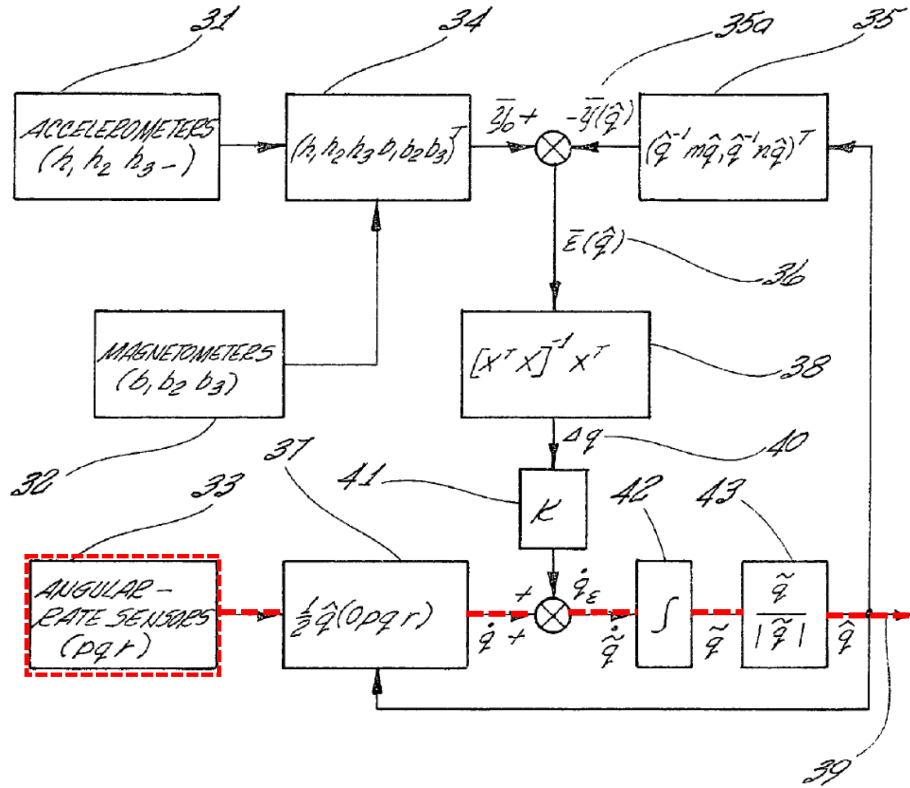
48. Bachmann’s FIG. 3 shows the filtering process used to calculate the device’s orientation from the nine sensor inputs. As I explain in the following sections, Bachmann’s filtering process corresponds to the calculations of the ’978 and ’438 patents. The output of this filtering process is an estimated orientation quaternion, $\hat{q}$. (Ex. 1004, 7:59-61, 10:10-14). This output is outlined in a red-dashed box in the annotated version of Bachmann’s FIG. 3 reproduced immediately below:



49. The inputs to Bachmann's filtering process are the outputs from the accelerometers 31, magnetometers 32, and angular-rate sensors 33 on the left side of FIG. 3. (Ex. 1004, 10:10-14). These sensors are shown boxed in red below:



50. The filtering process in Bachmann's FIG. 3 involves calculating a rate quaternion $\dot{q}$ based on angular rate information 37 from the angular rate sensor 33 and correcting it using a correction factor $\dot{q}_e$, which is based on signals from the accelerometer 31 and magnetometers 32. (Ex. 1004, 10:15-17, 10:38-42). The angular rate information 37 represents the angular rotation rates about three axes in the sensor coordinate frame (*i.e.*, a reference frame centered on the hand-held device). (Ex. 1004, 10:10-30). It is used to calculate the orientation quaternion $\hat{q}$ as shown by the boxes along the red line in the following annotated version of FIG. 3:



51. An ideal angular rate sensor 33 would produce noiseless, unbiased angular rate information 37 that could be used to find a perfectly precise rate quaternion. (Ex. 1004, 10:19-30). In real life, however, the angular rate information 37 from an angular rate sensor 33 may be imprecise and can drift over time. (Ex. 1004, 10:36-38). Fortunately, data from the accelerometers 31 and magnetometers 32 can be used to reduce this imprecision. (Ex. 1004, 10:38-45).

52. Boxes 34, 35, 35a, 36, 38, and 41 in Bachmann's FIG. 3 show how the accelerometer and magnetometer measurements are used to generate a correction factor, $\dot{q}_e$, that is applied to the rate quaternion. (Ex. 1004, 9:59-10:14). In box 34, the accelerometer and magnetometer measurements are combined to form a six-valued measurement vector $y_0 = [h_1 \ h_2 \ h_3 \ b_1 \ b_2 \ b_3]^T$, where h_1 , h_2 , and h_3 represent

acceleration along the accelerometer's X, Y, and Z axes, respectively, and b_1 , b_2 , and b_3 represent magnetism measurements along the magnetometer's X, Y, and Z axes, respectively. (Ex. 1004, 8:37-8:50). In boxes 35 and 35a, a predicted six-valued measurement vector $\bar{y}(\hat{q})$ is translated from a reference frame fixed with respect to the Earth to the sensors' reference frame. (Ex. 1004, 8:61-9:8). This predicted measurement vector is based on the angular rate information 37 from the angular rate sensor 33. (Ex. 1004, FIG. 3). Comparing the predicted measurement vector $\bar{y}(\hat{q})$ to the actual measurement vector y_0 yields a six-valued error vector $\bar{\epsilon}(\hat{q})$, numbered 36 in FIG. 3. (Ex. 1004, 9:9-17).

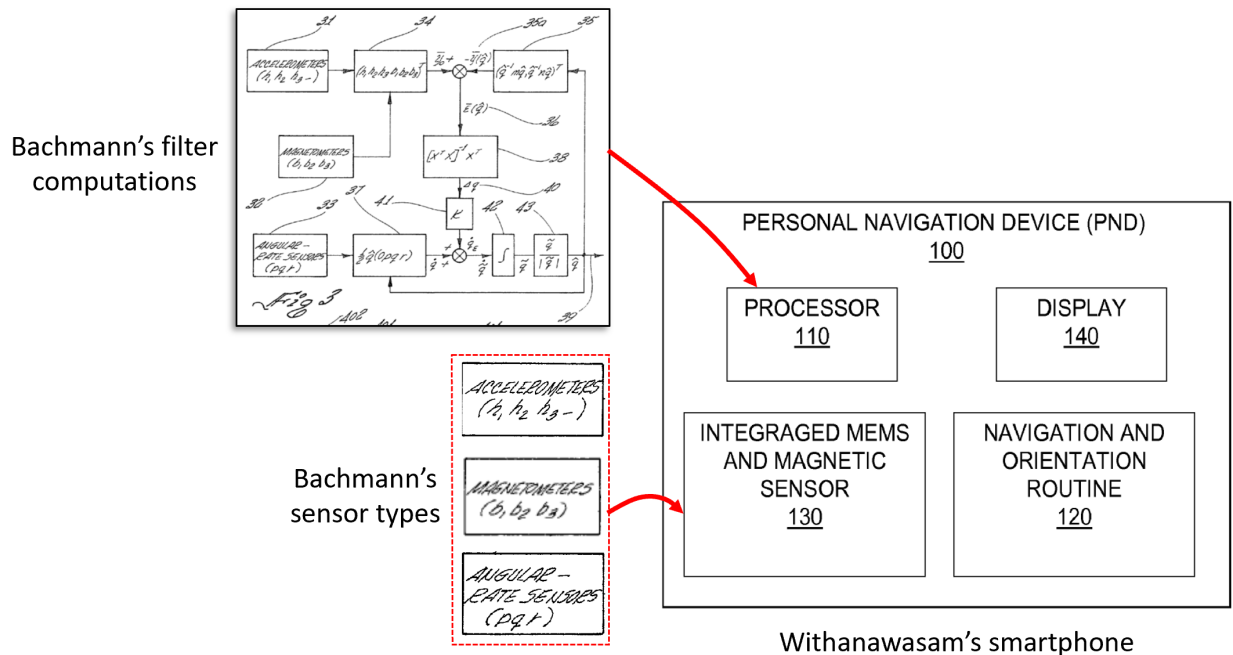
53. The six-valued error vector $\bar{\epsilon}(\hat{q})$ represents the difference between the actual and predicted accelerometer and magnetometer measurements. (Ex. 1004, 9:21-48). It is based on the orientation quaternion $\hat{q}$ generated from the angular rate sensor measurements as shown by the line in FIG. 3 connecting the orientation quaternion and box 35. (Ex. 1004, FIG. 3). The error vector $\bar{\epsilon}(\hat{q})$ is corrected using a Gauss-Newton iteration 38 to yield a full correction Δq_{full} 40. (Ex. 1004, 10:42-55). The full correction is scaled by a filter gain value k in box 41 to yield a correction factor $\dot{q}_\epsilon$ that minimizes the error vector $\bar{\epsilon}(\hat{q})$ —and hence the difference between the actual and predicted measurement vectors—when fed back through boxes 35, 35a, and 36 in FIG. 3. (Ex. 1004, 10:66-11:12).

54. Adding the rate quaternion $\dot{q}$ to the correction factor $\dot{q}_\epsilon$ yields a

corrected rate quaternion $\hat{\tilde{q}}$, which is integrated (box 42 in FIG. 3) and normalized (box 43) to yield the orientation quaternion at the output, $\hat{q}$. (Ex. 1004, 9:43-48). This compensates drift in the angular rate sensor that would otherwise corrupt the orientation output of the filter, $\hat{q}$. (Ex. 1004, 10:36-15).

C. Overview of the Combination

55. Withanawasam teaches a device, such as a smartphone, that uses sensors to obtain data that are processed to produce an orientation, where the orientation data can be displayed on a built-in display in a variety of ways. Withanawasam does not restrict the choice of sensors, and does not expressly teach a method of integrating sensor data (“sensor fusion”) to calculate a device orientation. Bachmann, however, teaches a method for accurately calculating a device orientation from three-axis magnetic, three-axis gyroscopic and three-axis acceleration sensors. In my opinion, it would have been obvious to use Bachmann’s choice of sensors and Bachmann’s method of calculating orientation by fusing magnetic, gyroscopic and acceleration sensor outputs to implement Withanawasam’s device, as shown in the following diagram, created for this proceeding:



D. Rationale for the Combination

56. In my opinion, there would have been motivation to make this combination. Specifically, a person of ordinary skill in the relevant timeframe would have understood from Withanawasam that smartphones with multiple sensors (including magnetic, gyroscopic and acceleration sensors) existed, and that these sensors were typically used to calculate a device orientation. (Ex. 1017, ¶¶0001). A person of ordinary skill would also have understood that the sensors themselves do not produce an orientation value as an output, but rather, the sensors' output data must be processed further, by Withanawasam's processor 110, to calculate a device orientation. (Ex. 1017, ¶¶0011-0012). Withanawasam, however, leaves open the exact configuration of sensors, and it does not expressly teach a method for mathematically fusing sensor data. Thus, a person of ordinary skill, seeking to

implement the smartphones described by Withanawasam, would have had a reason to look to relevant art to pick a known sensor configuration and method for mathematically fusing sensor data.

57. With regard to the choice of sensors, Withanawasam provides for a considerable amount of flexibility. (Ex. 1017, ¶¶0009-0013, 0015, 0017-0018, 0008, 00024). For example, Withanawasam states that:

“Orientation information is information relating to the present orientation of the PND 100, and can be determined using the **integrated MEMS and magnetic sensor 130** (also referred to herein as the integrated MEMS sensor). The integrated MEMS and magnetic sensor 130 provides information to the processor 110 relating to acceleration, roll, and directional data (that is, relating to a compass direction). **The PND 100 can use three axes of sensing for acceleration and gyroscope data in one single integrated MEMS sensor 130.** In alternative embodiments, **the PND 100 comprises a plurality of integrated MEMS sensors 130**, each for a different axis of acceleration or gyroscope data.”

(Ex. 1017, ¶0012)(Emphasis added). As disclosed in the paragraph above, the device of Withanawasam can have an integrated MEMS and magnetic sensor 130, where the “integrated MEMS” portion has “three axes of sensing for acceleration and gyroscope data”. (Ex. 1017, ¶0012). Withanawasam also teaches that “[i]n alternative embodiments, the PND 100 comprises a plurality of integrated MEMS

sensors 130”, meaning that even if nine axes of sensors (three magnetic, three gyroscopic and three acceleration) were not available in a single integrated sensor, Withanawasam teaches using multiple such sensors.

58. Withanawasam also teaches, with respect to Fig. 2C (shown below), that a single stacked sensor device 200" can have a MEMS sensor 220, which “can include **one or more** accelerometers, gyroscopes, **or combinations thereof....**” (Ex. 1017, ¶0015)(Emphasis added). Figure 2C also shows that “**one or more additional sensors 250** are located in electrically unused portions of the first substrate 210 **and** the second substrate 240 of the MEMS sensor device 200'.” (Ex. 1017, ¶0018)(Emphasis added). The sensors 250 can include “a magnetic sensor, a pressure sensor, a temperature sensor, or any type of suitable electronic circuitry.” (Ex. 1017, ¶0017).

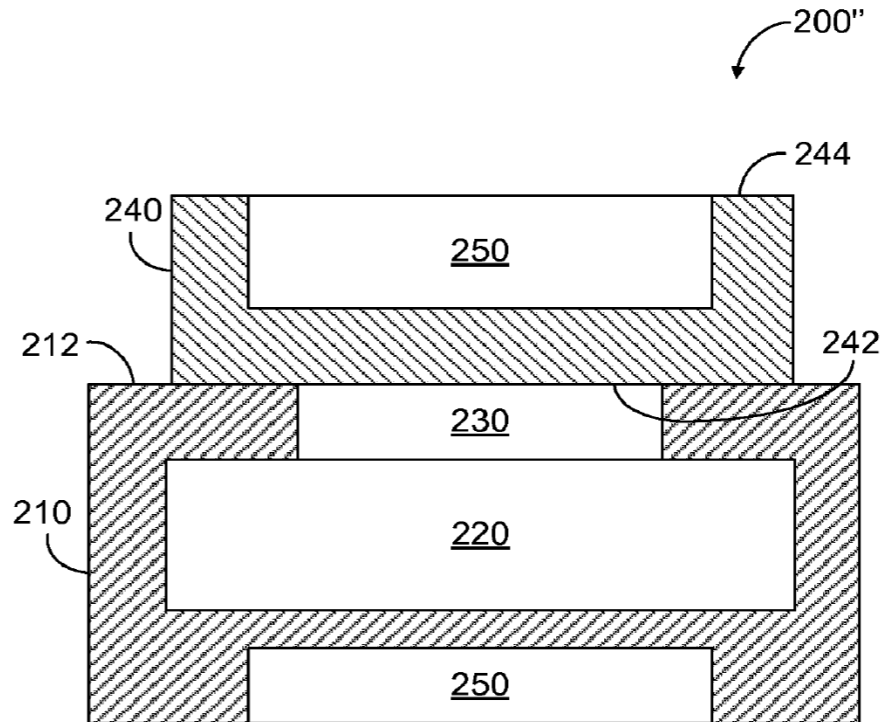


FIG. 2C

59. In Withanawasam's claims 15-19 (found on the last page of Withanawasam), Withanawasam describes a device that has "one or more micro-electro-mechanical systems (MEMS) sensors" and "one or more additional sensors", and "wherein the one or more MEMS sensors comprise **an accelerometer, a gyroscope**, a flow sensor, a gas detector, **or combinations thereof**" and "wherein the one or more additional sensors comprise a **magnetic sensor**, a pressure sensor, or combinations thereof." (Ex 1017, claims 15, 18, and 19)(Emphasis added).

60. It is thus clear that Withanawasam contemplated choosing sensors

flexibly, based on the application, but that within the scope of that flexibility, contemplated using three-axis gyroscopes and three-axis accelerometers, together with magnetometers.

61. In my opinion, a person of ordinary skill would have understood that using Bachmann's nine-axis sensor (three magnetic, three gyroscopic and three acceleration) in Withanawasam's smartphone would have provided several advantages. First, the teachings of Bachmann would have allowed a person of skill to choose sensors and fuse the sensor data accurately. Second, Bachmann's nine-axis sensor would have allowed Withanawasam's smartphone to obtain the orientation of the device in all rotational degrees of freedom (roll, pitch and yaw). Third, a person of ordinary skill would have understood that Bachmann's nine-axis sensor and sensor fusion method would have allowed for greater precision through overdetermination (the amount of information beyond that necessary to determine orientation), which in turn would have enabled better error control.

62. Bachmann's nine-axis sensors were well-known in the art in the relevant timeframe. Bachmann, which has a filing date of 2001 and issued in 2006, states that magnetic, angular rate and gravitational (acceleration) (MARG) sensors were already commercially available and could be integrated in a known fashion. Bachmann states:

“One example of a suitable sensor device is an analog MARG

sensor. In one embodiment such a sensor measures 10.1x5.5x2.5 cm. The analog output of the sensor is connected to a breakout header via a thin VGA monitor cable. Output range is 0-5 vdc. The power requirement of the sensors is 12 vdc at approximately 50 milliamperes. The primary sensing components are a triaxial accelerometer (e.g. a Model No. CXL04M3 manufactured by Crossbow, Inc.), a 3-axis magnetometer (e.g., Model No. HMC2003 from Honeywell), and three miniature angular rate detectors mounted in an orthogonal configuration (e.g., Tokin CG-16D series sensors available from Tokin American, Inc.). The individual components can be integrated using a single integrated circuit board with the accelerometers mounted separately. Rate sensor output voltage is amplified by a factor of five and filtered to attenuate rate sensor oscillator noise. **Such MARG sensors can be obtained from McKinney Technology of Prunedale, Calif. Software or hardware biasing can be used to successfully integrate the signal from the angular rate detectors with the rest of the system.”** (Ex. 1004, 14:37-57)(Emphasis added).

63. Bachmann further states that its sensors and filter processing can be used in hand-held devices (like Withanawasam’s):

“By mounting a plurality of sensors on a body, the posture of the body can be determined and tracked. **Sensors constructed in accordance with the principles of the present invention can be used to track motion and orientation of simple rigid**

bodies as long as they are made of non-magnetic materials. Examples include, but are not limited to **hand-held devices**, swords, pistols, or simulated weapons.”

(Ex. 1004, 13:42-48)(Emphasis added).

64. In my opinion, a person of ordinary skill in the art would have been motivated and able to use nine-axis MARG sensors like those in Bachmann to implement Withanawasam’s smartphone, and could have used Withanawasam’s integrated sensor devices to do so.

65. It would also have been obvious to use Bachmann’s specific sensor fusion method, which in Bachmann is a quaternion-based filter processing method (as illustrated, for example, in Fig. 3 of Bachmann). The quaternion-based filter processing was intended for use with nine-axis MARG sensors. (Ex. 1004, 7:18-45). In addition, a person of ordinary skill in the art would have understood that Bachmann’s quaternion-based filter processing is computationally more efficient than processing that uses spatial (*e.g.*, Euler) angle calculations. (Ex. 1004, 5:33-7:31). Bachmann’s quaternion-based techniques also avoid singularities that might otherwise occur at certain sensor orientations. (Ex. 1004, 5:33-7:31). Bachmann explains:

“The principles of the present invention use magnetometer and accelerometer input subject to filtering to track body posture. In one implementation, Euler angles and their related coordinate

transform matrices are used to calculate body orientation. Although computationally intensive, embodiments of the present invention can use Euler angle calculations to track body orientation. Additionally, angular velocity information can be used to correct for time lag errors. However, other embodiments of the present invention present a **particularly advantageous approach** for achieving body tracking using quaternion mathematics. **Such embodiments eliminate the Euler angle singularity problem, and reduce the computational complexity of the invention.”**

(Ex. 1004, 7:4-17)(Emphasis added).

66. In my opinion, the combination of Withanawasam and Bachmann presented here is nothing more than the combination of known elements to achieve an expected improvement. Withanawasam’s smartphone has a housing, sensors, and a processor that estimates the device’s orientation used the sensor outputs. Bachmann’s device does the same thing, but with different sensors and different processing. Bachmann’s sensors were available on the commercial market as of 2001, and Bachmann’s calculations were known at least as early as 2004.¹ Bachmann’s functional blocks (sensors and calculations) could have been

¹ Bachmann is a divisional of U.S. Application No. 10/020,719, which was filed in 2001 and issued in 2004 as U.S. Pat. No. 6,820,025.

substituted for the same functional blocks in Zhang using only ordinary skill as discussed below. The results would have been the *expected* improvement described in Bachmann.

67. Thus, a person of ordinary skill would have been motivated to use Bachmann's quaternion-based filter processing with a nine-axis MARG sensor because (1) that was its intended use, and (2) it performed better than the alternatives.

E. Reasonable Expectation of Success

68. In my opinion, a person of ordinary skill in the art in the relevant timeframe would have had a reasonable expectation of success in making the combination. As demonstrated by Withanawasam, smartphones and similar devices with sensors, orientation data and navigation applications were already widely available in the relevant timeframe (Ex. 1017, ¶0001), and a person of skill would have known how to construct and program these devices, or how to acquire that knowledge (for example, by working in a relevant team). The arrangement of sensors on a printed circuit board within a Withanawasam device was something that had been done on numerous occasions, as Withanawasam indicates. (Ex. 1017, ¶0001). Furthermore, the calculations taught by Bachmann could have been implemented in a standard microprocessor for portable devices, such as the one used by Withanawasam. (Ex. 1017, ¶0011). The sensors were already available on the commercial market, as indicated by both Withanawasam and Bachmann. (Ex. 1017,

generally)(Ex. 1004, 14:37-57). A person of ordinary skill, again, would have had the ability to integrate the specific sensor arrangement of Bachmann into a device like Withanawasam's, and to have those sensors appropriately mounted and producing data. Notably, the '438 and '978 patents contain very little information concerning how a person of ordinary skill would integrate sensors into a handheld device like a smartphone, but rather rely on common knowledge in the industry.

F. Analogous Art

69. In my opinion, both Withanawasam and Bachmann are analogous art. Both references relate to the field of the '438 and '978 patents, namely that of generating device orientations based on sensor outputs. (Ex. 1017, ¶¶0001, 0011-0012)(Ex. 1004, 1:18-20, 13:42-48). Both the Withanawasam and Bachmann references further would have been reasonably pertinent to the particular problem with which the inventor is involved. Withanawasam teaches the use of sensors within devices to determine orientation, while Bachmann teaches a specific selection of sensors and method for fusing sensor data to produce an orientation of a tracked device. In my opinion, these teachings are reasonably pertinent to the particular problem with which the inventors of the '438 and '978 patents were involved.

G. Specific Claim Limitations

70. I show how the combination of Withanawasam and Bachmann would meet the language of proposed amended claims in the following, where the claim

limitations are shown in ***bold italics***.

'978 Patent Proposed Amended Claim 19

“[19(a)] A method for compensating rotations of a 3D pointing device, which is handheld, comprising:”

71. Withanawasam teaches a **three-dimensional (3D) pointing device**, in the form of a portable navigation device that can be a smartphone running certain software. Withanawasam states:

“FIG. 1 is one embodiment of a personal navigation device (PND) 100 comprising an integrated MEMS and magnetic sensor 130. The PND 100 can be a mobile (**hand-held**) navigation device, a **smart phone**, or any similar mobile device **configured to aid a user in navigation and applications requiring orientation information.**”

(Ex. 1017, ¶0011)(Emphasis added). Figure 1 of Withanawasam is shown below.

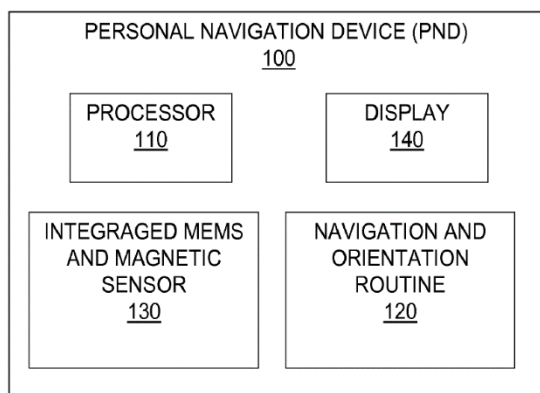


FIG. 1

72. Withanawasam’s smartphone, which functions as a personal navigation device, is a (3D) pointing device according to CyWee’s proposed construction of that term, because it is “a handheld device that detects the motion of said device in three-dimensions and is capable of translating the detected motions to control an output on a display.” First, as stated in the quote above, Withanawasam’s device is **handheld**. (Ex. 1017, ¶0011, claim 17).

73. Second, Withanawasam’s device “detects the motion of said device in three-dimensions and is capable of translating the detected motions to control an output on a display”. Withanawasam first describes detecting the motion of said device in three-dimensions. Withanawasam states:

“Orientation information is information relating to the present orientation of the PND 100, and can be determined using the integrated MEMS and magnetic sensor 130 (also referred to herein as the integrated MEMS sensor). The integrated MEMS and magnetic sensor 130 provides information to the processor 110 relating to acceleration, roll, and directional data (that is, relating to a compass direction). The PND 100 can use three axes of sensing for acceleration and gyroscope data in one single integrated MEMS sensor 130.”

(Ex. 1017, ¶0012, *see also* claim 15). Withanawasam also notes that smartphones typically have a “magnetic compass that have to work even when the device is not held level, which requires a micro-electromechanical systems (MEMS)

accelerometer or a gyroscope to be integrated with the magnetic sensors.” (Ex. 1017, ¶0001).

74. Third, the Withanawasam device is **capable of translating the detected motions to control an output on a display**. Specifically, Withanawasam’s device comprises “a display configured to present the positional information to a user.” (Ex. 1017, claim 16). For example, Withanawasam states:

“The PND 100 includes a processor 110 configured to run a navigation and orientation routine module 120. A **display 140** presents navigation information to the user, and can comprise a liquid crystal display (LCD), a digital display, or the like. Navigation information that can be displayed includes **positional information, orientation information, maps, compass directions, a predetermined path, or any other information useful in navigation.**”

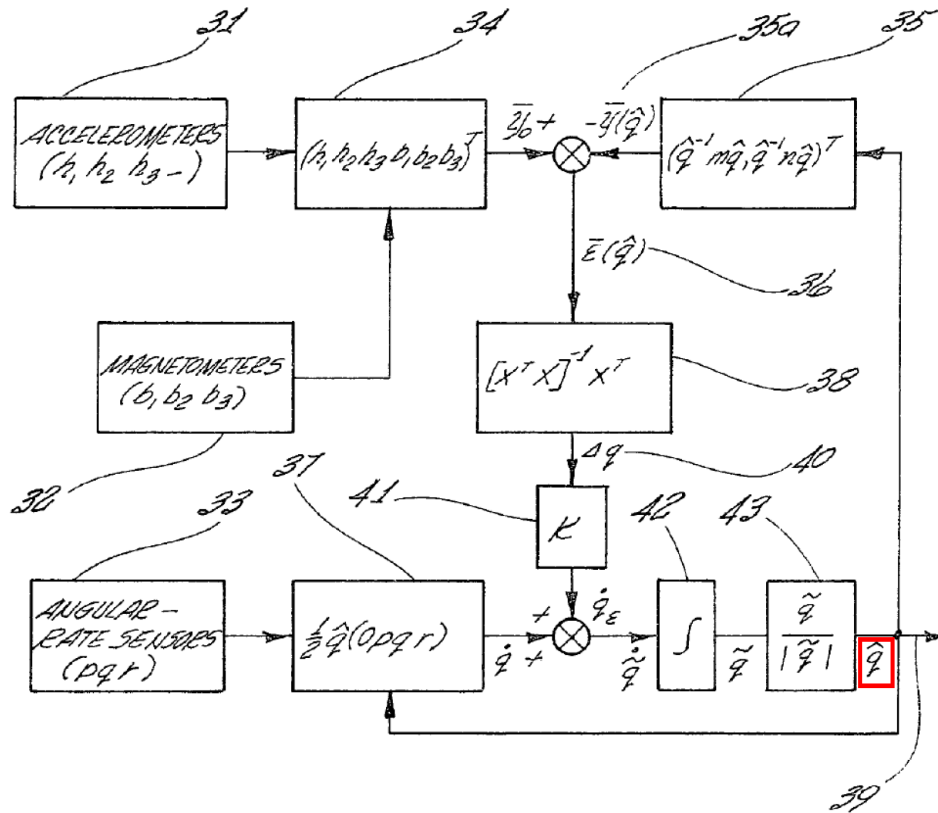
(Ex. 1017, ¶0011)(Emphasis added). This indicates that Withanawasam’s device is capable of translating the detected motions to control an output on a display, because the motions that are detected by a sensor are translated to a device orientation, which is used to control output on a display (by displaying the orientation, a compass direction, or a path).

75. As discussed above, it would have been obvious to combine Withanawasam’s smartphone with Bachmann’s nine-axis MARG sensor and filter processing to improve the determination of the pointing device’s orientation in

three-dimensional space. In operation, this combination would execute a **method of compensating rotations** of the device, as described in steps [19b]-[19h], below.

“[19(b)] 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;”

76. The combination of Withanawasam and Bachmann uses Bachmann’s quaternion-based filter processing to generate an orientation quaternion $\hat{q}$ that represents the device’s orientation. (Ex. 1004, 7:59-61). The orientation quaternion is the **orientation output** in 19[b]. It appears at the output of Bachmann’s filter processing shown in the lower right of Fig. 3 of Bachmann, which is reproduced below with the output $\hat{q}$ boxed in red.



77. The orientation quaternion is **associated with an orientation of the 3D pointing device** because it is generated from measurements by an accelerometer, magnetometer, and angular rate sensor made in the device’s frame of reference. Bachmann explains:

“[T]he filter inputs are from a three-axis accelerometer (h_1, h_2, h_3) 31, a three-axis magnetometer (b_1, b_2, b_3) 32, and a three-axis angular rate sensor (p, q, r) 33. Its **output is a quaternion representation of the orientation of the tracked object $\hat{q}$** 39.” (Ex. 1004, 10:10-14)(Emphasis added).

78. In the combination, the “tracked object” is Withanawasam’s 3D smartphone as explained above in ¶55.

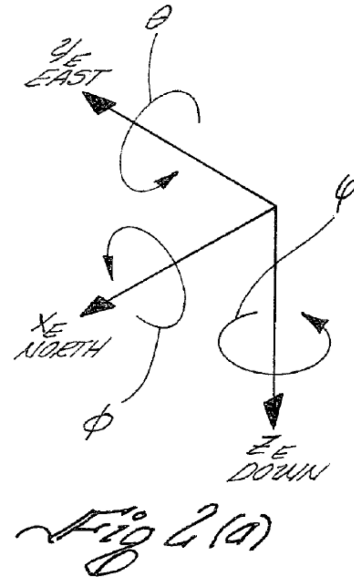
79. The orientation output $\hat{q}$ is **associated with three coordinate axes of a global reference frame associated with Earth** because represents a rotation between the spatial sensor frame of reference and a “flat Earth” or “earth fixed” reference frame. (Ex. 1004, 8:61-67, 5:50-61). Put differently, $\hat{q}$ represents the tracked body’s roll, pitch, and yaw between the sensor frame and Earth frame.

80. I take this mapping from Bachmann. Bachmann discloses calculating the output quaternion $\hat{q}$ from measurements of the tracked object’s *orientation* (*i.e.*, its roll, pitch, and yaw). (Ex. 1004, 9:59-10:14). Bachmann says that a tracked object’s orientation can be described using the Euler angles, also mentioned in the ’978 patent, referring to an Earth-associated coordinate system. Bachmann states:

“A conventional way of describing the **orientation of a rigid body** uses ‘**Euler angles**’ to describe the orientation of a rigid body in three dimensions. Euler angles describe the orientation of a rigid body using three rotations about specified axes. **One commonly used reference coordinate system is the local ‘flat Earth’ system.** Such reference systems use an arbitrarily selected origin on the surface of the earth with respect to coordinate axes X, Y, and Z. By convention, the X-direction corresponds to local north, the Y-direction corresponds to local east, and the Z-direction corresponds to down as depicted in FIG. 2(a).” (Ex. 1004, 5:50-61)(Emphasis added).

81. Bachmann’s Fig. 2(a) shows an Earth-associated coordinate system

reproduced at right. The angles shown in Fig. 2(a), specifically θ , ϕ , and φ , correspond to elevation (pitch), roll, and azimuth (yaw), respectively, about the X, Y, and Z axes. The X, Y, and Z axes in Bachmann's Fig. 2(a) are the **three coordinate axes** in claim element [19(b)]. (Ex. 1004, 6:1-10).



82. Computing orientation using Euler angles is computationally expensive and can result in singularities. (Ex. 1004, 6:25-7:3). To reduce this computational expense and avoid singularities, Bachmann estimates and represents orientation as the output quaternion introduced above. (Ex. 1004, 7:18-31). The output quaternion is just another way to express the tracked device's orientation. It represents the same information (roll, pitch, and yaw) as the Euler angles. Indeed, the '978 patent contemplates using a quaternion to represent orientation; otherwise proposed amended claim 20 would not say that "the orientation output is a rotation matrix, a **quaternion**, a rotation vector, or comprises three orientation angles." (Ex. 1001, claim 12)(Emphasis added).

83. Bachmann's quaternion is **associated with three coordinate axes of a global reference frame associated with Earth**. More specifically, it represents the rotation between the sensor (spatial pointer) reference frame and the Earth-fixed frame of reference. This can be seen from Equations (7) of Bachmann, which use

the inverse of the transformation described in ¶31 of my prior declaration, Ex. 1002 in IPR2018-01257, to rotate the gravitational and magnetism vectors (which are in an Earth-fixed frame) into the sensor frame of reference, using the quaternion multiplications $q^{-1}mq$ and $q^{-1}nq$ (Ex. 1004, 8:63-67). As described there, the normal rotation would be, for example, qmq^{-1} , not $q^{-1}mq$. The fact that the inverse rotation is used to go from an Earth-fixed frame to a sensor frame indicates that the orientation output quaternion $\hat{q}$ represents a rotation between the sensor frame and the Earth-fixed frame.

“[19(c)] generating a first signal set comprising axial accelerations associated with movements and rotations of the-3D pointing device in [the] a spatial reference frame;”

84. As mentioned above, the combination of Withanawasam and Bachmann would use a three-axis accelerometer that **generates a first signal set** representing measured acceleration. Bachmann explains as follows:

“In one embodiment, a three-axis accelerometer can be used to measure total acceleration (forced linear acceleration and gravitational reaction force) $\vec{a}_{measured}$ as over a fixed time period.”

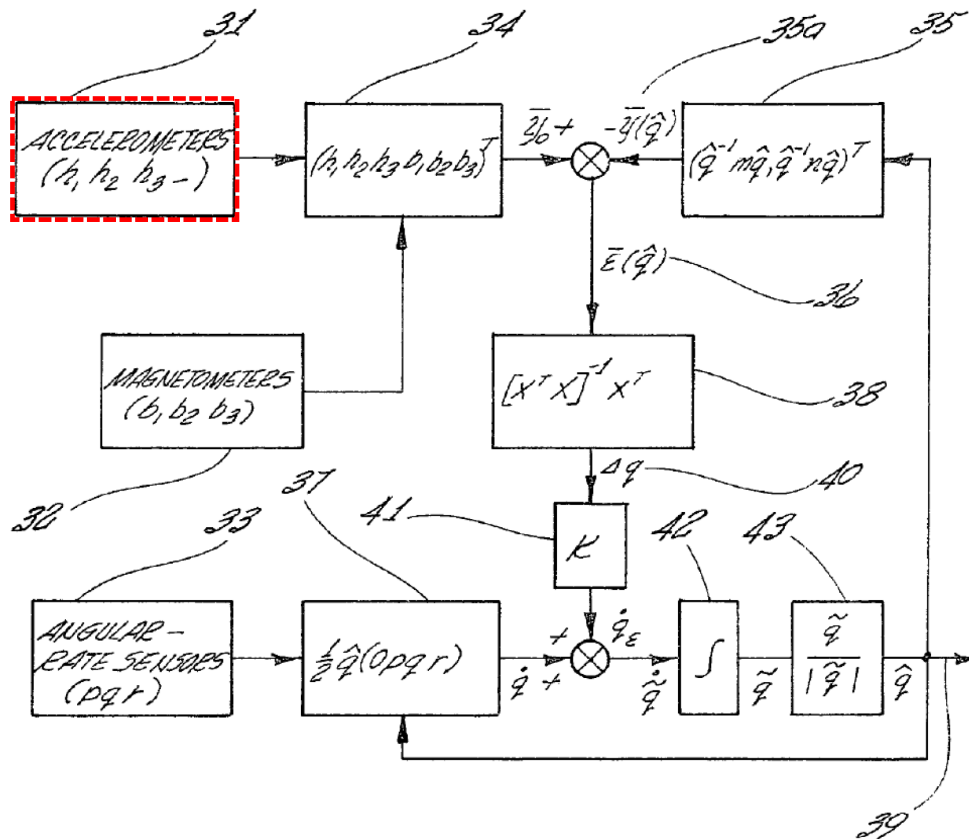
(Ex. 1004, 8:12-16).

85. This signal set is labeled $\vec{a}_{measured}$ and is equal to the sum of the device’s forced linear acceleration and the gravitational reaction force. (Ex. 1004, 10:10-14).

Bachmann's equation (1), reproduced below, gives this sum:

$$\vec{a}_{\text{measured}} = \vec{a} + \vec{g} \quad (1)$$

86. Bachmann also represents the measured acceleration as a vector or set of acceleration signals along different axes. Bachmann denotes this vector as (h_1, h_2, h_3) and derives it by low-pass filtering the measured acceleration to remove fast accelerations. (Ex. 1004, 8:13-42). This three-axis acceleration vector is one of the inputs to the quaternion-based filtering process shown in Bachmann's FIG. 3 (reproduced below with a red-dashed box around the three-axis accelerometer and the three-axis acceleration vector):



87. The measured acceleration **comprises axial accelerations associated**

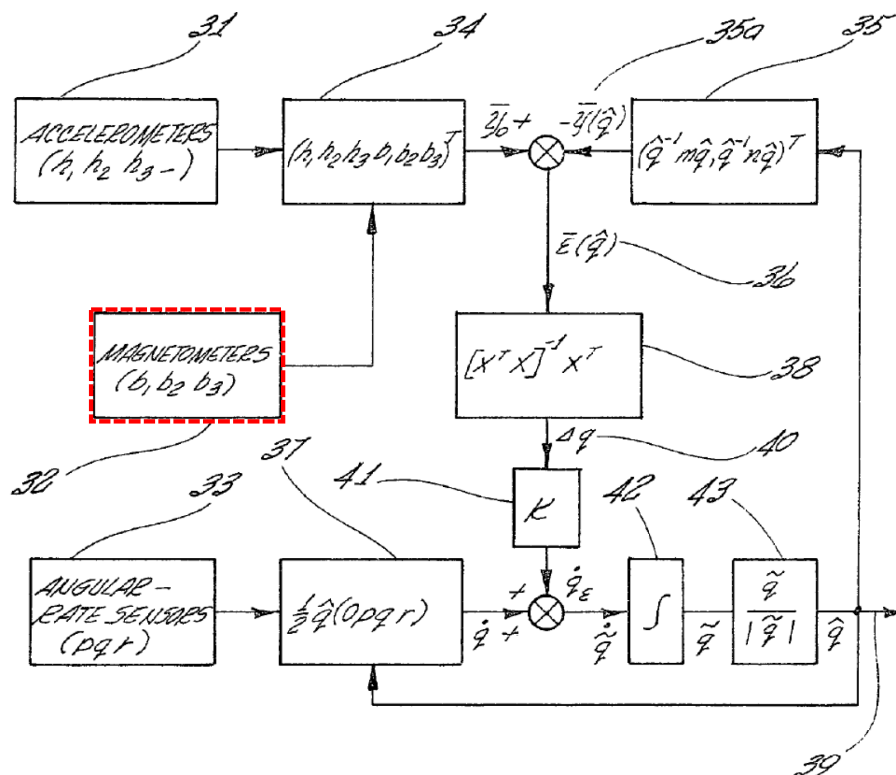
with movements and rotations of the 3D pointing device because (as shown in the block quote above) the signals $\vec{a}_{measured}$ comprise forced linear acceleration. (Ex. 1004, 8:12-16). The device experiences these forced linear accelerations as is it moved and rotated in three dimensions.

88. The measured acceleration is **in the spatial reference frame** because the accelerometer is part of the 3D pointing device. (Ex. 1005, ¶¶21 and 25). As a result, moving or rotating the 3D pointing device causes the accelerometer to move or rotate in the exact same way. In fact, Bachmann discloses transforming the vector m , which represents gravity in a fixed-Earth frame, to the sensor frame, which contains the accelerometer vector (h_1, h_2, h_3) . The accelerometer vector is just a low-pass filtered version of the measured acceleration (first signal set), which means that the accelerometer vector and the measured acceleration must be in the same reference frame—the sensor frame. Because the sensor is part of the 3D pointing device, the sensor frame is the same as the 3D pointing device’s frame of reference, which, in turn, is the **spatial reference frame** required by the claim, because its axes rotate and move with the device. (Ex. 1001, 5:60-64, 6:10-13).

“[19(d)] generating a second signal set associated with Earth's magnetism;”

89. The combination of Withanawasam and Bachmann would include a three-axis magnetometer, implemented as three orthogonally mounted single-axis

magnetometers. The magnetometers generate a **second signal set** (b_1, b_2, b_3). These signals are inputs to the filtering process shown in Bachmann's Fig. 3, reproduced below with a red-dashed box around the magnetometers and their output signals (b_1, b_2, b_3):



90. According to Bachmann, “[t]he magnetometers measure and return the direction of the local magnetic field vector (the unit vector b) 32.” (Ex. 1004, 7:63-65). The local magnetic field vector is **associated with Earth’s magnetism** because it points to magnetic north:

“An embodiment of the present invention makes use of the fact that a local magnetic field vector and local gravity vector can be defined. FIG. 1 is a simplified figurative illustration of the

surface of the earth 10 showing a local gravity vectors 11 and a **local magnetic field vector 13**. **In general, for any object positioned on the earth 10**, the gravity vectors always points to the earth’s center of mass, which may be defined as ‘down’. This phenomenon is simply illustrated in FIG. 1. Additionally, **the magnetic field vector 13 always points to magnetic north.**”

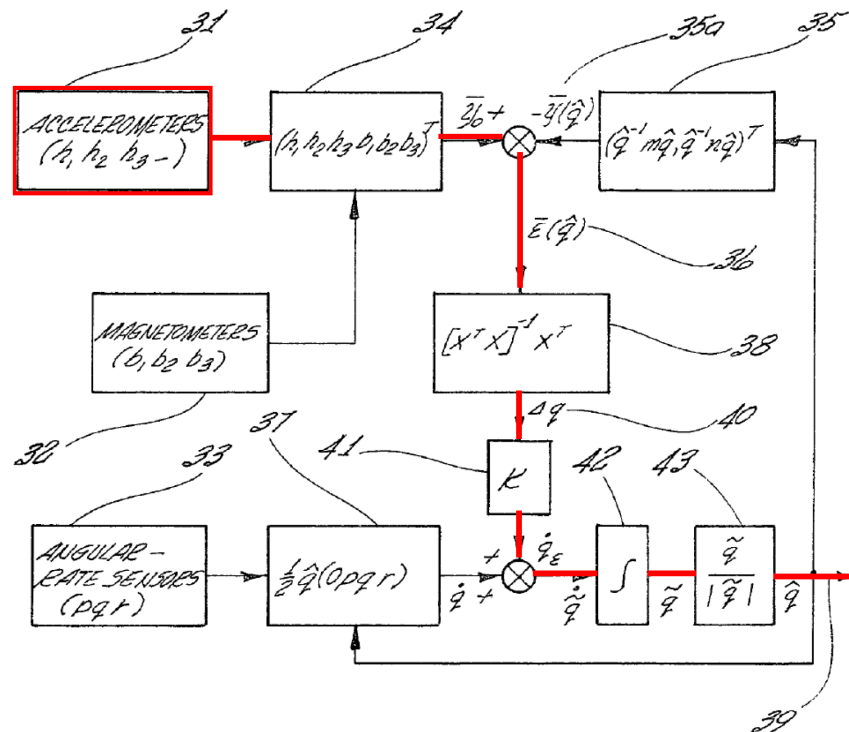
(Ex. 1004, 5:11-20)(Emphasis added).

“[19(e)] 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;”

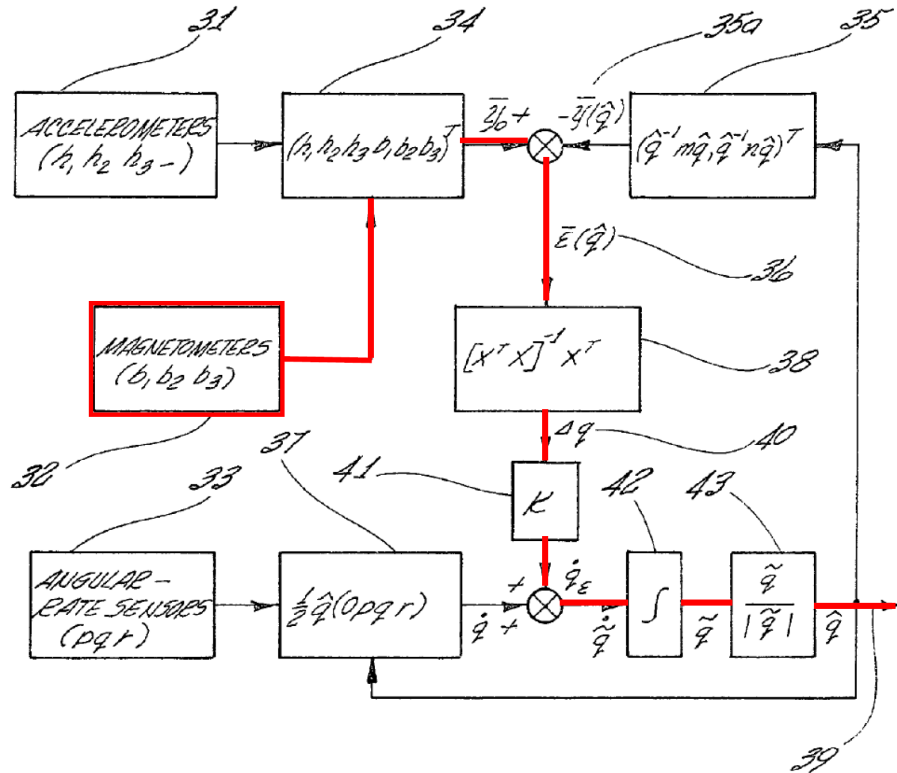
91. As explained above in ¶¶44–54, Bachmann generates the orientation output (orientation quaternion $\hat{q}$) both **based on the first signal set** (measured acceleration) **and the second signal set** (magnetometer outputs). The orientation output is also based on **the rotation output**, which is the angular rate information from the angular rate sensors. (Ex. 1004, 10:10-14)(Emphasis added).

92. The orientation output $\hat{q}$ is **based on the first signal set** ($\vec{a}_{measured}$). As explained above, the first signal set is low-pass filtered to yield an acceleration vector (h_1, h_2, h_3). (Ex. 1004, 8:63-67). Comparing the acceleration vector to predicted acceleration measurements $\bar{y}(\hat{q})$ yields a correction factor $\dot{q}_e$ that is added to a rate quaternion $\dot{q}$. (Ex. 1004, 9:9-17, 10:66-11:12). Integrating and normalizing the corrected rate quaternion yields the orientation output (orientation quaternion,

$\hat{q}$). (Ex. 1004, 9:43-48). This sequence of calculations is shown by the red lines in the following annotated version of Bachmann's Fig. 3:



93. The orientation output $\hat{q}$ is also **based on the second signal set** (b_1, b_2, b_3), which is produced by the magnetometers. Just like the first signal set, the second signal set is compared to predicted measurements $\bar{y}(\hat{q})$ and used to generate a correction factor $\dot{q}_e$ that is added to a rate quaternion $\dot{q}$. (Ex. 1004, 9:9-17, 10:66-11:12). As mentioned above, the corrected rate quaternion is then integrated and normalized to yield the orientation output, $\hat{q}$ (orientation quaternion, $\hat{q}$). (Ex. 1004, 9:43-48). These calculations are shown by the red lines in the following annotated version of Fig. 3:



94. The orientation output $\hat{q}$ is also **based on the rotation output**, which is simply the angular rate information 37 from the angular rate sensors 33 in Bachmann's Fig. 3. This rotation output is represented as an angular rate vector (p, q, r) . (Ex. 1004, 9:50-10:65). Bachmann explains:

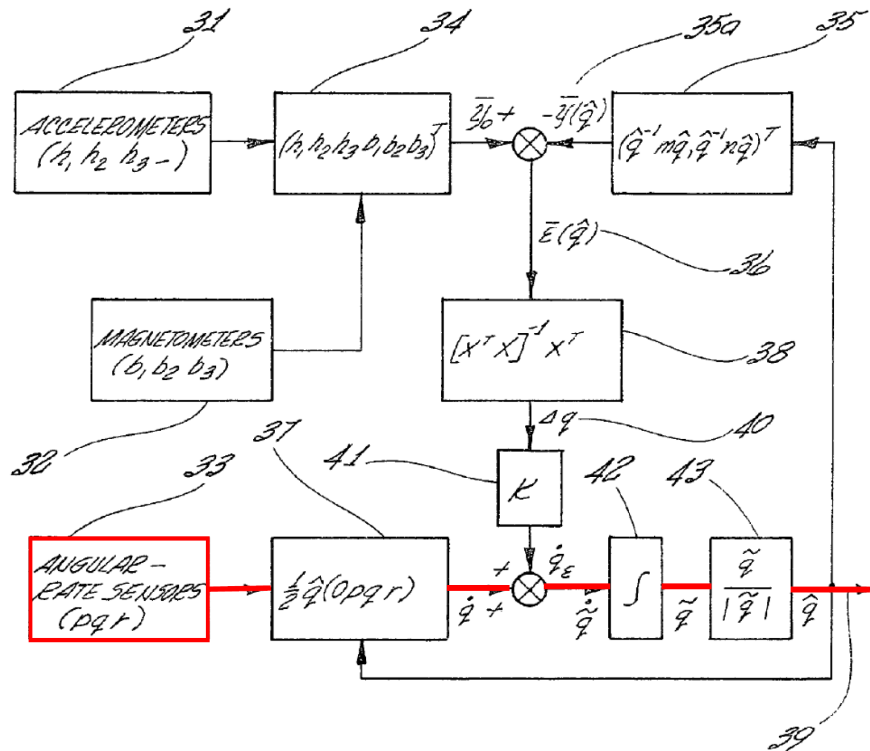
“FIG. 3 depicts the inputs from sensor embodiments that include **angular velocity (rate) detectors 33**. Interpreted in this way, such a filtering embodiment measures angular rate information 33, and uses measurements of local magnetic field 32 and local gravity 31 to correct the angular rate information or integrated angular rate information.”

(Ex. 1004, 9:52-58)(Emphasis added).

95. The “angular velocity (rate)” or angular rate information, represented

as (p, q, r) , is the **rotation output** recited in claim 10. (Ex. 1004, 10:10-14).

96. Bachmann's filtering process involves converting the rotation output (p, q, r) to the rate quaternion $\dot{q}$. (Ex. 1004, 10:15-45). This rate quaternion $\dot{q}$, is then corrected using the correction factor $\dot{q}_e$ generated from the first and second signal sets as described above and used to generate the orientation output $\hat{q}$. (Ex. 1004, 10:37-11:20). The calculations involving the rotation output are shown by the red lines in the following annotated version of Fig. 3:



97. Thus, the orientation output (orientation quaternion $\hat{q}$) is both (1) based on the first signal set, the second signal set and the rotation output and (2) based on the first signal set and the second signal set.

“[19(f)] generating a rotation output associated with a rotation of the 3D pointing device associated with three coordinate axes of [¶] the spatial reference frame associated with the 3D pointing device;”

98. As discussed immediately above, Bachmann uses angular velocity (rate) detectors 33 to **generate a rotation output**. This rotation output is a vector with components (p, q, r) and is **associated with three coordinate axes of a spatial reference frame associated with the 3D pointing device**.

99. To start, Bachmann’s angular rate sensor is a “**three-axis** angular rate sensor”. (Ex. 1004, 10:12)(Emphasis added). The three-axis angular rate sensor is mounted or affixed to the 3D pointing device, so its axes match or are at least fixed with respect to the axes of the 3D pointing device. As a result, rotating the 3D pointing device causes the three-axis angular rate sensor to rotate in the same way. Bachmann states that the angular rates are “measured in the sensor reference frame” (Ex. 1004, 10:17-30), which would be the same as or fixed with respect to the spatial reference frame because the sensor is fixed with respect to the 3D pointing device.

100. Moreover, a person of ordinary skill in the art would readily recognize that p, q, and r each represent angular velocity around a different **axis** within the spatial reference frame. This is standard notation, with p as the roll rate, q as the pitch rate, and r as the yaw rate. (Ex. 1004, 10:30-32).

“[19(g)] and using the orientation output and the rotation output to generate a transformed output associated with a fixed display reference frame associated with a display device built-in to and integrated with the 3D pointing device, wherein the orientation output and the rotation output is generated by a nine-axis motion sensor module;”

101. As discussed above under limitations [19e] and [19f], Bachmann discloses generating an **orientation output** $\hat{q}$ and a **rotation output** (p, q, r). These outputs are **generated by a nine-axis motion sensor module** with “a three-axis accelerometer (h_1, h_2, h_3) 31, a three-axis magnetometer (b_1, b_2, b_3) 32, and a three-axis angular rate sensor (p, q, r) 33.” (Ex. 1004, 10:10-14). This is the same type of nine-axis motion sensor module described in the '978 patent. (Ex. 1001, FIG. 4).

102. It would have been obvious to generate a **transformed output associated with a fixed reference frame associated with a display device**. Bachmann suggests that its orientation output be transformed to the coordinate system of a display device (e.g., in connection with Fig. 4).

103. It would have been obvious to **use the orientation output and the rotation output for this transformation**. In the combination here, the orientation output $\hat{q}$ represents the orientation of Withanawasam's smartphone. To translate difference angles to screen coordinates, a person of ordinary skill would have found it obvious to obtain the difference angles from the **orientation output** (orientation quaternion $\hat{q}$). Moreover, a person of ordinary skill in the art would have been

motivated to use the orientation quaternion $\hat{q}$ in order to increase the computational efficiency of the translation.

104. In combining Withanawasam and Bachmann, a person of ordinary skill in the art would **use the rotation output** as follows. First, because the orientation output is based on the rotation output (as discussed above under element [19e]), the transformation to display coordinates based on the orientation output would implicitly **use the rotation output**. Second, it would have been obvious to transform an estimate of angular velocity (e.g., the rotation rate $\dot{q}$) into display coordinates for the purpose of rendering any motion of Withanawasam's display more smoothly and consistently in response to rotation of the device.

“[19(h)] 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.”

105. It would have been obvious to obtain **a resultant deviation including a plurality of deviation angles** from the orientation output (Bachmann's orientation quaternion $\hat{q}$). As discussed above, the device's orientation can be represented using either an orientation quaternion or Euler (deviation) angles. **While Bachmann uses quaternions for computational advantage and to avoid angular singularities, it would have been obvious to convert the orientation output quaternion, $\hat{q}$, to Euler angles.** Indeed, Bachmann describes Euler angles as completely conventional:

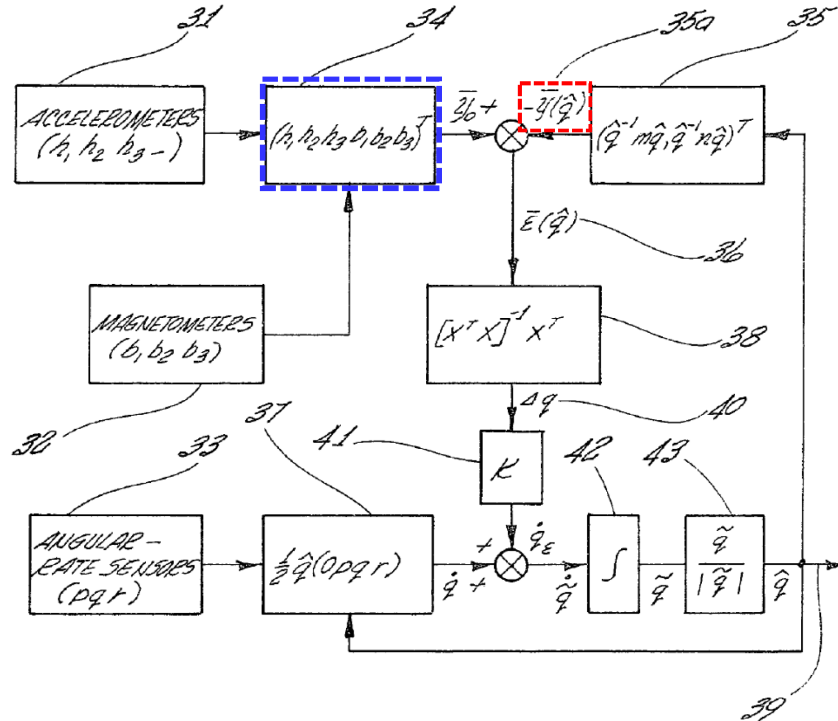
“A conventional way of describing the orientation of a rigid body uses ‘Euler angles’ to describe the orientation of a rigid body in three dimensions. Euler angles describe the orientation of a rigid body using three rotations about specified axes.”

(Ex. 1004, 5:50-55).

106. Euler angles and quaternions were both well-known circa 2009. Converting from quaternions to Euler angles (roll, pitch and yaw) would have been merely the substitution of one known element for another to achieve an expected result. Such a transformation was well within the level of ordinary skill in the art and could have been carried out using published techniques. And a person of ordinary skill in the art would have been motivated to perform such a transformation for any of a variety of reasons, including expression of the device’s orientation in the easily understood terms of roll, pitch, and yaw, which were known to be equivalent to rotation quaternions.

107. As explained above, the orientation output that would be converted into deviation angles is calculated **using a plurality of measured magnetisms M_x , M_y , M_z and a plurality of predicted magnetism[s] M_x' , M_y' , and M_z' for the second signal set.** Again, Bachmann teaches obtaining a second signal set (b_1, b_2, b_3), which are **a plurality of magnetisms M_x , M_y , M_z .** (Ex. 1004, 7:63-65, 8:37-8:50). Bachmann also teaches using **a plurality of predicted magnetism[s] M_x' , M_y' , and M_z'** in the form of a predicted measurement vector $y(\hat{q})$. (Ex. 1004, 8:61-9:8).

The following annotated version of Bachmann's Fig. 3 shows the measured magnetisms in a blue box and the predicted measurement vector $\bar{y}(\hat{q})$ in a red box:



108. Bachmann states that $\bar{y}(\hat{q})$ is a “computed measurement vector” containing predicted magnetisms (b_1, b_2, b_3) :

“Combining the vector parts of Eq. (7) yields a single 6x1 **computed measurement vector** $\bar{y}(\hat{q})$ 35a, wherein: $\bar{y}(\hat{q}) = [h_1 \ h_2 \ h_3 \ b_1 \ b_2 \ b_3]^T$ (8) and wherein the values for $h_1 \ h_2 \ h_3 \ b_1 \ b_2 \ b_3$ are generated by mapping m and n through as an estimated orientation quaternion.” (Ex. 1004, 9:1-8)(Emphasis added).

109. The (b_1, b_2, b_3) portion of the computed measurement vector is the **predicted magnetism M_x' , M_y' , and M_z'** . The predicted magnetisms are

associated with the **x, y, and z axes** in the spatial pointer reference frame because (1) they are translated from an Earth-fixed frame to the sensor frame in box 35 of Fig. 3; and (2) they are matched with the **three-axis** magnetometer measurements (b_1, b_2, b_3), which are in the sensor frame as explained above. (Ex. 1004, 8:57-9:17).

110. Bachmann further discloses that the measured and predicted magnetisms are **used to form the orientation output** (which, in turn, can be used to determine deviation angles). As explained above, Bachmann generates an error value ($\bar{\epsilon}(\hat{q})$) that represents the difference between the measured and predicted magnetisms. This error value is used to determine a correction factor $\dot{q}_\epsilon$ for the rate quaternion $\dot{q}$, which is used to generate the orientation output (orientation quaternion $\hat{q}$). Bachmann states:

“Again, a **6x1 measurement vector** y_0 34 in sensor coordinates **is produced** (Eqn. (4)). Again, in accordance with Eq. (7), Eq. (5), and Eq. (6) are approximations mapped from the earth fixed frame to the body frame through quaternion multiplication 35. **And a 6x1 computed measurement vector** $\bar{y}(\hat{q})$ 35a is generated. As previously described, the difference between the measurement vector y_0 and the computed measurement vector $\bar{y}(\hat{q})$ is the error vector $\{\text{right arrow over } \epsilon(\hat{q})\}$ 36 and the square of the filter modeling error is termed the criterion function. The error vector is then minimized....[A]s previously explained with respect to Eqns (9) and (10) a Gauss-Newton iteration 38 is performed to **correct a measured rate quaternion** (See,

FIG. 3, 36).” (Ex. 1004, 9:64-10:45)(Emphasis added).

Thus, the combination using Bachmann’s filter **obtains 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[s] M_x' , M_y' , and M_z' for the second signal set.**

’978 Patent Proposed Amended Claim 20

“[20] The method of claim 10, wherein the 3D pointing device is a smartphone, and wherein the orientation output is a rotation matrix, a quaternion, a rotation vector, or comprises three orientation angles.”

111. Withanawasam teaches that its device can be a smartphone. (Ex. 1017, ¶¶0011, 0001, claim 17).

112. As discussed above under proposed amended claim 19, element [19b], Bachmann discloses that the orientation output is a **quaternion** $\hat{q}$. (Ex. 1004, 10:12-14).

’438 Patent Proposed Amended Claim 20

[20(a)] “A three-dimensional (3D) pointing device, which is handheld, subject to movements and rotations in dynamic environments, comprising:”

113. Withanawasam teaches a **three-dimensional (3D) pointing device**, in the form of a portable navigation device that can be a smartphone running certain software. Withanawasam states:

“FIG. 1 is one embodiment of a personal navigation device (PND) 100 comprising an integrated MEMS and magnetic sensor 130. The PND 100 can be a mobile (**hand-held**) navigation device, a **smart phone**, or any similar mobile device **configured to aid a user in navigation and applications requiring orientation information.**”

(Ex. 1017, ¶0011)(Emphasis added). Figure 1 of Withanawasam is shown below.

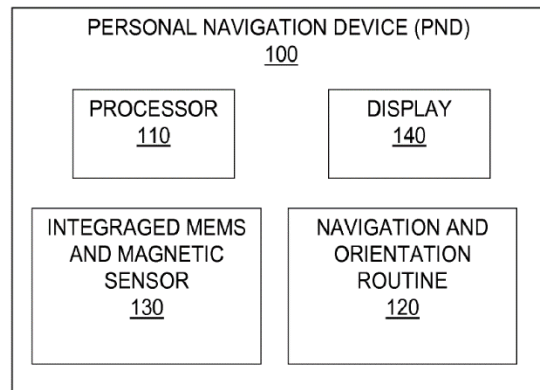


FIG. 1

114. Withanawasam’s smartphone, which functions as a personal navigation device, is a (3D) pointing device according to CyWee’s proposed construction of that term, because it is “a handheld device that detects the motion of said device in three-dimensions and is capable of translating the detected motions to control an output on a display.” First, as stated in the quote above, Withanawasam’s device is **handheld**. (Ex. 1017, ¶0011, claim 17).

115. Second, Withanawasam’s device “detects the motion of said device in

three-dimensions and is capable of translating the detected motions to control an output on a display”. Withanawasam first describes detecting the motion of said device in three-dimensions. Withanawasam states:

“Orientation information is information relating to the present orientation of the PND 100, and can be determined using the integrated MEMS and magnetic sensor 130 (also referred to herein as the integrated MEMS sensor). The integrated MEMS and magnetic sensor 130 provides information to the processor 110 relating to acceleration, roll, and directional data (that is, relating to a compass direction). The PND 100 can use three axes of sensing for acceleration and gyroscope data in one single integrated MEMS sensor 130.”

(Ex. 1017, ¶0012, *see also* claim 15). Withanawasam also notes that smart phones typically have a “magnetic compass that have to work even when the device is not held level, which requires a micro-electromechanical systems (MEMS) accelerometer or a gyroscope to be integrated with the magnetic sensors.” (Ex. 1017, ¶0001).

116. Third, the Withanawasam device is **capable of translating the detected motions to control an output on a display**. Specifically, Withanawasam’s device comprises “a display configured to present the positional information to a user.” (Ex. 1017, claim 16). For example, Withanawasam states:

“The PND 100 includes a processor 110 configured to run a

navigation and orientation routine module 120. A **display 140** presents navigation information to the user, and can comprise a liquid crystal display (LCD), a digital display, or the like. Navigation information that can be displayed includes **positional information, orientation information, maps, compass directions, a predetermined path, or any other information useful in navigation.**”

(Ex. 1017, ¶0011)(Emphasis added). This indicates that Withanawasam’s device is capable of translating the detected motions to control an output on a display, because the motions that are detected by a sensor are translated to a device orientation, which is used to control output on a display (by displaying the orientation, a compass direction, or a path).

117. For similar reasons, it was obvious that Withanawasam’s device was **subject to movements and rotations in dynamic environments**. A smartphone is “handheld”, as Withanawasam expressly states (Ex. 1017, ¶0011), and is thus designed to move with a user’s hand. Furthermore, Withanawasam would obviously not sense motion and, based thereon, calculate device position and orientation, if the device position and orientation were not subject to change. (Ex. 1017, ¶¶0011-0012).

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

118. It would have been obvious that Withanawasam’s smartphone device would have a **housing**. First, smartphones in the relevant time frame had housings. Second, Withanawasam’s device is “handheld” and has a display, a processor, sensors and a printed circuit board. (Ex. 1017, Fig. 1, ¶¶0011-0012, claims 15-17). This would have made a housing obvious, to protect sensitive electronic components that a user would otherwise be holding directly in his or her hand. Because the housing would be the part held by the user, and thus subject to the movements of the user’s hand, the housing would obviously be **associated with said movements and rotations of the 3D pointing device in a spatial pointer reference frames**.

“[20(c)] a printed circuit board (PCB) enclosed by the housing;”

119. Withanawasam teaches that its device has a printed circuit board (“PCB”). Withanawasam states:

“The present integrated MEMS sensor devices are miniature sensor devices that reduce the amount of semiconductor substrate material used in the device and concurrently reduce the PCB footprint of the packaged device.”

(Ex. 1017, ¶0010). A person of ordinary skill in the relevant timeframe would have understood this disclosure to mean that the MEMS sensor devices of Withanawasam are mounted on a PCB. The MEMS sensor devices are designed to be small, so that the MEMS sensor devices do not take up much area (“footprint”) of the PCB, such

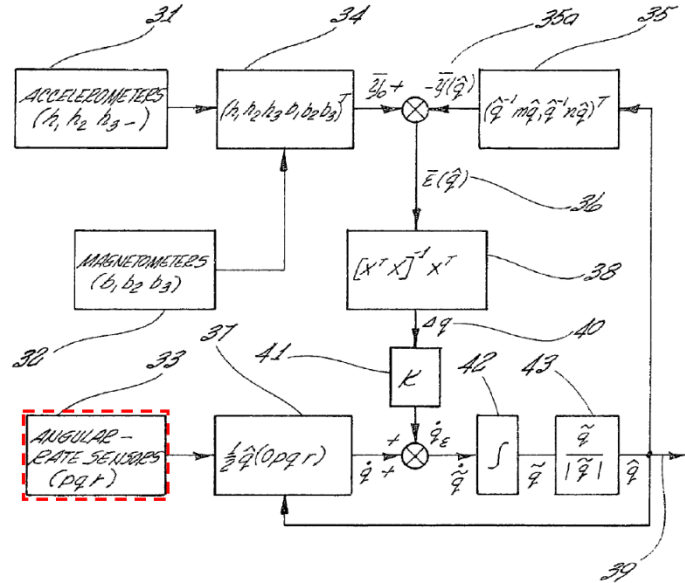
that other components can be placed on the PCB. This is further supported by the Background of Withanawasam. (Ex. 1017, ¶0001).

120. Furthermore, in the relevant timeframe, PCBs were ubiquitous in handheld electronic devices and computing systems, because they allowed simple and compact mounting and interconnection of small electronic components. It would have been obvious to use a PCB in Withanawasam's smartphone, based on the suggestions in its disclosure. (Ex. 1017, ¶¶0001, 0010). It would further have been obvious to put the PCB within the housing, because otherwise, the user of the smartphone, which is handheld, would directly touch the PCB and its circuits. This obviously would have been not only uncomfortable for the user, but also potentially damaging to the delicate circuits on the PCB.

“[20(d)] 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,”

121. Bachmann's angular rate sensors generate signals (p, q, r) that represent the **angular velocities Ω_x , Ω_y , Ω_z** . (Ex. 1004, 10:10-14). Specifically, Bachmann

uses angular velocity (rate) detectors 33 to **generate a first set of signals** (p, q, r) corresponding to the roll, pitch, and yaw of the 3D pointing device. These signals are shown in box 33 of Bachmann's Fig. 3 (outlined in a red-dashed box, at right).



122. The roll, pitch, and yaw signals are **associated with said movements and rotations of the 3D pointing device in the spatial pointer reference frame.** They are measured with respect to the angular rate sensor's frame of reference. Because the angular rate sensor is mounted to the 3D pointing device, its frame of reference (including its origin and axes) is fixed with respect to the 3D pointing device. If the angular rate sensor is mounted properly, its reference frame is the same as **the spatial reference frame of the pointer.** (Improper mounting may introduce a static offset with respect to the spatial reference frame of the pointer.) As a result, if the smartphone moves with respect to the Earth, the angular rate sensors move as well in the exact same way. This means that the angular velocities sensed by the angular rate sensors are “measured in the sensor reference frame.” (Ex. 1004, 10:17-30). Put differently, Bachmann's “sensor reference frame” is the

same as the “spatial pointer reference frame” in the ’438 patent.

123. The **spatial reference frame of the pointer** can be represented using **three axes**, such as Cartesian axes centered at a point on or within the 3D pointing device. Bachmann acknowledges this by calling the angular rate sensor a “**three-axis** angular rate sensor”. (Ex. 1004, 10:12)(Emphasis added). Withanawasam also refers to the three axes of the smartphone. (Ex. 1017, ¶0012).

124. It would have been **obvious to mount Bachmann’s sensors on Withanawasam’s PCB**. This is exactly what PCBs are for—to hold components like Bachmann’s sensors, and Withanawasam’s sensors are mounted on the printed circuit board. (Ex. 1017, ¶¶0010, 0001). The sensors can be mounted using three different axes of sensing. (Ex. 1017, ¶0012). Given Withanawasam’s disclosure of mounting sensors along three axes on a PCB (Ex. 1005, ¶0025), the similar mounting of Bachmann’s sensors, and the fact that components were commonly mounted to printed circuit boards in the relevant time frame, a person of ordinary skill would have found it obvious to mount **Bachmann’s sensors on Withanawasam’s PCB**.

“[20(e)] 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;”

125. The combination of Withanawasam and Bachmann has a three-axis accelerometer that **detects and generates a second signal set comprising axial**

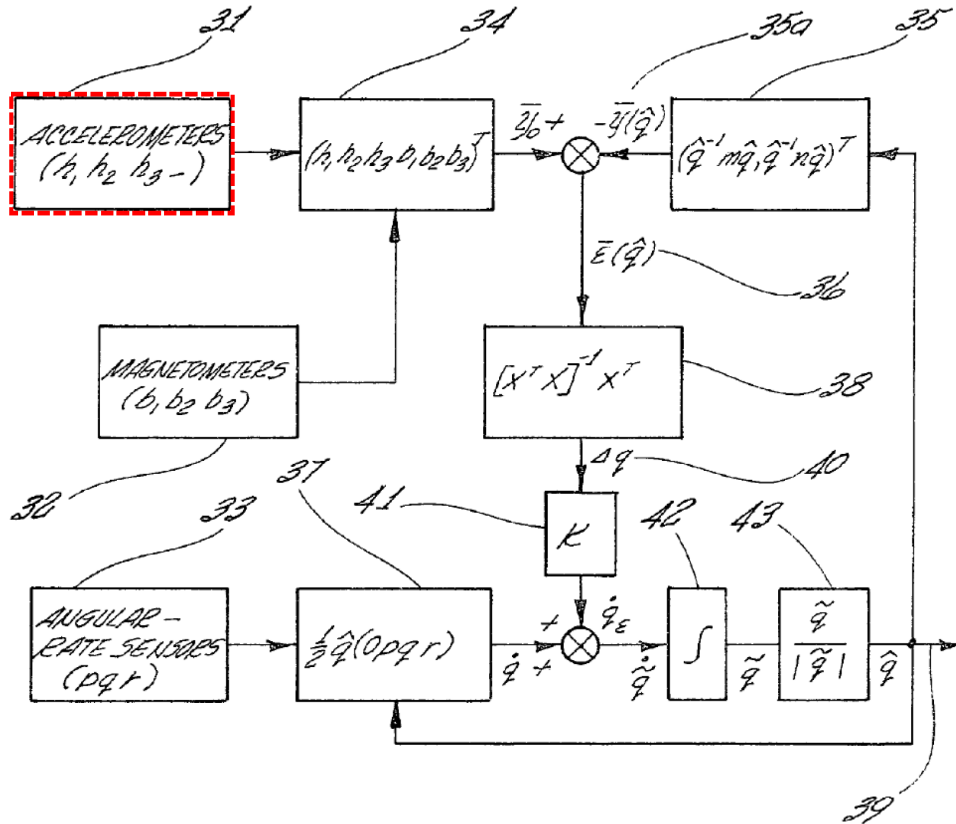
accelerations Ax, Ay, Az. (Ex. 1004, 10:10-14). Bachmann explains as follows:

“In one embodiment, a **three-axis accelerometer** can be used to measure total acceleration (forced linear acceleration and gravitational reaction force) $\vec{a}_{measured}$ as over a fixed time period.” (Ex. 1004, 8:12-16)(Emphasis added)

126. Bachmann gives the measured acceleration as the sum of the forced linear acceleration and the gravitational reaction force as:

$$\vec{a}_{measured} = \vec{a} + \vec{g} \quad (1)$$

127. The measured acceleration is low-pass filtered to remove fast accelerations, yielding a vector (h_1, h_2, h_3) , as shown in FIG. 3 of Bachmann. (Ex. 1004, 8:13-42). Figure 3 is reproduced below with a red box around the three-axis accelerometer and the filtered accelerometer vector (h_1, h_2, h_3) :



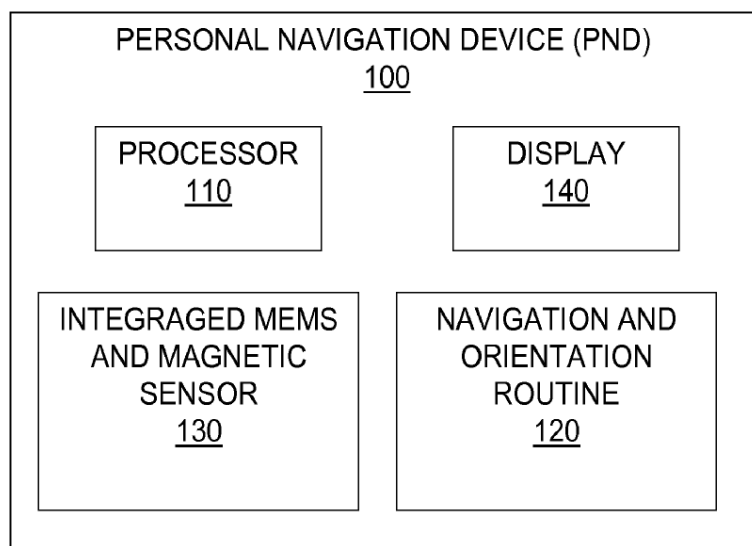
128. The measured accelerometer signals are **associated with said movements and rotations of the 3D pointing device in the spatial pointer reference frame**, because (as shown in the block quote above) they include a forced linear acceleration term. (Ex. 1004, 8:12-16). This forced linear acceleration term represents accelerations that the **3D pointing device** experiences as it is moved and rotated by the user.

129. Because the accelerometer is mounted to the 3D pointing device, it measures these accelerations **in the spatial pointer reference frame**, just like the angular rate sensor and magnetometer. (See ¶¶121-122, above). If this were not the case, then Bachmann would not have to transform the device's orientation from an

Earth-fixed frame to the spatial pointer reference frame before combining it with the accelerometer measurements. (Ex. 1004, Equation (7)). That is, Bachmann's Equation (7) transforms the vector m , which represents gravity in flat-Earth coordinates, to an estimated measured acceleration vector, which is the spatial pointer frame of reference, so that it can be subtracted from the measured acceleration vector. (Ex. 1004, 8:63-67). This transformation is required because the filtered accelerometer output h is in the **spatial pointer reference frame** required by the claim. (Ex. 1001, 5:60-64, 6:10-13).

“[20(f)] [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,”

130. Withanawasam teaches a device as shown in Fig. 1, reproduced below:



131. The processor 110 in FIG. 1 of Withanawasam provides the **computing processor** of claim 20. Alternatively, the processor 403 in Bachmann’s FIG. 4 could provide the computing processor of claim 1.

132. Withanawasam further teaches that “[t]he components of the PND 100 are communicatively coupled to one another as needed using suitable interfaces and interconnects.” (Ex. 1017, ¶0011). Here, the “components” that are connected include the processor 110 and the integrated MEMS and magnetic sensor 130, because Withanawasam teaches that “[t]he integrated MEMS and magnetic sensor 130 provides information to the processor 110 relating to acceleration, roll, and directional data (that is, relating to a compass direction).” (Ex. 1017, ¶0011). Thus, there are “suitable interfaces and interconnects” between the sensor 130 and processor 110, and these interfaces and interconnects form a **data transmitting unit electrically connected to the six-axis motion sensor module for transmitting said first and second signal sets thereof**. It was also well-known in the relevant timeframe that sensors might need interface circuits, such as A/D converters, in order to condition their outputs for use by a processor.

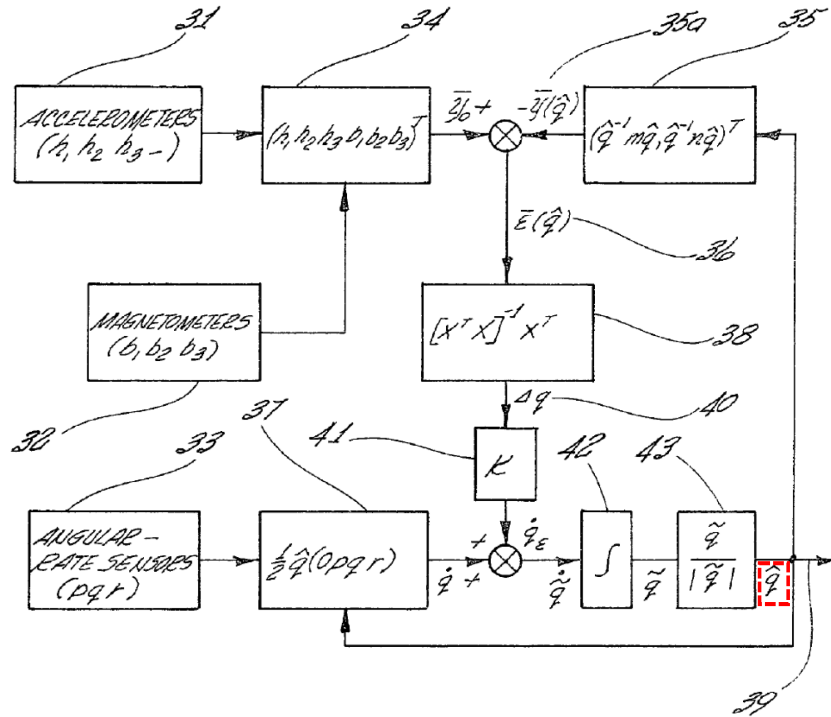
133. The **processor 110 (or processor 403) receives and calculates said first and second signal sets**. (Ex. 1017, ¶¶0011-0012, claim 15). More specifically, the processor 110 (or processor 403) receives the sensor measurements and uses them to calculate the 3D pointing device’s orientation. (*Id.*). In the combination,

the processor 110 or processor 403 would generate the orientation using Bachmann's quaternion-based filter processing.

“[20(g)] communicating with the six-axis motion sensor module to calculate a resulting deviation comprising resultant angles in said spatial pointer reference frame”

134. As discussed immediately above, in the combination of Withanawasam and Bachmann, the processor 110 of Withanawasam would **communicate with the six-axis motion sensor module**, by obtaining data from the sensors. (Ex. 1017, ¶¶0011-0012, claim 15).

135. In the combination, the processor (*e.g.* processor 110 of Withanawasam or the processor 403 of Bachmann) also **calculates a resulting deviation comprising resultant angles in said spatial pointer reference frame**. Specifically, as described above in ¶¶44-54, Bachmann discloses a filtering process that yields an “orientation of the tracked object.” (Ex. 1004, 10:10-14). Bachmann expresses the orientation output as an orientation quaternion, $\hat{q}$, but it can be expressed in other forms (*e.g.*, a set of Euler angles) as well. Bachmann's FIG. 3 shows the filtering process with the orientation output $\hat{q}$ at lower-right. An annotated version of FIG. 3 is reproduced below with a red-dashed box around it:



136. A quaternion represents orientation (rotation angles) using a four-valued vector. It can be used to translate an orientation measurement from one reference frame to another. Here, the orientation output $\hat{q}$ is a quaternion that represents a rotation from the sensor-based coordinate system (the **spatial reference frame** of claim 1) to a flat-Earth coordinate system. (Ex. 1001, 5:60-64, 6:10-13). In fact, Bachmann's Equation (7) uses the orientation output $\hat{q}$ to transform a magnetism vector m from the sensor frame to the Earth-fixed frame. (Ex. 1001, 5:60-64, 6:10-13). This transformation is expressed as $(h = \hat{q}^{-1} m \hat{q})$, where h is in the sensor frame and m is in the Earth-fixed frame. (Rotations in quaternion mathematics are expressed as conjugations, where h is equal to the conjugation of m by $\hat{q}$ in Equation (7).) Equation (7) shows that $\hat{q}$ represents a rotation between the

sensor frame and the Earth-fixed frame.

137. The combination renders obvious **calculating a resulting deviation comprising resultant angles** in two ways. First, the orientation output $\hat{q}$ is a **deviation** because it represents the same information as the standard Euler angles. Second, it would have been obvious to calculate **a resultant deviation including a plurality of deviation angles** from the orientation output $\hat{q}$ of Bachmann. It would have been obvious to convert the orientation output from a quaternion representation to Euler angles because Euler angles are conventional. Bachmann expressly states that:

“A **conventional** way of describing the orientation of a rigid body uses ‘**Euler angles**’ to describe the orientation of a rigid body in three dimensions. Euler angles describe the orientation of a rigid body using three rotations about specified axes.”

(Ex. 1004, 5:50-55)(Emphasis added).

138. Converting the orientation output quaternion, $\hat{q}$, into the “conventional” form of Euler angles (roll, pitch, and yaw) would have made the underlying orientation information easier to interpret by a human user. Withanawasam, for example, teaches displaying “orientation information”, “compass direction” (Ex. 1017, ¶0011), both of which would have been far easier to understand to a human user than a quaternion. The equations for such a transformation (from a quaternion to Euler angles) were widely known in the art. These Euler angles represent **a**

resultant deviation including a plurality of deviation angles.

139. As explained above, the orientation output quaternion $\hat{q}$ represents a rotation *from* the spatial pointer reference frame *to* the Earth-fixed frame. It therefore represents angles between the spatial pointer reference frame and the Earth-fixed frame. Converting the orientation output quaternion $\hat{q}$ into equivalent Euler angles makes that representation more explicit. And because the orientation output quaternion $\hat{q}$ goes from the spatial pointer reference frame to the Earth-fixed frame, it can be converted into equivalent Euler angles that are **in said spatial pointer reference frame.**

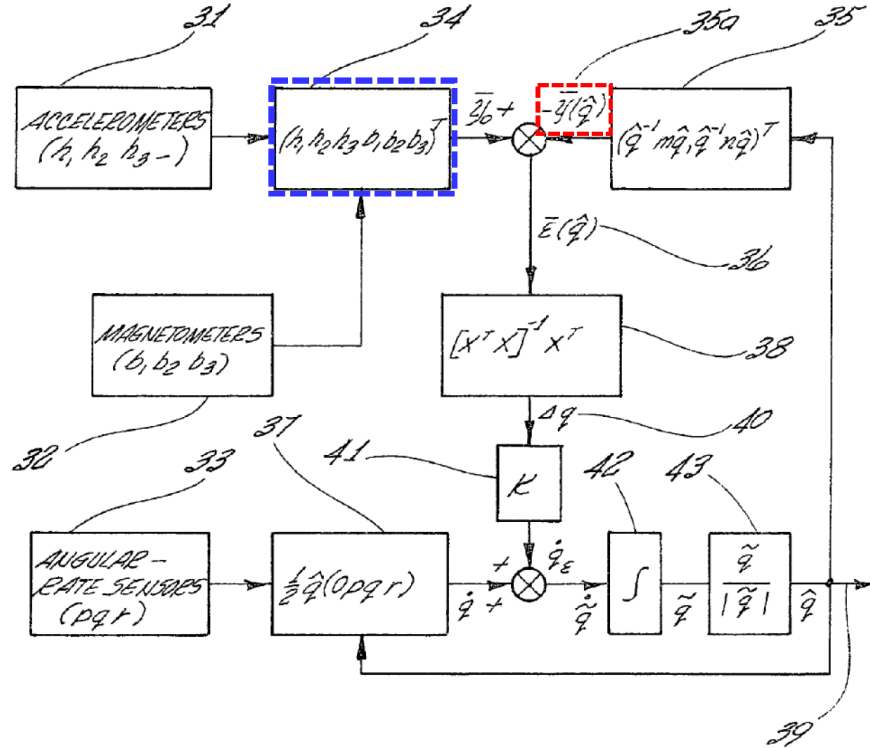
“[20(h)] by utilizing a comparison to compare the first signal set with the second signal set whereby said resultant angles in the spatial pointer reference frame of the resulting deviation of the six-axis motion sensor module of the 3D pointing device are obtained under said dynamic environments, wherein 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;”

140. Bachmann **utilizes a comparison to compare the first signal set with the second signal set** to obtain the resulting deviation. As explained above in ¶¶44-54, Bachmann’s filter calculates the orientation output quaternion $\hat{q}$ by integrating and normalizing the angular rate quaternion $\dot{q}$. The red dashed line in the following annotated version of FIG. 3 shows the corresponding pathway:

pointing frame in a way that reduces the effect of sensor noise. Bachmann performs these calculations in determining the correction factor $\dot{q}_\varepsilon$ in steps 34-41 of FIG. 3.

143. Bachmann forms a six-valued measurement vector ($h_1 \ h_2 \ h_3 \ b_1 \ b_2 \ b_3$), shown in box 34, from the *actual* accelerometer measurements² and magnetometer measurements. (Ex. 1004, 10:10-14, 3:13-17, 8:47-51). This vector includes acceleration and magnetic field measurements along the X, Y, and Z axes. (*Id.*). This **measurement vector is compared to a predicted measurement** vector $\bar{y}(\hat{q})$ by subtracting the predicted measurement vector from the actual measurement vector. (Ex. 1004, 9:9-17, 17:12-22). In the following annotated version of Fig. 3, the actual measurement vector is in a blue-dashed box and the predicted measurement vector $\bar{y}(\hat{q})$ is in a red-dashed box:

² The accelerometer measurements are low-pass filtered to remove high-frequency measurements representing sudden accelerations. (Ex. 1004, 8:12-20).



144. The difference between the predicted measurement vector and the actual measurement vector is a six-valued error vector $\bar{e}(\hat{q})$, numbered 36 in Fig. 3. (Ex. 1004, 9:9-17, 17:12-22). The subtraction that forms this vector is the claimed **comparison**, and happens in Fig. 3, above, directly between the blue and red-dashed boxes, at the junction $\frac{\bar{y}_6}{\bar{y}_6} + \frac{-\bar{y}(\hat{q})}{\bar{y}(\hat{q})}$. The error vector $\bar{e}(\hat{q})$ is used in boxes 38 and 41 to select a correction factor $\dot{q}_e$ that minimizes $\bar{e}(\hat{q})$. (Ex. 1004, 9:9-35). That is, adding correction factor $\dot{q}_e$ to $\dot{q}$ minimizes the difference between the actual and predicted measurement vectors. (Ex. 1004, 9:9-35). Minimizing this difference compensates the orientation output of the filter, $\hat{q}$.

145. The process described above is a “**comparison**” because it is used while

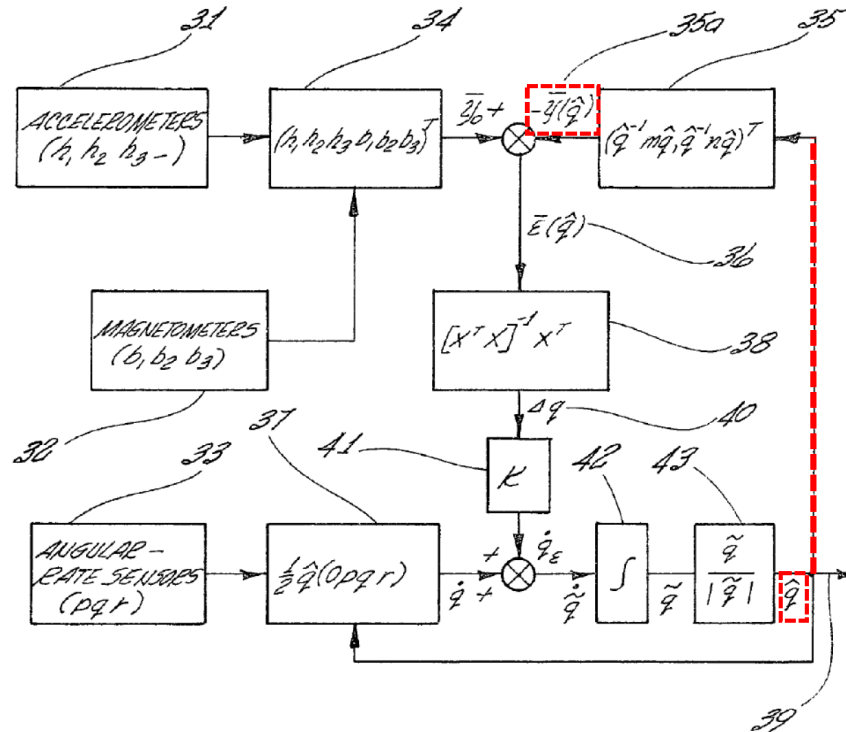
calculating and obtaining the orientation output quaternion $\hat{q}$, which is in turn used to calculate **the deviation angles with respect to the spatial pointer frame**. (¶¶134–138, *above*). The calculation also **utilizes signals generated by motion sensors while reducing or eliminating noises associated with said motion sensors**. Calculating the correction factor $\dot{q}_\varepsilon$ involves signals from the magnetometer, accelerometer, and angular rate sensors to reduce error associated with the sensors. As Bachmann explains:

“[I]n normal operating environment, **the output 33 of angular rate detectors tends to drift over time**. Thus, rate detector data 33 can be used to determine orientation only for relatively short periods of time unless this **orientation is continuously corrected using ‘complementary’ data from additional sensors** (here, accelerometer 31 and magnetometer 32). Thus, as previously explained with respect to Eqns. (9) and (10) a Gauss-Newton iteration 38 is performed **to correct a measured rate quaternion** (See FIG. 3, 36).”

(Ex. 1004, 10:36-45)(Emphasis added)(*see also* Ex. 1004, 9:1-48).

146. In the combination, Bachmann’s filter processing would be performed by a processor (*e.g.*, Withanawasam’s processor 110 or Bachmann’s processor 403) and would thus constitute an **update program**. The processor and thus the update program are part of the **processing and transmitting module**. The **updated state** is a new value of the orientation output quaternion $\hat{q}$. (Ex. 1004, 10:10-14).

147. The updated state is **based on a previous state** because the correction factor $\hat{q}_e$ is calculated using the predicted measurement vector based on the most recent orientation output (*i.e.*, **the previous state**). This is shown by the red-dashed line added to Fig. 3, below:



148. Box 35 in Bachmann's Fig. 3 and Bachmann's Equation (7) show that the prior orientation output quaternion $\hat{q}$ is used to calculate predicted measurements $\bar{y}(\hat{q})$.

149. The **previous state** (*i.e.*, the prior orientation output quaternion $\hat{q}$) is **associated with said first signal set**. The first signal set includes yaw, pitch, and roll signals (p, q, r) equivalent to the angular velocities $\Omega_x, \Omega_y, \Omega_z$. These first signals are used to calculate each output $\hat{q}$ (as explained above) and are therefore embedded

in each orientation output quaternion $\hat{q}$.

150. The measured state is **associated with said second signal set**. The claimed **measured state** includes both actual and predicted measurement vectors. The second signal set, as explained above in paragraphs 125-129, comprises axial accelerations A_x , A_y , A_z . The **measured state is associated with said second signal set** because the actual and predicted measurement vectors contain actual and predicted accelerations, respectively. Bachmann's Equation (8) shows the composition of the *predicted* measurement vector, including the predicted accelerations (h_1 , h_2 , h_3). (Ex. 1004, 8:63-9:48). Bachmann's Equation (8) is reproduced below:

$$y(\hat{q}) = [h_1 \ h_2 \ h_3 \ b_1 \ b_2 \ b_3]^T \quad (8)$$

“[20(i)] 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[.]”

151. As explained immediately above, the measured state includes actual **measurements of the second signal set** (*i.e.*, measured accelerations). The measured state also includes **predicted measurements of the second signal set** (*i.e.* predicted accelerations) in the vector $\bar{y}(\hat{q})$. (Ex. 1004, 8:63-9:48).

152. The predicted measurements of the second signal set are **obtained based on the first signal set without using any derivatives of the first signal set**.

Specifically, the predicted measurement vector $\bar{y}(\hat{q})$ is obtained by transforming the magnetic field vector n and the gravity vector m from an Earth-fixed frame to the sensor frame using the prior orientation output quaternion $\hat{q}$. Bachmann's Equation (7) shows this transformation:

$$h = \hat{q}^{-1} m \hat{q} \quad b = \hat{q}^{-1} n \hat{q} \quad (7)$$

153. (Ex. 1004, 8:52-67). Combining the resulting magnetic field and gravity vectors h and b yields the predicted measurement vector $\bar{y}(\hat{q})$. (Ex. 1004, 9:1-8).

154. Equation (7) and the predicted measurement vector are therefore **based on the first signal set** (*i.e.* angular velocities) because they are generated using the prior orientation output quaternion $\hat{q}$. The orientation output quaternion $\hat{q}$, in turn, is generated from the angular velocities (*i.e.* the first signal set) measured by the angular rate sensors 33. (§§140-150, *above*).

155. The **predicted measurements do not use any derivatives of the first signal set**. Specifically, Equation (7) does not use any derivatives of the first signal set (*i.e.*, derivatives of angular velocities). The gravity and magnetism vectors represent linear accelerations and magnetic field orientations, not derivatives of the angular velocities. (Ex. 1004, 8:52-62). And the prior orientation output quaternion $\hat{q}$ is a normalized *integral* (the opposite of a derivative) of the corrected rate quaternion $\hat{\tilde{q}}$. (Ex. 1004, 10:15-65). The corrected rate quaternion $\hat{\tilde{q}}$ itself is

formed by adding the rate quaternion $\dot{q}$ and the correction factor $\dot{q}_\varepsilon$. (Ex. 1004, Fig. 3, 10:46-11:26). The rate quaternion $\dot{q}$ is simply a quaternion representation of the angular velocities, not a derivative of the angular velocities. (Ex. 1004, Fig. 3, 10:46-11:26). That is, the rate quaternion $\dot{q}$ represents the angular velocities, not the angular accelerations.

156. The correction factor $\dot{q}_\varepsilon$ is formed using a matrix X , which uses derivatives. (Ex. 1004, 10:46-65). These derivatives are the partial derivatives of the acceleration and magnetism with respect to changes in orientation, not derivatives of the first signal set (angular acceleration). (Ex. 1004, 10:46-65). And the prior orientation output $\hat{q}$ is an integrated value of the rate quaternion (equivalent to the angular velocities), meaning that, if differentiated, it would simply yield the rate quaternion again, not a derivative of the angular velocities.

“[20(j)] and a display device built-in to and integrated with the 3D pointing device and associated with a display reference frame, wherein said resultant angles of the resulting deviation in the spatial pointer reference frame are translated to a movement pattern in the display reference frame.”

157. Withanawasam teaches that its smartphone has a built-in display device. Withanawasam states:

“The PND 100 includes a processor 110 configured to run a navigation and orientation routine module 120. A **display 140 presents navigation information to the user, and can**

comprise a liquid crystal display (LCD), a digital display, or the like. Navigation information that can be displayed includes positional information, orientation information, maps, compass directions, a predetermined path, or any other information useful in navigation.”

(Ex. 1017, ¶0011)(Emphasis added). Figure 1 of Withanawasam (reproduced below) shows the display within the device 100:

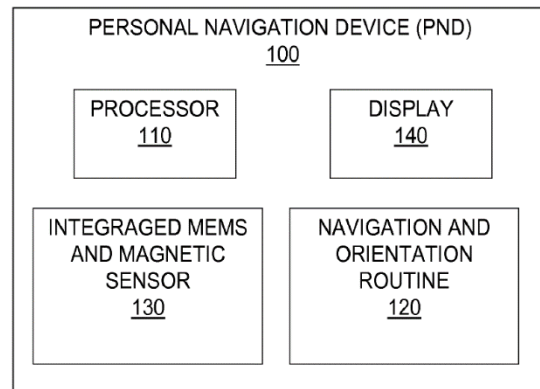


FIG. 1

158. Furthermore, it would have been well-understood and obvious in the relevant timeframe that the display 140 of Withanawasam, in a smartphone embodiment, would have been **built-in to and integrated with** the smartphone. This was typical for smartphones in the relevant timeframe, and would have been obvious to do, to protect the electrical circuits of the display and avoid forcing the user to carry the display as a separate element. A display built in to and integrated with the device would have inherently and obviously been “**associated with**” a **display reference frame**, which is simply a coordinate system that moves with the

display.

159. Withanawasam further teaches that its resultant angles of the **resulting deviation in the spatial pointer reference frame are translated to a movement pattern in the display reference frame**. For example, Withanawasam discloses that “[m]obile devices such as personal navigation devices (PND) and smart phones typically have some form of navigation and map orientation application.” (Ex. 1017, ¶0001). A person of ordinary skill in the art would have understood this in the relevant timeframe to mean an application that displays a map, and the user’s heading, as well as the user’s orientation.

160. Withanawasam further explains that its device’s display can be used to display a variety of things based on orientation information. Withanawasam states:

“FIG. 1 is one embodiment of a personal navigation device (PND) 100 comprising an integrated MEMS and magnetic sensor 130. The PND 100 can be a mobile (hand-held) navigation device, a smart phone, or any similar mobile device configured to aid a user in navigation and **applications requiring orientation information**. For example, a user can be a professional first responder or a member of the public. The PND 100 includes a processor 110 configured to run a navigation and orientation routine module 120. **A display 140 presents navigation information to the user, and can comprise a liquid crystal display (LCD), a digital display, or the like.** Navigation information that can be displayed includes **positional information, orientation information, maps, compass**

directions, a predetermined path, or any other information useful in navigation. [¶][0012] Orientation information is information relating to the present orientation of the PND 100, and can be determined using the integrated MEMS and magnetic sensor 130 (also referred to herein as the integrated MEMS sensor).”

(Ex. 1017, ¶¶0011-0012)(Emphasis added). When the orientation of the Withanawasam device changed, it was obvious that the displayed information (e.g., “orientation information”, “compass directions”, etc.) would have changed in a mapping or orientation application, thus **translating the resulting deviation into a movement pattern in the display reference frame.**

’438 Patent Proposed Amended Claim 21

“[21] The 3D pointing device of claim 1, wherein the 3D pointing device is a smartphone, and 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.”

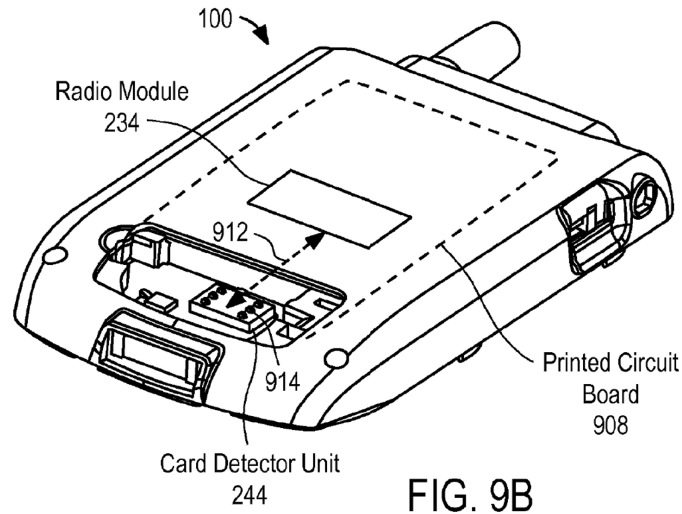
161. Withanawasam teaches that its device can be a smartphone. (Ex. 1017, ¶¶0011, 0001, claim 17). Withanawasam also teaches a PCB (as discussed above under proposed amended claim 20, element [20(c)]). A PCB is a **substrate** with interconnections and other elements.

162. Withanawasam does not expressly disclose that the PCB enclosed by the housing comprises at least one substrate having a first longitudinal side

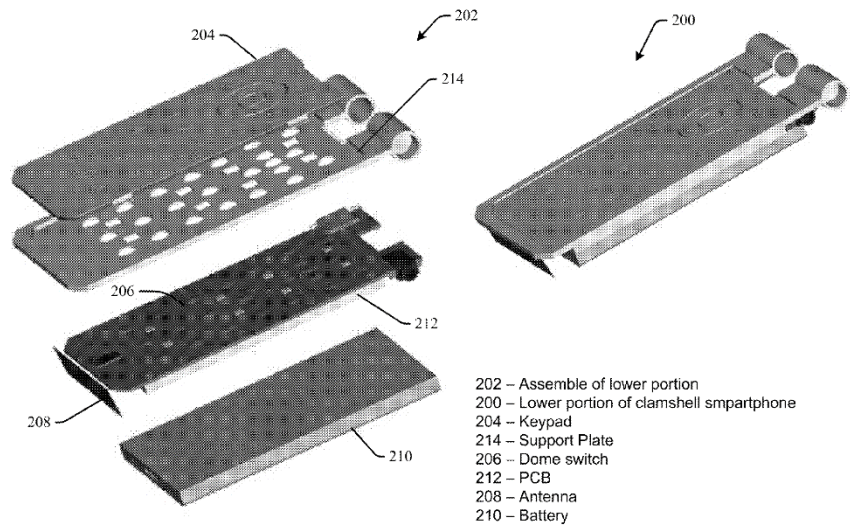
configured to be substantially parallel to a longitudinal surface of the housing. However, this would have been obvious based on the knowledge of a person of ordinary skill in the relevant timeframe. Specifically, in the relevant timeframe, it was typical for a smartphone with a PCB to have the PCB area fill all or most of the interior of the smartphone housing. This maximized the area of the PCB within the housing, thus increasing the area that could be consumed by components as “footprint”. Withanawasam teaches that it was desirable to limit the area consumed by components mounted to the PCB (Ex. 1017, ¶¶0001, 0010), and an obvious corollary of this is that a larger PCB would allow more components to be mounted. Thus, it was obvious in the relevant timeframe that a device PCB area would match the available area within the housing. In other words, the outline of the PCB would follow the internal outline of the housing. This naturally and obviously led to an arrangement 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.**

163. There are many examples of such designs in the prior art. For example, U.S. Pat. No. 7,356,361 to Hawkins (Ex. 1020), entitled “hand-held device”, filed in 2001 and issued in 2008, discloses a smartphone 100 having a printed circuit board 908 whose contours follow the sides of the housing, thus providing that the PCB has **a first longitudinal side configured to be substantially parallel to a longitudinal**

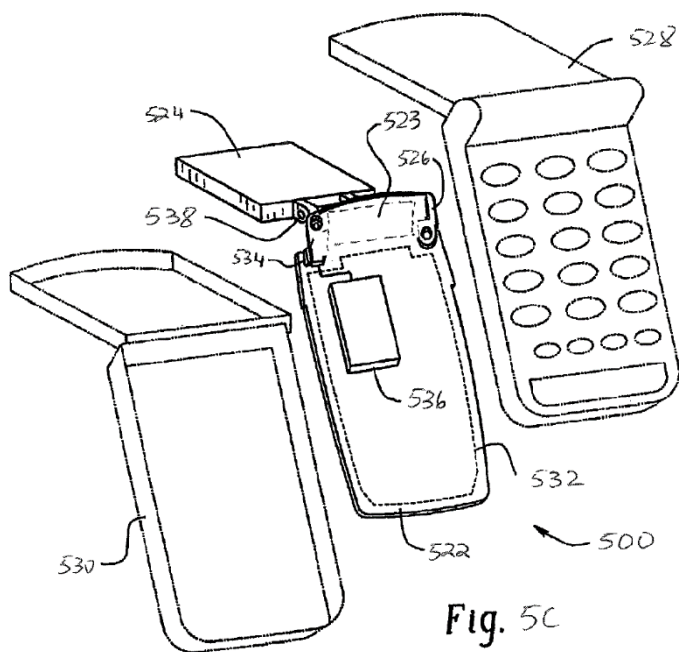
surface of the housing. This is shown in Fig. 9B of Hawkins, reproduced here:



164. As another example, U.S. Pat. No. 7,630,741 to Siddiqui (Ex. 1021), entitled “compact and durable messenger device”, filed in 2005 and issued in 2009, discloses a smartphone having a printed circuit board 212 whose contours follow the sides of the housing, thus providing that the PCB has a **first longitudinal side configured to be substantially parallel to a longitudinal surface of the housing.** This is shown in Fig. 2 of Siddiqui, reproduced at right.



165. As another example, U.S. Pat. No. 8,738,103 to Puente Baliarda (Ex. 1022), entitled “multiple-body configuration multimedia and smartphone multifunction wireless devices”, filed in 2006 and issued in 2014, discloses a smartphone having printed circuit boards 522 and 524 (Ex. 1022, 28:27-30). The contours of the PCBs follow the sides of the housing, thus providing that the PCBs have a **first longitudinal side configured to be substantially parallel to a longitudinal surface of the housing**. This is shown in Fig. 5c of Puente Baliarda, reproduced at right.



166. Thus, it would have been obvious based on the knowledge of a person of ordinary skill to implement a PCB that follows the inner contours of the smartphone housing, thus maximizing the available PCB area, and causing the PCB to have a **first longitudinal side configured to be substantially parallel to a longitudinal surface of the housing**.

VIII. OATH

168. This declaration and my opinions herein are made to the best of my knowledge and understanding, and based on the material available to me, at the time of signing this declaration. I declare under penalty of perjury under the laws of the United States of America that all statements made of my own knowledge are true and that all statements made on information and belief are believed to be true. I understand that willful false statements and the like are punishable by fine or imprisonment, or both (18 U.S.C. 1001) and may jeopardize the validity of the application or any patent issuing thereon.

Date: 6-17-2019

Signed: Majid Sfr