

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

SAMSUNG ELECTRONICS CO., LTD.,
Petitioner,

v.

CM HK LIMITED,
Patent Owner

IPR2025-01071
Patent 11,698,687

**EXPERT DECLARATION OF DR. JOSEPH LAVIOLA, PH.D., IN
SUPPORT OF PATENT OWNER'S RESPONSE**

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I, Joseph LaViola, declare as follows:

I. INTRODUCTION

1. I have been retained by Patent Owner CM HK Ltd. (“CM HK” or “Patent Owner”) as an independent technical expert in this proceeding as well as IPR2025-01023. I have been asked to review Dr. Sarrafzadeh’s declaration and the prior art references that Petitioner is relying on to challenge claims 1-7, 12, 14, and 25.

2. I am being compensated in this matter at my customary rate of \$500/hour. My compensation is not based on the substance of my opinions or the outcome of this matter. I have no financial interest in CM HK Ltd. or Samsung Electronics Co., Ltd. (“Petitioner”).

3. I was an expert on behalf of patent owner in IPR2018-01257, challenging U.S. Patent No. 8,552,978 (’978 patent), and IPR2018-01258, challenging U.S. Patent No. 8,441,438 (’438 patent), both of which are related to the ’687 patent. I submitted a declaration and gave deposition testimony in both proceedings.

II. QUALIFICATIONS AND PUBLICATIONS

4. My Curriculum Vitae is provided as Exhibit 2043. The following is a summary of my education and relevant experience.

5. I have over 25 years of experience working in the virtual reality (“VR”) and augmented reality (“AR”) fields, as well as advancing three-dimensional (“3D”) interaction techniques for use in both VR and AR environments. More

specifically, I have worked extensively on and with user and object motion tracking sensors, algorithms and systems.

6. I am the Charles N. Millican Professor of Computer Science in the Department of Computer Science at the University of Central Florida, located in Orlando, Florida. I also serve as the Director of the Interactive Computing Experiences Research Cluster at the University of Central Florida. Through these functions, I supervise over ten graduate and undergraduate students working on various research projects in human-computer interaction. In addition, between 2013 and 2018, I served as an Adjunct Associate Professor of Computer Science and between 2018 and 2024 I served as a Visiting Scholar of Computer Science at Brown University, located in Providence, Rhode Island.

7. I received my Bachelor of Science degree in Computer Science from Florida Atlantic University in 1996. I also hold two Masters degrees – an Sc.M. in Computer Science and an Sc.M. in Applied Mathematics from Brown University which were awarded in 2000 and 2001 respectively. I received my Ph.D. in Computer Science from Brown University in 2005.

8. I serve as Associate Editor for various publications in human computer interaction, including the International Journal of Human-Computer Studies and the Association for Computing Machinery's Transactions on Interactive Intelligent Systems. I have also served as Program Chair for the IEEE Virtual Reality

conference. In 2025, I was inducted into the IEEE VGTC Virtual Reality Academy.

9. I have contributed to more than 45 peer-reviewed journal publications and 175 refereed conferences and workshops, the majority of which deal with virtual and augmented reality and user and object motion tracking. For instance, I am the lead author of the second edition of the most comprehensive textbook on 3D user interaction, entitled “3D User Interfaces: Theory and Practice.” As part of that work, I analyzed many different types of input and output hardware, 3D user interfaces and general topics related to virtual and augmented reality. I have also worked specifically with sensors and algorithms related to the '846 and '687 Patents.

10. I have been working with recursive-style estimators, including Kalman filters and Extended Kalman Filters (“EKF”), for over 20 years. I have implemented Kalman filters and EKFs in practice and written several papers on them as part of my work in motion tracking and 3D interfaces, including the following:

Julier, S., and LaViola, J., “On Kalman Filtering with Nonlinear Equality Constraints”, IEEE Transactions on Signal Processing, 55(6):2774-2784, June 2007.

LaViola, J., “A Comparison of Unscented and Extended Kalman Filtering for Estimating Quaternion Motion”, In the Proceedings of

the 2003 American Control Conference, IEEE Press, 2435-2440, June 2003.

LaViola, J., “Double Exponential Smoothing: An Alternative to Kalman Filter-Based Predictive Tracking”, In the Proceedings of Immersive Projection Technology and Virtual Environments 2003, ACM Press, 199-206, May 2003.

11. I have also been teaching Kalman filters and EKFs to my students over the last 20 years. An example of work using EKFs that I published with one of my students follows:

Williamson, B., and Wingrave, C., and LaViola, J., “RealNav: Exploring Natural User Interfaces for Locomotion in Video Games”, Proceedings of the IEEE Symposium on 3D User Interfaces 2010, 3-10, March 2010.

12. I have done research exploring the function and operation of the Nintendo Wii Remote (Wiimote) device and written papers and given lectures on its operation. For example, I have explored how to use the Wiimote to support 3D gesture recognition interfaces:

Hoffman, M., Varcholik, P., and LaViola, J., “Breaking the Status Quo: Improving 3D Gesture Recognition with Spatially Convenient Input Devices”, Proceedings of IEEE Virtual Reality 2010, 59-66, March 2010.

13. In another example, I wrote a tutorial paper with my students on how the Wiimote works, how to use it in 3D interfaces, and what its strengths and weaknesses are as well as established a set of novel 3D interface techniques that takes advantage of its functionality:

Wingrave, C., Williamson, B., Varcholik, P., Rose, J., Miller, A., Charbonneau, E., Bott, J. and LaViola, J. “Wii Remote and Beyond: Using Spatially Convenient Devices for 3DUIs”, IEEE Computer Graphics and Applications, 30(2):71-85, March/April 2010.

14. I have submitted declarations, deposition testimony, or both in the following cases related to this matter:

Cywee v. Samsung, Case No. 2:17-cv-00140-RWS-RSP

Cywee v. Huawei, Case No. 2:17-cv-00495-RWS-RSP

Cywee v. HTC, Case No. 2:17-cv-00932-JLR

Cywee v. ZTE, Case No. 1:17-cv-00780-GMS

Cywee v. Motorola, Case No. 1:17-cv-00780-GMS

Google v. Cywee IPR, IPR2018-01257, IPR2018-01258,

ZTE v. Cywee IPR, IPR2019-00143

15. My opinions on claim construction have remained the same across all these proceedings, including this one, involving related patents.

III. MATERIALS REVIEWED

16. In forming my opinions expressed in this Declaration, I reviewed the following materials: The Petitions, Papers 14, Papers 20, Ex. 1001-1021, Ex. 2002-2041 from IPR2025-01023 and IPR2025-01071. I have been given access to all materials that have been filed in the IPR as of the date of this declaration.

17. I also considered any other documents or materials referenced in this Declaration.

18. In addition to the above documents, my opinions also based on my personal knowledge, professional judgment, education and experience gained through my years as a computer scientist, professor, and consultant.

IV. RELEVANT LEGAL PRINCIPLES

19. I have been asked to opine on whether claims 1, 3, 7, and 9 of the '687 Patent would have been nonobvious in light of the prior art to one skilled in the art at the time of the invention.

20. I am not an attorney. In preparing and expressing my opinions I relied on the following legal principles that were provided by counsel.

21. I understand that, in this inter partes review, the Petitioner has argued that claims 1, 3, 7, and 9 of the '687 Patent are obvious.

22. Counsel explained that under 35 U.S.C. § 103, a patent may be invalid as obvious if the differences between the subject matter patented and the prior art are such that, at the time that the invention was made, the subject matter as a whole would have been obvious to a person of ordinary skill in the art ("POSITA") to which said subject matter pertains. I understand that although the ultimate determination of obviousness is a question of law, there are factual issues underlying the ultimate obviousness decision.

23. I understand that the obviousness analysis is based on four underlying factual inquiries: (1) the scope and content of the prior art; (2) the differences

between the claims and the prior art; (3) the level of ordinary skill in the pertinent art; and (4) any secondary considerations of nonobviousness.

24. I understand that to sustain an obviousness challenge against a claim(s), a petitioner must show that the asserted prior art references in combination must teach or suggest all the limitations of the challenged claim(s).

25. I understand that a patent may be invalid as obvious in view of a single prior art reference or multiple prior art references together, and that the background knowledge of, and common-sense inferences that would be made by, a person of ordinary skill in the art may be considered in determining whether a claim is obvious.

26. Counsel informed that to qualify as prior art for an obviousness challenge, the asserted references must be of the same type of art or of an analogous art as the challenged patent. Counsel informed me that a reference may be “analogous” if it is either (1) in the same field of endeavor as the challenged patent, or (2) if it is in a different field of endeavor, it is still reasonably pertinent to the problem addressed by the challenged patent.

27. Counsel informed me that, because inventions often involve a combination of known elements that seem predictable in hindsight, to prevent hindsight invalidation of patent claims, the law requires some “teaching, suggestion or motivation” to combine cited references. Counsel informed me that motivation to

combine references may be found in the cited references themselves, in the knowledge of a POSITA at the time of invention, and/or in the nature of the problem to be solved.

28. Counsel informed me that a single prior art reference can only render a claim obvious if the petitioner demonstrates an *apparent reason* for a person of ordinary skill in the art to modify that reference in the specific manner required to arrive at the claimed invention. And that the apparent reason must be supported by actual evidence, not conclusory assertions.

29. I have also been informed that it is improper, in an obviousness analysis, to apply hindsight, and in particular to use the patent claims as a roadmap to assemble a collection of references or modifications to references. I understand that the proper question is what would have been obvious to a person of ordinary skill in the art without the benefit of hindsight and specifically without access to the patent at issue.

V. DEFINITION OF A PERSON OF ORDINARY SKILL IN THE ART.

30. Counsel explained that a person of ordinary skill in the relevant art is not a robot (or “automaton”), but instead a person with ordinary creativity and common sense who would apply that creativity and common sense, along with relevant background knowledge, to the problems at hand.

31. I understand there are multiple factors relevant to determining the level of ordinary skill in the pertinent art, including (1) the education level of the inventor; (2) the types of problems regularly encountered in the field; (3) the solutions of the prior art to those problems; (4) the rapidity with which innovations are made in the field; (5) the sophistication of the technology in the field; and (6) the levels of education and experience of persons working in the field at the time of the invention.

32. Petitioner proposes that a person having ordinary skill in the art at the time of the '687 Patent as of November 11, 2010, including late 2009 through early 2010, “would have had an undergraduate degree in electrical engineering, computer engineering, computer science, physics or a related field along with two years of work experience in the field of sensors (such as accelerometers, gyroscopes and magnetometers), sensor fusion algorithms, including Kalman Filters, quaternion mathematics, and mobile computing technologies.” Pet. at 4-5; Ex. 1002 at ¶ 17.

33. Dr. Sarrafzadeh testified that a POSITA only “need to understand the basics of quaternion math, and in the case of work experience, have worked with them ... [e]nough to understand them.” Ex. 2035, 214:24-215:12.

34. I agree that a person having ordinary skill in the art at the time of the '687 Patent as of November 11, 2010, including late 2009 through early 2010, would

have an undergraduate degree in electrical engineering, computer engineering, computer science, mechanical engineering, physics or a related field along with knowledge of sensors (such as accelerometers, gyroscopes and magnetometers), sensor fusion algorithms, Extended Kalman Filters, mobile computing technologies, and would understand the basics of quaternion math. I qualify as a POSITA under this definition.

35. The basics of quaternion math would cover the algebraic definition of a quaternion, the multiplication rules for the basic elements i , j , and k , conjugation, norm, and unit quaternions.

36. The basics of quaternion math also includes the Euler-Rodrigues-Hamilton theorem, which establishes that a vector can be rotated in three-dimensional space by multiplying the vector by a unit quaternion, and then multiplying the result by the conjugate of that quaternion. In other words, quaternions are not merely a way to store orientation, but a mathematical tool that actively performs rotations by transforming vectors between reference frames. This transformation property forms the foundation for using quaternions in motion tracking and sensor fusion systems. Ex. 2038 at 6-7 (deriving the transformation matrix as a function of quaternion components and showing how unit quaternions satisfying $q_1^2 + q_2^2 + q_3^2 + q_4^2 = 1$ encode rotations between coordinate frames).

37. This knowledge would allow a POSITA to generally understand a quaternion-based EKF. But would not be sufficient to allow a POSITA to convert an Extended Kalman filter written in Euler angles to an Extended Kalman filter that utilizes quaternions, as Dr. Sarrafzadeh did in his declaration. Ex. 1002 at ¶¶ 55-85.

VI. TECHNOLOGY BACKGROUND

A. MOTION SENSORS IN PORTABLE ELECTRONICS.

38. Before 2010, technological hurdles severely limited the applicability of motion sensors to portable electronic devices. For example, the sensors were often only accurate when static because they could not differentiate between different kinds of acceleration (e.g. linear, centrifugal, gravitational). Ex. 1001 at 3:14-35 (“said pointing device by Liberty cannot properly or accurately output the actual yaw, pitch and roll angles in the spatial reference frame XYZ...”).

39. Rapid, dynamic, and unexpected movements caused significant errors and inaccuracies. These hurdles were largely due to the fact that acceleration is inherently a “noisy” signal.

40. Angular acceleration is calculated as the derivative of angular velocity with respect to time, and angular velocity is itself the derivative of orientation with respect to time. Thus, small magnitudes of noise caused by small even imperceptible – changes in rotation can result in rather large derivatives.

41. This means that even seemingly minor noise from outside sources such as vibration or electrical fluctuations will be considerably amplified when measured at the acceleration level.

42. As a result, stationary devices will often still have notable noise when measured by accelerometers alone, and movement of the device will magnify that noise.

43. Since accelerometers measure linear and centripetal accelerations as well as the acceleration due to gravity, orientation estimates of certain movements of a device based on this type of sensor alone will not be accurate.

44. Prior to the invention of the '687 Patent, these difficulties were exacerbated by the miniaturization of sensors.

45. The development of micro-electromechanical systems ("MEMS") allowed for miniaturized motion sensors to be manufactured and incorporated on semiconductor chips; the sensors could then be used in smaller devices such as portable electronic devices.

46. MEMS sensors, however, also had significant limitations. For instance, a MEMS accelerometer could not distinguish between different types of acceleration.

47. Because of this, an enhanced filter method is necessary to correct for extraneous readings of other types of acceleration as high-frequency noise to produce a more accurate reading.

48. Another limitation of early MEMS sensors is the drift to which MEMS gyroscopes are prone that will accumulate over time without recalibration or correction by another sensor.

49. Each additional sensor that is added to a device brings the challenge of added noise and errors that must be accounted for when calculating the true orientation of the device.

50. Orientation cannot be properly calculated from a single type of MEMS sensor alone. For example, when using only a three-axis MEMS accelerometer to determine orientation, only pitch and roll can be measured, but not yaw.

51. When using only a MEMS gyroscope to measure angular velocity, only relative changes in orientation can be measured.

52. When using these different sensors together in combination with a fusion algorithm, the different sensors can be used to account for the errors of the other.

B. EULER ANGLES AND QUATERNIONS.

53. Three-dimensional orientation can be represented mathematically in several ways. Two of the most common are Euler angles and quaternions.

54. Euler angles represent orientation as three sequential angles (yaw, pitch, and roll) about three orthogonal axes. Ex. 2027 at 1; Ex. 2031 at ¶ 29.

55. Euler angles do not directly encode how to rotate a vector from one reference frame into another.

56. To perform such a rotation, Euler angles must be converted into a rotation matrix or quaternion.

57. Quaternions represent orientation as a four-dimensional unit vector. Ex. 1001 at 16:54-17:4; Ex. 1002 at pg. 18 (“[Q]uaternions are a well-known four-dimensional extensions of complex numbers that have the unique property of maintaining rotational relationships with relatively limited computational complexity”).

58. Quaternions are comprised of a three-dimensional vector and a scalar value to represent an axis and angle. Ex. 1015, 45:21-46:3.

59. A quaternion directly encodes a rotation operator so any vector can be rotated into another frame by applying the quaternion algebraically.

C. KALMAN FILTERS

60. Tracking the orientation of a moving device requires fusing noisy sensor measurements over time to produce a running estimate of the device's current state. The mathematical framework for doing this is recursive estimation — a class of algorithms that maintain a current best estimate of the system state and update it

each time a new measurement arrives, without needing to store or reprocess all prior measurements. Several recursive estimation filters have been developed for this purpose, each with different assumptions, computational costs, and accuracy tradeoffs.

61. The simplest approach is the complementary filter, which can blend gyroscope and accelerometer data using a frequency-domain weighting: the gyroscope, which is accurate at high frequencies but drifts over time, is weighted heavily for rapid dynamic motion, while the accelerometer, which is accurate at low frequencies but noisy under dynamic motion, is weighted heavily for slower, quasi-static movements. Complementary filters are computationally cheap and easy to implement, but they do not provide an optimal estimate in any statistically rigorous sense, and they do not adapt to changing noise characteristics.

62. The Kalman Filter (KF), developed by Rudolf Kálmán in 1960, is the optimal linear recursive estimator for systems with linear dynamics and Gaussian noise. It alternates between two steps: a prediction step, in which the filter uses a mathematical model of the system's dynamics to predict where the state will be at the next timestep, and a measurement update step, in which the filter corrects that prediction using the incoming sensor measurement, weighted by the relative uncertainty of the prediction and the measurement. The Kalman Filter is provably optimal for linear systems — no other algorithm can produce a lower-variance

estimate given the same information. However, orientation dynamics are inherently nonlinear: the relationship between angular velocity and the change in orientation cannot be expressed as a simple matrix multiplication, particularly when orientation is represented with quaternions.

63. The Extended Kalman Filter (EKF) extends the standard Kalman Filter to handle nonlinear systems by linearizing the system's dynamics around the current state estimate at each timestep. It does this by computing the Jacobian (which is a matrix of partial derivatives) of the nonlinear system equations with respect to the state variables. This linearization allows the standard Kalman Filter equations to be applied locally, even though the underlying system is nonlinear. The EKF is the most widely used filter for orientation estimation in inertial sensor fusion applications.

64. The Unscented Kalman Filter (UKF), developed by Julier and Uhlmann in the 1990s, addresses the linearization error of the EKF by using a deterministic sampling approach called the unscented transform. Instead of computing a Jacobian, the UKF propagates a set of carefully chosen sample points (called sigma points) through the full nonlinear system equations and uses the results to estimate the mean and covariance of the predicted state. This captures nonlinear effects more accurately than the EKF's first-order linearization, at the cost of greater computational complexity.

VII. OVERVIEW OF '687 PATENT AND ALLEGED PRIOR ART

A. THE '687 PATENT.

65. The '687 Patent describes an electronic device (claims 1-7, 12) and a method (claim 14, 25) that perform a series of calculations using quaternions exclusively to track an electronic devices orientation in a spatial reference frame, output as a resulting deviation comprising yaw, pitch, and roll angles:

1. An **electronic device** subject to movements and rotations in a **spatial reference frame**, comprising:

- a motion sensor module having sensor circuitry configured to generate measured angular velocities and measured axial accelerations; and

- a computing processor having processor circuitry configured to calculate a **resulting deviation** associated with the movements and the rotations of the **electronic device** in the **spatial reference frame** by performing the following in sequence:

- providing a **previous quaternion** corresponding to time T-1 based on the measured axial accelerations corresponding to time T-1 and the measured angular velocities corresponding to time T-1, without using the measured angular velocities corresponding to time T;

- converting measured angular velocities corresponding to time T, based on the previous quaternion, into a **current quaternion** corresponding to time T, without using measured axial accelerations corresponding to time T;

- converting variables of the current quaternion into **predicted axial accelerations** corresponding to time T, which is associated with the pitch and roll angles of the electronic device and without being associated with the yaw angle of the electronic device;

comparing the predicted axial accelerations with the measured axial accelerations corresponding to time T to obtain a first comparison result;

obtaining an **updated quaternion** associated with time T based on the current quaternion and the first comparison result;

using the updated quaternion as a next occurrence of the previous quaternion; and

providing the **resulting deviation** based on the updated quaternion;

wherein the processor circuitry is further configured to provide content based on the resulting deviation in the spatial reference frame

66. Claim 14 describes the same sensor fusion method recited in claim 1. The sensor fusion method described in claims 1 and 14 is shown in Figures 7, 8, 10, 11, 12. It starts with the previous quaternion from t-1 (**710** - first quaternion) and used in conjunction with measured angular velocities (**715**) and the differential equation described in Equation 1 to compute a current quaternion at time t (**720** - second quaternion). Ex. 1001 at 16:20-41. The current quaternion is used to compute the predicted axial accelerations (**730**). *Id.* at 17:12-18. Then the current quaternion (second quaternion), the predicted axial accelerations, and the measured axial accelerations are used to compute an updated quaternion (**735** - third quaternion) using Equations 5-11. *Id.* at 17:38-18:38.

67. Each step in this sequence is significant and builds on the one before it. Equation 1 is a quaternion kinematic equation that propagates the previous

orientation quaternion forward in time using the measured angular velocities from the gyroscope. This produces the current quaternion — a predicted orientation estimate based solely on how the device has rotated since the last timestep. Critically, this step uses only the gyroscope data and the previous quaternion; it does not yet use the accelerometer measurements for time T.

68. Equations 2 through 4 then convert the current quaternion into predicted axial accelerations, which are the gravitational acceleration components that the accelerometer *should* be measuring if the device were oriented exactly as the current quaternion describes and experiencing no dynamic (non-gravitational) acceleration. This is a direct mathematical transformation because the current quaternion encodes an orientation, and from that orientation, the direction of gravity relative to the device's body axes can be computed precisely. The result is predicted acceleration values, along the device's axes, derived from the current quaternion.

69. Equations 5 through 11 implement the measurement update step of the Extended Kalman Filter. By comparing the predicted axial accelerations (what gravity *should* look like given the current quaternion) to the measured axial accelerations (what the accelerometer measures), the EKF generates a correction term that accounts for the difference between prediction and measurement. The updated quaternion incorporates this correction, producing an orientation estimate

that is informed by both the gyroscope integration and the accelerometer measurement.

70. By comparing the predicted axial accelerations from the current quaternion to the measured axial accelerations, the '687 Patent can distinguish gravitational acceleration from non-gravitational (i.e., dynamic motion) acceleration. When the device is stationary or in smooth motion, the predicted and measured accelerations will closely match, and the accelerometer provides reliable orientation feedback. When the device undergoes rapid dynamic motion, the measured accelerations will deviate from the predicted gravitational component, and the filter down-weights the accelerometer accordingly. Using quaternions as the state representation, rather than Euler angles, is what enables the '687 Patent to derive the predicted axial accelerations directly from the orientation estimate (Equations 2-4), which allows it to separate out gravitational acceleration from dynamic accelerations.

71. The '687 patent teaches how to get roll, pitch, and yaw using a quaternion representation in an EKF. Due to gravity, it is difficult to get yaw from a 3-axis accelerometer. However, yaw can be obtained using a 3-axis gyroscope because it provides angular velocities for roll, pitch, and yaw. Equation 1 in the '687 Patent makes use of the gyroscope data to predict a current (2nd) quaternion by solving the quaternion differential equation. The resulting quaternion is also used to compute the predicted axial accelerations based on gravity using Equations 2, 3, and 4 and

finally uses equations 5-11 to calculate the updated quaternion using an EKF.

Figure 7 in the '687 Patent shows that once the 3rd quaternion is calculated, it provides deviation angles for roll, pitch, and yaw. Bassompierre does not teach this element of the '687 Patent and a POSITA would not be aware of this approach without the '687 Patent.

B. BASSOMPIÈRE (EX. 1006)¹

72. I have reviewed Bassompierre (Ex. 1006) in detail. In my opinion, the following summarizes what Bassompierre discloses and what a POSITA would understand from that disclosure.

73. Bassompierre describes a system for moving a pointer on a screen positioned in a vertical plane using sensor data from a handheld pointing device. Ex. 1006, 10:27-12:9, Fig. 2. The system acquires sensor data in a device reference frame (X, Y, Z), rotates that data into a carrier reference frame (u, v, w), calculates angular velocities ω_v and ω_w about the vertical and horizontal axes of the carrier frame, and uses those angular velocities to drive pointer movement on a separate, stationary screen. *Id.*

74. A POSITA would understand that Bassompierre's system moves the pointer based on angular velocities, not based on pitch, roll, or yaw angles. Ex. 1006, 15:3-

¹ All cites to Bassompierre will be to the internal pagination located at the top middle of the page.

7, Figs. 2–3. The absolute orientation of the device relative to the screen is therefore immaterial to pointer control. *Id.* In physical terms, rotating the device around the vertical carrier axis (w) moves the cursor left or right, while rotating around the right-pointing carrier axis (v) moves the cursor up or down, regardless of how the device is held relative to the carrier or display frame. *Id.* at 11:10-20, 11:10–12:8.

75. This design reflects Bassompierre’s solution to what it identifies as the “tilt” or “torsion” problem: when a user holds the pointing device at a non-horizontal angle, cursor movement on the screen goes diagonally rather than in the intended direction. Ex. 1006, 2:16–22, 10:28–29. Bassompierre’s solution is to decouple cursor movement from the pointer’s actual orientation and base movement and instead use angular velocities ω_v and ω_w in the carrier reference frame. Ex. 1006, 10:28-11:20.

76. A consequence of this design is that yaw plays no role in cursor control. Bassompierre’s own description confirms this: “[h]owever, given the definition of these reference frames, this angle is zero.” Ex. 1006, 17:10–13. Bassompierre’s system operates with only two degrees of freedom—roll and pitch—as reflected throughout its equations. *Id.* at 12-19 (Equations 1-24).

77. To estimate pitch and roll in real time, Bassompierre employs an Extended Kalman Filter (“EKF”) that fuses gyroscope and accelerometer measurements. Ex.

1006, 13:15-14:2. The EKF estimates the pitch and roll angles of the device with respect to the carrier reference frame, applies a coordinate transformation to re-express raw sensor readings in the carrier frame, and outputs angular velocity components ω_v and ω_w , which map directly to vertical and horizontal cursor displacement in the display frame, respectively. *Id.* at 11:25-12:9.

78. Bassompierre's architecture requires three distinct reference frames, each serving a separate function. The *device reference frame* (X, Y, Z) is fixed to the pointing device and is where raw accelerometer and gyroscope measurements are taken. Ex. 1006, 10:6-7 (“Whenever sensors are used, their measurements are read in the frame of reference of the pointer.”), 14:4-30, Figs. 2-3. The *carrier reference frame* (u, v, w) is defined with u and v in a horizontal plane aligned vertically with X and Y respectively, and w pointing down. Ex. 1006, 11:2-4, Figs. 2-3. Yaw, pitch, and roll are defined with respect to this frame. *Id.*, Fig. 2. The *screen reference frame* defines the fixed vertical plane in which horizontal and vertical displacement of the pointer is rendered. Ex. 1006, 10:30-31, 11:10-20, Fig. 2.

79. Every equation in Bassompierre's EKF is expressed in Euler-angle form. Ex. 1006, 17-19 (Eqs. 11-24); Ex. 2035, 337:12-18.

80. Dr. Sarrafzadeh testified that Bassompierre “states in several places that its EKF could be implemented using either Euler angles or quaternions in its state vector, expressing no preference for one over the other.” Ex. 2035 at 242:8-21,

246:21-247:5, 261:2-11, 265:5-8; Ex. 1006 at 6:3-8; 20:10-21:7; 27:13-17. I agree that Bassompierre expresses no preference for using quaternions over Euler angles. Ex. 1006 at 6:3-8; 20:10-21:7; 27:13-17.

81. Bassompierre's quaternion variant from page 22 is not implemented or disclosed sufficiently to allow a POSITA with only a knowledge of basic quaternion mathematics to derive it.

82. Specifically, Bassompierre discloses a general algebraic definition of a rotation quaternion (Eq. 25), a continuous-time quaternion kinematic differential equation (Eq. 26), and a frame transformation for angular velocities (Eq. 27). Ex. 1006, 20:10-21:7.

83. In my opinion, these disclosures are insufficient to enable a POSITA to implement a quaternion-based variant of Bassompierre's system. Bassompierre does not derive, implement, or fully disclose the process and measurement models that would be required to build a functioning quaternion EKF. Ex. 1006, 20-21.

84. In my opinion, none of Bassompierre's three reference frames encompasses both the pointing device and the display simultaneously.

85. Bassompierre's separation of the device and display reference frames is not incidental; it is a requirement for the system to function as designed. Bassompierre's solution to the tilt/torsion problem works because these frames are independent. The system acquires sensor data in the device reference frame, transforms it into

the carrier reference frame, and outputs angular velocities that drive cursor movement in the display reference frame. Each frame plays a distinct role in that pipeline. If the device and display frames were unified the tilt/torsion problem would return. The cursor would again move diagonally when the user holds the device at an angle, because any change in device orientation would be reflected directly in the display frame. That is the problem Bassompierre was designed to solve.

86. A POSITA reading Bassompierre would therefore understand that the separation of its reference frames is not a design choice that can be modified without undermining the system's core function. Ex. 1006, 2:16-22, 14:17-19.

87. Finally, I have compared Bassompierre (Ex. 1006) with its US counterpart (Ex. 2015) and found them to be identical in content.

VIII. CLAIM CONSTRUCTIONS

88. Counsel has informed me that the first step in a validity analysis involves construing the claims, as necessary, to determine their scope. The construed claim language may then be compared to the prior art disclosures. Counsel has informed me that in proceedings before the USPTO the claims are generally given their ordinary and customary meaning as understood by one of ordinary skill in the art at the time of the invention, in light of the patent specification.

89. For any claim terms not construed herein, I have applied the plain and ordinary meaning of the claim term as understood by a POSITA at the time of the invention. These constructions are consistent with the constructions I applied in the prior CyWee IPRs and CyWee Litigation.

90. I have applied the following claim constructions in my analysis:

<u>Claims</u>	<u>Claim Terms</u>	<u>Claim Constructions</u>
1, 3, 12, 14, 25	quaternion	Plain and ordinary meaning: A four-component mathematical representation used to represent three-dimensional orientation
1, 4, 14	Predicted axial acceleration	Gravitational acceleration along the electronic device's axes derived from the current quaternion
1, 2, 7, 14	spatial reference frame	frame of reference associated with the electronic device, which always has its origin at the same point in the device and in which the axes are always fixed with respect to the device
1, 7, 12, 14, 25	Resulting deviation	Orientation of the electronic device expressed as yaw, pitch, and roll angles.
1, 14	Provide/providing content based on the resulting deviation in the spatial reference frame.	Plain and ordinary: provide/providing content ... in the spatial reference frame

A. QUATERNION

91. I agree that the plain and ordinary meaning of “quaternion” is “a four-component mathematical representation used to represent three-dimensional orientation.”

92. This meaning is well established and uncontroversial in the field. A quaternion is defined by four real-valued components, one scalar part and three vector parts, satisfying the unit-norm constraint $q_0^2 + q_1^2 + q_2^2 + q_3^2 = 1$ when used to represent rotation. Dr. Sarrafzadeh confirmed this at his deposition. Ex. 2035 at 251:22-252:7.

93. The '687 Patent uses quaternion in its plain and ordinary meaning. Ex. 1001, 16:42-17:4.

94. Therefore, in my opinion, a person of ordinary skill in the art would understand the term “quaternion” to mean “A four-component mathematical representation used to represent three-dimensional orientation.”

B. PREDICTED AXIAL ACCELERATIONS

95. In my opinion, a person of ordinary skill in the art, would understand the term “predicted axial accelerations” as it’s used in the claims to refer to “gravitational accelerations along the electronic device’s axes derived from the current quaternion.”

96. This follows directly from how they are computed. As the patent describes, the predicted axial accelerations Ax' , Ay' , Az' are derived from the current quaternion using equations (2), (3), and (4). Ex. 1001, 17:18–36. A quaternion in this context is a mathematical representation of the device's orientation so it encodes a rotation in the device's spatial reference frame. Because the quaternion encodes orientation only, it carries no information about the device's linear motion or rotational velocity.

97. This is confirmed by the patent's description of the system's purpose. The predicted axial accelerations are compared against measured axial accelerations to isolate and remove “undesirable axial accelerations caused by undesirable external forces other than a force of gravity.” Ex. 1001, 18:42–59. That comparison only makes sense if the predicted axial accelerations are purely gravitational. If they contained linear or centrifugal components, the comparison could not isolate gravity from non-gravitational accelerations. The architecture of the system therefore confirms that a POSITA would understand “predicted axial accelerations” to represent gravitational acceleration along the device's axes exclusively.

98. I have reviewed Samsung's various positions regarding the meaning of “predicted axial accelerations” as asserted across multiple proceedings. These include Samsung's claim construction brief in the CyWee litigation, Ex. 2025; the

invalidity and noninfringement expert reports of Dr. Mercer, Ex. 2036, Ex. 2037; Samsung's positions in Papers 14 and 20 of this proceeding; and Dr. Sarrafzadeh's deposition testimony. Ex. 2035. In my opinion, these positions are technically irreconcilable. As I explain below, the position Samsung advances in the petition to establish invalidity is the literal opposite of the position Samsung's expert advanced to defeat infringement, and no technical reading of the claim term can accommodate both simultaneously.

99. Samsung's noninfringement expert, Dr. Mercer, opined that "predicted axial accelerations" cannot be limited to gravitational accelerations, instead it must be a composite of linear, centrifugal, and gravitational accelerations. Ex. 2036, ¶¶ 203, 262. Dr. Mercer further opined that the terms "estimated" and "predicted" are not interchangeable, because a "prediction" concerns a future unknown value while an "estimation" concerns a current value. *Id.*, ¶¶ 206, 246, 261.

100. The Petition, however, identifies Bassompierre's "a priori estimation of the acceleration" calculated using equation 22 as the "predicted axial accelerations." Pet. at 38-41. Dr. Sarrafzadeh testified at his deposition that equation 22 calculates a gravity-only value. Ex. 2035, 91:13-16.

101. These positions are technically irreconcilable for two independent reasons. First, Dr. Mercer's noninfringement position explicitly states that "predicted axial accelerations" cannot be the gravitational component alone, while the petition

relies on a gravity-only value in Bassompierre to satisfy the limitation. A POSITA would understand these to be literal opposites: a claim term either encompasses gravity-only values or it does not.

102. Second, Dr. Mercer's opinion that "estimated" and "predicted" carry different technical meanings directly undermines the petition's reliance on Bassompierre's "a priori estimation" to satisfy a limitation requiring a "prediction." If estimation and prediction are not interchangeable, as Dr. Mercer asserted, then a value Bassompierre describes as an estimation cannot satisfy a claim requiring a prediction. There is no technical basis on which both positions can simultaneously be correct. And Dr. Mercer believed that a "prediction" is a future unknown, whereas Bassompierre's "a priori estimation of the acceleration" calculated using equation 22 at the current time. This discrepancy cannot be reconciled either.

C. SPATIAL REFERENCE FRAME

103. I have reviewed the claim language of the '687 Patent and the parties' competing constructions of "spatial reference frame." In my opinion, a POSITA would understand "spatial reference frame" to mean "frame of reference associated with the electronic device, which always has its origin at the same point in the device and in which the axes are always fixed with respect to the device." As the electronic device moves and rotates, the spatial reference frame moves and rotates

with it. This is the standard technical meaning of a body-fixed reference frame, and it is fully consistent with how the '687 Patent uses the term.

104. The claim language makes clear that the “spatial reference frame” is associated with the “electronic device.” Claim 1 recites “the movements and the rotations of the electronic device within a spatial reference frame.” Ex. 1001, Claim 1. A POSITA reading this language would understand the “spatial reference frame” to be the reference frame of the electronic device as claimed, that is, the integrated device comprising both the display and the motion sensor module. Nothing in the claim language associates the spatial reference frame with a “3D pointing device” or any other device type not recited in the claims.

105. The technical significance of this distinction is reinforced by the relationship between the spatial reference frame and the display reference frame. Because the '687 Patent's claims associate the spatial reference frame with the electronic device, and the electronic device comprises a display, the display moves with the device in the spatial reference frame. A POSITA would understand this to be an integrated configuration, one in which the display and motion sensor occupy the same physical device and are therefore subject to the same movements and rotations. Petitioner's construction, which associates the spatial reference frame with a separate 3D pointing device, is technically inconsistent with this integrated

architecture and would exclude the display from the device that moves in the spatial reference frame.

D. RESULTING DEVIATIONS

106. I have reviewed the claim language and specification of the '687 Patent and in my opinion, a POSITA would understand “resulting deviation” to mean “orientation of the electronic device expressed as yaw, pitch, and roll angles.” This is the standard technical meaning in the context of 3D orientation estimation, and it is consistent with how the term is used throughout the patent.

107. From a technical standpoint, a complete description of a rigid body's orientation in three-dimensional space requires three independent angles. Yaw, pitch, and roll are the conventional set of Euler angles used for this purpose, each describing rotation about one of three orthogonal axes. A POSITA reading the '687 Patent would immediately recognize this as the standard framework for orientation representation in inertial sensing applications. A construction that identifies fewer than three angles, or leaves unspecified which angles are included, would be technically incomplete because it would fail to fully describe the device's orientation in the spatial reference frame and would not track its absolute position.

108. The specification further explains that the resulting deviation is obtained and output in an “absolute” manner, meaning it reflects the actual movements and rotations of the electronic device in the spatial reference frame rather than a

relative or partial measurement. *Id.* at 19:63-20:3, 22:55-62, 30:39-53 (“obtaining and outputting of deviation including 3D angles in a spatial reference frame in an ‘absolute’ manner of the present invention is too novel ... [and] cannot be easily achieved by any known arts or the combination thereof.”). The specification never uses “resultant deviation” to refer to any other set of angles, and never suggests the term encompasses fewer than all three. A POSITA would find this usage entirely consistent with the standard technical meaning. The patent's algorithm outputs a complete 3D orientation, and the resultant angles are a representation of that orientation. Providing those resultant angles in the spatial reference, as the claims require, presupposes knowledge of all three angles. A partial or indeterminate set of angles would not provide a sufficient technical basis for that translation.

E. PROVIDE CONTENT BASED ON THE RESULTING DEVIATION IN THE SPATIAL REFERENCE FRAME

109. In my opinion, a POSITA reading claims 1 and 14 would understand the phrase “provide/providing content based on the resulting deviation in the spatial reference frame” as specifying that the content itself is provided within the spatial reference frame; not as a further description of where the deviation resides.

110. A POSITA reading claim 1 in its entirety would recognize that the claim already establishes, earlier in its recitation, that the processor calculates “a resulting deviation associated with the movements and rotations of the electronic

device in the spatial reference frame.” By the time a POSITA reaches the wherein clause the deviation’s association with the spatial reference frame has been established. The deviation is, by definition at that point in the claim, a quantity that exists in and is associated with the spatial reference frame.

111. From a technical standpoint, a POSITA would therefore not read “in the spatial reference frame” at the end of the wherein clause as simply restating that same already-established fact. Engineers reading technical documents expect each element of a description to carry new information. A POSITA would read the phrase at the end of the wherein clause as doing new technical work: specifying that the content the processor provides is expressed and rendered within that same spatial reference frame, rather than being transformed into or presented in some other frame of reference.

112. From a systems engineering perspective, specifying the reference frame in which content is provided is a meaningful and important technical constraint. A spatial reference frame is fixed to and moves with the integrated device. Providing content “in the spatial reference frame” means that the content is rendered relative to the device's own orientation and motion and is expressed in the coordinate system of the device itself, with no transformation to an external or separate frame of reference. This is technically distinct from a system in which content is computed in one frame and then translated into another before being displayed.

113. A POSITA would understand that specifying the frame in which content is provided is not a trivial or redundant statement. In inertial sensing and motion-based applications, the choice of reference frame for output content has direct consequences for system design: it determines whether a coordinate transformation is required, what computational resources are needed, and how the output relates physically to the device and its environment. A claim that specifies content is provided in the device's spatial reference frame is communicating a technically meaningful architectural constraint.

114. In my opinion, the structure of claims 1, 7, and 8 reflects a technically coherent progression that is fully consistent with, and confirms, the reading described above.

115. Claim 1 describes an integrated electronic device comprising both a motion sensor module and a processor. The spatial reference frame is fixed to and moves with that integrated device. Because the device's display is physically part of the same integrated device, content rendered on that display inherently exists within the same spatial reference frame as the device. No translation to a separate frame is required in the architecture claim 1 describes.

116. Claim 7 introduces an additional, distinct technical operation: "wherein the processor circuitry is further configured to translate the resulting deviation in the spatial reference frame into a real-time movement pattern in a display reference

frame.” A POSITA would recognize that claim 7 introduces a new concept: a “display reference frame.” Claim 7 also introduces the new computational step of translation from one reference frame (the spatial reference frame of the device) into a different reference frame (the display reference frame).

117. Claim 8 adds the physical hardware associated with that display reference frame: “further comprising a display device associated with the display reference frame and configured to display the real-time movement pattern.” A POSITA would understand claim 8 as adding an external display element associated with the display reference frame, not the spatial reference frame.

118. A POSITA reading claims 1, 7, and 8 together would recognize a technically sensible progression: claim 1 covers the base-case architecture of an integrated device providing content in its own spatial reference frame; claim 7 adds the further capability of translating that content into a separate display reference frame (a step that is technically necessary when output must be directed to an external display operating in its own frame); and claim 8 adds that external display hardware itself. This progression is architecturally coherent.

119. For these reasons, it is my opinion that a POSITA reading the claim as a whole, including its internal structure and its relationship to dependent claims 7 and 8, would understand “in the spatial reference frame” in the wherein clause as

specifying that the content is provided within the device's spatial reference frame, consistent with an integrated-device architecture that requires no frame translation.

IX. CLAIM ELEMENTS NOT PRESENT IN BASSOMPIÈRE.

A. BASSOMPIÈRE DOES NOT DISCLOSE “QUATERNIONS.”

120. I have reviewed Bassompierre’s Equations 21, 22, and 23. In my opinion, each of these equations is expressed entirely in Euler-angle form. Equation 21 is a state transition equation whose state vector contains pitch and roll angles. Equation 22 computes a predicted acceleration from those Euler angles. Equation 23 is a measurement update equation that operates on the same Euler-angle state vector. Ex. 1006, 18-19. None of these equations contains a quaternion or quaternion-based computation. This is consistent with the broader architecture of Bassompierre's EKF, in which every process and measurement model is derived and implemented using Euler angles. Ex. 1006, 17-18 (Eqs. 11-24). A POSITA reviewing Bassompierre's Equations 21, 22, and 23 would find no quaternion, previous quaternion, current quaternion, or updated quaternion disclosed in any of them. Dr. Sarrafzadeh confirmed this at deposition. Ex. 2035, 259:7-261:20.

B. BASSOMPIÈRE DOES NOT DISCLOSE “PREDICTED AXIAL ACCELERATIONS”

121. I have reviewed Bassompierre with respect to the claim element requiring “predicted axial accelerations.” In my opinion, Bassompierre does not disclose this element.

122. As I explain above, a POSITA would understand “predicted axial accelerations” to mean gravitational accelerations along the device's axes derived from the current quaternion. This follows directly from the patent's use of equations (2), (3), and (4) to convert a quaternion into predicted axial accelerations. Ex. 1001, 17:17-36. Because a quaternion in this context encodes orientation only, the conversion yields the components of gravitational acceleration along each device axis and nothing more. Linear and centrifugal accelerations are not functions of orientation and cannot appear in this computation.

123. Bassompierre’s Equation 22 does not satisfy this requirement. Equation 22 computes a predicted acceleration value derived from pitch and roll Euler angles contained in Bassompierre’s state vector. Ex. 1006, 19:4-5. It contains no quaternion and is not derived from any quaternion. A POSITA reviewing Equation 22 would immediately recognize it as a Euler-angle computation with no connection to a current quaternion. Because the claim requires predicted axial accelerations derived from the current quaternion, Equation 22 cannot satisfy that requirement in unmodified form.

124. Bassompierre's quaternion disclosures do not fill this gap. Equations 25, 26, and 27 address quaternion kinematics and frame transformations for angular velocities, but none of them computes a predicted axial acceleration. Ex. 1006,

20:10-21:7. There is no equation or disclosure in Bassompierre that derives a predicted axial acceleration from a quaternion.

125. In my opinion, a POSITA would find nothing in Bassompierre that teaches or suggests “predicted axial accelerations” as the claim requires.

C. BASSOMPIÈRE DOES NOT DISCLOSE “RESULTING DEVIATION”

126. I have reviewed Bassompierre with respect to the claim element requiring a "resulting deviation" in the spatial reference frame. Under Patent Owner's construction, the “resulting deviation” is the “orientation of the electronic device expressed as yaw, pitch, and roll angles.” In my opinion, Bassompierre does not disclose this element under any embodiment..

127. Across every embodiment, Bassompierre drives cursor movement using angular velocities ω_v and ω_w , not by computing or outputting orientation as yaw, pitch, and roll angles. Ex. 1006, 10:27–12:9, Fig. 2. This is a deliberate design choice. Bassompierre explicitly states that “compensation of the pitch and roll angles is total, the displacement of the cursor on the screen then becomes independent of the orientation of the device on the carrier.” Ex. 1006, 14:17–19. A POSITA would understand that Bassompierre's system is specifically designed to decouple cursor movement from orientation angles—which is the opposite of what the claim requires. This deficiency is even more fundamental in the Euler angle embodiment: Bassompierre fixes yaw at zero by design. Ex. 1006, 11:25–30,

17:10–13 ("Here the angle represents the angle of yaw ... [h]owever, given the definition of these reference frames, this angle is zero..."). In my opinion, a system that sets yaw to zero by design is structurally incapable of producing a resulting deviation expressed as yaw, pitch, and roll angles — it cannot disclose all three components the claim requires.

128. In Bassompierre's quaternion embodiment, Equation 27 calculates the angular velocities ω_v and ω_w directly from the quaternion without computing yaw, pitch, or roll at any intermediate step. Ex. 1006, 21:4 (Eq. 27); 30:8–10 (Claim 14). In my opinion, Bassompierre's quaternion embodiment contains no teaching that orientation expressed as yaw, pitch, and roll is calculated at all. Even if a POSITA were to modify Bassompierre's Equations 21–23 to use quaternions, as Petitioner proposes, the modification would not produce a resulting deviation expressed as yaw, pitch, and roll. A POSITA following Bassompierre's own quaternion path would arrive at Equation 27, which extracts angular velocities directly from the quaternion without computing orientation angles. In my opinion, Petitioner's proposed modification eliminates rather than supplies the resulting deviation the claim requires.

129. I also note that neither the Petition nor Dr. Sarrafzadeh's declaration makes any mention of Equation 27. This omission is significant. Equation 27 is the only quaternion equation in Bassompierre that addresses the relationship between

quaternions and motion output. A POSITA performing the modification Samsung proposes would necessarily encounter Equation 27 and would recognize that it produces angular velocities, not orientation expressed as yaw, pitch, and roll. The absence of any analysis of Equation 27 in Petitioner's papers reflects a technically incomplete theory of modification.

D. BASSOMPIÈRE DOES NOT DISCLOSE A “DATA ASSOCIATION MODEL”

130. I have reviewed Bassompierre with respect to the claim element requiring a “data association model” in Claims 12 and 25. In my opinion, Bassompierre does not disclose this element.

131. Bassompierre's Equation 23 is part of its Euler-angle EKF and operates entirely on Euler-angle state vectors. Ex. 1006, 19. It contains no quaternion and is not derived from any quaternion computation. A POSITA would immediately recognize Equation 23 as a Euler-angle measurement update equation. Because claims 12 and 25 require a “data association model” that determines whether compensation is needed to obtain the updated quaternion, an equation that operates only on Euler-angle state vectors cannot satisfy that requirement.

132. I also note that Petitioner's characterization of Equation 23 contains a notational error that reflects a misunderstanding of the equation's function. The Petition describes the Equation 23 as:

accelerations”) on $\hat{x}_k^-$ (“current quaternion”). In other words, the value of the compensation data association model (Kalman gain times the difference between the measured acceleration and predicted acceleration) determines that amount by which the $\hat{x}_k^-$ (“current quaternion”) must be changed (compensated) to arrive at $\hat{x}_k$ (“updated quaternion”). That calculation is “based on the measured axial

Pet. at 58. A POSITA would recognize this as internally inconsistent because the current and updated state cannot be the same variable, $\hat{x}_k$.

X. THERE IS NO APPARENT REASON FOR A POSITA TO MODIFY BASSOMPIÈRE TO USE QUATERNIONS.

133. In my opinion, the computational efficiency advantage of quaternions over Euler angles—specifically, avoiding trigonometric function computation—was well known to a POSITA long before Bassompierre. This trade-off is discussed in foundational textbooks and technical literature on inertial navigation and sensor fusion that a POSITA would have been familiar with. A POSITA reading Bassompierre would therefore understand that its author was aware of this advantage and made a deliberate, informed decision to implement the system in Euler angles despite that knowledge. Rather than motivating a modification, that informed choice would have signaled to a POSITA that Euler angles were the appropriate representation for Bassompierre's particular application. In my opinion, a POSITA would not treat the existence of a known computational trade-off as a

reason to redesign a system whose author had already evaluated and rejected that option.

134. Similarly, implementing a quaternion-based EKF is substantially more complex than implementing a Euler-angle EKF, and that complexity would have discouraged a POSITA from making the modification Samsung proposes.

135. A quaternion-based orientation tracker requires propagating a quaternion kinematic differential equation, a system of four coupled ordinary differential equations that must be discretized and integrated numerically at each timestep Δt . A standard approach such as fourth-order Runge-Kutta requires four derivative evaluations per timestep. The practitioner must also carefully tune Δt to balance truncation error against computational cost and must normalize the quaternion after every integration step to prevent drift from the unit-norm constraint due to floating-point accumulation. These requirements add computational and implementation overhead that is absent from a Euler-angle implementation.

136. The quaternion EKF also requires more complex Jacobian matrices. Because a quaternion has four components while the orientation it represents has three degrees of freedom, the Kalman gain matrix must map between spaces of different dimensions, requiring a 4x3 matrix to project three-dimensional measurement updates into four-dimensional quaternion space. Deriving and

implementing these Jacobians correctly is substantially more demanding than the corresponding Euler-angle computation.

137. None of this added complexity yields any benefit for Bassompière's application. Bassompière tracks only two degrees of freedom, pitch and roll, and uses them to extract angular velocities in the carrier frame. A quaternion representation, which describes full three-dimensional orientation, is more than Bassompière's system requires. In my opinion, a POSITA would have recognized that the additional overhead of a quaternion implementation provides no performance advantage for a two-degree-of-freedom system like Bassompière's and would have had reason to avoid the modification rather than pursue it.

138. In my opinion, the approach Petitioner and Dr. Sarrafzadeh take is consistent with hindsight reconstruction rather than forward-looking modification of Bassompière.

139. A POSITA working forward from Bassompière's disclosure would start from the building blocks Bassompière's quaternion embodiment already provides: a rotation quaternion (Eq. 25), a quaternion kinematic differential equation (Eq. 26), and a frame transformation for angular velocities (Eq. 27). Ex. 1006, 20-23. A POSITA would then work toward Bassompière's stated objective: extracting angular velocities in the carrier reference frame about two axes. That forward path

leads to Equation 27, which is where Bassompierre's quaternion disclosure ends.

The result is angular velocities, not orientation angles.

140. Dr. Sarrafzadeh does not follow that path. Instead, he begins with Bassompierre's Euler-angle embodiment, ignore the quaternion equations Bassompierre provides, and constructs a quaternion EKF using derivations Bassompierre never performs, drawing on independent engineering knowledge and, as I explain below, equations from the '687 Patent itself. Ex. 1002, ¶¶ 55-79. In my opinion, starting from the Euler-angle embodiment, skipping Bassompierre's own quaternion equations, and arriving at a system that matches the '687 Patent's claims rather than Bassompierre's objectives is a path a POSITA would take only if they were using the '687 Patent as a guide.

141. In my opinion, Bassompierre's quaternion disclosure is insufficient to enable a POSITA to implement a quaternion-based EKF without supplying substantial additional knowledge from outside the reference.

142. Bassompierre provides exactly three numbered equations for its first variant quaternion embodiment: Equations 25, 26, and 27. Ex. 1006, 20-21. Equation 25 defines a rotation quaternion as a function of variables α , u_1 , u_2 , and u_3 , but Bassompierre never defines these variables in the context of the EKF, never explains how they would be obtained from sensor data, and never uses them in any

subsequent derivation. A POSITA would not know how to apply Equation 25 within Bassompierre's system from the disclosure provided.

143. Equation 26 is a continuous-time quaternion kinematic differential equation describing the rate of change of orientation. In my opinion, Dr. Sarrafzadeh mischaracterizes this equation as the orientation equivalent of Equation 21 from the Euler-angle embodiment. Ex. 1002, ¶¶ 57-85. Equation 21 is a discrete-time state transition equation that can be used directly in an EKF; Equation 26 is a continuous-time differential equation that must first be discretized and integrated before it can serve that role. These are not equivalent and bridging that gap requires derivation steps Bassompierre never provides.

144. Equation 27 provides a frame transformation for angular velocities but appears in Bassompierre without derivation or explanation of intermediate steps. Dr. Sarrafzadeh does not mention Equation 27 anywhere in his declaration. In my opinion, a POSITA attempting to implement a quaternion EKF from Bassompierre's disclosure would need to supply the missing derivations independently, relying on mathematical steps that go well beyond what Bassompierre discloses. A reference that does not enable what it discloses cannot render a claim obvious, and Bassompierre's meager quaternion disclosure does not enable a POSITA to build a functioning quaternion EKF.

145. Accordingly, in my opinion Bassompierre does not provide any apparent reason for a POSITA to modify its Euler-angle EKF to use quaternions.

XI. PETITION FILLS GAPS IN BASSOMPIÈRE’S TECHNICAL DISCLOSURES WITH EXPERT TESTIMONY.

146. The Petition asserts that a “POSITA would have understood that equation 26 is a quaternion form representation of equation 21.” Pet. at 35 (citing Ex. 1002, ¶¶ 68).

147. In my opinion, this assertion is technically incorrect. Equations 21 and 26 of Bassompierre are fundamentally different mathematical objects that serve different roles in an EKF framework. They are not equivalent representations of the same operation and treating them as such requires multiple derivation steps that Bassompierre does not disclose.

148. Equation 21 is a discrete-time update equation for Euler angles, specifically pitch Θ and roll Ψ , that produces an estimated orientation state at a specific point in time. Ex. 1002, ¶ 66. It is ready for direct use in an EKF without further mathematical development.

149. Equation 26, by contrast, is a continuous-time quaternion kinematic differential equation that describes the instantaneous rate of change of orientation, not the orientation itself. Ex. 1002, ¶¶ 66-71. Its output is a derivative, not an updated orientation state.

150. Dr. Sarrafzadeh admits this distinction when he states that “Equation 21 of Bassompière can be expressed as the rate of change of an orientation quaternion based on the angular velocities from a gyroscope.” Ex. 1002, ¶ 66. Describing Equation 21 as a “rate of change” confirms that what Dr. Sarrafzadeh is working with is Equation 26, a continuous differential equation, not a discrete state update.

151. To convert Equation 26 into something that functions like Equation 21 within an EKF, a POSITA would need to perform three additional steps that Bassompière never teaches: first, discretize the continuous-time equation into a finite-difference update suitable for digital implementation; second, numerically integrate the discretized equation over a timestep Δt ; and third, normalize the result after every integration step to maintain the unit-norm constraint and prevent floating-point drift. Dr. Sarrafzadeh acknowledges these steps are necessary. Ex. 1002, ¶ 67 (“To implement this, a person of ordinary skill in the art would integrate these differential equations over a time step ... followed by normalization of q_k to ensure it remains a unit quaternion.”). He also admitted that the quaternion Jacobian required in the EKF process model is a larger and more complex matrix than its Euler-angle counterpart. Ex. 2035, 257:15-23. None of these steps are taught by Bassompière.

152. Bassompierre's measurement model, Equation 22, expresses the predicted gravity components A_x , A_y , A_z as explicit trigonometric functions of pitch Θ and roll Ψ , written entirely in Euler angles with no quaternions. Ex. 1006, 19.

153. The Petition acknowledges this absence but asserts “a person of ordinary skill in the art would know how to derive the predicted acceleration of Bassompierre in quaternion form.” Pet. at 41. To do so, however, a POSITA would need to construct a direction cosine matrix $R(q)$, a 3x3 rotation matrix whose entries are quadratic functions of the four quaternion components q_0 , q_1 , q_2 , and q_3 , and apply that matrix to the gravity vector. This is a categorically different mathematical expression from Equation 22. Bassompierre never derives $R(q)$ and never expresses the predicted accelerations as functions of quaternion components. A quaternion measurement model does not exist in Bassompierre.

154. The Petition's assertion that a POSITA “would know how to derive the predicted acceleration of Bassompierre in quaternion form” conflates what a POSITA can theoretically derive using hindsight with what Bassompierre teaches. Pet. at 41.

155. For every quaternion EKF component that absent from Bassompierre, the Petition simply asserts that a POSITA would know how to derive it:

Thus, a POSITA would have been motivated to modify equation 21 to include quaternions instead of Euler angles.” Pet. at 34.

A POSITA would have understood that equation 26 is a quaternion form representation of equation 21. Pet. at 35.

While equation 21 above utilizes Euler angles to represent state vector, it would have been obvious to use quaternions in place of Euler angles. Pet. at 37.

A person of ordinary skill in the art would know how to derive the predicted acceleration of Bassompierre in quaternion form.” Pet. at 41.

While Bassompierre’s equation 23 involves Euler angles, a POSITA would have found it obvious to utilize quaternions in place of Euler angles. Pet. at 44.

156. Dr. Sarrafzadeh admitted that the following information is not taught by Bassompierre:

how to convert the Euler angle-based rotation matrix on page 18 into an equivalent quaternion-based rotation matrix, Ex. 2035, 274:8-21;

the rotation matrix in quaternion form, which he described as “knowledge that every person of ordinary skill in the art would have,” Ex. 2035, 279:12-16;

Equations 2 through 4 of the ’846 and ’687 Patents, Ex. 2035, 281:16-282:9;

how to convert quaternions to Euler angles, which he called “[b]asic knowledge,” Ex. 2035, 314:6-9;

the order of quaternion multiplication necessary to calculate a new quaternion based on pitch and roll, Ex. 2035, 291:8-293:10; and

quaternion multiplication itself, which he characterized as “basic knowledge, using matrix multiplication.” Ex. 2035, 301:11-14.

157. Each of these gaps represents nontrivial knowledge necessary for Dr. Sarrafzadeh’s derivations that is absent from Bassompierre.

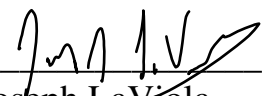
158. In my opinion, the Petition has not shown that Bassompierre discloses a quaternion EKF. It has shown only that Dr. Sarrafzadeh could construct one using engineering knowledge beyond what Bassompierre teaches.

XII. CONCLUSION

159. For the foregoing reasons, it is my opinion that Bassompierre does not render claims 1-7, 12, 14, and 25 of the '687 Patent unpatentable.

160. I declare that all statements made herein of my knowledge are true, and that all statements made on information and belief are believed to be true, and that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code.

Dated: April 6, 2026

By: 
Dr. Joseph LaViola