

**UNITED STATES PATENT AND TRADEMARK OFFICE**

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**BEFORE THE PATENT TRIAL AND APPEAL BOARD**

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Google LLC

Petitioner

v.

Cywee Group Ltd.

(record) Patent Owner

Patent No. 8,552,978

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**DECLARATION OF PROF. MAJID SARRAFZADEH**

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## **I. ENGAGEMENT AND COMPENSATION**

1. My name is Majid Sarrafzadeh. I have been retained by Google LLC for the purpose of providing my opinion with respect to the unpatentability of U.S. Pat. No. 8,552,978 (“the ’978 patent”). I am being compensated for my time in preparing this declaration at the rate of \$650/hr, and my compensation is not dependent upon my opinions or the outcome of the proceedings.

## **II. QUALIFICATIONS**

2. I currently hold the title of Distinguished Professor and Director of Embedded and Reconfigurable Computing (ER) Laboratory in the Computer Science Department at the University of California, Los Angeles (UCLA). I also have a courtesy appointment in the Department of Electrical Engineering at UCLA. I am the Co-Director of the Center for SMART Health, Co-Director for the BRITE Center on Minority Health Disparities, and a Co-Founder of the UCLA Wireless Health Institute.

3. I believe that I qualify as an expert in the field of sensors and sensor data processing, and as at least a person of ordinary skill in the art. My current Curriculum Vitae is attached to the end of this declaration, and summarizes my qualifications.

4. I received my Bachelor’s Degree from the University of Illinois at Urbana-Champaign in Electrical and Computer Engineering in 1982, a Master of

Science Degree in Electrical and Computer Engineering University of Illinois in 1984, and a Ph.D. in Electrical and Computer Engineering University of Illinois in 1987.

5. From 1987 to 1991, I was an Assistant Professor in the Department of Electrical and Computer Engineering at Northwestern University. From 1991-1997, I held the title of Associate Professor, also in the Department of Electrical and Computer Engineering at Northwestern University. From 1997-2000, I held the title of Full Professor in that department.

6. I am an author or co-author on more than 500 publications in electrical engineering and computer sciences. Many of my publications relate to the use of sensors and sensor networks to track human body movement and health indicators.

7. I have used various sensors including motion sensors in my research. I have designed and built hardware and software systems for motion tracking, gait analysis, 3D rehab systems, and gaming just to name a few. I have performed data capture, data processing and analytics with these mobile systems. I have utilized the design in remote monitoring systems. In many of my projects I have developed algorithms relating to sensor fusion. For example, I have used motion sensor fusion to cancel motion noise in other signals, such as when working with photoplethysmography (PPG). I have used pressure sensors, accelerator and gyroscope fusion to construct motion data.

### **III. SUMMARY OF OPINIONS**

8. In my opinion, claims 10 and 12 are obvious over the Zhang publication and Bachmann patent.

9. In my opinion, claims 10 and 12 are also obvious over the Liberty patent and Bachmann patent.

### **IV. MATERIALS REVIEWED**

10. In forming my opinions, I have relied of my knowledge of the field and my experience, and have specifically reviewed the following exhibits:

| <b>Exhibit No.</b> | <b>Description</b>                                  |
|--------------------|-----------------------------------------------------|
| 1001               | U.S. Pat. No. 8,552,978 (“the ’978 patent”)         |
| 1004               | U.S. Pat. No. 7,089,148 (“ <b>Bachmann</b> ”)       |
| 1005               | U.S. Pat. App. Pub. 2004/0095317 (“ <b>Zhang</b> ”) |
| 1006               | U.S. Pat. No. 7,158,118 (“ <b>Liberty</b> ”)        |
| 1009               | File History of U.S. Pat. App. 13/176,771           |

### **V. UNDERSTANDING OF THE RELEVANT LAW**

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

#### **A. Anticipation**

12. 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.

13. 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”.

## **B. Obviousness**

14. 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.

15. 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.

16. 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”.

17. The level of ordinary skill in the art is discussed in ¶24 below.

18. The relevant time frame for obviousness, the “time the invention was made”, is discussed in ¶25, below.

19. 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”.

20. 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.

21. 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.

22. 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.

23. 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.

## **VI. LEVEL OF ORDINARY SKILL IN THE ART**

24. 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 at least a Bachelor’s Degree in Computer Science, Electrical Engineering, Mechanical Engineering, or Physics, or equivalent work experience, along with knowledge of sensors (such as accelerometers, gyroscopes and magnetometers), and mobile computing technologies. I believe I would meet this definition, and would have met this definition in the relevant timeframe.

## **VII. RELEVANT TIMEFRAME FOR DETERMINING OBVIOUSNESS**

25. I understand that obviousness must be evaluated “at the time of the invention”. From the cover page of the ’978 patent, I can see that the first provisional

application for a patent 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 applicable to a longer period of time (at least a year) before January 6, 2010. My testimony is directed to this timeframe, even if I do not always use a past tense.

## **VIII. TECHNICAL INTRODUCTION**

26. The '978 patent discusses 3D pointing devices. (Ex. 1001, Title). Such devices are for “detecting motions of the device and translating the detected motions to a cursor display such as a cursor pointing on the screen...of a 2D display device....” (Ex. 1001, 1:31-33). As one example of such a device, a computer mouse could be adapted to detect movements and rotations in three dimensions. This would allow such movements to be translated into commands for a computer, for example. (Ex. 1001, 1:52-61). FIG. 1 of the '978 patent shows an example pointing device 110 and an associated display 120:

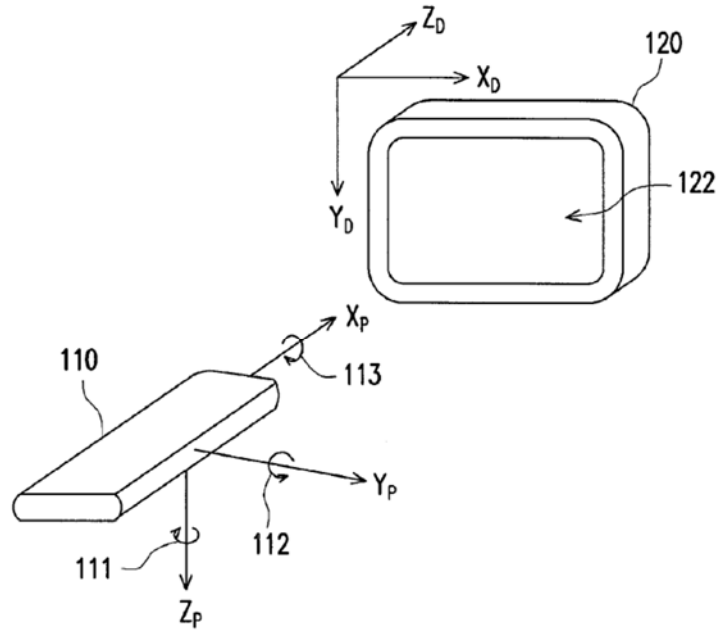


FIG. 1 (RELATED ART)

27. The '978 patent uses sensors within pointing devices to track movements and rotations. In the patent, three kinds of sensors are discussed: rotation sensors (for detecting the angular velocity of rotation), accelerometers (for detecting axial accelerations), and magnetometers (for detecting the local magnetic field). (Ex. 1001, FIG. 4). Such sensors can be mounted in 3D pointing device, and their outputs provide information on the movements and rotations of the device.

28. The '978 patent discusses using the output of the sensors to calculate the orientation of a 3D pointing device. (Ex. 1001, 4:15-57). Here, the word “orientation” describes how the device is rotated in space with respect to the axes of a given coordinate system, and is synonymous with the terms “attitude” and “tilt”. (Ex. 1001, 1:62-64). FIG. 2 of the '978 patent shows the same 3D pointing device 110 in a different “orientation”, having been rotated about the x-axis by 90 degrees:

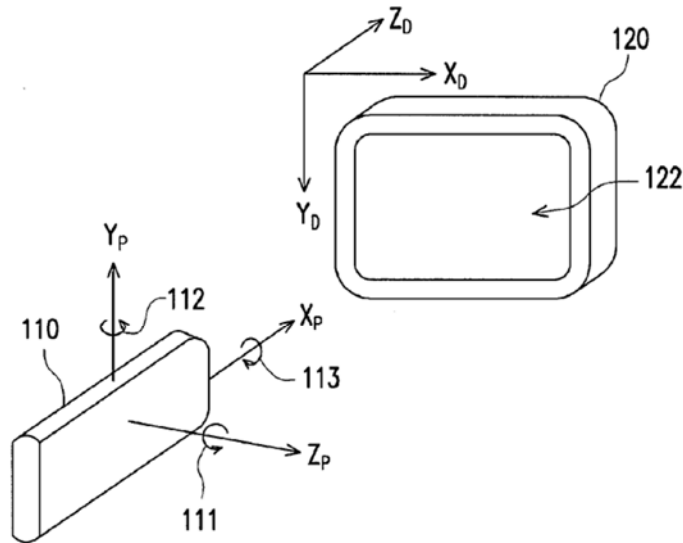


FIG. 2 (RELATED ART)

(Ex. 1001, 2:11-14).

29. “Orientation” can be represented in a number of different ways. One way is to use a set of angles, known as “Euler angles”. The Euler angles, called “yaw”, “pitch” and “roll,” represent rotation around three orthogonal axes. If the object whose orientation is being described is an airplane, the “yaw” could be thought of as the horizontal (compass) direction of the airplane, while the “pitch” is the inclination of the nose of the airplane, and the “roll” is the angle of wings. The Euler angles do not need to be defined relative to the axes that most naturally fit airplane flight, however, but can be with respect to any coordinate system with three orthogonal axes.

30. Orientation can also be represented by a quaternion. A quaternion is a four-valued vector ( $q_0 \ q_1 \ q_2 \ q_3$ ) that can be thought of as a generalization of a

complex number. Quaternions were first described in the 19<sup>th</sup> Century. The elements of a quaternion are usually thought of as having one real value ( $q_0$ ) and three values ( $q_1$   $q_2$   $q_3$ ) parallel with three different imaginary axes, labeled  $i$ ,  $j$  and  $k$ . For this reason, quaternions can also be represented with vector addition in the form  $q = a + bi + cj + dk$ , where  $i^2=j^2=k^2=ijk=-1$ , and where the following relations hold:  $ij=k$ ,  $ji=-k$ ,  $jk=i$ ,  $kj=-i$ ,  $ki=j$ ,  $ik=-j$ .

31. Quaternions have special mathematical properties that allow them to describe rotations efficiently. For any rotation of angle  $\Theta$  around a given axis defined by a vector  $(x,y,z)$ , a quaternion  $q$  representing the rotation can be defined such that  $q = \cos(\Theta/2) + \sin(\Theta/2)(xi + yj + zk)$ . Furthermore, multiplying two quaternions together using the distributive law and the relationships defined in 30, above results in an application of rotations described by both quaternions. Furthermore, and most usefully, any ordinary vector  $v=(v_1 v_2 v_3)$  can be defined as a quaternion with real component  $=0$ , e.g.  $v'=(0 v_1 v_2 v_3)$ . Then, any rotation defined by a quaternion  $q$  can be applied to  $v'$  to get a rotated quaternion  $r$ , by using  $q$  and its conjugate ( $q^{-1}$ ), in the following way  $r=qv'q^{-1}$ . In this equation, the application of the quaternion  $q$  is by quaternion multiplication using the distributive law and the relationships defined in 30. The conjugate of  $q$ , labeled  $q^{-1}$ , is simply  $q$  with the imaginary components negated.

32. The relationships described in ¶¶30-31 were well known in the relevant

timeframe, and are described in the prior art I reviewed. (e.g. Ex. 1004, 8:63-67)(Ex. 1006, 16:65-18:28). It was also well known that the Euler angles, described above in ¶29 could be equivalently represented by a quaternion. For example, the Liberty reference (Ex. 1006), states:

“Q is the normalized rotation quaternion that represents the rotation from the body frame to the user frame. Since the rotation quaternion to rotate from the user frame to the body frame is Q, we could replace Q with R\* where R is the rotation from the user frame to the body frame. Note that **Q can be represented in a number of equivalent forms including Euler angles** and the direction cosine matrix (DCM), and the above equations may vary slightly in their equivalent forms based upon different representations of Q.” (Ex. 1006, 17:36-44).

33. The '978 patent discusses prior art 3D pointing devices having sensors (such as the Liberty patent, described below), but criticizes the prior art devices as allegedly unable to calculate orientation accurately. (Ex. 1001, 2:41-3:52). The purpose that the '978 describes is to use additional sensors and to compensate the output of the sensors to improve the accuracy of the orientation calculation. (Ex. 1001, 1:22-27).

34. To “compensate” the output of the sensors, the '978 patent discloses a

mathematical method using quaternions. (Ex. 1001, 16:5 *et seq.*). Figure 7 of the '978 patent (right) shows an aspect of this method. The system obtains *measured* angular velocities at step 715 (Ex. 1001, 16:27-30). The system also obtains *measured* axial accelerations in step 725 (Ex. 1001, 16:60-64). Using the measured angular velocities, the system calculates predicted axial accelerations. (Ex. 1001, 17:2-9). By comparing the actual and predicted accelerations (step 735), the method purports to improve the estimate of orientation (called here the “updated state (3<sup>rd</sup> quaternion)” in box 735). (Ex. 1001, 18:25-55).

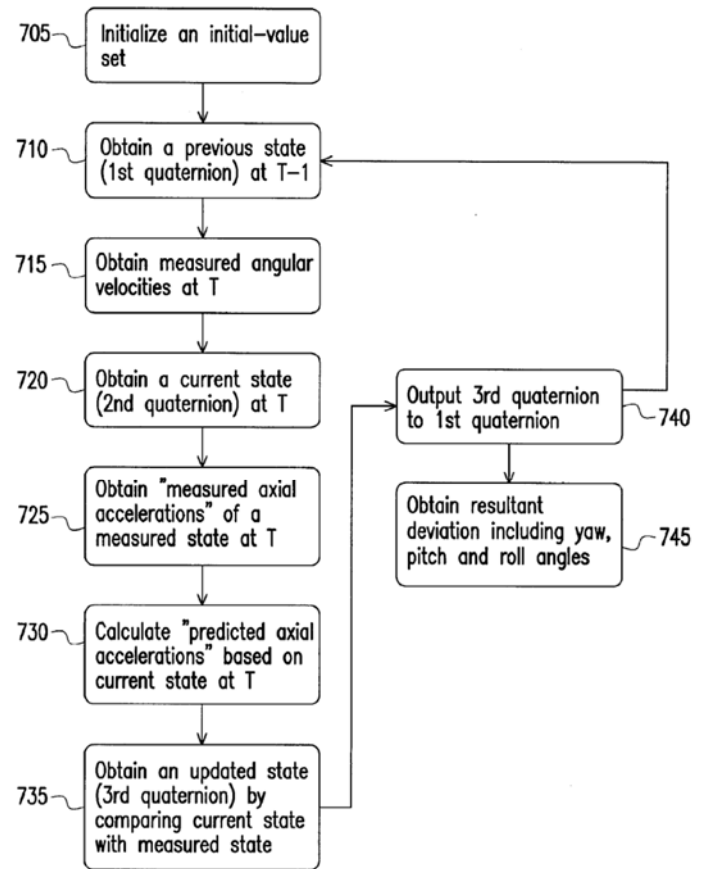


FIG. 7

## IX. CLAIM INTERPRETATION

35. I understand that it is sometimes necessary or useful for claim terms in a patent to be further explained or interpreted (“construed”). In the present proceeding, I understand generally that claims terms are construed according to their broadest reasonable interpretation in light of the specification, looking at the ordinary meaning to a person of ordinary skill in the art in the relevant timeframe

and considering the specification of the patent and the file history of the patent.

36. I have reviewed the claim interpretations in the corresponding petition for inter partes review, and I am of the opinion that they would have been reasonable to a person of ordinary skill in the art in the relevant timeframe in the context of the '978 patent. These interpretations are set forth in the following paragraphs, and my testimony applies these interpretations:

**A. Claim 10—“spatial reference frame” and “spatial reference frame associated with the 3D pointing device”**

37. The terms “spatial reference frame” and “spatial reference frame associated with the 3D pointing device” each mean “a reference frame associated with the 3D pointing device, which always has its origin at the same point in the device and in which the axes are always fixed with respect to the device.”

38. My interpretation of these terms is based on the claims and specification of the '978 patent. Claim 10 refers to several frames of reference, including (1) “a spatial reference frame associated with the 3D pointing device,” (2) “the spatial reference frame,” (3) a “global reference frame associated with Earth,” and (4) “a fixed reference frame associated with a display device.” Neither claim 10 nor dependent claims 11–18 defines “a spatial reference frame associated with the 3D pointing device” or “the spatial reference frame.” But claims 10–18 use these terms interchangeably, which leads me to conclude that they mean the same thing. The specification of the '978 patent supports this conclusion as explained below.

39. The specification of the '978 patent uses the terms “spatial reference frame” and “spatial reference frame associated with [a] 3D pointing device” to refer to the frames of reference of pointing devices like those shown in FIGS. 3, 5, 6, 9, and 13–15 of the '978 patent. The '978 patent does not define these terms in great detail, but it does liken the spatial reference frame to the reference frame associated with the 3D pointing device shown in FIGS. 1 and 2. For example, when describing the electronic device 300 shown in FIG. 3, the '978 patent states:

“The electronic device 300 is subject to movements and rotations in dynamic environments in a **spatial reference frame** such as a 3D reference frame. **The spatial reference frame is analogous to the reference frame  $X_P Y_P Z_P$  also shown in FIG. 1 and FIG. 2.**”

(Ex. 1001, 9:16-20)(Emphasis added). Similarly, when discussing the flowchart shown in FIG. 13, the '978 patent refers to “the three coordinate axes of a spatial reference frame associated with the 3D pointing device itself (**such as the reference frame  $X_P Y_P Z_P$  shown in FIG. 1 and FIG. 2.**)” (Ex. 1001, 30:60-30:63)(Emphasis added). I take these references to mean that the reference frame  $X_P Y_P Z_P$  shown in FIGS. 1 and 2 is an example of a spatial reference frame (associated with the 3D pointing device).

40. The reference frame  $X_P Y_P Z_P$  shown in FIGS. 1 and 2 (reproduced below) is called the “spatial pointer reference frame.” (Ex. 1001, 1:38–1:42). The

'978 patent states that the spatial pointer reference frame is “associated with the pointing device 110 [and] is defined by the coordinate axes  $X_P$ ,  $Y_P$  and  $Z_P$  as shown in FIG. 1.” (Ex. 1001, 1:43-1:45). Because the pointing device 110 can be “a 3D pointing device” (Ex. 1001, 1:30), I interpret the spatial pointer reference frame to be “a reference frame associated with the 3D pointing device” per the first part of my interpretation of “spatial reference frame.” This interpretation is consistent with the descriptions of spatial reference frames elsewhere in the specification of the '978 patent.

41. Next, I consider the second part of my interpretation, i.e., that the spatial reference frame “always has its **origin at the same point in the device** and in which the axes are always fixed with respect to the device.” This is based on FIGS. 1 and 2 of the '978 patent. These figures are reproduced below and show that the  $X_P$ ,  $Y_P$  and  $Z_P$  coordinate axes intersect at a point within the electronic device 110. See, for example, FIG. 1 of the '978 patent:

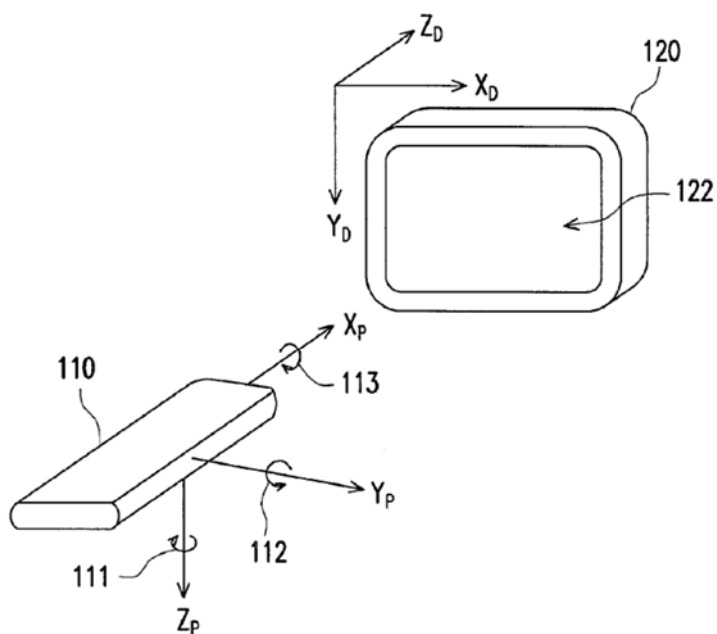


FIG. 1 (RELATED ART)

42. FIG. 2 (reproduced below) also shows that the intersection of the  $X_p$ ,  $Y_p$ , and  $Z_p$  coordinate axes is within the electronic device 110:

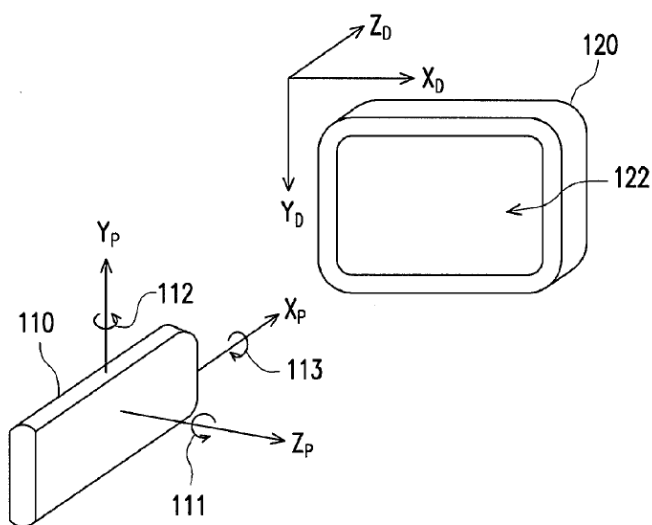


FIG. 2 (RELATED ART)

43. The intersection point of a set of coordinate axes is commonly called

the “origin” of the reference frame, hence my interpretation that the spatial reference frame (associated with the 3D pointing device) has an **origin in the device**.

44. Not only is the origin in the device, it is always at the same point in the device, even if the device is rotated or translated. This is because the  $X_P$ ,  $Y_P$ , and  $Z_P$  coordinate axes are always fixed with respect to the device. In other words, the coordinate frame does not move relative to the device, even if the device itself moves with respect to the display or the Earth.

45. FIG. 2 of the '978 patent shows that the  $X_P$ ,  $Y_P$ , and  $Z_P$  coordinates do not move with respect to the device when the device is rotated. More specifically, rotating the device counterclockwise by 90 degrees with respect to the screen 120 (i.e., around the  $X_P$  axis) causes the  $X_P$ ,  $Y_P$ , and  $Z_P$  coordinate axes to rotate counterclockwise by 90 degrees. This means that the  $X_P$ ,  $Y_P$ , and  $Z_P$  coordinate axes do not rotate with respect to the device. Similarly, it is my opinion that the  $X_P$ ,  $Y_P$ , and  $Z_P$  coordinate axes do not translate with respect to the device. In other words, the  $X_P$ ,  $Y_P$ , and  $Z_P$  coordinate axes are always fixed with respect to the device, hence my interpretation that the spatial reference frame has axes that “are always fixed with respect to the device.”

46. By definition, the coordinate axes are also fixed with each other. This means that their intersection point—the origin—is fixed with respect to the coordinate axes. And because the coordinate axes are fixed with respect to the

device, the origin is also fixed with respect to the device. This means that the origin is always in the same point in the device.

47. For these reasons, I interpret “spatial reference frame” and “spatial reference frame associated with the 3D pointing device” to have the same meaning: “a reference frame associated with the 3D pointing device, which always has its origin at the same point in the device and in which the axes are always fixed with respect to the device.”

#### **B. Claim 10—“rotation output”**

48. Claim 10 uses the phrase “rotation output”. I interpret this “rotation output” to be the “output of a rotation sensor” for the following reasons.

49. According to claim 10, the “rotation output” is “associated with a rotation of the 3D pointing device.” Claim 10 also states that “the rotation output is generated by a nine-axis motion sensor module”. Put differently, the nine-axis motion sensor module produces the rotation output as the 3D pointing device rotates.

50. The specification of the ’978 patent makes clear that the rotation output is the output of a rotation sensor that is part of the nine-axis sensor module. For example, the Summary of the ’978 patent states:

“The **rotation sensor generates a rotation output** associated with a rotation of the 3D pointing device associated with three coordinate axes of a spatial reference frame associated with the 3D pointing device.” (Ex. 1001, 7:61-64)(Emphasis added).

51. The Detailed Description of the '978 patent goes into more detail about the rotation output, rotation sensor, and nine-axis sensor module. It starts by disclosing a “nine-axis motion sensor module 302 [that] includes the rotation sensor 342”. (Ex. 1001, 9:60-61). It also states:

“The rotation sensor 342 of the nine-motion sensor module 302 detects and generates the first signal set including angular velocities  $\omega_x$ ,  $\omega_y$ ,  $\omega_z$  associated with the movements and rotations of the electronic device 300 about each of three orthogonal coordinate axes  $X_P Y_P Z_P$  of the spatial reference frame”. (Ex. 1001, 10:1-6).

52. This description is consistent with claim 10 and indicates that “rotation output” should be interpreted as “output of a rotation sensor”.

## **X. THE PRIOR ART (ZHANG, BACHMANN, AND LIBERTY)**

### **1. Overview of Zhang**

53. Zhang discloses a “handheld pointing device” for controlling a “computer pointing control system”. (Ex. 1005, Abstract). Zhang’s FIG. 2 (reproduced below) shows an example of this computer pointing control system with a handheld pointing device 100:

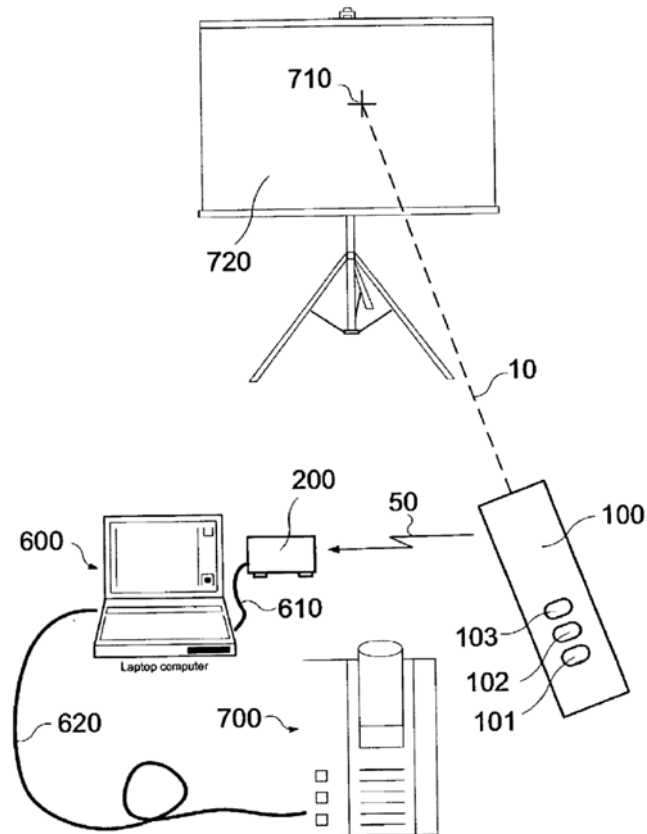


FIG. 2

54. Zhang’s device 100 includes several sensors that detect the device’s orientation. Zhang explains:

“A universal pointing control system for televisions and computer displays is disclosed. The system is comprised of a remote handheld device, a display control unit and a command delivery unit. The remote handheld device includes **a set of orientation sensors that detect the device’s current orientation.**” (Ex. 1005, ¶0008)(Emphasis added).

55. The set of orientation sensors “detects the device’s current orientation and generate[s] the pointing direction signal.” (Ex. 1005, ¶0021). This pointing direction signal indicates which way the device 100 is pointing. (Ex. 1005, ¶0021).

56. Zhang discloses that these different orientation sensors include a two-axis magnetic field sensor and a two-axis accelerometer. Zhang's FIG. 3 (reproduced immediately below) shows an example two-axis magnetic field sensor 120 and an example accelerometer 130 on a circuit board 160 inside the device 100 along with a microcontroller 110:

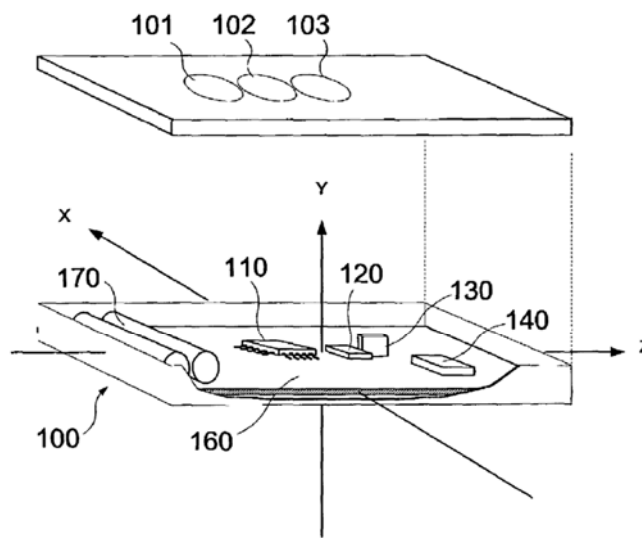


FIG. 3

57. FIG. 3 shows that the magnetic field sensor 120 and the accelerometer sensor 130 are mounted at right angles with respect to each other. (Ex. 1005, ¶0026). This is so that one sensor (here, the magnetic field sensor 120) detects the device's yaw (azimuth) angle and the other sensor (here, the accelerometer sensor 130) detects the device's pitch (inclination) angle. (Ex. 1005, ¶0025).

58. Zhang's FIG. 4a shows the magnetic field sensor 120, the yaw angle  $\phi$ ,

and the orientation of the Earth's magnetic field 25. The magnetic field sensor 120 “detects the device's orientation relative to the direction of the earth's magnetic field 25.” (Ex. 1005, ¶0026). Similarly, Zhang's FIG. 4b shows the accelerometer sensor 130 and the pitch angle  $\varepsilon$ . The accelerometer sensor 130 “sense[s] the device's heading change in the y-z plane.” (Ex. 1005, ¶0027). Zhang's FIGS. 4a and 4b are reproduced immediately below:

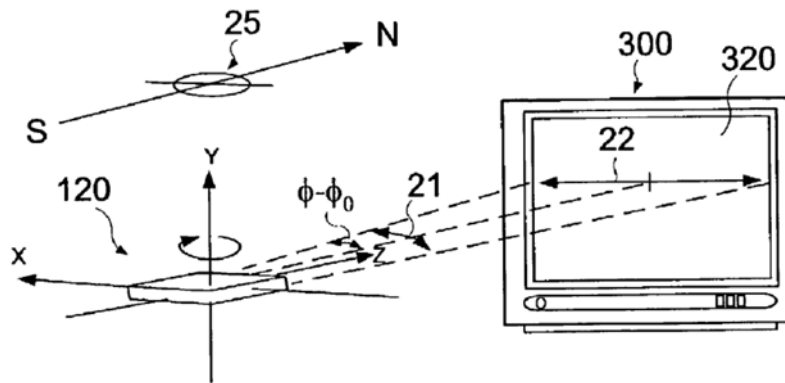


FIG. 4a

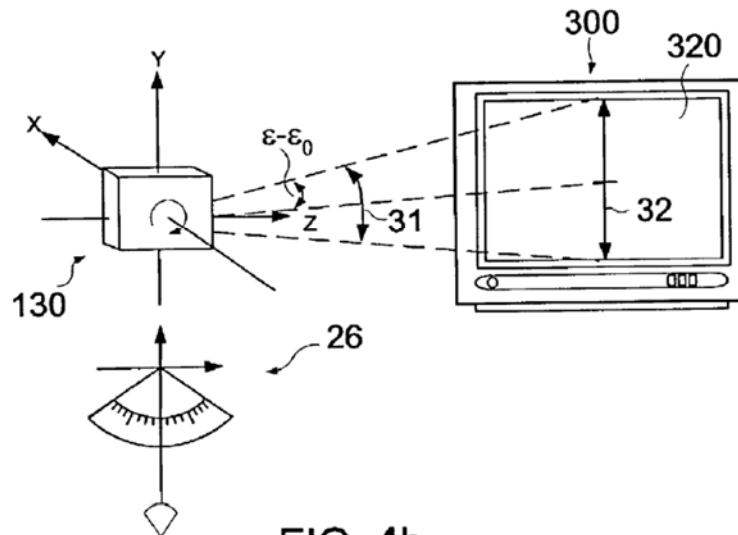


FIG. 4b

59. The microcontroller 110 determines the device's orientation from the

signals generated by the magnetic field sensor 120 and the accelerometer sensor 130. (Ex. 1005, ¶¶0025 and 0029). These signals are filtered, amplified, digitized, and processed using the components shown in the system diagram in Zhang's FIG. 5, an annotated version of which is reproduced immediately below. (Ex. 1005, ¶0029).

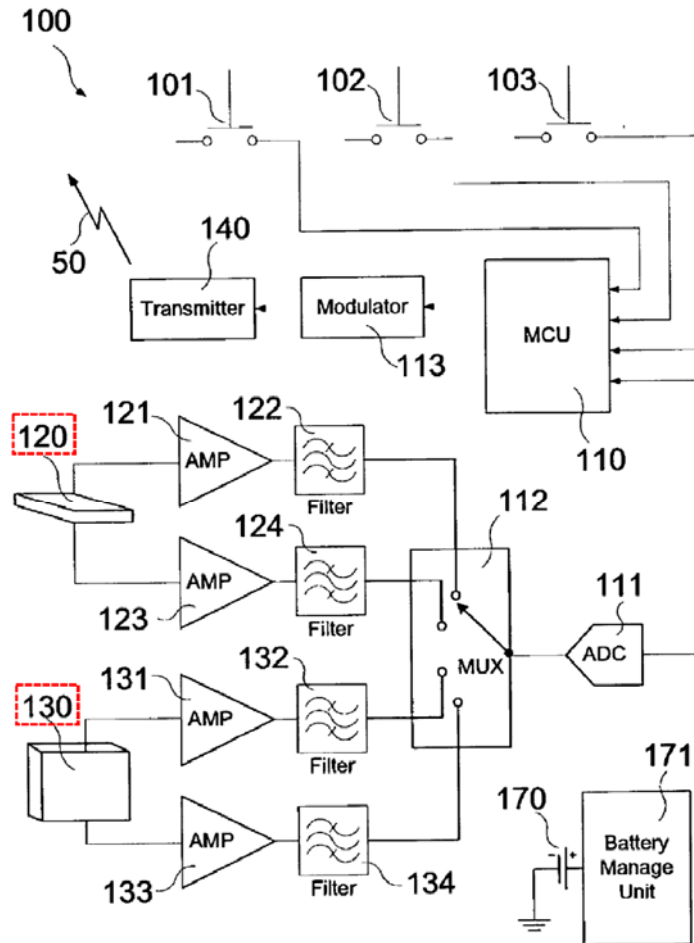


FIG. 5

60. The magnetic field sensor 120 and accelerometer sensor 130 appear in the lower left of FIG. 5 (numerals 120 and 130 are shown by red-dashed boxes). These sensors output signals to amplifiers 121, 123, 131, and 133, which amplify the sensor outputs. (Ex. 1005, ¶0029). Low-pass filters 122, 124, 132, and 134

remove high-frequency components from the amplified signals, which are multiplexed by a multiplexer 112 and digitized by an analog-to-digital converter (ADC) 111 before being processed by the microcontroller (MCU) 110. (Ex. 1005, ¶0029). The MCU 110 determines the device's orientation, including its azimuth and inclination angles, from the digitized signals. (Ex. 1005, ¶0029). Zhang's system uses the device's orientation to "determine[] the new coordinates of the pointer on the screen." (Ex. 1005, ¶0024, 0030).

61. Although Zhang's FIGS. 3–5 show a handheld pointing device 110 with a four-axis sensor module (i.e., the two-axis magnetic field sensor 120 and the two-axis accelerometer sensor 130), Zhang states that other versions of the handheld pointing device can have more and different sensors. Referring to FIG. 3, for example, Zhang states that the handheld pointing device could include a roll sensor: "Additional sensors (not show[n] in the picture) could be used to detect [the] device's roll angle which may provide an additional dimension of control." (Ex. 1005, ¶0025). In addition, Zhang states that the handheld pointing device could include gyro sensors (angular velocity sensors):

"The orientation sensors' mechanisms are shown in FIGS. 4a and 4b. The orientation sensor demonstrated in FIG. 4a is a magnetic field sensor, whereas the one in FIG. 4b is an accelerometer sensor. **However, the orientation detection may not be limited to these types of sensors. Other sensors,**

**for example, a gyro sensor, can also be used** in the pointing control system.” (Ex. 1005, ¶0026; *see also id.* at ¶0006 and claim 2)(Emphasis added).

62. Moreover, Zhang contemplates that the handheld pointing device can include different types of multi-axis sensors operating in concert. Indeed, the handheld pointing device in Zhang’s FIGS. 1 and 3–5 includes both a two-axis magnetic field sensor and a two-axis accelerometer sensor. (Ex. 1005, ¶¶0025–0027). And Zhang says the handheld pointing device in Zhang’s FIGS. 1 and 3–5 can also include a roll sensor or a gyro. (Ex. 1005, ¶¶0025 and 0026). These statements indicate that Zhang’s handheld pointing device could accommodate a wide variety of sensors.

63. Zhang also contemplates digital sensors. If the sensors output digital signals instead of analog signals, it is possible to omit the ADC: “Some variations of the orientation sensor convert the analog signal internally to a digital or time period-based signal. In those cases, the can be directly sampled by the microcontroller without an ADC chip.” (Ex. 1005, ¶0026).

## **2. Overview of Bachmann**

64. 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).

This combination of magnetometers, accelerometers, and angular rate detectors is the same combination suggested in ¶0025 of Zhang.

65. 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 date of the ’978 patent. (Ex. 1004, 14:37-59).

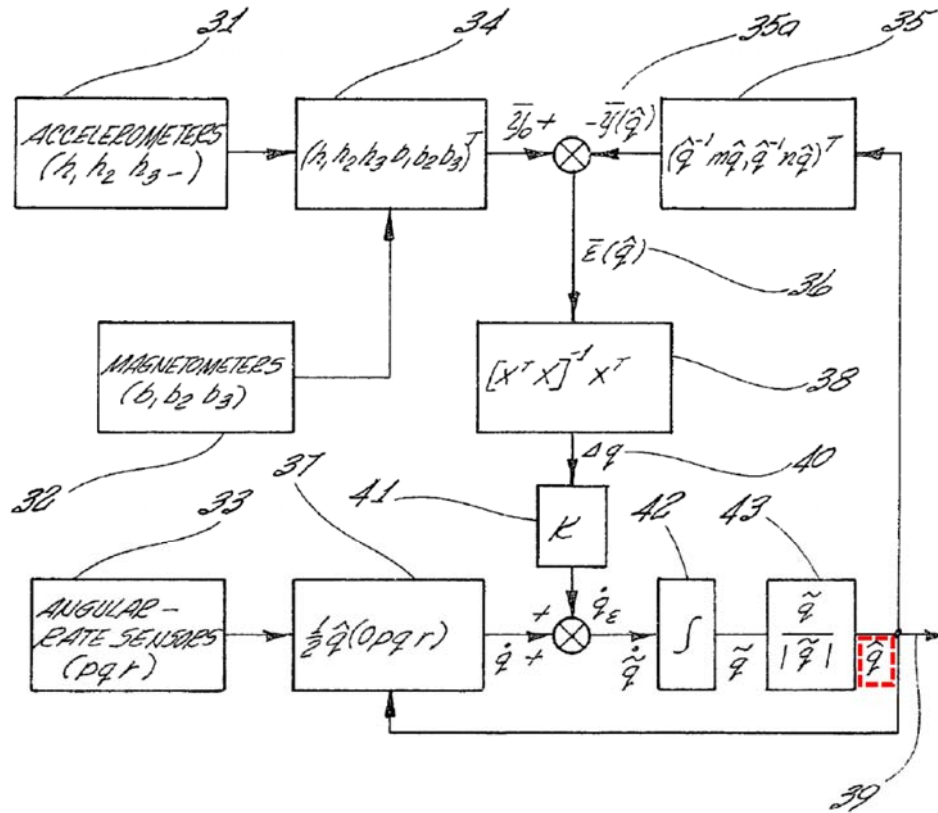
66. Bachmann uses a filter to generate a representation of the object’s orientation. This representation is a quaternion generated from the outputs of the accelerometer, magnetometer, and angular rate sensor in the MARG sensor. Bachmann states:

“[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

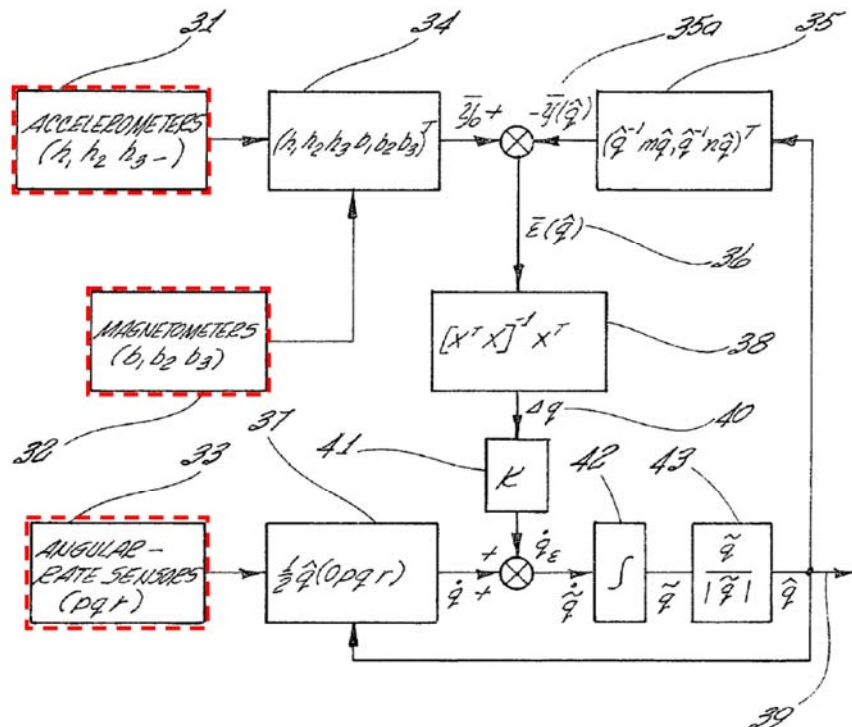
representation of the **orientation of the tracked object  $\hat{q}$  39.**”  
(Ex. 1004, 10:10-14)(Emphasis added).

67. 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.

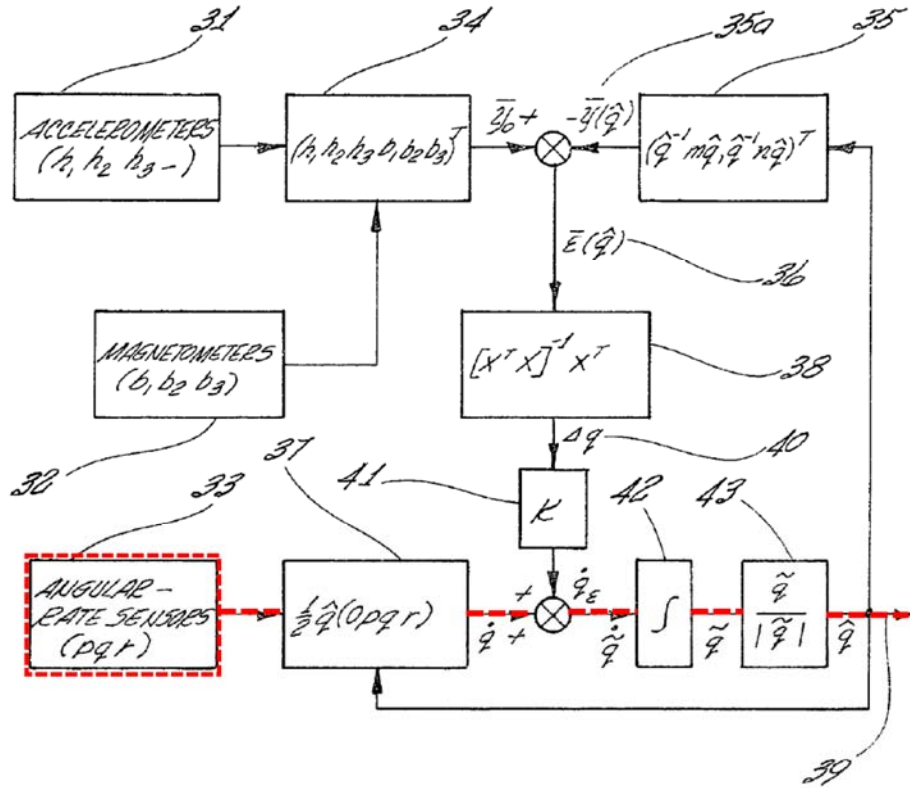
68. Bachmann’s FIG. 3 shows the filtering process used to calculate the device’s orientation from the nine sensor inputs. As I explain in the following sections, Bachmann’s filtering process corresponds to the calculations in claim 10 of the ’978 patent. The output of this filtering process is an estimated 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:



69. 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:



70. 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  $\dot{q}_\epsilon$ , 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:



71. 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).

72. 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).

73. 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  $\Delta q_{\text{full}}$  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).

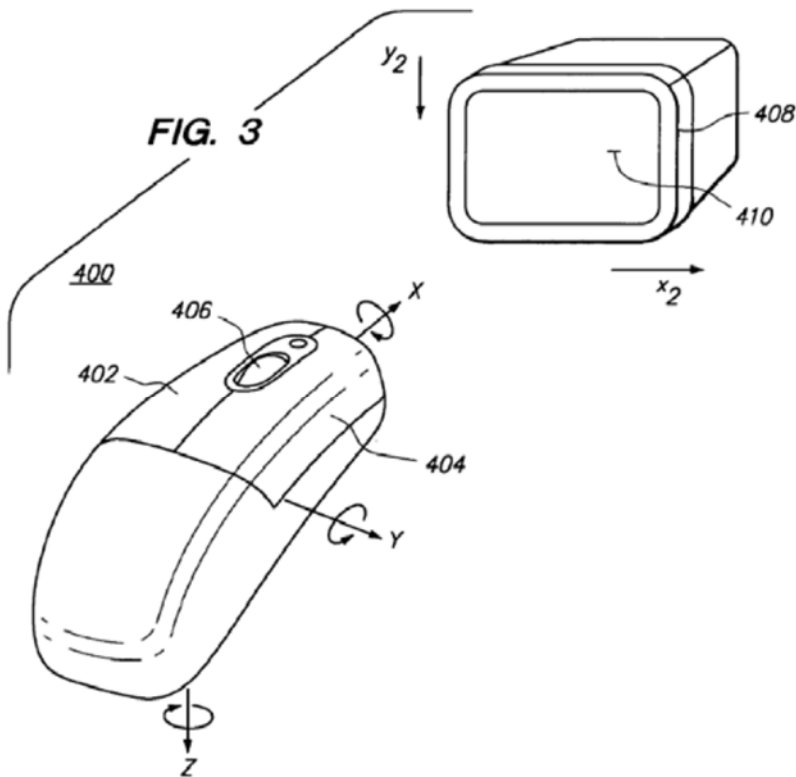
74. Adding the rate quaternion  $\dot{q}$  to the correction factor  $\dot{q}_\epsilon$  yields a

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).

### 3. Overview of Liberty

75. Liberty discloses “three-dimensional (hereinafter “**3D**”) **pointing devices** and techniques for tilt compensation and improved usability associated therewith.” (Ex. 1006, 1:31-34)(Emphasis added). More specifically, the 3D pointing device includes sensors to measure roll, pitch, and yaw. (Ex. 1006, 7:19-27). It uses the sensor measurements to “estimate[] both its position and its orientation.” (Ex. 1006, 16:62-64). Then it translates its position and orientation from the device reference frame to an inertial reference frame, such as the reference frame of a display. (Ex. 1006, 16:21-29). Liberty’s FIG. 9 illustrates an overview of this process. (Ex. 1006, FIG. 9).

76. Liberty’s FIG. 3 shows an example 3D pointing device 400 that is used to control a cursor 410 on a display 408. (Ex. 1006, 7:15-56). Liberty’s FIG. 3 is reproduced below:



77. Liberty describes the reference frame for the 3D pointing device 400 in FIG. 3 as follows:

“An exemplary **3D pointing device 400** is depicted in FIG. 3. Therein, **user movement of the 3D pointing can be defined, for example, in terms of a combination of x-axis attitude (roll), y-axis elevation (pitch) and/or z-axis heading (yaw) motion of the 3D pointing device 400.** In addition, some exemplary embodiments of the present invention can also measure linear movement of the 3D pointing device 400 along the x, y, and z axes to generate cursor movement or other user interface commands.” (Ex. 1006, 7:19-27)(Emphasis added).

78. Liberty’s FIG. 3 shows x, y, and z axes that intersect within the 3D

pointing device 400, just like the “spatial reference frame” in claim 10 of the ’978 patent. (See ¶¶37–47, *above*). This indicates that the x, y, and z axes in FIG. 3 form a similar spatial reference frame, i.e., one that is associated with the 3D pointing device and whose origin is at the same point in the device and whose axes are always fixed with respect to the device. The x, y, and z axes are also distinct from the display reference frame indicated by the  $x_2$  and  $y_2$  axes in FIG. 3. (Ex. 1006, 11:16-12:20).

79. Liberty’s 3D pointing device 400 includes two rotation sensors and a three-axis accelerometer to measure its movements in three dimensions. (Ex. 1006, 7:57-8:20, FIG. 4). One rotation sensor measures rotation about the y axis, and the other rotation sensor measures rotation about the z axis. (Ex. 1006, 8:54-9:2). The axial accelerometer measures acceleration along the x, y, and z axes. (Ex. 1006, 8:54-9:2).

80. Liberty explains that different types of error can corrupt the sensor measurements. (Ex. 1006, 8:44-53). These errors include errors intrinsic to the sensors themselves and user error. (Ex. 1006, 8:44-53). In Liberty’s words:

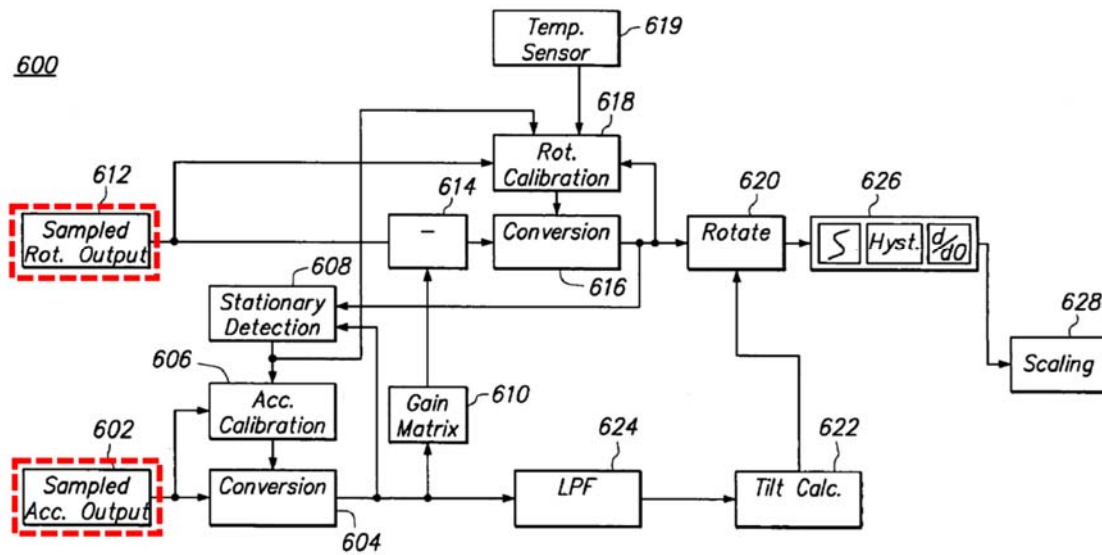
“[V]arious measurements and calculations are performed by the handheld device 400 which are used to adjust the outputs of one or more of the sensors 502, 504 and 506 and/or as part of the input used by a processor to determine an appropriate output for the user interface based on the outputs of the sensors 502, 504

and 506. These measurements and calculations are used to compensate for factors which fall broadly into two categories: (1) factors which are intrinsic to the 3D pointing device 400, e.g., errors associated with the particular sensors 502, 504 and 506 used in the device 400 or the way in which the sensors are mounted in the device 400 and (2) factors which are not intrinsic to the 3D pointing device 400, but are instead associated with the manner in which a user is using the 3D pointing device 400....” (Ex. 1006, 8:37-50).

81. The intrinsic errors appear in the sensor measurements as scale, offset, and/or misalignment errors. (Ex. 1006, 9:3-58). Scale and offset errors are sometimes due to manufacturing imperfections in the sensors, whereas misalignment errors are often due to how the components are mounted with respect to each other. (Ex. 1006, 9:3-58). Certain types of rotational sensors may be susceptible to measurement errors caused by linear accelerations. (Ex. 1006, 9:59-10:19).

82. Liberty discloses processing the outputs from the rotation sensors and accelerometer to account for measurement errors. (Ex. 1006, 8:21-53, 10:20-39). The following annotated version of Liberty’s FIG. 5 illustrates this processing at a high level and has red-dashed boxes added on the left side to show the sensor outputs (602 and 612):

**FIG. 5**



83. The accelerometer and rotation measurements can be compensated by subtracting offsets and multiplying by scale factors. (Ex. 1006, 9:3-11:15, Boxes 604 and 616 in FIG. 5). For the rotation measurements, “scale corrects for axis misalignment and rotational offset factors.” (Ex. 1006, 10:37-38). This mitigates the intrinsic errors.

84. Next, Liberty translates the rotation measurements from the device reference frame into an inertial reference frame. (Ex. 1006, 11:16-12:53, Box 620 in FIG. 5). Liberty adjusts the translation based on the accelerometer measurements to compensate for tilt during movement of the device. (Ex. 1006, 11:16-21). As Liberty explains:

“In order to provide an interface which is transparent to the user in terms of how the 3D pointing device 400 is held, **tilt compensation** according to exemplary embodiments of the

present invention **translates the readings output from rotational sensors 502 and 504** back into the inertial frame of reference as part of processing the readings from these sensors **into information indicative of rotational motion of the 3D pointing device 400**. According to exemplary embodiments of the present invention, returning to FIG. 5, **this can be accomplished by determining the tilt of the 3D pointing device 400** using the inputs y and z received from accelerometer 506 at function 622.” (Ex. 1006, 12:13-26)(Emphasis added).

85. According to Liberty, this inertial reference frame can be associated with a display. Liberty explains:

“[E]xemplary embodiments of the present invention process movement data received from sensor(s) in the 3D pointing device to **convert this data from the frame of reference of the 3D pointing device’s body into another frame of reference, e.g., the user’s frame of reference**. In the exemplary application of a 3D pointing device used to control a user interface displayed on a screen, e.g., a television, **the user’s frame of reference might be a coordinate system associated with the television screen**.” (Ex. 1006, 16:21-29)(Emphasis added).

86. The 3D pointing device 400 in Liberty’s FIG. 3 has a five-axis sensor module—two single-axis rotation sensors and a three-axis accelerometer. (Ex. 1006, 7:57-8:20, FIG. 4). (Claim 10 recites a “nine-axis sensor module.”) But Liberty

says that other embodiment may include more sensors and *different types* of sensors.

For example, Liberty states:

“**A variety of different sensors could be employed** as long as they measure motion with respect to the body of the device. Exemplary sensors include **accelerometers, rotational sensors, gyroscopes, magnetometers** and cameras.” (Ex. 1006, 18:30-33)(Emphasis added)

87. Other parts of Liberty disclose “rotational sensor(s), gyroscope(s), accelerometer(s), magnetometer(s), optical sensor(s), camera(s) or any combination thereof.” (Ex. 1006, 16:42-44). Liberty even says that ultrasound sensors can be used. (Ex. 1006, 19:62-20:13).

88. Liberty also states that gravity and magnetic field measurements can be combined with the acceleration and rotation measurements using different algorithms:

“Additional stability can be provided by constant field vectors including **gravity** and the **earth's magnetic field** and combined with the results above. **The combination can be achieved using several numerical and filtering methods** including, but not limited to, Kalman filtering.” (Ex. 1006, 18:24-29)(Emphasis added).

## **XI. CLAIMS 10 AND 12 WOULD HAVE BEEN OBVIOUS OVER ZHANG AND BACHMANN**

### **A. Summary of Opinion**

89. I am of the opinion that claims 10 and 12 would have been obvious over Zhang in view of Bachmann.

90. I addressed the level of ordinary skill in the art at the relevant timeframe in ¶¶24 and 25 above. The scope and content of the prior art, and the differences between the prior art and the claims, are discussed below. I am not aware of any secondary considerations that would make the claims less obvious.

### **B. Overview of the obviousness determination**

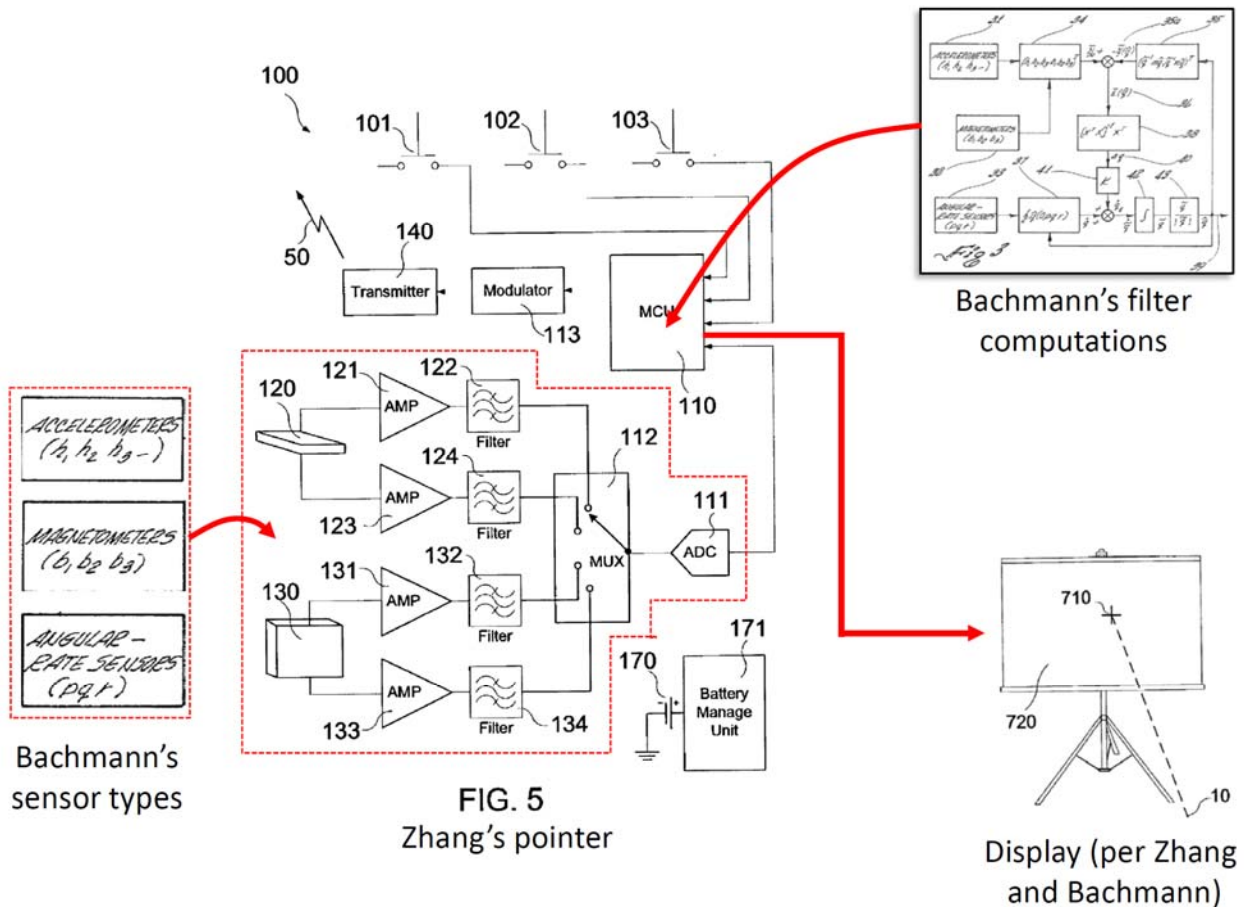
91. Claim 10 recites “[a] method for compensating rotations of a 3D pointing device.” Claim 12 depends from claim 10 and specifies possible representations of the “orientation output” of the 3D pointing device recited in claim 10. One possible representation of the “orientation output” in claim 12 is a quaternion.

92. Combining Zhang and Bachmann yields a method for compensating rotations of a 3D pointing device that includes representing the orientation of the 3D pointing device as a quaternion. Zhang discloses a 3D pointing device with two two-axis sensors for measuring the device’s rotations and a processor for compensating those rotations. Bachmann discloses measuring rotations with a nine-axis sensor module (three three-axis sensors) and compensating those rotations by processing

the sensor outputs as quaternions, including a quaternion representing the orientation of the 3D pointing device. A person of ordinary skill in the art would have been motivated to use Bachmann's nine-axis sensor module and processing with Zhang's 3D pointing device to (1) detect a variety of motions and (2) reduce error. This combination would have been well within the level of ordinary skill in the art the time the '978 patent was filed.

### **1. Combining Zhang and Bachmann**

93. The proposed combination of Zhang and Bachmann is simple: use Bachmann's nine-axis sensor and filtering process to estimate the orientation of Zhang's 3D pointer. The orientation of Zhang's 3D pointer can be converted to the coordinate system of a display, as disclosed in both Zhang and Bachmann. (Ex. 1005, ¶0021)(Ex. 1004, 14:20-29). The following figure shows how Zhang's 3D pointer can be modified to use Bachmann's sensors and filter processing:



## 2. Rationale for combining Zhang and Bachmann

94. In my opinion, it would have been obvious to a person of ordinary skill in the art during the relevant timeframe to use Zhang's 3D pointer with Bachmann's sensors and filter calculations as shown immediately above. As pointed out above in ¶62, Zhang says that the 3D pointer can include additional sensors, including angular rate sensors. (Ex. 1005, ¶¶0006, 0025, 0026, claim 2). Including Bachmann's nine-axis sensor in Zhang's 3D pointer is therefore nothing more than following Zhang's suggestions.

95. In addition, a person of ordinary skill would have understood that

adding Bachmann's nine-axis sensor to Zhang's 3D pointer would have improved Zhang's 3D pointer in at least two ways. First, Bachmann's nine-axis sensor would have allowed Zhang's 3D pointer to detect different modes of movement, including roll angle, thus providing the user with "an additional dimension of control." (Ex. 1005, ¶0025). In other words, the 3D pointer would be able to detect a wider variety of movements, enabling a wider variety of user inputs. Second, Bachmann's nine-axis sensor would have provided more measurements, increasing measurement precision through overdetermination (the amount information beyond that necessary to determine orientation), which in turn would have enabled better error control.

96. Furthermore, 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).

97. Bachmann further states that its sensors and filter processing can be used in hand-held devices (like Zhang’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).

98. In my opinion, a person of ordinary skill in the would have been motivated and able to use nine-axis MARG sensors like those in Bachmann to

improve Zhang's hand-held pointer, as suggested by Zhang and Bachmann.

99. Using Bachmann's quaternion-based filter processing (as illustrated, for example, in FIG. 3 of Bachmann) would have been a logical next step, in part because 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).

100. 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.

101. In my opinion, the combination of Zhang and Bachmann presented here is nothing more than the combination of known elements to achieve an expected improvement. Zhang's 3D pointer device 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.<sup>1</sup> Bachmann's functional blocks (sensors and calculations) could have been 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.

102. Finally, it would have been obvious to translate the orientation estimated by Bachmann's filtering process into coordinates that can be used on a display. After all, this is what Zhang's system is used for—translating a 3D pointer's

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<sup>1</sup> 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.

motion into cursor movements on a display. For example, Zhang states:

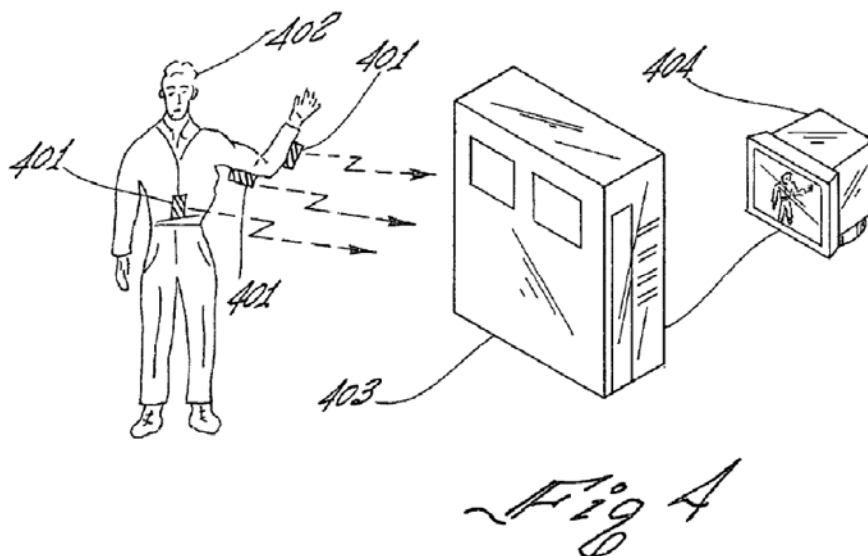
“The CPU in the display control unit interprets the direction information, sends the pointer move command to the computer’s peripheral port, and instructs the computer to move the pointer 710 on screen to the aimed place. This is analogous to moving the pointer by moving a regular computer mouse device, except that the moving information is in absolute coordinates instead of relative steps.” (Ex. 1005, ¶0024).

103. Zhang’s system instructs the computer to move the pointer by translating the device orientation from a device-centered reference frame to a reference frame fixed with respect to a display. Zhang explains:

“The CPU compares the **device’s azimuth and inclination angle data with the reference angles**, which are sampled and stored in the memory module 270 during the calibration procedure. The difference angles calculated are **translated into screen coordinates** and the target device is instructed to move the pointer to the new location.” (Ex. 1005, ¶0030)(Emphasis added).

104. Bachmann likewise discloses that its orientation output can be used with a display: “The system can further include a display for displaying the position and orientation of the body with respect to a synthetic environment.” (Ex. 1004, 4:26-28). This synthetic environment has a reference frame fixed with respect to the display so that the pointer can be shown on the display, as shown in Bachmann’s

FIG. 4, reproduced below:



105. FIG. 4 shows sensors 401 on a person's arm and torso track the person's movement, allowing a display screen 404 to show an image of the person in display screen coordinates. (Ex. 1004, 13:64-14:29). For the display screen 404 to show the image correctly, the sensors' orientations must be translated from the sensors' frames of reference to the display's frame of reference.

### **3. Ability to Implement and Reasonable Expectation of Success**

106. A person of skill in the art in the relevant timeframe could have implemented the proposed combination of Zhang and Bachmann with a reasonable expectation of success. As discussed above, nine-axis MARG sensors were widely available on the commercial market. And a person of ordinary skill would have been able to integrate these sensors into Zhang's 3D pointing device using standard amplifiers, filters, samplers, and analog-to-digital converters, adjusting as necessary.

107. Similarly, Bachmann's filter processing could have been executed by programming a commercially available, off-the-shelf microcontroller or other processor using only ordinary skill. Both Zhang and Bachmann teach implementing orientation calculations on computer chips, including Zhang's MCU 110 (Ex. 1005, ¶0029) or Bachmann's CPU 403 (Ex. 1004, 13:64-14:29). In the relevant timeframe, microprocessors and microcontrollers with sufficient power to implement Bachmann's filter would have been readily available. Indeed, Bachmann shows that these components and programming skills were available about a decade before the relevant time frame.<sup>2</sup>

108. Similarly, a person of ordinary skill in the art would have expected success translating Bachmann's orientation from the sensor frame of reference into a display's frame of reference.

109. The '978 patent itself indicates that this component integration and programming was well within the level of ordinary skill in the art. I say this because the '978 patent does not say anything about any difficulties in constructing circuits for conditioning the sensor or programming the microcontroller to estimate the orientation. In fact, the '978 patent does not explain how to implement sensor output

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<sup>2</sup> Bachmann's non-provisional priority date is almost 10 years earlier than the earliest claimed priority date of the '978 patent.

conditioning circuits or program the microcontroller. This suggests that the inventors of the '978 patent considered this level of detail unnecessary given the level of ordinary skill in the art.

110. A person of ordinary skill therefore would have been able to implement the combination of Zhang and Bachmann with a reasonable expectation of success.

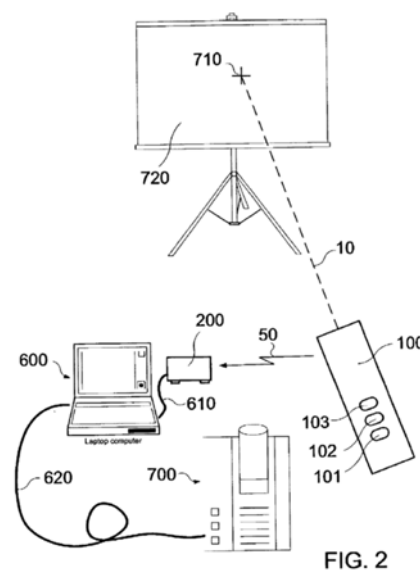
### C. How the Combination Meets the Elements of the Claims

111. I show how the combination of Zhang and Bachmann meets the elements of claims 10 and 12 in the following paragraphs. The relevant claim language appears in bold-italic font, and the mapping in the text that follows each claim element. In claim 10, lettering has been added to each element (e.g., [10b]) for clarity. This claim mapping section augments and should be read with the preceding remarks.

#### 1. Claim 10

***“10[a]. A method for compensating rotations of a 3D pointing device, comprising:”***

112. As discussed above, Zhang discloses a **3D pointing device**. (Ex. 1005, Title, Abstract). An example of such a 3D pointing device is the “handheld pointing device 100” in Zhang’s FIG. 2 (reproduced at right). (Ex. 1005, ¶0021). The handheld pointing device 100 controls the location of a pointer 710 on a screen. (Ex. 1005, ¶0024). It



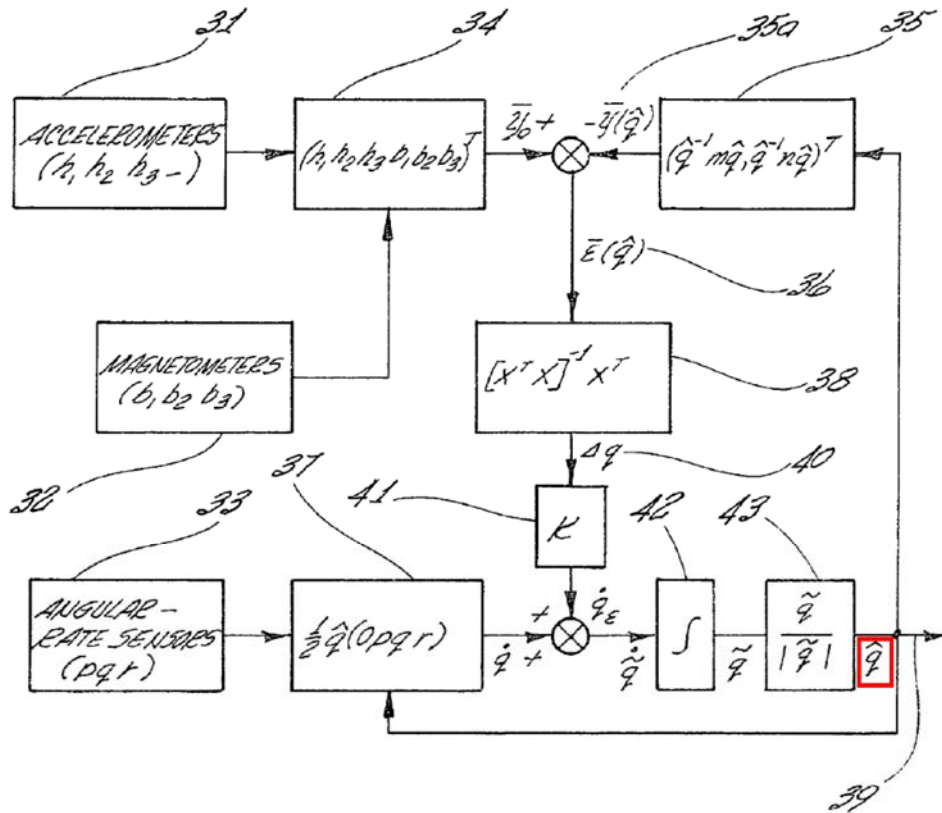
can also be used to control computer systems and home entertainment systems. (Ex. 1005, ¶0007).

113. Zhang’s handheld pointing device is a “**3D** pointing device” because it can be moved in three dimensions: e.g., forwards and backwards, up and down, and left and right.

114. As discussed above, it would have been obvious to combine Zhang’s handheld pointing device 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 [10b]-[10h], below.

***“[10b] 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;”***

115. The combination of Zhang 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 10[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.



116. 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).

117. In the combination, the “tracked object” is Zhang’s 3D pointing device as explained above in paragraphs ¶¶112 and 113.

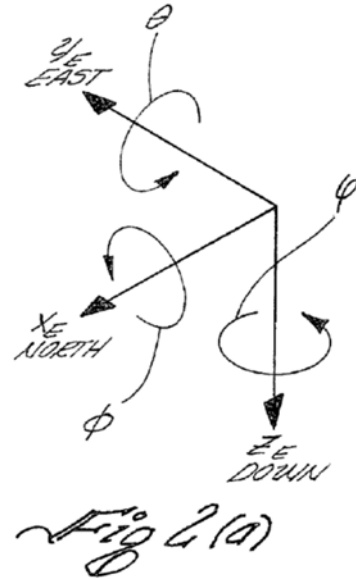
118. The orientation output  $\hat{q}$  is **associated with three coordinate axes of a global reference frame associated with Earth** because represents are rotation between the spatial sensor frame of reference and a “flat Earth” or “earth fixed” reference frame. (Ex. 1004, 8:61-67, 5:50-61). Put differently,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

119. 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).

120. Bachmann’s FIG. 2(a) shows an Earth-associated coordinate system

reproduced at right. The angles shown in FIG. 2(a), specifically  $\theta$ ,  $\phi$ , and  $\varphi$ , 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 10(b). (Ex. 1004, 6:1-10).



121. 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 dependent claim 12 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).

122. 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, above, 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 above in ¶31, 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.

***“[10c] generating a first signal set comprising axial accelerations associated with movements and rotations of the 3D pointing device in the spatial reference frame;”***

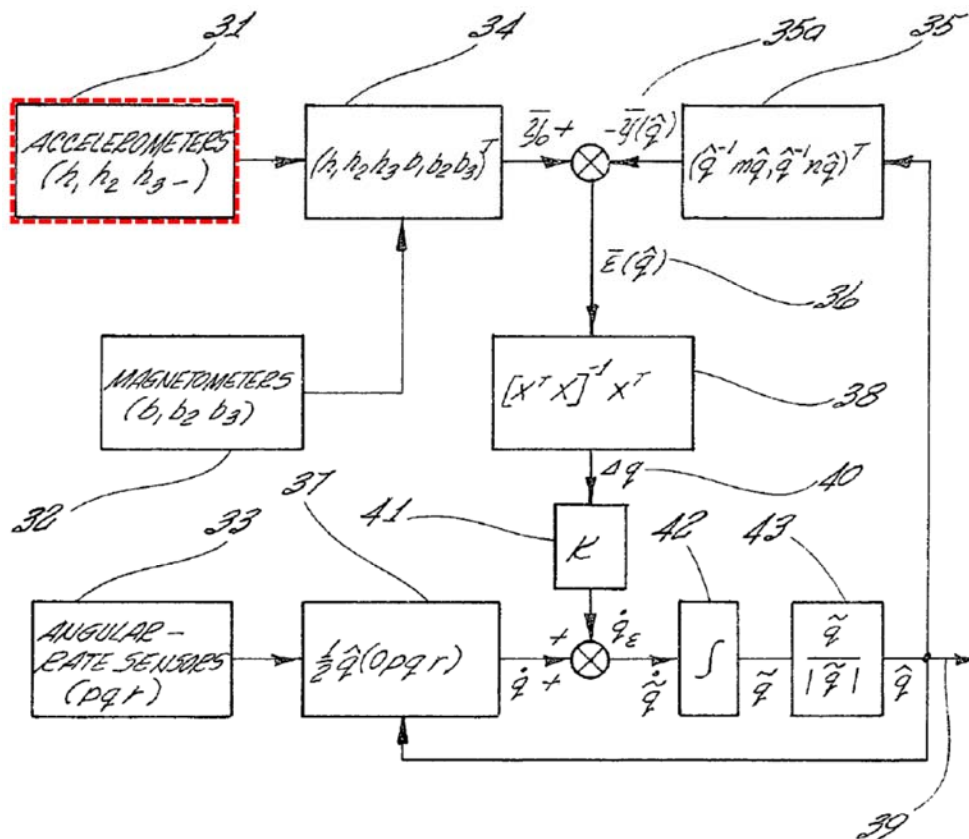
123. As mentioned above, the combination of Zhang and Bachmann would use a three-axis accelerometer that **generates a first signal set** representing measured acceleration. Bachmann explains as follows:

“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).

124. 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:

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

125. 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):



126. 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. In addition, the gravitational accelerations are also accelerations that the 3D pointing device experiences due to movements and rotations, as rotation of the device will alter the linear acceleration along each axis,  $A_x$ ,  $A_y$ ,  $A_z$ .

127. The measured acceleration is **in the spatial reference frame** (construed above in ¶¶37–47) 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).



65). The local magnetic field vector is **associated with Earth's magnetism** because it points to magnetic north:

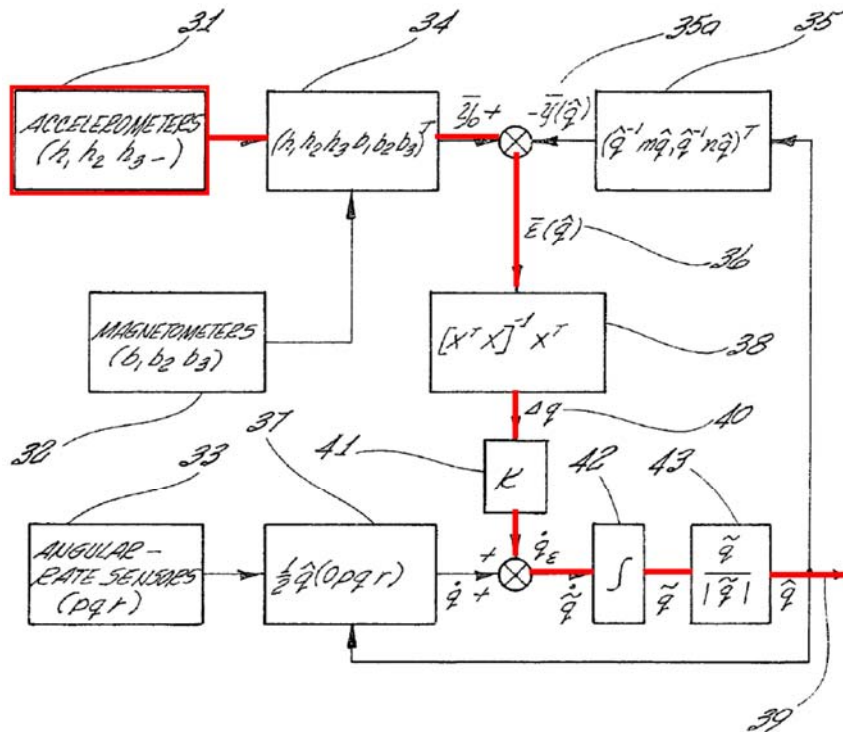
“An embodiment of the present invention makes use of the fact that a local magnetic field vector and local gravity vector can be defined. FIG. 1 is a simplified figurative illustration of the surface of the earth 10 showing a local gravity vectors 11 and a **local magnetic field vector 13. In general, 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).

***“[10e] 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;”***

130. As explained above in ¶¶64–74, 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).

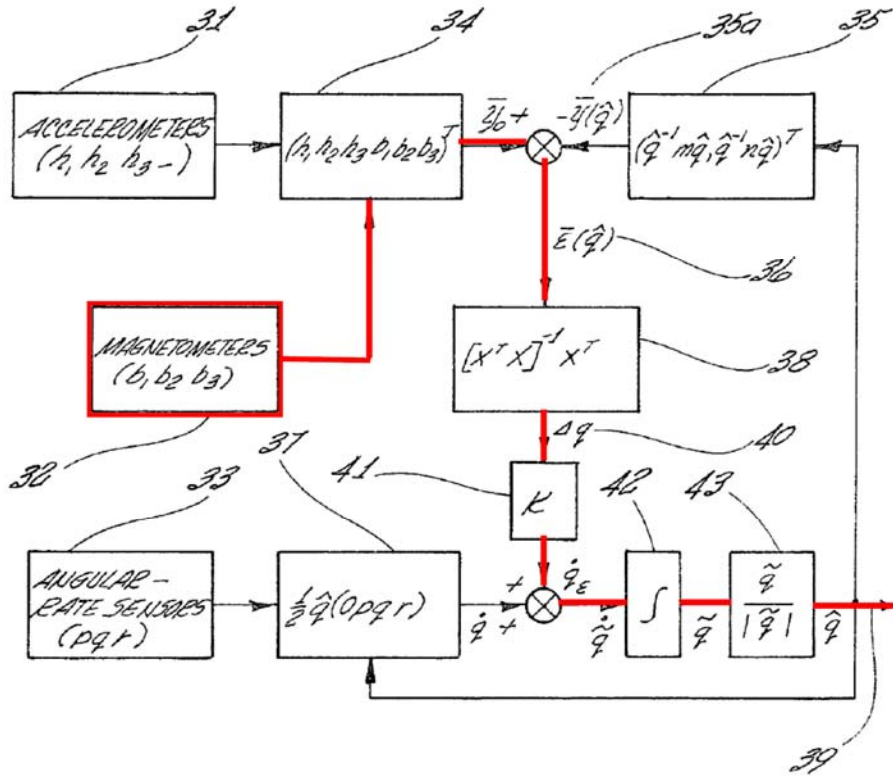
131. The orientation output  $\hat{q}$  is **based on the first signal set** ( $\vec{a}_{measured}$ ). As explained above, the first signal set is low-pass filtered to yield an acceleration vector ( $h_1, h_2, h_3$ ). (Ex. 1004, 8:63-67). Comparing the acceleration vector to

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:



132. 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 (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:



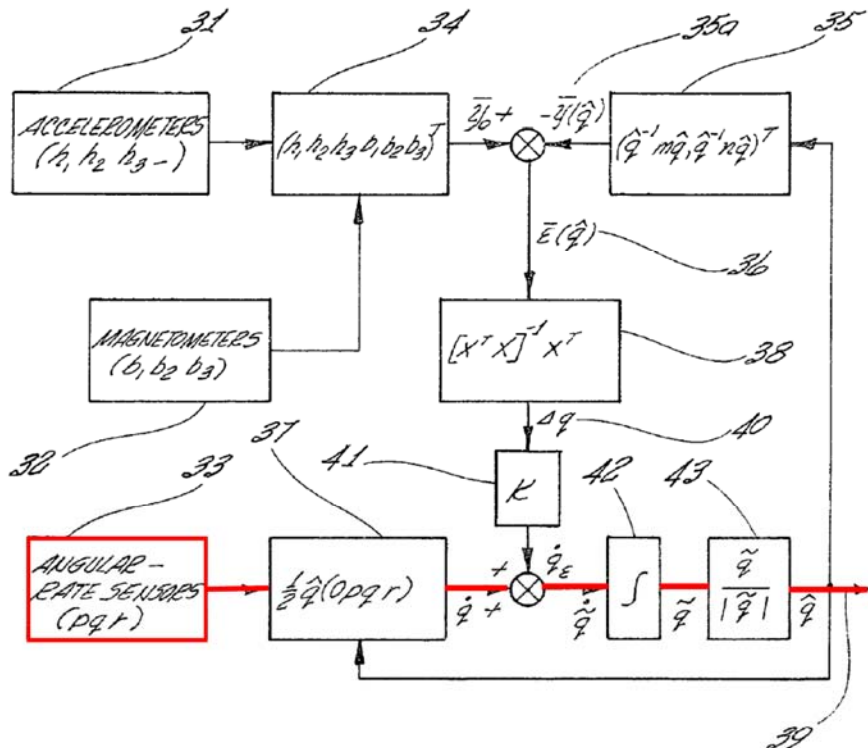
133. The orientation output  $\hat{q}$  is also **based on the rotation output**, which is simply the angular rate information 37 from the angular rate sensors 33 in Bachmann's FIG. 3. This rotation output is represented as an angular rate vector  $(p, q, r)$ . (Ex. 1004, 9:50-10:65). Bachmann explains:

"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).

134. 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).

135. 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  $\dot{q}_\epsilon$  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:



136. 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.

***“[10f] generating a rotation output associated with a rotation of the 3D pointing device associated with three coordinate axes of a spatial reference frame associated with the 3D pointing device;”***

137. 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**.

138. 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 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.

139. 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).

***“[10g] and using the orientation output and the rotation output to generate a transformed output associated with a fixed reference frame associated with a display device, wherein the orientation output and the rotation output is generated by a nine-axis motion sensor module;”***

140. As discussed above under limitations [10e] and [10f], 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).

141. 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). And Zhang discloses generating a transformed output associated with a fixed reference frame (“screen coordinates”) associated with a display device (the screen):

“The CPU compares **the device’s azimuth and inclination angle data with the reference angles**, which are sampled and stored in the memory module 270 during the calibration procedure. The difference angles calculated are **translated into screen coordinates** and the target device is instructed to move the pointer to the new location.” (Ex. 1005, ¶0030)(Emphasis

added).

142. As discussed above in paragraphs ¶¶94–105, 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 Zhang’s 3D pointing device. 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.

143. In combining Zhang 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 [10e]), 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 the motion of Zhang’s display pointer more smoothly and consistently in response to rotation of the 3D pointing device.

***“[10h] 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.”***

144. 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).

145. Euler angles and quaternions were both well-known in the relevant timeframe. 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, as described above in ¶32. Such a

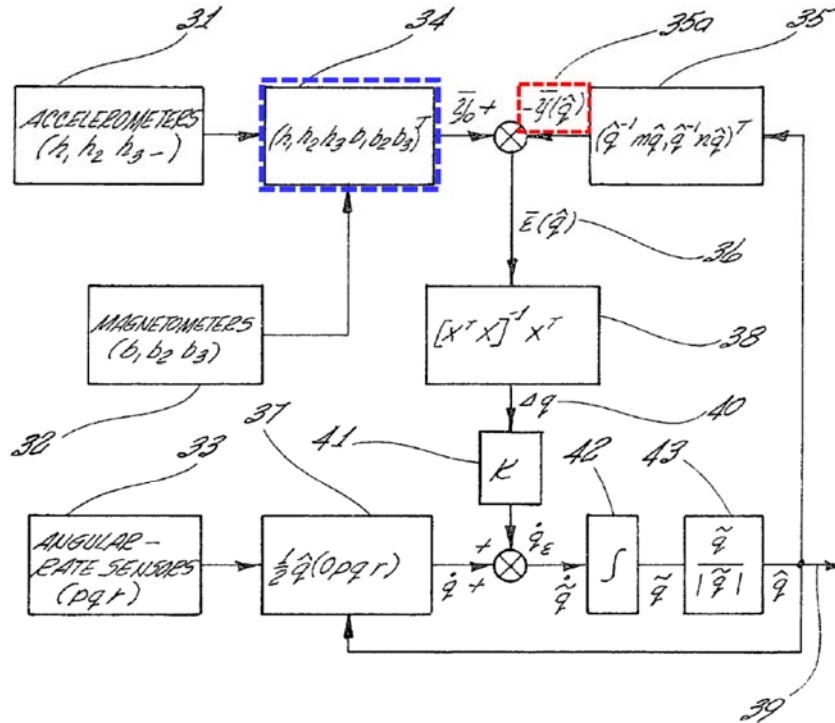
transformation would also have been obvious because Zhang uses Euler angles. Specifically, Zhang uses the rotation sensor 120 to determine yaw and pitch and expressly suggests determining the roll angle:

“The sensor 120 detects the device’s **yaw** (azimuth) angle and sensor 130 detects device’s **pitch** (inclination) angle. Additional sensors (not show in the picture) could be used to detect device’s **roll** angle which may provide an additional dimension of control. A microcontroller 110 provides computation power for calculating and encoding the orientation signal output from the orientation sensors.” (Ex. 1005, ¶0025)(Emphasis added).

Because Zhang’s output is in Euler angles, and because Bachmann outputs a quaternion equivalent to Euler angles, it would have been obvious to calculate Euler angles from Bachmann’s orientation output  $\hat{q}$  to meet Zhang’s output requirements. Again, this would have the added benefit of making the orientation output easier to grasp by human users. Thus, these Euler angles represent **a resultant deviation including a plurality of deviation angles**.

146. 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  $M_x'$ ,  $M_y'$  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]  $\mathbf{M}_x'$ ,  $\mathbf{M}_y'$  and  $\mathbf{M}_z'$  in the form of a predicted measurement vector  $\bar{\mathbf{y}}(\hat{\mathbf{q}})$ . (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  $\bar{\mathbf{y}}(\hat{\mathbf{q}})$  in a red box:



147. Bachmann states that  $\bar{\mathbf{y}}(\hat{\mathbf{q}})$  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**  $\bar{\mathbf{y}}(\hat{\mathbf{q}})$  35a, wherein:  $\mathbf{y}(\hat{\mathbf{q}}) = [h_1 \ h_2 \ h_3 \ b_1 \ b_2 \ b_3]^T$  (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).

148. 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).

149. 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  $\hat{q}$ ).

“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).

150. 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  $M_x'$ ,  $M_y'$  and  $M_z'$  for the second signal set.**

## **2. Claim 12**

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

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

## **XII. CLAIMS 10 AND 12 WOULD HAVE BEEN OBVIOUS OVER LIBERTY AND BACHMANN**

### **A. Summary of Opinion**

152. I am also of the opinion that claims 10 and 12 would have been obvious over Liberty in view of Bachmann.

153. I addressed the level of ordinary skill in the art at the relevant timeframe in ¶¶24 and 25 above. The scope and content of the prior art, and the differences between the prior art and the claims, are discussed below. I am not aware of any

secondary considerations that would make the claims less obvious.

## **B. Overview of the Obviousness Determination**

154. Claims 10 and 12 are unpatentable over Liberty in view of Bachmann. In my opinion, it would have been obvious to combine *Liberty's 3D pointing device* together with *Bachmann's extra sensors and rotation compensation*.

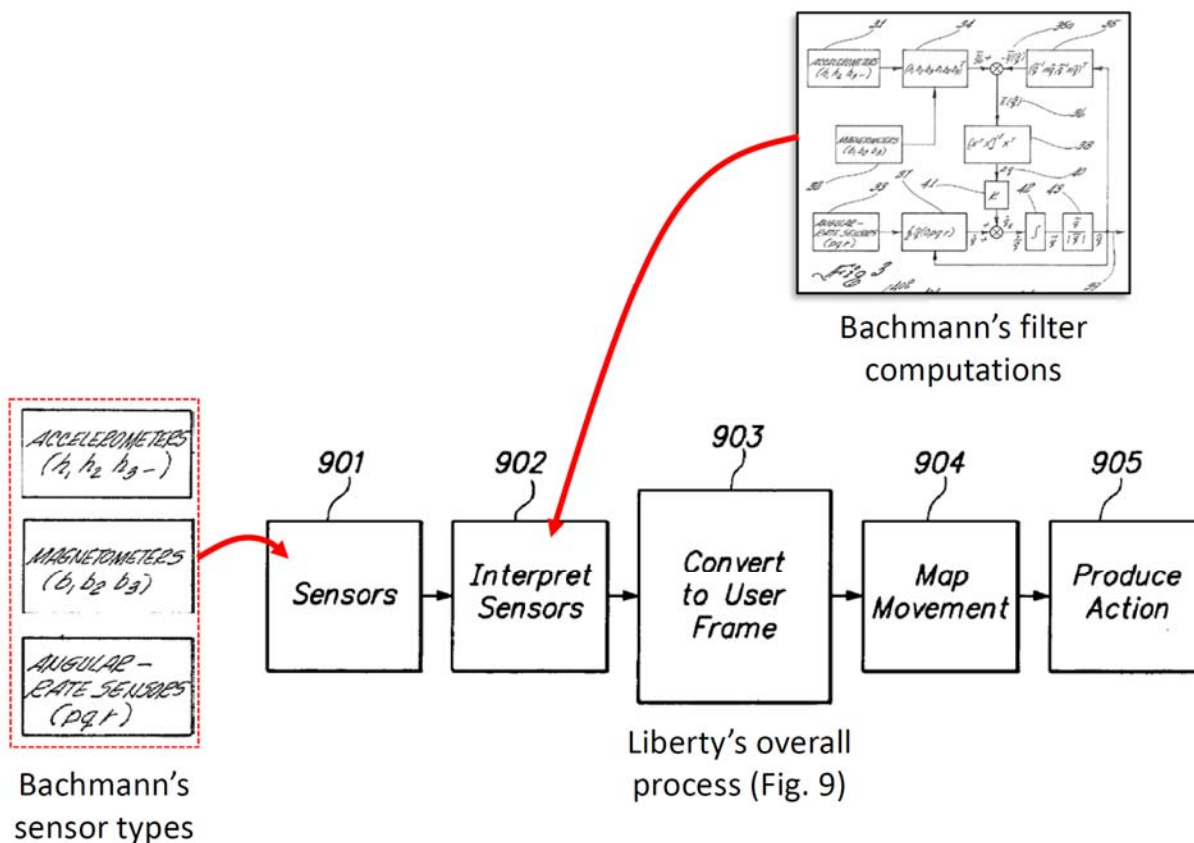
### **1. Combining Liberty and Bachmann**

155. Liberty discloses a 3D pointing device that measures its rotation and acceleration. Liberty further discloses using those measurements to determine the device's orientation in a device reference frame and to translate the device's orientation into a display reference frame. Liberty suggests but does not explicitly disclose a nine-axis sensor system.

156. Bachmann discloses a nine-axis sensor system that combines a three-axis accelerometer with a three-axis magnetometer and a three-axis angular velocity sensor. Bachmann also discloses a quaternion-based attitude estimation filter that produces an orientation estimate of a tracked object, such as a handheld device like Liberty's 3D pointing device. Bachmann's filter is discussed above in ¶¶64–74.

157. It would have been obvious to modify Liberty's 3D pointing device to use a nine-axis sensor module and quaternion-based filter processing as taught by Bachmann. The combination would use Liberty's 3D pointing device (modified to include additional sensors), together with Bachmann's filter process to calculate a

device orientation in the device coordinate frame. The device orientation is translated to a display reference frame, as disclosed in both Liberty and Bachmann. This combination is shown in the following Figure, which was created by Petitioner from Liberty's FIG. 9 and Bachmann's FIG. 3:



158. Bachmann's sensors are used, while Bachmann's filter calculations are added to help interpret the sensor output. The output is then converted to display coordinates per Liberty's disclosure.

## 2. Rationale for the Combination

159. It would have been obvious to a person of skill in the relevant timeframe to use Liberty's 3D pointing device with Bachmann's sensors and filter calculations.

As discussed above in ¶88, Liberty states that the 3D pointing device can include magnetometers, angular rate sensors, and gravity sensors like those in Bachmann. (Ex. 1006, 16:38-44, 18:29-33, 19:62-20:12). Thus, it would have made sense to add Bachmann's sensors to Liberty's 3D pointing device in response to Liberty's express suggestion.

160. Furthermore, a person of ordinary skill would have understood that additional sensors, and additional types of sensors, would have yielded the benefits discussed above with respect to Ground 1: (1) the ability to detect different modes of movement and (2) better error and noise control. (¶¶94–105, *above*).

161. Bachmann's nine-axis sensors were also well-known in the art in the relevant timeframe and could have been used in hand-held devices like Liberty's 3D pointing device. (¶¶94–105, *above*).

162. In using the MARG sensors suggested by Liberty and disclosed by Bachmann, it would have been obvious to use Bachmann's quaternion-based filter techniques because those filter techniques were adapted directly to MARG sensors. (Ex. 1004, 7:18-45)(¶¶94–105, *above*). A person of ordinary skill in the art would have been motivated to use Bachmann's filter techniques in part because they are computationally more efficient and avoid singularities that plague other techniques. (Ex. 1004, 5:33-7:31).

163. Thus, a person of ordinary skill would have used Bachmann's improved

quaternion-based filter (as illustrated in FIG. 3, e.g.) with the sensors for which it was designed, based on Bachmann's express recommendation.

164. Moreover, a person of ordinary skill in the art would have recognized that this combination of Liberty and Bachmann was nothing more than the combination of known elements using known methods to achieve predictable results. This observation applies to both the hardware (using Bachmann's nine-axis sensor module in Liberty's 3D pointing device) and the software (using Bachmann's processing with Liberty's 3D pointing device). Examples of the relevant components had been available for years before the '978 patent's filing date and could have implemented easily to improve the performance of Liberty's 3D pointing device. This is the same situation as the combination of Zhang and Bachmann discussed above. (¶¶106–110, *above*).

165. Finally, it would have been obvious to use the orientation calculated by Bachmann's filter to calculate coordinates that can be used on a display device. Again, the reasons discussed above with respect to Zhang and Bachmann apply here too. (¶¶106–110, *above*).

166. In addition, Liberty's 3D pointing device is used to translate human movements while holding the pointer into movements of a cursor. For example, Liberty states:

“[E]xemplary embodiments of the present invention process

movement data received from sensor(s) in the 3D pointing device to convert this data from the frame of reference of the 3D pointing device's body into another frame of reference, e.g., the user's frame of reference. In the exemplary application of a 3D pointing device used to control a user interface displayed on a screen, e.g., a television, the user's frame of reference might be a coordinate system associated with the television screen.” (Ex. 1006, 16:21-29).

167. To do this, Liberty's system translates the device orientation from a device reference frame to a display reference frame as explained above. (Ex. 1006, 16:21-19:22) (§85, *above*). Liberty discloses transforming all three dimensions of translational and rotational motion using any of a variety of reference frames and mappings between reference frames:

“[T]ransformations according to the present invention can be performed to transform the sensed motion in **all three dimensions**, for **translational motion and rotational motion** or any subset thereof, from the perspective of either the input side of the motion equation or the output side. Additionally, **the selection of the frame of reference into which the sensed motion is mapped or transformed can be made in a number of different ways**. One example provided above shows the second frame of reference being a user's frame of reference associated with **the tilt of the device**, however **many other variations are possible**. (Ex. 1006, 19:31-41)(Emphasis added)(*see also* 19:23-20:12).

168. Liberty further notes that the reference frame transformations can be combined with other data for mapping motion of a handheld device from one reference frame to another:

“[I]t will be appreciated that the present invention describes various techniques for mapping sensed motion of a handheld device from one frame of reference (e.g., a body frame of reference) to another frame of reference (e.g., a user's frame of reference). **These mappings can be independent from other mappings associated with the use of the handheld device, e.g., the mapping of sensed motion to cursor movement or can be combined therewith.**” (Ex. 1006, 23:31)(Emphasis added).

169. Bachmann also discloses mapping the orientation of a tracked object from a device reference frame to a display reference frame. (Ex. 1004, 4:26-28, 13:64-14:29, FIG. 4)(¶¶104 and 105, *above*). Thus, Liberty and Bachmann each discloses the translating device orientation from the device reference frame to a display device reference frame.

### **3. Ability to Implement and Reasonable Expectation of Success**

170. A person of skill in the art in the relevant timeframe would have been able to implement the combination and would have had a reasonable expectation of success. The discussion about implementation and expectations of success under Ground 1 is equally applicable here. (¶¶106–110, *above*).

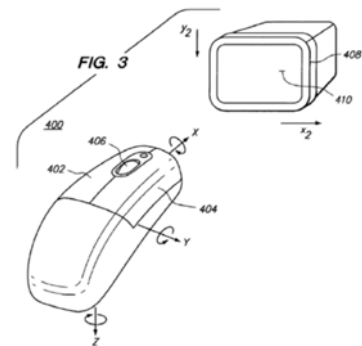
### C. How the Combination Meets the Elements of the Claims

171. I show how the combination of Liberty and Bachmann meets the elements of claims 10 and 12 in the following paragraphs. The relevant claim language appears in bold-italic font, and the mapping in the text that follows each claim element. In claim 10, lettering has been added to each element (e.g., [10b]) for clarity. This claim mapping section augments and should be read with the preceding remarks.

#### 1. *Claim 10*

***“10[a]. A method for compensating rotations of a 3D pointing device, comprising:”***

172. As discussed above, Liberty discloses a **3D pointing device**. (Ex. 1006, Title, Abstract). Liberty’s FIG. 3, reproduced at right, shows an example 3D pointing device 400. (Ex. 1006, 7:19-31).



173. Liberty states:

“The present invention relates generally to handheld, pointing devices and, more specifically to three-dimensional (hereinafter **“3D”**) **pointing devices** and techniques for tilt compensation and improved usability associated therewith.” (Ex. 1006, 1:31-34).

174. Liberty’s 3D pointing device is a **“3D pointing device”** because it can be moved in a user’s hand along three dimensions, e.g., forward and backward, up

and down, and left and right. (Ex. 1006, 4:48-55, 3:51-65). As discussed above, it would have been obvious to use Liberty with three-axis angular rate, axial acceleration and magnetism sensors to improve the determination of orientation in **three-dimensional** space. (¶¶157, 160, and 161, *above*).

175. The combination of Liberty and Bachmann yields a **method of compensating rotations** of the device, as described in steps [10b]-[10h], below.

***“[10b] 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;”***

176. The combination of Liberty and Bachmann uses Bachmann’s attitude estimation filter to generate an orientation quaternion. (¶¶64–74, *above*). This is performed in the same manner described for Bachmann in Ground 1, claim element [10b], starting at ¶115 *above*.

***“[10c] generating a first signal set comprising axial accelerations associated with movements and rotations of the 3D pointing device in the spatial reference frame;”***

177. The combination of Liberty and Bachmann would generate a first signal set comprising axial accelerations associated with movements and rotations of the 3D pointing device in the spatial reference frame. The discussion under Ground 1, element [10c] is equally applicable here. (¶¶123–127, *above*).

***“[10d] generating a second signal set associated with Earth's magnetism;”***

178. The combination of Liberty and Bachmann would generate a second signal set associated with Earth's magnetism. The discussion under Ground 1, element [10d] is equally applicable here. (¶¶128 and 129).

***“[10e] 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;”***

179. The combination of Liberty and Bachmann would generate the orientation output based on the first signal set, the second signal set and the rotation output or based on the first signal set and the second signal set. The discussion under Ground 1, element [10e] is equally applicable here. (¶¶130–136, *above*).

***“[10f] generating a rotation output associated with a rotation of the 3D pointing device associated with three coordinate axes of a spatial reference frame associated with the 3D pointing device;”***

180. The combination of Liberty and Bachmann would generate a rotation output associated with a rotation of the 3D pointing device associated with three coordinate axes of a spatial reference frame associated with the 3D pointing device. The discussion under Ground 1, element [10f] is equally applicable here. (¶¶137–139, *above*).

***“[10g] and using the orientation output and the rotation output to generate a transformed output associated with a fixed reference frame associated with a display device, wherein the orientation output and the rotation output is generated by a nine-axis motion sensor module;”***

181. As discussed above under limitations [10e] and [10f], Bachmann generates an **orientation output**  $\hat{q}$  and a **rotation output** (p, q, r) with a **nine-axis motion sensor module**. And as discussed above beginning with ¶¶155–169, it would have been obvious to generate a **transformed output associated with a fixed reference frame associated with a display device** from the orientation and rotation outputs. Bachmann suggests translating the orientation output to a display reference frame (e.g., in connection with FIG. 4). And Liberty discloses a similar translation:

“[E]xemplary embodiments of the present invention process movement data received from sensor(s) in the 3D pointing device to **convert this data from the frame of reference of the 3D pointing device’s body into another frame of reference, e.g., the user’s frame of reference**. In the exemplary application of a 3D pointing device used to control a user interface displayed on a screen, e.g., a television, **the user’s frame of reference might be a coordinate system associated with the television screen.**” (Ex. 1006, 16:21-29)(Emphasis added).

182. Per ¶¶159–169, *above*, it would have been obvious to **use the orientation output and the rotation output for this transformation**. In the

combination, the orientation output  $\hat{q}$  tracks the orientation of Liberty's 3D pointing device. To transform the orientation output into screen coordinates, a person of ordinary skill would have found it obvious to use the available estimate of orientation ("tilt" in Liberty's language)—i.e., Bachmann's **orientation quaternion**  $\hat{q}$ . Liberty discloses a similar quaternion: "Q is the normalized quaternion that represent the rotation from the body frame to the user frame." (Ex. 1006, 17:36-37). Given the use of quaternions for similar transformations in Bachmann and Liberty, coupled with Liberty's suggestion of alternative transformation techniques, using Bachmann's orientation quaternion would be obvious.

183. The combination of Liberty and Bachmann would also **use the rotation output** in the transformation in two ways as discussed above in ¶143.

*"[10h] 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."*

184. It would have been obvious to obtain **a resultant deviation including a plurality of deviation angles** from the orientation output  $\hat{q}$  of Bachmann. The orientation output  $\hat{q}$  is in quaternion form, which is an alternate representation of orientation using Euler angles (deviation angles). As Liberty states:

**"Q is the normalized rotation quaternion** that represents the rotation from the body frame to the user frame. Since the rotation quaternion to rotate from the user frame to the body

frame is  $Q^*$ , we could replace  $Q$  with  $R^*$  where  $R$  is the rotation from the user frame to the body frame. **Note that  $Q$  can be represented in a number of equivalent forms including Euler angles** and the direction cosine matrix (DCM), and the above equations may vary slightly in their equivalent forms based upon different representations of  $Q$ .” (Ex. 1006, 17:37-44)(Emphasis added)(*see also* Ex. 1006, 16:54-56).

185. While Bachmann uses quaternion for computational advantage, once the computations of the filter process were complete, it would have been obvious to convert the orientation output quaternion,  $\hat{q}$ , to Euler angles as explained above in ¶¶144–150.

## **2. Claim 12**

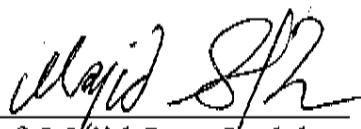
***“12. The method of claim 10, wherein the orientation output is a rotation matrix, a quaternion, a rotation vector, or comprises three orientation angles.”***

186. The combination of Liberty and Bachmann would generate an orientation output in the form of a quaternion. The discussion under Ground 1, claim 12 applies here too.

### **XIII. OATH**

187. 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: June 13, 2018

Signed:   
Prof. Majid Sarrafzadeh