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Declarations under Rule 4.17:

- as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))
- as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))
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[Continued on next page]

(54) Title: 3D INPUT DETECTION BY USING ANGLES OF JOINTS

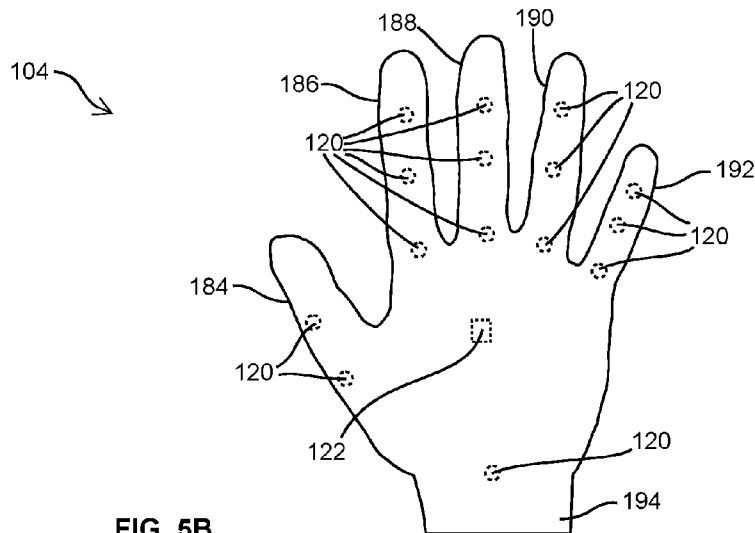
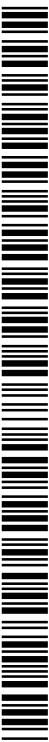


FIG. 5B

(57) Abstract: A 3D input system and an angle encoder are disclosed. The 3D input system comprises a computing device and one or more position sensing gloves. The position sensing glove comprises a plurality of angle encoders each installed thereon at a location about a finger joint. An inertial measurement unit (IMU) is installed on the glove. A firmware uses data from the angle encoders and IMU to calculate fingertip positions in a 3D space. The firmware generates keystrokes on a virtual keyboard based on the fingertip positions. The angle encoder comprises a first and a second components rotatable with respect to each other, and an encoder pattern comprising codewords for indicating the angle between the first and second components. The encoder pattern comprises a set of base encoder channels coded with a conventional Gray code, and a set of Booster channels for improving the resolution of angle measurement.



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AMENDED CLAIMS

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1 **WHAT IS CLAIMED IS:**

2 1. A position sensing apparatus for a hand, comprising:
3 a plurality of first sensors positioned about joints of a wrist and one or
4 more fingers of the hand, said sensors detecting the angles of the respective joints;
5 a controller coupled to the first sensors and receiving angle detection
6 data output therefrom; and
7 a communication interface coupled to the controller.

8
9 2. The apparatus of claim 1 further comprising:
10 a supportive substrate for attaching said device to the hand.

11
12 3. The apparatus of claim 1 further comprising:
13 a computing device communicating with the controller via the
14 communication interface.

15
16 4. The apparatus of claim 3 wherein the apparatus executes
17 computer-executable code for
18 calculating the fingertip positions of at least one of the one or more
19 fingers in a three-dimensional (3D) space using the angles detected by the first
20 sensors; and
21 generating one or more commands based on the calculated fingertip
22 positions in the 3D space.

23

1 5. The apparatus of claim 4 wherein the one or more commands
2 include one or more gestures.

3

4 6. The apparatus of claim 4 wherein the apparatus further
5 executes computer-executable code for generating a virtual keyboard, and wherein
6 the one or more commands include one or more keystrokes of the virtual keyboard.

7

8 7. The apparatus of claim 4 wherein the controller executes the
9 computer-executable code for calculating the fingertip positions of at least one of
10 the one or more fingers in the 3D space, wherein the communication interface
11 transmits the calculated fingertip positions in the 3D space to the computing device,
12 and wherein the computing device executes the computer-executable code for
13 generating one or more commands based on the calculated fingertip positions.

14

15 8. The apparatus of claim 4 wherein the controller executes the
16 computer-executable code for calculating the fingertip positions of the at least one
17 of the one or more fingers in the 3D space and the computer-executable code for
18 generating one or more commands based on the calculated fingertip positions in the
19 3D space, and wherein the communication interface transmits the generated one or
20 more commands to the computing device.

21

1 9. The apparatus of claim 6 wherein the apparatus further
2 executes computer-executable code for
3 detecting at least one of the fingertips hitting a key of the virtual
4 keyboard.

5

6 10. The apparatus of claim 9 wherein the computer-executable
7 code for detecting at least one of the fingertips hitting a key of the virtual keyboard
8 comprise computer-executable code for
9 detecting at least one of the fingertips hitting a key of the virtual
10 keyboard using a statistic estimation method.

11

12 11. The apparatus of claim 10 wherein the statistic estimation
13 method is a Neyman Pearson (NP) detection method.

14

15 12. The apparatus of claim 11 wherein the computer-executable
16 code for detecting at least one of the fingertips hitting a key of the virtual keyboard
17 further comprise computer-executable code for

18 a calibration process for determining parameters of a probability space
19 of a hypothesis of “fingertip not hitting any key” and a probability space of a
20 hypothesis of “fingertip hitting a key”; and

21 calculation of a key-pressing threshold for determining the at least one
22 of the one or more fingertips hitting a key of the virtual keyboard.

23

1 13. The apparatus of claim 12 wherein the key-pressing threshold
2 is a key-pressing velocity threshold, and wherein the computer-executable code for
3 detecting the at least one of the one or more fingertips hitting a key of the virtual
4 keyboard further comprises computer-executable code for

5 calculating the fingertip velocity of the at least one of the one or more
6 fingertips; and

7 determining the at least one of the one or more fingertips hitting a key
8 if the calculated fingertip velocity is higher than the key-pressing velocity threshold.

9

10 14. The apparatus of claim 10 wherein the statistic estimation
11 method comprises a Bayesian Filter.

12

13 15. The apparatus of claim 14 wherein the Bayesian Filter is a
14 Kalman Filter or Particle Filter.

15

16 16. The apparatus of claim 3 further comprising:

17 at least one second sensor for detecting the position of the hand in the
18 3D space.

19

20 17. The apparatus of claim 16 wherein the at least one second
21 sensor comprise at least one inertial measurement unit (IMU).

22

1 18. The apparatus of claim 16 wherein the at least one second
2 sensor comprise at least one of a magnetometer and a barometer.

3

4 19. The apparatus of claim 3 further comprising:

5 at least one sensor for measuring the Time of Arrival of a wireless
6 signal for detecting the position of the hand in the 3D space.

7

8 20. The apparatus of claim 16 wherein the apparatus executes
9 computer-executable code for

10 calculating the fingertip positions of at least one of the one or more
11 fingers in a 3D space using the angles detected by the first sensors and output of
12 the at least one second sensor; and

13 generating one or more commands based on the calculated fingertip
14 positions in the 3D space.

15

16 21. The apparatus of claim 6 wherein the virtual keyboard is
17 divided into a plurality of zones, and the apparatus further executes computer-
18 executable code for

19 detecting the zone of the virtual keyboard that the hand is therewithin;

20 calculating a corrective vector; and

21 revising the position of the hand within said zone using the corrective
22 vector for compensating for position drift of the hand.

23

1 22. A method of detecting the fingertip positions of one or more
2 fingers of a hand in a 3D space, comprising:

3 detecting the angles of the joints of the one or more fingers of the
4 hand and the angle of the joint of a wrist of the hand in the 3D space using one or
5 more first sensors; and

6 calculating the fingertip positions in the 3D space using the detected
7 angles of the joints of the one or more fingers and the angle of the joint of the wrist.

8

9 23. The method of claim 22 further comprising:

10 attaching the one or more first sensors to a person's hand using a
11 supportive substrate.

12

13 24. The method of claim 22 further comprising:

14 transmitting the calculated fingertip positions to a computing device.

15

16 25. The method of claim 22 further comprising:

17 generating one or more commands based on the calculated fingertip
18 positions in the 3D space.

19

20 26. The method of claim 25 further comprising:

21 transmitting the one or more commands to a computing device.

22

1 27. The method of claim 22 further comprising:
2 generating one or more gestures based on the calculated fingertip
3 positions in the 3D space.

4

5 28. The method of claim 22 further comprising:
6 generating a virtual keyboard; and
7 generating one or more keystrokes of the virtual keyboard based on
8 the calculated fingertip positions in the 3D space.

9

10 29. The method of claim 28 further comprising:
11 detecting at least one of the fingertips hitting a key of the virtual
12 keyboard.

13

14 30. The method of claim 28 further comprising:
15 detecting at least one of the fingertips hitting a key of the virtual
16 keyboard using a statistic estimation method.

17

18 31. The method of claim 28 further comprising:
19 detecting at least one of the fingertips hitting a key of the virtual
20 keyboard using a Neyman Pearson (NP) detection method.

21

1 32. The method of claim 31 wherein said detecting at least one of
2 the fingertips hitting a key of the virtual keyboard comprises:

3 determining parameters of a probability space of a hypothesis of
4 “fingertip not hitting any key” and a probability space of a hypothesis of “fingertip
5 hitting a key”; and

6 calculating a key-pressing threshold for determining the at least one of
7 the one or more fingertips hitting a key of the virtual keyboard.

8

9 33. The method of claim 32 wherein the key-pressing threshold is a
10 key-pressing velocity threshold, and wherein detecting the at least one of the one or
11 more fingertips hitting a key of the virtual keyboard further comprises:

12 calculating the fingertip velocity of the at least one of the one or more
13 fingertips; and

14 determining the at least one of the one or more fingertips hitting a key
15 if the calculated fingertip velocity is higher than the key-pressing velocity threshold.

16

17 34. The method of claim 28 further comprising:

18 detecting at least one of the fingertips hitting a key of the virtual
19 keyboard using a Bayesian Filter.

20

21 35. The method of claim 28 further comprising:

22 detecting at least one of the fingertips hitting a key of the virtual
23 keyboard using a Kalman Filter or Particle Filter.

1

2

36. The method of claim 22 further comprising:

3

detecting the hand position in the 3D spacing using at least one

4

second sensor; and wherein calculating the fingertip positions comprises:

5

calculating the fingertip positions in the 3D space using the detected

6

angles of the joints of the one or more fingers, the angle of the joint of the wrist and

7

the detected hand position.

8

9

37. The method of claim 36 wherein detecting the hand position in

the 3D spacing using at least one second sensor comprises:

11

detecting the hand position in the 3D spacing using at least one IMU.

12

13

38. The method of claim 36 wherein detecting the hand position in

the 3D spacing using at least one second sensor comprises:

15

detecting the hand position in the 3D spacing using at least one of a

16

magnetometer and a barometer.

17

18

39. The method of claim 36 wherein detecting the hand position in

the 3D spacing using at least one second sensor comprises:

20

detecting the hand position in the 3D spacing using at least one

21

sensor for measuring the Time of Arrival of a wireless signal

22

1 40. One or more non-transitory, computer readable media
2 comprising computer-executable code for:

3 receiving the angle measurements of the joints of the one or more
4 fingers of the hand and the angle of the joint of a wrist of the hand in the 3D space
5 from one or more first sensors;

6 calculating the fingertip positions of at least one of the one or more
7 fingers in a 3D space using the angles detected by the first sensors; and

8 generating one or more commands based on the calculated fingertip
9 positions in the 3D space.

10

11 41. The one or more non-transitory, computer readable media of
12 claim 40 wherein the one or more commands include one or more gestures.

13

14 42. The one or more non-transitory, computer readable media of
15 claim 40 further comprising computer-executable code for:

16 generating a virtual keyboard; and wherein the one or more
17 commands include one or more keystrokes of the virtual keyboard.

18

19 43. The one or more non-transitory, computer readable media of
20 claim 42 further comprising computer-executable code for:

21 detecting at least one of the fingertips hitting a key of the virtual
22 keyboard.

23

1 44. The one or more non-transitory, computer readable media of
2 claim 42 further comprising computer-executable code for:

3 detecting at least one of the fingertips hitting a key of the virtual
4 keyboard using a statistic estimation method.

5

6 45. The one or more non-transitory, computer readable media of
7 claim 44 wherein the statistic estimation method is a Neyman Pearson (NP)
8 detection method.

9

10 46. The one or more non-transitory, computer readable media of
11 claim 45 wherein the computer-executable code for detecting at least one of the
12 fingertips hitting a key of the virtual keyboard further comprise computer-executable
13 code for:

14 determining parameters of a probability space of a hypothesis of
15 “fingertip not hitting any key” and a probability space of a hypothesis of “fingertip
16 hitting a key”; and

17 calculating a key-pressing threshold for determining the at least one of
18 the one or more fingertips hitting a key of the virtual keyboard.

19

20 47. The one or more non-transitory, computer readable media of
21 claim 46 wherein the key-pressing threshold is a key-pressing velocity threshold,
22 and wherein the computer-executable code for detecting the at least one of the one

1 or more fingertips hitting a key of the virtual keyboard further comprises computer-
2 executable code for:

3 calculating the fingertip velocity of the at least one of the one or more
4 fingertips; and

5 determining the at least one of the one or more fingertips hitting a key
6 if the calculated fingertip velocity is higher than the key-pressing velocity threshold.

7

8 48. The one or more non-transitory, computer readable media of
9 claim 44 wherein the statistic estimation method comprises a Bayesian Filter.

10

11 49. The one or more non-transitory, computer readable media of
12 claim 45 wherein the Bayesian Filter is a Kalman Filter or Particle Filter.

13

14 50. The one or more non-transitory, computer readable media of
15 claim 40 wherein the computer-executable code for calculating the fingertip
16 positions of at least one of the one or more fingers comprises computer-executable
17 code for:

18 receiving measurements from at least one second sensor for detecting
19 the position of the hand in the 3D space.

20

21 51. The one or more non-transitory, computer readable media of
22 claim 50 wherein the computer executable codes for receiving measurements from

1 at least one second sensor comprises computer executable codes for receiving
2 measurements from at least one IMU.

3

4 52. The one or more non-transitory, computer readable media of
5 claim 50 wherein the computer executable codes for receiving measurements from
6 at least one second sensor comprises computer executable codes for receiving
7 measurements from at least one of a magnetometer and a barometer.

8

9 53. The one or more non-transitory, computer readable media of
10 claim 40 further comprising computer executable codes for:

11 receiving measurements from at least one sensor for measuring the
12 Time of Arrival of a wireless signal for detecting the position of the hand in the 3D
13 space.

14

15 54. The one or more non-transitory, computer readable media of
16 claim 50 further comprising computer-executable code for

17 calculating the fingertip positions of at least one of the one or more
18 fingers in a 3D space using the angles detected by the first sensors and output of
19 the at least one second sensor; and

20 generating one or more commands based on the calculated fingertip
21 positions in the 3D space.

22

1 55. The one or more non-transitory, computer readable media of
2 claim 42 wherein the virtual keyboard is divided into a plurality of zones, and the
3 one or more non-transitory, computer readable media further comprises computer-
4 executable code for
5 detecting the zone of the virtual keyboard that the hand is therewithin;
6 calculating a corrective vector; and
7 revising the position of the hand within said zone using the corrective
8 vector for compensating for position drift of the hand.

9