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IMPROVED DATA INPUT METHOD AND DEVICE

Field of the Invention

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The present invention relates to inertial based pen-like input apparatus especially for but not limited to portable equipment.

Prior Art and its Problem

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To replace the normal input apparatus such as keyboard, mouse, digitized board and so on, a pen-like input apparatus could be used to interface with computational units and human beings. The goal of this apparatus is to record the handwritten information at any writing surface without any special paper or board provided. To achieve this goal, Inertial Measurement Systems have been adopted in such pen-like input apparatus. Such pen-like devices comprise translation and/or rotation movement sensors to monitor pen tip or end movements and convert these into text or drawings, or to record on-screen selections, for example.

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Inertial measurement system based pen-like input apparatus are known for portable terminal instruments. There are two main problems in the detection of pen tip-end movement due to the difference between the actual movement of the tip-end and the sensor measurement because it is almost impossible to locate the inertial sensors at the pen tip-end. The first main problem is how to compensate for the variation of the pen shaft inclination which means the angle between the pen shaft and writing surface. The second main problem is how to compensate for the pen shaft rotation which means the conic rotation of the pen shaft with respect to the tip-end as the origin.

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JP 06067799 discloses a 3D acceleration sensor to sense the orientation and amount of the pen's movement, and then compensate the movement by the pen rotation with a piezoelectric vibration gyroscope. However, it cannot compensate for the effects caused by dynamic inclination (inclination variation during writing operation).

JP 07094716 discloses calculating the orientation and amount of the pen's movement from the polarity and the amplitude respectively transmitted from vibration gyroscopes perpendicularly disclosed to each other. However, this is not suitable for inputting figures and the like as it detects the rotational movements of the wrist and then derives the numeric values of the pen's movement in vector space. It does not contain any acceleration sensor. The movement amount and direction are calculated from the angular change measured by gyroscopes, so it cannot make precise determinations about tip end movement.

JP 070200127 uses two 2D acceleration sensors to sense the orientation and amount of the pen's 3D movement. However, it does not compensate any effects caused by dynamic inclination and rotation.

JP 060230886 uses a couple of acceleration sensors on different positions of the pen shaft to sense the orientation and amount of the pen's tip-end movement. However, the measurement of these accelerations could not result in the status of pen's rotation.

US Patent 6,229,102 discloses a pen-shaped handwriting input apparatus using both accelerometers and gyroscopes. The main structure of this system includes two types of sensors: 3 Acceleration sensors detect the accelerations in the X, Y and Z-axis and 3 Gyroscopes respectively detect the angular velocity around the X, Y and Z-axis. The two main compensation problems mentioned above

can be resolved in this system since the three-dimensional accelerometer and gyroscope produce all six parameters, i.e. translations in XYZ-axes and rotations around XYZ-axes, that are sufficient to precisely express the motion of the pen shaft mathematically at any time. However, the size of the pen using such a system is large because of the use of a number of gyroscopes inside the pen, gyroscopes being relatively large. This results in a large pen-like input apparatus which is not always appropriate or desirable for use with portable equipment.

Summary of Invention

The present invention aims to provide an improved pen-based input apparatus and method.

In general terms the present invention provides an inertial measurement based input device having a writing end and comprising at least three movement sensors located within the device such that it is possible to derive from their outputs the movement, including rotational movement, of the writing end. The writing end is arranged to indicate contact with a surface. For a pen-like device, the sensors are located to define a plane or 3D co-ordinate system. This allows the device to provide both rotation information about the longitudinal axis and rotation information about a transverse axis of the pen; in addition to lateral movements of the pen in 3D space. The determined writing end movements in this 3D space are then converted into a preferably gravity based co-ordinate system. Combined with the surface contact information, it is then possible to derive characters and other data to be entered using said device.

In particular, in one aspect the present invention provides an input apparatus for a pen shaped handwriting instrument having a writing end; the apparatus comprising:

5 a number of translation movement detection means for determining movement of said apparatus at a number of locations about said apparatus;

wherein the movement detection means are arranged such that all translation and rotation movements of said apparatus in a 3D co-ordinate system can be determined;

10 surface contact determining means located at said writing end.

The movement sensors are preferably accelerometers, however other movement sensors could alternatively be used. Preferably three 3D accelerometers are used which can provide translations and rotations in XYZ-axes. However a combination of 2D and 3D accelerometers
15 could alternatively be used as the acceleration along the pen-shaft axis is the same. Further, 1D accelerometers could be distributed about the device so long as all movements (lateral and rotational) of the device in 3D space or a co-ordinate system can be determined from their
20 outputs. Rotational movements being determined by the difference in the acceleration detected by two detectors detected in the same (or opposite) direction. Preferably however, the accelerometers are accumulated into 3D accelerometers located at 3 points defining a plane in a 3d co-ordinate system.

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In another aspect the present invention provides a calculation apparatus for determining 3D movement of a pen shaped handwriting instrument having a number of translation movement detection means located about the instrument; the calculation apparatus comprising:

means for receiving the outputs of said translation detection means;

means for determining translation and rotation movements of said instrument in a 3D co-ordinate system;

5 means for converting said detected movements from said coordinate system into a co-ordinate system independent of the orientation of said instrument.

10 **Brief Description of the Drawings**

The invention will now be described in detail with reference to the following drawings, by way of example only and without intending to be limiting, in which:

Figure 1 shows a prior art input pen device;

15 Figure 2 illustrates the movements a pen-like input device is subject to;

Figure 3 shows a pen-like input device according to an embodiment of the invention;

20 Figure 4 presents the translation relationship between a pen-shaft coordinate system and a gravity coordinate system for the device of Figure 3;

Figure 5 presents the translation relationship between pen-shaft coordinate system and gravity coordinate system in an initial stationary state.

25 Figure 6 shows the pen-coordinate system tracking process.

Figure 7 is a flow diagram of the calculation method of the embodiment; and

Figure 8 shows an enhanced embodiment input device.

5 **Detailed Description of Invention**

Referring to Figure 1, a prior art pen-like input device 2 is shown in contact with a writing surface 1. The input device 2 employs a 2D acceleration sensor 3 which detects acceleration in the XZ plane of the writing surface 1. The writing device 2 also includes a gyroscopic sensor 4 which detects rotation R_y in the Y axis. The device 2 also includes a contact sensor 5 which indicates contact with the writing surface 1. Thus it is possible to determine movement of the writing end (5) of the pen-like input device 2 on a writing surface 1, and from this determine an intended input, such as a letter or numerical character, for example. A problem with such a device, however, is that in practice it is not possible to locate the acceleration or force sensors 3 at the writing end or tip of the pen 2 so that in fact the device 2 is not detecting movement in the plane of the writing surface 1, but in a parallel plane. A further problem is that the pen 2 may be angled with respect of axis Y. Furthermore the pen 2 may be lifted between character strokes, and the writing surface 1 may also change orientation, particularly in the case of portable devices such as PDA's.

Figure 2 shows the various translations T and rotations R which the pen device 2 may be subject to in practice. It can be seen that translation movements and rotation movements are possible in any of the three perpendicular axes X, Y and Z.

An embodiment of the present invention is shown in Figure 3 and comprises a pen-like input device 12 having three 3D accelerometers 13a, 13b and 13c. The input device 12 also comprises a pressure sensor or touch switch 15 for detecting contact with a writing surface 11 which may have any orientation in 3D space.

The three 3D sensors are located within the input device 12 such that it is possible to determine the movement of the writing end (15) of the input device 12. This facility in addition to the contact detecting means 15 allows movements of the writing end 15 against the writing surface 11 to be determined and from this handwritten information such as characters as input information associated with the input device 12. In order to track the handwritten information, we need not only the pen tip end movements on the writing surface 11 but also the tip end movements between each character and also between each stroke of the input character.

The accelerometers 13 are arranged such that it is possible to determine translations in the X, Y and Z directions, and also rotations about the X, Y and Z axes. This is achieved by locating the three accelerometers 13a, 13b, 13c such that they are specially displaced from each other into perpendicular axes. Preferably two sensors (13a and 13b) are arranged to form a notional axis (y) in a pen shaft based co-ordinate system PCS, and the other sensor (13c) forms another axis (x) with one of the first sensors (13a or 13b).

Sensor 13c is spaced apart from sensor 13b by distance A in the X axis. Sensor 13a is separated from sensor 13b by $L2-L1$ in the Y axis. Distances L1 and L2 are the distances from respectively sensors 13a and 13b from the writing end 15 of the input device 12. Preferably sensors 13a and 13b are located on the longitudinal axis Y of the input

device 12 in order to simplify calculation. It can be seen that translations in the X, Y and Z directions will be detected evenly by the three sensors 13a, 13b and 13c assuming the input device 12 is not rotated. Rotation in any of these axes can be detected by noting the differences in readings or measurements in the various axes between the three sensors 13a, 13b, 13c. For example a rotation about the Y axis will not register with sensors 13a and 13b, however 13c will register an acceleration as it is rotated about the axis Y. Similarly, a rotation about the X axis will be registered differently by sensors 13a and 13b, and from this difference the pen device 12 rotation can be determined.

Whilst the sensors 13 of the first embodiment have been arranged for optimising calculation complexity, it would of course be possible to locate these three 3D sensors differently, so long as they define a 3D co-ordinate system.

In order for the pen-like input device 12 to operate correctly with a writing surface 11 of any (non-predetermined) orientation, it is necessary to convert the pen-shaft coordinate system PCS into a coordinate system independent of the pen, for example a gravity based coordinate system GCS. Once the measurements of the three sensors 13 have been translated into GCS, then it is possible to determine the input information irrespective of the orientation of the writing surface 11. The only other information that is required is the contact detection information provided by the pressure sensor 15 indicating that the pen is pressed against a writing surface.

Figure 3 shows the X, Y and Z axes of the PCS at each sensor 13 location. The figure 3 also shows the GCS, and Figure 4 shows the relationship between the two at an instant of time (a sampling interval).

It can be seen in Fig. 4 that θ , ϕ , ψ present the translation relation between the PCS and GCS. The θ , ϕ , ψ will change corresponding to the pen rotation movements (pitch, yaw and roll).

5 A method of operating the input device 12 according to the embodiment in order to determine handwritten information is shown schematically in Figure 5. The whole process is divided into five steps. As the pen 12 movements include translation movements and rotation movements, the tracking system not only tracks the pen tip movements but also records the pen-shaft coordinate system translation
10 relationship with the gravity coordinate system.

1. The initial inclination calculation.

As the acceleration sensors 13 can sense not only dynamic acceleration but also static acceleration such as gravity acceleration g , the initial pen 12 inclination is easily calculated based on the gravity
15 acceleration GS factor in each axis of the pen shaft coordinate system when the pen 12 is in static status. In equation 1, G represents the gravity acceleration in GCS. At the initial stage, the GCS X-Y will be pointed to the PCS X-Y plane as shown in Fig. 6. As the two coordinate systems share the same Z direction (the Z direction being
20 re-initialised at each initial stage in the gravity direction), the initial ψ would be 0 and θ would be equal to ϕ):

$$\cos \theta = |GS_x - GS_y| / |G|$$

$$\cos \phi = |GS_x - GS_y| / |G| \quad \text{-----}(1)$$

$$\cos \psi = 0$$

25 Also as the pen 12 is in a stationary state, the velocity and the movements of the pen are:

$$\begin{aligned}
X_{old} &= 0 & V_{X_{old}} &= 0 \\
Y_{old} &= 0 & V_{Y_{old}} &= 0 \\
Z_{old} &= 0 & V_{Z_{old}} &= 0
\end{aligned}
\tag{2}$$

5 2. The tip end acceleration calculation

10 The acceleration sensors 13 determine acceleration values in their own coordinate system (PSC). These values include the pen shaft rotation acceleration and the gravity acceleration g . However, as these values are in pen shaft coordinate system (PCS), we must convert them to gravity coordinate system (GCS).

Vectors are indicated in bold text.

15 For both gravity coordinate system and pen shaft coordinate system, the gravity acceleration $\mathbf{g}$ is constant. And for two sets of sensors (13a and 13b), the tip end movement accelerations are the same both in gravity coordinate system and pen shaft coordinate system as the pen could be regarded as a rigid body so the whole pen parallel movement has the same acceleration vector $\mathbf{a}$. For the rotation movements, it has the same angular acceleration vector $\boldsymbol{\omega}$ including pitch, yaw and roll, so the rotation accelerations are in direct ratio with the distance to the tip end.

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For the sensor 1 (13a) in pen shaft coordinate system, its value is:

$$\mathbf{a}_1 = \mathbf{g} + \mathbf{a} + L_1 \times \boldsymbol{\omega} \tag{3}$$

For the sensor 2 (13b) in pen shaft coordinate system, its value is:

$$\mathbf{a}_2 = \mathbf{g} + \mathbf{a} + L2 \times \omega \quad \text{-----}(4)$$

The difference between the acceleration movements is:

$$5 \quad \mathbf{a}_1 - \mathbf{a}_2 = (L1 - L2) \times \omega \quad \text{-----}(5)$$

and hence the tip end acceleration plus gravity acceleration in PCS is:

$$\mathbf{A} = \mathbf{g} + \mathbf{a} = \mathbf{a}_1 - L1 \times (\mathbf{a}_1 - \mathbf{a}_2) / (L1 - L2) \quad \text{-----}(6)$$

This value is the sum of the gravity acceleration and the tip end acceleration value in pen shaft coordinate system. The acceleration in GCS can be expressed by the following matrix calculation (7), where θ, ϕ, ψ denotes the Xs-Xg, Ys-Yg, Zs-Zg angle between pen shaft coordinate system and gravity coordinate system as shown in Fig. 7:

$$15 \quad \begin{bmatrix} A_{xg} \\ A_{yg} \\ A_{zg} \end{bmatrix} = \begin{bmatrix} \cos\psi\cos\theta & \sin\theta\sin\theta\cos\psi + \cos\theta\sin\psi & \cos\theta\sin\theta\cos\psi + \sin\theta\sin\psi \\ \sin\psi\cos\theta & \sin\theta\sin\theta\sin\psi + \cos\theta\cos\psi & \cos\theta\sin\theta\sin\psi + \sin\theta\cos\psi \\ -\sin\theta & \cos\theta & \sin\theta \end{bmatrix} \begin{bmatrix} A_{xs} \\ A_{ys} \\ A_{zs} \end{bmatrix} \quad \text{-----}(7)$$

As gravity acceleration is constant, we can get the tip end acceleration by the following formula (8):

$$25 \quad \mathbf{a} = \mathbf{A} - \mathbf{g} \quad \text{-----}(8)$$

3. Tip end movements amount and direction and velocity calculation

From the initial stationary point, we can continuously calculate the tip movement amounts and direction by the following formula (9):

$$\begin{aligned}
X_{new} &= X_{old} + 1/2a_{xg} \times t^2 + Vx_{old} & Vx_{new} &= Vx_{old} + a_{xg}xt \\
Y_{new} &= Y_{old} + 1/2a_{yg} \times t^2 + Vy_{old} & Vy_{new} &= Vy_{old} + a_{yg}xt \\
Z_{new} &= Z_{old} + 1/2a_{zg} \times t^2 + Vz_{old} & Vz_{new} &= Vz_{old} + a_{zg}xt
\end{aligned}
\tag{9}$$

4. The PCS and GCS translation relationship θ , ϕ , ψ angle calculation

5 Same as tip end, we can easily get the position of the three sets of sensors S_1 , S_2 and S_3 , then from Fig. 7:

The unit vector XS equals to:

$$X_s = (S_3 - S_2) / ((S_3 - S_2)^2)^{1/2} \tag{10}$$

The unit vector in YS equals to:

$$10 \quad Y_s = -(S_2 - S_1) / ((S_2 - S_1)^2)^{1/2} \tag{11}$$

The unit vector in ZS then equals to:

$$Z_s = Y_s \times X_s \tag{12}$$

Then angles θ , ϕ , ψ are obtained from the following equation (13):

$$\begin{aligned}
\cos \theta_{new} &= Y_y / ((X_y)^2 + (Y_y)^2 + (Z_y)^2)^{1/2} \\
\cos \phi_{new} &= X_x / ((X_x)^2 + (Y_x)^2 + (Z_x)^2)^{1/2} \\
\cos \psi_{new} &= Z_z / ((X_z)^2 + (Y_z)^2 + (Z_z)^2)^{1/2}
\end{aligned}
\tag{13}$$

5. Re-initialise the parameters, then repeat step 2-5 till end of the writing status.

$$\begin{aligned}
X_{old} &= X_{new} & Vx_{old} &= Vx_{new} & \theta_{old} &= \theta_{new} \\
Y_{old} &= Y_{new} & Vy_{old} &= Vy_{new} & \phi_{old} &= \phi_{new}
\end{aligned}
\tag{14}$$

$$Z_{old} = Z_{new} \quad Vz_{old} = Vz_{new} \quad \Psi_{old} = \Psi_{new}$$

Using the above method, the tip end movements can be tracked easily and precisely. During the tracking process, the inertial measurement system (accelerometers 13) measures the accelerations in PCS in three points. The calculation section calculates the tip end movements according to the above method.

The basic input device 12 may be enhanced with various other functional elements such as a communication section to transfer the calculated pen movements and writing strokes against the external surface to another device (not shown) such as a PDA, for example. The input device 12 may also comprise a storage section for storing the input information, and a display section for displaying this. This may be set up to display what is being written or to review previously entered information, for example. In a further alternative, the calculation function may be in a separate electronics device for example a PDA, the measurement outputs from the accelerometers 13 being wirelessly communicated from the pen 12 to the device having the calculation function.

An enhanced structure of the pen device 22 can be seen in Fig. 8 which contains seven sections that are: Writing Status Sensor Section (15), Acceleration Sensors Section (13a, 13b, 13c), Calculation Section (21), Power Supply Section (Battery) (22), Storage Section (23), Display Section (24) and Communication Section (25).

The enhanced embodiment uses the uniquely arranged accelerometers and unique calculation method to track all the pen 22 movements. As discussed above, the input device 22 uses three 3D accelerometers. One 13a is located near the tip-end 15 of the pen 12, another one 13b is around the middle of the pen shaft. Together these

two accelerometers 13a and 13b form an axis (y) in pen-shaft coordinate system (PCS). The third accelerometer 13c is added to form another axis (x) in PCS with the second sensor 13b. The pen-shaft coordinate system hence can be identified. The calculation
5 section 21 calculates the pen movements based on the accelerometers results.

By combining the function of storage section 23, display section 24 and wireless communication section 25, the tracking results can then be stored, loaded, displayed and sent to other computational
10 units.

Instead of requiring some special writing surface as in some prior art systems, the embodiment provides a pen-like input device that needs no pre-designed writing surface. The writing surface could be a table, paper, a wall and even the human body.

15 Instead of using multiple number of gyroscopes which are big, heavy and expensive, the embodiment only uses accelerometers 13 which are much smaller, lighter and cheaper, which makes the whole system small, light and convenient to be used.

By arranging accelerometers according to the invention, all the
20 pen movements including translation (in X-axis, Y-axis, Z-axis) and rotation (pitch, yaw and roll) can be determined.

By introducing display and communication sections into the input apparatus 22, the tracking results can be displayed at any time and can be transferred to other computing devices easily.

CLAIMS

1. An input apparatus for a pen shaped handwriting instrument having a writing end; the apparatus comprising:
a number of translation movement detection means for
5 determining movement of said apparatus at a number of locations about said apparatus;
wherein the movement detection means are arranged such that all translation and rotation movements of said apparatus in a 3D co-ordinate system can be determined;
10 surface contact determining means located at said writing end.
2. An apparatus according to claim 1 wherein the movement detection means are accelerometers.
- 15 3. An apparatus according to claim 1 or 2 wherein said accelerometers are accumulated into 2D and 3D accelerometers located at three points that define a plane within said co-ordinate system.
- 20 4. An apparatus according to claim 3 wherein two of said accumulated accelerometers are arranged to form one axis in said coordinate system, and the third said accumulated movement detection means is arranged to form another axis in said coordinate system with one of the other said accumulated movement detection means.
- 25 5. An apparatus according to any preceding claim further comprising calculation means for determining the movement of said writing end in said 3D co-ordinate system.

6. An apparatus as claimed in any preceding claim further comprising means for converting said detected movements from said coordinate system into a co-ordinate system independent of the orientation of said apparatus.

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7. An apparatus as claimed in claim 6 wherein said independent co-ordinate system is gravity based.

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8. An apparatus according to claim 6 or 7 further comprising calculation means for determining movement of said writing end with respect to said independent co-ordinate system.

9. An apparatus according to claim 8 further comprising calculation means for determining input characters based on said writing end movements and said writing end surface contacts.

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10. A pen shaped handwriting instrument comprising an input apparatus according to any preceding claim.

11. A computer or electronics system having an input apparatus according to any preceding claim.

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12. A calculation apparatus for determining 3D movement of a pen shaped handwriting instrument having a number of translation movement detection means located about the instrument; the calculation apparatus comprising:

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means for receiving the outputs of said translation detection means;

means for determining translation and rotation movements of said instrument in a 3D co-ordinate system;

means for converting said detected movements from said coordinate system into a co-ordinate system independent of the orientation of said instrument.

5 13. An apparatus according to claim 12 further comprising calculation means for determining the movement of a writing end of said instrument in said independent co-ordinate system.

10 14. An apparatus according to claim 13 further comprising calculation means having means for receiving surface contact indications from said writing end and means for determining input characters based on said writing end movements and said writing end surface contacts.

15 15. A method of determining the movement of an input apparatus in a 3D co-ordinate system, the method comprising:

receiving translation movement indications from a sufficient number of locations on said apparatus in order to determine all translation and rotation movements of said apparatus;

20 determining all translation and rotation movements of said apparatus in said co-ordinate system from said translation movement indications;

receiving external surface contact information from a writing end of said input apparatus.

16. A method of determining 3D movement of a pen shaped
handwriting instrument having a number of translation movement
detection means located about the instrument; the calculation
5 apparatus comprising:

determining translation and rotation movements of said
instrument in a 3D co-ordinate system from said translation movement
detection means;

10 converting said detected movements from said coordinate
system into a co-ordinate system independent of the orientation of said
instrument.