The On-line Falling Self-protection system Design

Pan-Chio Tuan[A], Chun Pei[A], Ching-Show Lin [A] *Member, ISG*

[A] *Graduate School of Gerontic Technology and Service management, Nan Kai Institute of Technology, Taiwan, ROC.*

Abstract—Fall and fall-induced disability are very common among the elderly. Usually those elderly who fall-induced fractures can't leave independently and need care assistance. In the past, sensors devices have been provided to detect elderly after fall in motion, and some alarm devices were used to transmit the fall signal to the care unit. However it still hardly to really recognize the true fall situation in advance and do the self-protection during the fall process. In this paper, we propose an algorithm to real time compute the body posture by using the output of a simple MEMS accelerometer as the sensor rather than using Gyro sensors.. We define the Body Posture Angle (BPA) to detect the possible time-varied body posture before fall down. While the time varied BPA has been detected during falling process, we can estimate the time to fall, and trigger a control command to stimulate a self-protection device, such as the air bag, to protect the falling body from injures. Simulation were presented and showed excellent results in this paper.

Key-Words: Fall detection**,** Body Posture Angle, MEMS, Accelerometer, Self-protection.

I INTRODUCTION

It is estimated that the incidence of falls for elder people aged over 75 is about13.6 percent per year in Taiwan [1]. The estimated incidence of falls and recurrent fall for independent people aged over 75 is at least 30 percent and 50 percent per year in USA [2]. Thus, fall detection becomes a major issue to improve the safety of such people. Some researchers use sensor devices and communication technology to provide the opportunity to improve the safety and security. Thomas Riisgaard Hansen et al.[3] set up a detect system which used 3-axis MEMS accelerometer and camera phone to detect and verify the fall of elderly. This 3-axis accelerometer worn by elderly persons detect potential situations where a fall might have occurred. Yilun Luo et al. [4] developed a real time recognition of human body motion which is based on MEMS accelerometer and gyro sensor. As we know, low-cost, small-size MEMS accelerometer has been provided to detect fall in translational motion only, it is still hardly to recognize the true fall situation in time unless the expensive and complicated gyro sensor is used. Padgoankar, A. J et al. [5] Measured a angular acceleration of a rigid body using linear accelerometers. Liu, Y.K. [6] also discussed the Measurement of angular acceleration of a rigid body using linear accelerometers. In this paper, we propose an algorithm using Body Posture Angle (BPA) to predict possible fall via transferring the output of a simple MEMS accelerometer rather than using the complicated and expensive gyroscope as the sensor. For describing fall situations, we define two BPA, one is the pitching angle, and the other is yaw angle illustrated as the Figure 1. Instead of using Gyro-sensors, MEMS accelerometer is used to mount on the subject and detects the subject's body accelerations when the subject loses balance. Since the linear translation measurement from MEMS is not enough to account for the true fall cases, we establish a dynamical algorithm to easily calculate the time- varied BPA only the output of MEMS is used. After the BPA have been detected during falling process, we could design a control command to stimulate a self-protection device, such as the air bag, to protect the falling body from injures.

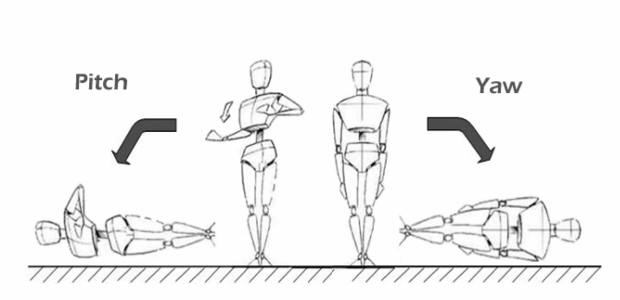

Fig 1 Fall body posture

II The derivation of the BPA

Let's consider MEMS investigate the accelerometer Model is:

$$\vec{f} = \vec{a} - \vec{G} \tag{1}$$

Here, $\vec{f}$ is the specific force and $\vec{a}$ is the acceleration of the body, $\vec{G}$ is the gravity. In this paper, we use two vector coordinate to describe the fall process. One is the body coordination system, the other is the Inertial-coordination system. C_i^b is defined as the transition matrix between two system, then the derivation cosine is [7]：

$$\dot{C}_b^i = C_b^i \left[\vec{\omega}_{ib}^b \times \right] \tag{2}$$

$\vec{\omega}_{ib}{}^b$ is the body angular velocity with respect to the inertial coordinate system. It is assumed that the body is rigid and falling motion is considered as the combination of pitch and yaw. The row motion is neglected. Now, if the initial posture angle is given as the C_0, then after a very short period of time, the body's posture angle can be written as

$$C_n = \Delta C_n \cdot \Delta C_{n-1} \cdots \cdot \Delta C_1 \cdot C_0 \tag{3}$$

Where

$$\Delta C_b^{b'} = \begin{bmatrix} 1 & 0 & -\Delta\theta_y \\ 0 & 1 & \Delta\theta_x \\ \Delta\theta_y & -\Delta\theta_x & 1 \end{bmatrix} \quad (4)$$

Here θ_X and θ_y is the pitch and yaw angle.

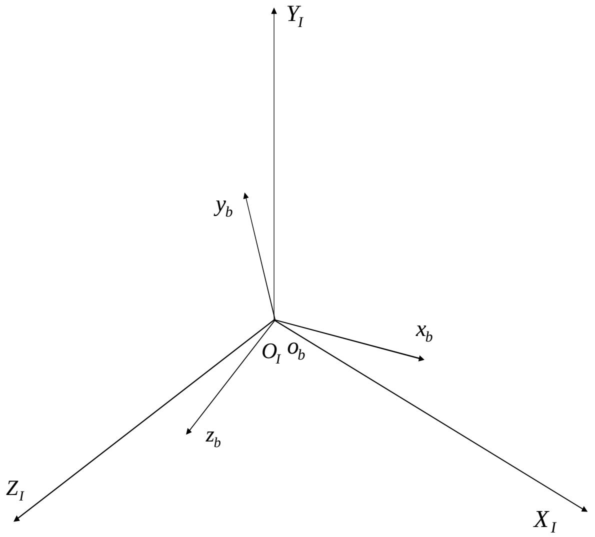

Fig. 2 Body and Initial coordinate System

It is known that $\vec{G}$ causes body fall and induces an angular acceleration $\vec{\alpha}$ which is function of mass m and moment of inertia I of the body.

$$\vec{\alpha}^b = [I]^{-1}\left(\vec{r}^b \times m\vec{G}^b\right) \quad (5)$$

From general dynamical model, we have the following equation related to linear acceleration and angular acceleration:

$$\vec{a}^b = \vec{\alpha}^b \times \vec{r}^b + \vec{\omega}^b \times \vec{\omega}^b \times \vec{r}^b \quad (6)$$

Substituting Eq.(6) to Eq.(1) we obtain the specific force

$$\vec{f}^b = \vec{\alpha}^b \times \vec{r}^b + \vec{\omega}^b \times \vec{\omega}^b \times \vec{r}^b + C_i^b \vec{G}^i \quad (7)$$

If we put the MEMS sensor at the place which makes $r^b \to 0$,then the output of MEMS can be written as [8]

$$\vec{f}^b = C_i^b \vec{G}^i = \begin{bmatrix} S_x \\ S_y \\ S_z \end{bmatrix} \quad (8)$$

Where $\vec{G}^i = \begin{bmatrix} 0 \\ 0 \\ g \end{bmatrix}$ (9)

$$C_i^b = \left[C_b^i\right]^{-1} = \begin{bmatrix} C(x_b,x_i) & C(x_b,y_i) & C(x_b,z_i) \\ C(y_b,x_i) & C(y_b,y_i) & C(y_b,z_i) \\ C(z_b,x_i) & C(z_b,y_i) & C(z_b,z_i) \end{bmatrix} \quad (10)$$

So that the Output of MEMS is

$$\begin{bmatrix} S_x \\ S_y \\ S_z \end{bmatrix} = \begin{bmatrix} C(x_b,z_i) \\ C(y_b,z_i) \\ C(z_b,z_i) \end{bmatrix} \cdot g \quad (11)$$

From Eq.(11) each BPA to the inertial Z axis is:

$$\theta_{x_b z_i} = \cos^{-1}\left(\frac{S_x}{g}\right) \quad (12)$$

$$\theta_{y_b z_i} = \cos^{-1}\left(\frac{S_y}{g}\right) \quad (13)$$

$$\theta_{z_b z_i} = \cos^{-1}\left(\frac{S_z}{g}\right) \quad (14)$$

III Simulation results

It is assumed that a body weighs 70kg, and the initial angular velocity ,angular acceleration are 0 rad/sec. consider MEMS error is within 0.01G.The moment of initial and initial C_0 are assummed as

$$[I] = \begin{bmatrix} 200 & 0 & 0 \\ 0 & 300 & 0 \\ 0 & 0 & 400 \end{bmatrix} \quad (15)$$

$$C_i^b(0) = \begin{bmatrix} 1 & 0 & \frac{5\pi}{180} \\ 0 & 1 & -\frac{5\pi}{180} \\ -\frac{5\pi}{180} & \frac{5\pi}{180} & 1 \end{bmatrix} \quad (16)$$

We try to use the above algorithm to compute the $\theta_{x_b z_i}$, $\theta_{y_b z_i}$ and $\theta_{z_b z_i}$. From Fig.3 to Fig.5, the computation simulation results show the excellent approach to the real angle.

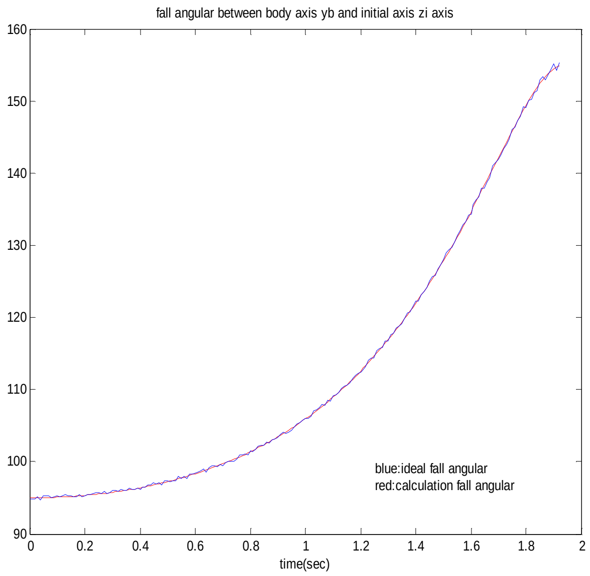

Figure 3 The real and computation $\theta_{x_b z_i}$

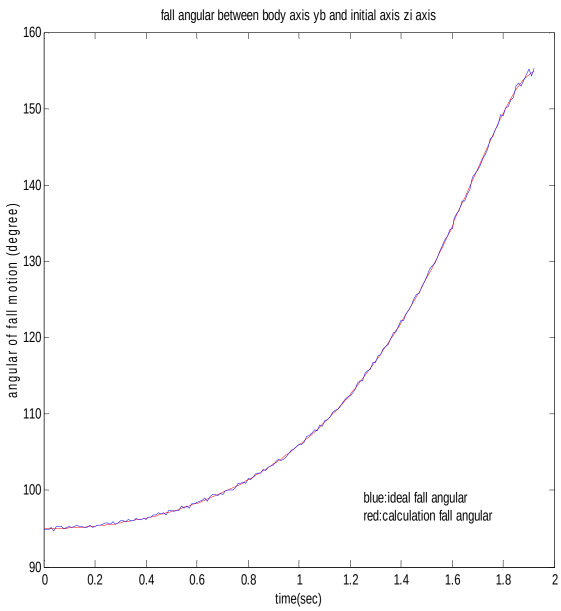

Figure 4 The real and computation θ_{y,Z_i}

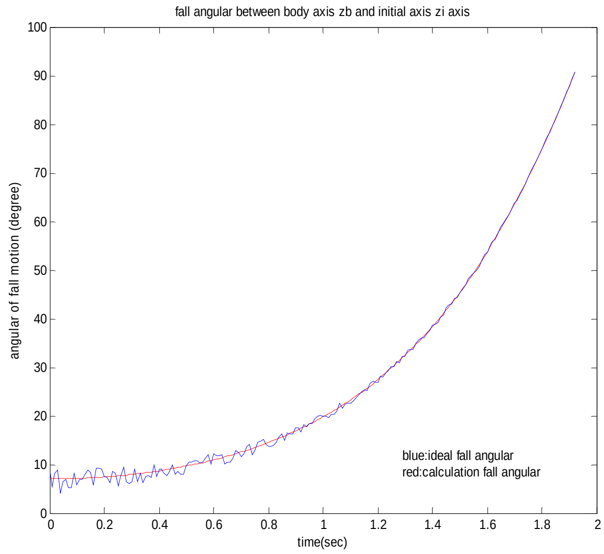

Figure 5 The real and computation θ_{Z,Z_i}

IV CONCLUSION

In this paper, we establish a mathematic model to calculate a body altitude change while it falls. Instead of using expensive Gyroscope to measure the attitude The low cost MEMS accelerometer is used to provide the linear translation output information and the body posture angle can be computed through MEMSE only. Simulation show the excellent estimate results in this paper. When the time varied body posture angle has been detected during falling process, we can estimate the time to fall, and then we could trigger a control command to stimulate a self-protection device, such as the air bag, to protect the falling body from injures.

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