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# FALL DETECTION SYSTEM BASED ON ANGLE CHANGE RATE WITH KINECT SENSOR

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**ABSTRACT** *Falling is one of the most dangerous emergency situations for elderly people who live alone. But how to detect falling effectively is a difficult problem. In recent years, angle feature-based methods are widely used in fall detection. However, the methods based on angle feature easily misjudge leaning, stooping motions as falling. To improve the detection rate, this paper presents a fall detection algorithm based on angle change rate. Firstly, skeleton images are obtained by using Kinect sensor, then the orientation of major axis is derived from skeleton data, and the time of each frame is marked by using the time stamp. Lastly, the angle change rate is calculated. When the angle change rate exceeds the given threshold, it shows that the fall has occurred. Experimental results show that the proposed algorithm has higher detection rate than the algorithm based on angle.*

**KEYWORDS : fall detection, skeleton image, angle change rate, kinect**

## INTRODUCTION

In modern society, with the intensification of aging, more and more elderly people have suffered from potential risk of falling. According to the Centers for Disease Control and Prevention, falling is the leading cause of injury and death for older adults, with one out of three adults 65 years and older falling each year. So it is very important to detect the falling of the elderly people and make them get immediate assistance. Noury et al.[1] have shown that getting help quickly after a fall reduces the risk of death by over 80% and the risk of hospitalization by 26%. Hence, a reliable and robust fall detection system is essential for the seniors' health.

According to the types of sensors and how to use sensors, fall detection approaches can be categorized into three groups[2]: wearable devices, ambience device and camera-based. The approaches based on wearable devices require the subject to wear wearable sensors. Noury et al.[3] conduct a survey about this kind of methodology in detail. This technique mainly uses accelerometers, which will measure the acceleration information, and when the acceleration's value exceed some specific threshold, it shows the fall has happened. The methods based on ambience device detect the fall signal by using vibration sensor installed in the surrounding environment. Majd Alwan et al.[4] describe minutely a fall detection system which is based on floor-vibration. In order to evaluate the floor's vibration patterns and generate a binary fall signal, they use a specific piezoelectric sensor coupled to the floor surface. Camera-based fall detection methods have been research focus in these years. Using this method, the human activity will be captured in a video in order to further analyze by using image processing and computer vision technique to detect and generate an alert. Michael et al.[5] presents a feature-based method to detect fallen people on the ground by a mobile robot equipped with a Kinect sensor. Samuele et al.[6] propose a fall detection method which extracts the elements, and implements a solution to classify all blobs in the scene. Michal et al.[7] propose an algorithm for fall detection using a ceiling-mounted 3D depth camera. The lying pose is separated from common daily activities by a k-NN classifier, which was trained on features expressing head-floor distance. Erik et al.[8] present a two-stage fall detection system. The first stage characterizes a person's vertical state in individual depth image frames, and then segments on ground events from the vertical state time series obtained by tracking the person over time. The second stage uses an ensemble of decision trees to compute a confidence that a fall preceded an on ground event.

## THE PROPOSED METHODS

### 1. ANALYSIS OF FALL CHARACTERISTIC

During falling, the person will lose balance, and the human body is inevitably inclined, it will generate a certain angle between the orientation of body and the ground floor. When the tilt angle calculated is lesser than a certain value, the fall can be detected[9][10][11]. But it will also misjudge when using this method to detect fall. When the people perform some activities of daily living, such as stooping, leaning, it will generate false alerts. The falling action is a transitional phase. If the angular position of human body has changed significantly in a short time, we can determine that the fall has occurred. The angle change rate feature not only describes the change of angle in space, but also reflects the change in time. Hence, this paper proposes the use of angle change rate to detect the fall.

### 2.THE PROPOSDE FALL DETECTION ALGORITHM

This paper proposes a new fall detection algorithm. The fall detection system firstly obtains human skeleton images by Kinect sensor, then the orientation of major axis is derived from skeleton data, and the time of each frame is marked by using the time stamp. Lastly, the angle change rate is calculated.

#### (1) ORIENATITON OF MAJOR AXIS

The orientation of major axis is defined as the angle between human major axis and X axis in this space coordinate system. The Kinect SDK can provide data in frames at a rate of 30 frames per second, and get the coordinates of each skeleton point. Specifically, for each joint on a skeleton, we can acquire the x, y and z coordinates of the joint. To estimate the major axis of the person, we choose three joints: the shoulder center, the spine, and the hip center, and acquire the x, y coordinates of each joint respectively. And in X-Y plane, we will utilize least square algorithm to fit the (x, y) coordinates of the three joints to be a straight line. According to the result of fitting the (x, y) coordinates of the three joints, we will get a linear equation:

$$y = kx + b \qquad (1)$$

According to the slope k, the angle between the major axis and the X axis can be calculated.

#### (2)MARK THE TIME OF EACH FRAME

To calculate the angle change rate, we need to get the time of each frame. Hence, we use the time stamp provided by Kinect SDK to mark the time of each frame T. If the time we get the i-th frame is Ti, and the time we get j-th frame is Tj, then the time difference Δt= Ti- Tj.

#### (3)CALCULATING THE ANGLE CHANGE RATE

We can calculate the angle A between the human body and the floor in each frame, and the corresponding T by (1) and (2). Assume that we calculate the angle Ai at Ti, and the angle Aj at Tj, the angle change rate R can be calculated as equation (2):

$$R = \frac{A_i - A_j}{T_i - T_j}$$

## EXPERIMENTAL RESULT AND DISCUSSION

We have implemented our proposed approach using C# in Windows 7 and displayed the results with Windows Presentation Foundation (WPF) interface. The Kinect sensor is fixed on a horizontal table, which

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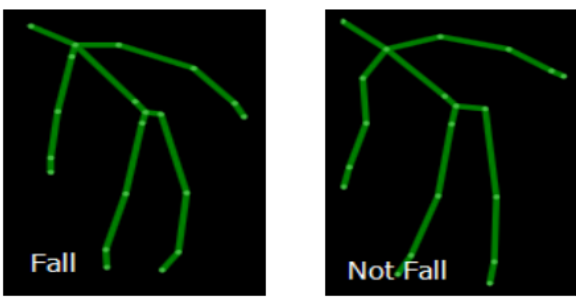
is at the height of 1.5 meters from the ground.

For the sake of evaluating our fall detection system, we perform three sets of experiments to obtain a set of data sets, which mainly contain two parts: falling and normal activities, including leaning, stooping actions. For each action scenario, we have tested it using two different methods: based on angle algorithm and based on the proposed algorithm. We label the testing result using "Fall" or "Not Fall". In our experiment, for testing the algorithm based on angle, we set the threshold $\alpha_T$=45°, if the angle calculated is less than $\alpha_T$, then the fall is detected. For testing the proposed algorithm, we have completed a set of fall actions, and get that the fall detection rate is the highest when we set the threshold $R_T$=5.56 through the sample set.

In the first experiment, we test leaning action. As shown in Figure 1. In Figure 1(a), the angle calculated is α=43°, the system detects it as a fall. But it is a leaning action shown in Figure 1(a). This shows that it is a false alert. In Figure 1(b), the angle calculated is α=40°, the angle change rate R=3.45, which is less than the threshold. The system shows "Not Fall".

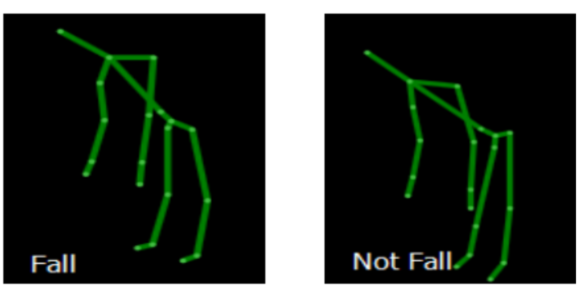
In the second experiment, we test stooping action. As shown in Figure 2. In Figure 2(a), the subject is stooping, the angle calculated is α=44°, the system shows "Fall". In Figure 2(b), the angle calculated is α=42°, and the angle change rate R=4.73, the system shows "Not Fall".

In the third experiment, we test the falling action. As shown in Figure 3. The angle calculated is α=41°in Figure 3(a), the system shows "Fall". In Figure 3(b), the angle calculated is α=41°, and the angle change rate R=5.74, which is greater than the threshold, the system shows "Fall".



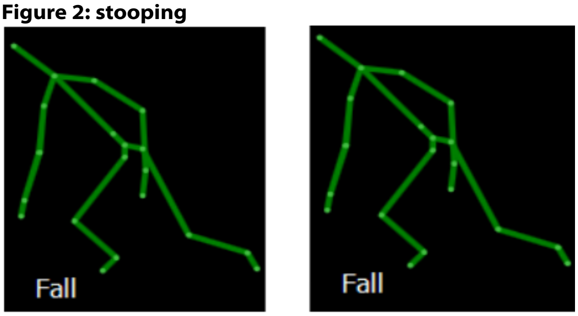

(a) (b)

**Figure 1: leaning**




(a) (b)

**Figure 2: stooping**




(a) (b)

**Figure 3: falling**

Table 1 shows the compared results of these three groups of experiments. From table 1, we can see that the algorithm based on angle can't correctly detect the fall. Some daily activities, such as stooping, leaning actions, are detected as fall, it is obviously incorrect. According to the experimental results, the proposed method demonstrates the ability to effectively avoid misjudging stooping, leaning motions as falling, and the fall detection precision are pretty good.

**TABLE – 1**
**COMPARED RESULTS OF THREE GROUPS OF EXPERIMENTS**

| Activities | Based on angle | | Based on the proposed algorithm | | |
|---|---|---|---|---|---|
| | α | Test Results | α | R | Test Results |
| Leaning | 43° | Fall | 40° | 3.45 | Not Fall |
| Stooping | 44° | Fall | 42° | 4.73 | Not Fall |
| Falling | 41° | Fall | 41° | 5.74 | Fall |

## CONCLUSIONS

This paper proposes a fall detection algorithm based on angle change rate. The fall detection system firstly obtains human skeleton images by Kinect sensor, and then performs specific algorithms to calculate the angle change rate. Falling can be detected when the angle change rate is greater than a certain threshold. The angle change rate feature not only describes the change of angle in space, but also reflects the change in time, so it can be able to avoid misjudging leaning, stooping actions as falling and improve the detection rate. Comparative analysis of the experimental results shows that the detection rate of the proposed algorithm is significantly higher than the algorithm based on angle.

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