Recognition of Human Motion Pattern Based on MEMS Inertial Sensors

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Abstract. In order to solve the problem of single information and low recognition accuracy of human multi-movement pattern recognition, a human motion pattern recognition algorithm based on MEMS inertial sensor information comprehensive discrimination is designed with considering the human motion information collected by MEMS inertial device and using the idea of binary tree layered recognition algorithm. The KMSE nuclear method is used to distinguish difficult planes from fast and slow walking. On the basis of the plane motion detection during the movement of the upper and lower floors, combined with the floor structure diagram of the building, the number of upper and lower floors is recognized. Combined with the experiment, the common algorithm of human body multi-motion pattern recognition is analyzed. The accuracy and efficiency of the algorithm are proved.

Introduction

A recognition algorithm for human motion patterns is a process of continuous human movement state recognition, it’s mainly used for pedestrian navigation and positioning, monitoring staff, sports, health monitoring and medical research and fire rescue, and so on [1,2]. A recognition algorithm for human motion patterns can be divided into based on image processing method and the method based on motion sensor processing from the use of the device. Gait recognition based on motion sensor for human movement state recognition, energy consumption evaluation, indoor pedestrian navigation and positioning, and other areas of the research has important research significance.

The recognition for human motion patterns was mostly used acceleration information of time domain or frequency domain characteristics [3,4]. The recognition algorithm of this paper designed fused line acceleration and Angle acceleration information, extracting the time domain features alone can quickly and effectively identify stand walking, running, walking fast, walking slow, going downstairs and going upstairs sports mode.

Data Processing

In the process of walk normally, the feet and the ground are always in contact and separated, the body is always repeatedly between single foot support and feet support state conversion. The state is defined as support phase when the feet contact with the ground, and the other state is defined as the swing phase when the feet off the ground forward swing. For example, Motion sensor worn on his left foot, when the left foot contact with the ground, at this time the output of the sensor body is the signals in the support phase state; When left foot off the ground, the sensor output signal of the human body is the signal in a state of swing phase [5].
The self-contained inertial sensor of this paper is MEMS inertial gyroscope that collects information about human movement. The device is made up of the MEMS inertial sensors of three parts, transmission cables, and the upper machine. Acceleration sensor of the sampling frequency is 400 Hz, sampling scope is \(-6\, \text{g} \sim +6\, \text{g}\); The angular velocity gyroscope sampling frequency is 400 Hz, sample range in \(-400^\circ/\text{s} \sim +400^\circ/\text{s}\). Signal acquisition device is shown in figure 1.

Figure 1. MEMS signal acquisition device.

The Characteristic Quantity of Angular Velocity

Due to the difference of the extreme values of the trough in the vertical direction in the plane motion and the bevel motion, the trough points exist in the single motion period of the plane motion; and due to the existence of the slope in the slope motion, there is no trough point in the single motion period.

In the process of plane mobility, the number of peaks and troughs feature points are roughly the same in the process of running, fast walking and slow walking plane movement; Due to a small turntable between two floors of the stairs, there is the plane movement between up and down the building movement, the output signal in the vertical direction of the angular velocity will be very little trough point. We can use the property that the number of the trough is different between plane movement and slope movement to distinguish plane motion from slant motion.

The Characteristic Quantity of Acceleration

In the paper multi-motion state pattern recognition, the processing of the acceleration signal is divided into two parts. The first part is the discriminative selection of the position of the short-term supporting phase of a single motion cycle during human motion; the other part is the discriminative extraction of the peak extremum point and the trough extreme point during human motion.

Figure 2. Output map of the support phase position point. Figure 3. Output map of the trough and peak.

In the discriminant extraction of the transient support phase position during human motion, the correlation processing output map for the acceleration signals in the X-axis direction and the Z-axis direction is as shown in Fig. 2. The processing output diagram of the peak and trough position points of the vertical direction acceleration signal in the up and down building motion is shown in Fig. 3.

Stratified Recognition Algorithm

The algorithm of this paper based on the fusion of gyroscope and accelerometer signals realizes a variety of human movement pattern recognition. In the data feature extraction, to ensure the
algorithm accuracy and reliability at the same time, improve the efficiency of the algorithm. The characteristics of acceleration and gyroscope are selected time domain characteristic. After MEMS sensor data were collected for filtering and feature extraction, first the human motion state can be divided into static standing, plane walk, up and down the stairs three motions based on the time domain feature of the gyroscope output data on the vertical; and then the going upstairs and downstairs can be differentiated through the analysis of the corresponding acceleration signal data in time domain; the last, using KMSE nuclear methods to distinguish running, fast walking and slow walking, it can accurately distinguish between running, walking quickly as well as the slow walking. The algorithm framework as shown in figure 4:

![Algorithm Framework](image)

The Recognition Algorithm of Plane Motion and Bevel Motion

Finding the difference between the function value of the position of the valley point and the function value of the relative zero position closest to the point, the position of the valley point whose difference value is smaller than the threshold value is removed by setting a threshold value to obtain a valley position point matrix satisfying the condition. Then, the matrix of the supporting phase position points is obtained by the corresponding function processing. Finally, the number of valley points obtained is compared with the number of support points, and the obtained value is multiplied by 10 to obtain the time domain feature quantity of the algorithm. The output of the angular velocity time domain feature of the multiple motion states is shown in Figure 5(a):

![Recognition Result](image)

It can be seen from the figure 5(a) that the time domain features of the vertical gyroscope are all greater than 6 during the plane motion, usually between 8 and 10; the feature quantity is less than 6 during the walking of the inclined plane (up and down), usually between 2 and 3. Therefore, for the discrimination of the time domain feature quantity in the vertical direction of the gyroscope, the feature quantity value of motion patterns greater than 6 is determined as the plane motion (plane fast walking, plane slow walking), On the contrary, it is discriminated as a slope movement.
**Plane Motion Recognition**

The MSE (Minimum Square Error) method is essentially a least squares method [6]. After the KMSE kernel method finds the corresponding discrimination direction $W$, the classification can be realized without designing a special classifier. The resulting discrimination direction $W$ can approximate the sample data to its corresponding category label. The physical meaning is: the corresponding discriminant vector extracts the feature of the sample in the feature space, and the result is closest to the sample class in the sense of the minimum mean square error, thereby realizing the classification.

For the recognition of the three modes of plane running and plane walking, due to the similarity of the three modes during the motion, the accelerometer output signals of the MEMS sensor are not particularly different. The pattern recognition based on the kernel method KMSE can realize the effective judgment of plane running and fast and slow walking by training the sample data. The layered recognition algorithm is used to realize the recognition of the plane motion (running and the fast and slow walking). Firstly, the running is separated from the fast and slow walking. Then use the same method to distinguish between fast walking and slow walking. The result of the differentiation is shown in Figure 5(b) and 5(c).

**Bevel Movement and Floor Recognition**

In the up and down floor movement mode, the tendency of the vertical direction acceleration is different during the movement. It is inclined upward when the movement mode is going upstairs, the peak extreme point will appear after the plane zero point; otherwise, the downstairs movement mode is the oblique downward movement, and the trough extreme point occurs after the plane zero point. According to this rationale, the movement pattern of the upper and lower floors can be distinguished.

In the identification of the upper and lower floors, since there is a plane turntable between the two floor stairs, the walking on the turntable belongs to the plane walking motion mode. While detecting the bevel motion (up and down floor), the plane walking mode in the upper and lower floor sports mode is identified, and then the design result of the stairs between the building floors is combined to realize the recognition of the upper and lower floors.

Regarding the recognition of the plane walking pattern during the movement of the upper and lower floors, firstly, the acceleration data in the vertical direction of the upper and lower building movements are divided according to the matrix of the support point position, and the time-domain feature quantity of the forward direction angular velocity signal is extracted. Discriminating the feature quantities of different time domains, dividing the suspicious plane motion period in the movement of the upper and lower floors; Then, the vertical acceleration signal of the suspicious motion cycle is discriminated; the time period of the plane motion in the up and down building motion is obtained; finally, combined the actual structure diagram of the stairs between the building floors, realizing the recognition of the floor number of the upper and lower floors.

**Analysis of Results**

In order to ensure the objectivity of the experimental data, there are 10 testers in this experiment, including 7 males and 3 females. Each tester completes six types of sports modes: standing, running, walking fast, and going up and down. During the experiment, the tester does not make special constraints on the walking process and completes the experiment according to his walking habits. The experimental result data is shown in Table 1. The recognition rate is the ratio of the number of correct recognitions to the total number of trials.

Table 1 lists the recognition accuracy of the six human motion patterns. In the common human motion state recognition, the algorithm can efficiently and accurately identify multiple behavior patterns of the human body, and the average recognition rate is 96.65%. Since the output signal of the acceleration output signal gyroscope in the standing state is distinct from other motion states, the recognition rate of the standing state reaches 100%. In addition to the standing posture, the
recognition rate of slow walking of the human body is the highest, it has reached 99.54%; the recognition accuracy of the up and down stair motion mode is relatively low, and the recognition rates have reached 92.56% and 93.34%. The overall recognition accuracy is better.

|                | standing | running | Fast walking | Slow walking | Going upstairs | Going downstairs | Number of floors | Total number |
|----------------|----------|---------|-------------|--------------|----------------|------------------|------------------|--------------|
| Number of experiments | 476      | 466     | 791         | 1076         | 793            | 691              | 124             | 4417         |
| misjudgment    | 0        | 22      | 8           | 5            | 59             | 46               | 8               | 148          |
| Recognition rate | 100      | 95.28   | 98.99       | 99.54        | 92.56          | 93.34            | 93.55           | 96.65        |

**Conclusion**

Compared with the existing human motion pattern recognition algorithm, the model algorithm comprehensively utilizes the linear acceleration and angular acceleration information during human motion, which can improve the accuracy of the algorithm and improve the calculation speed. Through the detection of the plane motion in the slope motion, combined with the floor structure diagram of the building to achieve the recognition of the upper and lower floors. After a large number of experimental data tests, the overall recognition rate of the algorithm reached 96.65%, and the recognition rate of the upper and lower floors was 93.55%. In the next study, in order to improve and continue the accuracy of the algorithm model, a new MEMS sensor will be added to collect the upper body motion information of the human body to assist in judging the human body motion state; or other methods will be used to assist in judging the human body motion state, In-depth study of other common daily sports patterns to meet the tracking and recognition of the complex state of human motion in daily life.

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