Recognition of Abnormal Posture of the Elderly Based on Gyroscope

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Abstract: Today's society is facing the problem of aging of the population, and reports of injuries received by the elderly in their lives are common. Therefore, people attention to posture recognition of the elderly is getting more and more attention. This article mainly collects data through the mobile phone's gyroscope, and then uses Kmeans clustering for data processing. The classification results obtained are good, which can solve the problem of the elderly's posture recognition to a certain extent, and then can determine whether the elderly fall. This research provides a strong guarantee for the safety of the elderly.

1. Introduction

With the rapid development of sensor technology, researchers have greatly facilitated the research on the posture of the human body. In terms of health, smart medicine, ward monitoring, etc. It have a wide range of applications [1]. China has entered an ageing population, and health care for the elderly is an issue that needs to be addressed urgently. If the elderly do not take timely treatment after a fall, a very ordinary fall may have very serious consequences. Therefore, the posture recognition of the elderly is a hot topic of current research.

After a period of research, some research results have been obtained. The wearable device-based method [2] has also produced many results in the research field of mobile terminals [3-5]. There are also image processing technologies applied to human pose recognition, such as: using keyframe technology of images [6]. Using virtual warehouses to conduct research on people ’s walking gestures [7], and so on. In waiting for these aspects, although there are also gyro-based studies of human poses [8] most of them are too complicated in terms of data collection. The use of multiple sensors, while improving accuracy, also brings users Inconvenience. On the other hand, for data processing, SVM, hidden Markov chain, BP neural network [9] and other methods are used to increase the amount of calculation. The processing of data cannot always be the result of feedback.

This article uses the smart phone's gyroscope to collect the attitude information of the elderly. The collected terminal mobile device is relatively simple, does not require many sensors, not only lower cost, but also can achieve better detection results. Users do not have to wear various terminal devices to make applications more natural. After detecting the fall of the elderly, a series of help-seeking messages can be taken to protect the health of the elderly.

The rest of this article is organized as follows: In Section 2, we introduced the working principle of the gyroscope. In Section 3, we introduce the principle and algorithm of Kmeans clustering in the third part. In Section 4, the collected experimental data are analyzed and evaluated. Finally, Section 5 gives the conclusion.

2. How a Gyroscope Works

A gyroscope, also called an angular velocity sensor, is a device designed based on the principle of conservation of angular momentum to measure the angular velocity of an object when it is deflected and tilted. Nowadays, there are multi-axis gyroscopes, which can measure physical

quantities of angular velocity in multiple directions. The structure of a three-axis gyroscope is shown in figure 1. With the continuous advancement of technology, multi-axis gyroscopes have also been continuously applied. This article mainly introduces the principle of the three-axis gyroscope, the purpose is to enable us to understand the principle of the gyroscope.

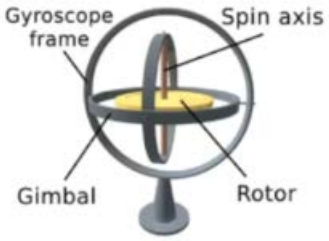

Figure 1. Structure of a three-axis gyroscope.

The three-axis gyroscope is composed of Gimbal, gyroscope frame, spin axis, rotor. The center of mass of the gyroscope is concentrated at the center. When the outer circle rotates around the center, the spatial orientation of the center of the gyroscope remains the same. This theory indicates that when the gyroscope is deflected, the rotor at the center has the same property, which can bring convenience to measurements in other directions.

Today, MEMS (Micro-Electro-Mechanical System) gyroscopes are commonly used on mobile phones [10]. They use the tangential force experienced by a rotating object when it moves in a radial direction.Coriolis force is proportional to angular velocity. When an object undergoes motion such as rotation, a Coriolis force that is perpendicular to the direction of particle motion [11] (see figure 2) will be generated, resulting in a change in the capacitance between the fixed electrode and the moving electrode, which can be converted into a detectable electrical parameter by the circuit .

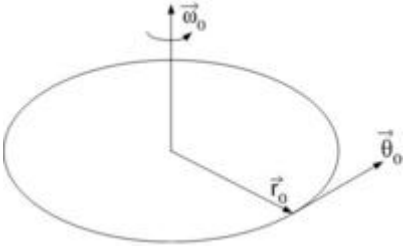

Figure 2 Coriolis force diagram.

Because the gyroscope can well detect the physical quantity of object movement, it has a wide range of applications in map navigation, aviation, user entertainment, and so on. The accuracy of the gyroscope can meet specific application requirements. In this paper, only the gyroscope of the mobile terminal is used to measure the relevant physical quantities, so as to detect the attitude and behavior of the elderly. Using this sensor, it can be naturally fused with the user, and a certain preventive effect can be achieved.

3. Kmeans Clustering

Clustering is to automatically divide some unlabeled data into a specified number of classes to ensure that each class has similar characteristics, which belongs to an unsupervised learning method. The algorithm idea of Kmeans clustering is to determine the number of clustering clusters K in advance for a given sample set, and cluster the smaller samples into a cluster according to the distance between the samples, so that the similarity of the samples in the same cluster higher, the difference between different clusters is higher. The Kmeans algorithm keeps the samples in the clusters as close as possible and the distance between the clusters is as large as possible. This algorithm attempts to divide the cluster data into n groups of independent data samples so that the variance between the n groups of clusters is equal. The mathematical description is to minimize the inertia or the sum of squares within the cluster. Kmeans clustering is a simple and easy to implement unsupervised algorithm, which is widely used in many fields, such as: astronomy,

agriculture, image processing, natural language processing, etc. Researchers are also constantly improving the Kmeans algorithm, and have also obtained certain research results [12-15].

3.1. Related concepts

K value: The user needs to divide the entire data into as many categories as the K value, which is determined according to the specific situation. Therefore, the selection of K value has always been a research hotspot.

Distance: Commonly used distances are Euclidean distance, Manhattan distance, Chebyshev distance and so on (all calculations need to be standardized). You can choose the appropriate distance according to actual needs.

Euclidean distance as formula(1): $x_i, y_i, z_i, (i \in [1, k])$ are used to represent the coordinate values of a point in space in three directions of x, y, z in the space rectangular coordinate system.

$$dis = \sqrt{(x, -x_2)^2 + (y, -y_2)^2 + (z_1 - z_2)^2} \tag{1}$$

Manhattan distance as formula (2):

$$dis = |\chi_1 - x_2| + |y_1 - y_2| + |z_1 - z_2| \tag{2}$$

Chebyshev distance as formula (3):

$$dis = max(|\chi_1 - x_2|, |y_1 - y_2|, |z_1 - z_2|) \tag{3}$$

Clustering center: The average of each dimension vector of the samples in each cluster is the center of the cluster to be clustered.

3.2 Mathematical principles

Suppose we divide all the sample data into K classes, and each class uses $C_1, C_i \ldots C_k, (i \in [1, k])$.The minimum squared error E we need is (4):

$$E = \sum_{i=1}^{k} \sum_{x \in c_i} \|\chi - \mu_i\|_2^2 \tag{4}$$

The above formula μ_i is the mean vector of the cluster corresponding to the class C_i,that is, the centroid. μ_i as formula (5).

$$\mu_i = \frac{1}{|C_i|} \sum_{x \in C_i} x \tag{5}$$

3.3 Algorithm

(1) Enter the original data to be processed, and determine how many categories the data is divided into, that is, enter the K value.

(2) Randomly select K data points as corresponding cluster centers

(3) Calculate the distance (various) from each sample point to each cluster center. The sample points belong to the centroid set with the smallest distance from the cluster center.

(4) After processing (3), all the data will be divided into K sets, and then calculate the centroid of each set.

(5) If the error between the calculated centroid and the original centroid is less than a certain threshold, we can say that the desired effect is achieved and the algorithm terminates. Conversely, if the error is large, then jump to (3) to continue the iteration.

3.4 Algorithms have advantages and disadvantages

This unsupervised classification method of Kmeans has certain effects on both discrete and linear data. The following are the advantages and disadvantages of the Kmeans clustering algorithm.

3.4.1 Advantages

(i) The algorithm process is simple, and the principles are easy to understand, which provides great convenience for subsequent improvements.

(ii) The complexity of the k-means algorithm is O (nkt), where n is the total number of objects, k is the number of clusters, and t is the number of iterations. In general, h << n and t << n. Therefore, the algorithm is relatively scalable and efficient for processing large data sets.

(iii) When the boundary between the clusters is obvious, it has a good effect.

3.4.2 Disadvantages

(i) Kmeans clustering is very sensitive to discrete points. A small number of discrete points may cause the division boundary between different clusters in the entire cluster to shift. A few discrete points have a greater impact on the clustering results.

(ii) The value of K needs to be specified, but the selection of K value does not have a good reference scheme. Sometimes it may take a lot of experiments to find the value of K. According to a certain indicator, the K value found may be lack of interpretability.

4. Data Processing

(1) Use the mobile phone's gyroscope to collect data in three directions: x, y, and z, respectively. Put the mobile phone in your pocket normally, and then simulate the activity of the elderly to measure the data, measure the value of the gyroscope under normal activities, and record it every second. The amount of collected data is 480 data, of which 240 are data measured to simulate the state of normal elderly people, and the other 240 data are simulated data that are measured when elderly people fall. The specific scatter diagram is shown in the following figure 3.

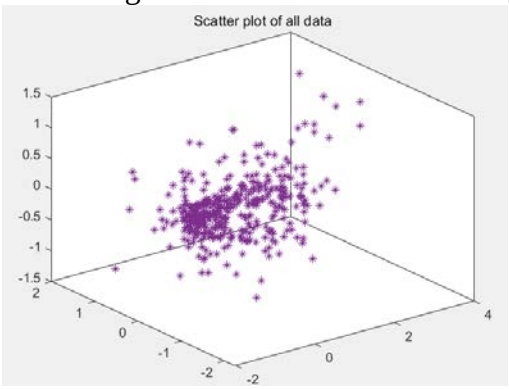

Figure3.Scatter plot of all data.

(2) Use Matlab's subclust function to calculate the cluster center. This function can calculate the number of cluster centers and the corresponding coordinates of the entire data when you do not specify the K value of the cluster. See the table for the spatial coordinates of the cluster center in table 1.

Table 1 Coordinate table of clustering center points obtained by subclust function.

	X Coordinate value	Y coordinate value	Z coordinate value
Point1	-0.2840	-0.0300	-0.0900
Point2	0.2190	-1.2660	0.5150

The Kmeans method is used for clustering, and the clustering is performed according to the algorithm flow in section 3.3 above. Given a value of K, the coordinates of the cluster center are calculated. The calculation results are shown in Table 2. The reason why the value of K is selected here is 2: The data is to detect whether the elderly fall, so there will be two results, one is that the elderly will fall, and the other is that the elderly will not fall. In the case of satisfying the interpretability constraint, the K value here can only be 2 in order to have practical significance.

Table 2 Kmeans clustering center point coordinate table.

	X Coordinate value	Y coordinate value	Z coordinate value
Point1	-0.2900	0.0350	-0.1420
Point2	0.3660	-0.7250	0.4180

The details of the coordinates of the points in Tables 1 and 2 in the three-dimensional diagram are shown in figure 4.

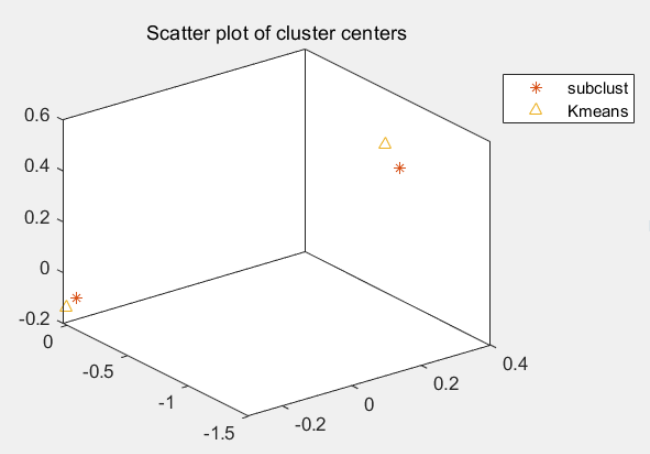

Figure 4 Scatter plot of cluster centers

By displaying the data in Figure 4 in the spatial coordinate system, we can intuitively observe the positions of the two calculated cluster centers, which is more convenient for us to have a clear understanding of data classification and a subjective feeling Although it may not be accurate, it can be of great reference value.

(3) Using the silhouette function in Matlab, this function is used to measure the similarity between a sample point and the cluster it belongs to compared to other clusters. A larger value indicates that this node more closely matches its genus cluster and does not match adjacent clusters, indicating that the cluster is appropriate. If many points have low or negative values, it means that there are too many or too few categories. The specific results are shown in figure 5.

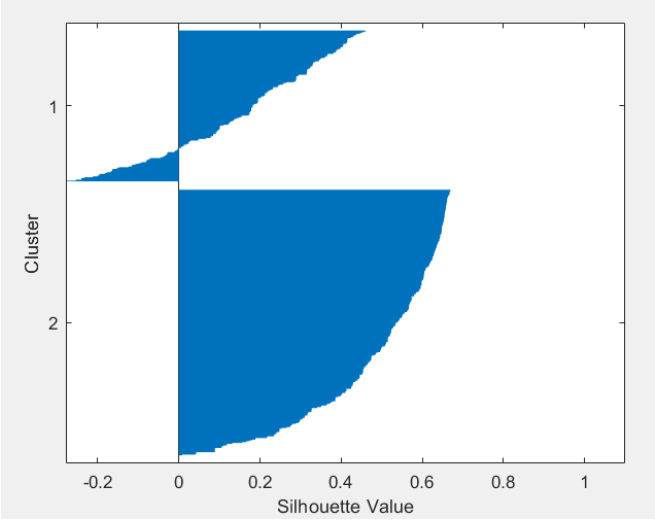

Figure 5 Silhouette function processing results.

According to the estimation of the grid, the part that is less than zero accounts for 4% of the overall data. This part of the data may be misclassified, and the other 96% can be classified almost correctly. This can basically meet the needs of research.

(4) The scatter plot after all data is aggregated into two categories by Kmeans is shown in figure.6. One is represented by '*' and the other is represented by a small triangle. Although the classification of some data is inaccurate, the scatter plot after Kmeans clustering can provide an

intuitive understanding of the clustered classification.

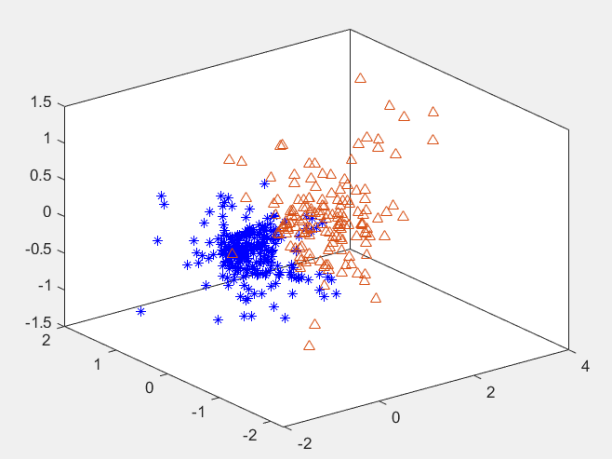

Figure 6 Scatter plot after clustering all data.

(5) In the data analysis stage, 240 groups in the original data are data that simulate the elderly when they fall. After clustering the original data by the Kmeans method, the data is statistically calculated to obtain the results in Table 3, where Category 1 represents the sample statistics of the elderly when they fall, and Category 2 represents the elderly when they are normally active. Sample statistics.

Table 3 Data statistics table.

	Number of samples before clustering	Number of samples after clustering
Category 1	240	199
Category 2	240	281
Sum	480	480

According to the commonly used evaluation measures, the accuracy rate is selected here as the measurement index, which is represented by P. In clustering, there are many indicators for evaluating models [16-18]. Here we choose the easiest and most intuitive indicator-accuracy rate.

$$P = \frac{199}{240} \times 100\% = 82.92\% \quad (6)$$

From the data collection to the Kmeans mean processing, the accuracy of the calculation is 82.92%. This result is only for the physical parameters measured by a gyroscope sensor, and a satisfactory result has been obtained. The introduction of multi-sensors will undoubtedly greatly improve the accuracy of the elderly's attitude detection, but it may also have a certain impact on power consumption and wearing comfort.

5. Conclusions

With the aging of the population, the health of the elderly affects the lifeblood of society, and more and more related industries have begun to develop. With the rapid development of science and technology, various smart wearable devices have also entered people's horizons. The integration degree of monitoring equipment is getting higher and higher, the monitoring parameters are more and more, and the system is becoming more and more complicated. Mobile phones have become a necessity for people's lives and have brought great convenience to our lives. Therefore, fully tapping the functions and data of mobile phone terminals can better serve the society. Compared to most expensive wearable smart devices, mobile phone gyroscopes appear cheaper and more convenient.

The article only uses the mobile phone terminal's gyroscope to collect the attitude data of the elderly, and then the data analysis method uses Kmeans clustering. After evaluating the model, the accuracy of the classification is 82.92%. It avoids the inconvenience of the elderly and the problem of wearing various equipment. Using a gyroscope for detection, the old man only needs to put a

mobile phone with a gyroscope in his pocket. Just using the gyroscope for detection, to a certain extent, a certain accuracy rate is lost, but compared to the high cost and convenience, it is still acceptable.

In the future, we will continue to work on gesture recognition, further improve the accuracy, and combine data mining, artificial intelligence and other algorithms to improve the system and make the safety of the elderly more secure.

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