Research on a fusion gait real-time recognition algorithm

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Abstract. Based on the current market prospects of wearable devices, gait recognition accuracy and real-time market demand, a fusion gait real-time recognition algorithm is designed. The paper introduces the method of limiting the original step signal by using the method of limiting filtering and moving smoothing filtering. At the same time, using dynamic threshold detection and similarity algorithm fusion method, using dynamic window method, the step data is sequentially subjected to dynamic threshold. Only if the two algorithms are simultaneously established, the decision step is established. The fusion gait recognition algorithm is designed to achieve real-time gait recognition, and finally obtain more accurate detection results.

1. Introduction
As a key indicator of human health, the accuracy of the exercise record directly determines the credibility of the data analysis. Therefore, it is necessary to have a better effect in the study of gait recognition algorithms in order to obtain more accurate results. This paper uses STM32 based on M3 core 32-bit processor, and uses ADXL345 three-axis accelerometer to collect three-axis data in motion state, and performs vector synthesis on three-axis acceleration data. We don’t consider special situations such as falling and lying on the back in this study.

2. Signal preprocessing

2.1. Raw data description
The original signal collected by the accelerometer contains various interference noises. To avoid noise interference, it is necessary to optimize and improve the hardware design and software algorithms. In terms of hardware design, it is necessary to design a stable power supply and power supply voltage regulator to avoid baseline drift caused by voltage instability. The hardware circuit design also needs to pay attention to high and low frequency separation. Decoupling capacitors are arranged next to the chip power supply pins to remove power frequency interference. Therefore, the design of the experiment is set: the step counter is placed on the waist and abdomen, thereby reducing the large error caused by the conventional device being placed on the wrist due to random swing, so that the gait recognition algorithm is simpler to handle.

Khalil A [1] uses the slope of the adjacent two samples to determine the state of the motion waveform based on the positive and negative slopes. The algorithm roughly determines the peak value. This simple peak judgment method requires the signal to be very filtered. Smooth, no burrs, it is difficult to achieve. Therefore, Mladenov M [2] improved the algorithm of Khalil A. According to the step-by-step characteristics, the window was set, the slope singular point of the fixed window was calculated, the fixed window peak was fixed, and all the peaks and troughs in the window were...
obtained. The weighted average is used as a condition for judging the threshold step. The peak value is indeed a relatively simple method of judging the number of steps, but this is very complicated for signal processing. The signal must be smoothed to a certain extent before it can be judged by this method. The filtering algorithm is very demanding, and the hardware MCU needs to have processing speed to guarantee the real-time and effectiveness of the algorithm.

It can be seen from the test data that the acceleration signal of human motion has noise interference in different axial and different frequency bands, and these noises need to be preprocessed. For real-time and effective data processing on the platform, in this paper, the original step signal is preprocessed by limiting filter and moving smoothing.

2.2. Improved limiting filter

Vector synthesized triaxial acceleration data, through MATLAB found that there are some data anomalies, the data value is large, the analysis may be caused by a sudden change in speed during the test, so we need to remove the data first. Limiting filtering can well remove randomly generated interference signals and eliminate the effects of transient instability of the acceleration sensor.

The sampling rate of the original signal is 25 Hz. During the sampling process, the sampling is continuously performed within two sampling intervals, that is, 0.04 s. The values of the adjacent two samples are compared, and the maximum variation is determined within a certain range. The amount of change needs to be generated through experimental experience. The empirical value of this experiment is set to 120. When the actual change amount is greater than the empirical value during the test, the collected signal is considered to be the interference signal, and the previous acquisition data is used instead of the current acquisition, and vice versa. The first data can’t be compared, the data error of the first 2s during sampling is large, so it is not used, and the data after 2s is used for testing [3].

First get the vector of the triaxial acceleration xyz and \( m_n \):

\[
m_n = \sqrt{x_n^2 + y_n^2 + z_n^2}
\]

Amplitude change of vector data:

\[
m_n = \begin{cases} 
m_n, & |m_n - m_{n-1}| \leq \Delta x \\
m_{n-1}, & |m_n - m_{n-1}| > \Delta x
\end{cases}
\]

The following is the composite waveform, and limited-improved waveform.

2.3. Moving smoothing filter

Mobile smoothing filter is often applied to digital signal processing. For time-series discrete data, smooth digital low-pass filter can be used to eliminate glitch and achieve smoothing effect. Smoothing filter is often used in time domain. Signal processing [4].

The smoothing filter processes the continuously sampled w acceleration signals. After one operation is completed, the end data in the array is removed, and the newly sampled acceleration data is inserted into the queue. The remaining w-1 data are moved back. Then, the w data of this queue is
calculated, and the input is \( m(k) \), the output is \( y(k) \), \( w \) is the smooth span, and the \( w/2 \) elements before and after \( m(k) \) are accumulated and averaged. The result is the output \( y(k) \). The formula is:

\[
y(k) = \frac{1}{w} \sum_{j=k-w/2}^{k+w/2} m(j)
\]

(3)

Figure 3. Moving smoothing filter output waveform

According to the gait waveform, first use the limiting filter to remove the singular acceleration signal points in the artificial case, and then use the motion smoothing filter to remove the glitch signal. The following is the Matlab simulation of the step data. The data is the acceleration raw data of the four-story stairs and the aisle walking for 60s in the first teaching building. The integrated filtering algorithm is used to denoise, and the moving smoothing window length is set to 6. See the front and back contrast waveforms shown in figure 4 and figure 5 below.

Figure 4. Human motion acceleration original signal diagram

Figure 5. Fusion filtered signal diagram

It can be concluded from the simulation results that the use of limiting filtering and moving smoothing filtering can remove signal interference better, and there is almost no glitch signal. The fused filtering algorithm can well realize the preprocessing of the counting signal.

3. Fusion pace decision algorithm design

Through the physical model of human walking, it can be known that after the data preprocessed by the step data, the signal source can be regarded as the processing of the sine wave, and the number of steps is the number of peaks of the sine wave, so the research focus is on Signal feature point extraction, peak search aspect. Combined with multi-party research, the following conclusions can be drawn: the dynamic threshold method alone can be used to determine the number of steps may be too small; the similarity algorithm alone may be too large, depending on the similarity coefficient value. Therefore, this paper adopts the fusion algorithm of dynamic threshold method and similarity algorithm, the advanced similarity degree operation judgment, and then the dynamic threshold judgment. When the two conditions are established at the same time, the step is established, otherwise not counting. This method greatly improves the accuracy of the algorithm.

3.1. Dynamic threshold detection improved algorithm

The dynamic threshold value of the preprocessed signal is determined by step counting. It can be considered that any sine wave has one and only one falling interval, so it is only necessary to detect the number of falling intervals to determine the number of steps. The algorithm diagram is shown in figure 6.
Figure 6. Schematic diagram of step counting dynamic threshold method

The dynamic threshold detection algorithm is to find out $S_{\text{max}}$ and $S_{\text{min}}$ of the sampled data within a certain time according to the motion frequency of the person, and calculate the average value as the dynamic threshold value, that is, the dynamic threshold $\text{threshold} = (S_{\text{max}} + S_{\text{min}})/2$. Under high frequency interference, the difference between two adjacent sampling points is greater than the dynamic threshold, and the acceleration curve traverses the dynamic threshold curve. From top to bottom, it is considered to be one step [5].

In this paper, the existing dynamic threshold method is improved. Due to the pre-processing of the signal, the step signal will appear like a sinusoidal waveform. For small peaks, only the mean value of the simple signal maximum and minimum values is used. Threshold determination, there will be a step error, so add a coefficient $K (2 > K > 1)$ in the threshold algorithm as follows:

$$\text{threshold} = k(S_{\text{max}} + S_{\text{min}})/2$$

(4)

The advantage of adding the coefficient $K$ is that the dynamic threshold can be higher than the small peak, and the calculation of the small peak is not performed, and the accuracy of the step determination is improved.

3.2. Waveform similarity algorithm

The step-by-step similarity determination algorithm is to measure the similarity between the processed acceleration signal and the standard signal to obtain the cardinality of the waveform similarity comparison. The similarity degree of the two waveforms is defined, and the two sets of signals are respectively $A(i)$ and $B(i)$, and the multiple $k$ makes $k*A(i)$ approach $B(i)$. The error energy is used to judge the similarity between the two sets of waveforms. Since the processed signal is similar to the cosine signal [6], the cosine signal is used for similarity measurement, and the processed step signal and the standard signal are similarly operated.

Let the original signal be:

$$A = A_0(a_1, a_2, a_3 \cdots a_n)$$

(5)

The signal after preprocessing is:

$$B = B_0(\beta_1, \beta_2, \beta_3 \cdots \beta_n)$$

(6)

Here, $N$ is the number of sampling points of the original waveform signal and the processed signal. The similarity of the two discrete signals can be represented by the $R_{AB}$, and the larger the $R_{AB}$, the higher the similarity of the two signals.

The similar algorithm coefficient $R_{AB}$ formula is as follows:

$$R_{AB} = \frac{\sum_{i=1}^{N} a_i \times \beta_n}{\sqrt{\sum_{i=1}^{N} a_i^2 \times \sum_{i=1}^{N} \beta_n^2}}$$

(7)
Since the motion waveform is a special periodic waveform, the data is not accurately matched to the original signal and the preprocessed signal. The dynamic window processing data is used. It is assumed that the signal data length is \( N \) and there are \( n \) waveforms. To improve accuracy, the design of the dynamic window has a step size of 1, and the total sliding distance is \( m \). After experimentation, the similarity is highest when \( m = 2N/n(n \geq 3) \).

The following Matlab simulation is the original acceleration data collected by the four testers (A/B/C/D). By comparing the similarity between the filtered data and the sinusoidal signal, the length of the signal segment is divided into 18, and the amplitude of the sinusoidal signal is Comprehensive consideration is based on the acceleration combined vector values. The following is a Matlab diagram of the walking 60-step similarity algorithm.

![Figure 7. A/B/C/D walking correlation coefficient map](image)

Table 1 is the statistics of the number of similarity signal segments by the ABCD four testers through similar algorithms. It can be seen from the table that the similarity is smaller, the matched signals are met. The more the number of segments, in order to be able to accurately judge the pace, it is necessary to combine other methods.

| Tester | Actual steps | Coefficient of 0.5 | Coefficient of 0.6 | Coefficient of 0.7 | Coefficient of 0.8 | Coefficient of 0.9 |
|--------|--------------|--------------------|--------------------|--------------------|--------------------|--------------------|
|        | Number of signal segments | Number of signal segments | Number of signal segments | Number of signal segments | Number of signal segments | Number of signal segments |
| A      | 60           | 427                | 364                | 295                | 206                | 87                 |
| B      | 60           | 432                | 368                | 278                | 175                | 67                 |
| C      | 60           | 695                | 603                | 502                | 352                | 75                 |
| D      | 60           | 763                | 639                | 506                | 303                | 28                 |

### 3.3. Fusion step counting algorithm

In order to improve the accuracy of the step counting, a single dynamic threshold algorithm and a similarity algorithm will interfere with the step determination. This paper uses fusion. The filtering algorithm uses the dynamic window method to sequentially perform the step-by-step data detection by the dynamic threshold method and the similarity algorithm. When both algorithms are determined, the step is established. The gait detection idea of the paper is to process the collected three-axis acceleration data and judge the number of steps. Figure 8 is a flow chart of the fusion gait recognition algorithm.
4. Experimental results and conclusions

As shown in table 2, the number of steps after testing the comprehensive step determination algorithm for four testers. It can be seen from table 2 that when the similarity is 50%, the fusion algorithm has higher precision. When the algorithm is transplanted, due to the limitation of the hardware platform, there is noise interference of the hardware circuit itself, which is controlled by artificial subjective consciousness. Motion interference increases the difficulty of processing. The 50% fusion determination algorithm is not the most accurate and requires multiple tests. In addition, the fusion algorithm does not consider special postures such as falling and lying, and the judgment of the pace in multiple states needs further study.

Table 2. Fusion step counting algorithm

| Tester | Actual steps | Similarity 50% fusion algorithm | Similarity 60% fusion algorithm | Similarity 70% fusion algorithm | Similarity 80% fusion algorithm | Similarity 90% fusion algorithm |
|--------|--------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|
| A      | 60           | 58                              | 56                              | 50                              | 50                              | 35                              |
| B      | 60           | 57                              | 55                              | 52                              | 42                              | 32                              |
| C      | 60           | 57                              | 57                              | 55                              | 55                              | 31                              |
| D      | 60           | 61                              | 59                              | 56                              | 51                              | 18                              |

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