Gait Recognition Based on MEMS Accelerometer

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***Abstract*—Recently, with the rapid development of MEMS technology, the micro-sensor's application in gait research has become more and more widespread, relying on its small size, low cost, light weight, and high precision characteristics. This paper presents a non-specific human gait type recognition system based on a single MEMS accelerometer, and will guide the further study in human identification, motion analysis, medical care, diet plans, etc. After a series of computing and processing the 3D raw acceleration data, by using the wavelet-threshold algorithm, the signal and noise are separated and gait cycles are easily divided. By adopting the pattern recognition theory and the combination method of time domain and frequency domain, the system realizes the gait type recognition. In the experiment the EER can reach 6.29% with 400 sets of acceleration data for test.**

Keywords-MEMS accelerometer; wavelet decomposition; correlation coefficient.

I. Introduction

Gait, as human behavioral characteristics, is currently one of the most active research topics in the field of biometric identification and motion analysis. Gait research needs a large number of reliable gait data. Although there are several open gait databases, they are all vision-based[1]. What's more, it is very difficult to capture the gait characteristics due to the dynamic environment, such as the light change, the shadow of the moving target, etc. Ailisto H. etc. proposed a novel method[2,3] for obtaining the gait data by using MEMS accelerometer, avoiding various effects from the dynamic environment and reducing the difficulty in processing the data, opening up a new way to obtain the gait data.

Recently, some researchers have studied on the gait identification based on the MEMS accelerometer and have achieved certain results. For example, the VTT Electronics in Finland[2,3], Huazhong University of Science and Technology in China[4], NTT DoCoMo Network Laboratory in Japan[5], Norway's Information Security Laboratory[6,7,8,9], and so on. However, the subjects were asked to walk in their normal pace on flat. So far, there is no research on gait recognition for different road conditions and movements being carried out. Therefore, designing a human gait type recognition system based on MEMS accelerometer will be of great significance. Combined with the theory of pattern recognition, the system will judge the type of movements (such as walking, running, etc.) based on the accelerations. It will have guidance for the practical application in human identification, motion analysis, rehabilitation tracking[5], medical care[10], diet plans, and so on.

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II. Gait Acquisition Device

In order to capture the acceleration signals during movement, we design a portable micro-based gait acquisition device which consists of several major parts: microcontroller, accelerometer and data wireless transfer part. Figure 1 shows the module architecture of the hardware circuit. The microcontroller μPD78F0547D produced by NEC Corporation, is 8-bit single-chip, 80-pin, with abundant resources, and also has on-chip debugging function; The accelerometer LIS3LV02DQ produced by ST, is a tri-axial MEMS inertial sensor, ranged -2g~+2g/-6g~+6g, digital signal output, so there is no need for A/D conversion, what users need to do is just directly reading through its internal register to obtain the 3D accelerations. When the acceleration is generated, it is transferred wirelessly to PC by employing the nRF2401A transceiver. In the experiment, we place the device in the location of the waist navel: X-axis pointed vertical direction, Y-axis to the left and Z-axis pointed forward.

The gait acquisition device is cost-effective, light weight, small size with 30mm×40mm for the overall area, easy for carrying in any part of the body without affecting normal activities.

The output data rate of accelerometer is set at 160Hz, however, the actual sampling rate of each axis is about 40 per second.

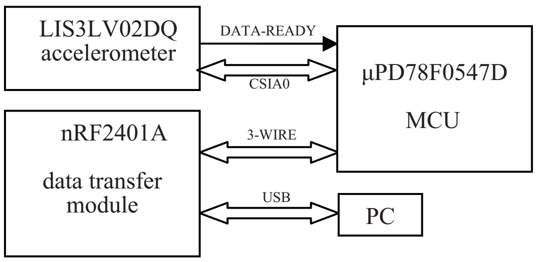

Figure 1. Module architecture of major circuit

III. Software Design of the System

A. Location of the Accelerometer Acquisition Device——Waist/Ankle/Toe

The location of the accelerometer acquisition device should be convenient for normal movement, relatively changeless, not prone to dislocation and loose. Above all, you can collect the closely related gait data. In previous researches, there usually have three options available: waist [11], ankle [6] and toe [12].

Through comprehensive and compare, we install the device in the waist, next to the navel. Considering no need for distinguishing left step from right step, and clinical studies of human movement have revealed that the pattern of movement and applied force to the center of gravity (COG) of the human body (COG is located near the pelvis) while walking is almost deterministic and undisturbed by individual characteristics[11].

B. *Software Designation*

The whole system consists of two processes——training process and identifying process. In training process, the main duty is to establish the gait templates including acceleration templates and fft templates. In identifying process, the main duty is to match the testing data with the templates, calculate the similarity, and recognize the gait type with integrated method of the time domain and frequency domain methods.

Figure 2 shows the acceleration waveform diagrams from each axis when someone walks and runs respectively.

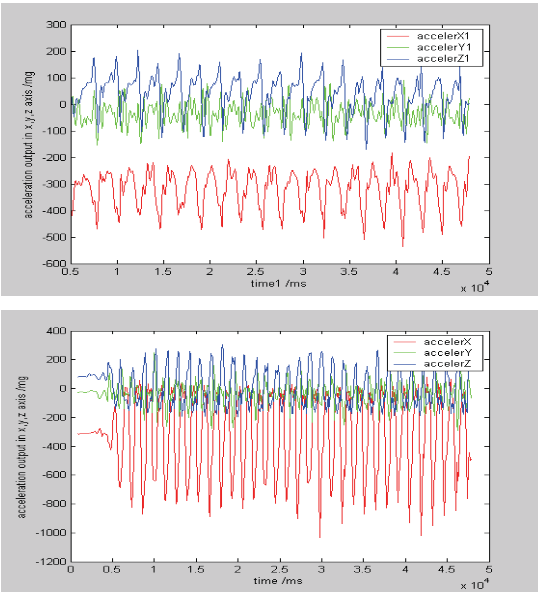

Figure 2. Acceleration waveform diagrams from each axis when someone walks and runs respectively

From the waveform, we can see that people's walking and running behaviors are obviously periodical, especially in vertical and forward direction, only the lateral acceleration waveform is not so. Considering my focus on non-specific human gait recognition, so we just process the acceleration data in vertical direction or forward separately.

The acceleration signal is low-frequency, but actually it is easily influenced by the environmental noise. As a result, it is necessary to eliminate the noise. The wavelet transform can more effectively remove the noise than the general digital filters by employing non-linear threshold method in different scales.

When using the wavelet to de-noise, the core choices are which wavelet, level of decomposition and threshold method to use. Here we select the Daubechies wavelet of order 8, default threshold method. Experimental results show the method is satisfying in noise suppression, preserving edges and details.

Furthermore, the lower level reconstructed signal has the same periodicity with the original signal, and can be more easily divided into cycles through searching the mean-value points in rising edges. Each cycle represents a left step of right. However, people always change speed during a natural walk or run, so the length may be different from cycle to cycle. We normalize all the gait cycles in both time and acceleration axis. Figure 3, 4, 5 shows the waveforms of original acceleration in vertical direction, the second level reconstructed signal after composition, and the normalized gait cycles respectively.

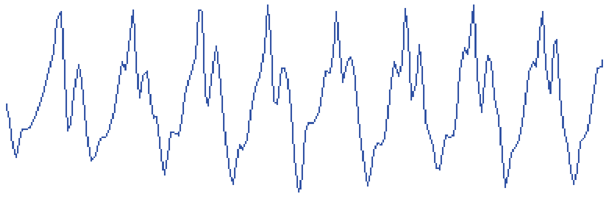

Figure 3. Original acceleration in vertical direction

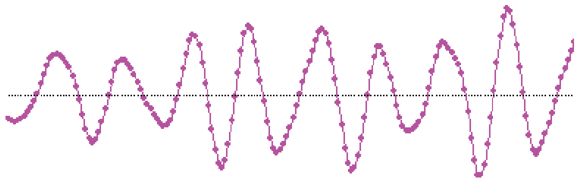

Figure 4. Second level reconstructed signal

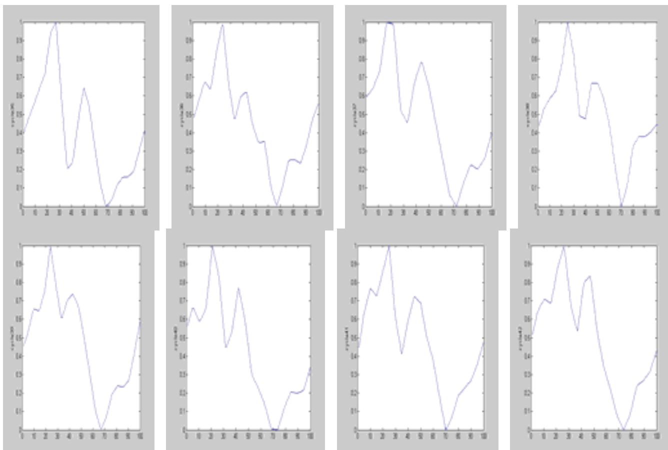

Figure 5. Diagrams for each normalized gait cycle

After normalizing each gait cycle, the most representative cycle is selected for establishing the acceleration template. The detailed process is shown as follows:

1) Calculating the correlation coefficient between each cycle and other cycles, and adding them together as the cycle's similarity;

Similarity_N=corrcoef(Step_N,Step_2)+corrcoef(Step_N,Step_3)+…+corrcoef(Step_N,Step_M)

2) Choosing the cycle with highest similarity as the most representative cycle;

3) Averaging the most representative cycles from different person as the final template;

IV. Experiment and Result

In the experiment, we collected gait data from 10 participants. Each one walked and ran in normal speed for a minute 10 times. By splitting each sample into two, we get 400 samples in total. Based on the data set, the gait type recognition EER reaches approximately 6.29% when selecting proper threshold T (correlation coefficient), as Figure 6 shown.

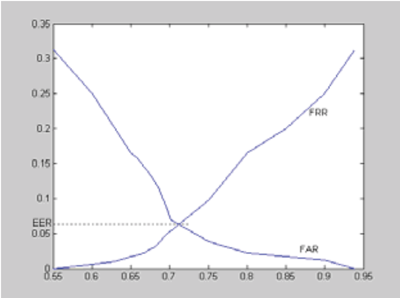

Figure 6. Error rate with change of the threshold T

In addition to recognition the gait type, the system can also calculate the velocity, distance and step length by integration method. It can even estimate the energy consumption during the movement using the formula as follows:

Calorie consumption (KJ) =body weight (Kg) × time(h) × speed (Km / h)

V. Conclusion

It is proved that the system can effectively recognize the gait type based on a single MEMS accelerometer. In future we will work to identify other types of movement, such as climbing, cycling.

Because of the MCU's limitation, the data collected are not processed in time, but stored in a binary file. In order to improve its real-time processing capability, we consider employing the DSP.

Because there is no public database on the WS(Wear Sensor)-based gait available, the data are not adequate. We plan to perform experiment on a larger population and check the performance of gait type recognition.

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