A Novel Biometric Approach in Human Verification by Photoplethysmographic Signals

Y. Y. Gu, Y. Zhang, and Y. T. Zhang
Joint Research Center for Biomedical Engineering
The Chinese University of Hong Kong, Shatin, N.T., Hong Kong, China
Email: ytzhang@ee.cuhk.edu.hk

***Abstract*-This paper presents a new human verification approach using photoplethysmography (PPG) signals that can be obtained easily from the fingertip. The experiment was performed on a group of 17 healthy subjects, and evident characteristics of the PPG signals were studied. These characteristics are unique identifiers specific to different persons while they are similar enough to recognize the same person. Four feature parameters were extracted from digitalized PPG signals. The template feature vector was formulated using part of the recorded signals, and then the discriminant function was applied to the remaining data for verification. The result with a successful rate of 94% shows that this method is promising for human verification.**
***Keywords*- Biometrics, Photoplethysmography (PPG), Verification, Euclidean distance**

I. INTRODUCTION

Automatic human identification using biometrics is gaining more importance. Its potential application can be great in many different areas such as telemedicine or e-banking. Nowadays, most systems that control access to financial transactions, computer networks, or secured locations still identify authorized persons by recognizing passwords, or ID cards. These systems are not reliable enough, because the information is easy to be stolen or forged. Being able to eliminate such common problems, biometric systems, which use unique human physical or behavioral characteristics to automatically identify a person, can ensure much greater security or confidentiality.

Certain characteristics of our bodies or features of our behaviors have been studied as means of human identification, such as fingerprint, face [1] [2], voice [3], retina/iris [4], lip movement [5], gait motion [6], electroencephalograph (EEG) [7], and electrocardiograph (ECG) [8] [9]. New applications based on these biometric approaches would provide us with a promising and irrefutable future of human identification. However, fingerprint can be recreated in latex, face recognition can be fooled by a photo, voice can be imitated [10], and the methods based on EEG or ECG are to some extent cumbersome because several electrodes are required to pick up the bio-signals.

In this paper, we propose to use photoplethysmographic (PPG) signals for human verification. Compared with other biometric approaches, PPG technique has several distinct advantages including low development cost, easy to use without any complicated procedure or special skill, and conveniently accessible to various sites of human body, such as finger, ear lobe, wrist or arm. The specific aim of this work is to investigate the feasibility of the new approach. The preliminary results of the experiments performed on the fingertip of the subjects demonstrate that the PPG approach is promising for human verification.

II. METHODOLOGY

PPG data recording was done on 17 healthy subjects. During the experiment, all the subjects sat still on a chair and let their muscle relax. The PPG probe (reflective), consisting of a LED and a photodetector, was attached on the fingertip (right index finger) by a belt. PPG signals were recorded continuously for about one minute from each person, and converted into digital signals at the sampling rate of 1K samples/s.

The raw data was preprocessed using a smoothing technique before feature extraction. A typical PPG signal is shown in Fig. 1. Four feature parameters -- peak number, time interval, upward slope and downward slope -- were extracted from the PPG signals of each subject (see Fig. 1). The template vector consisting of four averaged feature parameters was formulated for each subject. The four features are defined as follows:

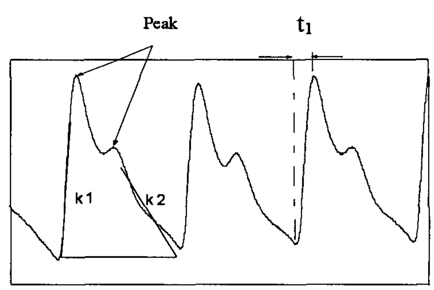

Fig. 1: A typical PPG signal with 2 peaks on each pulse of heart contraction circle.

1) The peak number M : the number of peaks on each pulse;
2) The upward slope k_1 : the slope between the bottom of each waveform and the first peak;
3) The downward slope k_2 : the slope between the last peak of each waveform and the bottom;
4) The time interval t_1 : the time interval between the bottom point and the first peak point;

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In order to determine the discriminability of the four features and the weight p_j of each parameter, a statistical analysis was performed. A ratio F_j between the interclass and intraclass variabilities as defined in Eq. (1) was calculated. The higher the ratio, the more discriminant the feature is.

$$F_j = \frac{Interclass\ Variability}{Intraclass\ Variability} = \frac{\sqrt{\frac{1}{N}\sum_{i=1}^{N}(\overline{y_{ij}} - \overline{u_j})^2}}{\frac{1}{N}\sum_{i=1}^{N}\sqrt{\frac{1}{K_i}\sum_{k=1}^{K_i}\left(y_{kij} - \overline{y_{ij}}\right)^2}} \quad , \qquad (1)$$

where F_j is the ratio for the jth feature, $\overline{y_{ij}}$ is the mean of the jth feature of the ith subject, $\overline{u_j}$ is the mean of jth feature, y_{kij} is the jth feature of the Kth pulse of the ith subject, N is the number of subjects, and K_i is the number of pulses used for feature extraction from the ith subject.

The verification was carried out by comparing the sample vector obtained at different periods of time with the template feature vector. The final decision was made based on the Euclidean distance d , combined with the weight p_j of each feature parameter,

$$d = \sqrt{\sum_{j=1}^{L} p_j (x_j - t_j)^2} \quad , \qquad (2)$$

where L being the dimension of the feature vector, p_j the weight coefficient which is determined by the percentage of F_j distributed to the jth feature, x_j the jth component of the sample feature vector, and t_j the jth component of the template feature vector.

The Euclidean distance d between each sample vector and each template vector was calculated. The decision of the verification was done on the subject with the minimum value of d .

III. RESULTS

Only one out of the 17 subjects could not be verified correctly, which yielded a successful rate of 94%. The only one error was attributed to the poor quality of the signals from the subject, perhaps due to respiration and motion artifacts, which resulted in a large standard deviation (SD) of the template feature vector and a large value of modified Euclidean distance d .

IV. DISCUSSION

A new idea of using PPG signals for human verification is proposed in this paper. The verification is accomplished by simply putting the fingertip on the PPG sensors. The result of our study shows that the PPG signals have predominant characteristics that can be used to identify different persons. According to our experimental results, the rate of correct verification can reach up to 94% (one out of seventeen in error).

However, it should be pointed out that PPG signals vary substantially under different conditions, especially under different pressures. Further research based on large database must be done in the future to improve this new method before it can be finally put into use in practice.

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