

Can Biological Motion be a Biometric?

Peeta Basa Pati ¹, A G Ramakrishnan ²

Department of EE, Indian Institute of Science
Bangalore, INDIA – 560012, pati@ee.iisc.ernet.in

² Department of EE, Indian Institute of Science
Bangalore, INDIA – 560012, ramkiag@ee.iisc.ernet.in

Abstract

Biological motion has successfully been used for analysis of a person's mood and other psychological traits. Efforts are made to use human gait as a non-invasive mode of biometric. In this reported work, we try to study the effectiveness of biological gait motion of people as a cue to biometric based person recognition. The data is 3D in nature and, hence, has more information with itself than the cues obtained from video-based gait patterns. The high accuracies of person recognition, using a simple linear model of data representation and simple neighborhood based classifiers, suggest that it is the nature of the data which is more important than the recognition scheme employed.

Key Words: *Biological motion, biometric, person identification, principal component analysis.*

1. INTRODUCTION

Biometrics are methods to automatically recognize a person based on a physiological or behavioral characteristic. Vision based human identification at a distance, from the person centric biometric traits, is gaining more and more popularity for various reasons. Examples of human traits used currently for biometric recognition include fingerprints, speech, face, handwritten signature. Face recognition has already been used in numerous commercial and law enforcement applications. All these traits are invasive techniques as they require a person's co-operation for its use. This is possible in application environments where the person has a genuine interest in getting verified for his/her identity. But there are situations where the person's motive could be to evade being identified. In such situations, non-invasive techniques are considered to be of more help. A person's gait pattern is such a trait.

Gait is a new biometric aimed to recognize subjects by the way they walk. Though the gait patterns of a person has been considered to be pregnant with person centric information, very limited research has been conducted to either find or prove its efficacy. However, with recent stress on non-invasive biometric traits, re-newed interest is generated in exploring gait as a possible solution to this situation [1], [2] and [3]. As the research is aiming to develop more efficient and robust techniques for recognition of a person from his/her gait patterns, Pillips *et. al.* [4] have made efforts to study the challenges and problems of collection of data and development of baseline algorithms for the same. However, these reported

researches have used the video frames of the gait of a person for the identification tasks. Thus, they try to identify the person from the 2D projected data of a person's walking.

Johansson [5] and [6] attached small point lights to the main joints of a person's body and filmed the scene as the person made movements in a dark room. He demonstrated that these lights, visible in front of a dark background, created a strong impression of a person's movement. Such impression could not be created from the static frames of the film, as these frames contained only dots of light spread across the frame. However, when these frames were joined together and displayed as a movie, it had the impact of making an impression of a human movement of a particular nature. He termed this kind of motion as "**biological motion**" and convincingly demonstrated the compelling power of this motion of some light points, each representing a joint in the body, to the psychological community.

Troje [7] has tried to decompose such biological motion on a linear framework. His data set contains the 3D walking data of people collected with the help of a Vicon motion capture system. He has employed a eigen analysis of such data and has demonstrated that such a linear model of the biological motion not only is efficient in modeling the motion pattern, but also is very efficient in synthesizing the person specific gait patterns. Later, Troje *et. al.* [8] have demonstrated that such biological motion data representing people's gait is effective in identification of a person. Zhang and Troje [9] have taken the 2D signatures of the above mentioned 3D biological motion data and have shown it to effective for person recognition in a view invariant scenario as well.

In the present paper, we try to demonstrate that the model proposed by Troje [7] is effective for automatic recognition of a person from the gait traits of the person, using the biological motion data.

2. DATA AND SYSTEM DESCRIPTION

Motion data from 81 people, 41 males and 40 females, has been collected. Most of these people were the staff and students of Ruhr-University, Bochum, Germany in the age range of 20 to 40 years. Data were recorded using a motion capture system (Vicon; Oxford Metrics, Oxford, UK) equipped with 9 CCD high-speed cameras. The system tracks the three-dimensional trajectories of the markers with spatial accuracy in the range of 1 mm and a temporal resolution of 120 Hz. A set of 38 retro-reflective markers was attached to their body

which was later reduced to 15 marker points representing the 15 major joints in a human body. A detailed description of the mechanism of data collection is present in [7].

Each person’s walking data was segmented into 10 slots of variable length. Some of these walking samples of data had overlapping regions in the walking cycles of a person. 5 instances of such segmented walk samples were used as training samples while the rest 5 samples were used for testing purpose. Every point on the body is represented with a 3 dimensional vector. It consists of the x-, y- and z-dimensional position of that joint in the 3D space. Each frame of motion, called a posture, has 15 joints on the body and, thus, has 45 data points. Thus, we have 45 dimensional time-series data to represent the person’s gait pattern.

A linear gait model as proposed by Troje [7] is adapted for this proposed scheme. A person’s walking data could be of variable length and hence has a variable number of postures. Lets assume a person’s data has N postures. The model applies PCA separately to the postures of each walker. Thus, each posture p could be decomposed as a linear combination of an average posture, p_0 and a linear combinations of the principal vectors.

$$\mathbf{p} = \mathbf{p}_0 \mathbf{p}_0 \mathbf{p}_0 \mathbf{p}_0 + \sum_i c_i \mathbf{p}_i^{(1)}$$

with p_i denoting the i^{th} principal component and c_i denoting the respective score. Troje [7], besides demonstrating that first four principal vectors are efficient enough to represent a person’s gait, has also shown that the score vectors of each of the first principal vectors are sinusoidal in nature. Thus, he states that it is sufficient to store the average posture p_0 and the first four principal vectors, p_i ; $i = 1, 2, 3$ and 4 and the parameters of the associated sinusoid. From this model he could generate the walk of the person and has demonstrated that human observers have identified such walks with 80% accuracy from the frontal view. However, for our purpose it suffices to have the model only.

In the proposed scheme, we have considered a principal vector p_i with its associated sinusoidal parameters (frequency, phase and amplitude) as a vector element. For the average posture, such a vector element consists of the p_0 and the associated sinusoidal parameters are zero values. Thus, for me each vector element, v_i is 48 dimensional and I have 5 such vector elements. We take any one or a combination of more than one such vector elements, v_i ’s to form a feature vector, v . This feature vector, v , is the representative of a person’s walk for me. We use this feature vector for the recognition of a person.

Nearest neighbor classifier (NNC) and k -near neighbor classifier (k -NNC) are employed to take decision on the identity of the person. For, k -NNC, we have used the value of k to be 3. A modified version of the k -NNC, mk -NNC [10] is also employed for the purpose.

3. EXPERIMENTAL RESULTS

In the first experiment, we tried to recognize each person by use of one of the vector elements, v_i , $i = 0, 1, 2, 3, 4$. The

TABLE 1: RECOGNITION ACCURACY FOR THE PERSON IDENTIFICATION EXPERIMENT USING ONE OF THE VECTOR ELEMENTS, v_i , ONLY. HERE, $i = 0$ STANDS FOR THE VECTOR REPRESENTING THE AVERAGE STATIC POSTURE WHILE i FROM 1 TO 4 REPRESENT THE FIRST FOUR PRINCIPAL VECTORS AND THEIR CORRESPONDING SINUSOIDAL PARAMETERS, RESPECTIVELY. $k = 3$.

| | p_0 | p_1 | p_2 | p_3 | p_4 |
|-------|-------|-------|-------|-------|-------|
| NN | 100.0 | 98.3 | 98.0 | 96.5 | 93.1 |
| k-NN | 99.3 | 86.9 | 79.3 | 81.0 | 78.8 |
| mk-NN | 100.0 | 95.6 | 95.3 | 94.6 | 91.4 |

TABLE 2: RECOGNITION ACCURACY FOR THE PERSON IDENTIFICATION EXPERIMENT USING A COMBINATION OF THE VECTOR ELEMENTS. HERE, v_{0-i} STANDS FOR THE FEATURE VECTOR CREATED BY APPENDING THE VECTOR ELEMENTS v_0, \dots, v_i . $k = 3$.

| | v_{0-1} | v_{0-2} | v_{0-3} | v_{0-4} |
|-------|-----------|-----------|-----------|-----------|
| NN | 99.3 | 99.3 | 98.3 | 98.3 |
| k-NN | 96.5 | 97.0 | 95.6 | 92.4 |
| mk-NN | 99.0 | 98.8 | 98.0 | 96.8 |

results of this experiment is presented in the table 1.

In the next experiment, an effort is made to recognize people using a combination of the vector elements. In this experiment, the feature vector, v , has the vector elements from v_0 to v_i , $i = 1, 2, 3$ and 4. Thus, a feature vector v is represented as v_{0-i} which means vector elements, v_i , from 0 to i are appended to form the feature vector. Here again, the three near neighborhood based classifiers are used.

In the next experiment, a variation to the value of k is made to determine the optimal value of k for this experiment. Table 3 presents the results for this experiment.

4. CONCLUSION & DISCUSSION

A scheme for automatic identification for persons using biological motion data is presented here. From the reported results it could be observed that a nearest neighbor classifier with a linearized model of the gait pattern of a person has a very high efficiency for recognition of the person. Thus it could be concluded that, gait satisfies as a biometric trait.

Though, the use of biological motion data as a non-invasive biometric trait has a promising future, however, the collection of this data with present available technology is not possible without a person’s co-operation. This accuracy achieved with this 3D data and its linear model, far out performs any of the techniques reported using the video based gait biometric. So it is important to improve the technology of data collection besides exploring ways to enhance the efficiency of various schemes using video data for gait analysis.

TABLE 3: RECOGNITION ACCURACY FOR THE PERSON IDENTIFICATION EXPERIMENT USING A COMBINATION OF ALL THE VECTOR ELEMENTS ($v = v_0, v_1, v_2, v_3, v_4$). HERE, THE VALUE OF THE PARAMETER k IS VARIED TO FIND ITS OPTIMAL VALUE.

| | $k = 2$ | $k = 3$ | $k = 4$ | $k = 5$ |
|-------|---------|---------|---------|---------|
| k-NN | 98.3 | 92.4 | 75.6 | 58.0 |
| mk-NN | 98.3 | 96.8 | 91.6 | 79.0 |

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