Spatio-temporal 3D Gait Recognition

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1 Introduction

In the current security climate, the need to identify unknown subjects quickly and efficiently has never been greater. In a real-world open-space scenario, it is often difficult to ensure the compliance of an unknown subject and the use of invasive contact biometrics such as fingerprint, iris or DNA would prove to be difficult and would cause congestion problems. For such a scenario, biometrics that can be observed from a distance such as face, ear and gait would prove the most useful. Facial recognition is a well understood problem, along with its relative merits and limitations[5]. The way in which one walks is often referred to as their *gait*; it is relatively easy to observe one's gait in a non-obtrusive manner and at a distance[1]. In the past, many different gait analysis techniques have been proposed[3]; although the vast majority of the algorithms have concentrated on two-dimensional video data. The use of three-dimensional video data removes problems such as viewpoint dependence and self-occlusion, which presents the opportunity to implement analysis techniques that exploit the additional information available from a three-dimensional represention of the subject. The shape of one's ear is a new and promising biometric, with the major advantage of showing very little variance once the subject has reached maturity. No biometric is perfect, all have a probability of incorrect classification, most are prone to various forms of attack or forgery and occlusion can sometimes make it difficult to collect a specific biometric. The use of several biometrics for classification is often referred to as *fusion*; the fusion of multiple biometrics results in a far more robust recognition system that can cope with partial occlusion and provides a significantly lower chance of incorrect classification.

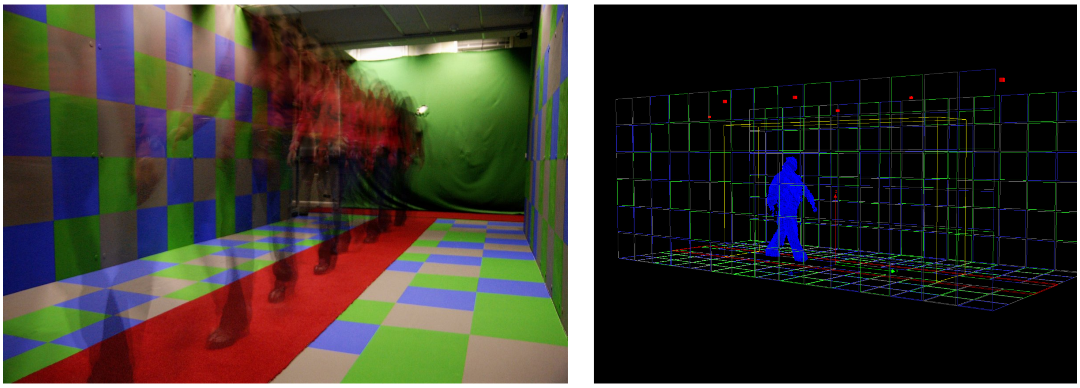
2 Current state of the system

The University of Southampton Biometric Tunnel was designed to allow the simultaneous capture of a subject's face, ear and gait[2]; the use of multiple biometrics enables the use of data-fusion techniques to improve recognition performance. Figure 1(a) shows the overall appearance of the facility. The tunnel provides a controlled environment to facilitate measurements in an efficient manner allowing four samples of a subject to be collected within two minutes.

A pair of break-beam sensors are placed at the entry and exit points of the tunnel to start and stop the capture process. Two high-resolution video cameras are placed in the tunnel to capture the subject's face and one of their ears as they walk through the tunnel. Eight firewire video cameras are placed around the perimeter of tunnel area and capture the subject walking through the tunnel area at 30 frames per second. A sequence of three-dimensional silhouettes are derived by visual hull reconstruction using the background segmented silhouettes from the video data. The resulting binary silhouettes have a voxel size of 1cm^3. Figure 1(b) shows an example 3D reconstruction from the system. Very little research has been done into the use of three-dimensional data for gait analysis; it is hoped that the data captured from the system will give a unique insight into 3D gait.

During data acquisition, only the raw camera data is stored, and all processing is carried out subsequently on the raw data. This approach eases development and evaluation of the various algorithms and also allows auditing of the system.

A small dataset containing forty gait samples from ten subjects was acquired using the biometric tunnel to test it's functionality. It was decided to use the well known average silhouette technique to test the performance of the system; 2D silhouettes were created using an orthogonal projection through the sagittal plane, then the average silhouette[4] was found from one complete gait cycle of the projected silhouettes. A correct classification rate of 97% was achieved, with the single error caused by data capture problems — rather than inherent problems with gait. This confirms that the system operates correctly and its captured data is useful.



(a) Subject walking through tunnel (b) Example Reconstruction

Figure 1: The Biometric Tunnel

A study has been conducted to investigate the potential for the detection of malicious intent. A small number of subjects were filmed carrying concealed containers around their upper body, filled and empty. This resulted in a difference in mass of 4 kilograms; we were able to show that there was a significant difference above chance in the subject's gait as measured by the average silhouette.

3 Ongoing work

Plans are underway to create a large multi-biometric dataset, containing over three-hundred subjects. Covariates will include clothing, footwear and a range of carried or concealed items. This will present a unique opportunity to investigate whether gait and multi-biometric fusion can be used in a large scale environment to assist identification. It is hoped that this *unique* dataset will give new insights into state of the art gait analysis, and whether gait is an applicable biometric for large scale identification.

The addition of several cameras placed near floor level will facilitate investigation into whether the use of extra cameras will infact improve performance and hopefully lead to better understanding of gait and its fundamental characteristics.

Work is also being carried out moving the system towards low-latency near real-time processing, reconstruction and ultimately recognition; this will help to improve the throughput of the system when capturing a large number of subjects and will also help to demonstate that it is possible to successfully use a multiple biometric system in a real environment.

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