New Area Based Metrics for Gait Recognition

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Gait is a new biometric aimed to recognise a subject by the manner in which they walk. Gait has several advantages over other biometrics, most notably that it is a non-invasive and perceivable at a distance when other biometrics are obscured. We present a new area based metric, called gait masks, which provides statistical data intimately related to the gait of the subject. Early results show promising results with a recognition rate of 90% on a small database of human subjects. In addition to this, we show how gait masks can also be used on subjects other than humans to provide information about the gait cycle of the subject.

Introduction

Gait is a new biometric primarily aimed at recognising a subject by the way they walk. Gait has several advantages over other biometrics. It is difficult to disguise (in fact disguising ones gait only has the effect of making oneself look more suspicious!) and gait can be recognised from a large distance where other biometrics fail and it is a non-invasive technique.

Medical work from Murray [1,2] supports the view that if all gait movements are considered then gait is unique. Psychological research from Johansson [3] shows that humans have a remarkable ability to recognise different types of motion. Johansson performed an experiment with moving light displays attached to body parts and showed that human observers can almost instantly recognise biological motion patterns, even when presented with only a few of these moving dots.

A more recent study by Stevenage [4] again confirmed the possibility of recognising people by their gait, but now using video. The study confirmed that, even under adverse conditions, gait could still be perceived. Psychological and medical studies therefore clearly support the view that gaits can be used for recognition.

Overview

This report will briefly look at previous approaches to gait recognition and present a new area based metric for gathering statistical data intimately related to the nature of gait. The technique will be performed upon both human and animal silhouettes and differences between the two will be examined.

Figure 1 shows an example of silhouette extraction from a human gait sequence. In this report we assume that the subject is walking normal to the camera's plane of view. The silhouettes are extracted using a combination of background subtraction and thresholding.

Fig. 1. Single Image from Gait Sequence converted to a silhouette

Previous approaches to gait Recognition

Approaches to gait masks can be divided into two categories, model based and holistic. Holistic approaches aim to derive data from the human walking sequence that is similar for each subject but different for different people. Examples of this type of approach include Murase and Sakai [5], Huang [6] and Little and Boyd [7]. Model based approaches aim to explicitly model human motion and rely on human movement being tracked and a model being fitted to the image data. An example of this approach is by Cunado [8]. Performance of this technique was good with high recognition rates, however the computational costs of this approach are high.

Gait masks using Human Silhouettes

Gait masks are a new approach to gait recognition aiming to combine some of the elements of both the holistic and model based approaches. The disadvantage of traditional holistic approaches is that they simply derive data that is different for each class. They have no "knowledge" of what each class represents; given pictures of an elephant rather than a human subject and a traditional holistic approach would try to classify the subject in the same way. In contrast, model based approaches directly recognise gait by using equations, however this would be difficult to extend to non-human gait.
Gait masks aim to combine holistic and model-based approaches by using statistical data that is intimately related to the nature of gait. Gait masks are used to transform human silhouettes into information directly related to the gait of the subject. **Figure 2** shows an example of some gait masks.

Fig. 2. Sample gait masks

Each gait mask aims to isolate a portion of the image and measure the area change within that area. The gait masks were chosen intuitively to represent area of the image likely to provide meaningful data about the gait of a subject. **Figure 3** shows examples of the results from Figure 2 on human silhouettes.

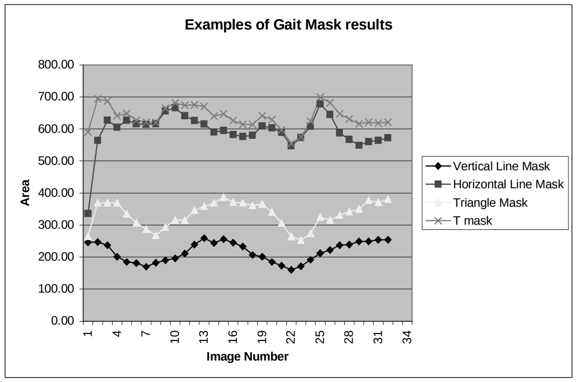

Fig. 3. Sample Gait Mask Results from one subject using 4 separate gait masks

The gait masks are combined with the silhouettes using the procedure detailed below. The set C_p labels each set of sequences of each individual person). Each item in the set ($\mathbf{S}_{P_j}$ **)** represents sequence *j* of person *p*.

$$C_p = \{\mathbf{S}_{p_j}\} \quad \textbf{(1)}$$

The set T_{p_j} represents the individual images (silhouettes) in each sequence from each subject. Each member of the set $\mathbf{S}_{p_j}(t)$ represents a specific image (*t*) as a vector from person *p* sample *j*.

$$T_{p_j} = \{\mathbf{S}_{p_j}(t)\} \quad \textbf{(2)}$$

The set *K* represents the set of gait masks, M_n, where each member represents each individual gait mask, each represented as a vector.

$$K = \{\mathbf{M}_n\} \quad \textbf{(3)}$$

For each gait mask, *n*, and each person *p,* and each sample *j*, **R** is the projection of each sample into a new space using gait mask $\mathbf{M}_n$.

$$\mathbf{R}_{np_j}(t) = \mathbf{M}_n \cdot \mathbf{S}_{p_j}(t) \quad \textbf{(4)}$$

The “vertical line mask” produces output that is sinusoidal in nature. The peaks in the graph represent when the legs are closest together and the dips represent where the legs are at furthest flexion. The gait masks are therefore providing statistics that are intimately related to the mechanics of gait.

It is possible to use these graphs, produced using the gait masks, to provide recognition capabilities. By comparing the graphs using least squares and using a database of all samples and finding the closest match, recognition rates of over 80% are possible (dependent on the mask chosen). Since the subject may start his walking cycle at a different point, the graphs are compared at all possible shifts along the axis and the maximal correlation is taken. **Table 1** shows the recognition rates of various gait masks using this technique.

Table 1. Recognition results from various gait masks.

Gait Mask	Recognition Rate
Horizontal Line Mask	71%
Vertical Line Mask	83%
Top Half Mask	58%
Right Half Mask	42%
Left Half Mask	33%
Bottom Left Mask	42%
Bottom Right Mask	38%
Triangle Mask	63%
T Mask	71%
Bottom Half Mask	54%
Mid Triangle Mask	83%

The results from the vertical line mask (recognition rate 83% on a database of six subjects with four samples each) were most encouraging as the output from this mask was directly related to the gait of the subject. However, once the input silhouettes were corrupted by even small amounts of noise the recognition rate dropped dramatically. Consequently, we decided to look at the results from this mask in greater detail.

To recognise a subject by their gait we are primarily concerned with the AC component of the data, that is the temporal component of the data. The DC component of the data represents static data about the subject; this could easily change due to the subject carrying something for example. The temporal nature of gait should be consistent amongst samples of the same person.

Figure 4 shows the sinusoidal patterns generated using the vertical line mask from 4 different people. Using the least square correlation technique, poor recognition rates were achieved. Using a more sophisticated technique, Canonical Analysis (CA), resulted in a dramatic performance increase.

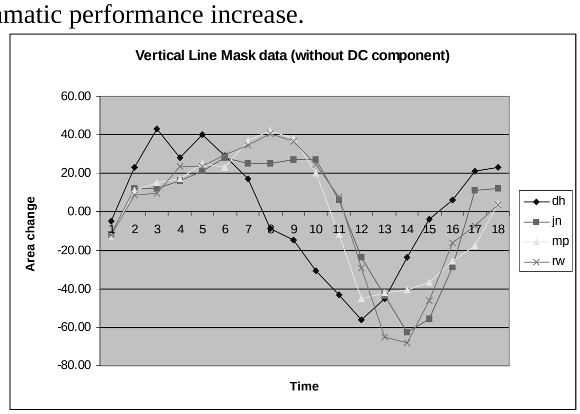

Fig. 4. Sinusoidal Patterns from 4 people using Vertical Line Mask

CA was used to produce a set of axes on which to project the data (the canonical axes). The data was divided into a set of training and test data. The training data consisted of three samples from each of the six subjects. The centroid of each subject in canonical space was recorded and the distance between this centroid and the test data was also noted. This was then used to calculate the recognition rate on the

SOTON database (which consists of 6 subjects with 4 samples each). Initial results were promising with a recognition rate of over 80% and good class separability.

To further evaluate the performance of the new technique the system was also tested on a larger database consisting of the SOTON database and each of the samples corrupted with various amounts of noise (1%, 2%, 4% and 8% noise). Performance remained high with a recognition rate of over 80% even in the presence of noise.

Gait masks using animal data

Gait masks can be used to quickly distinguish between the motion of a biped (e.g. a human) and a quadruped. The single vertical line mask was used to provide data to discriminate between human subjects. Using this technique with animal data yields ineffectual results that provide no information about the gait of the subject. This is simply because the center of a quadruped provides very little temporal information. **Figure 5** illustrates this.

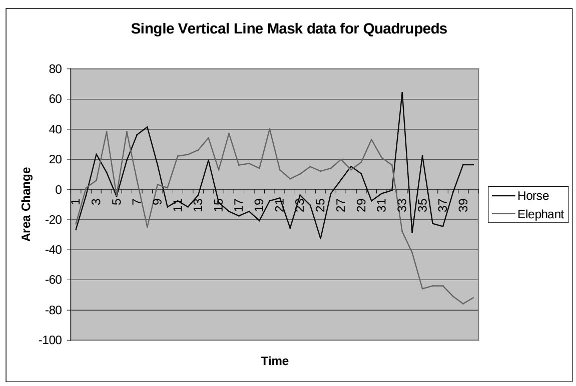

Fig. 5. Vertical Line Mask data using Animal Silhouettes

To provide information more relevant to the subject being analysed the gait masks were modified. Two vertical line masks were used, instead of the single vertical line mask used for human gait. By using these new gait masks it is possible to extract information relative to the subject being studied. **Figure 6** illustrates this:

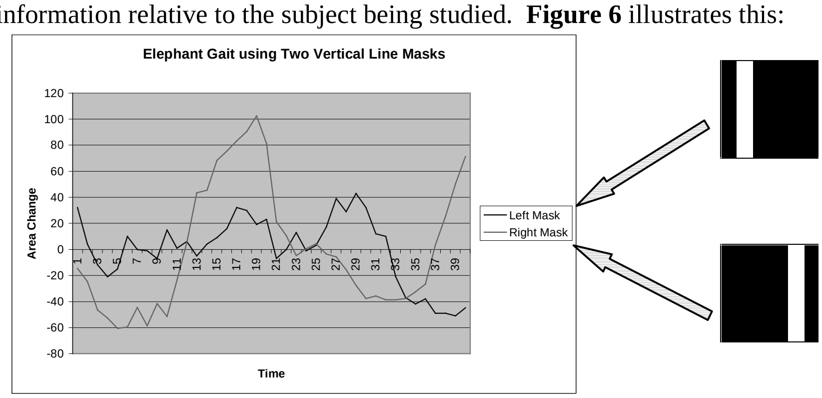

Fig. 6. Gait of an elephant described by Two Vertical Line Masks

By using the right mask the sinusoidal pattern of motion is clearly evident. The left mask data is not of a sinusoidal nature which is due to the trunk of the elephant swinging across the legs. This shows how the gait masks need to be adapted for each animal analysed. It also illustrates how gait masks can be used to provide information about gait for subjects other than humans.

Conclusions

We have presented a new area based metric for gait recognition that produces good results on a small database. We have shown (by removing the DC component of the data) that recognition is possible by only using the temporal components of the silhouette sequence. The technique produces encouraging results on a database of human subjects with recognition rates of over 80% even in the presence of noise.

Additionally we have shown the basic premise of gait masks is applicable to areas other than using human gait as a metric. Gait masks can provide information about the walking cycle that could be used to provide information such as the cadence of the subject.

References

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