An Algorithm for Recognising Walkers

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Abstract

In this paper, we present an algorithm to recognise walking people, based upon extracting the spatio-temporal trajectories of the joints of a walking subject.

Subjects are filmed with LEDs attached to their joints and head such that the lights are the only objects visible in the film sequence – a method known as moving light displays (MLDs). Lights are tracked through the sequence of frames and are labelled based on human walking behaviour. In the case of self-occluded lights, a radial basis function neural network was trained and used for predicting the positions of occluded markers. The trajectory of each MLD is transformed using a 2D fast Fourier transform. Components of the FFT for all MLDs are considered as the feature vector of each subject. This is fed to a multi-layer perceptron (MLP) for classification.

The algorithm was used to recognise four subjects – 3 males and 1 female. For each subject, 10 gait cycles were used for training and 5 for testing the MLP. Backpropagation was used to train the network. Results show that the algorithm is a promising technique for recognising subjects by their gait.

Keywords
Human motion perception – Gait recognition – Moving Light Displays – Neural Networks.

1 Introduction

The fact that one can identify a friend at a great distance is an impressive human capability, as at great distances familiarity cues such as facial features, hair style, clothing, etc. are practically obscured. Human gait motion has been of interest to researchers for decades. The development of photographic methods of recording a series of displacements of locomotion by the end of the nineteenth century encouraged researchers from different disciplines to study human motion and motion perception.

In the early experiments done by Marey [12], he observed an actor dressed in a black body stocking with white strips on his limbs. He studied the motion through observing the traces left on photographic plates as the actor walked laterally across the camera – an approach later known as *Moving Light Displays* (MLD). In [2], Braune & Fischer used a similar approach to study human motion, but they used light rods attached to the actor's limbs instead.

MLDs are image sequences containing only selected points of a 3-dimensional object in each frame. The method requires attaching a reflective tape or a light bulb to the joints/points of interest. If a reflective tape is used, then a strong light is focussed on the object. A video sequence is then recorded in which only patches of light can be seen by the viewer – see fig. 1.

Figure 1: a single frame of a walker having MLDs on joints and head

In 1973, Johansson [10], a psychophysist who was particularly interested in human motion perception, used MLDs in his experiments. He deduced that viewers cannot recognise any information from a single frame as in fig. 1, but can well recognise gaits when watching a sequence of such frames representing different activities such as walking, climbing stairs, dancing, etc. Cutting – Johansson's student – showed that using MLDs, one can recognise one's friends [5] and can determine the gender of a walker [6].

So, if humans can perceive gait with such a reduced spatio-temporal sequence, why not try to give a similar capability to machines?

Having a well defined structure that can be naturally decomposed into a hierarchy of parts, the human body was first modelled by Marr and Nishihara [13], a 3D model that was later used by Hogg [9]. Hogg proposed an approach that generated various poses of the given 3D model, projected them into the image and matched them with image edge data. His tracking procedure was based on examining the successive frames and averaging the size of clusters of points that are moving between frames with the assumption made about the position of the ground plane with respect to the camera.

Rashid [14] presented a computer system for MLDs which was able to track and cluster points belonging to independently moving objects. His tracking algorithm was based on the velocity of each point in a frame; he selected a correspondence that minimised the sum of the differences between the expected position and the actual position of a point in the following frame. Rashid filmed sequences of wire-frame figures moving so as to simulate a walking man, a dog and a moving toy-truck. The system was used successfully with one and two walking men, a man walking a dog and the moving toy-truck. Goddard [8] built a system that can recognise the gaits walking, jogging and running. He used the joint angles and angular velocities of the points of MLDs as input to his system. Bullpit & Allinson [3] describe a method that uses spatio-temporal neural

networks to interpret motion in MLDs. In [7], the authors use object shape features and a spatio-temporal classification method based on a hidden Markov model to build an automated system for MLD recognition.

In this paper, we present an algorithm for recognising walking persons based on MLD sequences using 2D fast Fourier transform.

2 Experiments

2.1 Environment, Data Collection and Preparation

The data collected for our experiments were taken according to the following conditions:

- Subjects are carrying no loads, i.e. only free normal walking is considered.
- Sequences are taken for subjects walking towards a stationary camera, i.e., the back and forth motion of the walker is not considered.
- Thirteen light bulbs are attached to each subject in the following distribution {1 Head, 2 Shoulders, 2 Elbows, 2 Wrists, 2 Hips, 2 Knees, 2 Ankles}

Data collection starts with filming the subject, sampling the film to a sequence of frames of still grey-level images and then estimating the centre of the blobs.

2.2 Scenario

Having estimated the coordinates of the MLD points in the first frame, the following scenario is adopted.

1. Follow the points through the frames estimating the coordinates of blobs and hence find the locus of the spatio-temporal trajectory of each point.
2. Extract the features from the trajectories obtained.
3. Use the feature vectors for recognition.

2.3 Implementation

2.3.1 Tracking and Labelling

This part is concerned with following the corresponding lights from one frame to the next and drawing the locus of the trajectories of each marker. Different tracking algorithms are mentioned in literature, varying in their level of complexity and accuracy – see for example [1] and [4]. Our algorithm uses a simple, yet reliable technique for tracking. The procedure assumes smooth motion. In the first frame having a window of fixed size is placed around each marker position, the Euclidean distance of each pair of coordinates of two successive frames is calculated for all markers lying inside the window and the coordinate pair with the shortest distance is considered as the winning candidate. In case of having ambiguities, i.e. more than one winning candidate, the choice is then based on the knowledge of human body structure and walking behaviour. For self-occluded markers, e.g. the hip marker hidden due to the arm swinging back and forth, we train a radial basis function neural network to predict the position of the hidden marker [11]. Figure 2 shows the locus of the trajectory of the head of a subject in both the $x-$ and $y-$directions.

2.3.2 Feature Extraction – 2D FFT

The features extracted are the components of the 2D FFT of each trajectory of each point – see fig.3. Components are then averaged by dividing their amplitudes by the number of samples.

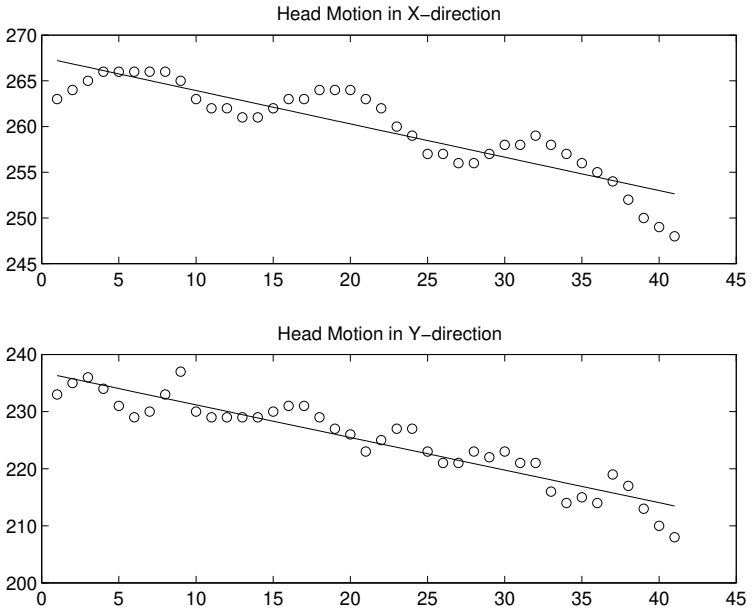

Figure 2: spatio-temporal trajectories of the head of a subject

2.3.3 Dimensionality Reduction

Although it might be ideal to consider all components of the Fourier transform, it is certainly not practical, e.g. for a one gait cycle[1] sequence, $\sim$ 16 frames are captured, i.e., 8 feature components for each of 13 points, giving 104 features, which is a huge number of input nodes for a neural network for such a simple classification task. Criteria must be considered to reduce the dimensionality of the features.

Principal component analysis applied to examine the relevance of the Fourier components showed that higher order harmonics are of lower relevance. Hence, only the fundamental and the next few harmonics are considered as features.

Another kind of reduction can also be considered, based upon the nature of human walking and the coordination of the movement of the joints. Statistically speaking, one should estimate the value of the correlation coefficients between the different points. Points that have strong correlation with other points can be discarded. The correlation criterion requires large data sets to draw general rules for human movement behaviour.

2.3.4 Recognition

A neural network is trained using the fft components of the points for several sequence sets. Then, the network is used for recognition. This phase is the last phase of the algorithm. A block diagram of the proposed algorithm is illustrated in fig. 4

3 Results and Discussion

The algorithm was applied to recognise four subjects – three males and a female. Based on principal component analysis, for each trajectory, we chose the fundamental and the next two harmonics as input to the neural network. The architecture of the network was: 39 input nodes (3 components $\times$13 points), 12 hidden nodes and 4 output nodes. Backpropagation was used to train the network. We had 15 gait cycle sequences for each subject – ten were used for training and five for testing.

[1] A *gait cycle* is defined as the time interval between two successive occurrences of one of the repetitive events of walking – usually between two heel strikes. [15]

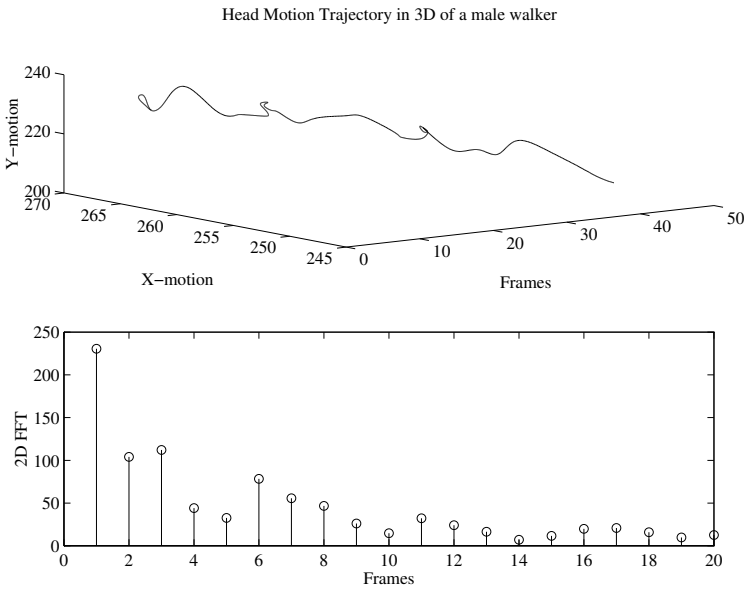

Figure 3: 2D FFT of head trajectory of a male subject

Table 1: Recognition Results for four subjects

Subject No.	Training Recognition Rate %	Testing Recognition Rate %
1 (male)	100	95
2 (male)	100	90
3 (male)	100	100
4 (female)	100	100

Table 1 shows the average recognition results obtained after cross validation of training and testing sets. Results show that the proposed algorithm is a promising technique in recognising people from their gait.

4 Conclusion and Future Work

We have developed a method for recognising people from their walk based on features extracted from the 2-D fast Fourier transform of the trajectories of their major joints. We used a backpropagation network as a classifier.

In future work we aim to take into consideration other walking parameters, e.g., stride length, velocity, etc. and investigate the possibility of having individual walking signatures. We also hope to investigate the motion correlation of different joints so as to deal with the dimensionality problem.

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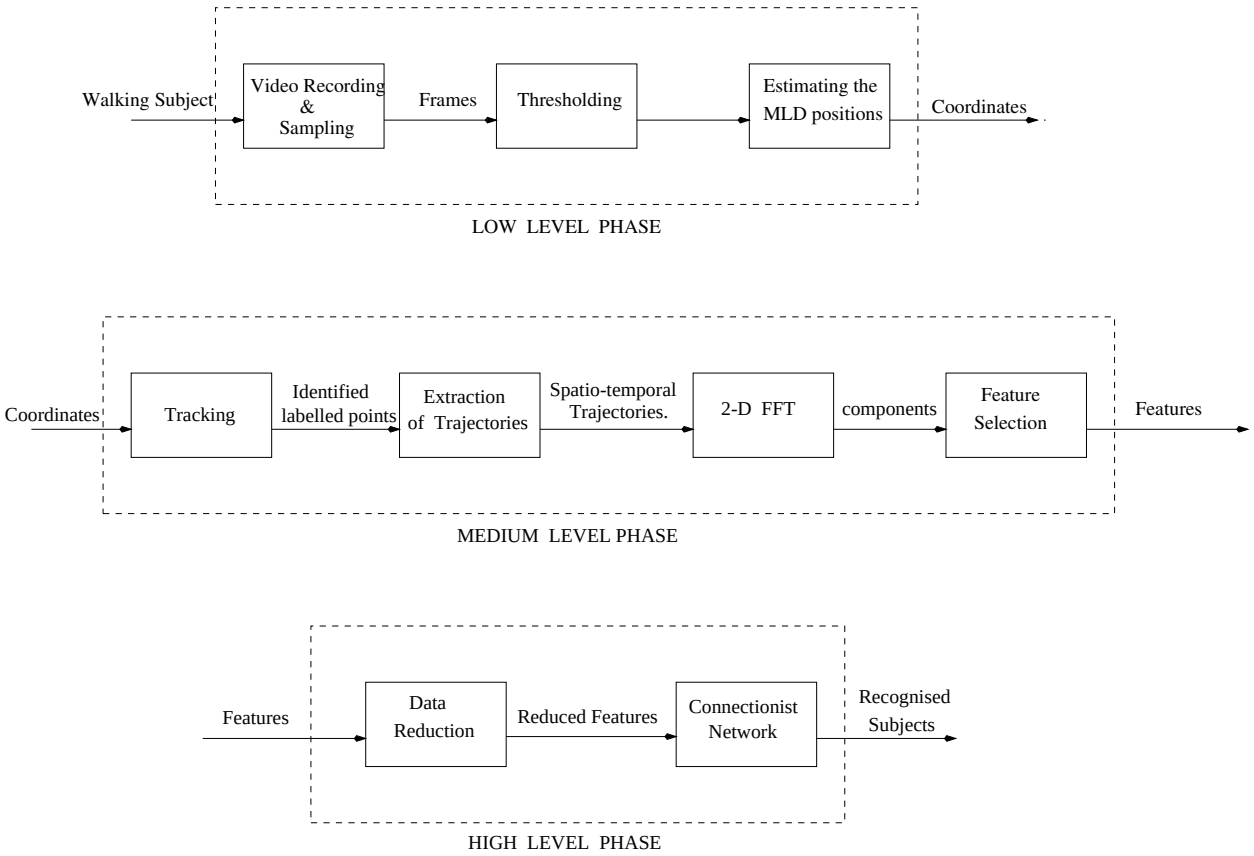

Figure 4: block diagram illustrating the main phases of the algorithm

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