Automatic Gait Recognition by Symmetry Analysis

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Abstract. We describe a new method for automatic gait recognition based on analysing the symmetry of human motion, by using the Generalised Symmetry Operator. This operator, rather than relying on the borders of a shape or on general appearance, locates features by their symmetrical properties. This approach is reinforced by the psychologists’ view that gait is a symmetrical pattern of motion and by other works. We applied our new method to two different databases and derived gait signatures for silhouettes and optical flow. The results show that the symmetry properties of individuals’ gait appear to be unique and can indeed be used for recognition. We have so far achieved promising recognition rates of over 95%. Performance analysis also suggests that symmetry enjoys practical advantages such as relative immunity to noise and missing frames, and with capability to handle occlusion.

1 Introduction

Recently, there has emerged a new application domain of computer vision dealing with the analysis of human images. This includes ear and face recognition, body tracking and hand gesture recognition, to mention just a few. Recently, gait recognition has been added to this domain. As a biometric, gait concerns recognising people by the way they walk. One major advantage of gait over other biometrics (e.g. fingerprints) is that it does not require contact. Further gait is difficult to disguise or conceal, in application scenarios like bank robbery. Currently, gait is also the only biometric at a distance. Though it could be argued that physical condition factors such as drunkenness, pregnancy and injuries involving joints can affect an individual’s motion, these factors are similar in principle to factors affecting other biometrics. The aim of gait recognition is to recognise people regardless of the clothes worn or the differing background. There have been allied studies of gait, notably among these are medical studies, psychological studies, modelling human motion and tracking people. Amongst these, psychologists suggest gait is a symmetrical pattern of motion[2] and that humans perceive gait as unique.

Although gait recognition is a fairly new research area, there is already a number of approaches. In the spatio-temporal approach, which is probably the earliest, the gait signature was derived from the spatio-temporal patterns of a walking person[7]. The different patterns of the motions of the head and the legs in translation and time were extracted. The patterns were then processed to determine the motion of the bounding contours from which a five-stick model was fitted. The gait signature was then
derived by normalising the fitted model in terms of velocity, that is by linear interpolation, and encouraging (85%) recognition rates were achieved.

In [4], optical flow was used to derive the gait signature by analysing the motion content (shape of motion) of a human walking. Generic object-motion characterisation is also another approach where the gait signature is derived from a parametric eigenspace[5] and the approach was applied to a database of seven subjects with ten image sequences each. The recognition rates were 88% and 100% for 8 and 16 eigenvectors, respectively. The approach was extended[3] to use canonical analysis, a model free approach to reduce the dimensionality of the input data whilst optimising class separability. Recently, Shutler et al extended statistical gait recognition via temporal moments [10]. This derived statistics with an intimate relationship to gait, with symmetry properties. In [6], gait signatures were derived from the frequency components of the variations in the inclination of the human thigh. As pendula modelled the periodic motion of the thigh during walking, this again suggests that symmetry analysis is suited to gait recognition.

2 Symmetry and Its Extraction

Symmetry is a fundamental (geometric) property suggesting it to be an important principle of perception[9]. An object is said be to symmetric if its shape is invariant to the application of symmetry operations. Boolean symmetry operations can only assess symmetry when the shape of the object is known in advance, rendering them inefficient. The discrete symmetry operator can estimate symmetricity without the knowledge of the object's shape, unlike feature extraction operators that find a shape by relying on its border. The symmetry transform assigns a symmetry measure to each point in the image and is determined with respect to a given point-symmetry group. It has also been shown that the performance of the symmetry transform is not affected by existence of several objects in the scene[9].

To extract the symmetry of a walking human subject, feature templates are extracted from gait sequences to give template sequences. The symmetry operator uses an edge map of images in the sequences to assign symmetry magnitude and orientation to image points, accumulated at the midpoint of each pair of points.

![Figure 1. The symmetry contribution of edge points P_i and P_j.](image-url)