TOWARDS A MARKER-LESS HUMAN GAIT ANALYSIS SYSTEM

Karl J. Sharman, Mark S. Nixon and John N. Carter
Electronics and Computer Science, University of Southampton, SO17 1BJ, UK
{kjs98r, msn, jnc}@ecs.soton.ac.uk

KEY WORDS: Human Gait Analysis, Dynamic Object Analysis, Volume Intersection, 3D Reconstruction, Computer Vision

ABSTRACT

A non–invasive system is described which is capable of extracting and describing the three–dimensional nature of human gait thereby extending the use of gait as a biometric. Of current three–dimensional systems, those using multiple views appear to be the most suitable. Reformulating the three–dimensional analysis algorithm known as Volume Intersection as an evidence gathering process for moving object extraction gives means to overcome concavities and to handle noise and occlusion. Results on synthetic imagery show that the technique does indeed process a multi-view image sequence to derive the parameters of interest thereby providing a suitable basis for future development as a marker-less gait analysis system.

1 INTRODUCTION

For many years it has been observed that we can identify others by the manner with which they walk; Shakespeare makes several such claims, for example, in *Julius Caesar, ACT I, Scene iii*

Casca Stand close awhile, for here comes one in haste.

Cassius 'Tis Cinna; I do know him by his gait;
He is a friend.

Such claims are now also backed by psychologists whose experiments, commonly using dynamic point–light arrays indicate that individuals can indeed be recognised by their gait. (Nixon et al., 1999) surveys the use of gait as a biometric.

Generalised application for recognising people by their gait mandates research into the development of a three–dimensional analysis system. This system must be able to handle known factors, especially that gait is inherently self occluding: one leg can obscure the other; arms (and apparel) can hide the legs. Further, for recognition to be of application potential, we require a system that is non–invasive, without subject contact. Finally, it is not unlikely that recognition by gait will encounter images of poor quality (as in surveillance videos) suggesting capability to handle noise should be considered at the outset.

The main approaches to three–dimensional vision are well established now. They include laser based range systems, but these are often unsuited to an application which includes the head. Further, application requirements show that video is more suitable, obviating use of laser systems. The video–based three–dimensional systems include shape from a single frame, by texture, defocus, or shading. These all require known assumptions concerning the environment. On the other hand, more recent multiple view techniques appear to be superseding stereo in applications requiring high accuracy with better ability to resolve hidden surfaces. As such, a technique based on multiple views would appear preferential for contactless three–dimensional gait analysis.

Earlier work by Martin and Aggarwal (Martin and Aggarwal, 1983) demonstrated a means of combining multiple calibrated views to generate a surface description of objects. The views were segmented to produce silhouettes whose boundary points were then orthogonally projected through 3D space, producing the *Volume Intersection* (VI). The object was shown to exist within the intersection of these projected views. It was noted that problems existed in the algorithm such as concavities which were later described by the *visual hull* (Laurentini, 1995). Others, including (Potmesil, 1987), used a perspective or conic projection, possibly more appropriate since many of the images used in the investigation of the orthogonal intersection method were actually sourced from perspective views.

Recently a multiview technique has been proposed for three–dimensional moving object analysis. This uses VI separately on each frame and then tracks the object through the sequence (Bottino et al., 1998), but neither uses evidence gathering

Trial	Exact values	Trial using measure $\frac{v}{\sqrt{p}}$	Trial using measure $\frac{v}{p}$
H_0	-12.0, 14.4, 0.0	-12.0, 17.0, 0.0	-12.0, 13.2, 0.0
H_{width}	6.6	7.4	6.2
θ_d	0.0	0.0	0.0
s	1.0	1.0	1.0
H_v	20.0	20.0	20.0
H_{va1} H_{vb1}	0.0, 2.0	0.0, 2.0	-0.5, 2.0
H_{ya1} H_{yb1}	1.6, 0.0	3.6, 1.6	0.2, 1.0
T_0	0.0	0.0	0.0
T_{a1} T_{b1}	0.0, -30.0	0.0, -25.0	0.0, -30.0
Votes, v	3902	5572	3179
Possible votes, p	4714	8326	3654
$\frac{v}{\sqrt{p}}$	58.832	61.065	52.590
$\frac{v}{p}$	0.828	0.669	0.870

Table 3: Extraction results of a walking synthetic human

4 CONCLUSION

We have presented a new formulation of the Volume Intersection method which incorporates grey scale into an evidence gathering technique. It is capable of processing multi–view images of a scene to produce a three–dimensional representation. This algorithm has been shown to be capable of resolving concavities that the silhouette–based VI cannot. The statistical nature of this evidence gathering method now provides noise tolerance to a previously intolerant construction algorithm.

For a synthetic dynamic scene, we have demonstrated that the combination of the three–dimensional scene generation and the parameter estimation algorithms, both of which are evidence gathering techniques, successfully reproduces the parameters for a simple gait model. Increasing the complexity of the model, including incorporating a larger number of harmonics will produce a non–invasive human gait analysis system.

In conclusion, we have therefore described a system that is capable of estimating three–dimensional motion parameters from multi-view images by non–invasive means.

REFERENCES

Bottino, A., Laurentini, A. and Zuccone, P., 1998. Toward non-instrusive motion capture. *Computer Vision – ACCV'98* **2**, pp. 416–423.

Cunado, D., Nash, J., Nixon, M. and Carter, J., 1999. Gait extraction and description by evidence–gathering. *Proceedings of AVBPA 99* pp. 43–48.

Hough, P., 1962. *Method and means for recognising complex patterns*. US Patent, 3,069,654.

Laurentini, A., 1995. How far 3D shapes can be understood from 2D silhouettes. *IEEE Transactions on PAMI* **17**(2), pp. 188–195.

Martin, W. and Aggarwal, J., 1983. Volumetric descriptions of objects from multiple views. *IEEE Transactions on PAMI* **5**(2), pp. 150–158.

Nash, J., Carter, J. and Nixon, M., 1997. *Dynamic feature extraction via the velocity Hough transform*. Pattern Recognition Letters **18**, pp. 1035–1047.

Nixon, M., Carter, J., Cunado, D., Huang, P. and Stevenage, S., 1999. Automatic Gait Recognition. *BIOMETRICS: Personal Identification in Networked Society.* Editors A.K. Jain et al. Kluwer Academic Publishing. pp231–250.

Potmesil, M., 1987. Generating octree models of 3D objects from their silhouettes in a sequence of images. *Computer Vision, Graphics and Image Processing* **40**, pp. 1–29.