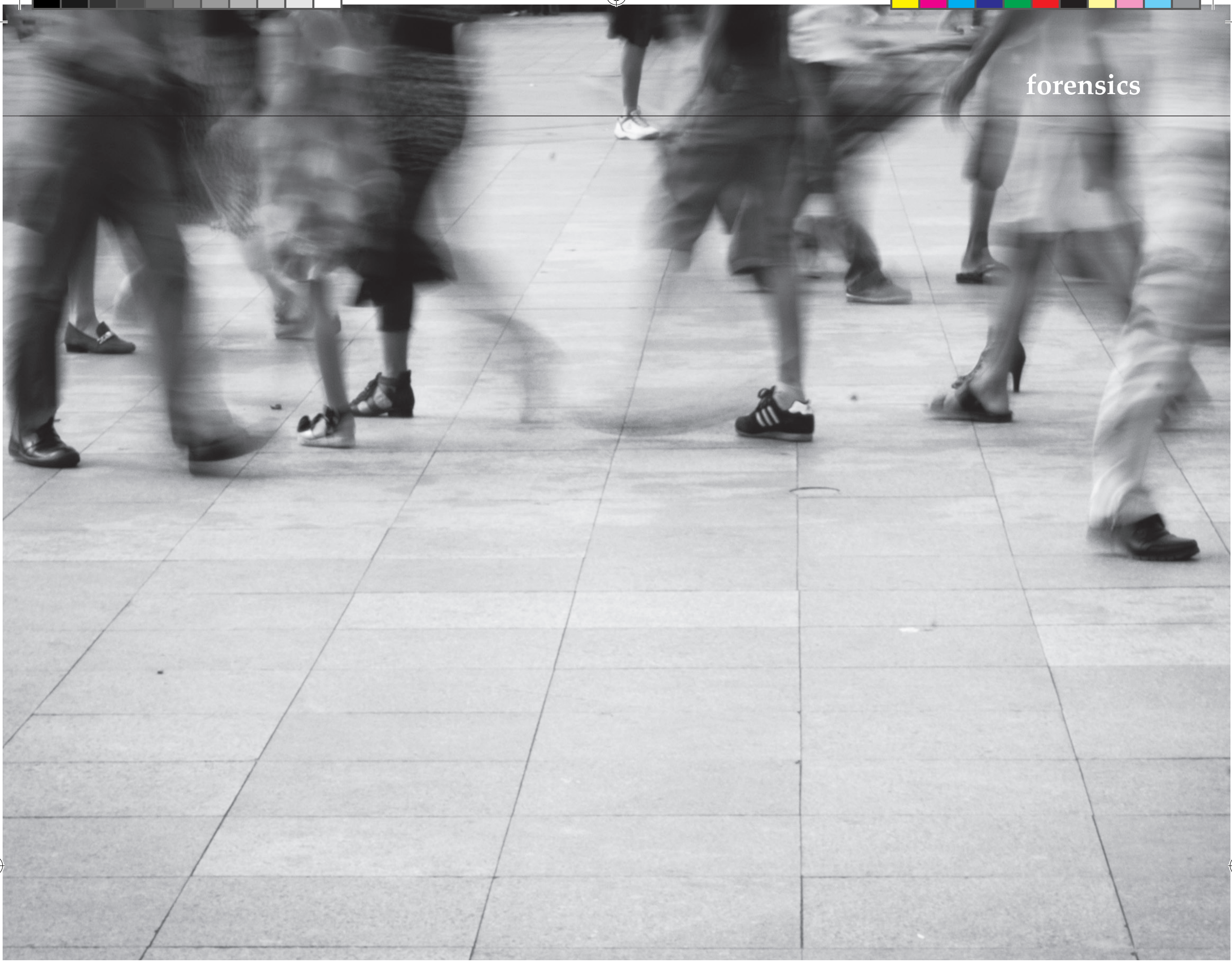

The way we walk

Mark Nixon and **John Carter** reveal how developments in biometrics could mean the increasing use of biometric evidence such ear shape and gait to identify defendants

We have investigated ways to identify people by their gait, the way they walk, since 1994. Essentially, we use techniques derived from computer vision to convert image sequences of walking subjects into sets of numbers. The set of numbers is unique for each person and repeatable, in that each time the same person walks the same set of numbers is derived.

The main advantage of gait in applications is that it can be derived at a distance when other personal traits are only visable at extremely low a resolution, or too small, to be recognised.

Recognising people by their gait resides within the field now called biometrics. In this field, people become represented by sets of numbers which represent the personal trait being studied. To be a valid biometric, the trait should be universal, unique and permanent and one which a subject is prepared to reveal.

Recognition is then achieved by something a subject possesses as opposed to something they know. As such, fingerprints have achieved routine biometric and forensic use and there are immigration systems, often to be found at airports, which can allow automated immigration processing allowing faster entry to a destination than is usually experienced in passport control queues.

The most established biometrics are fingerprint, palmprint, face and iris. Newer biometrics include: ear, heartbeat, vascular pattern (palm and finger) and gait. Some of these are less suited to forensic deployment, but of the newer technologies, images of the ear and of walking suspects have already been used to secure convictions.

In order to derive a set of numbers many of these biometrics require an image of the human trait. By a series of techniques which largely derive from mathematics, a repeatable procedure is derived. For fingerprints this usually concentrates on detection of minutiae and then describing the fingerprint as a collection of these interest points; for face recognition the signature can be derived from the size and relative positions of the facial organs. In gait biometrics, the set of numbers is derived not from a single image, but from a sequence of images. The length of the sequence is usually defined by the human gait cycle which starts with a heel strike (when the heel first makes contact with the ground) of one foot and lasts until the next heel strike of the same foot.

In these processes, there are two procedures: the first is feature extraction and the second is feature description. The variation in the inclination of the human thigh during a gait cycle has been well studied in biomechanics. The variation in inclination is not a set of numbers which can be easily deployed to compare subjects. It is usually transformed into frequency components using the Discrete Fourier Transform and the most significant of these encode the subject's unique walking pattern. This is termed model based analysis. An alternative procedure is to derive the set of numbers from a subject's silhouette, thereby encoding their body shape and its movement. The latter approach is much less suited to forensic application, since the perceived shape changes much with the variation of camera viewpoint to the subject, whereas the change in model based approaches is better known.

When approached by the police concerning the need to establish the same identity of a subject on two different occasions of the same crime, we sought to compare the subject within the images acquired during the crimes, and to provide a measure of the significance resulting from this comparison.

Our analysis was published in the Journal of Forensic Sciences (I. Bouchrika, M. Goffredo, J. N. Carter, and M. S. Nixon, 'On Using Gait in Forensic Biometrics', Journal of Forensic Sciences, 56(4). pp. 882-889, 2011). Gait was the only technique available since the suspect had concealed the more usual identification material by wearing a motorcycle helmet and gloves, but wore very similar apparel on both occasions. The video material was labelled manually to derive the vertex locations in each image. It was not possible to compare the video footage of the suspect in custody with that of the crime scene since the cameras at each site had different frame rates. Further, capturing gait motion was not an option due to the low-frame rates. A measure of the similarity was then derived between the sequences of the two crimes and a match is suggested when the difference is small. For these cases it was sufficiently small to suggest a match.

It was then necessary to provide a measure of confidence in the match measure. For this, we derived the match measure by randomly selecting subsets of the 101 subjects in the CASIA database and determining the match between the subjects. The match scores both for the same subject and for the different subjects stabilise as the database size increases. Further, the variance in the match also decreases with increasing database size.

As such, the match differs from same subject to different subjects, and since the match in the scene of crime videos was considerably less than that achieved for the same subjects, then we could state that we were confident the match achieved was beyond reasonable doubt.

Clearly, we have been following the guidelines of the Daubert standard and by the procedures defined in this case and with other media and scientific coverage suggest that this standard is now met. As this is research, the technology underlying these approaches could be refined and delivered in a more useable way and there is now a gait forensic system available.

Our task was to provide an analysis and there are more comparisons possible and other methods. There is a richer vein of technique already existing in gait biometrics which could be mined to enhance recognition procedure. An early analysis studied the size of the database necessary to convince of recognition capability, though the study on this topic is rather scant.

> **"There is a richer vein of technique already existing in gait biometrics which could be mined to enhance recognition procedure"**

Clearly such approaches also have implications on surveillance technology: a common setting for video cameras is to record images at intervals of one second but this is far too low for gait; many surveillance cameras are placed in a manner suited to human analysis of their data rather than to automated analysis.

In order to advance though, a university such as ours requires funding for research and we have yet to find an appropriate source to advance forensic procedure. There is the EU COST programme which enables European researchers to share research in biometrics in forensics. The COST programme has led to the First International Workshop on Biometrics in Forensics which will be held in Lisbon in 2013.

There are newer techniques in the offing, which could translate well to forensic use. Ears have already been used for identification from CCTV imagery of a robbery; the newer soft biometrics recognise people by associating verbal descriptions with video material for recognition purposes, alleviating the need to be able to see a subject's legs which is implicit in the studies described earlier. Biometrics can and have been put to forensic use, and for gait this is simply the beginning of that end.

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