Science and Justice 54 (2014) 159–163

Contents lists available at ScienceDirect

Science and Justice

journal homepage: www.elsevier.com/locate/scijus

The effect of frame rate on the ability of experienced gait analysts to identify characteristics of gait from closed circuit television footage

Ivan Birch [a,*], Wesley Vernon [a], Gordon Burrow [b], Jeremy Walker [a]

[a] Sheffield Community Services, Jordanthorpe Health Centre, 1 Dyche Close, Sheffield, England, S8 8DJ, United Kingdom
[b] Glasgow Caledonian University, Cowcaddens Road, Glasgow, Scotland, G4 0BA, United Kingdom

ARTICLE INFO

Article history:
Received 4 July 2013
Received in revised form 9 September 2013
Accepted 25 October 2013

Keywords:
CCTV
Frame rate
Gait analysis

ABSTRACT

Forensic gait analysis is increasingly being used as part of criminal investigations. A major issue is the quality of the closed circuit television (CCTV) footage used, particularly the frame rate which can vary from 25 frames per second to one frame every 4 s. To date, no study has investigated the effect of frame rate on forensic gait analysis. A single subject was fitted with an ankle foot orthosis and recorded walking at 25 frames per second. 3D motion data were also collected, providing an absolute assessment of the gait characteristics. The CCTV footage was then edited to produce a set of eight additional pieces of footage, at various frame rates. Practitioners with knowledge of forensic gait analysis were recruited and instructed to record their observations regarding the characteristics of the subject's gait from the footage. They were sequentially sent web links to the nine pieces of footage, lowest frame rate first, and a simple observation recording form, over a period of 8 months. A sample-based Pearson product-moment correlation analysis of the results demonstrated a significant positive relationship between frame rate and scores ($r = 0.868$, $p = 0.002$). The results of this study show that frame rate affects the ability of experienced practitioners to identify characteristics of gait captured on CCTV footage. Every effort should therefore be made to ensure that CCTV footage likely to be used in criminal proceedings is captured at as high a frame rate as possible.

1. Introduction

In recent years, there has been a significant increase in the number of closed circuit television (CCTV) cameras in operation throughout the world. The number in operation in the UK is open to debate and estimates have varied considerably, with McCahill and Norris (2002) [1], suggesting 4.2 million, and, more recently, Gerrard and Thompson (2011) [2], suggesting 1.85 million. These cameras are installed for a range of purposes, including the monitoring of traffic flow, crowd control, the recording of events in and around buildings at risk from crime such as banks and shops, and as a general deterrent to criminal activity. Whatever their exact number and purpose, CCTV cameras are now commonplace in the UK. As a consequence, there has been a significant increase in the likelihood of a perpetrator being filmed committing a crime [3]. CCTV footage availability is now an accepted facet of criminal investigations and expert witnesses are being called upon to offer their opinion as to whether a suspect, filmed after the event, is the same person as the one recorded carrying out the crime [4].

The quality of the images presented for analysis varies considerably for a number of reasons, including the lighting, the resolution, the angle from which the footage was recorded, the specification of the camera, and the specification of the storage medium. This variation, coupled with the propensity of criminals to cover what they consider to be recognisable features, renders a good deal of CCTV footage unusable for direct identification [5]. The use of gait as a method of identification has increased as it can be employed when the subject is at a distance from the camera and when other strategies, such as facial recognition, cannot be used [5,6]. The role of experienced gait analysts in criminal proceedings is supported by the findings of Birch et al. (2013) [7], whose research showed that analysts with experience in visual gait analysis are consistently able to identify persons by their gait.

Gait is the pattern of movement utilized during locomotion, key elements being its dynamic and repetitive nature. CCTV footage has the potential to capture the kinematic [1] detail of the gait of a person and, therefore, contribute to their identification on the basis of that information. However, in order for a credible judgment to be made, the CCTV footage needs to provide sufficient and appropriate data. As gait is a dynamic process, the capture of the kinematics of the subject is a fundamental prerequisite in terms of the quality of any footage that may

* Corresponding author. Tel.: +44 1323 762724, +44 7970 047114 (mobile).
E-mail addresses: ivanbirch@btinternet.com (I. Birch), wesley.vernon@nhs.net (W. Vernon), J.G.Burrow@gcu.ac.uk (G. Burrow), jeremy.walker@nhs.net (J. Walker).

[1] Kinematics is the study of motion without consideration of the causes of that motion, as opposed to kinetics, which is the study of motion and its causes. In biomechanics kinematic data is usually captured using 2D and 3D motion analysis systems, while kinetic data are usually captured using force and pressure measurement systems.

1355-0306/$ – see front matter
http://dx.doi.org/10.1016/j.scijus.2013.10.002

potentially be used for forensic gait analysis. Human gait involves a complex combination of movements of varying speeds and duration, many of which may be lost at low capture or storage frame rates. Frame rate is therefore a key determinant of the suitability of CCTV footage for use in forensic gait analysis.

The frame rate of footage submitted for consideration for use in forensic gait analysis varies considerably. Although the frame rates of 25 frames per second (fps) or above are commonplace for home entertainment, on the basis of the professional experience of the authors and members of the Forensic Podiatry Special Interest Group of the Society of Chiropodists and Podiatrists, footage recoded in police custody suites and submitted for use in forensic gait analysis has been found to be recorded at frame rates as low as 2 fps [6]. Footage submitted from other sources has been found to be at frame rates as low as 1 frame every 4 s. At such low frame rates, the value of the CCTV footage in terms of its ability to demonstrate the kinematics of gait may be compromised, and therefore so does its potential in forensic gait analysis.

Larsen et al. (2008) [4] reported that in their experience, 15 Hz was an ideal recording frequency for examining certain dynamic features of gait. In the context of work being reported, this presumably equates to 15 frames per second. They go on to report that previous workers [8,9] had also found this frame rate to be sufficient for obtaining joint angles and automatic gait recognition. However, no explanation is given as to the basis for this judgment, and it can therefore only be assumed that this frame rate was found by them to be ideal through personal experience rather than systematic investigation. Larsen et al. also reported that while recording frequencies of 5 Hz could be sufficient for the examination of “more static features” of gait, others such as dorsal/plantar flexion at heel strike could not be examined at this frequency. They comment that recording frequencies of as low as 2 Hz, which they acknowledge as being a series of still images, had been used to identify a “bow-legged left knee,” suggesting that a single image could sometimes be useful if the feature of gait captured could be deemed to be characteristic. Whether the analysis of a single still image should be described as gait analysis is open to debate.

To date, no work has been published with regard to the impact of frame rate on the ability of experienced analysts to identify features of gait from CCTV footage. This paper reports the findings of a study undertaken to investigate this key aspect of forensic gait analysis.

2. Methods

Approval was received from the ethics committee of the School of Health and Life Sciences, Glasgow Caledonian University. A risk assessment was also undertaken using the standard Glasgow Caledonian University protocol.

A single-blind experimental design was used to test the null hypothesis that “frame rate has no effect on the ability of experienced gait analysts to identify characteristics of gait from closed circuit television footage.”

All calibration and data collection procedures were undertaken in the human movement laboratory, Glasgow Caledonian University, using a seven metre 7 m walkway and a 16-camera Qualisys three-dimensional motion analysis system, running version 2.5 software. System calibration was undertaken in accordance with manufacturer's guidelines using a dynamic wand technique. A single JVC CCTV camera, fitted with an 8-mm monofocal fixed iris lens, was placed at one end of the walkway, 1 m from the longitudinal centre line and 2.28 m above the surface of the walkway, as shown in Fig. 1.

For the recording of the footage to be used in the study, one 58-year-old male subject with no significant biomechanical anomalies or injuries was recruited with informed consent. For the purposes of the calibration procedures, the subject was dressed in shoes and shorts only. An off-the-shelf ankle foot orthosis was securely fitted to the subject's right foot and leg using zinc oxide tape while the subject was seated. The fitting of the orthosis ensured a consistent and substantial limitation

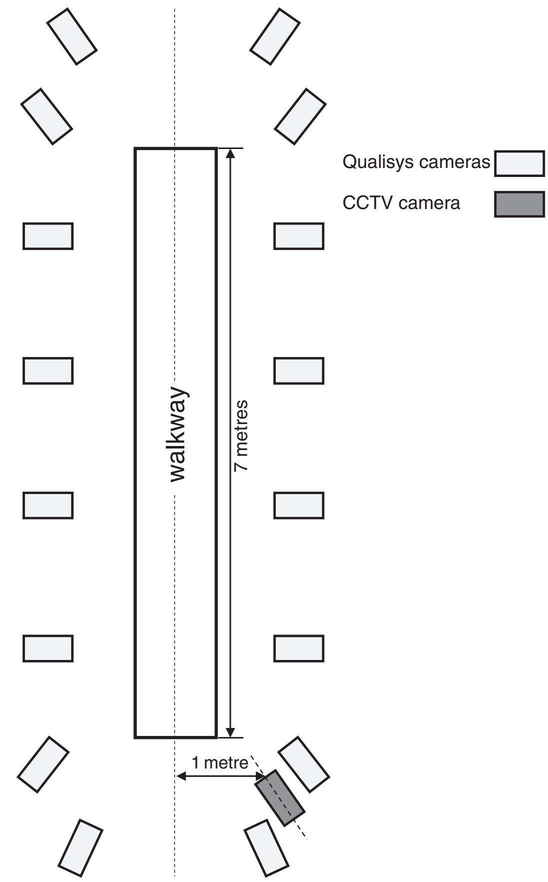

Fig. 1. Relative positioning of walkway, Qualisys cameras, and CCTV camera used during collection of 3D motion data and CCTV footage.

of the range of motion of the right ankle/subtalar joint complex, resulting in the necessary adoption of a series of mechanical compensations by the subject in order to walk.

A whole body marker placement model was used to locate the Qualisys reflective markers on the subject, and a static subject-specific calibration was performed to ensure alignment of the marker placement model with the system measurement framework. Table 1 shows the locations of the Qualisys markers.

The subject was instructed to walk at their usual pace for the full length of the walkway, allowing the naturally occurring compensatory mechanisms to take place to accommodate the limited range of motion of the right ankle. The subject was allowed to walk up and down the walkway until they felt comfortable with the procedure. Ten data collections were then executed capturing movement data simultaneously with the Qualisys system and the CCTV camera. These data collections would be used to establish the actual characteristics of gait occurring with the ankle foot orthosis fitted and provide a template of characteristics of gait against which subsequent observational analysis could be assessed. The Qualisys markers were then removed and the subject put on jeans and a casual shirt, together with a balaclava, to hide their

Table 1
Anatomical location of Qualisys markers.

Segment	Marker location
Torso	Acromion, anterior superior iliac spine
Upper limb	Lateral epicondyle of humerus, styloid process of ulna
Thigh	Greater trochanter, thigh (×4 marker cluster)
Leg	Lateral condyle of femur, shank (×4 marker cluster)
Foot	1st metatarsophalangeal joint, 5th metatarsophalangeal joint, heel