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A comparative study of photogrammetric methods using panoramic photography in a forensic context

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ABSTRACT

Taking measurements of a scene is an integral aspect of the crime scene documentation process, and accepted limits of accuracy for taking measurements at a crime scene vary throughout the world. In the UK, there is no published accepted limit of accuracy, whereas the United States has an accepted limit of accuracy of 0.25 inch. As part of the International organisation for Standardisation 17020 accreditation competency testing is required for all work conducted at the crime scene. As part of this, all measuring devices need to be calibrated within known tolerances in order to meet the required standard, and measurements will be required to have a clearly defined limit of accuracy. This investigation sought to compare measurement capabilities of two different methods for measuring crime scenes; using a tape measure, and a 360° camera with complimentary photogrammetry software application. Participants measured ten fixed and non-fixed items using both methods and these were compared to control measurements taken using a laser distance measure. Statistical analysis using a Wilcoxon Signed Rank test demonstrated statistically significant differences between the tape, software and control measurements. The majority of the differences were negligible, amounting to millimetre differences. The tape measure was found to be more accurate than the software application, which offered greater precision. Measurement errors were attributed to human error in understanding the operation of the software, suggesting that training be given before using the software to take measurements. Transcription errors were present with the tape measure approach. Measurements taken using the photogrammetry software were more reproducible than the tape measure approach, and offered flexibility with regards to the time and location of the documentation process, unlike manual tape measuring.

1. Introduction

One of the most important aspects of conducting a criminal investigation involves comprehensively recording and documenting the crime scene, given that the process can ultimately determine the success of the subsequent investigation [1]. Crime scenes often present unstable and short-lived environments, containing ephemeral evidence, which can prove difficult for Scene of Crime Officers (SOCO's) to document efficiently [2]. The documentation process is often laborious and time-consuming [3], as the resultant documentation must provide a thorough and permanent record of the scene, comprising written, graphical, photographic, and video evidence of all contextual information [4,5]. This may require effective communication of the crime scene environment and the distribution of evidence to other individuals who were not present at the scene [6]. Communication may be via 2D photographs, sketches, or more recently, using 360° visualisation technology and 3D modelling [7]. The adoption of such new technologies within police services is therefore further driven by the need to improve efficiency and effectiveness both for forensic scientists, police and the jury within the criminal justice system [8]. Such technology produces three-dimensional representations of crime scenes, providing spatial perception, and the opportunity for the viewer to navigate themselves throughout the scene in a highly detailed immersive environment [9]. This is not possible with 2D photography.

During scene documentation measurements of objects and evidence within the scene are taken, which establish their precise location and relationship to one another [10]. The position and location of evidence is crucial to an investigation because it can help to reconstruct a sequence of events, which may be used to

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support or refute an individual's account of what happened at the scene, or theories about what may have happened. It is therefore essential that such information be accurately recorded. Measurements are frequently taken using a tape measure [11], which are deemed 'adequate' for measuring a crime scene 'in situ' [12]. With 360° technology the user has the ability to take measurements from digital images using photogrammetry software applications. Photogrammetry allows measurements to be taken from photographs using triangulation methods, which derive the location of features using 3D coordinates (X, Y and Z) [13]. The process requires two or more photographic images to be taken from different positions or viewing directions within a scene [14]. The accuracy of measurements taken using a tape measure or photogrammetry software applications are not only dependent on the accuracy of the instrument, but also rely on the competency of the user. The accuracy of the instrument is frequently reported by the manufacturer. However, details of the experimental work used to support the margin of error are often not transparent, and therefore it is difficult to establish the reliability of such data.

Currently the accepted limits of accuracy vary throughout the world. For example, in the UK there is no published accepted limit of accuracy, whereas in the United States the accepted limit of accuracy is 0.25 inch [15]. However, as part of the International Organisation for Standardisation (ISO) 17020 accreditation competency testing is required for all work conducted at the crime scene. Under the scope of ISO 17020, all measuring devices will need to be calibrated within known tolerances in order to meet the required standard, and measurements will be required to have a clearly defined limit of accuracy [16].

It is important to investigate the accuracy with which photogrammetry software applications are able to record measurements compared to tape measures, which are established within Courts of Law. Without robust and independent study it is not possible to reliably implement their use as part of crime scene documentation. Inaccuracies within crime scene documentation could have profound effects on the interpretation of casework, as described. This investigation has examined the accuracy with which a photogrammetry software application was able to measure items within a mock crime scene, and to evaluate practicalities associated with the use of such technology. The results of this study and their interpretation are likely to be of interest and benefit to any person(s) involved in crime scene work, and will help those involved to make an informed choice when considering options for crime scene documentation.

2. Method

2.1. Measuring a single blank wall

A white painted interior wall was measured ten times using a DeWalt DW03050 Laser Distance Measure. The device had a typical measuring tolerance when applied to 100% target reflectivity (such as white painted walls) of +/−1.5 mm. These tolerances apply between 0.05 m–10 m, with a confidence level of 95% [17]. The same wall was then photographed with a Spheron SceneCam (Spheron VR AG), which was positioned in the approximate centre of the room (1.50 m from the wall of interest). The Spheron SceneCam (Fig. 1) utilised in this investigation consists of a fisheye Nikon 16 mm f/2.8 D lens and a CCD (Charge Coupled Device) with a tri-linear RGB chip which produced 50 MP (megapixel) images. The resolution of the white wall image was 2828 × 2724 pixels.

Following calibration of the instrument, two 360° scans of the environment were taken; one at the cameras lower position (146 cm from the floor to the centre of the camera lens), and one at the cameras highest position (207 cm from the floor to the centre of the camera lens), according to the manufacturer's instructions [18]. The panoramas were uploaded onto the complimentary SceneCenter software, and measurements were taken by the researcher along the ceiling and floor line. The height of the wall was sectioned into five areas, as shown in Fig. 2. For each of the five areas ten repeat measurements were taken. No lens distortion correction was necessary because the system employs an algorithm which automatically corrects any distortion from the fisheye lens. This means that the user is only required to select the distance endpoints under study.

Five pairs of 8 mm diameter paper dots were applied to two opposite corners of the wall (Fig. 3). The pairs were positioned to replicate the five areas used in the previous study (Fig. 2). A DeWalt DW088K cross line laser was used to ensure that the position of the dot pairs were level. All photographs and measurements were taken using a Spheron SceneCam and ten repeat measurements

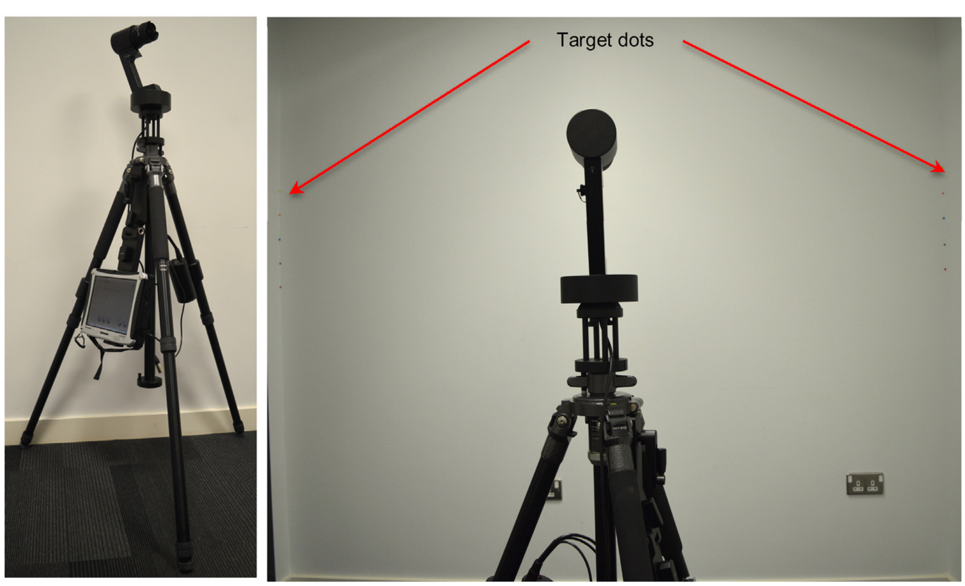

Fig. 1. Left: Spheron SceneCam. Right: Spheron SceneCam facing the wall of interest with the target dots on each wall corner.