A Mobile, Multi-Camera Setup for 3D Full Body Imaging in Combination with Post-Mortem Computed Tomography Procedures

Sören KOTTNER[1], Lars C. EBERT[1], Garyfalia AMPANOZI[1],
Marcel BRAUN[2], Michael J. THALI[1], Dominic GASCHO[1]
[1] Zurich Institute of Forensic Medicine, University of Zurich, Zurich, Switzerland;
[2] Forensic Science Institute, Zurich, Switzerland

Abstract

Three dimensional (3D) models of deceased and injured people in combination with 3D scans of injury causing objects can assist forensic investigations in reconstructing event scenes. Medical imaging techniques, such as post-mortem computed tomography (PMCT) and post-mortem magnetic resonance imaging (PMMR), have been successfully applied to forensic investigations and can add beneficial value to standard autopsy examinations. These imaging modalities can be helpful for 3D reconstructions, especially when internal findings, such as bone fractures, organ damage and internal bleeding, are relevant for the investigation. However, none of these techniques can adequately visualize pattern injuries, such as boot prints and bite marks, or any type of blunt force trauma that forms distinct discolorations on the body's surface. This is why 3D surface imaging techniques have been introduced to the forensic community. Unfortunately, many commercially available optical scanning systems are cost intensive, time consuming and can only be applied before or after a CT scan has been performed. In this article, we present a mobile, multi-camera rig based on close-range photogrammetry that is inexpensive, fast in acquisition time and can be combined with automated CT scanning protocols. The multi-camera setup comprises seven digital single-lens reflex (DSLR) cameras that are mounted on a mobile frame. Each camera is equipped with a remote control that can trigger the shutter release of all cameras simultaneously. In combination with a medical CT scanner, image acquisition of the multi camera setup can be included into an automated CT scanning procedure. In our preliminary study, textured 3D models of one side of the body were created in less than 15 minutes. The photo acquisition time combined with the modified CT scanning protocols lasted 3:34 minutes whereas the subsequent computation of a textured 3D model based on a low resolution mesh lasted 10:55 minutes. The mobile, multi-camera setup can also be used manually in combination with examination couches, lifting carts and autopsy tables. Finally, the system is not limited to post-mortem investigations but can also be applied to living people and may be used in clinical settings.

Keywords: 3D body scanning, multi-camera setup, forensic imaging, 3D surface documentation

1. Introduction

Forensic imaging, especially three-dimensional (3D) imaging, has become a great help for forensic investigations. Three-dimensional data of injured and deceased people in combination with 3D scans or computer-aided design (CAD) models of injury causing objects can assist in reconstructing event scenes[1]–[4]. This reconstruction allows complicated three-dimensional relationships to be understood and visualized in a comprehensible way [1]–[8].

Medical imaging modalities, such as post-mortem computed tomography (PMCT) and post-mortem magnetic resonance imaging (PMMR), have been successfully applied to forensic investigations and have been proven to add beneficial value to standard autopsy examinations [9]–[15]. With respect to three-dimensional reconstructions of event scenes, these imaging techniques are especially helpful when internal findings, such as bone fractures, organ damage and internal bleeding, are relevant to the investigation [6], [7]. If, however, forensically relevant injuries form patterns on the body's surface due to discolorations (e.g., colour of haematomas or abrasions), neither of these imaging techniques can adequately visualize these findings. Injuries that form distinct discoloration patterns on the body's surface are called pattern injuries. These injuries can be the result of various types of blunt force trauma. Common examples are bite marks [4] and boot prints. To adequately document, measure and analyse pattern injuries, 3D surface imaging techniques have been introduced to the forensic community [16]–[18]. Unfortunately, most commercially available optical scanning systems are still cost intensive and can become time consuming when scanning a whole body. Furthermore, commercially available optical scanning systems can typically only be applied before or after a CT scan has been performed [8], [19]–[24].

Three-dimensional body scanning techniques have been used in a wide range of applications and are, of course, not only used in a forensic context [25]–[31]. The limitations, however, remain the same. Short scanning times are most practical to prevent motion artefacts due to, for example, changes in posture and respiration. This is why multi-camera setups have been used as body imaging systems [29], [32]–[36]. Chamber solutions with a cylindrical or spherical arrangement of cameras allow 360 degrees coverage of an object's surface [35], [37]. The overlapping 2D photographs that can be acquired when using a multi-camera setup can be used to reconstruct a textured 3D model based on, for example, a triangular mesh [38], [39].

In this technical note we introduce a mobile, multi-camera setup for 3D full body surface imaging. We present a semi-automatic usage in combination with post-mortem computed tomography procedures as well as a workflow for manual photo acquisition in combination with body carrying setups, such as examination couches, lifting carts and autopsy tables. The setup is based on a mobile frame and comprises seven digital cameras. Each camera is equipped with a radio controller that allows the simultaneous triggering of the shutter release of all cameras.

2. Methods

2.1 The multi-camera setup

The multi-camera rig comprises seven Canon EOS 100D (Canon Inc., Tokyo, Japan) digital single-lens reflex (DSLR) cameras. All camera bodies are equipped with a Canon EF lens with a fixed focal length of 50 mm and a wireless remote shutter control (Yongnou RF-603C II, YongNuo Photographic Equipment Co., Ltd, Shenzhen, China). The remote shutter release of all cameras is actuated simultaneously with a separate radio controller. Each camera is connected with a tripod ball head (G-10X, SIRUI Europe GmbH, Berlin, Germany or BALL 19P, NOVOFLEX Präzisionstechnik GmbH, Memmingen, Germany) to a mobile right-angled frame. This frame is composed of two stands with a horizontal crosslink. Base plates are attached to the bottom end of the frame. Each base plate is equipped with swivel casters to ensure transportability of the system. At the top end of the frame, a mounting board allows adequate adjusting of the cameras to follow the arc of a circle. An additional laptop shelf is attached to the right stand of the frame. An overview of the multi-camera setup is provided in Figure 1.

Fig. 1. Setup of the multi-camera rig

2.2 Photo-acquisition workflow in combination with PMCT scanning procedures

In combination with a medical x-ray computed tomography (CT) scanner (Somatom Definition Flash, Siemens Medical Solutions, Forchheim, Germany), the multi-camera rig is used to acquire overlapping multi-view images of a body. For this purpose the multi-camera rig is placed centrally above the CT table in front of the CT gantry (Fig. 2a). With the help of the operating software of the CT scanner (Syngo CT 2012B, VA44A, Siemens Medical Solutions, Forchheim, Germany), the CT table movement is synchronized with the remote shutter release of the multi-camera rig. This enables the CT table to move automatically during the scanning process step-by-step beneath the rig. The step-by-step movement of the CT table is paused every 10 cm and is initiated by an announcement to manually trigger the remote shutter release (Fig. 2b). This procedure is continued until all photos covering the full length of the body are acquired.

Fig. 2. a: Setup in combination with a medical CT scanner; b: PMCT scout view
with a visualization of the modified step-by-step PMCT scanning protocol

2.3 Photo-acquisition workflow in combination with examination couches, lifting carts and autopsy tables

Close-range photogrammetry with the help of the multi-camera rig can also be performed manually without a CT scanning setup. In this scenario, the multi-camera rig can be used in combination with a body-carrying setup, such as an examination couch, a lifting cart (Fig. 3a) or an autopsy table (Fig. 3b). The multi-camera rig is placed at the top or bottom end of the body carrying setup and is aligned centrally above the body. Subsequently, the multi-camera rig is moved manually step-by-step across the body-carrying area. Every 10 cm, the rig is stopped, and the remote shutter release is triggered manually by the radio controller. This procedure is continued until the rig is moved to the other end of the body-carrying setup. The use of the multi-camera rig in conjunction with a lifting cart and an autopsy table is shown in Figure 3.

Fig. 3. Use of the multi-camera setup a: in combination with lifting carts; b: in conjunction with autopsy tables

2.4 Photogrammetric reconstruction from multi-view images

Subsequent to the photo acquisition procedure all photos that are collected with the help of the multi-camera rig are transferred manually to a separate workstation (2 Intel® Xeon® CPUs with 16 cores, Intel Corporation, Santa Clara, USA, 36 GB RAM, Nvidia Quadro® FX 1800 GPU, NVIDIA Corporation, Santa Clara, USA, Microsoft Windows 7, 64 Bit, Service Pack 1 operating system, Microsoft Corporation, Redmond, USA). With the help of PhotoScan (Agisoft PhotoScan Professional Edition, Version 1.2.4, Agisoft LLC, St. Petersburg, Russia), the photogrammetric reconstruction is computed. All seven cameras on the multi-camera rig are used uncalibrated and the default parameters in the PhotoScan Software are used for the computation procedure instead. After a textured 3D model is computed, the model is scaled on the basis of the reference markers that are applied to the body's surface prior to the photo acquisition procedure.

3. Results

Photo acquisition in conjunction with the automated PMCT scanning procedures lasted 3:34 minutes to acquire 126 overlapping photographs. Photogrammetric reconstructions in PhotoScan delivered a textured 3D model based on a low-resolution mesh in 10:55 minutes. The data size of the 3D model accounted for 6613 KiB and comprised 135430 faces. An exemplary illustration of the computed 3D model is shown in Figure 4.
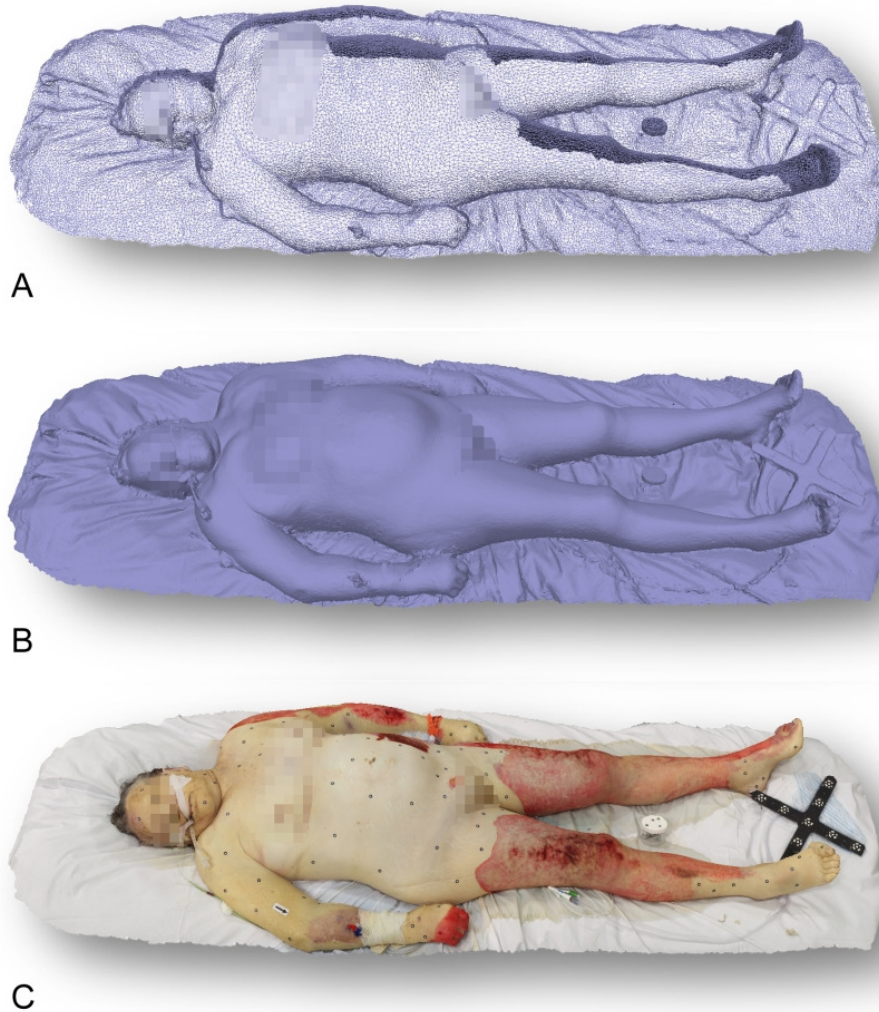
Fig. 4. 3D model based on 126 overlapping photographs a: model displayed in wireframe mode b: model displayed in solid mode c: model displayed in textured mode

4. Conclusions

Based on our preliminary results, the mobile, multi-camera rig offers short scanning and computation times for 3D full-body documentation. The setup can help standardize 3D full-body scanning procedures and can be used to document the three-dimensional surface of deceased and living people. In comparison to other commercially available 3D scanning systems, the multi-camera rig offers a great advantage in terms of its low acquisition and maintenance costs. Overall, the multi-camera setup appears to be a practical and fast 3D full-body scanning alternative for forensic investigations. However, further studies with a larger sample size are necessary to evaluate the feasibility of the system.

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Disclosure

The authors declare that there are no conflicts of interest.

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