Journal of Forensic Radiology and Imaging 2 (2014) 213–216

Contents lists available at ScienceDirect

Journal of Forensic Radiology and Imaging

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

Technical note

Improving post-mortem surface documentation with a CT mounted marker board

Agnieszka D. Sekula, Michael J. Thali, Robert Breitbeck*

Institute of Forensic Medicine, University of Zurich, Winterthurerstrasse 190/52, CH-8057 Zurich, Switzerland

ARTICLE INFO

Article history:
Received 23 May 2014
Accepted 25 June 2014
Available online 20 July 2014

Keywords:
Photogrammetry
Surface scanning
Forensic documentation
Image transformation
Virtopsy
3D visualization

ABSTRACT

Three-dimensional surface documentation of large or complex objects requires accurate dataset transformations to ensure reliability of obtained models. Currently used artificial markers that aid this process are most commonly temporary and generate obstructions. This paper examines a better adapted method, which utilizes a permanent system of coded markers, ensuring transformation of numerous images without obstructions. This easy-to-use, time-saving tool can be utilized in all fields that use photogrammetry or optical surface scanning as daily practice.

1. Introduction

Recent years have been marked by rapid developments in documentation methods within the forensic field [1–5]. One of these cutting-edge methods is the Virtobot, which is a multifunctional robotic system that is capable of performing digital close-range photogrammetry, optical 3D surface scanning and biopsy operations on deceased bodies [6–8]. Its integration into CT operating rooms (Siemens Somatom Definition Flash (Siemens Healthcare, Erlangen Germany)) allows for both procedures to take place subsequently, thus enabling these procedures to become part of an everyday workflow (Fig. 1). The robotic arm, which was developed as a custom design by Integrated Microsystems Austria GmbH (Wiener Neustadt, Austria), is programmed for automated procedures for full body documentation and for manually controlled recordings of specific sites of interest. Each of the 25 standard positions was designed to capture a distinct part of the body and to form a high level of overlap with at least a few other scans. Manual control can be obtained in each axis of the arm, thus yielding an exhaustive number of possible configurations. Two documentation tools are currently being used to obtain a comprehensive model: a DSLR camera Nikon D700 with a wide-angle lens AF Nikkor 20 mm (Nikon Corporation, Tokyo, Japan) is initially used for the photogrammetry procedure and an optical 3D surface scanner ATOS Compact Scan 5 M (GOM mbH, Braunschweig, Germany) is subsequently used for surface scanning. Because the total body volume is larger than the measurement volume of either tool, a complete scan of the entire object cannot be performed in a single shot. As a result, numerous scans have to be combined for a complete 3D model [9]. For this purpose, the photogrammetry method aims to record coordinate points that aid in the fusion of polygon data from individual surface scans and to simultaneously assist in projecting color information recorded in photographs onto the finished 3D model.

Detailed descriptions of data transformation procedures are crucial for the accuracy of models and can represent a major complication in 3D documentation procedures of large or complex objects. Such complications can be resolved by implementing identification points on the scanned object, which allow for improved recognition of specific coordinate points during the photogrammetry procedure. Elements of this system are recognized by ATOS Professional V7.5 SR2 software (GOM mbH, Braunschweig, Germany) and can be used as a reference to guide the merging of overlapping data sets.

A standard method for photogrammetric reconstructions involves ring coding markers, which take the form of standardized circular pads with a black background, a white central point and a white surrounding circular structure [10]. The last feature varies from marker to marker, a fact that allows the software to recognize each individual marker and to code it with a specifically assigned number. In forensic settings, these markers are often arranged on large plastic crosses, each of which accommodates 9 coded markers. This method is relatively fast, but it nonetheless has to be planned and applied each time anew, which requires some degree of experience (Fig. 2). Crosses that are approximately 29 cm in diameter are most often placed on the object itself, which results in the obstruction of some of its parts and therefore creates gaps in the acquired data.

* Corresponding author. Tel.: +41 44 635 5611; fax: +41 44 635 6851.
E-mail address: robert.breitbeck@virtopsy.com (R. Breitbeck).

http://dx.doi.org/10.1016/j.jofri.2014.06.005
2212-4780/

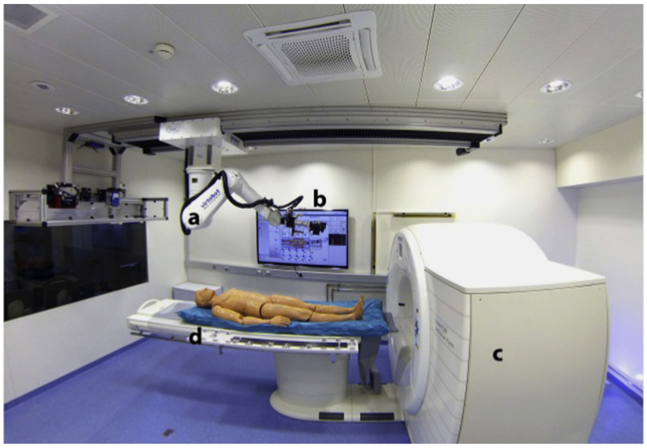

Fig. 1. A Virtobot during a demonstration: a. robotic arm, b. Nikon D700 camera, c. CT, and d. CT table. The robotic arm rotates around the dummy to capture images from each of the 25 standard positions with the Nikon D700 camera. Data are fed directly into the ATOS Professional software.

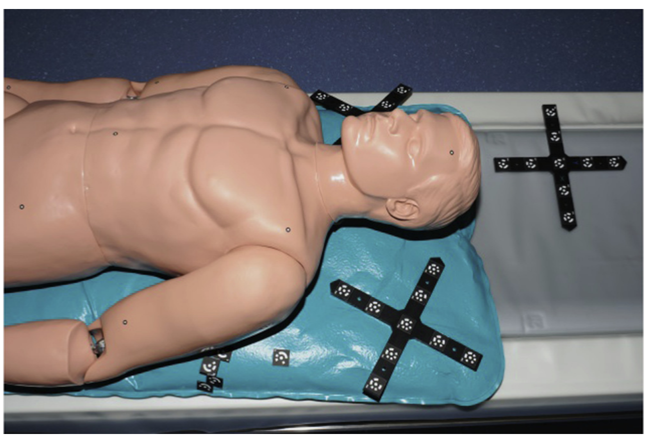

Fig. 2. Commonly used coded crosses.

Surface scanning requires an additional reference system, which most often takes the form of small, black and white adhesive labels. These labels are placed directly on the body (or any other scanned object in other professional fields) at a density that ensures that at least 4 markers are present in each overlapping scan. Accurately placing these markers requires a certain level of competence, especially with complex or extensive injuries. Because these markers are identical, the software cannot distinguish between them; it can only determine their relative position to each other. This system necessitates a large quantity and a good distribution of markers. For example, stickers cannot be arranged in a regular manner because the visibility of each has to be ensured on numerous images. Consequently, the placement of these markers (and the subsequent removal of the artifacts) can be a very time-consuming process.

In addition to the two marking systems described here, an indication of scale is also required for detailed documentation. For this purpose, two scale bars are commonly placed next to the object, and these two scale bars can be cross-referenced to ensure accuracy.

Markers that are not coded, coded markers and scale bars are all fundamental components of 3D documentation involving surface scanning and photogrammetry procedures. As a consequence of the limitations that have been described for these techniques, current attempts to improve this situation are focused on several major objectives. First, it will be important to improve the visibility of coded markers on various scans and images, an issue that is closely related to the angular distortion between the markers and the camera. Second, it would be desirable to utilize a permanent set up to reduce scanning time (and therefore costs) and to eliminate possible errors due to improper marker placement. Third, the number of markers placed on the body should be reduced to prevent obscuring the scanned object. Finally, the limited space that is available on the CT table, which is not sufficient to accommodate such unanticipated equipment, resulted in the need to assemble markers in a different location.

An efficient method to support scan fusions and color projections to obtain full 3D models of entire objects is presented and discussed in this paper.

2. Methodology

To optimize performance, this new system was developed simultaneously along with the designation of scanning positions in the software controlling the robotic arm. These positions, in addition to the immediate surroundings, informed the general structure of the new scheme. Two long, narrow benches were located on each side of the CT table and were used to determine the extent of the markers' positions. A total of 54 coded markers were permanently assembled onto these boards, and they were arranged one by one according to the aforementioned Virtobot positions following a constant feedback process. Out of those, 50 markers were placed on wooden blocks that were each tilted 30°. In addition, two scale bars were placed next to each other on one of the two boards. These scale bars serve to allow for determinations of the scale of the acquired data, and the second bar provides a control mechanism for the first, which eliminates many potential errors. The last 4 coded markers were placed flat on these bars (two on each) to mark the corners (Fig. 3).

The designed boards received simple mounting mechanisms to allow for a straightforward assembly onto the existing structure of the CT table (Fig. 4). The attachment surface consisted of two metal rails on each side, which were incorporated into the immobile part of the CT table as a standard element for mounting medical devices. Two metal clamps at the bottom of each board can either be easily slipped onto the rails or tightened with a bolt, if necessary. Widely available materials and straightforward fabrication allow for such a system to be erected at local centers within a few working days.

3. Discussion

The entire robotic complex was assembled alongside the boards at the same time; therefore it is difficult to evaluate the

Fig. 3. Arrangement of coded markers on the boards.