Creating crime scene 3D model with body wear camera footage

Tworzenie obrazu 3D miejsca zdarzenia kryminalnego w oparciu o zapis video z rejestratorów służb interwencyjnych

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Abstract

The aim of this study is to develop a methodology for creating 3D images of crime scenes based on footage from cameras used by emergency services. To accomplish this, a research experiment was conducted, which consisted of re-enactment of a crime scene and simulation of the actions of the emergency team. The experiment did not illustrate a real case. The scenario was developed and dedicated for the purpose of the research.

The research material of this study consists of footage recorded in digital video format. The footage shows the course of a re-enacted intervention of emergency services at the crime scene. The re-enactment, which was a research experiment, was arranged under conditions close to real ones.

The 3D model of the scene was created in three stages: video analysis and 3D reconstruction of the spatial position of the camera; 3D modelling of the figure of the participant with reconstruction of the position similar to the one in the recording; and 3D scanning of the scene of the simulated crime, assembly of individual elements, and scaling to real dimensions.

The result (a 3D model) was presented in the form of a set of images: horizontal projections, vertical sections, and isometric and perspective views of the model. Technical data of the research equipment as well as other relevant information was presented in tables and diagrams.

This study demonstrated that graphic data obtained unintentionally and through alternative recording sources may significantly complement the data collected in the course of routine medico-legal and forensic activities. The use of cameras during the actions of rescue and emergency services allows us to obtain information of significant importance for medico-legal and forensic analyses. The footage from cameras of emergency services makes it possible to obtain a 3D image of the crime scene for further medico-legal and forensic analyses.

Streszczenie

Celem pracy jest opracowanie metodyki tworzenia obrazu 3D miejsc zdarzeń o charakterze kryminalnym w oparciu o zapis video z rejestratorów na wyposażeniu służb interwencyjnych. Dla realizacji tego celu przeprowadzono eksperyment badawczy. Opierał się on na inscenizacji miejsca zdarzenia i zasymulowaniu czynności zespołu interweniującego.

Materiał badawczy pracy stanowi obraz zarejestrowany w cyfrowym formacie video. Obrazem tym jest przebieg inscenizacji interwencji służb ratunkowych w miejscu zdarzenia o charakterze kryminalnym. Inscenizację będącą eksperymentem badawczym zaaranżowano w warunkach zbliżonych do rzeczywistych.

Tworzenie modelu 3D miejsca zdarzenia było trójetapowe: analiza video i rekonstrukcja 3D pozycji przestrzennej kamery; modelowanie 3D sylwetki uczestnika z odtworzeniem pozycji zbliżonej do tej na nagraniu; skanowanie 3D miejsca symulowanego zdarzenia i złożenie całości oraz skalowanie do wymiarów rzeczywistych.

Rezultat (model 3D) przedstawiono w formie zestawu obrazów – rzutów poziomymi, przekroi pionowych, ujęć izometrycznych i perspektywicznych modelu. Danetechniczne sprzętu badawczego jak też inne istotne informacje zawarto w tabelach i schematach.

W pracy wykazano że, dane graficzne pozyskiwane w nieintencjonalny sposób i alternatywnymi źródłami ich rejestracji, mogą stanowić istotne uzupełnienie dla danych gromadzonych w rutynowych czynnościach medyczno-sądowych i kryminalistycznych. Zastosowanie rejestratorów obrazu podczas czynności służb ratunkowych i interwencyjnych pozwala na pozyskanie informacji o istotnym znaczeniu dla analiz medyczno-sądowych i kryminalistycznych. W oparciu o zapis video z rejestratorów służb interwencyjnych możliwym jest uzyskanie obrazu 3D miejsca zdarzenia kryminalnego dla dalszych analiz medyczno-sądowych i kryminalistycznych.

Słowa kluczowe
Skanowanie 3D, Animacja 3D, Rekonstrukcja, analiza obrazu, CCTV

Introduction

The initial observers of crime scenes are most often broadly defined as emergency services (mostly the police, fire service, and ambulance). A reconstruction of the sequence of events that took place at such scenes requires acquiring and archiving data describing the space, elements, and participants of these events. Information potentially acquired by intervening officers may have significant implications for medico-legal and forensic analysis of the sequence of events [1,2]. At the same time, it should be remembered that the presence of officers at the scene and the actions they undertake may lead to a distortion or even obliteration of relevant information. Therefore, video recording of the course of an intervention is justified [1]. The above goal can be accomplished by using field-proven video recording technologies. The special nature of the intervention, the associated required actions, and the often-accompanying situational stress require automatic and unattended video recording. Such technologies have already been put into general practice [3]. Examples include static cameras (CCTV cameras, speed camera) and mobile cameras (dashcams, drones) used by both the public sector and individual users [2,4,5]. The footage obtained from cameras can be processed and used in medico-legal and forensic analysis of the sequence of events [6]. For the purpose of the above analysis, it is important to establish mutual relations and spatial interactions among elements of the scene and its participants. Forensic and medico-legal practice of the authors and other scientific centres proves that digital 3D imaging can be an effective tool for conducting such analyses [7,8].

Aim

The aim of this study is to develop a methodology for creating 3D images of crime scenes based on footage from cameras used by emergency services. To accomplish this, a research experiment was conducted, which consisted of re-enactment of a crime scene and simulation of the actions of the emergency team.

Material and methods

The research material of this study consists of footage recorded in digital video format. The footage shows the course of a re-enacted intervention of emergency services at a crime scene. The re-enactment, which was a research experiment, was arranged under conditions close to real ones.

The experiment was performed under the conditions of a simulated intervention and routine actions of paramedics in the scene space. The aim was to minimize the impact of the camera on the officer. This was made possible by deliberate selection of equipment (lightweight, small, with high resolution) and automatic video recording, without requiring the attention and effort of the officer (operator). The camera from the HTC One M8 device was used, with the following parameters: 4MP 1/3-inch CMOS sensor, 2.0 um pixel pitch, F2.0 aperture, 28mm equivalent focal length, HD video 1080p, 30 FPS.

The footage was recorded by digital video cameras mounted on the heads of the officers. In practice, such position of the cameras minimizes the inconvenience of use while providing the maximum possible field of view. The re-enactment scene

was the courtyard atrial area of an apartment building, chosen without any preconditions based on the premise that this method should work in all places and conditions. The footage was recorded in daylight and partly in the semi-darkness of the restricted space of a communication tunnel. The ground and other surfaces were wet and semi-reflective after rainfall, representing different colours, textures, and materials. The re-enactment was performed by three role players – two of whom took the part of officers with cameras while the third one was lying on the ground as a possible victim.

The cameras recorded the approach of the officers to the lying role player and the start of rescue activities. In order to objectify the conditions of the experiment and bring them closer to reality, a single recording was made without any reshoots. Figure 1 shows the source material samples .

The first step was to increase video quality and render image sequence using *Adobe After Effects and Adobe Photoshop* software. The next step was the 3D reconstruction of the camera positions. This operation allows observation of the space of a 3D model through the point of view of a virtual camera with the optics and position similar to the real camera. As a result, the created 3D geometric shapes can be modelled and positioned in digital space. Two different methods were chosen for camera position reconstruction. The first method uses the 'camera tracking' tool and was performed with a *Bojou* software. An application algorithm reconstructs the spatial position of the camera and changes in its position in the 3D environment by tracking changes in the position of distinctive image points. The effect of this action is presented in Fig. 2. However, because of low footage quality application process failed, not delivering any usable data in result.

Fig. 1. *The source material. A – body wear camera footage, B – environmental photos*

The footage was processed using the following computer software:

| Thumbnail	Software Name	Research Use
Ps	Adobe Photoshop	2D image processing
Ae	Adobe After Effects	2D video processing, video to image sequence rendering
RealityCapture	Epic Games Reality Capture	Automatic photogrammetry
Autodesk ImageModeler	Autodesk Image Modeler	Manual photogrammetry
AUTODESK 3DS MAX	Autodesk 3D Studio Max	3D modelling and animation
boujou	Vicon Bojou	Camera tracking and resolve
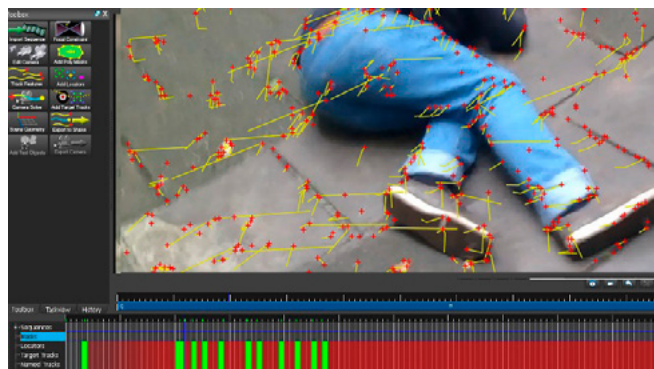
Fig. 2. *Camera tracking process. Green blocks indicate successful processing, red blocks show lack of data in whole movie sequence bar*

The second method consisted in converting the footage into individual frames. Because the recording equipment was moving, the recording was accompanied by unwanted image shake that made the footage blurry. The least distorted frames in the sequence were selected (shown as figure 3).

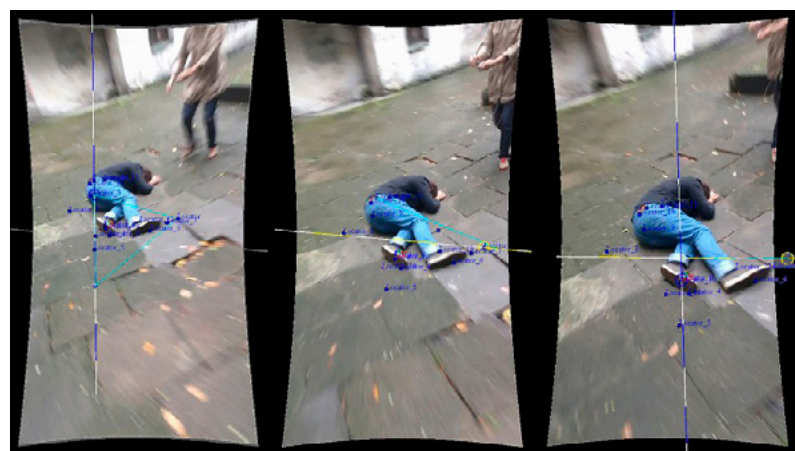*Fig. 3.* *Converting video to images (frames), choosing most undistorted images, digital sharpening*

Fig. 4. *Manual characteristic points detection to support application process*

The set of selected images was processed computationally by *Epic Games Reality Capture* application algorithm. Its aim is to analyse a series of images of the same space and reconstruct the spatial position of the camera in the 3D environment based on the principles of photogrammetry. Due to the unsatisfactory results of the automatic algorithm of the above application, the frames were also processed in an application with semi-automated tools – *Autodesk Image Modeler*, where the operator reconstructs the model based on image analysis and manual refinement of calculations (shown as figure 4).

In the second method, the spatial position of the camera was determined. Automatic application algorithm delivered point cloud information, and manual application allowed viewport manual modelling process (shown as figure 5).

Fig. 5. *A – Point cloud from automatic algorithm of Reality Capture, B – manual model made with manual algorithm of Image Modeler*
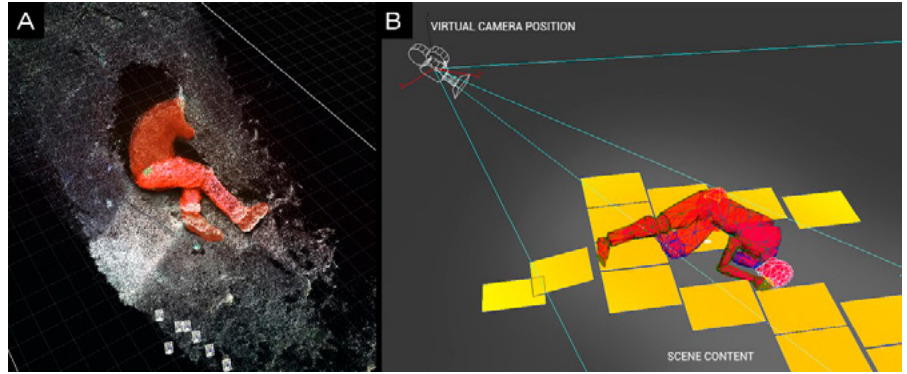
All the 3D data was imported to **Autodesk 3D Studio Max.** An animated figure of the role player was created. Next, using virtual camera view with a background integrated image, a fragment of the pavement was recreated (shown as figure 6). Concrete pavement blocks were used as a reference object to find a position and match a scale of body and environment 3D model (created in the next steps).

Fig. 6. *Virtual Camera view allows 3D creation of pavement blocks*
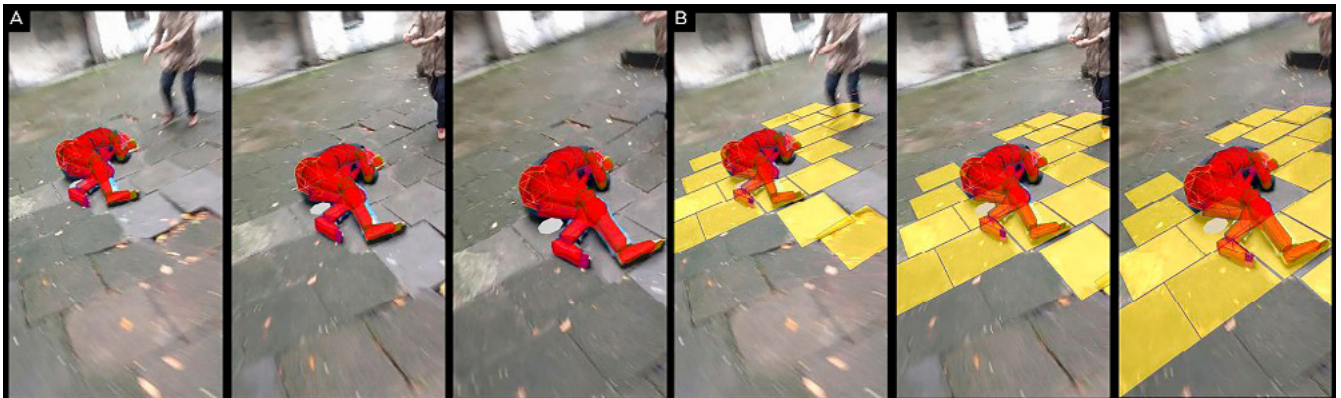
Next, a 3D model was made of the simulated crime scene. For this purpose, a series of photographs was taken of the surroundings, which was converted to a 3D model using a computer application. The photographs were taken with a still camera following the guidelines in the application manual. A series of control measurements was performed to verify that the obtained scan had correct geometry and was set on the correct scale. The obtained 3D model of the victim was combined with the 3D scan of the environment and resized to the correct full scale. Methodology scheme of the whole reconstruction is shown below.

Results

Results obtained are enumerated below:

1. The methodology for creating a 3D model of the re-enacted crime scene based on footage from body wear cameras of emergency services (shown as figure 7).

2. The 3D model of the re-enacted crime scene based on footage from body wear cameras of emergency services (shown as figure 8).

3. Video presentation of methodology and reconstruction results (shown as figure 9- supplementary material).

Fig. 7. Methodology scheme

Fig. 8. The 3D model of the re-enacted crime scene based on footage from body wear cameras of emergency services.
A , B – Perspective views,
C , D, E – Elevation Views

Fig. 9. The reconstruction accuracy depends on source material quality and needs to be examined in every case individually. In the research case study, dimensions from reconstruction were compared to laser disto physical survey. The summary measure error did not exceed 5%. This number is not valid as it can differ in other cases
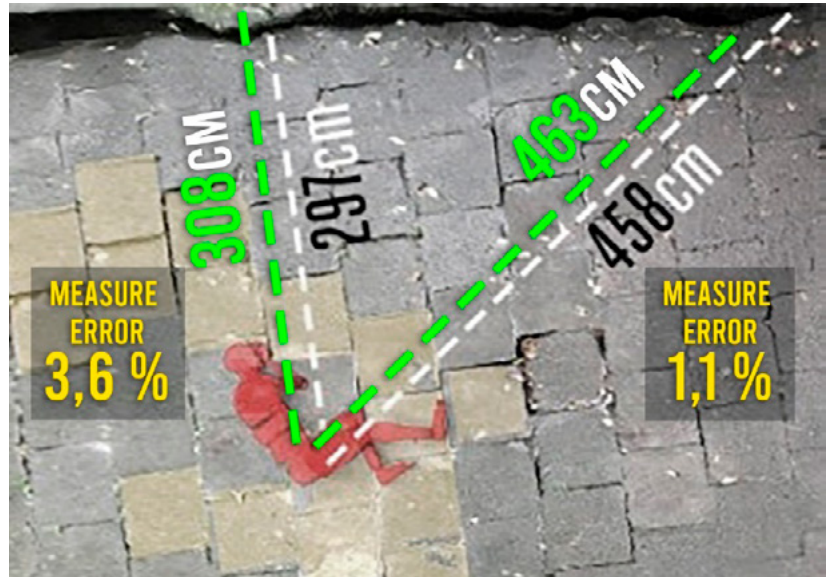

Fig. 10. Video presentation of methodology and reconstruction results

Discussion

Body worn camera has obvious advantages, but could be physically and mentally uncomfortable for the operator [1,9,10]. Mainly because it is further additional equipment that operator needs to deal with, but also because it is recording operator's actions in difficult conditions, where some controversial decision can be made and recorded. Intervention is an emergency situation where human life may be – and usually is – in jeopardy. In order to minimize the impact of this study on the course of an actual intervention, the authors decided to conduct research in the mode of a simulated sequence of events.

The priority of the responding officers is to perform the tasks directly related to the intervention, therefore it was necessary to choose the method of video recording that would not require the attention and involvement of the operator and would respect the local law in this matter [5]. An analysis of possible conditions of an intervention in the context of the subsequent 3D reconstruction of the sequence of events should take into account several important issues.

Reconstruction is based on selected photogrammetric methods and techniques. Photogrammetry is a collection of techniques for acquiring information about spatial geometry and dimensions as well as spatial imaging in a 3D environment [11]. A 3D model of the examined space is obtained from a sequence of 2D images of that space. Those images must differ from one another by the adopted position of their recording (photographs taken from different locations). The recoding and spatial conditions during the recording process should be as stable as possible to increase the accuracy of the 3D model being created.

The officer and, consequently, also the camera are in constant motion. Elements of the space and other participants at the crime scene are in motion as well. The totality of the circumstances of the crime is characterized by high dynamics. Therefore, the image is shaking during the recording, which significantly decreases the quality of the footage [12]. As the officer moves his head, the field of view of the head-mounted camera

changes over time, so the video recording sequences of a particular object are short. This makes photogrammetric reconstruction of the footage more challenging. Changing lighting conditions (e.g. warning lights of an ambulance) also complicate application of photogrammetry in reconstruction.

The conditions of an intervention are difficult and unpredictable, which is why the camera should be versatile and non-interfering with the course of the intervention. Therefore, for practical reasons it should be small and lightweight. In general, the recording equipment with such parameters is characterized by low versatility and the quality of the recorded footage is low.

To improve the accuracy of the 3D reconstruction, at least two different methods should be used and the results obtained should be correlated. Just one measurement of the physical space is required to reconstruct the model scale. On the other hand, two additional dimensions of the physical space must be obtained to verify the geometric correctness of the model.

The footage from cameras of emergency services was used to obtain a 3D image of the re-enacted crime scene. The 3D model is presented as a set of drawings and video sequences. The drawings are horizontal projections, vertical sections, and isometric and perspective views of the model, and could be presented in numerous other ways [13].

The results of the research experiment have shown the potential usefulness of the proposed methods of video recording of the crime [14].

Traditional ways of obtaining data about the scene and sequence of events have their limitations. The main one is image capture or drawing up a description after a significant time has passed since the crime. Significant traces (information) may be lost due to the course of the intervention and other factors not directly related to the intervention (atmospheric phenomena, accidental users of the space, and natural destruction). The above applies to the traces resulting from the intervention itself and those that appeared later on. It is, therefore, justifiable to seek methods that would minimize this problem.

The methods proposed in this study allow us to obtain an image of the course of intervention that is as close as possible to the actual image of the space at the time of the crime. In addition, these methods enable archiving of unpredictable and non-standard elements of the crime scene and the details relevant to the case [15]. They can also incidentally archive objects and processes taking place in the space that could be omitted using other methods of documentation. The randomness of the recorded data can lead to the acquisition of material that is more valuable than the material intentionally accumulated in the case [16].

The results of the research experiment have demonstrated the potential usefulness of the proposed methods of recording the image of the crime scene space and its 3D reconstruction. Owing to their indisputable advantages, the methods proposed by the authors can provide a valuable complement to the traditional methods [17,18]. However, due to their shortcomings, they cannot constitute an independent recording method. Traditional methods and the methods proposed in this study should be viewed as complementary rather than alternative approaches.

Conclusions

The graphic data obtained unintentionally by rescue and emergency services and through alternative recording sources may significantly complement the data collected in the course of routine medico-legal and forensic activities. Unfortunately, the graphic data obtained unintentionally and under specific circumstances may be characterized by insufficient technical quality. Therefore, its processing and analysis requires appropriate elaboration and appropriate critical judgment.

The footage from cameras of emergency services makes it possible to obtain a 3D image of the crime scene for further medico-legal and forensic analyses. Further research and consideration should focus on assessment of the application of cameras under circumstances similar to the executed studies, made by officers of emergency services. It should be emphasized that both traditional methods of acquiring data about the crime scene and the methods proposed in this study should be viewed as complementary rather than alternative approaches.

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