Imaging documentation in the on-site investigation of explosion/ fire events

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Abstract. Explosion/fire investigation is a procedure that involves significant resources of time and activities. The most important of the basic activities performed by the investigator/investigation team is the on-site research, which, if properly performed, allows the elaboration, foundation, and verification of hypotheses, while playing a defining role in establishing the final conclusions regarding the place of initiation and cause of the event.

For these types of phenomena, the on-site investigation is hampered by the damage caused by the event, making it difficult to identify footprints or traces, or by the disruptive effects of the extinguishing products used. The investigation is carried out in the area of the outbreak as well as in all the areas where the fire spread and aims to examine the fire footprint, the set of traces, objects, and materials present in the burnt area, seen in interaction, both with each other and with the surrounding space and environment.

Traditional verbal or written methods of presenting evidence or traces collected at the crime scene are no longer sufficient today, as technological advances are also evident in these areas. Important benefits include the coverage of the entire crime scene, which allows for complete and efficient documentation, using spherical or panoramic photography, or the use of spatial, three-dimensional scans.

This paper aims to present the important contribution made by on-site documentation activities using SceneCam Forensic imaging scanning equipment, based on a high-resolution (HDR) image capture device capable of capturing spherical, 360° x 180° images at a resolution of up to 50 Megapixels in a single scanning operation (Spheron Cam VR).

1 Introduction

In the case of fires and explosions, it is often not possible to speak of a simple forensic, forensic or technical expertise, as these events require a multidisciplinary investigation, with the participation of experts from several fields, thus requiring complex expertise. Examination of physical or chemical evidence remaining at the scene may provide if there

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are few changes, valuable clues that may lead to the determination of the cause, the place of initiation, and the nature of the flammable/explosive substances that triggered the event.

The documentation process is often laborious and time-consuming, the final documentation having to provide a complete and permanent record of the scene, containing written, graphical, photographic, and video evidence of all information obtained [1, 2].

Judicial photography plays a key role in investigating this type of event, being involved in almost every stage of research. The technologies used include 2D photographs, sketches, modern 360° visualization techniques, 3D modeling, or virtual reality (VR) environments. Such new technologies were adopted by the need to improve efficiency and effectiveness, both for forensic scientists, police, and the criminal justice system [2]. The most important action in the investigation consists in inspecting the place where the event took place [3], the assessment of traces and evidence, and the documentation of the case in a form that can be presented in court.

If during the last decade, not much progress has been made in terms of the traditional photo-video technique used to photograph the crime scene, the quality of spherical, panoramic cameras and their accessibility has significantly improved. Two main technologies are used today for digital image recording:

- Photographic technique, through which panoramic images are obtained by combining several images, using specialized software (eg Photosynth);
- 3D representations or automatic panoramic images, which eliminate the need for editing or processing by combining several flat images; 3D laser scanning technologies in point clouds.

Both panoramic cameras and 3D laser scanning equipment consist of two main components: a hardware component - the scanning device itself - either the laser scanning unit or the panoramic camera, and a software component. The software component allows image acquisition and processing in a three-dimensional format, and advanced post-processing functions provide capabilities for reconstruction of the analyzed space, VR (virtual reality) features: movement within the model, detail analysis, etc.

Spherical or 360° photography is a photographic technique that combines a series of planar photographs taken from a single position around a central point [4, 5], creating a detailed visual representation of a scene. The image obtained after the scanning process is an equirectangular projection of a scene, a 3D data type, which can be flattened onto a 2D plane. Using specialized software, the operator is transposed in the center of the scene and can navigate through the digital environment moving left, right, up and down, zooming in or out, and interacting with the different kinds of data associated with the scene, even taking precise measurements [6]. The position and location of evidence and the measurements of objects or structural dimensions within the scene are crucial to an investigation because they can help to reconstruct the scene and the conditions before the event took part [2, 7 - 9]. It is therefore essential that all the information be accurately recorded. In traditional practice, measurements are taken mainly using a tape measure or laser devices, that are considered adequate for in situ measurements. Photogrammetry or 360° photography gives the user the ability to take measurements from digital images, using specialized applications.

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2 SceneCam Forensic Equipment

SceneCam Forensic equipment is a high-resolution (HDR) image capture device capable of capturing spherical, 360° x 180° images at a resolution of up to 50 Megapixels in a single scan. The camera is operated using the touch screen of the tripod-mounted tablet via an intuitive software interface. The camera's High Dynamic Range (HDR) imaging technology allows it to capture all levels of light within the scene: from the darkest shadows to the brightest light, all in a single scan [1]. The camera is capable of a full 32-bit image data path and supports various HDR formats: Radiance, Open EXR, or 32-bit floating-point TIFF.

The fisheye lens (Nikon 16mm f/2.8D) is individually calibrated to compensate for spherical distortion, vignetting, and chromatic aberration.

The Spheron Cam VR provides a dynamic range of up to 26 f-stops in one single scan. This provides brightness attenuation of brightly lit objects and spaces while amplifying dimly lit ones.

The used digital camera is a hybrid between a video camera and a still camera. It is composed of an optical system and electronic equipment, making it easy to operate and ultimately obtain a spherical image of the highest quality. Using this device, we are transported to the scene of the event and are given a three-dimensional perspective of the scene. Using the software, it is possible to take immersive (three-dimensional) measurements on the resulting spherical image. The spherical images that have been produced are stored and protected against any kind of modification by using a unique digital signature. The system can be equipped with a powerful light source, called SCANLIGHT, to perfectly illuminate the scene. This LED-based light source allows total independence from local lighting conditions or sources, providing a constant luminous flux throughout the entire scan (fig. 1).

Fig. 1. SPHERON VR imaging system.

Knowledge of measurable details (distances, dimensions, and spatial orientation) is essential in the documentation process. The SceneCam solution allows accurate 3D measurements to be taken directly from the captured image, or from 3D point clouds (using third-party applications).

The SPHERON camera allows the operator to set the following resolutions [10]:

- 58.3MP - maximum resolution;
- High resolution @ 14.5 MP;
- Medium resolution @3.6 MP;
- Low-resolution @0.9 MP.

Resolutions are equivalent to EXR 8K, 4K, 2K, and 1K outputs, with 4K resolution being optimal for point cloud coloring.

In the post-processing stage, it is possible to use software techniques to increase the original resolution by up to 300%, resulting in 168.6 MP images. This is made possible by the SPHERON camera's use of an RGB chip, which allows for a 100% RGB fill factor, as well as full scene scanning.

Primary post-processing (optional) is done using the native SpheronVR application, SpheronViewer (.EXR viewer). Using this application, .SPH files can be processed and converted to the OpenEXR-compliant .EXR format, so that they can later be viewed as three-dimensional, panoramic space. The processing time ranges from 1min 45s for a high-resolution image (15MP) to 5-6 minutes for a full-resolution image (58MP) on an i7 computing system. The resulting file inherits the same name as the source file, with the addition of the _viewer ending and the .exr extension. Alternatively, the software allows the conversion of the spherical image into the most common formats for use in other third-party applications: JPEG, OpenEXR (HDR format), RADIANCE (compressed HDS file format), TIFF (8, 16, or 32 bit/color, with compression option).

Advanced Processing, SceneCenter Forensics

SceneCenter Forensics is a component of the SpheronVR SceneWorks Solution for crime scene documentation in forensic investigation. The suite of applications allows a wide range of actions to be performed, starting with the photographic recording of the area under investigation and ending with the generation and publication of a scene investigation report that can be edited and presented to the authorities. The interface of the application is very flexible, as the applications it calls upon are non-linear. There are thus situations when a specific task can be solved by several methods [4, 6].

Whether it is the forensic investigation of an event, or the on-site investigation, following fire/explosion events, the use of the application package involves the following distinct steps:

- Performing panoramic on-site scanning;
- Transmitting captured images to a standalone workstation or the SceneCenter Forensic application server;
- Integration of all case-specific data, under a wide range of accepted formats, a process that can be performed independently by each licensed user of the application, involved in the research of the event;
- Elaboration and presentation of the research report, to investigate the case.

Figure 2 shows some of the options available to the user when editing the case:

- A complete representation of the analyzed environment, using panoramic images and detailed reproduction of colors;
- Management of all additional data, necessary for research instrumentation;
- The possibility of spatial orientation in the analyzed space, by incorporating fully panoramic and conventional images (planar), GIS data, plans or notes, and elements that can be related to different types of data;
- Simultaneous viewing of spherical images, GIS data, plans, and documents in electronic format, in different tabs, and in the same interface.

Taking on-demand 3D measurements enables the capture of actual 3D information, allowing to easily measure 3D points and/or sizes of objects or distances within the full spherical image. The measurement involves performing a paired panoramic scan. A pair of measurements thus consists of two completely spherical images, taken from the same location but at two different heights, well known in advance, thus obtaining two distinct perspectives.

Placing the crime scene in the GIS map system allows location information to be contextualized on a GIS data collection, helping to improve situational awareness and increase end-user understanding (Fig. 3).

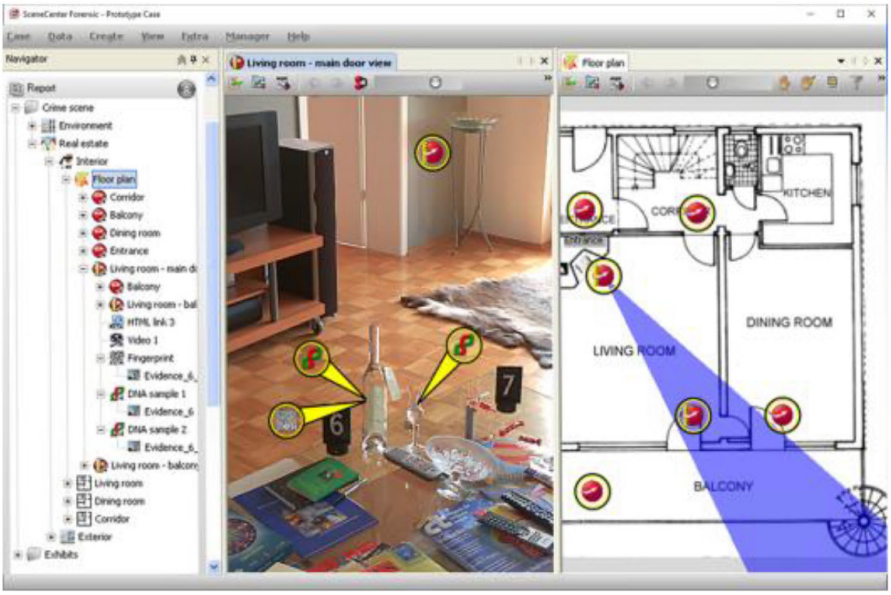

Fig. 2. SceneCenter Forensic user interface.

Establishing viewpoints. Separate viewpoints can be set to memorize and recall preferred viewing directions, exposure, and zoom settings for GIS maps, spherical and planar images. Viewpoints make it easy to define areas of interest.

Creating hotspots: In SceneCenter Forensic, you can create connections between all data to full spherical or conventional images, as well as to plans, by creating so-called hotspots, which are visual links that can be placed within an image. Hotspots allow moving from one view to another, facilitating visual navigation. As an observer, one can spatially capture the scene of a crime/event and define visual connections between evidence and traces and the location where they were found.

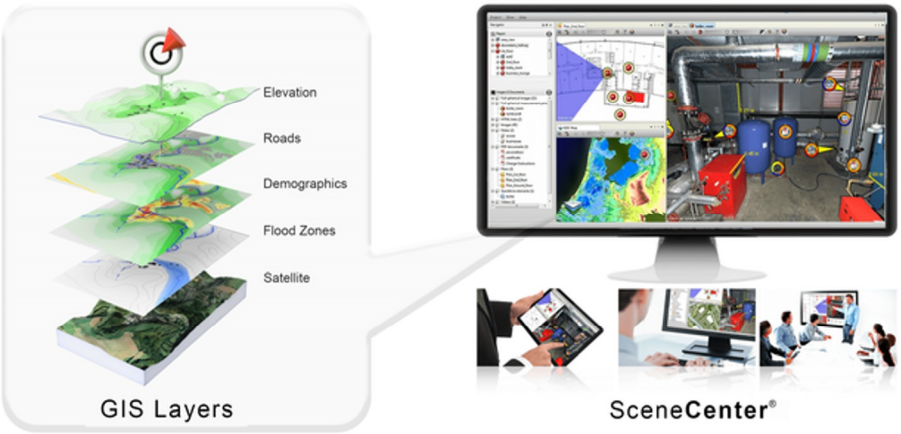

Fig. 3. Simultaneous integration of multiple GIS data sources, and compatibility with leading GIS technology vendors on the market.

3 On-site, spherical panoramic image capture technique

Steps in the spherical image capture process include:

a) Equipment preparation stage;
b) The stage of operating the camera at the scene;
c) The post-processing stage.

In the equipment preparation stage, the operator must ensure the whole set of conditions necessary for the optimal functioning of the camera, namely: charging the batteries, selecting the necessary light sources, proper functioning of the tablet attached to the device, from where its activity is coordinated, etc.

Device operation at the scene of the event involves installing the camera on the support tripod, preferably located in the center of the space being analyzed, and connecting the multi-role cable (power and data transfer). The positioning of the camera usually depends on the nature of the event under investigation and the arrangement of objects in the vicinity. In the case of indoor imaging scans, the location is chosen, if possible, as close as possible to the center of the room. In the case of outdoor events, it is often necessary to take multiple captures, with the device being placed in the vicinity of areas of interest (containing traces or evidence, measurable landmarks, etc.). The SceneCam Easy app provides an intuitive interface that guides the operator through the steps of the spherical image capture process. It allows basic operations to be performed: initial calibration of the system, selection of the scan resolution, activation of the optional light source, viewing the battery charge level, and the storage system. If access to advanced device settings is desired (shutter speed adjustment, CCD sensor calibration, delayed start, lens aperture control, area of interest specification, resolution control, white balance, ISO control, image capture direction, preview, dynamic adjustment of capture settings, histogram display, various warnings about overexposure or light oversaturation, tone-mapping, etc.), it is necessary to use the SpheronCam Solution software application, which is made for Microsoft Windows operating systems.

Following capture, an .SPH output file is immediately processed, which converts the recorded raw data into a color tone mapped image, exported for preview in common JPEG format.

The post-processing stage involves a series of activities that take place at the investigator's premises, with the final aim of photographically documenting the scene of the event, which is part of the expert report. Complete spherical images are the foundation of the concept of visually-oriented documentation. Images captured automatically from SceneCam are imported into SceneCenter Forensic software. Subsequently, the software allows the integration of several types of analysis information, such as all trace evidence samples (blood, fiber traces, fingerprints, hair samples, DNA, etc.) plus detailed photographs, notes, videos, and more (situation sketches, plans, documentation, detail photographs, etc.).

4 Case study

At INSEMEX, the imaging scanning system has been successfully used in several determinations, with dimensional measurements, in on-site research activities for technical-scientific expertise.

Figures 4 and 5 show panoramic images taken during the on-site investigation of a fire in the underground car park of a block of flats, which subsequently spread to the apartments upstairs.

Fig. 4. Unfolded spherical image (preview) captured inside the underground car park.

Fig. 5. Unfolded spherical image captured outside the building.

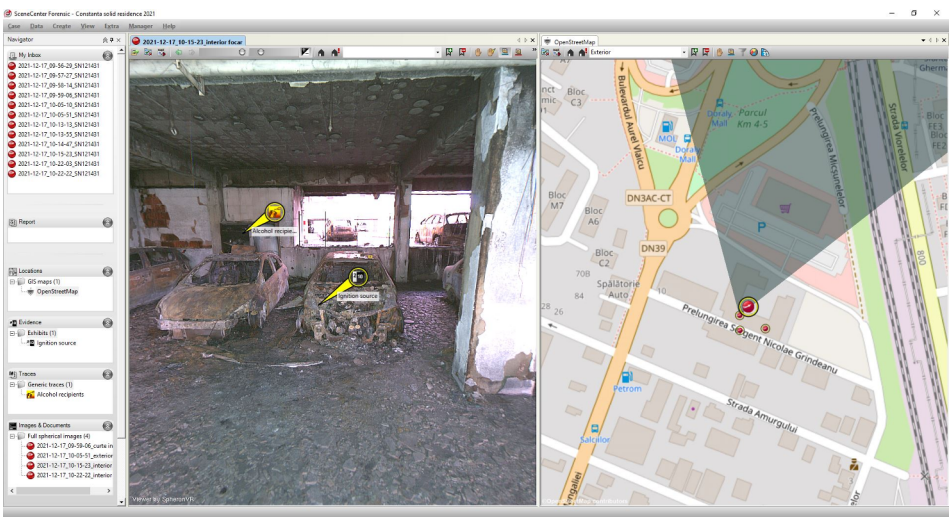

Fig. 6. Fixing the samples and the initial outbreak, within the analyzed scene, respectively locating the event site on the map, using GIS resources and GPS coordinates attached to the panoramic photo.

The Spheron system was also successfully used in another technical-scientific expertise, following an event in a block of flats in Satu Mare County, an explosion started by an efficient source (lighter), the natural gas coming from a gas supply pipe whose valve was

accidentally opened. Fig. 7 and 8 show panoramic images captured on-site using the Spheron VR camera.

Fig. 7. Unfolded spherical image (preview) captured inside the apartment.

The SceneCenter Forensic software can also generate automatically, as output data, a „test and exhibits" file, containing all the identification information for the specific case, together with the relevant data regarding the relevant evidence and exhibits from the attached database: name, type, description, identification number, date of seizing and person, disposition, etc.

The final report is also automatically generated, based on all the information provided by the user, and it is completely customizable. The report can be saved in .pdf or editable format, constituting an important piece in the investigation file.

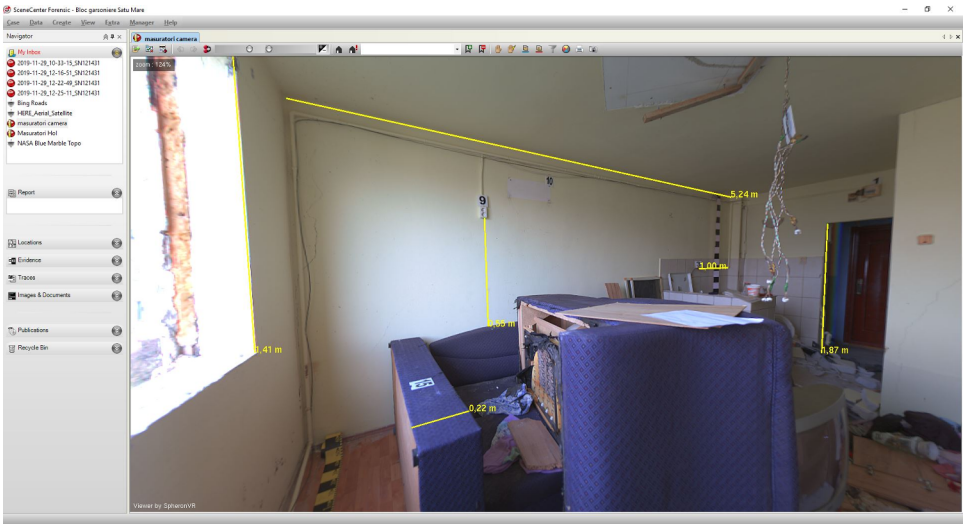

Fig. 8. Measurements performed using the SceneCenter Forensic application.

5 Conclusions

Spherical images and three-dimensional representations can transmit spatial perception to the observer and allow the reconstruction of the event scene at any time, including measurements and the addition of new case-related information as they appear during the investigation.

The undeniable advantage of these methods is the possibility of obtaining precise, objective, complete, and factual spatial documentation, associated with vast sources of information. Working with spatial data and panoramic images offers specialists an immersive, realistic experience, with truthful descriptions of all the associated aspects. Unlike other techniques, such as traditional photography, it can provide measurable data even in low light conditions, at night, or in dark environments. At the same time, after capturing spherical images of a space, they can be used for various analyzes, in different projects, without requiring a new scan or new photos to cover the missing data on the spot, it is known that after a short period, the scene of an event undergoes changes or degradations from a forensic point of view.

The limitations of these techniques consist of the relatively high costs required to purchase the hardware and the periodic maintenance of the software, along with the need to use high-performance computing resources, in the case of large space scans.

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