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# Virtual Reality for CSI Training

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## ABSTRACT

The EU-funded project, Real-Time On-Site Forensic Trace Qualification (RISEN) aims to enable the use of advanced sensors in the field in order to get results in near real-time. The project also aims to visualize the data by innovative means, such as in virtual reality (VR). The Swedish National Forensic Centre, NFC, has been developing methods for 3D modeling of crime scenes since 2016, and have conducted several studies in the use of VR for CSI application. This paper describes the status and possibilities with VR for CSI training and how the results from the RISEN project can be utilized within forensic training.

**Keywords:** Virtual Reality, VR, CSI training, Police, Sensors

## 1. INTRODUCTION

The Swedish Police Authority started activities within VR-visualization in 2016 by acquiring an Oculus Rift head-mounted display (HMD), and in the spring of 2017 a study on the use of VR within the forensic process was carried out. The study concluded that VR would indeed be a useful tool within the forensic process but that more studies were needed in order to figure out exactly how and where it would be useful. In 2018 another project was carried out that concluded that VR could be useful but that the effort that would be needed to create accurate 3D models would be unfeasible for most forensic cases. However, the use within forensic training was concluded feasible.

In 2019 the Swedish Police joined a consortium planning a proposal for a Horizon 2020 call with the name RISEN, short for "Real-tIme on-site forenSic tracE qualificatioN". The project received funding from the European Union and started the first of July 2020 and will continue until the end of 2024. The aim of the RISEN project is to develop a set of rapid, contactless sensors and an Augmented Crime Scene Investigation system. The system aims for the optimization of trace identification, classification and interpretation on site. One part of the solution is new sensor technologies for facilitating crime scene investigation on-site. Another is a 3D reconstruction and positioning tool to reconstruct the crime scene and map all the sensor measurements onto this reconstruction. Sensor data fused together with the RISEN 3D Augmented Crime Scene Investigation system will allow for increased analysis of traces while reducing laboratory activities for further analysis, faster information exchange, and digitalization of documentation and the chain of custody.

In order for the system to be used within real crime scene work, more validation and development will be needed. The results of the project will be a proof of concept system. The RISEN project is not focused on either VR or forensic training. However, parts of the solution will most likely be possible to use for forensic training applications.

## 2. VR IN FORENSICS

Nowadays, VR finds applications in many fields and industries, including healthcare, entertainment, automotive, education, space & military, architecture, digital marketing, occupational safety, social science and psychology, and

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tourism. Depending on the field, VR can be used for training and education, entertainment, therapy, product development, or marketing purposes [1-4].

There also exist many studies that show practical use of VR as a tool in forensics, supporting crime investigations and training [5-29]. The potential of using real-time virtual environments as an additional tool in crime scene investigation was already noticed over 20 years ago. It was associated with developing tools for forensic 3D scene reconstruction [5]. The identified potential applications of VR technology in the field of crime scene investigation included data analysis, witness statement evaluation, witness assistance, route visualization, briefing officers, hypothesis evaluation, training, lighting evaluation, security planning, crime prevention, and courtroom uses [6]. The 3D documentation and computer-generated animations in VR were recognized as ideal media to accurately visualize crime or accident scenes, to help understand the situation and retain complex spatial information [7-9]. However, it was also noticed that even animations with high level-of-detail, due to many reasons, had only limited use in courtrooms because of their admissibility [8,10].

The role of VR technology in forensics will grow with the development of the technologies allowing more precise and detailed 3D reconstruction of crime scenes [11-13]. It is clear that 3D technology opens opportunities for extended forensic analysis, even in the first steps of crime scene investigation. It can provide robust technical assistance on everything from documentation to visualization of the scene presented in court. 3D technology paves the way for VR to become an efficient tool in crime fighting at all stages of the forensic process, from initial scene assessment, through investigation and finally in the courtroom by providing a 3D crime scene virtual tour.

Developments in 3D technologies may also enable fully immersive VR experiences that are indistinguishable from reality, allowing for real-time immersive telepresence or virtual incident scene walkthrough [13,14]. Such use of VR will be beneficial for many reasons, including, for example, the lack of a high number of specialized forensic experts who could attend crime scenes, which is a problem for geographically large countries. A telepresence solution could be very beneficial.

However, to fully use the potential of 3D and VR more work is needed, and in the area of VR further development of necessary technologies, such as wearable devices and protocols for safe data transmission, as well as standardized procedures and ways of working is needed [15].

# 3. CRIME SCENE DOCUMENTATION

In the real-world crime scenes are being documented mostly by conventional DSLR cameras, i.e. photographs, these photographs are usually taken at varying levels of details for example overview photographs capturing the relationship between objects and detail photographs capturing individual objects such as a knife or a blood stain. These images are later used to give investigators and others in the forensic process an understanding of the crime scene, often in combination with floor plans or maps.

An important aspect of the crime scene documentation is to accurately record the measurements of objects and evidence within the scene to establish their precise location and relationship to one another. The correct measurement of objects and evidence and locations can help to reconstruct a sequence of events and make hypotheses about the occurred events. It is therefore essential that such information is accurately recorded. This is usually done by manual measurements but in complex crime scenes terrestrial laser scanning (TLS) can be very beneficial.

Reconstructing a crime scene in VR requires tools to conduct multi-angle and omnidirectional three-dimensional spatial data collection of crime scenes, such as laser scanners or structured light scanners [16,17]. There is a need to implement a standard operating procedure (SOP) allowing the scene to be recreated in Virtual Reality (VR) [19]. The RISEN-project aims at bringing together the best practices of creating such a data collection (a digital twin of the crime scene) making use of all available sensor technology, taking steps forward such a SOP.

Furthermore, in order to visualize in VR a combination of 3D VR-headsets in conjunction with tracked controllers is needed [18]. The latter set of tools for visualization of 3D data offers more than just visualizing static crime scene reconstructions.

### 3.1 Laser Scanning

A LiDAR-sensor (Light detection and ranging) is an active measuring technique where a laser pulse is sent and where its reflection is measured in order to calculate the distance and reflectivity. TLS-scanners are a subset of LiDAR-equipment, typically used for terrain and landscape mapping but also indoor scenarios. TLS-scanners basically work by measuring distances to objects in a 360 sphere around itself, each measurement results in a coordinate in 3D-space, and multiple measurements (usually millions) results in a so-called point cloud. The point cloud contains information of distance and intensity, i.e. how far the point is and how much of the laser light that was reflected, which produces something that looks like a grayscale image if you present it on the screen. The points can also include other information such as color information from a visual camera (textured).

The point cloud can be used to visualize the overall environment and physical structures as well as relationships and distances between objects. Since it is a 3D-representation of the scene it is also possible to navigate the scene and look at it from different angles. It is also possible to remove certain points in order to create a view that would not be possible in reality, for example removing a wall or ceiling for the purpose of better understanding how rooms are aligned.

Nevertheless, the model lacks fine details which are quite commonly needed for training specific procedures required to complete tasks. Figure 1 illustrates the difference of visual resolution between a photo and a laser scanned shelf that is a very small part of a room sized model.

Figure 1. Example of presenting fine details in terrestrial laser scanned models (upper image) and photograph (lower image)

The point density of the scanning can be increased for improving the accuracy, but scanning time increases rapidly and dense point clouds require very expensive computers to render the models in real-time. Also, no scanner provides such a dense scanning mode that matches with the visual camera quality. Point clouds may also have holes and distortions, since for example transparent, specular or mirror-like surfaces are difficult to map using TLS.

### 3.2 Photogrammetry

Photogrammetry is the art and science of calculating 3D information from photographs, i.e. using conventional RGB-images to create 3D-information. In general, reconstructing 3D information from images requires a relatively large set of images taken from different views of the scene. The idea is that 3D points visible in two or more images can be estimated, by means of triangulation using photogrammetry software. Photographs are taken of a scene or object and loaded into the software which creates a point cloud similar to the output from a TLS approach. The main difference is that the point cloud is calculated and not measured which in general means lesser accuracy (depending on the scene). The main upside is that standard photo equipment can be used, however mapping a large scene requires an excessive number of photos.

In addition, assuring that all details are well covered needs careful and skilled planning. Also, the model itself may suffer from distortions, depending on the visual texture on surfaces in the photos. If the surface does not provide enough unique features, the photo matching may fail and create distortions into the 3D model.

## 4. CURRENT FORENSIC TRAINING

Currently, the most important applications of VR in forensic science is its use for training and education, and this is probably where the most upcoming development will be seen [21-29]. However, much work remains for it to become a standard training method and for it to gain acceptance on a broader scale. For example, within the Swedish Police Authority VR is currently not used for forensic training at all. It is important to note that the forensic field is highly specialized and that it is a highly practical field where much of the training is carried out as practical exercises in realistically mocked crime scenes. Several projects have been conducted but overall the organization has not yet been convinced of the benefits. In 2021 one project investigated if the BPA-training could benefit from the use of VR. The project concluded that the VR-solutions available at the time were not good enough to compete with a physical scene, however there could be benefit in being able to better understand the entire scene. For example, a scenario could take place in multiple rooms virtually while the blood stains only were created physically in a subset of the scene. However, it was also concluded that having a 3D-model presented on an ordinary computer screen would be good enough to give a good understanding of the scene and hence that VR would not make a difference.

However, several studies show the benefits, and it is clear that simulated VR scenarios for police practitioner allows trainees to practice in a safe and controlled environment, without the risk of contaminating or damaging real crime scenes. This can also be particularly useful for scenarios that are difficult to recreate in real life, such as hazardous or complex crime scenes. Additionally, VR technology can also provide instant feedback to trainees, allowing them to review and evaluate their performance. This can help trainees to identify areas of strength and weakness, and work on improving their skills.

In terms of scoring the ability of the person under training, VR technology can be programmed to track and measure a range of factors, such as accuracy of evidence collection, adherence to proper investigative procedures, and time management. This data can be used to provide trainees with a score or rating, which can help to objectively measure their progress and skill level. Overall, VR has the potential to revolutionize crime scene investigation training, providing a safe and effective way to prepare trainees for real-world scenarios, while also allowing for the tracking and assessment of their skills and abilities.

In 2018 it was found that VR-based training was effective in improving the accuracy and completeness of crime scene investigation by providing trainees with an immersive and interactive experience [30]. The study also noted that the use of VR technology allowed for more efficient and cost-effective training compared to traditional methods. Another study found that the VR-based training was effective in improving the accuracy and confidence of trainees in bloodstain pattern analysis [31].

In terms of scoring the ability of trainees, a study published in the Journal of Virtual Reality and Broadcasting in 2018 explored the use of objective measures to evaluate the performance of trainees in a VR-based crime scene investigation training program. The study found that the use of objective measures, such as accuracy of evidence collection and adherence to proper procedures, could effectively assess the skill level of trainees [32].

VR allows trainees to investigate multiple crime scene scenarios, including previously investigated and 3D reconstructed real cases. Thanks to hardware advances, the generation of 3D worlds is possible whose graphical resolution and frame rates can approach 'real life' and hence can offer an immersive and worthwhile experience [21, 22]. Cardwell et al. reported studies on developing VR:CSI methodology for teaching crime scene investigation and tested it on a group of forensic students [23]. The results showed that VR could effectively deliver students interactive teaching and educational experiences. Students can experience a realistic CSI environment cheaply and safely, where an instructor can easily teach and engage them in CSI procedures.

Importantly, in the discussion of previously reported studies on VR, authors indicated the importance of presence in VR for creating a realistic experience. Cardwell et al. also investigated whether diegetic interface elements in VR may improve trainee experience; however, it was found that no elevated sense of presence was experienced by trainees involved in the studies [24]. In fact, significantly higher levels of workload and completion times were recorded. Also, other studies reporting the use of Virtual Reality as a support in the training of forensic science and crime scene investigation showed that VR is a helpful tool for learning and practicing problem-solving skills [25, 26]. As reported by Khalilia et al., [25] students had a positive experience with the collaboration strategies and activities during learning crime scene investigation using a virtual environment. Kader et al. have shown that with the use of WebVR technologies, VR glasses, and smartphones teaching forensic students of a crime scene investigation can be done cost-effectively [26]. Although, in other studies, it was pointed out that the poor quality of tools may reduce the effect of VR teaching in forensic science, as insufficient level of detail could be visible [27]. Therefore, access to the newest technologies for 3D environment recreation will be necessary to ensure efficient training of forensic professionals. Another important aspect of using VR for training is that it requires designing and implementing serious games that can be used as educational tools [28, 29].

The implementation of VR technologies in forensic training showed that it is an engaging and effective method for imparting practical crime scene skills [21,22]. These technologies, with advances in their development, are becoming more accessible and may offer a broader range of more cost-effective solutions than conventional methods. However, it is essential to point out that VR technologies have to be wisely and timely introduced into the learning process of forensic and CSI specialists and certainly will never replace conventional practical experience. The implementation of the VR technologies has to proceed by properly introducing the trainees into the field of training. In addition, VR technologies have to be also carefully selected to serve their purpose properly [21, 22].

Recently, VR has also been shown to provide the technical capabilities to perform an identification parade; however, this application of VR still has to be investigated [20].

## 5. RISEN RESULTS

Since the start of the project in July 2020 two major 3D-trials have been carried out, one in Frascati in Italy in 2021 and one in Riga in Latvia in 2022 and more trials are planned. The trials have been focused on comparing best practices for crime scene documentation utilizing different technologies and methods such as laser scanning and photogrammetry.

During the first RISEN-trials sessions in Frascati photogrammetry performed on more than 100 pictures acquired with DJI Mavic mini drone was processed and compared to traditional laser scanner acquisition showing good level of accuracy (0.8%) for preliminary measurement on the scene terrain. (figure 2).

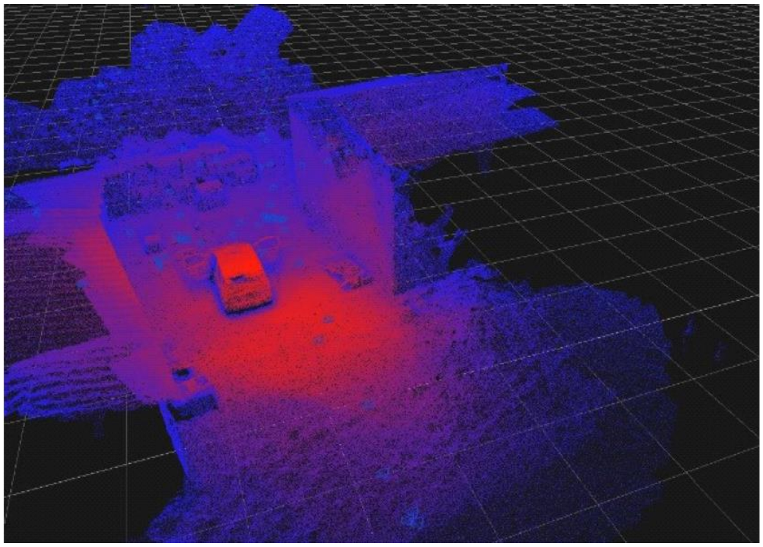

Figure 2. Photo consistency of point cloud

In figure 2 the coloring shows the photo consistency provided by the photogrammetry calculation, i.e. how consistent the point cloud is with the information provided by different images. Red points mean higher consistency than blue ones. This can be useful information for the user and depending on how the end result will be used more or less pictures should be taken to ensure the right quality. Or even to suggest other acquisition techniques such as laser scanning if high quality is needed. In addition, assuring that all details are well covered needs careful and skilled planning. Also, the model itself may suffer from distortions, depending on the visual texture on surfaces in the photos. If the surface does not provide enough unique features, the photo matching may fail and create distortions into the 3D model.

Figure 3. Point cloud calculated by drone images

Figure 4. Meta quest 2 extracted image of Frascati Virtual Scenario.

Figure 3 shows the point cloud created from the drone images, from a distance the quality seems reasonable to give a good overview. However, meshing the point cloud and putting it into VR results in highly distorted and "bubbly" views as shown in Figure 4 which shows a screen capture from a VR headset (Meta Quest 2). It is important to note that this result highly depends on the use case. If the need is to give a quick overview of the crime scene and its overall layout and proportions, the result may well be good enough. The scene, even with low accuracy, provided a good metric simulation of the real scenario offering the possibility to move through the scene and place virtual evidence markers as reference and rulers to provide a direct measurement on the virtual scene (figure 4). However, for more complex scenarios, where more details are needed the results are definitely insufficient.

The ideal solution will most probably be a mix of different technologies such as a combination of photogrammetry and laser scanning, giving the best of two worlds.

## 6. FUTURE WORK

It is clear that combining sensor technologies has an advantage, the RISEN project aims at fusing data from a wide variety of sensors utilizing the best features of each and to create a complete digital twin of the crime scene. Such a model can improve both the efficiency and effectiveness in the investigations and the criminal justice system and the training of police forces. These techniques can better guide jurors and the court and assist attorneys through virtual walkthroughs in the crime scene, better representations of the spatial situations, without the requirement for perfectly scaled models and the generation of forensic evidence or expert analysis required to stand the rigor of court testimony [33].

Digitalization of crime scenes, and resulting metric 3D models, facilitate a virtual return of LEAs to the crime scene to perform measurements from digital images providing spatial perception, to navigate throughout the scene in a highly detailed immersive environment, to perform additional observations and measurements with rigor, thoroughness, and accuracy, or to view the evidence from different angles after the crime scene was released.

However, much work remains before we will see the conventional DLSR-cameras being left behind. For many years to come 3D-sensing technology will merely serve as a complement to the conventional images. However, within the training domain, it will probably be possible to transition to VR completely within different topics quite soon. Solutions such as the RISEN 3D Augmented Crime Scene Investigation system will be able to create environments realistic enough for training applications.

Also, 3D-reconstruction solutions are also rapidly evolving. Smartphones and tablets equipped with LiDAR sensors capable of creating 3D-models utilizing a fusion of LiDAR and photos out of the box paves the way for easier creation of high-quality 3D models suitable for CSI training applications.

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## REFERENCES

[1] Xie, B., Liu, H., Alghofaili, R., Zhang, Y., Jiang, Y., Lobo, F.D., Li, C., Li, W., Huang. H., Akdere, M., Mousas, C. and Yu, L.-F. "A Review on Virtual Reality Skill Training Applications." Front. Virtual Real., 2, 645153 (2021).

[2] Radianti, J., Majchrzak,T.A., Fromm, J., Wohlgenannt, I. "A systematic review of immersive virtual reality applications for higher education: Design elements, lessons learned, and research agenda," Comput. Educ., 147, 103778 (2020).

[3] Srivastava, K., Das, R.C., Chaudhury, S. "Virtual reality applications in mental health: Challenges and perspectives." Ind. Psychiatry J. 23(2), 83-85 (2014).

[4] Choi, S., Jung, K., Noh, S.D. "Virtual reality applications in manufacturing industries: Past research, present findings, and future directions." Concurrent Eng.-Res. Appl. (1), 40-63 (2015).

[5] Robey, D., Palmer, I., Chilton, N., Dabeedin, J., Ingham, P. and Bramble, S., "From crime scene to computer screen: the use of virtual reality in crime scene investigation." In Proceedings of the 7th UK VR-SIG Conference (pp. 1-12) (2000).

[6] Howard, T.L.J., Murta, A.D., Gibson, S. "Virtual environments for scene of crime reconstruction and analysis," Proc. SPIE 3960, 41-48 (2000).

[7] Schofield, D., "Graphical evidence: forensic animations and virtual reconstructions." Aust. J. Forensic Sci., 41(2), 131-145 (2009).

[8] Ma, M., Zheng, H. and Lallie, H. "Virtual Reality and 3D Animation in Forensic Visualization." J. Forensic Sci., 55, 1227-1231 (2010).

[9] Buck, U., Naether, S., Räss, B., Jackowski, C. and Thali, M.J., "Accident or homicide–virtual crime scene reconstruction using 3D methods." Forensic Sci. Int. 225(1-3), 75-84 (2013).

[10] Burton, A.M., Schofield, D., Goodwin, L.M. "Gate of global perception: forensic graphics for evidence presentation." Proceedings of the 13th Annual ACM International Conference on Multimedia; 2005 Nov 6–11; Singapore. New York, NY: Association for Computing Machinery, 103–11 (2005).

[11] Engström, P. "Virtual Reality for Crime Scene Visualization" Proc. SPIE 10666, 102-108 (2018).

[12] Jegatheswaran, R., Ramachandiran, C.R. and Juremi, J., "Implementation of virtual reality in solving crime scene investigation." J. Appl. Technol. Innov. 5, 28-32 (2021).

[13] Engström, P. "Telepresence as a forensic visualization tool." Proc. SPIE 11166, 90-96 (2019).

[14] Sieberth, T., Dobay, A., Affolter, R. and Ebert, L., "Applying virtual reality in forensics – a virtual scene walkthrough." Forensic Sci. Med. Pathol. 15, 41–47 (2019).

[15] Lee, C.L., Fang, Y., Huang, Y.H., Lee, S.H. and Yeh, W.C.C., "Application of wearable devices in crime scene investigation and virtual reality." In 2019 IEEE Symposium Series on Computational Intelligence (SSCI), 206-210 (2019).

[16] Wang, J., Li, Z., Hu, W., Shao, Y., Wang, L., Wu, R., Ma, K., Zou, D. and Chen, Y., "Virtual reality and integrated crime scene scanning for immersive and heterogeneous crime scene reconstruction." Forensic Sci. Int. 303, 109943 (2019).

[17] Galanakis, G.; Zabulis, X.; Evdaimon, T.; Fikenscher, S.-E.; Allertseder, S.; Tsikrika, T.; Vrochidis S. A "Study of 3D Digitisation Modalities for Crime Scene Investigation." Forensic. Sci. 1, 56–85 (2021).
[18] Sieberth, T., Dobay, A., Affolter, R. and Ebert, L., "A toolbox for the rapid prototyping of crime scene reconstructions in virtual reality," Forensic Sci. Int. 305, 110006 (2019).
[19] Yu, S.H., Thomson, G., Rinaldi, V., Rowland, C. and Daeid, N.N., "Development of a Dundee Ground Truth imaging protocol for recording indoor crime scenes to facilitate virtual reality reconstruction," Sci. Justice., 63, 238-250 (2023).
[20] Sieberth, T. and Seckiner, D., "Identification parade in immersive virtual reality-A technical setup." Forensic Sci. Int. 111602 (2023)
[21] Mayne, R. and Green, H., "Virtual reality for teaching and learning in crime scene investigation," Sci. Justice., 60, 466-472 (2020).
[22] Engström, P. "Visualizations techniques for forensic training applications." Proc. SPIE 11426, 54-60 (2020).
[23] Cardwell, A., Murray, J., Croxton, R. and Nurse, B., "The Use Of Virtual Reality In Education And Learning: A Case Study For Teaching Crime Scene Investigation." In *EDULEARN17 Proceedings*, 3005-3015 (2017).
[24] Dickinson, P., Cardwell, A., Parke, A., Gerling, K. and Murray, J., "Diegetic Tool Management in a Virtual Reality Training Simulation." In 2021 IEEE Virtual Reality and 3D User Interfaces (VR)", 131-139 (2021).
[25] Kader, S.N., Ng, W.B., Tan, S.W.L. and Fung, F.M., "Building an Interactive Immersive Virtual Reality Crime Scene for Future Chemists to Learn Forensic Science Chemistry" J. Chem. Educ. 97, 2651−2656 (2020).
[26] Khalilia, W.M., Gombár, M., Palková, Z., Palko, M., Valiček, J. and Harničárová, M., "Using Virtual Reality as Support to the Learning Process of Forensic Scenarios." IEEE Access, 10, 83297-83310 (2022).
[27] Drakou, M. and Lanitis, A., "On the development and evaluation of a serious game for forensic examination training." In 2016 18th Mediterranean Electrotechnical Conference (MELECON), 1-6 (2016).
[28] Acampora, G.; Trinchese, P.; Trinchese, R.; Vitiello, A. "A Serious Mixed-Reality Game for Training Police Officers in Tagging Crime Scenes." Appl. Sci. 13, 1177 (2023).
[29] Chen, Y.R., Chang-Liao, Y.Q., Lin, C.Y., Tsai, D.R., Lim, J.H., Hong, R.H. and Chang, A.R., "Forensic science education by crime scene investigation in virtual reality." In 2021 IEEE International Conference on Artificial Intelligence and Virtual Reality (AIVR), 205-206 (2021).
[30] International Journal of Virtual Reality, "Development of a Virtual Reality Environment for Crime Scene Investigation Training," DOI: 10.20870/IJVR.2018.17.1.2235
[31] Journal of Forensic Sciences, "An Evaluation of Virtual Reality Bloodstain Pattern Analysis Training," DOI: 10.1111/1556-4029.13948
[32] Journal of Virtual Reality and Broadcasting, "The Performance and Training Assessment of a VR-Based Crime Scene Investigation System," DOI: 10.20385/1860-2037/12.2018.8
[33] Chapman B and Colwill S (2019) Three-Dimensional Crime Scene and Impression Reconstruction with Photogrammetry. J Forensic Res 10: 440; Galanakis, G.; Zabulis, X.; Evdaimon, T.; Fikenscher, S.-E.; Allertseder, S.; Tsikrika, T.; Vrochidis S. A Study of 3D Digitisation Modalities for Crime Scene Investigation. Forensic. Sci. 2021, 1, 56–85. https://doi.org/10.3390/forensicsci1020008).