Abstract

Three-dimensional (3D) reconstructions of evidence offer great potential in the field of forensic science. They can help in the presentation of complex spatial and temporal data to a non-technical audience. In addition to these 3D technologies, the digital age has brought a plethora of new evidence forms, evidence detection methods, and means of evidence presentation.

This position paper describes the previous use of 3D reconstruction evidence in courtrooms. It then outlines the forensic process in terms of tasks and phases involved, and describes the state of the art in terms of digital technology usage. The paper then presents a taxonomy of these phases in terms of a technology continuum. It goes on to highlight areas where new applications of 3D digital technologies could be used to enhance particular phases of the forensic process. This paper does not deal with security issues relevant to the devices discussed.

Keywords--- Forensics, Evidence, Visualisation, Reconstruction, Augmented Reality, Virtual Reality, Mixed Reality.

1. Introduction

The modern information and technology explosion is bringing a plethora of new technologies into the field of international security and forensic investigative science, many of which will end up needing to be admitted to these courtrooms as evidence. In most jurisdictions technology is slow to become accepted in the world’s courtrooms. While efficient trials within the world’s courts can potentially quickly remove terrorists and criminals from society and ensure rapid outcomes to protracted criminal investigations and complex fraud cases, there are also a number of problems with the global use of the technology available to ensure this occurs. Courtroom presentation (in some jurisdictions) has already been enhanced by the introduction of such technologies as video conferencing to bring remote witnesses to the courtroom, voice recognition software to transcribe proceedings, and the use of three-dimensional (3D) computer reconstructions as a means of portraying complex evidence to a non-technical audience [1, 2].

This position paper reports on the author’s experiences of using 3D reconstructions as forensic courtroom presentations. It beyond the scope of this paper to discuss the application of other forms of forensic imaging (digital images, QuickTime VR panoramas etc.) The paper then gives an overview of the forensic process, and describes the current usage of digital technologies within the distinctive phases of the process. The paper then introduces a proposed taxonomy highlighting the parts of the forensic process where the technologies are being used, and also where they are not.

2. Examples of the Use of 3D Technologies

The use of new technologies in order to gather, analyse and present evidence is of the utmost importance in today’s technologically advanced world. Better collection and analysis of evidence from a wide range of digital media technologies can be achieved by the use of data from the devices of witnesses, and those involved in incidents. The devices which may provide additional evidence include mobile phones, PDAs, digital cameras, and closed-circuit TV. Recent terrorist incident have highlighted these new forms of evidence as mobile phone images and video are collected from members of the public who were at the scene of the incident. The use of such evidence in the courtroom creates enormous problems such as ownership, bias, veracity, ethics and the security of the chain of custody of the evidence.

Presentation of the evidence relating to a particular incident in a courtroom can bring about the need for arduous descriptions by lawyers to get across the specifics of complex spatial and temporal data. As Burns [3] states “The presentation typically takes the form of a report, and the scientist must be prepared to explain this report in such a way that a typically science-phobic judge and jury are able to comprehend it. Presentation is everything.”
Presenting data related to road traffic accidents in the courtroom is a prime example of this need to relate spatial and temporal data, for which the use of 3D computer generated reconstruction technology has been extensively adopted [4]. In such cases, a computer generated forensic reconstruction is built using a 3D virtual model of an incident or scene created from actual measurements taken by police at the time of the incident, and using scientific calculations based on those measurements. This computer model can then be rendered to create an animation, or a series of animations, which describe the scene or incident. These forensic animations, when used in court, must support and corroborate existing evidence and the supportive evidence must be used in conjunction with the animation to be admissible as substantive evidence in any courtroom [5].

Using computer graphics technology, it has been possible to show views of an accident from the positions of the vehicles and pedestrians involved, and also those of the witnesses [4]. Images from two computer generated animated reconstructions (created by the author) which have been presented as evidence in a UK court are shown in Figures 1a and 1b. Figure 1a is a view from evidence created regarding a road traffic accident where two motorcyclists were killed when they collided with the side of a car [5]. Figure 1b shows a pathology reconstruction used in a murder case to investigate the nature of a stabbing incident [6].

The use of computer generated forensic animations has been taken a stage further with the introduction to courtrooms of interactive ‘real time’ applications. This offers a unique platform for the collation, interrogation, analysis and presentation of complex forensic data across a wide spectrum of crime-scene and accident scenarios. 3D interactive reconstructions of incidents have allowed the user to visualise views from multiple relevant positions within the virtual environment, something which can be beneficial within the dynamic, adversarial environment of the courtroom.

The author has applied interactive, ‘real time’, virtual environment technology to numerous criminal cases1. Two recent high profile examples are described below:

For the case of the murder of PC Malcolm Walker, a motorcycle policeman in Birmingham, UK [1, 7] an interactive virtual environment was created (Figure 1c). It was designed to specify and identify all debris found at the scene of the incident, by using context-sensitive links to the scenes of crime digital photograph evidence. It was used during the trial as evidence to successfully convict the defendant, Nicholas Walters, of murder.

For the high profile case of the shooting of Leticia Shakespeare and Charlene Ellis in Birmingham, UK, the police commissioned a forensic reconstruction. In this case, two teenage girls were shot dead during an all-night party at a hairdressing salon whilst celebrating the New Year. A 3D interactive environment was created (Figure 1d), it was designed to allow the user to visualize the positions of the victims and suspects, by using context-sensitive links to the scenes of crime digital photograph evidence. It was used during the trial as evidence to successfully convict the defendant, Nicholas Walters, of murder.

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1 The majority of these interactive forensic reconstructions are powered by commercially available computer game engines.
3. Defining the Forensic Process

The successful use of the 3D technology described above in a courtroom raises the question of whether there are any other parts of the forensic process that may be suited to the use of modern digital technologies. In order to define areas of the forensic process which may be enhanced by novel digital technology use, it is necessary first to break down the process into its constituent phases. Many books and papers have been published that summarise the steps involved in forensic investigation into generalised stages [9, 10, 11]. These publications usually incorporate similar steps, although the nomenclature and the order may vary slightly.

More recently, researchers have tried to generalise models for digital forensic investigations [12, 13, 14]. Carrier and Spafford [15] suggested describing a linked digital and physical forensic examination, assuming that each individual digital device was treated as a separate crime scene. A computer is considered as a single piece of physical evidence at a crime scene, but it may contain hundreds of discrete and vital pieces of digital evidence. The investigation of the digital and physical crime scenes could then take place independently, whilst using evidence from one to guide further investigation in the other. This arrangement also allows the digital investigation to be structured in a similar way to the ‘tried and tested’ structure of the physical investigation. Figure 2 illustrates a generic flow diagram developed by the author based upon work conducted by Carrier and Spafford [15].

As illustrated in Figure 2, the forensic process is both complicated and iterative, but it can be divided into three major phases, those of evidence collection, evidence analysis and evidence presentation.

4. Digital Technology Used

This paper will concentrate on evidence presentation. However a brief overview of the other stages in a forensic investigation will be given.

4.1. Evidence Collection

Digital technology has been utilised in the forensic evidence collection field in three main areas. Those of:

- Digital evidence forms
- Digital capture of the scene
- Digital data management systems

Recent other uses of such technologies for forensic evidence collection include using mobile phone location information as additional evidence placing a suspect at the scene of the crime/incident at a particular point in time. Digital technologies can also be considered for the capture of the physical crime scene in the survey/document physical evidence phases of the process in Figure 2. Crime scene measurements previously taken with a tape and notebook are now routinely taken using electronic distance measurement (EDM) surveying technology or 3D laser scanners [16].

The need for rigorous documentation of crime and incident scene data has brought about the development of several technical systems to assist with the process, examples include HOLMES 2 [17], SOCRATES 18] and LOCARD [19] and Mobile Data [20].

Research is currently ongoing at the University of Birmingham, UK, into the use of wearable computers to...
support expert forensic scientists [21]. The aim is to create a ‘narrative’ of an investigation through tracking the location, movement and activity of the investigator.

4.2. Evidence Analysis and Processing

There are numerous forensic analysis techniques which may be utilised dependent on the type of crime/incident and the forms of evidence present. Such methods as DNA, fibres, and fingerprint analysis; psychological analyses, analyses of location data from mobile phones, tracking systems and CCTV footage can be used. This paper however is more concerned with identifying new digital technology uses and so shall not discuss these in depth.

Certain types of forensic evidence, such as fingerprints and DNA evidence require laboratory comparison to the suspect’s supplied samples. These comparisons can be made utilising digital analysis techniques. Facial and physical attribute recognition (biometrics) is also a field where digital technologies are being applied to analyse images from closed-circuit television (CCTV) or other footage.

Analysis of digital data storage is often a key area in crimes, so much so in fact, that the computer is sometimes now considered as a separate crime scene as discussed in Section 3 of this paper. The computer may hold evidence in the form of documents, e-mail records, web history and caches, login dates and times of access, and illegal files, to name but a few. The digital evidence process has become so focused around this area, that disk analysis has become known, by some authors as ‘forensic computing’ [21, 22].

Arguably no other type of scientific evidence is exposed to anywhere near as many opportunities for destruction, mishandling and contamination as forensic evidence. The documented travel path of the evidence, or audit trail, seeks to record the history of the entire forensic process as well as the chain of accountability. These processes remain labour intensive and error-prone, and currently, a considerable amount of a forensic scientist’s time is often spent managing this audit trail rather than undertaking forensic investigation.

4.3. Evidence Presentation

Forensic science advances in leaps and bounds and the public who regularly watch high-technology crime scene investigation on TV now expect to see similar visual representations of technical information, spatially distributed evidence and event chronologies in the courtroom. Courtroom environments, which have been one of the last bastions of the oral tradition, are slowly morphing into cinematic display environments. Many lawyers now rely on slick visuals to replace rhetoric and depend on their audience adapting a ‘seeing is believing’ attitude to persuade juries to believe in their hypothesis.

The use of digital display systems (particularly 3D reconstructions) for courtroom presentation worldwide has raised a number of issues, which have been discussed in depth in numerous publications by the author [1, 2, 4, 5, 6, 16]. Most of the issues raised affect the admissibility of the reconstructions as courtroom evidence in the various global jurisdictions, and can be summarised as a list of advantages and disadvantages:-

Advantages of using the technology include:

- Comprehension Increase – 3D reconstructions have the ability to improve the comprehension, and the memory retention of complex spatial and temporal data and evidence.
- Efficiency – 3D technology can improve the speed with which complex information can be imparted to a courtroom audience, and therefore may shorten the length of a case. They may alternatively, on occasion, be responsible for extra points of confusion and cause an increase in case length.
- Persuasiveness – According to research conducted in the USA [23] people are twice as likely to be persuaded when arguments are supported by visual aids.
- Attention Increase – People’s attention is drawn to moving objects. They rank top on the hierarchy of methods to draw attention which spans from actions, through objects, pictures, diagrams, written word, to spoken word [2]. This increased attention should lead to the triers of fact (usually a judge and jury) studying the evidence more intently.

Disadvantages of using the technology include:

- Prejudice – Visual displays when used can introduce levels of prejudice, if one side has such evidence and the other does not.
- Bias – 3D reconstruction technology is potentially prone to allowing bias into the presentation, whether that be conscious bias (a form of evidence tampering) or subconscious bias. In an attempt to reduce this, all computer generated evidence must be backed up with a comprehensive audit trail, and the expert witness presenting such evidence must be able to prove the accuracy of the reconstruction, both in terms of the original data used to reconstruct the incident, and the accuracy of the reconstruction [24].
- Relaxation of Critical Faculties - again this is an issue of the ‘persuasiveness’ of the technology. It has been shown that when a subject is shown a 3D computer-generated reconstruction of an event they often feel mesmerised, or that they are seeing the actual event happen. Jurors may have a ‘seeing is believing’ attitude [16], as has been shown to be the case with television viewing. There is therefore a potential reduction in their level of critical appraisal of the reconstructed evidence.

In summary, the main benefit of the use of 3D reconstructions in the courtroom is their ability to persuade a jury. In terms of admissibility in courtrooms around the world, this persuasive nature may also bring about a variety of objections to its use.

In most legal jurisdictions, some legislation and case law exists that governs (or can be applied to govern) the admissibility of computer-generated evidence in court.
The uses for digital technologies in evidence collection, analysis and presentation can be categorised and segregated in many ways. The author proposes a taxonomy displaying them in relation to a technology continuum. This clearly lays out the current technology usage in the forensic evidence field. This can be used to identify areas where novel uses for digital (particularly visualisation) technologies may be of benefit.

5. Proposed Taxonomy

Milgram and Kishino [25] described a “virtuality continuum” which connects real environments to virtual ones. Between completely real and completely virtual the continuum spans a region of mixed reality which may be mainly real (Augmented Reality) or mainly virtual (Augmented Virtuality).

Relevant digital technology usage in the field of forensics, as described in the previous section has mainly involved the documentation of evidence collection and analysis, and the production of completely virtual environments in order to assist with presentation. As evidence documentation appears as a major usage the author has added ‘Documented Reality’ to the technology continuum representing real objects with some form of tagging or explanation attached to them. The technology continuum axis then extends through Mixed Reality to Virtual Reality.

Breaking the process down into collection, analysis and presentation of evidence gives the second axis for the taxonomy. The author has also considered a third variable, that of whether the technology usage is at the incident scene, or away from the incident scene. This third variable has been labelled In-Situ (at the scene) or Ex-Situ (away from the scene). This addition essentially gives a third dimension to the taxonomy, but is represented in the taxonomy (Figure 3) by doubling up the y-axis to give a simplified presentation.

The individual items on the taxonomy itself are depicted either in bold or plain text, representing whether they are a new (proposed) technology or an existing technology/techniques.

6. Novel uses of Digital Technology

This section of the paper describes proposals for novel uses of technologies in the forensic evidence collection, analysis and presentation field. They aim to demonstrate available technologies which could be exploited to bring innovative methods into forensic evidence collection, analysis, and presentation. These innovative methods fill some of the gaps in the author’s proposed taxonomy.

6.1. Evidence Collection

Traditional methods of collection of evidence have been improved by the implementation of new electronic evidence tagging and tracking devices, as described in Section 4.2 of this paper. Previously unavailable forms of evidence are created by the use of personal portable technologies, including mobile phones and vehicle tracking devices, such as GPS (Global Positioning System) navigation systems or vehicle tracking systems.

During the “identification of eye-witness” phase of the forensic process (figure 2), the use of recorded GPS and communications data information could be adopted to find potential witnesses and directly appeal to them by the mobile phone SMS, mail or personal call. The use of GPS and communications data information in real time could also be adopted for sending Short Message Service (SMS) text messages to people passing through the area of an incident to appeal for witnesses. This could be compared to the existing practice of putting up signs at road traffic accident or crime scene locations to appeal for witnesses.

The use of mobile devices to contact witnesses and collect visual and evidence information raises numerous ethical and legal issues. There is certainly a case for research to be undertaken investigating these issues, running concurrently with any technical development work in these fields.

6.2 Evidence Analysis and Processing

The author believes that the use of mobile devices has the potential to enhance the dissemination of spatial information about a crime or incident scene. Mobile devices could be used to augment the actual incident scene with location specific information in a variety of media forms. Users visiting the scene could be equipped with a mobile device and a spatial position tracking device. The system would track the user’s position and orientation in order that relevant information can be passed to the user via the mobile device. The information displayed on the device could consist of various media forms (e.g. digital images, video, audio, textual information, 3D virtual environments, web browser based information). It could brief the user about each item of evidence, describing exactly where and in what state that evidence was found using text, images or other digital media as necessary. It could also potentially explain conclusions that may be drawn from the evidence items.

In the case of documenting a murder weapon for example, this could include such information as a description or image of the weapon, dimensions describing exactly where it was found (with photos), details of any DNA evidence found on it, details of finger print evidence, along with any other information considered as relevant in the specific case. The device would, in essence, document the real scene giving rise to an ‘In-Situ Documented Reality’ technology using the terms from the taxonomy.

Developed further as Evidence Management Systems (EMS) and Evidence Presentation Systems (EPS), mobile devices have the potential to be used during the crime investigation in order to record the evidential information as it is collected.
This would then allow the briefing of officers, scientists and witnesses (both expert and eye witnesses) in the current state of evidence completeness. Such an EMS has the advantage over previously described systems of offering automatic in-situ crime scene briefing, allowing users to experience the scene first-hand whilst having any scene alterations and details of the evidence fully explained, in a spatially relevant context, by the device.

The use of these devices as in-situ presentation systems could help to improve the formation of theories from the evidence (evidence analysis) through better information dissemination. These systems could also record and replay evidence for archiving, dissemination and even training purposes, thus fulfilling the role of a full Evidence Management Systems (EMS).

6.3 Evidence Presentation

This section will therefore mainly address evidence presentation uses. It begins with documented reality and moves along the technology continuum defined in the taxonomy.

Crime and incident scenes are both sensitive and transient environments. From the time when a crime or incident occurs, many aspects of the environment in which it occurred will change. Lighting/weather conditions changing, liquids drying, people and objects moving, plants growing and finger prints being wiped away are just a few examples.

It is expected that the use of mobile devices to display context sensitive forensic information, in the manner proposed above, could remove some of the prejudicial problems described in Section 4.3 of this paper. Such a system would have the ability to visualise features of the scene as they were initially found at the time of the incident. Giving detailed on-site information to investigators and triers of fact would allow a better understanding of events. This would in turn lead to a fairer trial. The user would also have control of movement around the scene and access to the media on the mobile device which could give them all the information they require in order to understand a range of evidential items.

Also new technologies are continuing to evolve which the author believes could improve on the realism of such 3D reconstructions and give jurors and triers of fact a greater depth of immersion in the virtual incidents. One of the problems with building virtual models of environments is the difficulty in creating realism. Most incident reconstructions would concentrate on accurate modelling of the parts of the scene which are crucial to the incident, with little or no time spent on the rest of the surrounding environment. Modelling surroundings accurately would be time consuming and may be deemed unnecessary.

However it may be the case that increased realism of an environment would be useful. It could provide additional reference points for witnesses, jurors and judiciary to use to help them understand the complex spatial information being represented. It may also aid...
witnesses in pinpointing positions of relevant objects, people or vehicles during a reconstruction [2].

Augmented Reality (AR) technology would allow a courtroom audience to visualise accident details and locations with greater realism of the physical landmarks at the scene, increasing their feeling of presence. If the video footage can be described as 'Ex-Situ Reality', then this augmented video footage is 'Ex-Situ Augmented (or Mixed) Reality', and would fit into the taxonomy in Figure 3 as such.

This is a more technology intensive variation of the mobile device system described above, in which dynamic images of the real world would be overlaid with computer-generated three-dimensional representations of evidence using AR technology. It would then be possible to revisit the scene of a crime, weeks, months or years after the event and to see virtual evidence items in their original location and state. This system may be described in terms of the taxonomy in Figure 4 as 'In-Situ Augmented (or Mixed) Reality'. A view from a prototype of this system is shown in the inset to Figure 3. It would also be possible to overlay dynamic, computer-generated witness statements or proposed chronological event scenarios onto the real world environment.

This would also potentially act as an aid in the ‘presentation of the complete theory’ phase of the forensic process diagram (Figure 2) and could in turn pave the way for greater use of computer crime/incident reconstruction technologies by the reducing costs involved in their production.

Such an AR system could remove the prejudicial problems discussed previously in this paper. The subsequent changes in the incident scene could be overlaid by objects as they were at the time of recording, thus allowing the incident scene to be replayed as it was at the time of initial investigation.

7. Conclusions

This paper has highlighted stages where novel digital and mobile technologies may bring improvement to the forensic process. It underlines the fact that, until recently, 3D forensic reconstruction techniques have been used (along with other multimedia technologies) mainly to present forensic evidence in the courtroom. The technologies have been targeted in this area due to their success in communicating highly complex, technical spatial and temporal evidential information to the general public.

The proposed taxonomy of current usage of new technologies highlights their minimal uptake in the forensic process. The suggested novel uses for the technologies fill many of the gaps highlighted by the taxonomy in Figure 3 with the proposed novel technologies being highlighted in bold italics.

The main challenges identified for the future research of the use of digital and mobile technologies in forensics are:

- The application of digital technologies earlier in the forensic process when the final ‘complete theory’ for the incident is yet undecided. These technologies could keep an investigative team fully in touch with developments in a case and be of assistance in forming theories about events.
- Use of the public and their own mobile devices, and data relating to those devices, to identify suspects and witnesses; or to create new means of transference of information to track and identify witnesses and suspects.
- The application of new technologies in the production of reconstructions to give increased accuracy or speed of the reconstruction process and to reduce costs involved.
- The application of digital technologies for the training of officers and forensic staff involved in the whole physical and digital crime scene investigation phases.

Inevitably tools will be developed that exploit the novel technologies discussed in this paper, bringing about greater speed and accuracy in forensic data collection and analysis; and greatly enhanced methods for realism in recreated crime and accident scene evidence presentations.

As these tools become integrated into forensic processes there will be a need for thorough empirical testing of the impact and effectiveness of their application.

It is worth noting that the majority of the technologies discussed in this paper would probably be developed initially as presentation methods. This is because the direct presentation process is probably seen as the most straightforward way to utilise such new technology within the forensic field.

8. References


Advantage System Solutions. LOCARD Evidence Tracking System – From Crime to Court, available from URL: http://www.locard.co.uk/.


