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Technology Corner Visualising Forensic Data: Evidence (Part 1)

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TECHNOLOGY CORNER VISUALISING FORENSIC DATA: EVIDENCE (PART 1)

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ABSTRACT

Visualisation is becoming increasingly important for understanding information, such as investigative data (for example: computing, medical and crime scene evidence) and analysis (for example: network capability assessment, data file reconstruction and planning scenarios). Investigative data visualisation is used to reconstruct a scene or item and is used to assist the viewer (who may well be a member of the general public with little or no understanding of the subject matter) to understand what is being presented. Analysis visualisations, on the other hand, are usually developed to review data, information and assess competing scenario hypotheses for those who usually have an understanding of the subject matter.

Visualisation represents information that has been digitally recorded (for example: pictures, video and sound), hand written and/or spoken data, to show what may have, could have, did happen or is believed to have happened. That is why visualising data is an important development in the analysis and investigation realms, as visualisation explores the accuracies, inconsistencies and discrepancies of the collected data and information.

This paper introduces some of the various graphical techniques and technology used to display digital information in a courtroom. The advantages and disadvantages involved in the implementation of this technology are also

discussed. This paper is part one of a two part series that aims to describe the use of, and provide guidelines for, the use of graphical displays in courtrooms.

1. INTRODUCTION

At the end of the 18th Century William Playfair, a Scottish inventor, introduced the line graph, bar chart and pie chart into statistics. He demonstrated how much could be learned if one plotted data graphically and looked for suggestive patterns to provide evidence for pursuing research. However, due to the novelty of the graphical forms, Playfair had to include extensive directions for the viewer informing them how to read the data visualised from the graphs and charts he created (Tufte 1997). Today these graphs (and many other more complex graphical representations) are a vital and everyday part of communication in science and technology, business, education and the mass media (Cleveland & McGill, 1984).

Scientists and scholars have always used graphical techniques to describe, represent, and create knowledge. Traditionally, these techniques have focused on the communication of quantitative data and information (e.g., graphs and charts) although a variety of methods have also emerged to communicate more qualitative information including behavioral maps, and perspective renderings (Ramasubramanian and McNeil, 2004).

The human visual system has the ability to interpret and comprehend pictures, video, and charts much faster than reading a description of the same material. The human brain performs some processing early in the chain of processing visual input; this process starts in the eyes. Hence, images are interpreted much faster than textual descriptions as the brain processes the visual input much earlier than textual input. This results in the human visual system's ability to examine graphics in parallel, whereas humans can only process text serially (Teerlink and Erbacher, 2006).

A visualisation is an image, diagram, graphic or animation representing data that is intended to give a better understanding of that data. There are many different visualisation areas, differing mostly by the domain of the visualised information. Examples include: *mathematical & scientific* visualisations (results from equations and formulas); *product* visualisation and *three-dimensional design* (images, photos or computer aided design software) and *medical imaging* (information and images from medical machines such as magnetic resonance imaging scanners).

Visualisation, in its broadest sense, is a communicative process that relies on encoded meanings that can be transferred from creators and organizers of information to users and receivers of the same information (Shannon, 1948). Edward Tuft (1997) proposes that visualisation is as much an art as a science, where the processes of arranging data and information in order to achieve representation, communication, and explanation are consistent regardless of the nature of substantive content or the technologies used to display the information. Marty (2008) stated:

> *"It is not just the expedited browsing capabilities that visualization has to offer, but often a visual representation—in contrast to a textual representation"*

2. VISUAL EVIDENCE

In a modern courtroom, the presentation of forensic evidence by an expert witness can bring about the need for arduous descriptions by lawyers and experts to get across the specific details of complicated scientific, spatial and temporal data. Within the realms of forensic science, the use of new technologies in order to gather, analyse and present evidence is of the utmost importance in the modern world. Better collection and analysis of evidence from a wide range of digital media can be achieved by the use of data from the devices of perpetrators, victims and witnesses involved in incidents. The devices which may provide additional evidence include mobile phones, PDAs, tablets, digital cameras, computers and closed-circuit TV. Recent terrorist event 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 an incident (Schofield, 2007).

Digital visual evidence presentation systems (including digital displays, computer-generated graphical presentations and three-dimension simulations) have already been used in many jurisdictions. As courtrooms transform into multi-media, cinematic display environments, this has enormous implications for the legal processes taking place with them. One must ask whether the decisions made in these visual courtrooms are affected by the manner in which the evidence is presented, and in truth, no one really knows the answer to this important question.

Gerald Lefcourt (2003), a criminal defence lawyer in New York, has made the following comments about members of the public who attend court:

> *"These are people who by and large have grown up on television ... The day of the lawyers droning on is really gone. I think that jurors today, particularly the young ones, expect quickness and things they can see."*

Forensic visualisation methods for two specific areas (investigation and presentation) have a common thread; that is, that data visualisation is still relatively new within the forensic and evidential thematic area. There is further research required to establish an accepted framework of what visual is suitable and acceptable for investigation and presentation in relation to the target audience.

3. WHY VISUALISE DATA

There is a famous expression that "a picture paints a thousand words" but this epigram is only true if the viewer has some understanding of what is being presented and why it is being presented. The inability of the general public to understand William Playfair's first graphs and charts is a prime example of this problem (Tufte 1997). Consider the image shown below (Figure 1) and its potential ability to confuse a viewer unfamiliar with the information types being visualised.

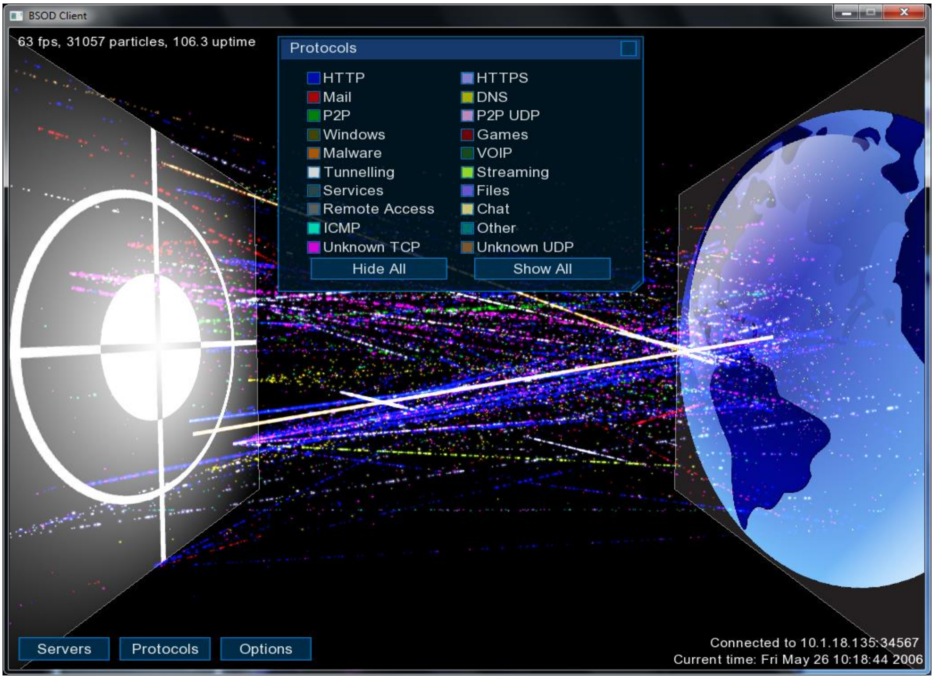

Figure 1 Visual Representation of Computer Network Traffic (Wand n.d.)

The image above shows computer network traffic in a graphical format, the data is captured from a live network interface, visualising the flow of network data between hosts, providing (at a glance) information about network usage. To a person trained in computer network traffic analysis the image has meaning and provides displays information but to a layperson it will require the provision of a detailed explanation. How information and data is viewed, interpreted and understood depends on what is presented, to whom it is presented and why it is being presented. Visualisations are only effective when the right kind of pictorial representation is chosen and can be manipulated to show useful information (Lowman, 2010).

Many forensic disciplines are facing an ever-growing amount of data and information that needs to be analysed, processed, and communicated. Those who have to look at, browse, or understand the data (judges, lawyers, jurors, etc.) need ways to display relevant information graphically to assist in understanding the data, analysing it, and remembering parts of it.

The ability of a computer to create synthetic copies of an event or issue (whether as a static image, a plan or schematic, a computer animation or a virtual reality simulation) provides the opportunity to enhance the viewer's current understanding. These visualisations allow users to learn, question and interact within the computer-generated environment and it provides the opportunity to make mistakes, revisit and review, without necessarily putting themselves at risk (Fowle and Schofield, 2011).

4. INVESTIGATION VISUALISATION

Analysis of digital data storage is often a key area in modern crime scene investigation, so much so in fact, that the computer is sometimes now considered as a separate crime scene. 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' (Schofield and Mason, 2012).

Today's digital forensic investigator has "hundreds of specific and unique application software packages and hardware devices that could qualify as cyber forensic tools…hundreds of utilities available for the same task" (Marcella and Menendez, 2007). The basic requirement for a computer forensics tool is to convert specific files into a human readable format for analysis by a forensic investigator.

This analysis can be difficult and time-consuming and often involves trawling through large amounts of text-based data. Efficient and effective visual interfaces and visualisations can vastly improve the time it takes to analyse data. These graphical tools can help users gain an overview of data, spot patterns and anomalies, and so reduce errors and tedium (Lowman and Ferguson 2011).

In the case of a digital forensic investigation, an investigator may need to examine the network traffic on a defendant's computer. The investigators would begin by investigating network traffic log files taken from the computer in question. Marty (2008) reports that instead of showing a jury a log file that describes how a digital event occurred, a picture or visual representation of the log records should be used (such as the one shown in Figure 1). At one glance, a picture such as this is potentially capable of communicating the content of this log. So long as viewers are made aware of the context and content of the image, most viewers can process this information in a fraction of time that it would take them to read the original log (Fielder, 2003).

In the area of forensic surveying, the use of visuals to reconstruct the crime scene from all the collected and recorded information (whether it be text, photographs, sketches, or survey information) is invaluable. The crime scene will not be available in its initial condition forever; evidence is often transitory and ephemeral. Evidence and information needs to be recorded before crime scene officers collect and remove any items of interest (thereby changing the original condition of the crime scene).

The court is usually provided with some form of visual representation of the crime scene. Traditionally, a hand created drawing (or map) based on the use of traditional drafting techniques is represented as a two-dimensional (2D) diagram, such as the one shown in Figure 2. In the past this may have been crudely drawn or plotted to varying degrees of accuracy.

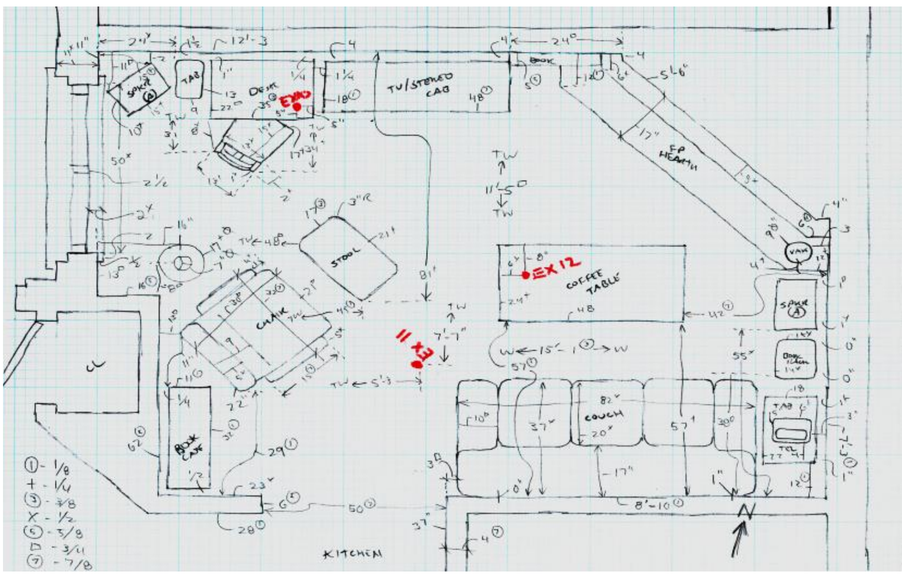

Figure 2 Hand Drawn Crime Scene Plan
(Courtesy of Mr. G. Schofield, Toronto Police)

Over the past few decades, the widespread introduction and acceptance of computer technology has meant that courts have become used to seeing maps and plans rendered digitally. The technology used to create these two-dimensional displays varies, from simple freeware drafting programs to complex mechanical engineering based drafting tools such as Autocad's Mechanical Desktop©. Often investigators use drafting technology that is tied to their scene-measuring instrument; for example, many police surveyors draft plans using software that download data from their electronic theodolites.

Currently, investigators are starting to see the use of three-dimensional laser scanning technology for scene measurement and capture. These devices provide a combination of laser scanning surveying and digital photography. The technology is capable of capturing all physical aspects of a scene in true three dimensions (in the x, y and z planes) for accurate interrogation and analysis. Figure 3 depicts an image of three-dimensional (3D) laser scan data; the black spot (void) is where the scanner was placed to capture the crime scene. The three-dimensional model represents a quantitative, objective database of measurements, which different operators and investigators can share for subsequent analysis.

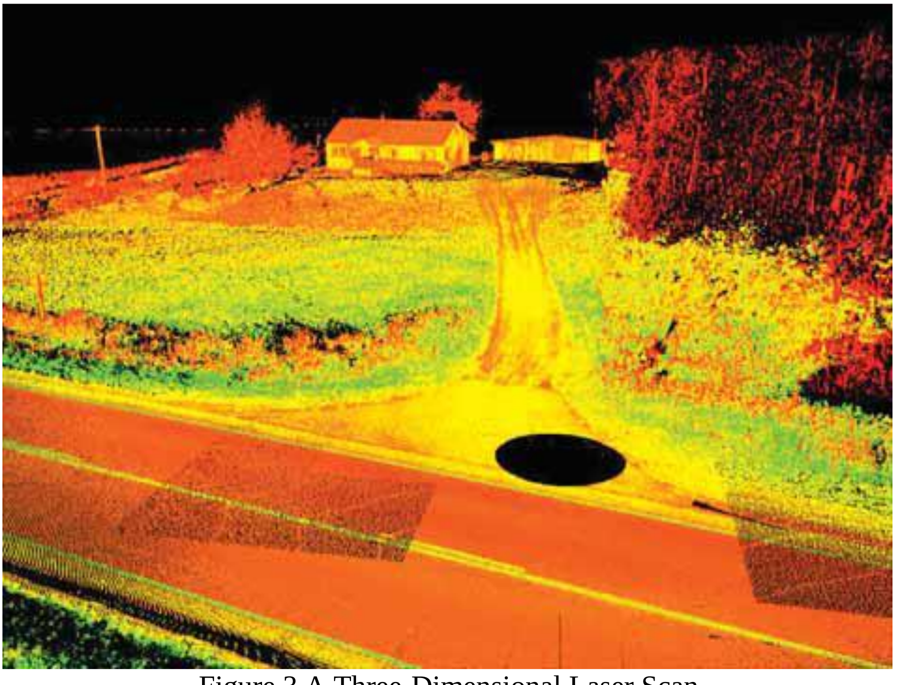

Figure 3 A Three-Dimensional Laser Scan
(Courtesy of Mr. M. Haag, Albuquerque Police)

5. ANIMATING EVIDENCE

Computer-generated graphical evidence in the US has primarily been used in civil cases. One of the first major uses of forensic animation took place in the federal civil case for the Delta flight 191 crash. In August 1985 the Delta airplane with 163 people aboard was caught in a wind vortex and crashed while attempting to land at Dallas-Fort Worth Airport, a mile from the runway. In the subsequent litigation the US Government offered a 55-minute computer-generated presentation, including forensic animations to the court to explain details pertaining to each item of evidence (Marcotte, 1989).

There is an extensive precedent concerning the use of a range of computer-generated evidence in the United States, but very little in comparison in many other jurisdictions. Consequently, judges in other jurisdictions may look to the US for guidance in considering issues of admissibility. This has been particularly true for the introduction of computer-generated animations and virtual simulations in courtrooms in the UK and Australia. The legal precedents for the admissibility of this technology into courtrooms have been extensively discussed in other publications (Galves, 2000; Girvan, 2001; Schofield, 2007; Schofield and Mason, 2012).

Presenting data related to road traffic accidents in the courtroom (such as the example in Figure 4) provides is a prime example of the need to relate spatial and temporal data, for which the use of virtual environment technology has been extensively adopted (Schofield, et al., 2001). In such cases, a computer-generated forensic reconstruction is built using a three-dimensional virtual environment of a scene created from actual measurements, which are usually taken by the police or investigators at the time of the incident.

Figure 4 An Image from a Forensic Animation of a Road Traffic Accident

Dynamic vehicle movements are often then simulated using scientific calculations based on those measurements and the experience of the reconstruction engineer. This computer model can then be rendered to create a series of images and animations, which describe the scene or incident. These virtual environments, when viewed in court, must support and corroborate existing evidence to be admissible as substantive evidence in any courtroom (Noond and Schofield, 2002).

In this example, the images in Figure 5 show a pathology reconstruction used in a murder case to investigate the nature of a stabbing incident. In this case the autopsy report described the injuries sustained by a 30-year-old male who had received a number of blunt force injuries to the face and chest, and a stab wound to the back measuring 3.4 cm in length. The autopsy reported that the cause of death was attributed to the extensive internal bleeding caused by the stab wound which pierced the heart. It was also concluded that a large amount of force would be necessary to cause the incision to the eleventh thoracic vertebra and that the bruising to the victim’s body suggested some degree of violent struggle prior to the fatal injury (March, et al., 2004; Noond, et al., 2002).

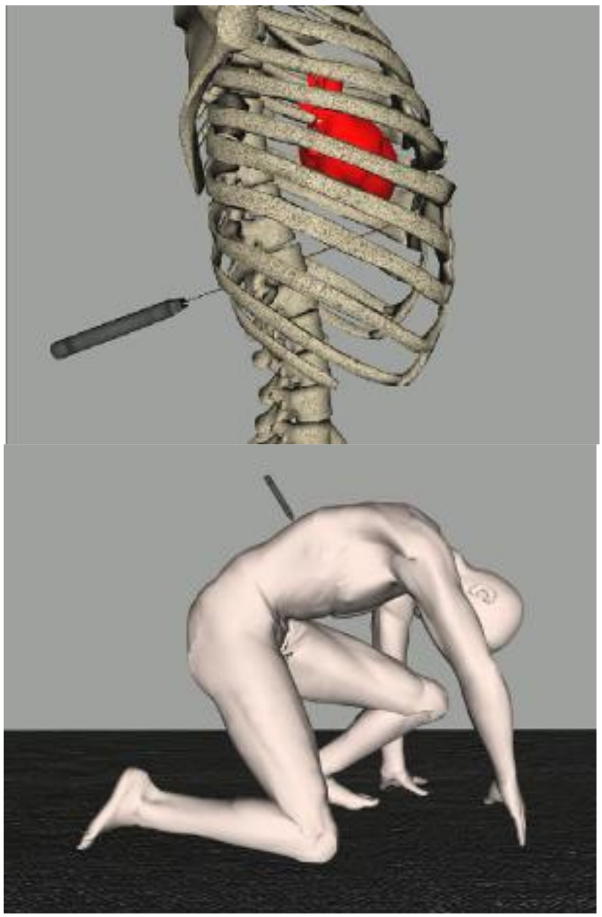

Figure 5 An Image from a Forensic Animation based on Autopsy Information

The left-hand image (Figure 5) shows the angle of the blade as it entered the body, cutting through the vertebra. The right hand image (Figure 5) shows a hypothetical body dynamic produced to illustrate the position of the victim so that the damage to the internal organs matches up with the angle of the knife entry (March, et al., 2004).

Unlike the environment surrounding a road traffic accident or crime scene reconstruction, where exact, surveyed measurements are usually available, pathology or medical visualisations are often based on descriptive post-mortem findings or approximate measurements. The use of generic anatomical computer models allows the recreation of dynamic events in which wounding or damage to a human body occurs. Such a reconstruction is, by its very nature, often dependent on the knowledge, expertise and opinion of medical experts. Hence, in many of these cases the advice of the expert is seen as crucial in creating a graphical representation that accurately matches the medical opinion. However, the potential inaccuracies involved mean that these reconstructions must be viewed cautiously, and the uncertainty associated with the exact position of virtual objects must be explained to the viewer (Schofield and Mason, 2012).

Stephenson v. Honda Motors Ltd. of America (Cal. Super. Case No. 81067, 25th June 1992) is generally accepted to be the first case to admit evidence using a computer game engine (real-time simulator). The attorney convinced a California Superior Court of the need to use the visual component of a virtual reality simulation to help a jury understand the nature of the terrain over which an accident victim chose to drive her Honda motorcycle (Dunn, 2001). Honda argued that the terrain was obviously too treacherous for the safe operation of a motorcycle, and that, while two-dimensional photographs and videos would help provide the jury with some idea of what the terrain was like, a three-dimensional, interactive simulator was much more realistic. In allowing the evidence, the court determined that the three-dimensional simulation was more informative, relevant, and probative.

Since this initial success, the sporadic worldwide application of such computer game based, real-time technology in courtroom situations has (in most cases) offered a unique platform for the collection, interrogation, analysis and presentation of complex forensic data across a wide spectrum of crime-scene and accident scenarios. Three-dimensional reconstructions of incidents have allowed the user to interactively visualise views from multiple relevant positions within the virtual environment, something that can be beneficial within the dynamic, adversarial environment of the courtroom.

The USA has a larger precedent for the admissibility of such technology into courtrooms (Schofield and Mason, 2012). All of the above information has been collected, extracted and produced by qualified people and/or experts in their respective field. They understand the visuals they create and use and understand what it is being shown. These visuals are often used as explanatory tools for juries and non-experts. However, the general public are rarely presented with these visuals without extensive expert explanation, as there is a possibility that they may not understand the raw visualisation, misconstrue the data presented, or may infer a biased view from them.

6. ADVANTAGES AND DISADVANTAGES OF THE USE OF THE TECHNOLOGY

By their very nature, any discussion of the issues involved in the presentation of the whole range of digital evidence is likely to be basic and generic relating to broad generalisations about the use of this technology across diverse courtroom application areas. Many of the issues raised in the previous section affect the admissibility of the reconstructions as courtroom evidence in the various global jurisdictions. Consideration of these issues is crucial if such technology is to be successfully used. As Wheate (2006) stated:

> *"It is difficult to determine how well twelve untrained, underpaid and usually inconvenienced strangers comprehend and utilise the evidence they hear in court, especially in cases where the evidence is provided by highly trained experts such as forensic scientists."*

It is possible to summarise a list of advantages and disadvantages of the use of this technology.

Advantages of using the technology include:

- *Comprehension Increase* – Three-dimensional reconstructions have the ability to improve the comprehension, and the memory retention, of complex spatial and temporal data and evidence.
- *Efficiency* – Reconstruction 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 rarely, on occasion, be responsible for extra points of confusion and cause an increase in case length.
- *Persuasiveness* – According to research conducted in the USA (Lederer and Solomon, 1997) 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 (Schofield, 2006). 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* – Graphics-based reconstruction technology is potentially prone to allowing bias into the presentation, whether that is conscious bias (a form of evidence tampering) or subconscious bias. In an attempt to reduce this, all computer-generated graphical evidence must be backed up with a comprehensive audit trail, and the expert witness presenting such evidence must be able to substantiate the accuracy of the reconstruction, both in terms of the original data used to reconstruct the incident, and the accuracy of the reconstruction (Schofield and Mason, 2012).
- *Relaxation of Critical Faculties* – this is an issue of the 'persuasiveness' of the technology. It is possible that when a subject is shown a 'realistic' computer-generated reconstruction of an event they may feel mesmerised, or believe that they are seeing the actual event happen. Jurors may hence adopt a 'seeing is believing' attitude, as has been shown to sometimes be the case with television viewing (Fielder, 2003; Schofield, 2007; Speisel and Feigenson, 2009). There is therefore a potential reduction in their level of critical appraisal of the reconstructed evidence.

It does not make sense to use technology just for the sake of using something new. However, as many lawyers and expert witnesses continue to push towards the dynamic presentations of video, text, documents and other forms of evidence, it seems likely that these complex data visualisations and forensic virtual models will become a more pervasive and effective alternative to the sketches, drawings and photographs traditionally used to portray demonstrative evidence in the courtroom (Bailenson, 2006; Galves, 2000; Girvan, 2001; O'Flaherty, 1996; Schofield, 2011).

It could be said that when visualising data, a person must have the knowledge of the data they are visualising, but they must also have knowledge of how to apply the visualising techniques for their audience. Marty (2008) supports this reasoning: he reports that most people who are trying to visualise data have knowledge of the data itself and what it means, even if they do not necessarily understand the visualisation. The viewer tends to visualise only the information collected or generated by a specific solution.

The use of advanced visualization tools (specifically three-dimensional computer models) allows for the recreation of an incident illustrating the chronological sequence of events. However, such a reconstruction is, by its very nature, often dependent on the knowledge, expertise and opinion of the experts. These must be viewed cautiously and the uncertainty associated with each item's position and action within the reconstruction must be explained by the person presenting the visual to the audience.

It should be noted that during both investigation and courtroom presentation there should be some concern that the investigator/reviewer will be focused on the visual images rather than the data source. This is of importance since visual evidence has the potential to be particularly misleading and it is possible that people may focus only on the elements that have a high degree of visual appeal. In all these situations, new visualisation techniques and products may be used inappropriately or used to deflect the viewer's focus away from key evidential issues.

In summary, the main benefit of the use of these 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 their use.

7. CONCLUSIONS

Our culture is dominated with images whose value may be simultaneously over-determined and indeterminate, whose layers of significance can only be teased apart with difficulty. Different academic disciplines (including critical theory, psychology, education, media studies, art history, and semiotics) help explain how audiences interpret visual imagery. The continuing digital revolution has had an enormous impact on the way forensic evidence is collected, analysed, interpreted and presented and has even led to the defining of new types of digital evidence (for example, digital imagery and video, hard drives and digital storage devices). Much of this digital media will end up needing to be admitted into courtrooms as evidence. In most jurisdictions around the world technology can be slow to become legally accepted. It is fair to say that, in general, legislation for the admissibility of digital media usually lags behind the technological development (Schofield and Mason, 2012). In a very real and practical sense, the analysis of courtroom imagery and its interpretation by jurors and other courtroom participants)is only just beginning (Speisel and Feigenson, 2009).

This paper has highlighted thematic areas where novel technologies may bring improvement to the forensic process. It underlines the fact that, recently, three-dimensional forensic reconstruction techniques are being increasing used (along with other multimedia technologies) 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.

Forensic science technology advances rapidly, and the public, who regularly watch high-technology crime scene investigation on television, expect to see their TV experience duplicated in the real courtroom environment. The public expects professional visual representations illustrating complex forensic evidence, polished digital media displays demonstrating the location of spatially distributed evidence and dynamic animated graphics showing event chronologies.

Modern systems for creating visualisations have evolved to the extent that non-experts can create meaningful representations of their data. However, the process is still not easy enough, mainly because the visual effects of processing, realising and rendering data are not well-understood by the user, and the mechanisms used to create visualisations can be a largely ad hoc process (Rogowitz and Treinish, 2006).

Commercial media companies often magically appear offering 'professional graphics', 'forensic animation' and 'crime scene reconstruction' services similar to those seen on the televised forensic/crime shows. In countries all around the world, many lawyers and expert witnesses now use, and have to confront in an adversarial manner, computer-generated animations, three-dimensional virtual reconstructions, real time interactive environments and graphical computer simulations (Schofield, 2007). However, there is little research being undertaken to consider the impact this technology is having in the courtroom, in particular how it is affecting the decisions being made (Schofield, 2011).

This concludes part one of this two part investigation into the use of digital displays in the courtroom. Part two of this paper will analyse and discuss specific problems in relation to the use of this technology in the courtroom.

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BIOGRAPHICAL DETAILS

Dr. Schofield (PhD) is currently Director of Human Computer Interaction (Associate Professor) at the State University of New York (SUNY) Oswego, USA, and an Adjunct Associate Professor of Digital Forensics in the School of Computer and Security Science at Edith Cowan University, Perth, Australia.

Previous to this position he held the title of Associate Professor of Computer Games and Digital Media, in the School of Creative Media at RMIT University in Melbourne, Australia. In his earlier career he was one of the managers of the internationally renowned Mixed Reality Lab (MRL) at the University of Nottingham in the UK.

Dr. Schofield has also been on the management board of both the Visual Learning Lab (a UK HEFCE centre of excellence) and the Learning Sciences Research Institute (UK). Dr. Schofield also remains a director and major shareholder of Aims Solutions Ltd., a UK based company providing computer graphics visualisation services and virtual reality based simulation training products to a wide range of public and private sector organisations.

Dr. Schofield has been involved in developing crime scene reconstructions using computer games/graphics technology for over 15 years. His research is specifically concerned with representation and understanding of visual information in the courtroom environment. The reconstructions he and his team create cover a wide range of forensic visualisation from computational fluid dynamics models to blood spatter patterns at crime scenes, from road traffic accident reconstruction to post-mortem pathology visualisation. Dr. Schofield is regularly used as an expert witness in courts all over the world and has worked on many high profile cases.

Dr. Schofield has been involved in forensic casework in the UK, Australia, the USA and Malaysia. A few years ago, he was responsible for the facial reconstruction of an Egyptian mummy for a documentary called Nefertiti Reserected on the Discovery Channel. For the last six years he has also been working on a major facial biometric project for the FBI (Federal Bureau of Investigation) in the USA.

Ken Fowle (PhD) is currently the Head of School (Associate Professor), Computer and Security Science, at Edith Cowan University (ECU), Western Australian and an Adjunct Associate Professor at the University of Western Australia, Centre of Forensic Science (CFS). Prior to moving over to academia, Dr Fowle was employed by the Department of Mines and Petroleum in the Investigation Branch.

Dr Fowle's interest in visualisation and accident reconstruct started back in 1996, when seconded to the departments Mine Safety Branch to assist with developing computer applications for mining accident and incidents. This interest was further enhanced in 1999 when he was seconded to Central Tafe to establish a research and development group specifically for developing computer graphics for the resource sectors of Western Australia. During his time at Central Tafe, Dr Fowle undertook a PhD with the University of Nottingham's AIM's research group.

In 2003 Dr Fowle returned to the Department of Mines and Petroleum where he continued his research into visualisation and won funding from the WA Government, to continue research in the use of 3D environments for accident reconstruction. This research interest continues at ECU with collaboration with the WA Police Service, London Metropolitan Police, Northumbria University, State University of New York and local and national research groups such as IVEC, CFS and ECU's Security Research Institute.

Dr Fowle is past president of the Australian and New Zealand Forensic Science Society and is still an active committee member, is a member of the International Association for Forensic Survey and Metrology, American Society for Industrial Security, Australian Computer Society and the Australian Law Enforcement Forensic Surveying Working Group.