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Original Article

Integration of Laser Scanning and Three-dimensional Models in the Legal Process Following an Industrial Accident

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ABSTRACT

Background: In order to obtain a deeper understanding of an incident, it needs to be investigated to "peel back the layers" and examine both immediate and underlying failures that contributed to the event itself. One of the key elements of an effective accident investigation is recording the scene for future reference. In recent years, however, there have been major advances in survey technology, which have provided the ability to capture scenes in three dimension to an unprecedented level of detail, using laser scanners.
Methods: A case study involving a fatal incident was surveyed using three-dimensional laser scanning, and subsequently recreated through virtual and physical models. The created models were then utilized in both accident investigation and legal process, to explore the technologies used in this setting.
Results: Benefits include explanation of the event and environment, incident reconstruction, preservation of evidence, reducing the need for site visits, and testing of theories. Drawbacks include limited technology within courtrooms, confusion caused by models, cost, and personal interpretation and acceptance in the data.
Conclusion: Laser scanning surveys can be of considerable use in jury trials, for example, in case the location supports the use of a high-definition survey, or an object has to be altered after the accident and it has a specific influence on the case and needs to be recorded. However, consideration has to be made in its application and to ensure a fair trial, with emphasis being placed on the facts of the case and personal interpretation controlled.

1. Introduction

Accidents occur, resulting in life-changing effects. However, industry is committed to reducing accidents, with improved health and safety performance, aiming to eliminate incidents at work. An accident can have wide-ranging implications, particularly if there has been a fatality. A recent survey undertaken by the Health and Safety Executive revealed that 118 people were killed while at work in 2011/2012 [1]. However, in addition to fatal incidents, 40 million working days were lost through work-related injuries, costing UK businesses £2.5 billion [2]. The problem is not restricted to the UK, with an estimated 4.6 million occupational accidents occurring every year in the European Union, resulting in a loss of 146 million working hours [3]. Accidents have considerable physical and financial implications, and studies have shown that for every £1 a business spends on insurance, it can lose £8–36 in uninsured costs [2].

Considering these figures, it is clear that there are humanitarian and financial benefits that can be achieved through managing risks more effectively. In recent years, this has been largely understood and businesses have focused greatly on health and safety, working with additional legislation. This can be demonstrated by examining fatal injury statistics. In the UK, it can be seen that in 1981, a total of 441 people were fatally injured while at work, compared with 118 between 2011 and 2012, as previously stated [4]. There are a number of possible factors that have contributed to this reduction, such as improved accident investigation and analysis [2]. However, accidents are still occurring, and the number of fatalities across all industries is still significant. Further improvements can still be made by concentrating on

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reducing the reoccurrence of similar accidents, complementary to investigation and analysis.

1.1. Developments in digital data acquisition

There have been considerable advancements in sensor development in recent years, allowing the capture of the real world in unprecedented levels of detail [5]. One such development is terrestrial laser scanning utilizing laser measurement to remotely measure spatial data. In addition, horizontal and vertical angles are measured on the instrument using electronic encoders. Modern terrestrial laser scanning instruments can perform this operation up to 1 million times a second [6], resulting in a comprehensive dataset, referred to as a point cloud.

The point cloud in many applications requires postprocessing for the end user to extract relevant information [7]. One such commonly used algorithm is iterative closest point, largely used to join the captured point clouds together [8,9]. With this in mind, throughout the development, there have been considerable advancements in software applications used to process the data obtained. It is now considered commonplace for three-dimensional (3D) point cloud data to be incorporated into many Computer Aided Design (CAD) packages. The data collected can be used to create 2D plans or 3D models of a scene where 3D laser scanning is likened to taking a photograph with depth information [10]. Furthermore, advancements in computer hardware have provided the ability to perform complex surface reconstructions to create highly accurate 3D models [11].

1.2. Use of digital data in accident investigation

In recent years, there have been considerable technological advancements in everyday activities, which have created increased reliance on the use of digital data [12]. Development of smart phones is a perfect example to illustrate this, providing the user with a magnitude of different functions, including taking phone calls, storing data, and accessing the Internet, with a vast amount of applications available on a device small enough to fit in a pocket.

In many cases, technology is driven by consumer demand for the products, with companies continually developing new products to gain an edge over their industry rivals. However, the legal system can be slow to accept the technology. The delay is largely due to the need for the development of legislation surrounding the admission of digital evidence within the judicial system [13]. This, in turn, can create complications within the accident investigation process when new technologies are incorporated, particularly if there has been a breach of the law in the events surrounding the incident.

Increased focus on technology and computing specifications has led to the development of surveying techniques capturing the world in unprecedented levels of detail, through the use of laser scanning and modern photogrammetric techniques. Laser scanning has provided the ability to capture millions of 3D survey points of an accident, and systems have been used extensively to record major crimes or road traffic collisions [14–17].

Members of the jury often rely on oral evidence presented by the prosecution and the defense. In legal proceedings, witnesses will be called to give evidence on behalf of the court. Witnesses can be ordinary people who hold information that is relevant to the court, or they can be experts who have been called to provide evidence related to their specific expertise. In certain cases, expert witnesses may have to provide complex descriptions regarding the events, environment, and relevant scientific data. It has been found that images can be used to provide clear and easily accessible explanations of complex events without sacrificing accuracy [18]. Further integration of computer-generated technology has begun to play a part within the modern courtroom to aid in the explanation and demonstrate possible hypotheses [12,19,20].

2. Materials and methods

2.1. Case study: fatal accident, 2010

In 2010, an elderly lady died after disembarking a passenger ferry at a quay, when she fell from some quayside steps into a river below [21]. The steps and landing platform within a quay are shown in Fig. 1.

Subsequent to the incident and upon recommendation of the Health and Safety Executive, a number of changes were made to provide a safer means of access and egress to the ferry. Changes made to the steps are shown in Fig. 2.

The authors were asked by the Health and Safety Executive to attend and survey the scene, provide a physical record of the environment, and demonstrate the various revisions that had been made to the steps after the incident, in the form of a 3D model.

2.2. Laser scanning

It has become accepted that the use of 3D data in accident investigation can help in analyzing what has happened [14]. For

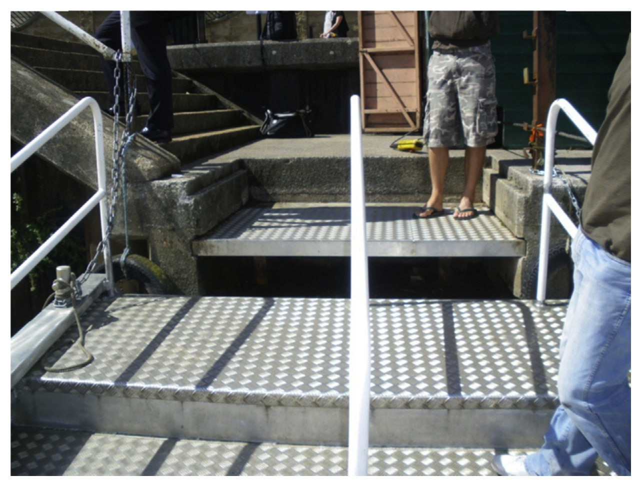

Fig. 1. Steps and landing platform.

Fig. 2. Changes made to steps following the incident.

example, when undertaking an accident survey, there are time-related problems, such as scene decay and associated pressures in relation to restoring the scene, which can become problematic factors when an investigator generally has to revisit the scene numerous times [22]. Human errors should also be considered, with reference to mismeasurements and subjective interpretation of surfaces by a surveyor.

2.2.1. Survey methodology

When undertaking a 3D survey, it is important to consider the best locations of the laser scanner in order to ensure the following [10]:

- Optimal scanner setup positions
- Full visibility of the scene
- Visibility of survey control
- Safety of the surveyor
- The scene being within the range of the instrument

In this instance, as the scene of the incident was outside, it can be classed as a dynamic environment with moving water, people, and trees. Dynamic environments can be problematic in laser scanning, as the instrument will be used to record the scene initially from one position. When the instrument is moved to another location and the survey is undertaken again, the scene may not necessarily be the same as when it was first recorded, e.g., things might have been blown by the wind. To control this, when undertaking this survey, targets were located at fixed positions that remained static within scans, thus maintaining accuracy within the registration process.

The key area that was required to be recorded included the bottom step of the quay and the infrastructure surrounding the stair area. Therefore, laser scan locations were selected in order to record the steps from all angles. In addition, laser scans of the surrounding area were taken in order to provide further contextual information. A plan of the scan locations is shown in Fig. 3.

After each laser scan setup, photographs were taken using a panoramic camera mount, which allows the lens to be positioned in the same location of the emitted laser beam. In addition to the panoramic photographs, another 34 photographs were taken with a standard 35 mm lens to be used as references and to assist with a solid 3D model.

2.2.2. Data processing

Time taken on site to record the physical data is relatively short, particularly with the most recent instruments. Processing the data on a computer is the most time-intensive aspect of using laser scanning technology. In addition, depending on the deliverables required by the client, the complexity of a project can vary greatly, from simple point clouds to full virtual 3D models and video animations, constructed from the survey data. In this particular incident, a virtual 3D model and video animation were required to play in the courtroom to demonstrate the safety improvements that had been made following the incident.

2.2.2.1. Registration. First, the various scan locations had to be joined together (or registered) in order to produce a complete survey of the scene. This was done in Leica Cyclone. There are two principal methods of registration:

- Registration using vertex alignment of targets
- Registration using cloud constraints

Various targets can be purchased from equipment manufacturers, where the center point remains the same in any rotation or tilt of the target. These allow the surveyor to take a laser scan from one position and move to the next rotating the target to suit. These targets are recognized by the software and a vertex assigned to the center of the target. At least three targets are required between scan locations to ensure a mathematical match for the registration process.

In certain situations, it may be impracticable to position targets around the area to be surveyed. In such cases, the user can manually assign points in the software that are the same between the two scan locations. This is known as cloud to cloud registration. It is important, when undertaking this type of registration, that

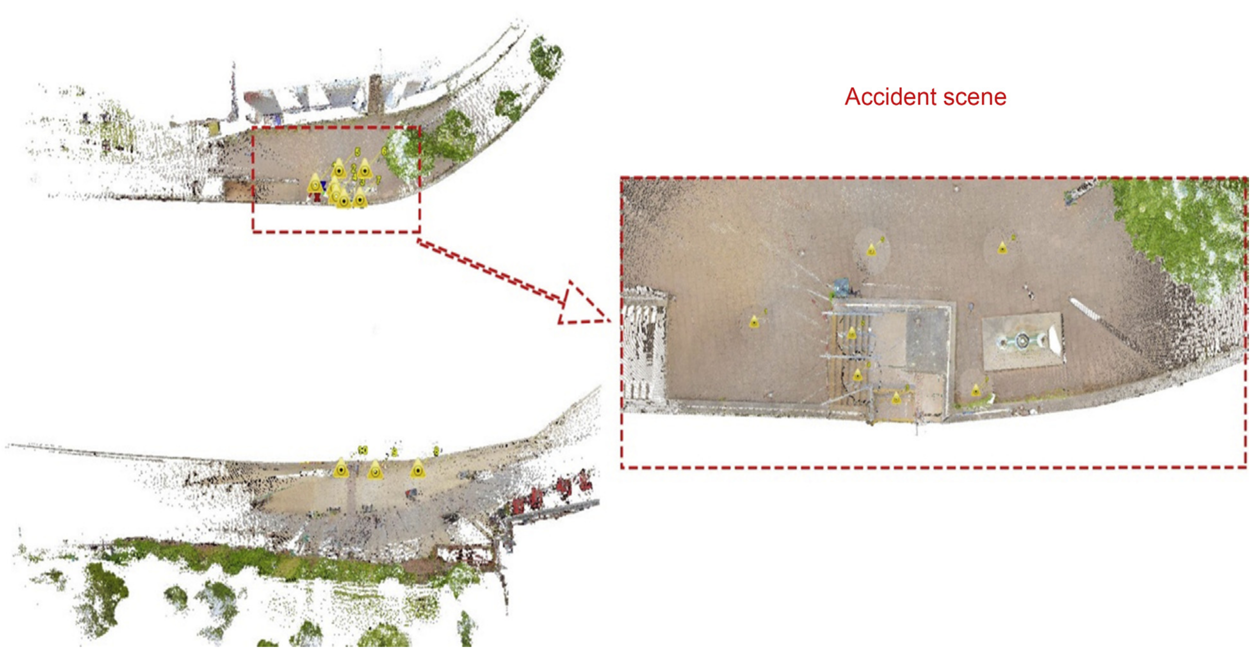

Fig. 3. Plan of scanner locations.

Fig. 4. Photo-textured point cloud.

considerable overlap (40%) has been obtained between the two setup locations in order to ensure enough comparable data between scans.

Similar to all types of survey techniques, registration will create some errors that have to be assessed by the surveyor in order to ensure the integrity of the survey. In the above case, a combination of two registration techniques were used, in that targets were used to control the survey and cloud constraints to "smooth" the point clouds, the result being a maximum alignment error of 13 mm. In view of the equipment used and the environmental conditions, this alignment error was deemed to be within acceptable limits.

2.2.2.2. Application of photographs. Once a geometrically accurate model has been created, photographs can be applied to the point cloud providing a true visual representation of the scene. As the photographs were taken from the same location as the laser scan, the images can be converted first into a panoramic equirectangular image and then to a cube map. The cube map can be imported into point processing software such as Leica Cyclone and then projected outward texturing the survey points, the result of which is shown in Fig. 4.

In some cases, the data required by the client may be just a point cloud deliverable, which can be used to take measurements, create sections, and see representations of an object position with respect to others. In addition, fly-through animations can be made at this stage using only point cloud data.

2.2.2.3. Three-dimensional modeling. As a point cloud, by its very nature, is made up of millions of points, dense point clouds can be problematic given the hardware capabilities of a computer, having the result that not all points can be displayed. This is common in large scenes, where the computer cannot display the sheer amount of detail captured. Furthermore, as a point cloud is not a "solid" object and animations are needed, for example, to test hypotheses and perform cause analysis, a mesh model is generally required.

In certain situations, solid virtual 3D reconstructions are required in order to better understand the events surrounding an incident and to maximize the benefits of the rich dataset. In these cases, a point cloud is used as a reference and the base for the creation of a 3D model. Using 3D modeling software, mesh models can be made by drawing around the objects in the scene. However, it is important to maintain the integrity of the survey data and not make assumptions on an object's geometry.

Various software applications can be used to create models and they can be very specific to the task in hand, for example, organic or complex models may require specialist mesh triangulation software to be modeled accurately. Using this case study as an example, this point is illustrated with regard to the locations of the handrails as shown in Fig. 2, which were very important to the case. Pipe modeling software was used in order to obtain a precise location of the handrails within the scene. This software is used extensively in the oil and gas industry, to model plants, where data are captured using a laser scanner. With this in mind, it is very important to understand the scope of the assignment, and consider which areas need particular attention and others that are there for contextual information, in which the accuracy can be assessed.

In order to demonstrate the integrity of a 3D model, specialist software can be used to demonstrate visually the deviation between the point cloud and the virtual model, as shown in Fig. 5.

This step is very important if the model is going to be used in a courtroom, where the surveyor may be asked questions relating to its accuracy and relevance to the case. With this in mind, the survey must be undertaken using a calibrated instrument, with the registration of the point cloud's accuracy being maintained with errors kept to a minimum. An audit trail may be requested by the court with regard to the equipment specifications and the processes used to maintain the integrity of the dataset provided

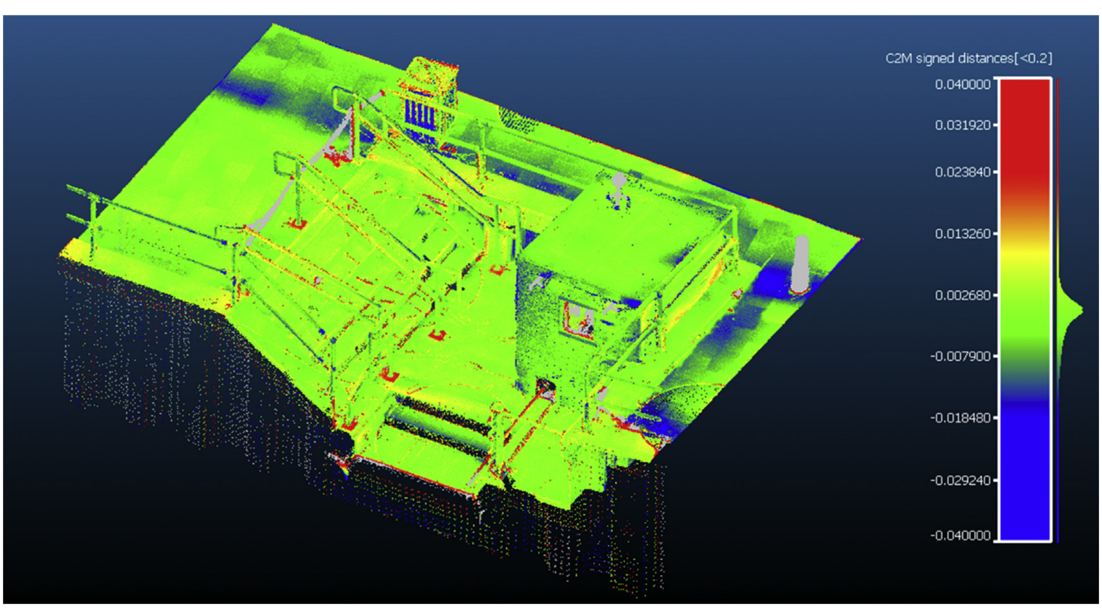

Fig. 5. Deviation analysis.

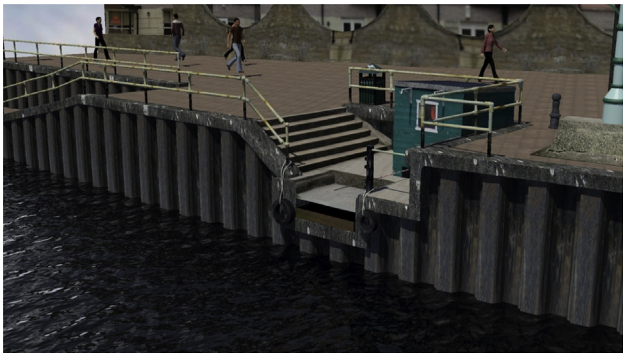

Fig. 6. Screenshot of 3D model. 3D, three dimensional.

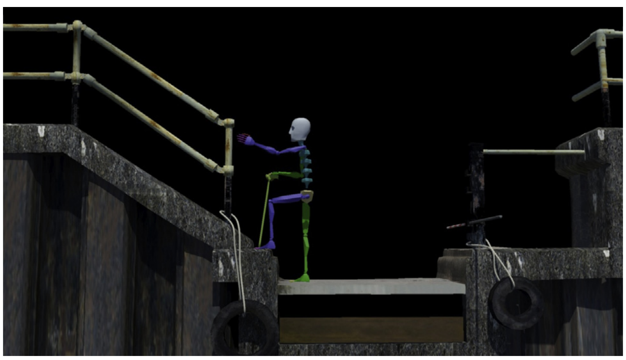

Fig. 7. Scaled person in the scene.

(registration statistics), in order to ensure that the digital evidence is admissible. The 3D model subsequently created from the survey data can then be checked against the point cloud data, as illustrated in Fig. 5; this then provides clarity on the objects' geometry in relation the original dataset.

In this particular case, the quay area was modeled to very high accuracy. A second check was also performed through a comparison between physical measurements taken on the scene and those from the point cloud to provide further integrity.

Once modeled, textures need to be applied to the surfaces in the form of photographs, creating an accurate visual representation of the scene. In addition to photographs, lighting can be applied using certain modeling software to add realism, by casting shadows and adding a natural feeling to the "lit" environment. In addition, environmental conditions of the geographical location of the incident, such as time and date, can be applied to the model for more realistic lighting. A screenshot of the completed 3D model for the above case is shown in Fig. 6.

Once a 3D model has been created, it can be used for various purposes, e.g., in cause analysis to check the hypotheses of the investigator, examining if they are plausible in the virtual environment of the incident. In addition, 3D models can help explain the events surrounding an incident to people unconnected to an accident. In this case, video animations could be beneficial.

2.2.2.4. Addition of scaled 3D person. Once the environment had been accurately modeled, a scaled person was constructed in order to demonstrate the body movement of the deceased climbing the steps. As the laser scan survey was performed retrospectively following on from the time of the incident, the body was not available for reference to create the model. Therefore, the mean body data were used to scale a 3D skeleton, which was then animated as an aid to explain the movement involved in climbing the steps. A profile view of the model in the scene is shown in Fig. 7. However, a number of complications are associated with the use of a 3D representation of an individual in a model within the courtroom and it was deemed inadmissible evidence (explained in the conclusions).

2.2.2.5. Video production. In order to produce a video animation of a scene, virtual cameras have to be located within the environment and paths to be created in which they are constrained to travel. A sequence of still images can be produced (or rendered) from the software, which can later be joined to create a video. In this particular case, the purpose of the 3D model was to demonstrate the changes in the steps and handrails. Animations were created from different camera locations that corresponded to photographs that were taken during the investigation process. An example of this is shown in Fig. 8.

Following this, video blends were used to represent a photograph location with reference to the 3D model, providing a smooth transition. As a number of changes were made to the steps, animations were made to illustrate this, where additions were shown in green and removals in red. An example of this is shown in Fig. 9.

2.2.2.6. Physical 3D models. In addition to virtual reconstructions, physical 3D models can also be considered to aid in the explanation of events surrounding an incident. Using the measured data, physical reconstructions of an accident environment can be made.

Rapid prototyping machines have made the possibility of making accurate 3D models a reality. This can be done in a number of ways, e.g., using a 3D printer. Three-dimensional printers allow a user to create a physical 3D model directly from a CAD program. These 3D printers print in thin layers of nylon, building up the model

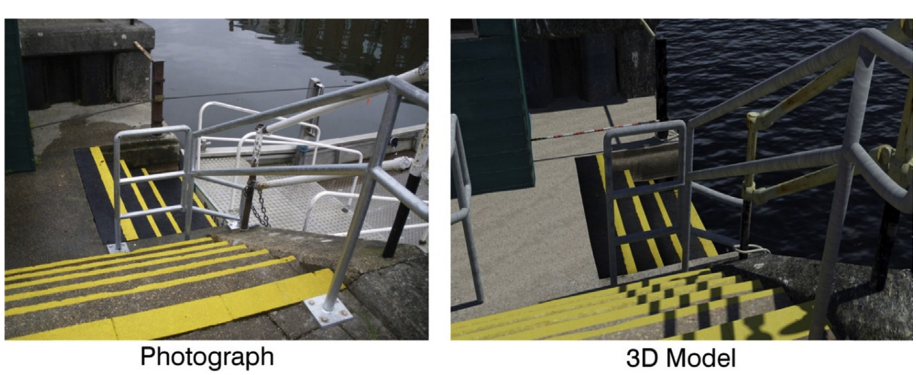

Fig. 8. Comparison of photograph with the 3D model. 3D, three dimensional.

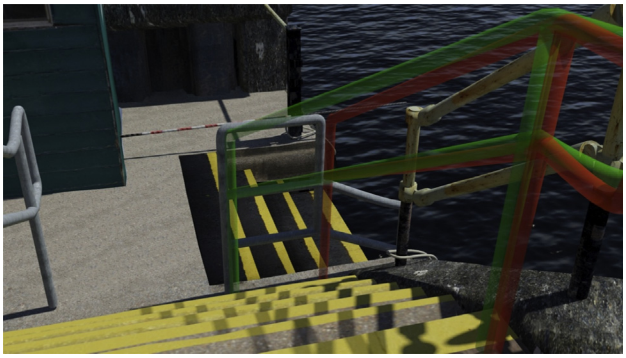

Fig. 9. Illustration of changes to the steps.

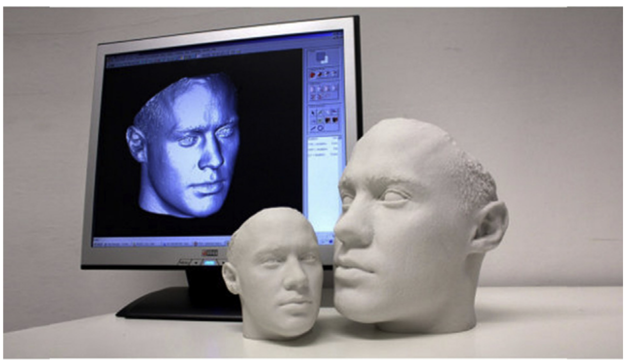

Fig. 10. Example of a 3D printed model. 3D, three dimensional.

gradually until the design is complete. A complex geometry can be created using this method to a high degree of accuracy. However, the size of the model that can be printed is limited, with the largest printers having a build tray of only 1,000 × 800 × 500 mm^3 [23]. As the technology is in its infancy, the price of 3D printing to create large models is considerably high. However, hobbyists' machines can create small-scale models at a relativity small expense. An example of a 3D printed model is shown in Fig. 10 [24].

For large 1:1 scale models of "simple" geometry, such as the profile of the steps in this case study, models can be made from wood cut accurately to size and fixed together. An example of a model constructed to for the above incident and its integration with the steps is shown in Fig. 11. This constructed model was used in the courtroom in order to provide a visual reference to the jury on the dimensions of the steps. In addition, the physical model was of considerable use in assisting the explanation of the expert witness testimony, where the model was referenced multiple times demonstrating the methodology of measurements undertaken during the investigation.

3. Results

3.1. Use within a courtroom

There are a number of ways in which 3D technology can be used in a courtroom in order to help explain the circumstances regarding a case, providing descriptive, contextual, and also measurement data as required. The information can be presented to the court as follows:

- Two-dimensional representations taken from the point cloud data, in the form of plans or rendered images from the 3D model (These would be submitted to the court within the jury bundle.)
- Three-dimensional animations and videos that can be shown to the court on a screen within the courtroom
- A physical 3D model that can be placed within the courtroom for illustration or a point of reference

3.1.1. Benefits

Key benefits can be obtained by incorporating the laser scanning technology into court proceedings, and these have been demonstrated in this case study.

3.1.1.1. Explanation to people unconnected to the event. The data obtained through laser scanning can be very rich and provide a dense, full 3D representation of a scene, which, when photographs are applied, becomes a realistic visual representation. This allows the court to observe the relationship between everything within the scene, both geometrically and with true RGB colors. The 3D data can also be easier to understand in comparison with a number of photographs and 2D plans of the incident scene, improving data clarity to people unconnected to the event or from a nontechnical background.

3.1.1.2. Explanation of complex environments. Occasionally, accident scenes can be very complicated involving a number of different key objects and locations within the environment that contributed to the incident. A barrister has the task of trying to explain these using conventional methodology, and this can be very

Fig. 11. Three-dimensional wooden model of the steps.

difficult, especially when referring to multiple pieces of evidence and written statements. A 3D model can provide the ability to demonstrate the scene visually, which can be easier for the audience to absorb.

3.1.1.3. Enabling incident reconstruction. Once a 3D model has been created, animation paths can be set virtually within the software to demonstrate the events surrounding the incident to provide before, during, and after representations. The information used to create this can be taken from witness statements in order to recreate those statements visually.

3.1.1.4. Demonstration of environment in different stages. It may be necessary to demonstrate, to the court, the changes that had occurred in the scene over a timeframe. A model of the scene at any point in time can be created and used to create a visual display in 3D. This was a key component of the case study, as one of the purposes of the model was to demonstrate the height of the bottom step at the time of the incident and the changes made to the set of steps following the incident, as shown in Fig. 9.

3.1.1.5. Witness statement verification/first person viewpoints. A virtual camera can be located within the 3D surveyed environment, which can be used in order to demonstrate what the person would have seen. This can then be used in order to address the reliability of the witness account.

3.1.1.6. Site visits. In certain circumstances, it may be necessary for the jury to be taken to the scene to illustrate specific details concerning the case. However, the logistics of taking a jury to the scene may be difficult. For example, the scene may be inaccessible or demolished, or time may be limited.

With this in mind, a 3D model (physical or virtual) may provide adequate information to aid in the explanation without the need for an “actual” scene visit.

3.1.1.7. Preservation of evidence. Depending on the timing of the court case with reference to the date of incident, there can be problems in demonstrating key details, especially if the environment has changed, e.g., when referring to a witness statement that was made at the time of the incident and it may be hard to envisage what the conditions were at that time. Once recorded, the scene can be archived providing evidence of the true conditions at the time of an incident.

3.1.1.8. Testing of theories. There can sometimes be conflicting views on the events surrounding an incident, and the different explanations of these can sometimes be difficult to visualize. The use of a 3D model can become a valuable tool to aid in the explanation of the events and possible scenarios that may have been contributing factors for the incident.

3.1.2. Drawbacks

There are limitations to the use of 3D models that can occur within a courtroom.

3.1.2.1. Limitations in technology within courts. As laser scan technology is relatively new, its use in a courtroom can sometimes be limited to the technology that is available (such as audio and visual display equipment). This can be the case particularly in older courtrooms that may not have the facilities to show a virtual model in detail.

3.1.2.2. Confusion caused by models. Occasionally, in complex accident scenes, a number of changes might have been made to the environment over a length of time, e.g., a number of alterations might have been made to the stair infrastructure in order to ensure that the site is safe. These scenes can sometimes be problematic to show, as a considerable number of changes may have to be demonstrated. This can make a video animation appear cluttered and hard to understand.

3.1.2.3. Trust in the data. Again as laser scanning is relatively new, there may not be trust in the data produced. People may consider that 3D models and environments that are created as computer-generated illustrations do not hold true geometric accuracy. However, acceptance of the data may come in time when the technology is used more frequently, in a world that is ever more media focused and digitally driven.

3.1.2.4. Cost. Owing to the high costs associated with the construction of either a virtual or a physical 3D model, it may not be appropriate to use such a model in every case. Consideration must be given to the benefit brought to the case by adopting a 3D model, and cost incurred must be agreed within the court by both sides.

3.1.2.5. Complexity of an expert’s statement. As discussed previously, a number of steps have to be considered in order to produce a model for use in a courtroom. If a model has been produced for a case, it may be necessary for the expert to explain the methodologies that have been undertaken. This can sometimes be confusing for people to understand, particularly if they are not from a technical background.

3.1.2.6. Personal interpretation. Data captured by a laser scanner is indiscriminate and can be modeled to a high level of accuracy. Despite this, there are still occasions where additions to the scene have to be made, sometimes without clear evidence for their existence, and thus extreme caution in regard to their addition has to be exercised. For example, with reference to the above case study, the laser scan survey of the incident was performed retrospectively. This meant that the body was not available for accurate body measurements to be made and mean body data were used. This was not, therefore, a completely “true” representation (in the absence of an accurate pathologist’s record). In addition, it was not known from witness statements where the walking stick was placed, either on the step or on the landing platform. In the video animation, the walking stick was placed on the step, which made its validity open to discussion and therefore it was not used in the proceedings.

4. Discussion

The use of 3D models are very effective to stress a point of view, bringing the case “alive” to both the witnesses and the court, through a virtual site reconstruction, with 3D models being used in a number of cases in recent years.

However, although to scale, many of the models have been computer-generated representations of a scene and may not reflect the “true” geometry of the environment. This is particularly the case when considering a complex geometry, and therefore laser scanning can offer a new aspect to this already exciting investigative approach.

It could be argued that when demonstrating a witness point of view, the use of a computer-generated 3D model may not truly represent the actual environment and may cause ambiguity. However, as a laser scanner offers the ability to capture the environment to a high degree of accuracy from any given position, laser scanning can be used to help clarify this. The authors have used the equipment within vehicles, for example, to demonstrate the view of a driver while considering the complex geometry within the cab.

Performing this operation in the cab of a vehicle is relatively straightforward, as the location of the scanner is fixed, and only the height of the instrument is required to establish the driver's field of view.

Complications can arise in determining the exact placement of a witness in an open environment, unlike that of a driver within a constrained location. The operation of determining the placement of a witness can also be performed virtually through the creation of a virtual camera within a generated model or positioning of a laser scanner in the "real world," but the same problem arises due to uncertainty of the exact witness placement.

Therefore, care should be taken when performing this operation in order to ensure the placement of the camera or the scanner is accurate to the actual position of the witness. In addition, if a witness has problems relating to their vision, a scanner will not be able to account for this. However, in many cases, this can result in the "evidence" becoming inadmissible in a court.

In many cases (such as in this case study), 3D models can be used to recreate the event, providing a chronology of an incident as it unfolds or of changes in the environment. However, as in this case study, the chronology should not be open to personal interpretation such as the placement of the 3D person detailed above. The inclusion of human figures in the surveyed environment is subject to considerable contest within a court. Using the above case study as an example, the fundamental problems (unknown to the authors at the time) of using a 3D person was highlighted and will now be discussed.

First, as the laser scan survey of the incident occurring was conducted retrospectively, the body data of the deceased were not available for use. The mean body data were used to create the scaled person; this resulted in data ambiguity as the model was being used to demonstrate the reach of the person involved. Therefore, the use of the scaled person could have been unreliable in court, owing to the model not exactly representing reality.

In addition, the placement of the foot could have also been contested, in much the same way as discussed previously with respect to witness statement verification. Therefore, these data were not used in the court case, and the final rendered video did not include the animated person.

The fundamental benefit of the 3D model in the above case study was to demonstrate the changes to the stairs over the period between the incident and the subsequent court case. The model was needed owing to the sheer amount of changes that had occurred within the environment, resulting in the jury being presented with a large number of images of the infrastructure, which would have been hard to picturize without the clarity of the 3D model.

One of the problems that had to be overcome was how to prevent the animation from becoming "cluttered" given the numerous changes that had to be expressed. This was resolved (detailed above in the paper), and it reduced the need for the jury to perform a site visit. In addition, a site visit may have added to the confusion as the scene did not represent the environment at the time of the incident.

This then leads to the next significant benefit, in respect of the preservation of the scene and of complications regarding transient evidence. As the scene of an accident is in an immediate state of decay from the moment the event occurs, it is important to document the scene quickly.

The use of conventional surveying methodologies has numerous limitations with regard to the time taken to record the evidence, density of the information that can be collected, and human errors associated with collecting discrete points of a scene. Most of these problems are resolved by capturing the geospatial data through laser scanning, which is unrivalled by any other technique in a narrow timeframe. For example, the survey undertaken in the above case study was conducted in 10 laser scan positions, with the equipment set to capture the data in high resolution (approximately 4 million points per scan), each scan taking 3.5 minutes. This resulted in a dataset of 40 million points, whereas to capture this amount of detail with conventional means would be unattainable.

Current technology still has some limitations, and manufacturers are applying and adopting solutions continually. When new applications are developed, research is essential to assess their accuracy, before they are trusted to be referenced as evidence in a courtroom. In addition, the capability of the current technology needs to be explored and education needs to be focused through research, in order to assist nontechnical persons in their understanding of the accuracy that can be obtained and the drawbacks that can be associated with embracing a new technology.

Conflicts of interest

All contributing authors declare no conflicts of interest.

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