Forensic Animation: Measuring the Reliability and Accuracy of Computer Generated Animation Used in the Courtroom

Dr M Tarek Shalaby, Ms. N Hussin, and Dr D Schofield
The University of Nottingham

Abstract

This paper discusses the findings of ongoing research into forensic animation at the University of Nottingham. The paper has six sections. The Introduction part explains the general context about the use of forensic animation for court litigation. The second part describes challenges for the computer animation in the courtroom. The third section deals with procedures used to develop a particular forensic animation case study. It depicts a fatal road accident involving a car and two motorbikes on a dual carriage-way in the UK. The fourth section discusses the development of a new methodology for measuring the reliability and accuracy of forensic animation. The fifth section elucidates analysis on knowledge theory and deductive reasoning. Finally, the conclusion part focuses on demonstrating the extent to which a particular frame of animation carries reliable and accurate information (evidence) which will help a judge and jury to understand complex events.

Keywords: Forensic animation, accident reconstruction, syllogism, virtual reality.

1: Introduction

Recent and rapid developments in PC technology and the huge potential market for desktop Virtual Reality (VR) have created a climate where novel applications have emerged. The computer games market has driven the development of software tools for the creation of 3D environments alongside specialist 3D graphics accelerator boards and input/output (I/O) peripherals for PC games systems. Whilst much of the development is for the leisure industry, there are many real industrial applications being developed under rigorous guidelines [1].

Forensic animation involves the use of animated computer graphics to recreate an event such as an automobile accident, the collapse of a building, an assault, or the workings of a mechanical device, from a variety of perspectives [2].

In a legal context, evidence is information by which facts tend to be proved, and the law of evidence is that body of legal rules regulating the means by which facts may be proved in courts of law and tribunals and arbitration in which the strict rules of evidence apply [3].

Computers may be used to illustrate evidence, but it does not necessarily make the evidence more accurate or reliable. To create an animation, data has to be entered into the computer. An animation is, therefore, only as good as the information upon which it is based. There is no substitute for meticulous investigation and careful analysis.

2: The challenges for computer animation in the courtroom

A visual image can have a very strong impact on a jury. Such images can be easily manipulated, and the potential for misleading a jury is ever present. A good example of this (in a situation that is analogous to a computer simulation) is Gladhill v. General Motors. In this case, a videotaped demonstration (by the defense) of the braking characteristics of a 1980 Chevrolet Citation was admitted into evidence. The issue was that the Plaintiff's accident occurred at night, on a sharp downhill curve, and the Defense's demonstration was done in the daytime, on level ground, and was conducted by an experienced test driver. The defense tried to argue that the test was not a reconstruction of the accident, but rather *"a demonstration of certain operating characteristics of the vehicle in question"*. The court of appeal did not agree with this argument and held that such evidence was misleading: *It is easy to understand why the jury might be unable to visualise the plaintiffs' version of events after watching this video. Indeed, the circumstances of the accident, as alleged, were so different from the*

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demonstration as to make the results largely irrelevant if not misleading [4].

There is a great deal of scope for tampering with the evidence in computer-generated displays. This possibility was recognised in the dissenting judgement of Justice Van Graafeiland in the US case of *Perma Research & Development v Singer* [5] . The learned judge stated that although a computer has tremendous potential for generating more meaningful evidence, "it presents a real danger of being the vehicle for introducing erroneous, misleading or unreliable evidence."

Even where there is no deliberate attempt to tamper with the evidence, computer-generated displays can be unintentionally misleading. Computer animations in particular rely a great deal upon data collection, human judgement and speculation at each step of the animation process.

In view of the potential for misleading the jury and tampering with the evidence, it is evident that the most vital issue in animation is the reliability and accuracy of the information that may be used to create the animation.

Two questions that may be regarded as essential in this respect are (1) the objective of the animation, e.g. the police investigator instructed the animator to animate the evidence demonstrating that the car had made the turn at the junction, hence, the sequence of animation shows that the car driver could not see the motorbike coming from the opposite direction; and (2) what is the critical issue(s) from the judge and jurors' point of view, e.g. the trial may look at various traffic offences with regard to the accident.

Several courts have voiced specific criteria that an animation must meet before it can be admitted as evidence :–

- The animation must be a fair and accurate representation of the evidence to which it relates;
- It must be relevant; and
- Its probative value must substantially outweigh the danger of unfair prejudice, confusion of the issues, or misleading the jury. [6]

A computer animation is predominantly used only as a presentation tool; it is not often used as an analytical tool. An animation is usually created based on information provided by a witness or data provided by an expert [7].

3: A forensic animation case study

This case study refers to a fatal accident, which took place on a dual carriageway in the UK. It involved two motorbikes and a car. The car was making a turn into a junction and the two motorbikes were approaching from the opposite direction. At the mid-point of the turn, the motorbikes collided with the car and both motorcyclists were killed.

The data acquisition process in this case involved obtaining evidence from :–

- Police accident reports.
- Original police photographs.
- Witness' statements.
- Police drawings (e.g. Figure 1).
- Crash investigation reports (e.g. Figure 2).

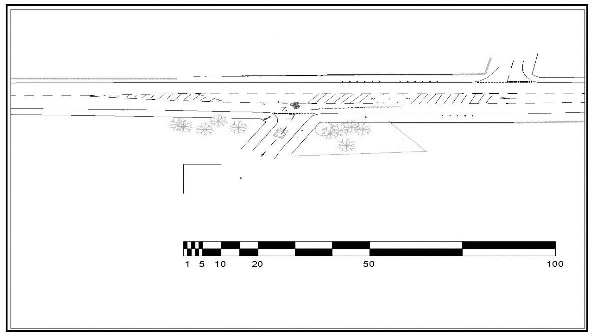
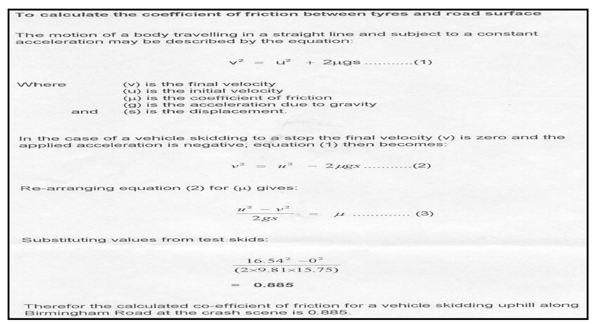


Figure 1: Police plan illustrating the layout of the accident scene


To calculate the coefficient of friction between tyres and road surface

The motion of a body travelling in a straight line and subject to a constant acceleration may be described by the equation:

$$v^2 = u^2 + 2\mu gs \text{ ....(1)}$$

Where (v) is the final velocity
(u) is the initial velocity
(μ) is the coefficient of friction
(g) is the acceleration due to gravity
and (s) is the displacement.

In the case of a vehicle skidding to a stop the final velocity (v) is zero and the applied acceleration is negative; equation (1) then becomes:

$$v^2 = u^2 - 2\mu gs \text{ ....(2)}$$

Re-arranging equation (2) for (μ) gives:

$$\frac{u^2 - v^2}{2gs} = \mu \text{ .... (3)}$$

Substituting values from test skids:

$$\frac{16.54^2 - 0^2}{(2\times9.81\times15.75)}$$

$$= \mathbf{0.885}$$

Therefor the calculated co-efficient of friction for a vehicle skidding uphill along Birmingham Road at the crash scene is 0.885.

Figure 2: Crash investigation report describing the calculation of the coefficient of friction between the vehicle tyres and road surface

The first task undertaken was the development of the three-dimensional computer model of the immediate environs. The model was developed based on the ordinance survey road layout plan of the scene and police survey data. The features in the model were accurately positioned using the available data (from the geometry of the road layout to the positions of street furniture such as lamp posts and bus stops).

Three-dimensional models were created to represent the vehicles in the scene including the car and the two motorbikes involved in the accident. The three-dimensional vehicle models used were created such that the dimensions accurately matched the measurements specified in the accident reports.

A number of calculations were undertaken to allow the vehicles to be accurately animated within the virtual world. The animated vehicle positions are based on the results of police calculations and further calculations were undertaken to correlate the police results to a series of small time increments of between 0.1 of a second and 1.0 second. Calculations were performed at each time interval to allow the animator accurately position a vehicle within a template at that particular moment of time. For example, as the motorbikes approach the junction, available data is limited and the police accident investigator assumed a constant velocity, hence the animator used an interval of 1.0 second for the calculation templates. However, when the motorbikes begin to skid, more accurate data on the calculation is available, and the event happens very quickly, so the interval used during this time period was 0.1 of a second.

Figure 3: Still from a computer generated animation demonstrating the point where the car is making the turning

Figure 4: Still from a computer generated animation demonstrating the movement of the two motorbikes

The rendered images and animations were then added to a browser based presentation system, allowing easy access and recall of all of the information created. Multiple views of the virtual world were created, these consisted of both static and animated viewpoints (from overhead views generated for clarity to views demonstrating witness viewpoints). Rendered frames from the animations reduced are shown in Figures 3 and 4.

During the production process, steps must be taken to ensure accuracy and reliability. The animator and expert witness who assisted in directing the animation must be ready to testify:-

- that the underlying data are accurate,
- that the process by which the data were fed into the computer provides reasonable assurance that error was avoided, and
- that tests were used to maintain the accuracy and reliability of the hardware and software employed. [7]

Items that fall under the category of collision evidence include positions of rest, tire marks, roadway markings, damage to vehicles, and damage to property.

Wherever possible, a technique that takes into account both accident scene information and vehicle damage information should be used to perform the collision reconstruction.

In the mathematical calculations in this case study, prepared by a senior crash investigator, the calculation of the coefficient of friction between the tyres and road surface utilised a trajectory-based technique, making use of the Law of Physics principle. Hence, the forensic animator had used the result of the calculation from the crash investigation to animate the accident.

4: The proposed approach

Epistemology is the branch of philosophy that studies knowledge. It attempts to answer the basic question: what distinguishes true (adequate) knowledge from false (inadequate) knowledge? [8].

The theory of knowledge seems to be an effective way to measure the reliability and accuracy of computer animation as a way of presenting evidence in the courtroom.

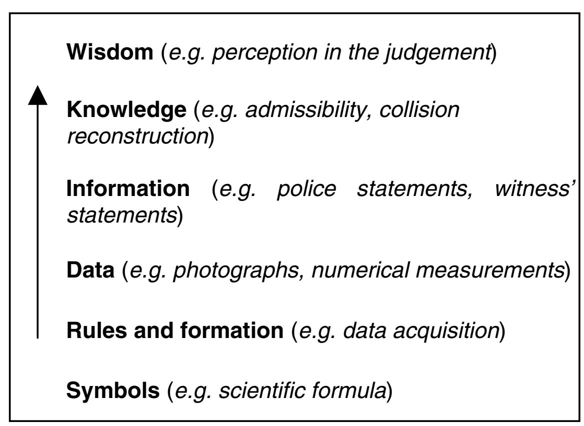


Figure 5: Knowledge hierarchy explaining the evolution from "symbols" to "wisdom"

Figure 5 illustrate the knowledge hierarchy from the "symbols" through to "wisdom". Data means letters, numbers, lines, graphs and symbols, etc. – that are used to represent events and their state organised according to formal rules and conventions. Examples of data may be represented by numerical measurements, photographs of vehicles and photographs of the accident scene.

Information means the cognitive state of awareness (as being informed) given representation in physical form (data). This physical representation facilitates the process of knowing. Examples of information may include references to the chain of events, which occurred as stated in the witness' statements, police statements, and the post-mortem report.

Knowledge means the cognitive state beyond awareness. Knowledge implies an active involvement and understanding and the ability to extend the level of understanding to meet life's contingencies. Examples of knowledge may refer to the concepts in developing the animation such as, collision reconstruction, demonstrative evidence, expert witness testimony and admissibility.

Wisdom implies the application of knowledge as contained in human judgment centered on certain criteria or values that are generally accepted by the culture of society. Wisdom is the point where judgment and verdict shall take place. The perception (wisdom) of judge and jury in analysing how information (e.g. the animation) can prove knowledge (e.g. the concepts) by using data (e.g. the substantive evidence).

In applying this approach, this paper embraces a deductive reasoning pattern. Deductive reasoning is a part of human thought process, often categorised under Human Computer Interaction (HCI). Deductive reasoning works from the more general to the more specific. Figure 6 illustrates the pattern of analysis in deductive reasoning.

Theory:
A set of ideas formulated to explain something.

General hhypotheses:
Supposition or conjecture put forth in the form of a prediction according to a theory, observation, problem.

Figure 6: Deductive is reasoning from the general to the particular

A deductive argument offers two or more assertions that lead automatically to a conclusion. In the research undertaken at Nottingham, which is described in this paper, deductive analysis has been used to examine the presence of evidence in a particular animation. Then, if the evidence is reflected in the animation, the researchers have attempted to measure the extent to which the animation is reliable and accurate, based on the evidence.

The following is an example of a sound deductive syllogism:

Premise: All birds have wings.
Premise: A parrot is a bird,
Conclusion: A parrot has wings. [9]

Figure 7, illustrates the pattern, based on the rules of deductive reasoning which have been used in measuring the reliability and accuracy of the computer-generated animation against evidence, concepts and issues.

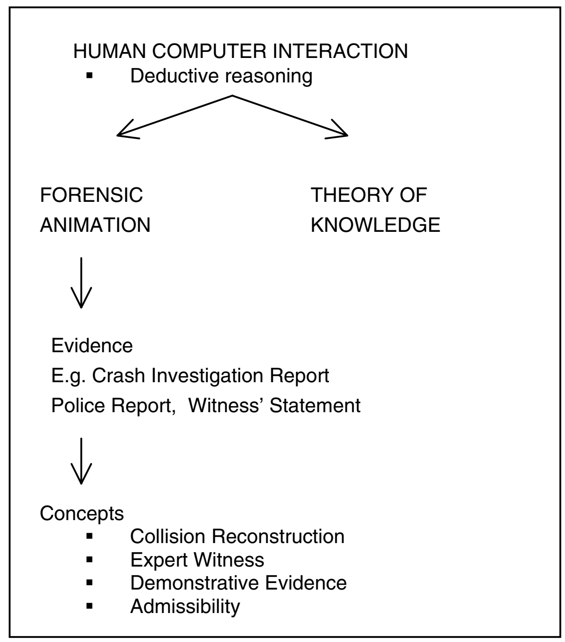


Figure 7: Link between Forensic Animation, Theory of Knowledge and Human Computer Interaction

The measurement is concerned with the analysis as to whether animation and simulation may or may not help to explain complex events.

As mentioned in the earlier part of this paper, most studies of knowledge attempt to answer the question of: *what distinguishes true (adequate) knowledge from false (inadequate) knowledge?* What is important in examining the reliability and accuracy of an animation, is to investigate which evidence has been used in developing the particular animations.

As presented in court, the animation should carry accurate and reliable information from the evidence. The judge and jury will view the animation and ask the expert witness questions such as :–

- How did you determine at what particular time the car made the turn ?
- Why did you assume that the surface of the road is viewed in such manner ?

5: Analysis using theory of knowledge

In analysing this issue, two main areas from theory of knowledge can be taken into account :–

- Types of knowledge.
- Conditions for knowledge.

5.1: Types of Knowledge

The first type of knowledge is *competence*. An example of competence is when an individual displays competence, the interpretation is, that he or she knows how.

The second type is *acquaintance*. An example of acquaintance is when an individual may be said to know that with which he or she is acquainted. To say that one knows something in this sense is to say that they have had some experience with what they know.

The third type is *recognition of information as being correct* – this is knowledge in the (correct) "information" sense. To know is to recognise correct information as being correct. Example: *I know that 2 + 2 = 4 because I possess the information that 2 + 2 = 4, the information is correct, I consider it to be correct, and I have a good idea why I think it is correct.*

The following is a witness statement from our case study:

Mrs. R: *Remember? Well I couldn't actually see them hitting me because I'm on the driver's side and they are partly shielded by the window line on my nearside from the photographs that I've seen in the paper.*

This witness statement is illustrative of the different types of knowledge mentioned above.

Competence – The statement, *"they are partly shielded by the window line on my nearside from the photographs that I've seen in the paper"*, demonstrates competent knowledge on the part of Mrs. R, based on what she saw in the paper.

Acquaintance – This is demonstrated in the statement, *"Well I couldn't actually see them hitting me because I'm on the driver's side."*

There is an association with competence here, in that there is knowledge (*"the photographs that I've seen in the paper"*) in cases where the individual does not have the ability to recognise the thing (*I couldn't actually see them hitting me because I'm on the driver's side*).

Recognition of information as being correct – Mere possession of information (*"the photographs that I've seen in the paper"*) is not sufficient to be considered correct knowledge. In her statement, Mrs. R may have regard the photographs she saw in the paper as conveying correct information, but the accident investigation still has to determine the correctness of her statement.

5.2: Conditions for knowledge

There are three conditions for knowledge. The first condition is truth. The second condition is acceptance and the third one is justification [10].

The example below demonstrates how the conditions for knowledge apply to another witness statement from our case study

Mrs. R : *At the junction with J Road, I pulled into the protected area and waited while two or three other cars passed in the opposite direction.*

Truth – *"J Road"* is true if and only if J Road exists. In this case "J Road" exists, hence, it is true in her statement.

Acceptance – Mrs. R's statement, *"I pulled into the protected area and waited while two or three other cars passed in the opposite direction"*, may be accepted as being her version of events, but may not necessarily be endorsed as being what actually took place.

Justification – Whether or not Mrs. R had actually pulled into the protected area carries a level of justification between reasonableness and complete certainty, for the accident investigator and animator.

By taking these two main areas, (i.e. the types of and condition for knowledge) as the main components in this measurement of accuracy and reliability, an analysis can be done by cross-tabbing the animation with substantive evidence and concepts illustrated in Figure 7. This syllogism pattern could be applied as a useful tool for examining the type of knowledge and the conditions for knowledge.

5.3: Deductive Reasoning

Further details on the analysis using deductive reasoning can be seen in Figure 8 below, which explains:- that the information from the crash investigation (CI) has been used in the computer generated animation (CGA), based on the collision reconstruction (CR), therefore, aspects of the animation which are assessed in this manner can be certified to be reliable and accurate.

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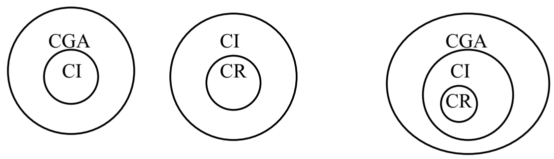

C1=CGA CR=C1, therefore CR=CGA

Figure 8: Relationship between crash investigation (CI), computer generated animation (CGA), and collision reconstruction (CR)

6: Conclusion

The reliability and accuracy of a forensic animation depends on the precision and verifiability of the data used to create it. In the road accident case study, for example, it is important to know prior-to-impact data including the speeds of the two vehicles, the precise directions in which they were traveling, the masses of each vehicle, the points on each vehicle at which contact was first made, and whether or not (and to what extent) either vehicle was accelerating or decelerating. This data might be gathered from the testimony of one or both drivers, eyewitnesses, police officers who came to the scene after the accident, or engineers who analysed the structural damage to the vehicles and the skid marks (if any) left on the roadway. The nature and condition of the pavement, the weather, the condition of each vehicle's tires, and the reaction times of the drivers could provide important additional data. Even a slight change in one of the parameters and concepts can result in a drastic change in the legal judgment.

The effectiveness of the epistemological approach using types of knowledge, conditions for knowledge and the deductive reasoning can be seen in the paper. The analysis of the types of knowledge distinguishes the type of information itself when looking at a particular statement. The conditions for knowledge can be used to make a specific analysis to determine the truth, acceptance and justification values in the witness statement. The authors believe that the deductive reasoning patterns described are a sound methods for investigating as to whether the animation reflects reliable and accurate information from the evidence used.

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