Integrating Technology with Crime

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A thesis submitted in partial fulfillment

of the requirements for the degree of

Bachelor of Science (Specialized)

Algoma University College

Sault Ste. Marie, Ontario

March 2007

Abstract

Technology is solving many problems and conflicts today that we were unable to solve in the past. Tennis matches now turn to a *three dimensional* (*3D)* recreated replay to determine where the ball landed and baseballs are being tracked in 3D to reveal the exact distance that the player hit the ball. These examples are great for entertainment purposes, but how can we put this technology to better use or to possibly determine someone's fate.

Hollywood teaches us that you can zoom in to the n^{th} degree and still have 100% clarity. If this were true, cameras everywhere would be zooming miles and miles away with perfect precision. Hollywood also teaches us that with a few keystrokes, we can pull up a 3D *wireframe render* of any building in the world. However, the real world has real tools and real boundaries on what can be done. These boundaries are especially true when it comes to *3D graphics* and *forensic science*.

The *restrictions* on what 3D graphics can accomplish are in many ways outweighed by what can be achieved with the technology available today. Using today's technology, it is possible to recreate full scenes, whether it is an indoor room or an outside field, with exact *dimensions* and can eliminate the need to depend on photographs and best guesses. The technology today also allows evidence to be rebuilt and manipulated in ways that could not be imagined years

ago. However, as the tools become more accurate and flexible, the boundaries become more prevalent. Every forensic scientist wants to do more and every computer scientist is working to try to fulfill those needs. No matter what, *randomness* is hard to detect and *simulate* with 3D graphics. It works well with hard facts and concrete evidence but when foreshadowing and speculation need to be factored in, technology is somewhat behind.

To show the current state of 3D graphics and its limitations, Mini-Cases will be developed using the latest tools available. These Mini-Cases will illustrate the broad range of ways that 3D graphics can be implemented into forensic science. They will also demonstrate how *two dimensional (2D) photography* and *2D graphics* are now almost obsolete but are still needed in various 3D programs and applications.

This thesis reveals that although there are certain limitations on what 3D graphics can accomplish, there are still plenty of ways that they can be implemented in the court systems as well as in forensic science.

KEYWORDS: *three dimensional (3D), render, wireframe, 3D graphics, forensic science, restrictions, dimensions, evidence, randomness, simulate, two dimensional (2D), 2D photography, 2D graphics.*

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Chapter I

Introduction

A small blood splatter, a shred of broken glass, one sliver of hair and a large empty room with only one way in and one way out. A high paid lawyer is going to prove that his client had no part in this investigation. Using 3D graphics and technology, this lawyer can let the facts prove the case by recreating this crime scene and reliving the event. It allows for no errors and is reliant on facts and dimensions.

1.1 Problem Definition

Crime scenes have been recreated since the pencil and paper have existed. Artists used their skills to draw the most realistic scene or evidence on paper in 2D format. Technology today can be used to take those 2D images and construct a 3D environment. A scene can be turned into a virtual world where one can walk around and see through the eyes of an individual who was actually there at the time. A piece of evidence that has been destroyed or broken can also be restored in 3D. Tools today and tools of the future can help aid lawyers, scientists and police in order to prove a case.

1.2 Objective

The principal objective behind this thesis is to attempt to illustrate different ways in which 3D graphics and technology can be used in everyday crime cases and to demonstrate the many advantages they bring to proving or solving a case. Through demonstration and experimentation, it will be apparent that 3D graphics and technology should be exercised more often in court. To accomplish this task, mini-cases will be developed to establish the numerous ways that 3D graphics can assist courts. Each case has its own role and meaning towards the purpose of this thesis. They will each involve different tools and techniques to identify various ways that 3D graphics can be applied to the real world and crime.

1.3 Thesis Overview

Chapter 2 presents a history of 3D graphics and a discussion of how 2D is turned into 3D. Chapter 3 shows what technology is capable of today and briefly discusses what its limits are it. This will lead into chapter 4, which discusses those exact limitations and analyzes what we will be able to do in the future. Chapter 5 presents the advantages as well as the disadvantages of using 3D graphics with today's technology as well as future technology. Chapter 6 presents and discusses the mini-cases that were developed. Finally, chapter 7 presents the conclusion of the thesis as well as further work that may be done in the future.

Chapter II

History of 3D Graphics

This chapter gives a history of how 3D graphics came about in forensic science. It discusses the leap that was made from 2D to 3D and the techniques that were being used as well as those still currently in use. The chapter is divided up into two sections; Background and Turning 2D into 3D. The first section will examine the timeline of graphics, both 2D and 3D, and how it has grown over the years. The second section will discuss the importance of 2D graphics and how it is a vital part in the creation of 3D graphics.

2.1 Background

Since the earliest days of solving crime, detectives or officers have tried to find simpler ways to represent and illustrate what their eyes have witnessed. To achieve this, the use of hand drawn images and photography were used [10, 3]. These images would be used to blueprint a crime scene or to give the court a visual representation of a scene or a piece of evidence.

As time went on, the use of hand-drawn images and photography evolved immensely. To this day, it is still an essential part of any crime scene [15]. However, the accuracy of these images is not always perfect. Much of it relied on the estimation of the artist and his/her interpretation of evidence. Today's use of 2D is more accurate with the use of "markers" in the photograph. Such markers

can be a dollar bill or a ruler. With an accurate 2D model, a scene can be easily transformed into 3D with the use of 3D tools.

2.2 Turning 2D to 3D

Hand-drawn images and photography were a form of 2D evidence. 2D is defined by having two-dimensional geometry, flat, and characterized by Cartesian (x, y) coordinates [17, 1]. While 2D provided the best solution to representing a crime scene or evidence, it has now become a tool for a better solution. 3D graphics, which can be defined as having three dimensions, characterized by Cartesian (x, y, z) coordinates, gives a better depiction of what 2D is trying to describe [17, 10]. The 'z' value or axis transforms 2D to 3D and allows for greater manipulation. A flat blueprint does not allow for real-time change or for any change at all. When a room is created in 3D, the parameters can be changed instantly to allow for many different results while using up very little time.

In a photograph, the lighting is static and so are the objects. It still takes a certain degree of imagination to envision a victim being thrown from one side of the room to another. Once a 3D scene is created, everything becomes dynamic and with the correct tools, things such as lighting and characters can be changed to allow for less imagination and to allow the brain to see the facts.

The most common way to change 2D to 3D is by using the blueprint modeling technique. This technique requires at least two views of one object (although

three views will give you the best, most accurate result). If a table were to be modeled, ideally, it would be beneficial to have the top view and side view. If detail is required, the front and/or back view would also be needed to ensure accuracy. This method of 3D modeling is extended from two-dimensional methods by including considerations for the z coordinate [7, 1]. *Please refer to the Chapter 2 folder on the CD to see an example of a front, back, right and top blueprint.*

Another less practical way to advance 2D graphics into 3D is to use a technique called immersive imaging. Immersive imaging is the process of stitching images together from multiple photographs, in order to create a seamless 360-degree view. This can be done with many of today's digital cameras and the process is often referred to as panoramic photography. An example of this can be found on the CD under Appendix C (.gif files must be opened in Internet Explorer to view the animation). To stitch the photographs, each photo must be lined up with the previous photo with a recommended 33% overlap to guarantee that there will be no part of the photo left out. Once the newly formed image is created, it will look as though it is one image has a viewing angle of 360 degrees. This image could be inserted into different programs that allow the user control to pan left/right and to view the room as if the view was standing right in the center of the room.

The technique of immersive imaging was used in the courts to give the judge and/or jury a better look at the crime scene. It was rarely used to solve a crime or

to be used as the main source of evidence, but it was able to allow others to get a sense of feeling and insight about the crime scene. The problem with immersive imaging was that it had very defined boundaries and was limited to simply panning left and right and allowing for a minimal zoom. Since it was an actual photograph, the zooming would distort the image and become vague. Appendix C deals with immersive imaging and how a possible case can be solved.

Chapter III

Today's Technology

This chapter gives an understanding as to what can be done with technology today, how these achievements are being accomplished, and what is holding certain achievements back. The chapter is divided up into four sections; Today's Achievements, Today's Tools, Tools Being Used and Limitations. The first two sections deal with what can be achieved with 3D graphics and the tools that are being used to make these achievements. The third section gives a list of companies that are currently taking advantage of 3D graphics with respect to solving crime. The fourth section deals with the limitations that are still presented with 3D graphics.

3.1 Today's Achievements

Since making the leap from 2D to 3D, there is a lot that can be done with the tools that we have today. These tools are able to attain graphics that have never been seen before, and the tools allow realistic scenarios to be recreated with complete accuracy.

3.1.1 Realism in Graphics

At this current moment in time, there is a lot that can be achieved using 3D graphics. The realism that can be presented is almost photorealistic where the eyes and brain have a difficult time figuring out what is real and what is created

by 3D graphics [19]. *Please refer to image on CD titles Photorealism. This image is of a real life picture and a 3D rendered image.* To achieve this, six areas must be dealt with. Firstly, the shape of an object, meaning to have a 3D object to match the shape of its realistic counterpart. Secondly, the texture of an object, which deals with what is on the surface of your 3D object, has to have the right color, texture and reflectance. The third area is lighting, which gives an appearance of weight as well as providing shadows and shading. Perspective is the fourth area that deals with distance and angles of which the user views an object. Depth of Field is an optical effect that helps the appearance of an object being in focus or not. Finally, the sixth area of realism is Anti-aliasing. This technique is used for computers attempting to show a curved or diagonal line as appearing smooth not jagged [4, 1].

If all six areas of realism are met, a photorealistic or nearly photorealistic 3D object should be created. When dealing with crime scenes, all of these steps are crucial for giving a judge or jury a better representation of a crime scene or evidence.

3.1.2 Realism in Physics

When dealing with bullet trajectories or blood splatter, graphics are not the main issue. There is no need to achieve the most realistic looking blood when trying to determine what angle the blunt object struck a victim. Many times very low polygon models are used within a scene. This is because graphics are not the

main focus of the scene. Everyone can imagine what a human looks like, whether it is realistically modeled or not. This is used to the artists' advantage because it allows them to concentrate more on the physics of the scene instead of creating a realistic human body.

3.2 Today's Tools

There are plenty of tools on the market to purchase and download that deal with 3D crime and graphics. However, only a few are groundbreaking, and can provide great flexibility and results.

3.2.1 NaturalMotion's Endorphin

Endorphin is a dynamic motion synthesis software that uses adaptive behaviours so that 3D characters will animate themselves [13]. Endorphin is not currently being used for 3D animation involving crime scenes but it does have the potential to do so with its groundbreaking self-animation. *Please refer to animations on CD under Appendix D.*

3.2.2 Total Station

Total Station is used to gather information such as distances and angles on a room or outdoor area and compute them into a 2D diagram or layout. With the help of trigonometry, these angles and distances are used to calculate the coordinates of actual positions of surveyed points, or the position of the instrument from known points, in absolute terms. Total Station is capable of

measuring angles down to the 0.5 arc-second (arc-second is defined as being 1/3600th of a degree) and also measuring distance within 0.1 millimetres [18].

3.2.3 CrimeZone

CrimeZone is an inexpensive alternative to creating 2D as well as 3D images of a crime scene. CrimeZone allows you to create 2D blueprints inside of its application and it features a "one click" 3D button that will turn your blueprints into a 3D environment. Its 2D tools work much like AutoCAD in the creation of lines and the use of toolbars. CrimeZone also goes by the name of CrashZone because it too has the ability to map out car crashes and any vehicular related accidents [3]. *Please refer to CD under Chapter 3, for an image called CrimeZone to see what the tool looks like.*

3.2.4 DeltaSphere 3000

DeltaSphere 3000 is the latest of the DeltaSphere series and is designed specifically for law enforcement and scene reconstruction. The DeltaSphere 3000 uses a laser rangefinder, positional motors that make thousands of measurements per second. It then uses the technique of immersive imaging to stitch all of its data and newly photographs together in a seamless way. Once finished its 2D model, it takes the 360 degree image and turns it into a 3D model that can be viewed from any angle. DeltaSphere 3000 has a built in digital camera to capture color and this allows the recreation of blood splatter and the automatic analyzing of the splatter marks. On average, it can take anywhere from

two to twelve minutes to calculate the data collected [6]. *Please refer to CD under Chapter 3, for images called "Delta" to see what the tool looks like.*

3.2.5 Instant Scene Modeler

Instant Scene Modeler (iSM) first started on the planet Mars before it made its way into a crime scene. In Toronto, Canada, a company called MD Robotics (MDA) wanted to eliminate the tape measure and rulers that the police use today. With iSM a stereo camera is used to create realistic 3D models of people, places and things by stitching together hundreds of photographs into a single 3D image. All of this can be done in seconds and eliminates the need for 2D software, such as AutoCAD. Currently, it is not yet being used by any police or investigators, but hopefully that will change in the near future [14]. *Please refer to CD under Chapter 3, for a folder called ISM to see what the tool looks like.*

3.2.6 Autodesk 3D Studio Max

Autodesk 3D Studio Max (3DSM) allows the user to create 3D objects using various techniques and gives the user the ability to animate these models. With 3DSM, photorealistic images can be obtained due to the ability to change the shape and texture of the objects, the lighting and perspective of how the object is viewed, and the depth of field and anti-aliasing can be turned on of off within the studios work environment. 3DSM is currently being used by the Ontario Provincial Police (OPP) to recreate crime scenes and evidence. The OPP use

AutoCAD for the 2D blueprints and then transform these blueprints into a 3D recreation using 3DSM.

3.2.7 Autodesk AutoCAD

AutoCAD is a 2D drafting tool that has limited 3D tools. It is vector based and allows for quick 2D creations of blueprints and other 2D drawings. While it has the ability to turn the 2D graphics to 3D, the newly created 3D model is not very flexible and can only be edited to a limited degree. The OPP also use this tool in conjunction with 3DSM to easily create 2D blueprints that can be transformed into 3D. AutoCAD is also used for detail in one object. A single object can be created, depicting each small detail, such as a screw or nail, and can be dissected into these separate parts [2].

3.2.8 iWitness

iWitness allows police and forensic scientists to obtain a 3D environment without the use of Total Station, or a tool that requires line-of-sight. iWitness is a close range photogrammetry system that can accurately calculate bullet trajectories, as well as create 3D models of objects at crime scenes. In order to create these models, iWitness requires three angles of a single object. A scene can be recreated in less than two hours and most importantly, with iWitness, any digital camera can be used, as long as it outputs in EXIF format. iWitness is a direct competitor with Total Station and is currently being used all over the United States in selected Police Stations [11].

3.3 Using the Tools

In Canada, the tools currently being used by the OPP are Autodesk 3D Studio Max, Autodesk AutoCAD, and Total Station. All 3D animations and recreations are primarily done in 3DSM with blueprints and primitive objects being created in AutoCAD [5]. A large scene, such as a road accident or any outdoor scene modeling is done through Total Station. Total Station has the ability to gather data and measurements up to 2.1 kilometres away. This is ideal for the officers because it eliminates the use of a standard tape measure. However, it does not eliminate the job of modeling a scene.

3.3 Limitations

A machine can take measurements and model a 3D object with almost 100% accuracy. The same can be done by a human with complete 100% accuracy. The limitations in 3D graphics though, do not only include the measuring or obtaining of data and how that data is used to create a 3D object. The limitations are with the act of randomness and how a computer or application cannot predict all the possibilities of what might have happened. When recreating a scene in reverse, that is taking the current state and the starting state of the scene and trying to determine what happened to get to the current state, a computer can only give its best guess of what happened. NaturalMotion's Endorphin can be used to predict the exact speed of a vehicle and the force that the body left the vehicle, but it cannot take the act of randomness into consideration. If the car

flips and rolls over, it may bounce a certain way that is unpredictable, resulting in the crime scene looking nothing like the original accident.

Another example of not being able to predict the unpredictable, are with falls and human actions. *Please refer to animation on CD under Appendix D.* When the body was pushed off the balcony, NaturalMotion's Endorphin generated the exact physics of the fall. Those physics and attributes can be changed and altered to try to match the crime scene, but it may not always work. If there was a small nail sticking out of the top of the balcony, and by chance, the body's shoelace wrapped around the nail, it may have contorted the fall to look like something else. An innocent fall may now be presumed to look like the body was pushed or thrown.

Chapter IV

Future Developments

This chapter discusses the future of 3D technology and the possibilities that will be available. The first section explains what the capabilities are of future tools and what their potential really is. The second section discusses the same tools, and describes the limitations that will still exist, and new limitations that will occur. The last section mentions other limitations that are not a result of new technology but instead are a result of the environment.

4.1 Future Tools

With the rapid growth of technology, new tools are becoming available every year, updates from previous versions are occurring almost monthly and new downloadable content is available daily. However, to determine what the significant future tools are, the limitations of today must first be conquered. Such things as speed and realism will be more available in the future. How much speed and realism has not yet been determined. NaturalMotion's Endorphin will be releasing its next version that will be capable of computing more intense physics at a quicker duration. Autodesk is constantly releasing new versions of its products, each more capable than the previous version. Such updates in the latest versions are realism in cloth and fire, as well as easier to use interface to navigate around.

Recent developments in 3D crime have been centered around accuracy and speed. In the future however, the tools that are released must be able to predict the unpredictable. Determinants such as slippery surfaces, unconventional falls and other unusual movements by humans have to be taken into consideration in order to help the courts and the juries determine what happened in between the start of the crime and the end result.

4.2 Future Limitations

The bounds of limitations are always pushed and bent, but they are never broken. Once the randomness can be accounted for and therefore become predictable, new boundaries will come into existence. 3D graphics are currently being used for conventional crimes such as car crashes and murder scenes. If someone wants to use 3D graphics for other reasons, such as bridges collapsing due to weight, then the detail must be more exact and the physics engine must be able to compute different weights of different materials. A bridge can no longer be modeled by just a 3D tool anymore, it has to be chemically modeled from the inside and outside in order to determine what materials broke down and why.

At some point, realism will really matter and the rendering time will be astronomical. To achieve this, the speed of rendering must be quick so that it will bring down the hours of work that one is putting into a scene.

4.3 Other Limitations

Some limitations that exist today will always exist no matter how great the technology. These are the limitation of people and what they are capable of doing. Data will always be somewhat skewed and companies will always have the ability to favour the person that pays them. In order to eliminate biased data, a third party must take control of collecting and providing the information. That third, unbiased party may be a possible new company and business that might one day exist. In Canada, that third party is currently the police and they are also the ones creating the scenes with their own data.

The limitations of computers will always exist because computers are never fast enough for what could be possible. Just when computers become quick enough for one task, a new task is created that the current computers cannot keep up with.

Chapter V

Advantages and Disadvantages

In this chapter, the strength and weaknesses of using 3D graphics to depict crime scenes and to recreate scenarios are investigated. The first section describes the benefits of 3D graphics with respect to the accuracy it provides, the time it saves and visualization it provides to a person who has never seen the crime scene or any of the evidence. The last section lists the detriments that are associated with using 3D graphics such as the possibility of a high cost, the ability to skew data and the inability to predict the unpredictable.

5.1 Advantages

The mind has a tendency to wander and to manipulate facts in order to justify what the brain thinks. Even when the brain is confronted with facts, it can still have a hard time putting all the data into perspective. A fact may be that a room is eight feet by nine feet with a height of eight feet. For the brain, this can be easily interpreted because all of the dimensions are whole numbers. Eight feet is the standard height of a room and eight feet by nine feet can be visualized in the brain without much difficulty. However, when the facts get more complex, the brain cannot easily visualize or interpret them. When the brain is faced with decimals or a large amount of data, it can be very difficult to envision a room with those parameters. A room that has seven walls with each wall being a different

size will present the brain with a complicated scenario and one that would be interpreted differently from brain to brain.

This is one of the great aspects of 3D recreation because it allows judges, jury's, the media and everyone else to view the crime scene as it was when it first happened. However, the justice system is not always moving at a fast pace, and it could take months until someone is tried in court. During that time, the crime scene can change or disappear completely. If the scene is mapped out in 3D, then that recreation will never change and will only provide the facts that were presented the day of the crime.

With certain crime scenes, lighting is a critical component in solving the case. For example, if a person is standing 30 feet away from a crime, is it possible with only one light source coming from a streetlamp to witness the crime that took place? This question can be answered with the help of 3D graphics and lighting. If this crime scene is modeled in 3D, the lighting can be changed instantly to different settings in order to determine at what lighting the person would or would not be able to witness the crime.

If a car is traveling at a certain speed, and the result of the crash does not quite fit the crime scene, then when this scene is modeled, the speed of the car can be changed to try and best fit the crash scene. In a 3D environment, variables can be changed immediately which will result in a different outputted scenario [9, 66].

NaturalMotion's Endorphin takes advantage of this by allowing the user to change the variables in real time and view a different reaction each time.

In addition, 3D graphics are an improvement from the old techniques of physical prototypes. When physical prototypes were made, they were very costly and time-consuming to build and test. These prototypes were also a one-time use, because if they were destroyed in the testing then they would have to be rebuilt all over again [12, 200]. By using 3D graphics, a model can be destroyed and manipulated without any worry of losing the original model. This allows for much testing and editing in a short period of time and also allows for multiple edits to occur at once if more than one person is working on the same model on two or more computers.

5.2 Disadvantages

As mentioned, one of the most difficult tasks in recreating a crime scene is being able to predict the unpredictable. A scenario that depicts a man falling off a balcony and through a glass table can be simulated using tools such as NaturalMotion's Endorphin and 3D Studio Max. However, if the man falls off the balcony, and somehow his shoelace is caught on the top of the balcony and he falls awkwardly headfirst and lands in an awkward position, it would be very hard to recreate the exact way his shoelace got caught. It may also lead to the conclusion that he might have fallen a different way and the conclusion might be completely incorrect. Other scenarios that are hard to simulate are slippery or

wet textures that will affect a car sliding or a person falling down freshly waxed stairs. A push down a flight of stairs may look the same as one slipping down the stairs. In order to avoid this, a great amount of detail has to be taken in measuring all parameters of the scene and various ways it could be recreated.

A new trend that is being discovered in the United States is that people are taking advantage of 3D graphics and skewing data to fit their case. It is the circumstances that 'he, who pays for the 3d recreation, has it developed with his data'. This common trend in the United States is occurring for crimes such as car crashes, building structures, and even larger crimes such as breaking and entering. What is happening is that Person A is paying Company X a certain amount of money to prove that Person B is at fault. While using 3D graphics is a great way to recreate a car crash scene, if the data is not 100% accurate, it can lead to a very one sided court case. Since Person A is providing Company X with the money, Company X will use the data from Person A and this information can be biased in order to fit the case for Person A [5]. This trend however, is not being found in Canada and that is due to a third party with no bias creating the 3D graphics. This is obvious with the OPP creating crime scenes with their own data and not the data of a victim.

The cost of a complete scene, including software and person-hours can become astronomical. Although, the software is relatively inexpensive (depending on your budget) and the time put into creating a 3D scene can be short (depending on

detail of scene) it can still add up to an extreme cost. This is because oftentimes, many hours are put into a 3D recreation and if the defendant pleads guilty before all of this data goes to court, then the 3D recreated will never be seen or used. When detail is crucial, the hours spent in creating an accurate 3D representation of a crime scene can be enormous [8]. If at the 200 or 300 hour mark, a strand of hair is found at the crime scene and it now becomes an closed case, all of those hours are somewhat wasted.

Chapter VI

Developed Mini Cases

In this chapter, all the mini-cases that were developed for this thesis will be discussed. The chapter is separated into three sections; Purpose, Technology, and Results. The first section will describe the roles of each mini-case towards the purpose of this thesis. The second section discusses the technology used while developing the mini-cases. Finally, the last section discusses the accomplishments and successes of the mini-cases as an involvement with the thesis.

6.1 Purpose

Each mini-case fulfilled its own purpose towards the thesis by each analyzing a different aspect of 3D crime. The tools used are the same tools that are used today by police officers, forensic scientists and certain companies who are being paid to model a crime. The tools are used to show how 3D graphics can be utilized to compare two different products, for example, in a case of copyright and design patent infringement. They can also be applied to modeling with realism and at the same time accuracy. Finally, the tools can be used to show how a scene can be completed without knowing what exactly happened.

6.2 Technology

The technology used for the developed mini-cases were Autodesk 3D Studio Max, NaturalMotion's Endorphin, and a standard digital camera. A few 2D tools were used for the immersive imaging technique and two of those being Photoshop and ADGPano Tools. Autodesk 3DSM was used to achieve a semi-realistic scene with total accuracy to the millimetre. All measurements were done with a standard tape measure and recorded on paper with a pencil. This created a blueprint that was then transformed into 3D manually. NaturalMotion's Endorphin was used to obtain a realistic fall from a balcony with the ability to change the ending position of the man, which would therefore change the fall. The file was outputted to an .avi file but could easily be changed within the program and tweaked to different results, and outputted again. ADGPano Tools automatically took a set of pictures and stitched them together to create a 360-degree image. Photoshop was used to create a second 360-degree image that was made manually with a tedious cut, paste and transform method. It is possible to use 2D editing tools other than Photoshop, such as Corel Paint, or MS Paint, however Photoshop is the market standard.

6.3 Results

Currently, the mini-cases only show a handful of tools that are on the market today and show only a limited amount of techniques. However, the mini-cases were created to show the most common tools and techniques being used today. With these tools and techniques, enough was shown to prove that 3D graphics

are a viable asset to crime solving and recreation. Other tools could have been used but due to the high cost of the applications and the lack of demos available, it was not possible.

Chapter VII

Conclusion

7.1 Conclusion

This thesis, through discussing the various ways 3D graphics can be intertwined with solving crimes and better representing crime scenes, has explained why it is crucial to involve 3D graphics in the involvement of forensics and crime. This establishment is the groundwork for several advantages and disadvantages that were discussed. Mini-Cases were developed to demonstrate some of the tools being used in today's world, as well as some of the techniques being used to create different crime scenes for various scenarios.

3D graphics were found to have the following advantages: 1) improved visualization of the crime, 2) the dynamic ability to change a scene in real time to suit the needs of newer or more accurate data, 3) the ability to fill in the gaps and the missing pieces of a crime scene by knowing the start and end of the crime, 4) reduced time on creating physical models that usually have a one-time use, 5) reduced time measuring all details by using a tool such as Total Station or one of its competitors, 6) preservation of data and objects when involving a scene that may be destroyed for various reasons. However, 3D graphics were found to have the following disadvantages: 1) the high cost that may result in spending hours creating a detailed scene and the scene may never be used if a guilty plead if declared, 2) the skewing of data by biased companies or people due to clients

paying companies to see their results, 3) the impossibility of predicting the unpredictable with the randomness of human actions such as falls, slips and irregular actions.

It was also discovered that not all crime scenes will benefit from using 3D graphics. Currently, there are still some limitations on what 3D graphics can do, and these limitations translate into certain crime scenes not benefiting from the use of 3D graphics. Such crime scenes would be ones involving the breakdown of materials and the chemical reactions of objects.

Regardless of the few disadvantages and faults that coincide with using 3D graphics, it is still worth using 3D graphics over 2D graphics due to the vast improvements 3D has as well as the many other advantages previously discussed.

7.2 Further Work

The study of 3D graphics and how it can be utilized with crime can be continually discussed and further researched. Tools such as NaturalMotion's Endorphin can be researched more intensely to find out why it is currently not being used for more crimes. It is possible with deeper research, that Endorphin may not be suited for recreating crime scenes.

The developed mini-cases can provide a stepping stone for future research into Endorphin, as well as immersive imaging and the use of 3D applications. With further research, immersive imaging may be found to have other uses in crime scene investigations. Engineers may be interested in researching further into developing tools to deal with materials, their weight and their chemical make up.

Appendix A

Appendix A is part of the mini-case development for the project portion of the thesis. It will go into further detail and description to explain how 3D graphics are beneficial to the courts and to forensic scientists. Appendix A uses 3D Studio Max by Autodesk and compares two similar yet different products. The basis of this mini-case is to demonstrate how turning evidence into 3D makes viewing the similarities and differences much easier.

Product A vs. Product B

Company A, called U Save Big (USB), developed a 4 GB USB key in 2001 priced at $149.99. It was released to the public in March of that same year. At the time, it was the best selling USB key with hardly any competition. It stayed that way until November 2001 where Company B, named All Thumbs, released its own USB key (which they coined "thumb" drive). It too was 4 GB in size, but it was only $129.99. Since All Thumbs did not have any customer support or history, they needed to do something big to get the consumers attention. A price drop of $20 dollars did not seem significant enough considering U Save Big had been holding the market share and customers knew and trusted their name and product.

All Thumbs decided that if their product was similar in size, shape and look, that possible Christmas shoppers would see both U Save Big and All Thumbs

products and choose All Thumbs thinking that it is the same but cheaper. This strategy seemed successful because in January of 2002, U Save Big took All Thumbs to court. They sued them on the basis that their product was too similar and that all of their sales were due to the fact that customers were confused and made the "wrong" decision.

U Save Big claimed in more detail that their product was known by its customers for its unique design. It was rounded in shape with extruded edges going down the body of the key. For easier use, it was bevelled down in the middle to provide a place to put your thumb.

All Thumbs fought back claiming that there may be a slight similarity between the two products but that there was enough of a difference to distinguish between each product. All Thumbs claimed that the ridges on the sides were different, and the length, width and height were all different. A chart was put together to show the differences between each of the products. With the dimensions of the products being exact, the numbers involve decimal places that create an even more difficult time to visualize what you are viewing. See Chart 1.

Specs	Product A	Product B
Overall		
Length	8 cm	8.5 cm
Width	2.39	2.4 cm
Height	1.227 cm	1.335 cm
Weight	35 grams	36 grams
Body		
Length	4 cm	4 cm
Cap		
Length	4 cm	4.5 cm
Look	3 ridges per side	4 ridges per side
Memory	4 GB	4 GB
Price	149.99	129.99

Chart 1

You Save Big however, created a 3D representation of the products to give the judge and jury a better understanding of how similar the products are. They produced different images that showed side by side in open and closed positions how the two products compared. They also produced a few images of what the two products would look like beside each other in a store scenario.

The 3D rendered images can be view on the CD under Appendix A.

The outcome of the case is completely up to the judge or jury and this mini-case does not give an outcome of the fictional trial. It instead gives an understanding of how 3D graphics can be used in a simple case.

Appendix B

Appendix B is part of the mini-case development for the project portion of the thesis. It will compare a standard photograph of a "crime scene" to a 3D rendered recreation of the same "crime scene". The basis of this mini-case is to demonstrate how 3D recreation can be accurate and more dynamic than a regular photograph. The tools that are used for this Appendix are 3D Studio Max by Autodesk and a 6.0 mega pixel Canon Power Shot SD100.

Photography vs. 3D Recreation

In the early days of crime solving, photography was used to capture the scene and to bring the scene to others so they could have a better awareness and insight on the case itself. These photographs were enlarged in front of the courtroom in order to show everyone the crime scene. However, when you enlarge a photograph, it loses detail along with much of its quality. With 3D recreations of a photograph, the scene can be scaled to any size without the loss of detail or quality.

The photos taken were at a work place in the backroom. The photograph captured many different angles of the room and with these images, an immersive image was created. This 360-degree image gives an insight on the room itself but is not very dynamic due to its limited options. While these photographs will

give the idea of what the backroom looks like, it will not give you in the interactivity as a 3D recreation would.

The 3D and 2D files can be found on the CD under Appendix B. There is a movie clip in avi format that shows the 3D scan of the room as well as a 2D immersive image that shows the photography scan of the room.

Appendix C

Appendix C is part of the mini-case development for the project portion of the thesis. It will show a room that has been recreated using the technique of immersive imaging by using a digital camera and stitching-assist software. The tools that are used for this Appendix are a 6.0 mega pixel Canon Power Shot SD100 and ADGPano Tools and Photoshop.

Immersive Imaging

Immersive imaging can prove the vision that one could have from a certain point in a room. Since immersive imaging produces a 360-degree viewing from a single point, that point can be used as a person's vision.

The 2D files can be found on the CD under Appendix B. The .gif animations showing a classroom can be used to identify the actual viewing of a person sitting in that particular seat. For instance, if the door was open in the room, it would be possible to determine from that seat, how much can be seen outside the room. If there was a crime that happened and the witness claimed that they were sitting without a line of sight from outside, this technique could be used to determine the truth.

With technology today, there are newer techniques to achieve this, such as creating a 3D recreation of the room and being able to determine exactly what

can be seen from each chair in the classroom. This is more efficient because with immersive imaging, new photos must be taken for each seat in the classroom.

The stitching done in the mini-case was completed with two different tools, ADGPano Tools and Photoshop. ADGPano Tools is an automatic stitching software that accepts photos as input and matches them together along the edges to create 360-degree photo. The same technique can be done manually using image editing tools such as Adobe Photoshop. A tedious cut, paste and transform are applied to all images in order to have all photos stitched together. However when using Photoshop, different tools such as blend and blur can be applied to make the 360-degree photo look seamless.

To compare and contrast, please see both .gif files (must be opened in Internet Explorer to see animation), on the CD under Appendix C.

Appendix D

Appendix D is part of the mini-case development for the project portion of the thesis. It will demonstrate one of the latest tools available on the market. NaturalMotion's Endorphin is simulation tool that allows for self-animation and will demonstrate how the self-animation works. The tools used for this mini-case are a standard PC and NaturalMotion's Endorphin software.

NaturalMotion's Endorphin

NaturalMotion's Endorphin is currently being used for videogames and movies. Its self-animating characters make it easier for artists to create a realistic scene with realistic physics. It is currently not used for anything related to crime, but it has the potential to make a big impact on how crimes are solved.

It accurately takes data and transforms it into a scene with accurate physics. It can handle many situations including car crashes, pushes and throws, and falls from any height. Another advantage of Endorphin is that it creates all of this in real time and can be changed in real time to output different scenarios. It is currently able to import models from other 3D applications, but future versions of Endorphin will have a built in modeller as well as possibly a feature that will enable the user to texture models.

The animations that were created can be found on the CD under Appendix D. The animations were created with the Endorphin software and shows how a person could fall off a balcony and the result of a car crash scene. The only thing required to create the scenes were the beginning and ending position; the rest was self-animated.

References

(1) Autodesk. 3D Studio Max. 2007. http://usa.autodesk.com/adsk/servlet/index?id=5659302&siteID=123112

(2) Autodesk. AutoCAD. 2007. http://usa.autodesk.com/adsk/servlet/index?siteID=123112&id=2704278

(3) Cad Zone. The Crime Zone – Law Enforcement. 2007. http://www.cadzone.com/

(4) Curt Franklin. How 3-D Graphics Work. July 15, 2000. http://computer.howstuffworks.com/3dgraphics.htm

(5) Hawke, Darryl. Telephone Interview. November 2006.

(6) DeltaSphere. DeltaSphere 3000 – Capturing the Real World in 3D and Color. http://www.deltasphere.com/DeltaSphere-3000.htm

(7) Donald Hearn, M. Pauline Baker. Computer Graphics. Prentice Hall, Englewood Cliffs, New Jersey.

(8) Francis, Paul. "At the Scene of the Crime". Point Of Beginning September 3 2006.

(9) Galves, Fred. " Where the Not-So-Wild Things Are: Computers in the Courtroom, the Federal Rules of Evidence, and the Need For Institutional Reform and more Judicial Acceptance". Harvard Journal of Law and Technology Volume 13 (2000).

(10) Greek, Cecil. VISUAL CRIMINOLOGY: Using Photography as an Ethnographic Research Method in Criminal Justice Settings. March 5, 2005.

(11) iWitness. iWitness – Close Range Photogrammetry. 2007. http://www.iwitnessphoto.com/

(12) MacKrell, John and Bertram Herzog. Computer Graphics Companion. Nature Publishing Group: Buffalo, New York, 2002.

(13) NaturalMotion. Endorphin. 2006. http://www.naturalmotion.com/endorphin.htm

(14) Piquepaille, Roland. "Watching Crime Scenes in 3D". Technology Trends. March 11, 2005.

(15) Spraggs, David. "The Next Dimension". POLICE Magazine: November 2004.

(16) Staggs, Steven. Crime Scene and Evidence Photographer's Guide. Staggs Publishing: 1997.

(17) Stephen M. Ervin and Hope H. Hasbrouck. Professional Architecture. McGraw-Hill: 2001.

(18) Total Station. Total Station Guide. 2007. http://totalstation.org/

(19) Watt, Alan. 3D Computers Graphics (3rd Edition). Addison Wesley: 2000.