

# **Chapter 00**

## **Introduction to Crime Scene Reconstruction using Real-Time Interactive 3D Technology**

**by**

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This introduction to crime scene reconstruction using real-time interactive 3D technology explains how real-time interactive 3D technology is used to recreate crime scenes and illustrates the differences between rendered 3D video and real-time 3D.

The 21<sup>st</sup> century society is dominated by technology with forensic science and law enforcement relying on this technology to help discover the truth. Some growth areas are interactive media and the visual arts. The saying that a picture is worth a thousand words has never been truer. Twenty-four hour news events are absorbed faster than ever. The world is viewed through electronic eyes of television, the Internet, and the movies. The visual image is comparable with the real, replacing the real with the virtual.

The following information provides an introduction to 3D modeling and animation which will help to set the stage for future advancements in forensic science. A description on current display technologies, methods of 3D delivery and related applications to crime scene reconstruction will also be discussed. An introduction to 3D crime scene reconstruction methods will be presented. New technologies such as VR2Go™ and KidsVR™ will show how new virtual reality technology is changing how reality is viewed.

## **00.02 Introduction to 3D Modeling and Animation**

### **[a] 3D Coordinates**

A standard computer monitor is an example of a two dimensional screen that is represented by an X-axis (left and right) and a Y-axis (top and bottom). All images in a two dimensional view are represented by the X and Y coordinates only. A three dimensional image is represented by the X-axis (left and right), Y-axis (top and bottom) and the Z-axis (in and out). The Z-axis is the third coordinate that makes an image three-dimensional. Standard two-dimensional interfaces allow movement left and right (X-axis) and up and down (Y-axis). Three-dimensional interfaces allow movement forward into the screen and backwards out of the screen. (Fig. 00-1)

### **[b] 3D Rendering**

Making a three-dimensional image into something that can be displayed on a computer monitor is called rendering. The rendered output is generated from a camera view. This is very similar to a real camera taking a picture. The developed image is the image that is viewed through the lens. This rendering can produce a single image or multiple images. Each object in the three-dimensional image is known as a model. A model is a three-dimensional representation of a solid object and is created in a 3D modeling program. These programs help 3D modelers and animators create three-dimensional models of any object like buildings, streets and people. Each model is created with a series of triangles. A triangle is also known as a polygon. A complex object may have thousands of polygons or a simple object like a box can have as little as 12 polygons. Breaking a box into its component sides shows that a box has 6 sides with 2 polygons or triangles per side totaling 12 polygons. Viewing these triangles directly without any surfaces or textures covering the triangles is called a wireframe. A surface that covers the triangles or polygons is called a map or image map. This image map can be an image or a photograph. (Fig 00-2) Any object can be modeled to create a geometrically accurate representation. The quality of these models depends on the number of polygons (smoother edges) and resolution of the image maps or textures. These models are individual elements that make up a three-dimensional scene. A scene can contain hundreds of models and thousands of polygons. Any scene can be created in this way. (Fig. 00-3A, 3B)

### **[c] 3D Animation**

All 3D is viewed from a virtual camera that has similar attributes to a real world camera. Everything seen on the screen is presented from the camera. When making a movie of a walking down the sidewalk of a city the camera moves down the sidewalk along a predetermined path. The camera view is what is viewed. An animation is a sequence of moving objects. The simplest scene is a single image of a model viewed from a single stationary camera, like a frog sitting on a tabletop. Even though the frog is a three-dimensional model it is represented as a 2D image. (Fig. 00-4A) If the camera is stationary and the frog is moving and the frog hops from the left side of the tabletop to the center then to the right side then the output would be a series of images of the frog's movement. This series of five images makes up the animation of the moving frog. This is still a 2D animation even though the frog is a 3D representation and because the movement is in two dimensions (X & Y). (Fig. 00-4B) Using only X and Y coordinates produces a two-dimensional scene. To create a three-dimensional scene the Z-axis must be added. Moving along the Z-axis creates motion forward and backward through a three-dimensional scene. An example is walking down a city street. When moving forward, objects in front become larger and objects on the sides pass by. (Fig. 00-5A, 5B)

### **00.03 Current 3D Display Technologies, Methods of 3D Delivery and Related Applications**

#### **[a] 3D Viewing (HMD, CAVE, Anaglyph Glasses)**

Viewing 3D can be accomplished using a standard CRT or LCD monitor. The illusion of depth is achieved by using image perspectives. Objects that are further away look smaller than closer objects. Television and movie theaters use this technique with great success. A technique of stereoscopy is used to create the illusion of depth. To confuse the issue this is sometimes called 3D. When someone says they saw a 3D movie they meant they saw a stereoscopic movie. There are many techniques of producing stereoscopic images. One of the first devices to view stereo images was the ViewMaster® viewer. This device uses a round disk of images that contains stereo image pairs. An image pair contains a left eye image and a right eye image. One of the most popular and simplest methods for viewing stereo images is anaglyph glasses. These are the glasses that have a red and blue lens to separate the left and right images for each eye. (Fig. 00-6) Other viewing methods move into the area of virtual reality. Virtual reality is an area of study that immersion is used to achieve a more realistic visual experience. A head mounted display is a virtual reality device that incorporates two small LCD displays that are placed directly in front of the eyes. Using optics the small displays fill the entire field of view. It is like looking into the real world. These stereoscopic head mounted displays (HMD) create a true illusion of depth. Another virtual reality device is a CAVE™ environment. (Fig. 00-8A, 8B) This is a projection room where all the walls, floor and ceiling are visual projections. When in this room the computer generated visualization produces a visual reality similar to being there. An augmented reality viewer is mounted on a swivel base and can be easily rotated to view the entire crime scene. Looking through the viewer a 3D representation of the crime scene would be displayed in exact detail. The crime scene can now be modified or augmented with computer software. (Fig. 00-7)

#### **[b] 3D Methods (3D rendered video and real-time 3D)**

Today there are two different methods of producing three-dimensional content, rendered 3D video and real-time 3D. The first is used to create still images, movie effects and movies. Animated movies are very popular. The Pixar® movies are a great example of a rendered 3D movie. These movies are created using 3D graphics. As in all 3D movies a series of images are used to create the movie. Most video runs at 30 frames per second (FPS) that means that a new image appears every 1/30 of a second. To create a high quality high definition 3D image requires a large amount of processing power. Movie studios use render farms to create these images. A render farm is bank of computers used to render 3D images into movies. Even with a render farm it requires a large amount of time to render each image. Most 3D animations used for law enforcement are created on a single computer that could take hours to render 1 minute of animated video. The 3D generated movies are used with great success and help to win cases today. Real-time 3D is what drives the video game industry. The U.S. Army uses 3D gaming technology for recruitment and training. This real-time 3D technology renders a single frame in less than 1/30 of a second as compared to minutes and hours for rendered 3D video. In a video game the image renders as the viewer moves. This requires high performance graphics acceleration. Due to the popularity of video games 3D graphics performance has been continuing to improve at an accelerated rate. The main difference between 3D rendered video and real-time 3D is that 3D rendered video requires a 3D modeler or animator to create a new view or animation. For example, if an attorney wanted to view the crime scene from a vehicle traveling from the west and the original video had a vehicle traveling from the north then the animator would have to create a new video based on the new parameters. Each time a new perspective or view is required additional time and money would be required to create the new video. Real-time 3D renders the scene as the camera or viewer moves through the scene. After the 3D model is created and the evidence placed in the scene the user interface can be designed to enable the user to easily move to any location in the scene with only the touch of a button. There would be no need to spend time and money having a new video produced. There would be two options of moving around in the scene, one would be to use the arrow keys to walk through the scene or two, the walk through the scene could be recorded and played back at the users

discretion. Real-time 3D technology is important in law enforcement, medicine, history, education, entertainment, marketing and the Internet. 3D Video games and interactive media have influenced a new generation of jurors, legal professionals, educators and law enforcement.

### **[c] 3D Web Development (Reality Studio)**

Today real-time 3D technology is providing a new Web experience for millions. Breaking the boundaries of two- dimensions has improved the scope of possibilities for the Internet. Using 3D on the Web is as easy as launching the browser. Several established Internet technologies are available for 3D Web applications such as Adobe Acrobat, Shockwave, Flash, VRML and X3D. (Fig. 00-9A, 9B) These Web-based technologies continue to expand the range of applications available on the Internet. Now the Internet is an invaluable part of all institutions. Without email these institutions could not operate. New Internet technologies enable researchers, investigators, and scientists to collaborate in real-time in shared environments similar to the massively multiplayer games.

### **[d] 3D Philosophy**

Crimes are committed in the three-dimensional world even though the media is dominated by a two-dimensional reality. As a result of the gaming and movie industries the flat two-dimensional world is transcending into a three-dimensional reality. Learning and interacting in three-dimensional environments are similar to the real world with three-dimensional simulations helping to illuminate it. The future is today.

### **[e] 3D Accident Scene Reconstruction (law3D)**

Reconstructing accident scenes in three-dimensions promotes a better understanding of the events surrounding automobile accidents. New software tools enable real-time accident scene reconstruction in the courtroom. Now a witness can draw the paths of automobiles they witnessed as the jury sees the accident through the eyes of the witness. Courtroom and investigative tools that use real-time 3D technology provide a more accurate analysis of accidents and help to reduce them in the future. (Fig. 00-10A, 10B) In the courtroom the jury uses a projection screen for viewing. When the witness is called they would use an LCD graphics tablet to draw the paths of the vehicles they witnessed. The graphics tablet and the projection would show the accident scene from above. After the paths of the vehicles are drawn a 3D animation of the accident would be displayed. Upon cross-examination the witness would indicate the animation shown is what they witnessed. The jury would have seen the accident through the eyes of the witness. Attorneys could also use this real-time tool to elaborate on the accident.

### **[f] 3D Medical Applications (Virtual Schizophrenia)**

The use of real-time 3D and virtual reality technology in medical applications has long been a valuable means of providing educational, diagnostic and research to educators and physicians worldwide. 3D technology and virtual reality can help to educate law enforcement, legal professionals and juries on the plight of the persons with mental illness. Virtual reality software has been developed to educate law enforcement, family members, physicians, and juries on what it is like to be a schizophrenic. This software uses virtual reality simulation technology to view schizophrenia through the eyes of a schizophrenic. The Doctor's office simulation is an animated scenario that places the viewer with a doctor trying to listen to what the doctor is saying with auditory and visual hallucinations interfering with their complementation. (Fig. 00-11A) The Pharmacy simulation is a photo-realistic scenario that places the viewer at the pharmacy trying to fill a prescription with auditory and visual hallucinations interfering with their complementation. (Fig. 00-11B) A police simulation was developed that involves a police officer observing a male subject at a "typical" street corner with vehicles driving by and some pedestrians. The subject is disheveled, gesticulating, talking to self and making threatening gestures at passerby vehicles. The scene transitions into

the subject's "head" where the subject observes the world from their vantage point. The psychotic phenomena are injected into the scene's auditory hallucinations (including command hallucinations) visual hallucinations (vehicle drivers' faces will be seen leering at the subject) paranoia (depicted by reacting to the officer's presence). The scene transitions out of the subject's head to the officer's head with an observational mental status examination performed by the officer. These types of three-dimensional simulations help to better understand patients and suspects with mental illness.

#### **00.04 Introduction to 3D Crime Scene Reconstruction Methods**

##### **[a] 3D Crime Scene Reconstruction (city, subway, library, bedroom)**

Reconstructing a crime scene in three dimensions is an extension of current crime scene investigative techniques. Viewing crime scenes in three dimensions is a crucial part of investigations and education. The first step in reconstructing a crime scene is to develop an accurate 3D model of the crime scene. This is an extension of forensic photography. The crime scene photography is a vital asset in creating a 3D model of the crime scene. Also other data that the crime scene investigators collect including detailed measurements all aide in creating an accurate 3D crime scene model. A 3D model is an accurate mathematical representation of the actual crime scene. Sometimes building blueprints, surveying data or other site information are required to maintain the accuracy of the model. The forensic photographer will also be required to take pictures that will be used as image maps. These are images that will be applied to models to create a more realistic and accurate scene. Since the model of the scene is mathematically accurate then the perspective will be identical to the actual scene. When blood splatter images are used as models and textures and are placed in their exact locations, their trajectories can be accurately calculated. A geometrically accurate 3D model is identical in perspective to the real location. Investigating the crime in the 3D domain can be an effective means to better understand the details of the crime.

##### **[b] Acquire all the data the investigators have gathered.**

All photographs, measurements and pertinent evidence data will help to create an accurate 3D representation of the crime scene. The data acquired by the crime scene investigators would be given to the 3D crime scene reconstruction designer. The 3D crime scene reconstruction designer would use that data to create the crime scene model. Sometimes the 3D modeler or animator would go to the site to acquire additional information to aide in building the 3D model of the crime scene. Eventually the crime scene investigators would be educated to the needs of the 3D crime scene reconstruction team.

##### **[c] Determine the level of detail required.**

A highly detailed 3D model of the crime scene may not be necessary for all crimes. Sometimes a lower detail model is all that is needed. An example is a crime committed on a city street. Only the locations of the buildings and gray boxes to represent the building might be needed. Streets and sidewalks may also be low detail. (Fig. 00-12A, 12B) The accuracy of the model would still be maintained to aide in the investigation or training. Another example is a crime committed in a home, for instance in a bedroom. Sometimes a generic bed model can be used instead of the actual bed, especially if the crime was not committed on the bed. Also generic furniture can be substituted for the real furniture. These shortcuts reduce the time and cost of creating the 3D model and do not reduce the usefulness of the crime scene model. The development of a 3D model of the city of Pittsburgh was accomplished by reviewing the CAD files at the city planning office. The animator used this data to construct the entire city of Pittsburgh model with the accurate data provided by the city. Once all the buildings and streets were placed in the scene the animator took digital pictures of all the fronts of the building to use as image maps. This project illustrated the feasibility of creating an accurate city model. Most cities and building offices have information to help in reconstructing crime scenes.

**[d] Determine what additional data is required.**

Sometimes when building a 3D model of the crime scene the information the investigators need may not be provided. An example is if the crime was committed on a city street then only the location data of the streets and buildings are required to create an accurate representation of the scene. Getting the data from the city planning office or going to the site may be required if the data is not provided by the investigators. The same is true of the inside of a building. In most cases this data is available or purchased models and objects can be used. A crime committed on a city street near buildings on a sidewalk could use any building model in place of the actual building. As long as the scale of the models is correct the substitution would not effect the investigation of the crime. The same is true of other crime scenes. If objects don't have a direct bearing on the crime a substitution model can be used. This expedites the construction of the crime scene without compromising its integrity. 3D models are available from a wide variety of locations on the Internet. Models range in price from a few dollars to hundreds of colors.

**[e] Build a basic model of the crime scene.**

A basic model is the minimum required to reconstruct a crime scene. The outside facade of buildings and inside walls would be displayed with plain colors. Building a 3D model is very similar to building a real building or environment. Simple geometric shapes are created to represent elements within the scene. An example is a building on a street. If the building has a basic rectangular shape it is a simple matter to create a box and place photographs of the sides of the building to the outside surfaces of the box. (Fig. 00-2) Also interiors of the buildings are constructed in the same way. Interior walls are flat surfaces with photographs of the walls placed on their surfaces. The crime scene photographer would be responsible for photographing surfaces that would be used as image maps. Determining the resolution of the 3D crime scene model depends on each individual case. If only the general view of the crime is required and/or the budget dictates a low-resolution 3D model then gray boxes can be used for objects in the scene. (Fig 00-12A, 12B) If it looks like the case can be won with the jury feeling like they are watching a video of the actual crime then a higher resolution model may be appropriate. These higher resolution models require additional development time and could increase the cost. (Fig. 00-13A, 13B)

**[f] The 3D environment versus reality**

The 3D model is an accurate geometric representation of reality and gives the illusion of a real space. This representation provides a means of investigating crime scenes without having to revisit the site. With the ability to visit the crime scene on the Internet the investigators can to visit the crime scene from anywhere in the world. These real-time 3D representations of crime scenes enables investigators the opportunity to view the crime scene from any prospective by just moving to new location just like walking. This technology also enables multiple investigators to investigate the crime scene at the same time. This is similar to the massively multiplayer games that are available online. Once a 3D crime scene is completed it will remain uncontaminated no matter how many people walk through it. Combining the attributes of a 3D reconstructed crime scene with the real crime scene provides an invaluable resource to understanding the crime. Any crime scene can be created using real-time 3D technology. If a crime was committed in a subway then a 3D subway crime scene could be created. (Fig. 00-14A, 14B)

**[g] The legal uses of real-time 3D crime scene reconstructions**

There are many uses for crime scenes created using real-time 3D technology. As discussed, 3D crime scene reconstructions help investigators analyze crime scenes. These 3D reconstructions also provide legal teams the ability to educate the jury on the circumstances surrounding the crime. Taking the jury to the crime scene is one of the most powerful methods to improve their understanding of the crime. It also helps in finding the truth. Once the 3D crime scene model is completed the evidence can be inserted into the scene as it becomes



available. The 3D model and the evidence in the crime scene could be used as a visual interface to access important crime scene data. This visual interface would tie into the crime database to help investigators retrieve information quickly and easily. An example is the DNA report. Using the mouse to click on the blood surrounding the body would bring up the DNA report on the victim or clicking on some strands of hair for it's DNA report. These hotspots would give investigators access to all information about the case. Since the 3D crime scene is online it can be easily accessed from anywhere anytime.

#### **[h] Real-time 3D crime scene reconstruction for education.**

Education is another area where real-time 3D crime scene reconstructions are useful and necessary. With the popularity of online learning and the advancements in Internet technology forensic science curriculums can now utilize real-time 3D reconstruction software. This new technology will help students investigate crime scenes online as part of their higher education. Student investigators can visit a crime scene as often as necessary to complete their studies. Students can investigate actual and instructor conceived crime scenes. Easy to use software is available to help educators create custom crime scene training. This software lets educators select the crime scene, the type of crime and the evidence. Once a crime scene and the type of crime are selected the educator can easily add or remove evidence using a simple drag-and-drop interface. The way the software works is as follows: First the URL must be entered into the browser to launch the software. After entering the username and password the software would prompt for the case number. A top down view of the 2D crime scene would appear in the edit window. Pressing a single button will switch to the 3D view. Walking around the crime scene would be as easy as pressing the arrow keys. This would give the illusion of being at the actual crime scene. Pressing the space bar would return to the edit window. The crime scene could be modified as new information became available. Saving the crime scene would enable others to view the updated crime scene. Student could view the 3D crime scene online anytime. Password protecting the scene editing would limit editing to authorized individuals. (Fig. 00-15A, 15B, 15C, 15D)

### **00.05 VR<sub>2</sub>Go™ A New Method for Virtual Reality Development**

#### **[a] VR<sub>2</sub>Go™ Introduction**

VR<sub>2</sub>Go™ is a new technology for developing virtual reality content that expands the virtual reality market by reducing the costs and enabling all creative developers including children to develop content. This new technology creates an environment for forensic research. (Fig. 00-8A, 8B, 00-15A, 15B)

Virtual Reality concepts date back to around 370 B.C. with the writing of Book VII of the Republic by Plato. In the "Allegory of the Cave" Plato described a CAVE™ environment in which he explores the ideas of perception, reality and illusion.

In 1950, science fiction author Ray Bradbury wrote "The Veldt" where he describes a CAVE™ environment.

In early 1963, Ivan Sutherland developed his legendary Sketchpad system. In 1965 he wrote "The Ultimate Display" that influenced a generation of scientists, computer artists, and media theorists. In 1966, he invented the head-mounted display

In 1992 the "CAVE" (Cave Automatic Virtual Environment) was presented at the Electronic Visualization Laboratory at the University of Illinois in Chicago, USA.

In 1999 PMS Microdesign, Inc. developed a virtual reality simulation of Schizophrenia that was showcased on ABC News 20/20 and the New York Times. This simulation software proved virtual reality development need not be expensive.

Today PMS Microdesign, Inc. has developed a new technology for reducing the cost of virtual reality development

## **[b] VR2Go™ Exposition**

VR<sub>2</sub>Go™ is a new technology for developing virtual reality content that expands the market by reducing the costs and complexity of virtual reality development. The VR<sub>2</sub>Go™ application requires a 3D scene to be created in a 3D application such as Maya®, Lightwave®, 3D Studio Max®, KidsVR® or other 3D applications. A 3D artist creates a scene that contains all the 3D elements (models, cameras, lights, surfaces, key-frame animations, etc.) and interactive control information. The scene is exported in the VR<sub>2</sub>Go™ format.

The VR<sub>2</sub>Go™ formatted scene is copied to each of the computers. For a V-CAVE configuration, three computers are used, one master and two slaves. VR<sub>2</sub>Go™ applications are required for virtual reality scene playback, the master and slave. The master VR<sub>2</sub>Go™ application controls the cluster of slave computers through a high speed Ethernet network (10 megabit, 100 megabit, or 1 gigabit). In addition to CAVE communications, the master is responsible for all audio, input devices and user interface tasks. The slave VR<sub>2</sub>Go™ applications control each screen.

High-speed communications are an important component of any CAVE™ environment. A peer-to-peer communications network using the TCP/IP protocol was developed. Once the Master has booted, it shares its IP address with all the slaves using simple file sharing. The slaves can now connect to the host. After knowing the host's IP address, the slaves then connect directly to the host in a peer-to-peer configuration. A server application is also available allowing many CAVES™ to communicate with each other to create a shared environment. Other cluster communications formats are used including UDP, serial and file sharing.

Peripherals connect to the master computer. Currently joysticks, head trackers, ultrasonic rangefinders, floor sensors and cameras are used. A serial and USB communications engine was developed to easily add peripherals.

Three-dimensional sound is achieved by two means; 3D sound software (creates a spatial illusion with two speakers) and 3D sound hardware (creates a spatial illusion with eight speakers placed in the corners). All sound control occurs on the master.

Stereoscopic vision is accomplished by using a separate computer for each eye that improved performance and image quality. This is an extension to the unified concept of having only one 3D scene created for all the viewing systems. A special adapter is used for LCD and DLP projectors for use in 3D CAVES™. Several manufacturers produce VR glasses with separate inputs for each eye where an adapter is not needed. The same VR<sub>2</sub>Go™ scene is used for both eyes needing only an x-axis adjustment for high-resolution stereo.

## **[c] VR2Go™ References**

RANDELL PACKER AND KEN JORDAN, "Multimedia: from Wagner to virtual reality"

## **00.06 Conclusion**

The future is bright for crime scene reconstruction using real-time interactive 3D technology. In this new world of the Matrix human interaction is forever changed. The Internet is now a place where dreams and aspirations are shared, a world space in three dimensions.

## **00.07 Glossary**

**Acrobat®** – document viewing software from Adobe.

**Adobe®** – a company who makes image, video and multimedia software including Acrobat® and Photoshop®.

**Anaglyph** – a method of encoding a three-dimensional image in a single image by superimposing a pair of images.

**Animated** – images that are moving.

**Animation** – a series of images viewed to create the illusion of motion.

**Animator** – an individual who creates animations.

**Augmented Reality** – a field of study of mixing real world data with computer generated data.

**Browser** – software that is used view interactive documents on the Internet.

**Camera** – a viewing device used for displaying the rendered output of a three-dimensional environment.

**CAD** – Computer Aided Design

**CAVE™** - Cave Automatic Virtual Environment is a projection room that displays computer-generated graphics on the walls and the floor.

**Cluster** – A group of computers that work together through a computer network

**Coordinates** – location or points in a geometric space

**CRT** – Cathode Ray Tube

**Database** – accessible organized data

**Depth** – in regard to computer graphics is the distance toward the horizon.

**DLP** – Digital Light Processing, used in video projectors

**DNA** - Deoxyribonucleic acid, the building blocks of life

**Drag-and-Drop** – a user interface that utilizes a mouse to select a graphic object, drag it and drop in a new location.

**Email** – mail sent over the Internet.

**Ethernet** – computer local area network.

**Field-of-View** – FOV, the observable view

**Flash** – Web-based multimedia software from Adobe.

**Forensic Science** – the use of science for legal analysis.

**FPS** – Frames per Second, the image sequence rate.

**Frames per second** – FPS, the image sequence rate.

**Gigabit** - 1 gigabit =  $10^9$  = 1,000,000,000 bits

**Graphics Tablet** – an electronic drawing tablet with an imbedded LCD display.

**Head Mounted Display** – HMD, a wearable visual display that incorporates small LCD displays placed in front of the eyes.

**Head Tracker** – a device that outputs head movement angles (X,Y,Z).

**Host** – the leading computer is a server system.

**Hotspots** – links to external Web sites from within a browser.

**HMD** – Head Mounted Display, a wearable visual display that incorporates small LCD displays placed in front of the eyes.

**Image map** – an image used to cover the surface of a 3D model

**Immersion** – being absorbed into a computer generated reality.

**Internet** – a collection of interconnected computers

**Interface** – a connection between humans and machines

**IP** – Internet Protocol

**Joystick** – a device used for video game play

**Key-frame** – a frame in an animated sequence of frames

**KidsVR™** - software for children to create 3D and virtual reality content.

**LCD** – Liquid Crystal Display

**Lights** – illuminating areas within a 3D world

**Map** – an image used for the surface of models.

**Master** – the controlling computer in a system of multiple computers.

**Matrix** – multiple computer networks for simulation.

**Megabit** - 1 megabit =  $10^6$  = 1,000,000 bits

**Model** – a 3D representation of an object.

**Modeler** – an individual who builds 3D models.

**Network** – a group of computers connected over multiple communications links.

**Online** – connected to the Internet.

**Photo-realistic** – computer graphics that incorporate the realism of photography.

**Peer-to-Peer** – a direct connection between computers

**Perspective** – the way the world looks to the eye.

**Pixar®** - Pixar Animation Studios is an award-winning American computer-generated imagery (CGI) animation division of the Walt Disney Company based in Emeryville, California.

**Polygon** - a finite number of sequential line segments used to create a 3D model.

**Protocol** – a rule-based system of computer communications..

**Real** – based on reality.

**Real-time** – operating immediately.

**Rendering** – producing an image from a 3D model.

**Render Farm** – a group of networked computers for rendering 3D models.

**Resolution** – level of detail of an image.

**Scale** – the relative size of an object.

**Scene** – a group of 3D models organized into a coherent view.

**Schizophrenia** – a mental illness where auditory and visual hallucinations interfere with comprehension.

**Schizophrenic** – an individual with Schizophrenia.

**Server** – a computer system that serves data to external computers.

**Shockwave** – a technology for delivering multimedia through a Web browser.

**Simulation** – a creation that is similar to reality

**Slave** – A single computer that communicates independently to a master computer.

**Software** – a sequence of instructions that controls a computer.

**Spatial** – location of points in three-dimensional space

**Stereo** – related to two units

**Stereoscopic** – the illusion of depth.

**Stereoscopy** – creating the illusion of depth in an image.

**Surface** – an area over a 3D model.

**Texture** – An image placed over the surface of a 3D model.

**3D** – three dimensions of X, Y and Z

**TCP/IP** – Transmission Control Protocol (TCP) and the Internet Protocol (IP).

**Three-dimensional** – (3D), three dimensions of X, Y and Z

**Top-down** – viewing an image from above.

**Triangle** – three points used to create a polygon.

**2D** – two dimensions of X and Y.

**Two-dimensional** – (2D), two dimensions of X and Y.

**UDP** – User Datagram Protocol, high performance Internet communications without error checking

**Ultrasonic Rangers** – a sensor that sends an audio pulse and calculates the return pulse using the speed of sound. This calculation can determine the distance.

**URL** – Uniform Resource Locator, an IP address.

**USB** – Universal Serial Bus, a serial communications link connecting PCs to peripherals.

**V-CAVE** – a CAVE™ environment that uses two video projection screens configured in to a 90° V.

**Video Game** – computer generated interactive entertainment.

**Viewmaster®** - system for viewing stereo images was invented by William Gruber in Portland, Oregon.

**Virtual** – not being a physical entity.

**Virtual Reality** – a computer generated reality.

**Visualization** – the act of viewing images.

**VRML** – Virtual Reality Modeling Language, a Web-based programming language for creating interactive 3D.

**VR2Go™** - an easy to use 3D and virtual reality development tool

**VR** – Virtual Reality, a computer generated reality.

**Web** – a hypertext system for viewing documents on the World Wide Web

**Wireframe** – the underlying structure of a 3D model.

**X-Axis** – two points creating a horizontal line

**X3D** – an ISO standard for real-time 3D computer graphics

**Y-Axis** – two points creating a vertical line

**Z-Axis** – two points creating a line that goes into the screen,

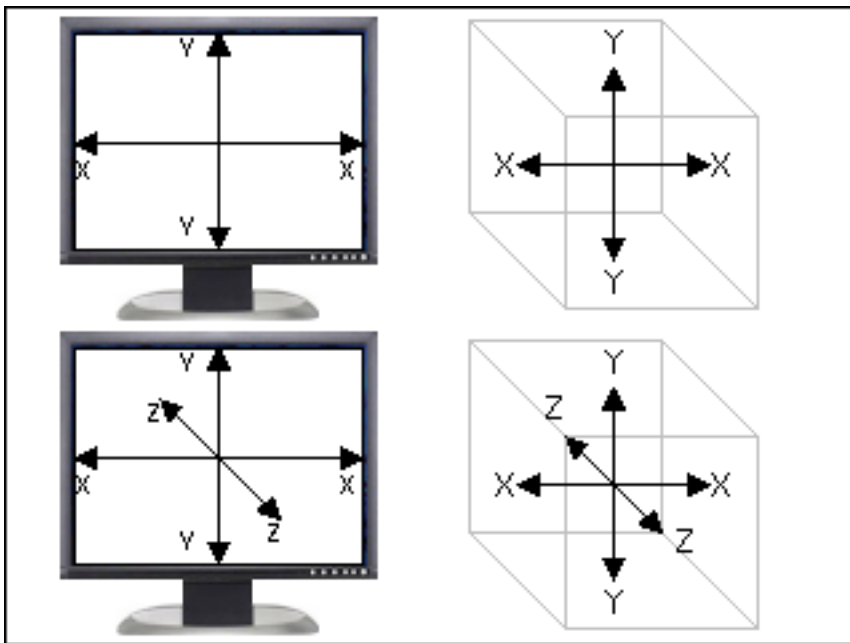


Fig. 00-1 Two-dimensional screen (X, Y),  
Three-dimensional screen adds Z (X, Y, Z)

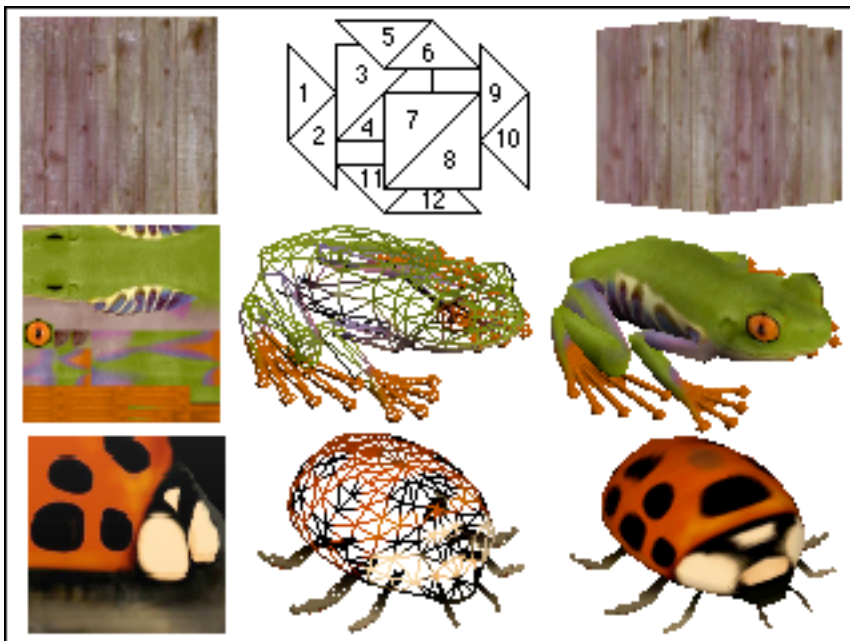


Fig 00-2 Image maps, wireframes and rendered models.



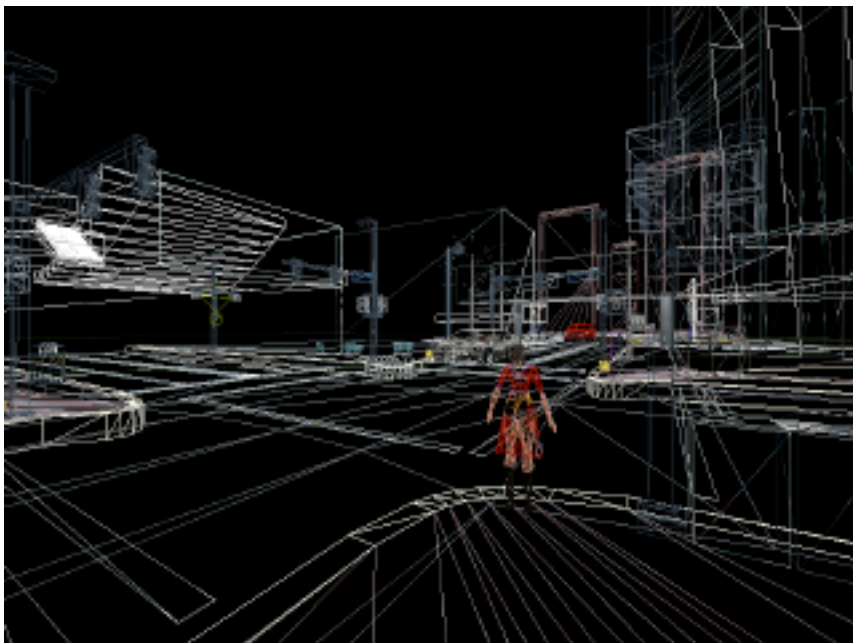


Fig 00-3A Wireframe of a three-dimensional city scene.



Fig 00-3B Rendered three-dimensional city scene.



Fig. 00-4A Stationary camera and stationary frog.



Fig. 00-4B Stationary camera and moving frog.



Fig. 00-5A      Stationary scene moving camera (far)



Fig. 00-5B      Stationary scene moving camera (close)

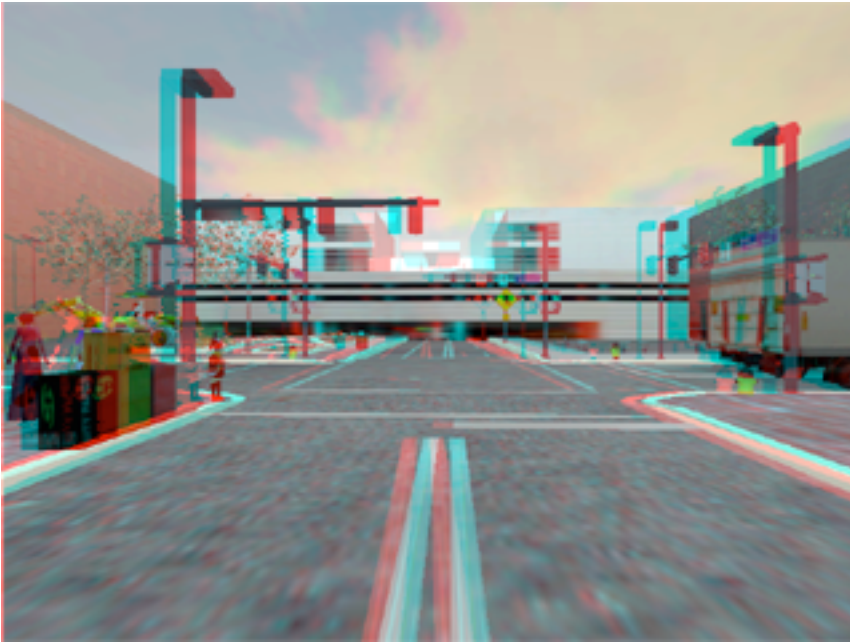


Fig. 00-6 Anaglyph stereo scene.



Fig. 00 -7 An augmented reality viewer, stereoscopic head mounted display, lightweight head mounted display and anaglyph glasses.

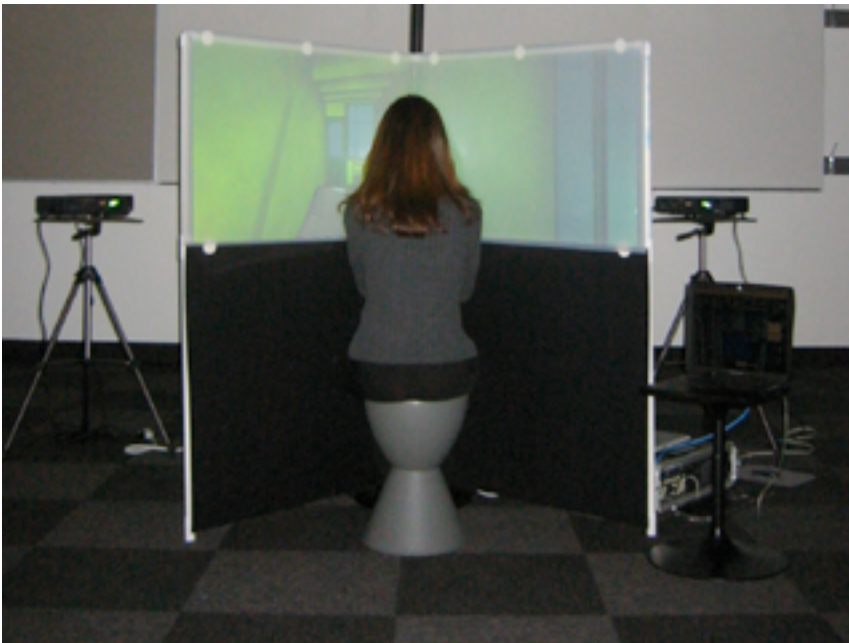


Fig. 00-8A V-CAVE environment.

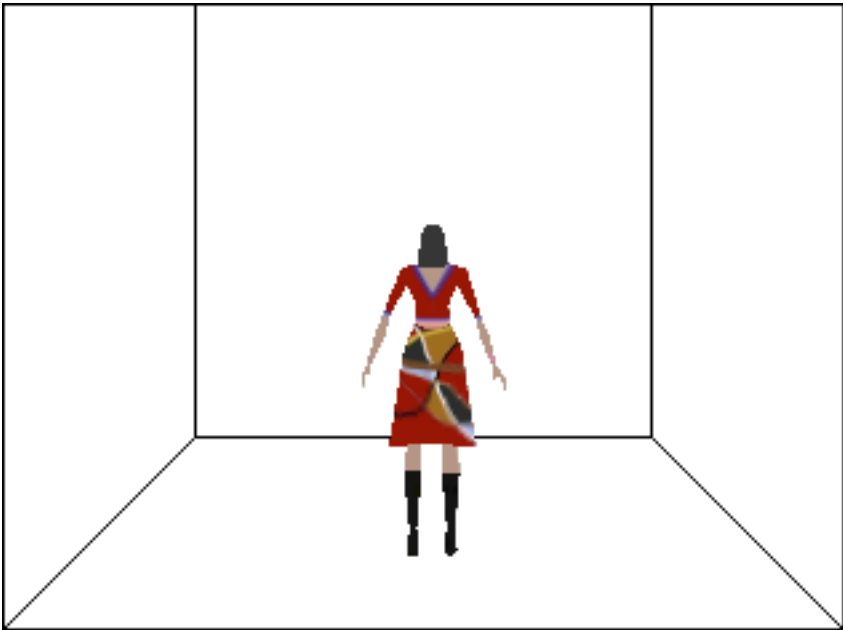


Fig. 00-8B Traditional CAVE environment (3 walls & floor)





Fig. 00-9A     Three-dimensional linked Web site. (virtual office)



Fig. 00-9B     Three-dimensional linked Web site. (virtual office)

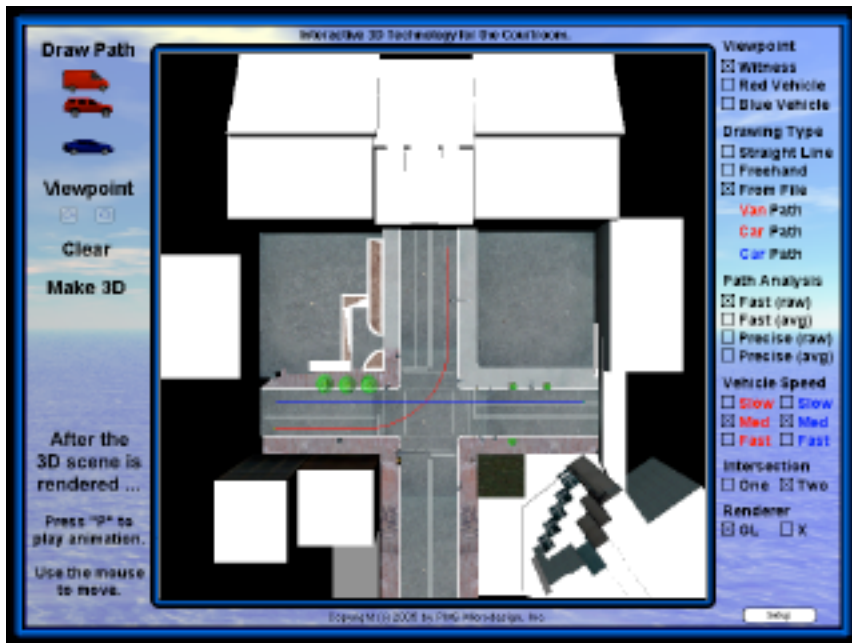


Fig. 00-10A Accident scene reconstruction edit window.



Fig. 00-10B Real time rendered 3D accident animation.



Fig. 00-11A Virtual reality simulation of Schizophrenia. (Doctors Office)



Fig. 00-11B Virtual reality simulation of Schizophrenia. (Pharmacy)



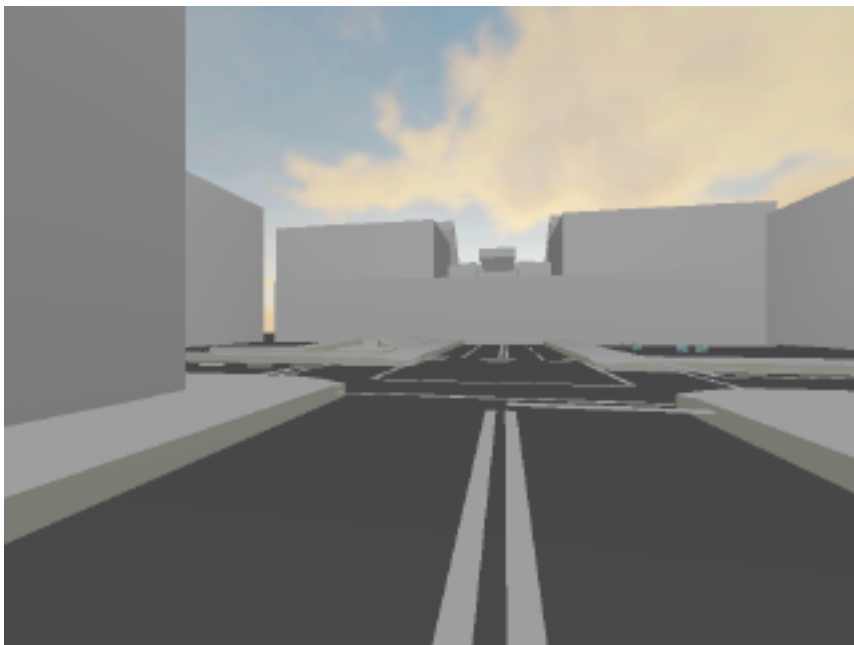


Fig. 00-12A Low detail rendering of crime scene



Fig. 00-12B Low detail rendering of crime scene

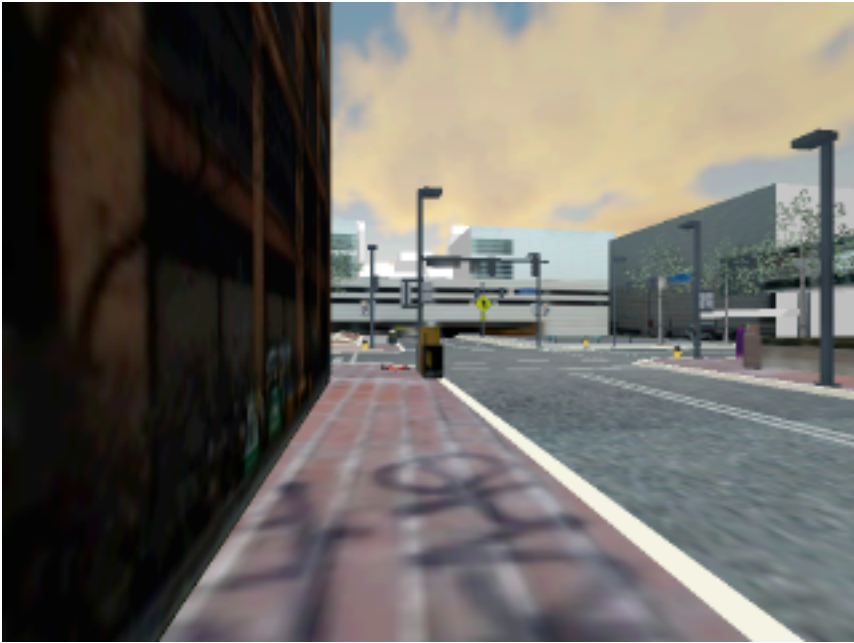


Fig. 00-13A High detail rendering of crime scene. (far)



Fig. 00-13B High detail rendering of crime scene. (close)

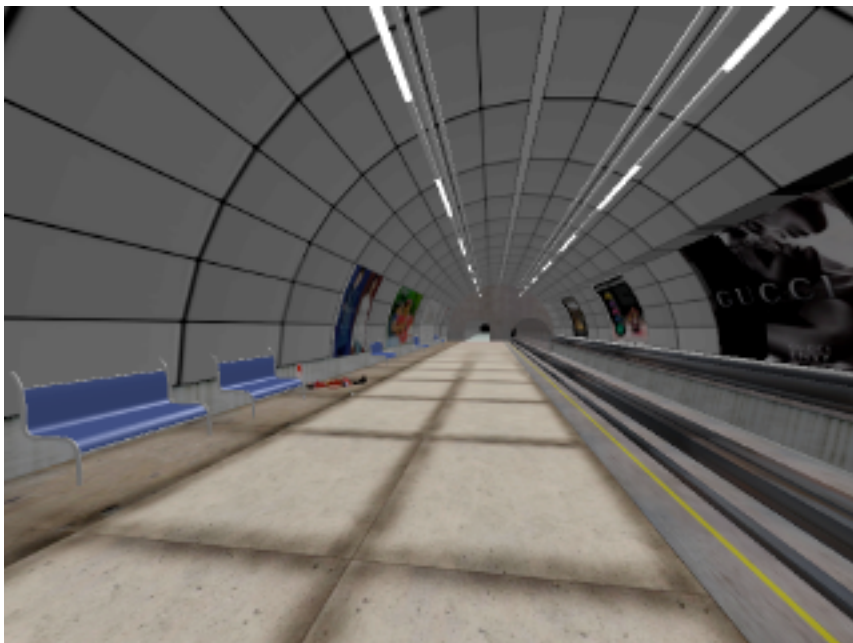


Fig. 00-14A Rendered subway crime scene (far)

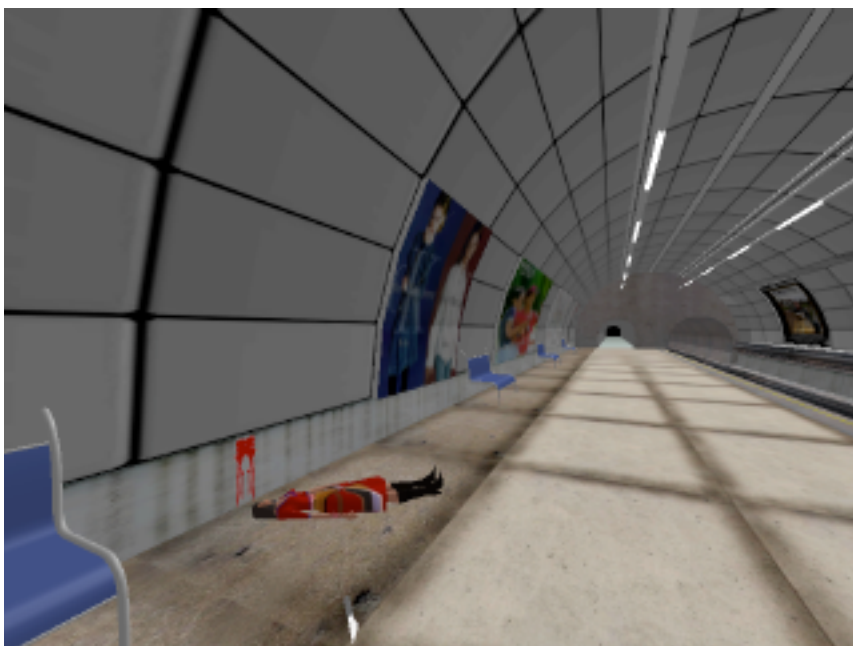


Fig. 00-14B Rendered subway crime scene (close)

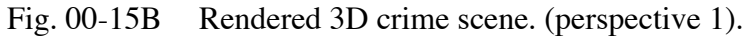




Fig. 00-15C Rendered 3D crime scene. (perspective 2).



Fig. 00-15D Rendered 3D crime scene. (perspective 3).