PC GAME TECHNOLOGY: APPLICATIONS FOR SIMULATION & TRAINING

INTRODUCTION

Recent advances in PC hardware and software have presented many new options to simulation designers. The ability to reach close to the computing power of large and expensive closed proprietary systems on commodity PCs has opened the door for high fidelity training simulations for a fraction of the costs incurred in the past. The lines between a secretary's word processor and an engineer's workstation have blurred to the point that training in a real-time interactive environment can be given to everyone who needs it without the high costs and slow turnaround times encountered in the past.

The Virtual Environment Simulation for Shipboard Incident Management (VESSIM) trainer could take full advantage of the PC environment. The need to train many sailors in first aid and damage control procedures in a team environment could place too great a strain on resources (money, space, development, maintenance, etc.) if a proprietary system is used.

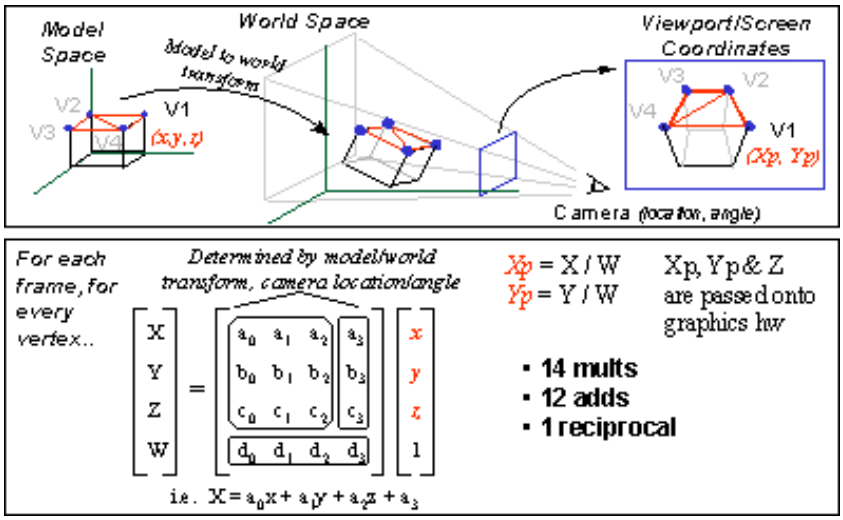
PC GAMING

Driving the Market

The last five years have shown tremendous growth in the PC market, both economically and technologically. One of the largest factors in this growth is the increasing need for more speed from the latest games. This drives constant innovation. The ongoing push for bigger and better special effects and the desire for more frames per second (fps) has been driving hardware manufacturers to work to outperform their competition.

The computer industry now includes games such as Quake III, MDK2, and Unreal Tournament to supplement computer system benchmarks when evaluating the speed and features of new hardware. Graphics benchmarks are shifting away from measuring the 2D performance needed for word processing and now rely almost exclusively on the 3D performance needed for the complex environments in first person perspective games.
Industry giants Intel and AMD also are catering to the gaming community by adding SSE and 3DNow! instructions to their Pentium III and IV processors and Athlon processors, respectively. SSE is an acronym for Streaming SIMD (single instruction, multiple data) Extensions. Both SSE and 3DNow! allow for one computer instruction to operate on

multiple pairs of floating-point numbers in only one clock cycle. This is directly applicable to the 3D vertex transform operations that are required to render a 3D scene. Hardware drivers and applications that take advantage of the new instructions can show large performance gains in 3D, sound, and other operations.



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Hardware Development Pace

The technology used for PC gaming has shattered Moore's law over the last three years as CPU speeds and the power of video processors have progressed at breakneck speeds. Moore's Law states that the amount of information storable on a given amount of silicon has roughly doubled every year since the technology was invented. This relation, first proposed in 1964 by semiconductor engineer Gordon Moore (who co-founded Intel four years later) held until the late 1970s, at which point the doubling period slowed to 18 months.

But we have observed that competition between Intel and AMD actually has pushed the change from 300 Mhz in 1997 to 1.4 Ghz in 2000.Besides the change in clock frequencies of modern CPUs, architectural changes to instruction sets and memory subsystems have made processors faster, clock for clock, than those of the past.

The competition between these two companies does not reside solely on the performance front. Prices have taken as much of a nosedive as performance has increased. In 1997, a top end home computer cost approximately $3,500. An equivalently equipped home computer, based on year 2001 technology can now be purchased for just under $2,000. A similar drop in prices can be seen in the PC workstation market, as well.

The performance of a computer system does not lie solely on the power of the CPU, however. Many subsystems within a computer can bottleneck a computer and cripple the performance of a neighboring subsystem. Video, memory, and bus speeds, along with many other components, contribute to the total performance of a computer system. These systems are being improved, as well.

In 1997, a then-unknown company named 3dfx revolutionized the home PC industry. Their first product, the Voodoo 1 graphics processor, allowed stunning 3D graphics to be displayed in real-time on the PC. Several software developers ported games to run on the 3D accelerator, but it wasn't until id Software ported its game, Quake, to run on the Voodoo chip that the 3D graphics market exploded.

As with the CPU side of the computer industry, the performance of 3D graphics chips also has been fueled by competition. The main competitors are: 3dfx (Note: 3dfx was purchased by nVidia in December 2000), nVidia, and ATI. Since Voodoo 1 came out, fill rates for graphics cards have increased from 45 million pixels per second to over 1 billion pixels per second. Features that were once only found on very expensive systems from SGI and Evans and Sutherland can now be found on graphics cards purchased at the local mall. Competition among the top graphics chip manufacturers has mandated a six to nine month product cycle. Features such as full scene anti-aliasing and hardware accelerated transformation and lighting of geometry are constantly being updated and improved. New rendering methods, such as tile-based or deferred rendering are promising up to three times greater performance over traditional rendering techniques. Texture compression and embedded VRAM will allow for very high resolution textures, to be used at real-time speeds and per-pixel shading will allow for realistic lighting, shadows, and other effects. All of this is being done to fuel the ever-increasing desire of game consumers for the highest fidelity graphics at the highest frame rate possible.

Developers and manufacturers of single purpose gaming peripherals also have found the market robust enough to bring out low-cost gaming specific hardware. Advanced display technologies, 3D audio, voice over IP, and force feedback devices are available - and affordable.

Competition in Software

The introduction of Windows 95 in August of 1995 brought easy access to computer games to a wider market. The DirectX multimedia API provided a common interface that software developers could write to and access functions on hardware from many different manufacturers - without having to rewrite code for each

manufacturer separately. This allows for a greater portion of a developer's resources to be used in content creation, rather than hardware compatibility.

DirectX is a family of APIs that is broken down into separate multimedia functions. DirectInput controls joysticks, keyboards, and mice. 2D graphics acceleration is accessed through DirectDraw. DirectSound, DirectMusic, DirectPlay, and DirectShow allow access to sound, music, network communications, and streaming video. Direct3D, however, is the flashiest component of the DirectX API. Direct3D allowed access to the functions on 3D graphics chips. At the time Direct3D was introduced, there were several competing proprietary APIs from graphics chip manufacturers. Glide from 3DFX, PowerSGL from PowerVR, and OpenGL were the main competition to Direct3D. Currently, the only two APIs in widespread use are Direct3D and OpenGL.

OpenGL was originally created in 1992 as a portable, interactive graphics-rendering environment. It found great popularity in CAD/CAM/CAE and 3D rendering applications on Unix and Windows NT workstations. One of OpenGL's greatest strengths is its availability on all platforms and its independent review board for structured growth of the API. Broad industry support makes OpenGL the only truly open graphics standard. It wasn't until mid-1997, with the introduction of GLQuake, that OpenGL made its mark on the PC world. Now, almost all major graphics chip manufacturers ship OpenGL ICDs (Installable Client Driver) with their products.

The availability of these 3D graphics APIs has allowed game developers to build gaming engines that display impressive graphics at high speeds. Game engines distinguish themselves from each other by the functions that the developers want to emphasize. The current top-of-the-line games using first-person perspectives include:

- Quake III by id Software;
- Unreal Tournament by Epic;
- Half-Life by Valve;
- Delta Force by NovaLogic;
- No One Lives Forever by Monolith, using the Lithtech engine; and
- Rogue Spear by Red Storm Entertainment.

Quake III distinguishes itself from the other games with its high polygon counts, network performance, and beautiful graphics, while Lithtech was designed to help game developers produce games faster. As hardware performance increases, game developers

are scrambling to take advantage of the increased power by creating higher polygon count models, larger textures, and increased special effects to maintain a competitive edge.

Game developers also have been able to take advantage of the pervasiveness of the Internet. Developers regularly talk to the public on message boards and IRC chats about the latest developments in their games and large virtual communities grow around the developers. The game players feel that they are part of the development of the games and the game developers feed the feeling of belonging by releasing the development tools used in the creation of the games. Game players can now develop their own maps and models to share with their friends. In addition to maps and models, certain areas of the source code for the games have been released to the public to allow people to modify the games to their liking. If a player would like to see a new feature added to the game, he/she could write a 'mod' and play the game the way they want to, rather than the way it was shipped. Very large online communities have grown around games such as Quake III, Unreal Tournament and Half Life and several of the prominent game programmers and modelers have become celebrities in the gaming community.

In the PC gaming community, game developers and hardware manufacturers work hand-in-hand to determine the direction the industry will take. Game developers such as id Software and Epic Games often tell hardware manufacturers like nVidia and 3dfx what features they would like to see accelerated in hardware, while the hardware developers help the game designers implement the latest features available on the graphics chips. This relationship fuels the competition between game developers to have the best features in their games and the hardware designers to have the fastest chips to feed the ever-increasing complexity of games.

Power of Graphics Engines

Current 3D game engines have many advanced features to make scenes more realistic. Texture mapping, multicolored lighting and shadowing, mip mapping, curved surfaces, transparencies, environment mapping, raytraced and enveloping lights, lens flare and coronas, and full 32bit color are some of the graphics features in almost all of the latest game engines. Collision detection, gravity, and other physics effects are already included and available for modification. Artificial intelligence for computer-controlled actors is built-in with interfaces for programming additional behaviors. Multiple human controlled actors can interact in a scene over a LAN or over the Internet, with smooth movement on modem connections. These are just a few of the features that most games provide out of the box.

All of the advanced features available in these engines require a great deal of processing power. That is why most games come with user definable quality settings. The ability to

scale the graphics quality is a necessity in the world of PC gaming. Many configurations of hardware must be taken into account in order to ensure the largest market possible. This makes it possible for a user of an older, lower power computer to decrease the quality of the game and still play at a reasonable frame rate. It also allows people with state-of-the-art systems to have all of the graphical richness that the game developers have built into their product. The current batch of games generally runs at about 50 frames per second on average, with all quality settings set on maximum on a top-end personal computer. This includes large (512x512 pixels) textures, 32-bit color depth, high (>10,000 polygons per scene) geometry detail, and multitexture support for environmental mapping and shiny surfaces.

A less tangible quality of modern PC games is the editing capability of the engine. The majority of games, 3D first-person or not, include a way to make new maps or levels. Some games go even further and include a user programmable scripting language - and a few games go so far as to make some portions of the source code available for the public to tinker with. Generally, the portion of most games that is not available to the public is the graphics-rendering engine.

Third Party Hardware and Software

For years, the lack of processing power has relegated the PC to low horsepower office work. The idea of using the PC platform for simulation and training was just a dream and high-end virtual reality peripheral manufacturers ignored the platform. The recent surge in PC performance, however, has made virtual reality hardware feasible on the PC platform and several tools are currently available. Voice, video, and force feedback input devices are on the shelves at local stores and are available online. These tools are targeted at game players and have price points that are affordable to the average consumer. The peripherals are also programmed to be compatible with the latest games on the market.

There are several products available to enhance the audio fidelity of games. Most of the major sound cards on the market have 3D positional audio support available. EAX is a collection of audio technologies from Creative Labs that includes both hardware and software elements that adds 3D sounds to the PC. EAX was first used on the Sound

Blaster Live! series of sound cards, and included hardware acceleration for sound and algorithms to produce 3D positional sound though only two speakers. The DSP chip uses a time scaling algorithm to give the illusion that a sound has front to back spacing, in addition to the side-to-side spacing that two speakers produce. The time scaling technology would greatly enhance the audio fidelity in a training system, when used with a HMD with built-in headphones. EAX can also be used in a four-speaker configuration to produce true surround sound.

Voice recognition and voice-over ip hardware and software peripherals are also available on the PC. The Microsoft Sidewinder Game Voice offers both voice-over-ip capabilities and limited voice recognition for all of the most popular games on the market. The Sidewinder Game Voice comes with a headset, including a microphone, and a control pad with eight programmable buttons to enable team chat, command broadcasts, and selectable voice channels. The chat feature is enabled outside of the games and runs in the background on Microsoft's Messenger software. Voice commands with the Game Voice uses a phonetically-based voice recognition engine. Commands can be typed in phonetically and the computer will read back the word using its own interpretation. The word must be changed until the command is spoken the way the user speaks. While limited in functionality, the voice recognition capability would be helpful to provide additional control interfaces to use in conjunction with an HMD.

Roger Wilco, by Hear Me, is a free chat program that can be used with many games on the market. Similar to the Microsoft Sidewinder Game Voice, Roger Wilco enables real-time voice communications over the Internet in a walkie-talkie fashion. It does not have the voice recognition capabilities of the Game Voice, however, it is a free download and is available for both Windows and Macintosh. A software development kit is available for integrating Roger Wilco's voice technology into games and applications.

Head mounted displays, like most technologies, are becoming available to home users. Interactive Imaging Systems has a low cost HMD with motion tracker, the VFX3D, which is built for the computer game player. The VFX3D incorporates a three-degree of freedom motion tracker, and has tracking support for many games on the market. At just under $1,800, it is still too expensive for all but the most hardcore game players but it provides a low-cost alternative for simulation and training.

Problems with PC Games for Simulation and Training

With the tremendous increase in performance of PC hardware in the last few years, and the graphics capabilities of modern game engines, it may seem like an easy translation from proprietary hardware and software to PC game engines. As with any other change in technology, there are going to be issues and trade-offs.

One of the major issues is interface. PC games have their interfaces designed for the average PC peripherals. Keyboard and mouse are the normal interface devices. Three-dimensional input devices are still very expensive and only a tiny fraction of computer users have access to them. While a keyboard/mouse interface may not be very realistic, the combination provides a very easy and accurate way to interact in a first-person perspective scene. For first-person shooters like Quake, the nearly unanimous choice for most effective control by game players is the keyboard/mouse combination. In a poll conducted by the gaming web site PlanetQuake, fully 95% of responders indicated they used and preferred a keyboard/mouse combination.

The popularity of games like Quake provides benefits for using game engines for simulation and training. Many of the sailors/marines who would train on VESSIM are younger and have a higher probability of already knowing the control scheme. Also, the interface has been tried and tested on a very large population with great success. While it is not as immersive as other control schemes, the cost, speed, and ease of learning the control scheme may make it more beneficial to rapid deployment of training than a more complicated system. Further study into this area would be needed.

Another issue is that gaming on the PC is a moving target in that hardware manufacturers are not designing their chips to hit a set performance requirement. The competitive nature of the industry has set the target of each manufacturer to be faster than the competition's fastest chip. This constantly shifting target represents a double-edged sword. Features that are impossible or impractical to implement may be standard a few months later. A game that runs very slowly on computers during development may play very smoothly when it is released. However, this also makes development a guessing game. A feature anticipated being hardware accelerated might never see the light of day. A target not anticipated far enough into the future may look crude and unrefined next to its contemporaries, while a target that is placed too far might make a game unplayable on the most powerful computer.

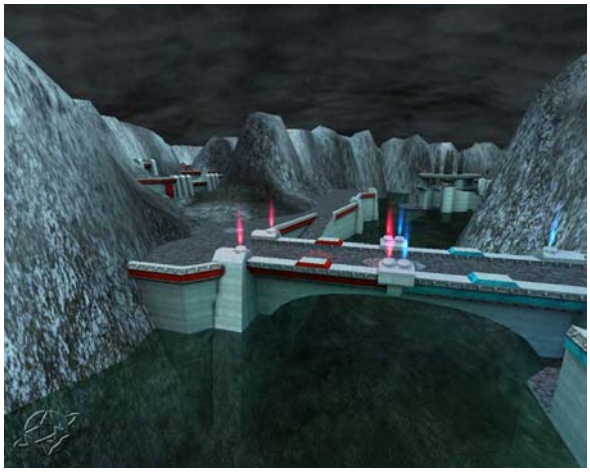
1st PERSON PERSPECTIVE 3D GAMES

Quake III

Quake III Arena was written by id Software and arrived in stores in late 1999. It was designed to be a strictly multiplayer game with efficient networking support for fast Internet play.

Quake III is considered by many to have the best graphics engine on the market. As a game, there is some criticism about its lack of depth, but from the graphics, networking, and programmability aspects, it is considered to be the best game available. The Quake III engine is capable of displaying in full 32-bit color, with curved surfaces and high polygon counts. Written in OpenGL, Quake III is available for Windows, Macintosh, Linux, and an IRIX version is currently in beta testing on SGI systems. Another aspect of Quake III that makes it unique among games is that it can take advantage of multiple processors.

Editing Quake III requires a combination of free tools available for download over the Internet and commercial packages such as 3DStudio Max and Photoshop or equivalent software. Changes to the code can be done with any code editing tools, from Notepad to Visual C++. A compiler is included in the game to compile user written code into Quake Script, or the new code can be compiled into a DLL with a C++ compiler.



Many functions for interacting with the environment are already built into the game engine. Collision detection is abstracted with a rectangular bounding box. This limits accuracy, but greatly reduces the CPU overhead of a skeletal collision detection scheme. Gravity is provided and can be adjusted to fit the scenario. Triggers can be placed on most objects to create switches and levers. Triggers can also be placed on invisible objects to create scripted events for building scenarios. Ladders are not included in the shipping game; however, they can easily be added into the engine.

The speed and the efficiency of the rendering engine is a major selling point of Quake III. On a top-end PC with a 1Ghz processor and a GeForce 2 Ultra graphics board, average frame-rates of 55 fps can be achieved with all graphics setting set to their maximum quality at 1600x1200 pixel screen resolution. With a GeForce 3 graphics card, full-scene anti-aliasing at 1024x768 resolution is possible at 60Hz. A PC with the necessary components to run at this speed can be built for less than $3,000, including 21" monitor.

One of the major drawbacks of the Quake III engine for use in simulation and training is that it does not use Microsoft's Direct X API. Because of this, there are some peripherals that will not work with the game, including a stereoscopic HMD and motion tracker.

The networking code in Quake III is extremely efficient. Players are able to connect to the Internet on a standard 28.8k modem and can play with up to 16 other players on the same map. A dedicated server may be set up to host a game, as well. The server will keep track of the location of all of the players on the map and will pass information to all of the clients connected to it. Currently, 5,000 players play regularly online.

Half-Life

Half-Life was developed by Valve and released in November 1998. It uses a heavily modified version of the Quake I engine from id Software. Half-Life has received almost every award in the gaming industry. At the time of its release, Half-Life set a new standard, in terms of interactivity and artificial intelligence.

Light switches, microwaves, doors, and elevators worked. Scripted events within the game led players through the story. Character models spoke with the lips synched to the words and teams of Army soldiers worked in teams, using tactics and making intelligent use of cover. In addition to the single player game, Half-Life also included an Internet-ready network play mode.

Even after two years on the market, Half-Life is still one of the most popular games available. The primary reason for its popularity is the mod community and large online user base. Except for the Massively Multiplayer Online Role Playing Game genre, Half-Life and its modifications have the largest active user community with almost 5,000 active servers and over 20,000 active users.

The mod that has blasted Half-Life to the top of the charts is Counter Strike. Counter Strike is a swat team mod that pits player controlled swat team members against other players controlling terrorists and other criminals. Real world weapons are modeled, such as the MP5, flash bang, and AK-47. The real key to Counter Strike's success has been the teamwork required to become successful. Strategy, teamwork, communication, and coordination are all required for a side, whether swat team or terrorist, to win.

Like Quake III, Half-Life provides an SDK to allow modifications to be made to the engine. Worldcraft is a free software package that is used to create maps for Half-Life. Models and textures can be made with any 3D rendering or 2D paint application on the market.

The biggest drawback to using Half-Life for simulation and training is the age of the engine. Newer engines take advantage of more advanced lighting and higher polygon counts, thus producing more convincing environments. With that said, the Half-Life engine still produces clean graphics with fluid animation. The strength of the scripting features and interactivity may outweigh the dated graphics for use in simulation and training.

Unreal Tournament

Unreal Tournament was released in early 2000. Unreal Tournament uses an enhanced version of the Unreal engine from EpicGames.

The Unreal engine is available on PCs and Macintoshes and will run in OpenGL, Direct3D, and Glide. Unlike the Quake III engine, the Unreal engine was originally written in Glide and is heavily optimized for 3DFX graphics cards, however, the Direct3D implementation of Unreal Tournament is sufficient to allow smooth game play on the majority of graphics chips on the market.

Compared to the Quake III engine, the Unreal engine is less efficient and slightly less advanced. Lower polygon counts, texture sizes, and screen resolutions are required to maintain

sufficient frame rates for smooth game play. The lighting model also seems to produce less realistic scenes than Quake III, however, it is still one of the best game engines on the market.

Where the Unreal engine shines is in displaying large open areas. Long lines of sight are possible and this produces realistic open areas. Animation in the engine is also very fluid and realistic. Interpolation and tweening of mesh animation help to keep animation files short and transitions between different animations smooth.

Unreal provides three modification types. Each type affects a different aspect of the game. Mutators are the easiest type of modification. They are simple changes that do not affect the game in a significant way. An example of a mutator is a rocket launcher that fires faster than the standard rocket launcher in the game. A second type of modification is a GameType mod. GameTypes are a much larger class of mod. They do everything the Mutator can't and allow a developer to access to a much larger range of functionality. This is the type of modification that VESSIM would fall under. The third type of modification is referred to as the "Everything Else" mod. These include new weapons or player models that do not affect the game play itself.

Like Quake III, the Unreal engine comes with a toolkit to modify the game. Unreal Editor is a map building tool and a code-editing tool in one. It is also possible to edit the code using any other commercially available integrated development environment like Microsoft Visual C++. 3DStudio Max and Photoshop, or equivalent software, are required to develop new models and textures.

The Unreal engine has been used in many games on the market. Currently, there are thirteen games on the market or in development that utilize the Unreal engine. The online user community for Unreal is also very strong.

The Unreal engine shows promise for use in the VESSIM project. The game engine includes many features that can bring a scene to life. Triggers, movers, and other

interactions are built into the engine to manipulate the environment. A head mounted display with motion tracker is available that is pre-programmed to work with the Unreal engine.

Rainbow Six: Rogue Spear

In 1998, Red Storm Entertainment released a game based on Tom Clancy's novel, Rainbow Six. The game differed from other first person shooters by straying from a fantasy setting and placing the player in a realistic setting. Playing the role of team leader of an international anti-terrorism squad, the player is responsible for designing and executing mission plans for multiple teams of soldiers. The player uses real-world weapons and CQB tactics modeled from actual SWAT and special ops members.

Rogue Spear is the sequel to Rainbow Six. It features enhanced graphics and game play, while maintaining the same feel as the original game. Rogue Spear has a built in mission editor and it has available plug-ins for 3D Studio Max to generate models and objects. The mod community is not as large as Quake3 or UnrealTournament, but is actively creating new additions.

The main appeal of Rogue Spear is its realism. Weapons kill with a single shot and are modeled after their real life counterparts. The locations are realistic, such as inside a 747, an oil tanker, or the Met museum in New York City. This is particularly significant for our application, since VESSIM must model the large interior spaces of the LPD-17.

A large part of Rainbow Six is mission planning. Before every mission, the player must create a plan for the teams to follow. A multi-level schematic of the location is presented to the player to position paths and waypoints. Waypoints can have activities assigned to them, such as *breach a door with explosives* or *clear a room*. In addition, modes of operation can be assigned at waypoints; for example *move stealthily* or *charge ahead as fast as possible*. Teams also can be ordered to wait at a waypoint until a command is given. This portion of the game is extremely important to mission success. It requires the player to be familiar with combat tactics and strategy and apply them in various situations.

After the mission plan is created, the player then executes the plan. The player leads one of the teams and can deviate from the plan, if required. Other computer-controlled teams will follow the paths and waypoints assigned in the mission plan and execute tactical maneuvers, such as eliminating targets, covering corners and opening doors. The teams either proceed automatically, or on user defined "Go codes." This level of automation is similar to that required in VESSIM, since damage control teams aboard ship consist of approximately 10 sailors.

In addition to computer-controlled units, the game supports network play. Up to 16 players can play in one mission on the same or different teams. Voice over IP software, such as Roger Wilco is commonly used by players on the Internet. Teams that use VoIP have a distinct advantage over teams that do not. The players are able to coordinate movement and tactics much more easily with teammates. Team coordination is one of the issues to be addressed by VESSIM. Many teams form "clans" and play against rival clans. The clans are monitored by a site, such as Mplayer.com, that ranks them according to wins. Clans commonly meet online and practice with other clan members. Complex signals and attack plans are designed and tested by the players, many of whom are former military personnel.

Delta Force 2

The Delta Force 2 graphics engine makes it different than all of the other first-person perspective games.. The VoxelSpace 32 engine is based on voxel-based rendering, rather than polygon rendering. The engine can render polygons as well, but only some objects in the game can be rendered with polygons. Buildings, vehicles, and character models can all be modeled using polygons, however, the main attraction to the game, the terrain, is modeled using voxels. This has several advantages and disadvantages.

A volume element, commonly known as voxel, is similar to a pixel, but in 3D. A pixel being a 2D rectangle, a voxel is a 3D box. But unlike pixels, which can take many values, voxels are usually full or empty. Voxels can be used to represent virtually anything, from human skulls in medicine to full 3D worlds. The more voxels, the more precise the model will be. One of the major problems today is that there is too little memory to store very complex scenes, so low-resolution voxelisations are used. The programmer must therefore use clever algorithms to render the "voxelated" world in a smooth fashion on the screen.

The VoxelSpace 32 engine can render very large terrain with very long lines of sight very well. By using voxels, tall grass can be rendered and used as cover. Gentle rolling hills and other landmarks can be produced, as well. Another benefit of the voxel-based terrain is the ability to combine Digital Terrain Elevation Data (DTED) with raster imagery, such as satellite photographs, to produce a 3D environment in seconds that can be used in simulation or real-time mission applications.

The use of voxels, however, also makes graphics very blocky and appear smudged. While the engine can display high grass - even showing individual blades - the effects are far from realistic. The objects in the game that are rendered using polygons look better than the voxel objects, however, they get very pixilated when viewed up close. High system requirements also limit the frame rates and screen resolution the game can run smoothly in.

A feature that Delta Force 2 incorporates is a realistic ballistics model. Objects in the game have density values and some projectiles can travel through wooden doors or even people and can hit objects behind them. Distance and wind also affect the projectiles in flight.

Multiplayer support is very good in Delta Force 2. Delta Force 2 includes NovaLogic's Voice-Over-Net. This is a push-to-talk technology that allows players connected over the Internet to use the NovaWorld servers to communicate without having to type in a message. Games can also accommodate up to 50 players simultaneously.

Delta Force 2 may have made the biggest move into simulation and training compared to any other game software. On March 21, 2000, NovaLogic and the Army Training and Doctrine Command Analysis Center in Monterey, California announced a project based on the Land Warrior system, using the Delta Force 2 game. NovaLogic Systems, a wholly-owned subsidiary of NovaLogic, is also in contact with several foreign military organizations to customize Delta Force 2 for their required tasks. The modified Delta

Force 2 game will allow the US Army to evaluate the weapons and tactics that will be used in the real-life Land Warrior system.

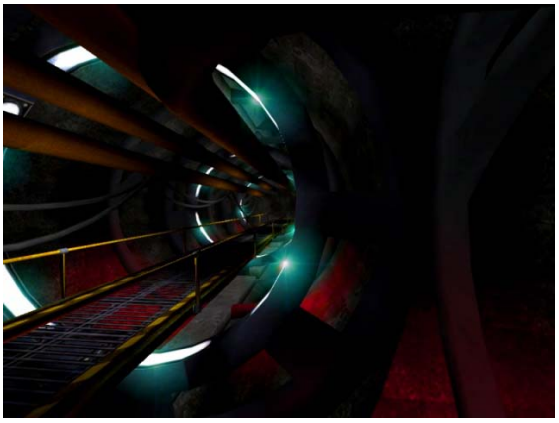
The main modification that is being made to the game is the ability to move the weapon separately from the body. This allows for soldiers to place weapons around corners without exposing themselves to enemy fire. Another modification is a video camera feed from the end of the weapon to survey a scene from behind cover. Real-life locations also have been accurately modeled to provide mission rehearsal capabilities.

While Delta Force 2 has many excellent features and excels at providing the functionality called for by its target audience, this game is not a good match for the VESSIM project. The shipboard environments targeted in VESSIM nullify the benefits of the VoxelSpace 32 engine. Coupled with the high system requirements and lackluster graphics, Delta Force 2 would be an inappropriate 3D engine for the project. The only function that would make sense to use for VESSIM is the large multiplayer support.

Lithtech

Lithtech is a game development system originally created by Monolith Productions in 1996. Lithtech was spun off in February 2000 as a subsidiary of Monolith Productions in order to effectively focus its attention on technology licensing and customer support. The engine has been used in many games, including: Shogo: Mobile Armor Division, Blood, Septerra Core, No One Lives Forever and Sanity: Aiken's Artifact.

Lithtech was designed from the ground up to be a fully integrated game development environment. Although a 3D modeling tool such as Discreet's 3DStudio Max is still required, Lithtech comes with tools to ensure that the models generated interact correctly with the environment and other models in the game. Level and special effects editors are provided in the development suite, however, third party tools can be used if desired. By attempting to streamline the game creation process with integrated tools and good customer support, Lithtech hopes to entice developers away from the more popular Quake III and Unreal engines.



The Lithtech engine has taken some criticism from the gaming press over a few perceived weaknesses. Many of the issues can be attributed as well to all of the game engines presented here, such as rendering speed on low-end computers. The primary issue with the Lithtech engine is the tendency for games using Lithtech to have a "cartoonish" appearance. Much of this is due to the fact that games developed with the engine were designed to have that feel. The lighting algorithms used may also contribute to this perception. Recent screen captures of the latest incarnation of the engine show more realistic lighting effects, however, this cannot be confirmed unless an independent study or a game is released to prove it.

GAMING AND SIMULATION MIDDLEWARE

The term *middleware* is used to describe separate products that serve as the glue between two applications. Middleware is sometimes called *plumbing* because it connects two sides of an application and passes data between them. For games and simulation, middleware refers to a layer of software that abstracts low-level API calls, whether DirectX or OpenGL, into a library or toolkit to allow for easier development of applications. By building these libraries to perform low-level functions such as rendering, collision detection, physics, and network support, developers are able to focus on content and gameplay, rather than the technology itself. As games and simulations become more complex and as hardware advances to the point that photorealistic 3D is commonplace, companies will turn to middleware instead of re-inventing technology and engines.

Unlike a game engine, middleware only provides a framework on which to build. Middleware provides for a far greater ability to customize a game or simulation than using a pre-built game, however, far more work must be done in order to create a product using a middleware solution.

Criterion Renderware

Renderware is Criterion Software's latest middleware solution for game developers. It allows for simultaneous development across many platforms, including PC, Playstation 2, and Dreamcast. Renderware includes a development framework for incorporating 2D/3D graphics, audio, and physics into a game. Support for models created in 3DStudio Max, Maya, and SoftImage is included through exporter plug-ins.

Alias/Wavefront Maya Real Time SDK

Alias/Wavefront is a leader in the 3D graphics industry. Their product, Maya, is considered to be the most powerful 3D rendering, animation, and visual effects software in the industry. It is used intensively in the film, video, broadcast, game development, interactive, and location based entertainment markets. Alias/Wavefront has created areal time SDK to leverage the power and popularity of Maya for use in creating 3D games for the PC and other popular game consoles.

The primary advantage of the Maya Real Time SDK is the ability to directly use 3D models created with Maya in a game engine. Currently, art assets are developed completely separate from the game engines. The geometry and textures go through a conversion process to optimize the models for maximum performance on the game engine. This extra step can add considerable time to the development process of a product, especially considering the many changes that take place as a product evolves.

The real time SDK includes systems that implement 3D graphics, dynamics, particle systems, inverse kinematics, and animation. The 3D rendering subsystem is designed to render a model or scene created in Maya in a WYSIWYG (what you see is what you get) fashion. Material properties such as texture mapping, detail texturing, opacity mapping, luminosity mapping, specular mapping, bump mapping, and environment mapping may all be applied in any combination. The resulting real time rendered scene will be nearly indistinguishable from a pre-rendered cut scene.

SGI and Multigen/Paradigm

Silicon Graphics, Inc. and Multigen-Paradigm Inc. are well-known leaders in the visual simulation industry. SGI creates high performance computing hardware for 3D visualization and has a close working relationship with Multigen-Paradigm, which creates an extensive suite of 3D modeling tools and real-time virtual environment generation APIs.

Multigen-Paradigm Vega

Vega is Multigen-Paradigm's software environment for real-time visual simulation. It is available for SGI IRIX and Microsoft Windows NT operating systems. Vega provides a host of tools and APIs to generate interactive simulations.

The Vega API is written in C and applications can be built in C/C++. The LynX tool allows users to quickly create and customize simulation parameters and entities in a graphical environment. Using LynX, application-specific modules can used to extend Vega's functionality to include DIS/HLA, special effects, and human motion, as well as many other options.

The OpenFlight standard is the primary scene description format. This is advantageous to the military simulation community since the majority of models available within the DOD are in OpenFlight format. Multigen Creator is a 3D modeling tool that is available for developing models for use with Vega.

The biggest disadvantage to using Vega is the lighting quality. While geometry and textures appear properly, the lighting effects produce a "flat" picture that takes away from the realism in a scene. Subsequent revisions may add more advanced lighting algorithms to Vega.

SGI Hardware

SGI is the leading provider of high performance image generators for a good reason. The SGI Onyx family of computers offers scalability and performance that is virtually unmatched in the industry. The Onyx 3000 series offers unique features such as clip-mapping, texture-paging, volume rendering, multistream HDTV video manipulation, multichannel output, and immersion support. A single Onyx system can have up to 512 CPUs, 1 TB of main memory and 16 graphics pipelines. Additionally, multiple systems may be clustered together to provide a truly scalable solution. The systems run the IRIX operating system and has full support for the OpenGL graphics API. Entry-level price is approximately $50,000 (August 2000).

SGI also offers lower-end visual workstations such as the Octane2. The Octane2 comes in a single or dual R12K processor configuration and up to 8 GB of RAM. The SGI VPro graphics subsystem powers the Octane2 and provides 48 bit color precision, and up to 128 MB of video RAM. Octane2 systems start at $17,495 (July 2000).

The true advantage of SGI systems, like the Onyx 3000 series, is the level of scalability. Processing power, rendering speed, and the number of video channels can all be upgraded or used in parallel to render extremely high fidelity virtual environments. The

ability to scale from simple single user simulations up to complex multiple user environments is SGI's strongest selling point.

Available Tools for Simulation and Training

There are a number of 3rd party hardware and software tools available for SGI/Vega systems. Head mounted displays, motion tracking equipment and multiple styles of input devices are available that can greatly enhance the immersiveness of VR systems. Haptic and force-feedback devices can be used to provide immediate tactile sensations to the users. SGI has worked closely with numerous suppliers of these devices and Multigen-Paradigm has included drivers to interface with most of these devices.

Cost Issues

Like all industry-leading products, SGI and Multigen-Paradigm products come with industry leading prices. On the lower end, the starting price of a single processor Octane2 is $17,495 with a moderately equipped Onyx running into the six digits. For the price of a base Octane, an entire training lab could be purchased, including two fully equipped PC systems with HMD and motion tracker.

In addition to the hardware costs, software costs are high, as well. Development licenses for the required modules of Vega for VESSIM are estimated to be $30,000 to $40,000. And, runtime licenses for each computer will cost over $8,200.

CONCLUSIONS

With the exception of a few issues, PC game engines may provide an inexpensive platform to build a training simulation on. One issue is the ability to connect with existing military simulations. DIS/HLA is the standard network protocol used for simulation. Currently, no standard is used by the gaming industry. Each game developer optimizes network communications for each game. It will be difficult for games to be used for simulation unless that barrier can be breached. Another obstacle to the acceptance of PC games in simulation and training is the large amount of data that has already been created by the DoD. Even though the pre-existing models and textures can be converted for use in a game engine, leaving the safety of a system that has been tested and validated for a new technology is a daunting proposition.

However, with the smart usage of the available computing resources, high fidelity simulations can be fielded for a fraction of the cost per system than by using proprietary solutions. Soft skills such as teamwork, communication, and coordination cannot be trained in isolation. Reduction of costs is essential for providing a training simulation

that can exercise those skills. The entertainment industry is providing the simulation and training community with some alternatives that may provide the low cost, high fidelity training needed in the modern military. In fact, it is apparent that there are some applications today that could benefit from current gaming technology –because a higher level of fidelity is not required and development time and funding are limited. Certainly, more study is required concerning these trade-offs and the effectiveness of game engine-based simulations. It is our intention that the VESSIM Project will serve as a tool for further consideration of these issues.

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