3D technology in simulation

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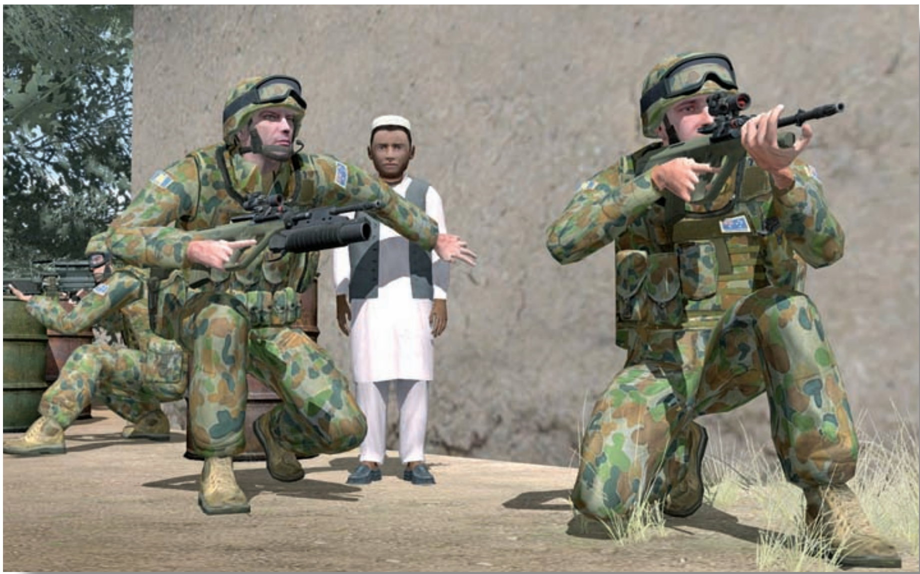


Virtual Battle Space (VBS) rendered synthetic imagery.

THREE dimensional (3D) display technology crossed an important threshold in the past two years, with explosive growth expected in the commercial sector and, increasingly, a feature of military simulations. Such displays provide the viewer with depth perception, and thus an illusion of reality that cannot be achieved with a conventional '2D' display. But growth in 3D will be tied to the availability of products to be displayed, which is a major impediment, even though there are a number of top end 3D LCD (Active Matrix Liquid Crystal Display) and PDP (Plasma Display Panels) HDTV (High Definition Television) sets now available to consumers. As yet, 3D encoded Blu-ray disks are scarce, 3D capable Blu-ray players are scarce, and no television is being broadcast using 3D modulation.

To date, 3D display technology has been most prominent in cinema, and the success of movies such as 'Avatar' shows the capabilities of the technology, and its current limitations. While Avatar illustrates the potential of the technology, the enormous cost to produce this work, all of which was rapidly recouped, underscores the difficulties with what is still a maturing technology base.

What is abundantly clear is that over the coming decade the commercial sector will produce high volumes of consumer priced basic technology for 3D display of imagery, and products for generating 3D content. In turn, this technology will open up valuable opportunities for military users, across a wide range of training activities.

3D visualisation systems are designed to 'fool' the brain's visual cortex to perceive a spatial image with illusory depth by presenting right eye and left eye images of the viewed scene.

Case Study – The Virtual Battle Space

The Virtual Battle Space 1 and 2 software products have formed the basis of a number of military simulation products now used for training military personnel. The evolution of the product presents an excellent case study of adapting consumer technology to military applications, and thus leveraging commercial market funded Research and Development to provide low cost high payoff military training products.

The origins of this family of products lie in the desktop computer military gaming market, where Czech Republic startup company Bohemia Interactive commenced just over a decade ago. After winning a number of international computer gaming awards for their gaming products, the company diversified into meeting the individual needs of military, law enforcement, homeland defense, and first responder training environments by adapting their consumer gaming software product. Further development has seen the technology adapted to cover additional military training applications, with the Complete Aircrew Training System (CATS) intended for rotary wing aircrew training, a VR Marshalling Simulator for tarmac personnel training, and a VR simulator for training snipers. The Australian Army Aviation Corps has procured 7 systems, 1 VR Marshalling Simulator, and 2 VR Sniper simulators. In the United Kingdom, the product has been procured for the Army Air Corps' Middle Wallop based Army Aviation Training Centre.

A typical CATS simulation arrangement comprises a helicopter fuselage mockup, more than often comprising little more than a fuselage frame with original seating, as the visuals of the interior of the aircraft and exterior are all rendered synthetically in VR. A physical emulator for the flexibly mounted M134 rotary minigun is available if required.

Each crewmember is provided with a set of VR goggles, which attach to the standard Gentex 56P helmet via the NVG mount. Head tracking in 6 axes (x/y/z translation and pitch/roll/yaw) is provided by a Polhemus head tracker. Each helmet is tethered by cable to an industry standard personal computer running the VR software, and equipped with Nvidia graphics adaptors. Each eyepiece contains an Emagin active matrix OLED emissive display with a resolution of 1280 x 1024 pixels, and 70 degree diagonal field of view.

The product allows aircrew training in a wide range of scenarios, with synthetically rendered terrain, buildings, threat platforms and troops, the intent being to provide as realistic as possible a training environment. Tracer fire and muzzle flash effects of guns are emulated, as well as projectile impacts and damage effects to targets.

While the VBS family of products is now mature and available, it has considerable further growth potential and we should not be surprised to see further evolution as more powerful GPUs and higher resolution VR displays become available.

Growth of 3D productions

Cinema with 3D content had an early start during the 20th Century, with high popularity during the 1950s. However, technological limitations resulted in severe eye fatigue, and the technology slumped until it was revived in Imax high resolution productions some years ago. Even much improved Imax presentation would still produce unwanted visual artefacts.

The simplest technique for capturing 3D on film or video involves pairing two synchronised cameras, with lenses displaced to emulate the effect of eye spacing in a human observer. Various techniques are then used to manipulate spacing and thus the perceived depth and distance of the observer. The angular field of view of the cameras can be an issue, as the human eye processes in detail a narrow angular sector (foveal vision) and a wider surrounding sector (peripheral) vision.

In Computer Generated Imagery (CGI), whether produced for cinema or interactive applications, the computer graphics hardware and software has to render an image from the perspective of each eye, again using similar techniques to capture to generate the desired depth and observer placement.

The problem of effectively fooling the human cortex is not always that simple, though, since the eye will automatically manipulate its iris (aperture) to focus vision on objects of interest. Even conventional photography can create an illusion of depth if the image is of very high resolution, optics are sharp, and the depth of focus is properly set to the foreground object of interest. This is a factor in capturing high quality 3D for cinema or television applications, but must also be managed properly in CGI applications if the observer is to be comfortable and his or her visual cortex properly seduced by the image. The 'unreal' image quality of some CGI 3D product reflects lack of attention to detail in producing output to effectively fool the human visual cortex.

Until recently, high resolution imagery rendering as used in cinematic CGI could not be computed in real time. This is because general purpose processing chips or Graphics Processing Units (GPU) weren't fast enough at computing scenes and rendering them for display at a viable image frame rate. 'Flicker' free frame rates must be of the order of 25 – 50 frames per second, depending on the display technology – any slower and eye fatigue results, as the eye and cortex can detect individual frames of the scene changing. Smoothness in object motion is another consideration and similar criteria apply.

Cinematic CGI of high quality would take hours, minutes or seconds to render per frame, depending on the hardware in use.

Moore's Law being what it is, we are now at a point when usable imagery of the order of a Megapixel or more per frame can be generated in real time to support viable display frame rates. A High Definition computer or TV display with 1920 x 1080 pixels is a 2 Megapixel (2,073,600 pixel) display.

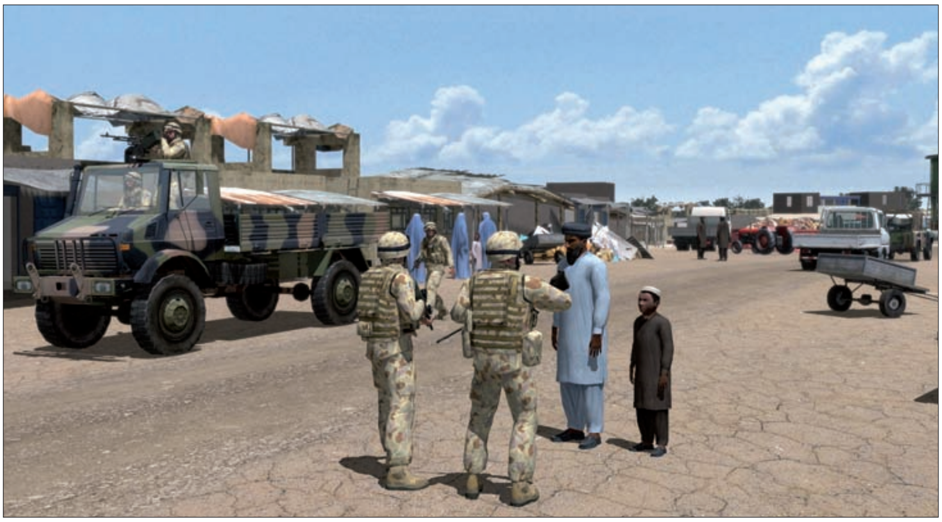
For comparison, professional still image digital camera backs for Hasselblad V-series and Mamiya 645AF series cameras currently top out at 80 Megapixels (PhaseOne IQ180). Red Digital Cinema is currently manufacturing digital cine cameras with 9.4 Megapixel resolution, with claims of developmental products with 28 Megapixel cine capability, or 261 Megapixel still capability.

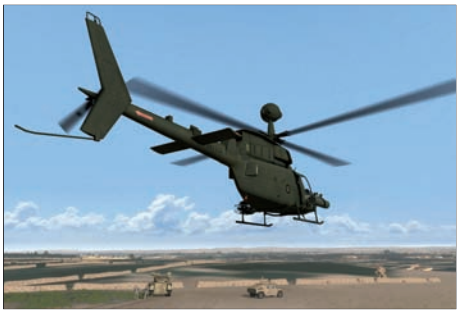
At present, the capability to capture lifelike very high resolution digital imagery, 2D and 3D, for both still and cine applications is well ahead of technology for displaying such imagery. This gap is likely to persist over time, since compact CMOS or CCD sensor chips are easier to develop than advanced high resolution displays, and very much cheaper to make.

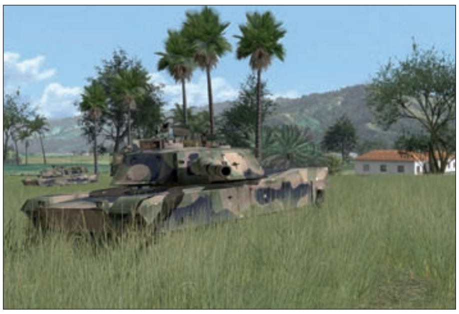
Importantly though, display technology of Megapixel class resolution in itself provides valuable military applications, and with commercial applications driving the Moore's Law curve, the resolution will only get better over time, and costs will decline.

Military applications of 3D technology

The military was one of the first users of 3D capture technology, then labelled stereoscopic photography. As far back as the 1940s reconnaissance imagery interpreters used 'synthetic' stereoscopic techniques to produce depth perception in studying reconnaissance photos captured by aircraft.







Virtual Battle Space (VBS) rendered synthetic imagery of vehicles, personnel, a tank and helicopter.

The technique relied on the fact that these cameras took series of images in succession on rolls of film, which meant that the motion of the aircraft displaced the viewpoint from which consecutive frames were captured by the camera. Viewing equipment which allowed separate frames to be viewed simultaneously each by one eye produced much the same effect as a stereoscopic or 3D cine camera. This was a valuable tool in 'looking beneath' enemy camouflage and measuring the elevation of structures, etc.

Current high definition category still and cine imaging chips have direct applications in Intelligence Surveillance Reconnaissance (ISR) sensors, whether carried by aircraft manned or unmanned. Indeed many such chips started appearing in military targeting and reconnaissance pods a decade ago. The principal barrier to fully exploiting very high resolution still and cine imaging chips will be providing the necessary optical stabilisation to exploit the sharpness of the optical motion stabilisation.

A much larger domain of applications however exists for 3D display technology. Broadly, these can be divided into applications based on head mounted displays, and applications based on screen displays.

Latter applications will directly track commercial applications, and will use commodity commercial screen displays or projectors, or computer displays. In the near term the dominant resolution will be the HDTV standard at 1920 x 1080 pixels, and users will make use of COTS technology throughout.

What this means in practical terms is that any existing screen based 2D application can be adapted for 3D applications.

While existing synthetic stereoscopic techniques for imagery interpretation are an obvious candidate, the technology could be further extended to improve the quality of live video product currently produced by imaging sensors on UAVs, with some inevitable limitations arising from platform motion and sensor performance.

Training media such as film may work much more effectively in 3D, especially where the training task is one where depth perception matters. This encompasses a wide range of training activities where the participant is involved in working at short distances, where depth perception does matter.

For comparison, the traditional flight simulator application is one where mostly depth does not matter when looking outside the aircraft. It does come into play during fixed wing aircraft landings, but more importantly with rotary wing aircraft during low altitude activities, such as hovering or Nap Of the Earth (NEO) flight.

Other existing screen based applications will also benefit. For more than a decade top end Computer Aided Design (CAD) tools for drawing and rendering 3D objects such as mechanical components have usually provided the option of a 3D display, using very expensive high speed monitors and one or another form of 3D viewing goggles. This technology was often useful in checking the shape of designs, mechanical clearances in component assemblies or component fitting. With commodity low cost 3D viewing displays, this technique will become much more widely used.

Far more interesting however is the use of Head Mounted Displays (HMD) for 3D visualisation, colloquially referred to as 'Virtual Reality' or VR displays.

Until now two primary limitations in basic technology prevented wide use of VR, be it for consumer gaming applications and military simulations.

Affordable high speed graphics rendering hardware and general purpose processors were one key constraint. Flight simulators of even a decade ago required multiple racks if not room sized equipment areas to provide a high quality wide area image.

The lucrative gaming market and Moore's Law changed everything over the past decade, with the market currently dominated by Nvidia and AMD (formerly ATI). Contemporary GPU (Graphics Processing Unit) chips deliver so much computing performance that they are being adapted for use in clustered supercomputing applications for scientific use. With standard computer and HD computer display rendering high image quality in real-time, these chips have become an enabling basic technology for a range of applications, including military simulations.

Head Mounted Display technology has been another long standing obstacle, which is now being overcome.

Cathode ray tube displays still dominate operational HMD applications, but are typically limited to single colour rendering.

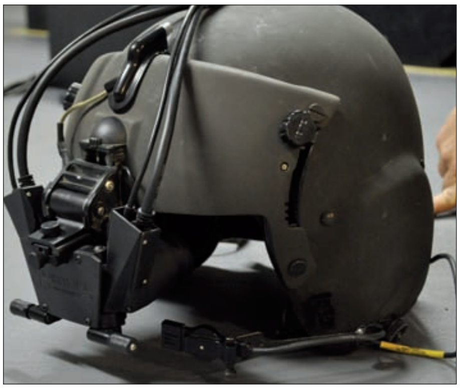
For VR displays, two technologies are now on the rise. The first are variations on the LCD (Liquid Crystal Display) theme, evolved from high resolution compact displays used for cellular telephones and consumer digital camera preview displays. Both markets have seen increasing demands for image sharpness and colour quality in turn resulting in image quality viable for a HMD VR application.

The newcomer in this technology base are Organic Light Emitting Diode (OLED) displays, typically based on Light Emitting Polymers (LEP). This technology has been known for nearly four decades but only recently achieved the durability and environmental robustness for production use. The technology is best known for its potential uses in flexible displays, laminated on to plastic sheets. Whereas LCD displays require a backlight source to illuminate the transmissive display panel, OLED/LEP displays are emissive and produce their own red, green and blue light output. They are considered to produce better contrast than LCD displays.

The advent of suitable lightweight compact displays for VR goggle applications is an important breakthrough, as this remained an obstacle in advancing VR techniques for well over a decade.

Importantly, the commercial imperative to produce low cost high production volume very high resolution displays for handheld consumer devices such as phones and digital cameras will guarantee ongoing investment in developing these technologies to higher resolution, lower cost and better durability.

Proponents of Moore's Law like to say "the best is yet to come". The accelerating pace of development and availability of several new basic technologies make this statement very true for 3D technology. Military training will without doubt become a major beneficiary of these important advances.



A VSS Virtual Reality display device attached to a pilot's Gentex 56P flight helmet.

Virtual Battle Space (VBS) rendered synthetic imagery of a night operation.