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Making a

Sharpening up on simulator visuals is a constant preoccupation for technologists bent on improving the fidelity with which scenes representing real life are presented to mariners under training. **George Marsh** reports.

Seeing is believing — but only if the simulated visual environment looks sufficiently real. The Marine Simulation Group (MARSIG) of the Image Society, a body concerned with developments in simulation, is clear that vision is the most important feedback mechanism in ship handling and that high levels of fidelity augment the training value of simulators.

Achieving a high level of apparent reality is a tough challenge given the highly dynamic medium in which ships operate. Fortunately, trends in commercial information and display technology have come to the rescue. According to MARSIG, a new generation of high performance, abundantly detailed, finely textured realistic visual scenes with full scene anti-aliasing are today displayable at a fraction of the cost of just a few years ago. This has been enabled by a transition from expensive custom platforms to PC-based image generators (IG), along with advances in projector technologies. Databases have benefited from distributed processing, open systems and new software tools.

Moving on

Proprietary bespoke systems have given way to commercial off-the-shelf (COTS) systems configured with open architectures based on distributed processors, typically PCs. This has increased system commonality and reduced costs: 'more pixels per penny' as one industry insider puts it. While high-speed processors and parallel processing techniques keep simulators up to speed, commercial software, together with effects and techniques imported from the video gaming world, have transformed the speed and scope of modelling.

Recent Image Society annual conferences suggest that these trends will continue. Ross Smith of Quantum3D Inc, recalling a prediction a decade ago that PCs would one day dominate the Vis-Sim industry, has confirmed that leading visuals companies like Northrop Grumman, L-3 Communications, Evans and Sutherland etc, plus Quantum3D itself, are now focused on PC-based systems, software and technologies. Widespread adoption of new technology, he told delegates, is not only helping to meet users' growing expectations of superb image quality, but is also driving down costs. Current systems deliver high processing speeds, large numbers of pixels and polygons, high contrast ratios and high refresh rates. Previous 'merchant technology', he argued, could scarcely have delivered these results whilst also meeting other requirements for such aspects as drift-free synchronisation between channels, compatibility with existing systems, high reliability and adequate service life.

Moving to multiple image generators and parallel rendering architectures provided a technical answer when traditional visual systems based on single expensive custom graphic platforms ran into limits on bandwidth, processing speed and capacity. At the same time, adopting commercial graphics chips proved to be economically advantageous, especially as the COTS approach showed itself no less capable in terms of performance and fidelity. Using widely available hardware and software has enabled simulator engineers to concentrate less on proprietary technologies and focus more on contributing to shared progress. Accepting influences from other fields has increased the pace of innovation.

As an example, US company Quantum3D claims to have complemented commercial image generation technology with a refinement that significantly enhances image quality. The key to generating realistic images, it says, is to take note of what the video gaming and movie industries have achieved and to manipulate the appearance of each picture element (pixel). This 'shader technology' enables, it asserts, a range of difficult scenes to be rendered. Ocean scenes can be presented complete with light and shade, clouds of authentic volumetric appearance, surface reflections and other realistic effects.

Dynamic shadowing helps in representing various sea states, terrain features and the movement of other vessels. The ready programmability of commercial IGs, along with the ability of contemporary parallel architectures to manage hundreds of thousands of fully processed polygons, have helped secure these benefits. Shader-based, parallel rendering architectures are at the heart of the new wave in visual simulation.

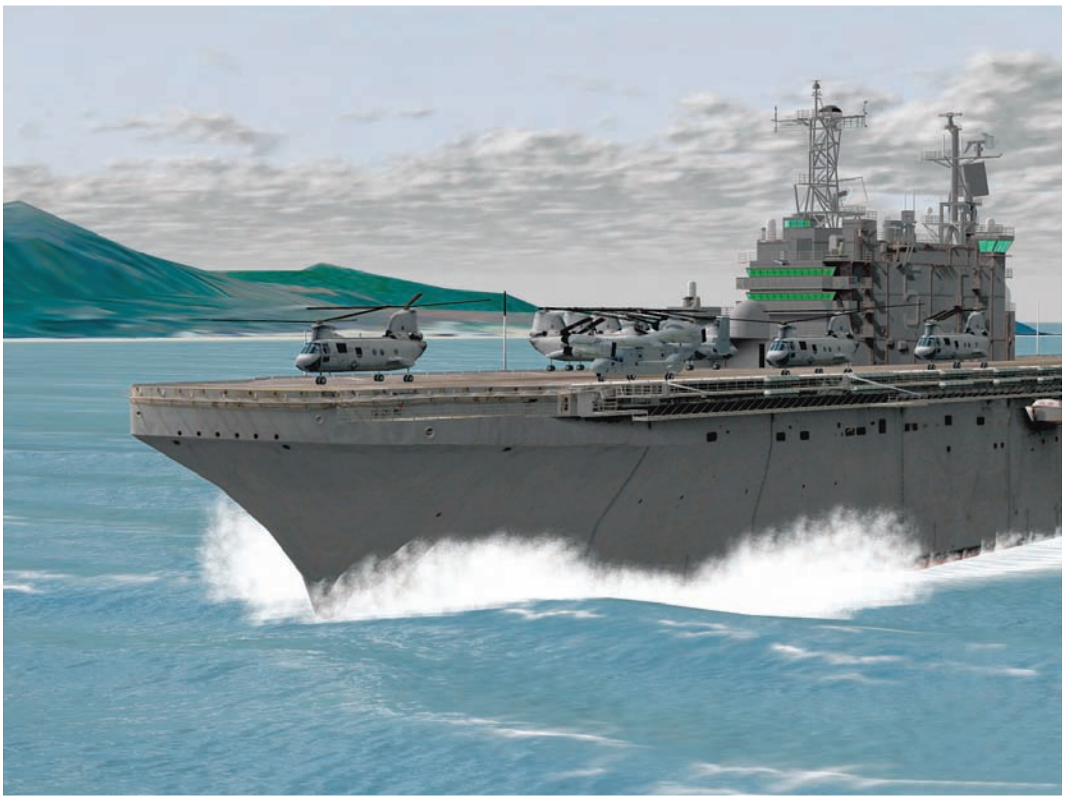
Quantum3D's Heavy Metal, a visual system that couples advanced PC-based components with sub-systems and technologies developed in house, features in the ShipVision 5000 system used in Ship Analytics bridge simulators. The rugged rack-mounted visual system offers high sustained real-time frame rates across single or multiple synchronised channels. It has an open architecture and is readily scalable. Using Heavy Metal enabled Ship Analytics customers to enjoy better graphics for less cost than hitherto, according to a spokesperson.

Projection

Generating high-fidelity imagery is one thing, displaying it undistorted and seamlessly on a cylindrical, conical or spherical screen is another. Field of view requirements can range from a single quadrant to a 360 degree horizontal view or, for full mission simulation, a complete hemispherical dome. Mike Mulvenon of Flight Safety International, sister organisation of maritime simulation and training specialist Marine Safety International (similar visual technologies underpin advanced marine and aviation simulators), told a recent Image Society conference that new types of display will continue to displace the once-ubiquitous CRT.

Advances in laser, liquid crystal display (LCD), digital light processing (DLP) liquid crystal on silicon (LCoS), and digital direct drive image light amplifier (D-ILA) projector technologies are making it possible for these successors to deliver imagery of impressive resolution and acuity, along with high contrast ratios. Solid-state technology requires less space, power and maintenance

SCENE



than traditional CRTs, and can be more reliable.

Moving to one of the new solid-state light engines brings with it the disadvantage, however, that the methods normally used to correct for geometric distortions induced in an image by particular screen types are no longer valid. With CRT-based products, system installers typically map the projection screen to define the required image shape, then adjust the CRT projector manually to match a projected test pattern to the screen map. According to Display Solutions Inc, a specialist in the field, high-end CRT projectors typically have the ability to control geometry in 50 or more semi-independent zones. Although setting up the CRT manually is a time consuming process that needs repeating as the associated analogue circuits drift, it is generally effective. Solid-state digital projectors lack this inherent 'warping' capability, though they are virtually immune from drift.

One answer to the warping deficiency is to correct image geometry electronically by pre-processing the projector video signals. The need to adjust units individually could be avoided by incorporating in each projector warping circuitry in which the parameters are preset according to the type of screen the system is designed for. This solution, however, gives rise to projector standardisation and life cycle cost issues. Display Solutions Inc prefers warping systems that retain the 'real time' adjustment facility, enabling geometry to be manipulated while the projected image is actually viewed on screen. Modifications can then be made via screen mapping in a similar fashion to the CRT method. In carrying out screen mapping,

Quantum 3D users 'shader' algorithms to allow the rendering of ocean scenes with light and shade, clouds of authentic volumetric appearance and surface reflections

Display Solutions uses an automated geometry alignment process in which the visual system is modelled in a simple CAD theatre design package (CompactDesigner from 3D Perception of Norway). An associated user interface calculates the geometry distortions required to correct for screen shape and projector angles, and downloads the results directly to a warping processor.

According to the company, the resulting projected image is as accurate as if hundreds of control points had been used in a conventional CRT procedure. Achieving optimum registration between channels where the sectors of a composite image blend with each other should require only minimal 'touch-up' correction. A further benefit of the method, devised by Display Solutions in close cooperation with warping processor provider 3D Perception, is that it avoids the need to mark reference points on the screen with ultraviolet or LED markers.

Increasingly capable solid-state projectors are not only routinely chosen for new installations, but are also specified for retrofit. As one example, when Electric Picture Display Systems replaced 12 older maintenance-intensive CRT projectors in a 360 degree bridge simulator at a leading marine simulation centre in Florida with Christie 1280DX projectors, it was able to claim a substantial reduction in operating costs. The Christie three-chip DLP units were also chosen because of their stable colour maintenance and established reliability. 3D Perception's UTM processors were used to correct the geometry for dome projection at the RTM Star Center, and to blend the images together seamlessly.

Databases

Modelling ever greater swathes of reality — sea, sky, weather, other vessels, coastal features, ports, harbour installations, human factors, ship systems from ECDIS to radar, vessel types ranging from submersibles to wing-in-ground-effect (WIG) machines, weapon systems, plus entire multi-platform mission scenarios to name a few — in ever greater detail requires increasingly large, complex and capable databases. Basic data storage capacity is less of an issue than the tasks of assembling and maintaining all the necessary database elements and compiling new code. Fortunately, as with image generation and projection, advances in commercial IT have shifted the boundaries of what is possible. The ability to port open applications to PC based systems readily and quickly has been critical, according to MARSIG. At the same time, new software tools and libraries have revolutionised environmental data acquisition and modelling to enable faster, more detailed and more accurate database development.

In the field

A small sample of what is being achieved in practice serves to illustrate the levels of authenticity now being delivered by contemporary technology.

At the Marine Institute's Centre for Marine Simulation in St Johns, Newfoundland, a high-capability bridge simulator regularly transfixes trainees with the closeness of its approximations to reality. At the system's visual core, a 360 degree horizontal field of view is filled by 10 high-resolution projectors which convey advanced computer-generated imagery portraying seascapes, target ships and land masses as well as own ship features and behaviour.

Replicas of vessel controls (helm, machinery controls etc); an integrated navigation system including compass, ECS, DGPS and radar; GMDSS and other bridge systems react synchronously and in real-time to student actions, all in according with the progress of the simulated voyage. Scenarios take place in either a generalised sea environment or in selected geographical areas with recognisable land and sea features and navigation aids. As a result of a recent upgrade, the system can also simulate harsh environments, including ice. Simulation is facilitated by a database of geographical, environmental and ship-specific data developed on site.

The system's 6m high projection screen surrounds a full-size (8.8m by 5.5m) bridge weighing 4t, the two being mounted on a moving platform first developed several years ago by aircraft simulator specialist CAE for Boeing 747 jumbo-jet simulation. This hydraulically actuated platform subjects bridge occupants to motions in six axes, complete with special buffet effects, wave and engine-induced vibration and, in the most drastic simulation, collision effects. To further enhance realism, a four-channel sound system reproduces the sounds of engines, sea, wind and vessel movement.

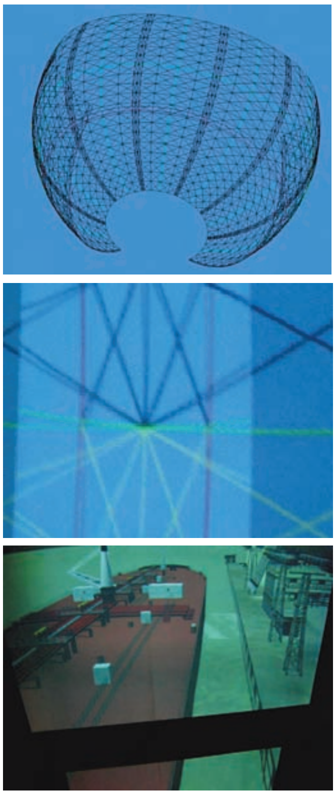
One of the first fully OpenGL-compliant PC-based image generation systems developed for the simulator market was simFusion from Evans & Sutherland. A 1280 by 1024 resolution, full-scene subpixel anti-aliasing, 32-bit colour rendering, 16MB of texture memory and ChanLock channel synchronisation were among the tempting advertised features. Kongsberg Marine has

Warping deficiencies can be corrected by pre-processing the projector video signals

used this system, re-branded as SeaView II, in a number of its Polaris bridge simulators. Image definition and update rates are such that trainees can readily spot critical land and sea marks required for safe passage in tight navigational scenarios. Users have found the system to be readily integrated with existing databases, and can work with existing Windows hosts and applications.

An early adopter of the Polaris/SeaViewII combination was the Royal Australian Navy, with a system able to handle 60,000 polygons simultaneously. For the RAN, this translated into an ability to manage a visual database representing some 200 nautical miles of coast, a capability it exploited in modelling nine major exercise areas.

Critical areas of the Australian coast are included — the Torres Strait, the Whitsunday Islands, Melbourne and its surrounds, Fremantle, Adelaide etc. Models were built using



Display Solutions uses an automated geometry alignment process in which the visual system is initially modelled in a simple CAD theatre-design package

CC-Cad, a PC-based program designed for model and terrain creation.

High fidelity visuals are complemented by a motion platform that reacts, sometimes with sickening (literally) effect, when the simulated ship crashes into waves or bumps against a pier.

In recent months an extensive simulation facility at the United States Merchant Marine Academy in New York State has been upgraded. A modified Kongsberg Polaris bridge system, termed a visual bridge ship-handling simulator (VBSS), utilises a mathematical model from Force Technology, formerly the Danish Maritime Institute, and an image system from MultiGen Paradigm Image Generation. Nine Davis 3D Perception DLP projectors display a 240 degree field of view visual scene (radius 29ft), with an additional 53 degree field of view astern of the vessel. An extensive bridge mock-up replicates, in addition to the total marine scene, effects of the environment (wind, water, current, depth, bank forces etc) and hydrodynamic interactions between own ship and passing vessels. It also simulates the behaviour of ship control, navigation and communication systems.

Pilots and watch keepers can see visuals dynamically representing various harbours. Scenes include other traffic, navigational aids and land, the latter to the level of detail of individual buildings and structures. Radar, depth sounder and other sub-system imagery is displayed on reproduction displays, the visuals being complemented by audio depictions of the sounds from ships, buoys, sea and weather. Depictions are adjusted automatically for a range of selectable sea states. A pair of virtual reality (VR) binoculars provides over-the-side visualisation.

A secondary VBSS, with a 186 degree visual scene is interfaced with the first so that the two simulators combined

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can provide total ship-handling interaction. Currently 12 geographic databases are available for use by either or both of the VBSS simulators.

Other manufacturers have likewise enlisted technological advances to enhance training realism. Transas Marine's state of the art Seagull Vis 4000 system paints a highly realistic synthetic visual scene that includes advanced depictions of fog and clouds, sun and moon lighting on the water's surface, changing lighting conditions at the horizon and the true positions of the sun, moon and other astronomical bodies for particular times and dates. Rain and snow precipitation changes direction as the vessel's speed and course change. A 3D bow wave and wakes alter according to ship speed and sea state.

Dynamic bump mapping surface texturing enlivens the 3D sea model, which also benefits from new sea wave textures and white caps. Such cues, together with the sight of other vessels pitching and rolling, enable trainees to judge wave direction and height. For coastwise navigation, the realistic spreading of water over drying areas and the changing colours as tides flood and recede helps users judge distances to islands, reefs and shallows.

Quantum3D's Heavy Metal racked system offers high sustained real-time frame rates across single or multiple synchronised channels

Finally, the capabilities of video gaming and high-end simulation are converging as both leverage commercial PC-based technology and open systems. Marine Simulation LLC is one company to have brought a surprisingly high level of simulated realism to PC screens in affordable primer simulators used before students progress to full bridge versions.

In achieving this, Marine Simulation has utilised Microsoft Windows XP Pro and Vista, Apple OS X and Linux operating systems; Javascript, Python, Lingo, C, Actionscript, HTML and PHP programming languages; 3DS, Max, Alias Maya, Cinema 4D, Blender and FREEship animation tools; plus OpenGL and DirectX graphic environments.

Paul Unterweiser, the company's founder, helped produce the submarine simulation game Seawolf SSN-21 for Electronic Arts before he became involved in 3D simulation development for professional training purposes. The company's vShip full bridge simulator is said to achieve a level of realism never before seen on a personal computer.

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