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66. Virtual Scylla: Interactive 3D and Artificial Life for Marine Virtual Heritage

Introduction

Virtual Heritage has become one of the very few active application domains to survive the technology-driven Virtual Reality (VR) "era" of the 1990s. Projects conducted over the past 15 years or so have produced a range of interactive 3D archaeological "exhibits", including 3D models of Stonehenge, Pompeii, and the Caves of Lascaux[2]. Unfortunately, many of these demonstrators have been very "sterile" – lacking the dynamic natural features evident in the real world, such as environmental effects and the life cycles of flora and fauna. From a maritime heritage perspective, again very few examples exist and, of those that have been developed, most exist in a form that is not accessible to a wide population of beneficiaries, including scientists, schoolchildren, and the general public. More recently, the exploitation of high-quality computer games and associated software tools, such as those underpinning (for example) popular "first person shooter" or "role-playing" titles, has led to a resurrection of interest in VR, courtesy of what is known as the "serious games" movement. Developments in serious games are helping to make educationally rich interactive 3D applications more affordable and accessible than ever before. The Virtual Scylla Project is an example of one such application[3].

The Virtual Scylla Project began in 2005 and seeks to develop a fundamental understanding of how artificial life (or "ALife") concepts can be used to drive feature- and function-rich serious games-based simulations of the evolution of British coastal marine flora and fauna communities on and around a VR of Europe's first artificial reef, the ex-Royal Navy Frigate HMS *Scylla.* The research is also relevant to maritime archaeology activities, from the digital archiving of historical wreck sites and associated artefacts, pre-dive planning and safety training, to larger coastal and marine management programmes.

Artificial life is the scientific study of the behaviour of biological organisms and systems in order to simulate how they interact with, and exploit, their natural environments in order to survive, reproduce, colonise, and evolve. Langton[4] describes ALife as "the study of man-made systems that exhibit behaviours characteristic of natural living systems" and how such systems attempt to "synthesise life-like behaviours within computers and other artificial media". One of the fundamental concepts in ALife is *emergence* which, as described by Holland[5], is a sense of "much coming from little", where the behaviour of the whole is much more complex than the behaviour of the parts. Extracting the principles behind nature's fundamental mechanisms into a set of simple rules for ecosystem-specific problem solving is gaining more and more international research attention[6].

Environmental and species data from the Scylla Reef have been used to undertake early research into the relationship that different measures of complexity have on simulations of Marine Biology. Experiments on behavioural, model, and data complexity have examined how these measures affect the results of simulations, especially with regard to accuracy in comparison to real-life data. The integration of ALife and Virtual Environments to develop visually rich, interactive scientific tools for assessing and predicting the status of ecosystems based on biological lifecycles and environmental change offers a new, challenging, and highly topical research opportunity.

Very few researchers have tackled the complexities of merging the two fields of endeavour and only one example has been found that specifically addresses the marine environment. That project[7] was based on a multi-participant virtual aquarium simulating a region of the Great Barrier Reef. However, the project was highly conceptual in nature and did not result in any real-world implementation.

Background to the Virtual Scylla Project

The early motivation behind the Virtual Scylla Project evolved from a research study that re-

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[2] Stone 1999.

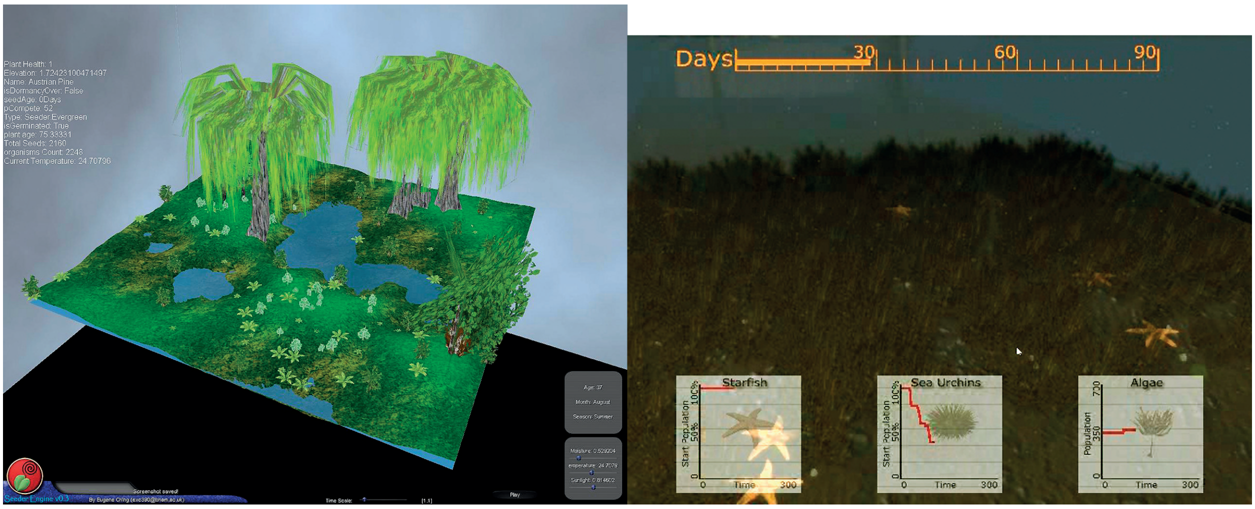
[3] e.g. Stone 2005.

[4] Langton 1986; 1989; 1995.

[5] Holland 1998.

[6] Kim / Cho 2006.

[7] Refsland et al. 1998.



Plant Health: 1
Elevation: 1.72423100471497
Name: Austrian Pine
isDormancyOver: False
seedAge: 0Days
pCompete: 52
Type: Seeder.Evergreen
isGerminated: True
plant age: 75.33331
Total Seeds: 2160
organisms Count: 2248
Current Temperature: 24.70796

Age: 37
Month: August
Season: Summer

Moisture: 0.529204
emperature: 24.7079
Sunlight: 0.814602

Screenshot saved!

Figure 66.1. Simulated growth of Mesolithic era vegetation using the *SeederEngine* (left image) and a screen shot of the *GEL* Engine "climate change game" (right image) showing 3D representations of starfish, sea urchins, and algae, together with population change graphs.

sulted in the development of a VR representation of a world that existed in Mesolithic time, over 10,000 years ago, before the Ice Age glaciers melted and flooded what is today the Southern Basin of the North Sea. In the mid-to-late 1990s, seismic datasets from this region revealed topological evidence of part of a large river valley, some 600 m wide with an observed length of 27.5 km. The river landscape seemed to form part of a large plain which, during the period from 18,000–8000 years before the present day, according to geographical and archaeological specialists[8], offered habitable conditions for hunter-gatherers moving between what is now the British Isles and Continental Europe.

A group of geological, geographical, and archaeological researchers at the University of Birmingham was established to exploit these datasets as part of a unique research project with two main aims. The first aim was to develop theories relating to the migratory and settlement patterns of ancient civilisations from continental Europe to the British Isles. The second aim was to develop a dynamic virtual reconstruction of the Mesolithic plain and riverbed to investigate how these patterns may have been influenced by the existence of natural food and dwelling construction resources. To do this, a new ALife visualisation system was developed called the *SeederEngine*[9]. The basic premises behind the functioning of this engine were quite simple. Building on the premises put forward by Kim & Cho[10] mentioned above, each artificial life entity has the ability to sense and react to environmental changes and each entity has a preferred condition with upper and lower tolerances for sunlight, moisture, temperature, elevation, soil type, nutrients, carbon dioxide, and space. As the condition exceeds the preferred level, the health of the ALife entity decreases until it expires.

The *SeederEngine* consisted of three main modules: a Real-Time Rendering Engine, an ALife Engine, and a "Seeder Manager" which managed the environment and plants. The environment component managed the initial settings of the virtual environment, such as the 3D terrain, simulated temperatures, moisture, sunlight and season, stored as an Ecosystem XML file. The plant component of the Seeder Manager managed the different species of plants, including 3D representations of growth stages from seed to maturity and characteristics of reproduction, competition, and adaptation to environmental factors. Predictions of large-scale past vegetation for specific regions of Mesolithic Northern England, at a latitude that approximates that of the Shotton River Valley, were based on research by Spikins[11] and others. The Rendering Engine was integrated with the ALife engine, displaying the state of growth of individual virtual plants as they grew and competed for simulated resources (e.g. *Figure 66.1*, left image).

Experiments with the *SeederEngine*, addressing the collective interaction between synthetic vegetation and simulated environmental factors, produced a range of impressive results, many comparable to their natural counterparts. Indeed, the results of these experiments established the *SeederEngine* concept as a strong scientific framework for supporting geo-archaeological and landscape vi-

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[8] e.g. REID 1913.
[9] CH'NG / STONE 2006.
[10] KIM / CHO 2006.
[11] SPIKINS 1999.

sualisation and for understanding the collective behaviours of these types of artificial vegetation[12]. However, a fundamental challenge still faced the development team in their attempts to establish credibility for this promising ALife tool. Without the ability to validate, or (at the very least) compare and contrast the results of the ALife simulations with real-world counterparts, the research might well become just an interesting academic software exercise. Consequently, attention was focused on attempting to identify a more contemporary ecosystem for study – one that was at an early stage of development, was accessible for comparative research exercises and was reasonably straightforward to incorporate into a real-time visualisation package. It was at this point that the Scylla Reef became the focus of interest.

HMS Scylla

On 27 March, 2004, the ex-Royal Navy Batch 3 Leander Class Frigate, HMS *Scylla* was deliberately scuttled by the National Marine Aquarium (NMA) in Whitsand Bay (off the southeast Cornish coast) to become Europe's first artificial reef[13] *(Figure 66.2)*. HMS *Scylla* was the last frigate to be built at nearby Devonport Dockyard in 1968. During her service in the Royal Navy between 1970 and 2003, she saw action in the Icelandic Cod Wars of the 1970s, confronting and ramming the Icelandic gunboat *Aegir.* She missed active duty during the Falklands crisis in 1982, due to an extensive modernisation programme, as a result of which she was equipped with Exocet and Seawolf missile systems. Much later, in 1991, *Scylla* took part in Operation Desert Storm in the Middle East.

After decommissioning in 1993, *Scylla* was moored in Fareham Creek near Portsmouth, from where she would normally have been removed in due course for dismantling at a commercial scrap yard or sold on to another one of the world's navies. However, some seven years later, and supported by the South West Regional Development Agency, she was purchased by the NMA for £200,000 and towed back to her "birthplace" in Devonport Dockyard for stripping, cleaning and hull modifications to support safe penetration by divers.

Figure 66.2. Final Detonation of scuttling charges onboard HMS *Scylla*; Whitsand Bay, 27 March 2004 (image courtesy of National Marine Aquarium).

Today resting on the sea floor at a depth of 24–26 m, the *Scylla* provides an excellent opportunity for conducting regular validation and verification studies throughout the course of the Virtual Scylla Project. Indeed, at the time of writing, the authors of the present paper have undertaken four expeditions to the wreck, accompanied by marine and technical specialists from the NMA. The expeditions have yielded a considerable amount of information about the declining condition of the vessel and colonisation cycles of various forms of marine life, and the use of the Aquarium's *VideoRay* remotely operated vehicle (ROV) has been invaluable in this respect. As well as the NMA, stakeholder and technical support for the project has been forthcoming from the Marine Biological Association (MBA), the Royal Navy (Flag Officer Sea Training – Hydrography, Meteorology and Oceanography, FOST HM), the Society for Underwater Technology, Plymouth Marine Laboratory, and the University of Plymouth's Marine Institute.

The Virtual Scylla

As a result of earlier developments in visualising the submerged Mesolithic riverbed and plain, the first 3D development toolkit and games engine to be investigated as a potential candidate to create the Virtual Scylla environment was the CryEngine and CryEngine Sandbox. As well as the engine's ability to support large areas of open water (as is evident during the opening sequences of the action game *FarCry*, for which the CryEngine was originally developed), the engine was particularly noted for its ability to accept imported 3D geometries relatively seamlessly. The Birmingham Team set out to obtain as much data as possible about the *Scylla*, up to the point when she was scuttled in 2004, in order to construct as accurate a 3D model as possible. In the event, and with the exception of images and schematics forthcoming from the NMA, plus access to a scale model built using plans held by Her Majesty's Naval Base at Devonport, very little information was available. Consequently the early 3D model of the vessel and her new underwater

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[12] Ch'ng / Stone 2006.

[13] Leece 2006.

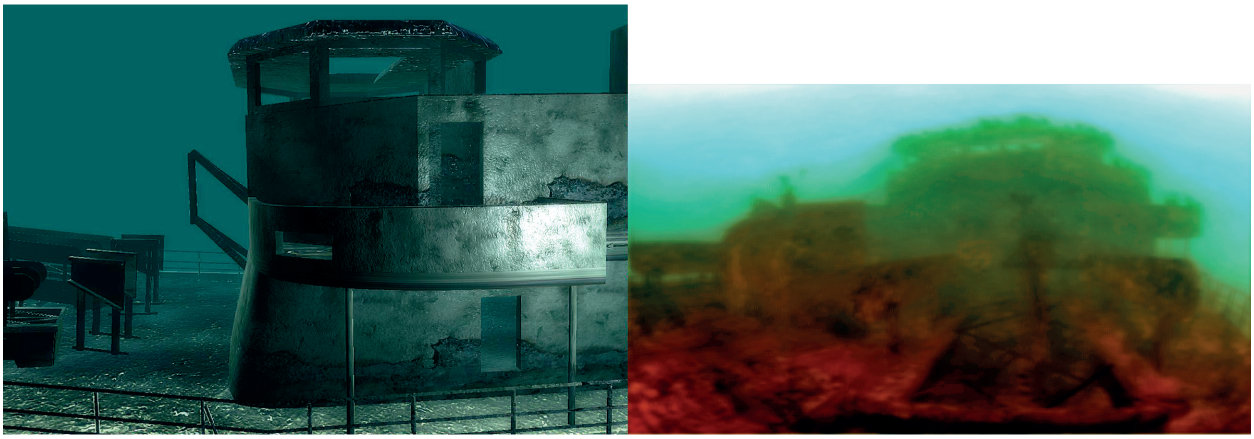

Figure 66.3. 3D models of the *Scylla* wreck. The image on the left was developed using the CryEngine Sandbox; on the right using Quest3D.

environment had to be constructed from scratch. However, early *VideoRay* ROV expeditions to the wreck, accompanied by divers from the Marine Biological Association, helped significantly, as did bottom profiling and sidescan sonar surveys of the wreck site, made available to the team by FOST HM.

Once the 3D (3ds max) model of the *Scylla* was completed it was imported into the CryEngine test environment to be scaled and textured. Whilst the *Scylla* model itself looked reasonably convincing, the complete virtual environment was still devoid of an underwater "ambience" (*Figure 66.3*, left image). At that point, it was discovered that the CryEngine's underwater fogging capabilities were less accurate than its above-water counterpart. To overcome these limitations (and, in doing so, avoid having to invest considerable sums of money to secure full access to the CryEngine's software technologies), the decision was taken to investigate the capabilities of a relatively new (at that time) real-time 3D environment development tool, Quest3D. The Quest3D tool has many advantages over using commercial games engines, not least the fact that the product supports royalty-free licensing for developed applications. From the perspective of the Virtual Scylla Project, Quest3D provided support for the creation of an accurate and realistic control system for the virtual ROV, implemented using a Microsoft *Xbox* gamepad controller. In addition, it was possible to create more realistic subsea lighting, particle and ROV camera dome distortion effects (*Figure 66.3*, right image).

GEL Artificial Life Engine

As well as the Virtual Scylla's potential in delivering real-time visualisation of colonisation processes for education and marine biology (to mention but two applications), a key benefit for academic endeavours is the ability to exploit the Scylla Reef as a test bed for fundamental simulation research. The Reef provides researchers access to a significant amount of complex data on the marine population, due to its location and status as a destination for the diving community, its promotion by the NMA, and exposure by the media. First-hand accounts from dive teams of the annual rise and decline of communities of species provide rich datasets that can be reproduced for simulation. In addition, maintenance by the Marine Biological Association of MarLIN, the online Marine Life Information Network[14], which encourages volunteer recording through the MBA's Sealife Survey, provides comprehensive records on the majority of species present on and around the Scylla Reef, as well as references to key marine biology research papers.

Exploiting the *Scylla* as source of marine biological data has enabled an early examination of how models and simulations of marine ecologies behave under different measures of complexity. Complexity in this case has been defined as three factors: behaviour – the level of detail of behaviour assigned to ALife agents; data – the resolution and form of input data; and scale – the spatial and population scales of simulations. A series of early experiments were conducted to investigate the relationships between different measures of complexity and how they affect the results of simulations of marine biology. The experiments were based on a simple ecosystem comprising starfish, sea urchins, and algae. From the MarLIN database, basic lifecycle characteristics of these three agents were identified. For example, starfish (predators of sea urchins) feeding rates are inhibited by rising temperatures; sea urch-

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[14] Hiscock / Tyler-Walters 2006.

ins predate on algae; higher water temperature negatively affects the growth rate of algae.

The experimental results were visualised using custom built software libraries that as a package were named the GEL engine (Graphics and Environmental Libraries). The engine was written in C++, and the graphics were rendered using DirectX 9.0, although future incarnations of the engine would be required to be updated to DirectX 10.0 for the purposes of optimisation and the use of effects such as instancing – drawing multiple similar 3D objects in one rendering pass.

Space precludes including the results of the many experiments that were conducted to support this research into simulation complexity[15]. However, of relevance to the focus of the Virtual Scylla Project is the exploitation of the underlying software of the ALife engine developed for the complexity research in the production of an interactive climate change "serious game" (*Figure 66.1*, right image).

At the start of the "game" the user is made aware of each species' predatory behaviours and how higher temperatures may affect this and other behaviours. Two different choices are then given – firstly, the level of temperature change that will be simulated, from normal to normal-plus-5 Degrees C, and secondly, the ratios of the predator species to each other. For example, the user can choose large numbers of starfish, large numbers of sea urchins, or equal amounts of both.

The aim is that the user learns that predation is not always a negative factor. A few starfish eating sea urchins will allow a greater abundance of barnacles and algae without decimating the population of sea urchins. If too many starfish are present, the sea urchin population will be significantly reduced, and this will in turn result in increased mortality of starfish through starvation. The end user also learns that climate change could also lead to greater diversity, but perhaps only at certain temperatures. Normal sea temperatures could lead to starfish populations consuming most, if not all, sea urchin populations. If rising temperatures lead to a reduction in this consumption, then sea urchins could potentially thrive. Higher temperatures could, however, result in the reduction of algae and barnacles, reducing the food source for urchins, and hence the food source for starfish.

Conclusions and Next Steps

As well as the academic and scientific activities undertaken during these early phases of the Virtual Scylla Project, the virtual reconstruction and games-like interactivity of the virtual wreck site and GEL Engine ALife demonstrators have been highly successful in educational "outreach" events. Experiences with audiences of adults and schoolchildren at lectures and events have stimulated the NMA to install permanent "exhibits" of these demonstrators. These will exist alongside another serious game project under way at the time of writing, addressing the transfer of children's remote handling skills from a virtual representation of the Aquarium's ROV "Aquatheatre" – in effect a large tank featuring an ROV "assault course" – to control of the real submersibles in the real tank.

Future opportunities are also being explored with the aim of expanding the ecosystem database and to bring the Virtual Scylla model up-to-date in conjunction with the National Marine Aquarium and the Marine Biological Association. In support of this, WebScylla is a project that attempts to demonstrate emerging Web3D technologies through the creation of a 3D model of the *Scylla* artificial reef for delivery over the Web. The focus of the project will be on developing an interactive 3D visualisation of scientific data collated by marine biology specialists, such as the MarLIN Database mentioned earlier, and other sources of Whitsand Bay environmental research[16].

In addition to *Scylla*-related activities, a new requirement for a more generic interactive 3D tool supporting subsea visualisation based on serious games technologies has recently arisen. As mentioned earlier, during the course of the Virtual Scylla Project, the Birmingham and NMA team received considerable support from the Royal Navy. In particular, using the bottom profiling and side-scan sonar data provided by FOST HM, the Virtual Scylla Team has been able to identify structural changes to the wreck over time. This has supported the planning of activities during the short windows of opportunity available to conduct ROV surveys on the actual wreck. Whilst presenting the Virtual Scylla Project at an NMA public event, a representative of FOST HM expressed interest in developing the serious games effort further, to address the visualisation of seabed topography and artefacts, using bathymetric data collected by the Navy's hydrographic fleet. Since the early meetings with FOST HM, the requirement has evolved further into the development of a visualisation tool based on real bathymetric data that could be exploited not only by the Royal Navy, but also by marine and maritime heritage organisations for the mapping of seabed sites and artefacts and the planning of expeditions to those sites.

A process to support the rapid conversion of bathymetric data into a format suitable for real-time exploration using a modified games engine

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[15] For these, see Stone et al. 2009.

[16] Francis / Stone 2009.

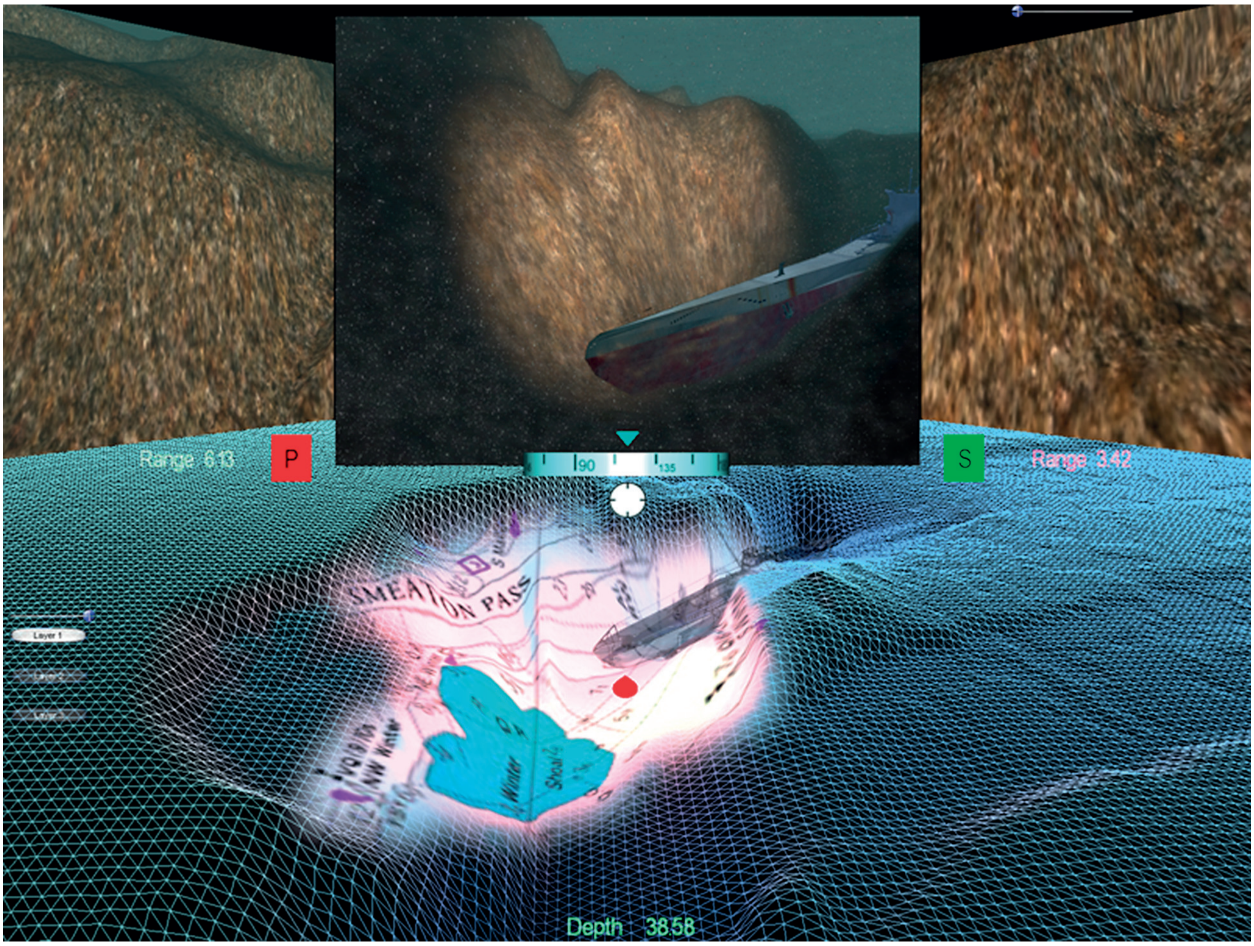

Figure 66.4. A multi-window interface concept capability demonstrator for visualising seabed topology, based on real-time virtual reconstructions of bathymetric data and simulated ROV/probe camera views.

has been completed. The conversion takes high-resolution greyscale height map images derived from Fledermaus bathymetric survey datasets (in the present case data from surveys in Plymouth Sound) and uses the brightness levels to generate a topographical map in 3D, using the 3ds max modelling package. This map is then converted into a polygonal representation, suitable for import into a real-time games (or rendering) engine and development toolkit – again Quest3D – where it can be enhanced using a variety of visualisation techniques, added to (using other 3D models, for example) and interacted with using a range of data input and display technologies. In addition, an early concept human-system interface has been developed around the converted bathymetric data to demonstrate a multi-window interface format *(Figure 66.4)*, depicting close-proximity seabed topography and simulated views from port-, front-, starboard- and downward-pointing virtual cameras onboard a deployed probe, or ROV, which can be controlled using an Xbox hand controller. The next stage is to develop realistic and abstract visual methods of depicting a range of man-made artefacts likely to exist on the seabed, together with representations of sediment data (type, roughness, mobility, backscatter qualities, reverberation), bathymetric data (building on and refining the current conversion technique and linking models to predicted tides where there are large ranges), and tidal stream data (strength and direction of stream which affects ROV piloting and also affects seabed objects' burial profiles).

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