Marine GIS: 3D Graphics Applied to Maritime Safety

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1. Introduction

Maritime safety is growing in importance with the constant growth of the sea shipping as well as pleasure boats and other boats segments. A gradually growing number of cargo ships that carry hazardous loads make possible collisions and groundings of sea vessels poise serious treat to the environment, as well as the life and health of the people and animals inhabiting coastal zones. Growing number of pleasure boats makes collisions between big ships and small crafts more and more likely to happen, with often fatal consequences to the lives of the crews of the second. The disaster and damage caused in the event of major sea collision can be very difficult and costly to deal with. Maritime safety has also a huge impact on the world economy where the cost of shipping, clearly related to the level of safety, is an important factor.

In order to decrease the number of accidents the world sea authorities introduced many standards and new technologies like ECDIS and AIS (IMO, 2004). However these did not solve all of the issues and there are many points of the marine safety management process where improvements can be introduced. These include bathymetry data collection and processing, nautical charts production, providing navigation aid software on-board the boats, vessel traffic planning, analysis and monitoring, as well as improving the level of training accessible for mariners.

One particular aspect of maritime safety involves the visualization of the situation close to any particular ship, so that appropriate action may be taken. While many features may be seen directly from the bridge in good conditions, bad lighting and weather may obscure them, and much of the necessary information concerns maritime control, and is only available on charts or in pilot books.

It seems clear that an integration of all these components within a single simple view would improve maritime safety. A sufficiently-good integrated computer display, if it could mimic the real view from the bridge, could be developed at moderate cost and should be sufficiently straightforward to match with the real world while adding those extra features necessary for navigation. Modern PC-laptops are powerful enough to run such system, and so it would make cheap but superior alternative to chart plotters used by boats owners nowadays.

Based on this observation we proposed a new type of special GIS software, based on kinetic 2- or 3-dimensional data structures, a sophisticated 3D visualization engine, and intelligent navigation rules. The Marine GIS as a navigation aid is meant for use on board of marine vessels using a PC-laptop integrated with on-board equipment (GPS, AIS, ARPA) through the standard NMEA interface.

2. Creation of the Marine GIS

Ford (2002) demonstrated the idea of 3D navigational charts and concluded that 3D visualization of chart data had the potential to be an information decision support tool for reducing vessel navigational risks. Our intention was to adapt IHO S-57 Standard Electronic Navigation Charts (IHO 2001) for 3D visualization.

Several components are required for such a system. Firstly, an appropriate 3D graphics view of the surrounding land- and sea-scape is needed. Secondly, we needed to populate this engine with the terrain, landscape, buildings and ships appropriate to the geographic location. Thirdly, bathymetry was modeled directly from samples of survey soundings, giving a triangulated terrain model of the sea floor. Fourthly we needed to create models of specific navigational (ships, buoys and lighthouses). Fifthly, chart information was obtained from ENC data, and new techniques were needed to view this 2D information in 3D. The steps described above were implemented in prototype form in the work of Gold et al. (2004), although extensive revisions are being performed. Sixthly, to provide real-time data of ships a preliminary interface between the Marine GIS and the AIS has been developed by Stroch and Schuldt (2006).

2.1 The 3D Graphics Engine

The development of our graphics system is based on Graphic Object Tree that manages the spatial relationships between graphic objects. These objects may be drawable (such as houses, boats and triangulated surfaces) or non-drawable (cameras and lights). The basis of the tree is that objects can be arranged in a hierarchy, with geometric transformations expressing the position and orientation of an object with respect to its parent – for example the position of a light in a lighthouse, or a camera on a boat. This was described in (Gold et al., 2004). Our recent work was to take the tools already developed, and add features specific to marine navigation.

2.2 Terrain, buildings, objects

After the development of GOT we had to develop a landscape model close to the coast, in order to permit reasonable coastline silhouettes (Dakowicz and Gold, 2003), and in step three we added the bathymetry based on samples of the survey soundings. Shoreline points were calculated from the intersection of the triangulated terrain model with the sea surface, which may be changed at any time to simulate tides.

These shoreline points were incorporated within a kinetic Voronoi diagram layer, expressing the neighbourhood relations on the sea surface, and this was used for collision detection by adding the real-time ship locations.

2.3 IHO data display

Marine features identified in the IHO S57 standards were incorporated. Figure 1 shows the selection of particular S57 data items for display. These included navigational buoys, lights, soundings, depth contours, anchorage areas, and others.

Selecting a ship permits the viewpoint to be changed to that ship, permitting an evaluation of the point of view of the oncoming traffic. Other selected objects may be queried for their attributes.

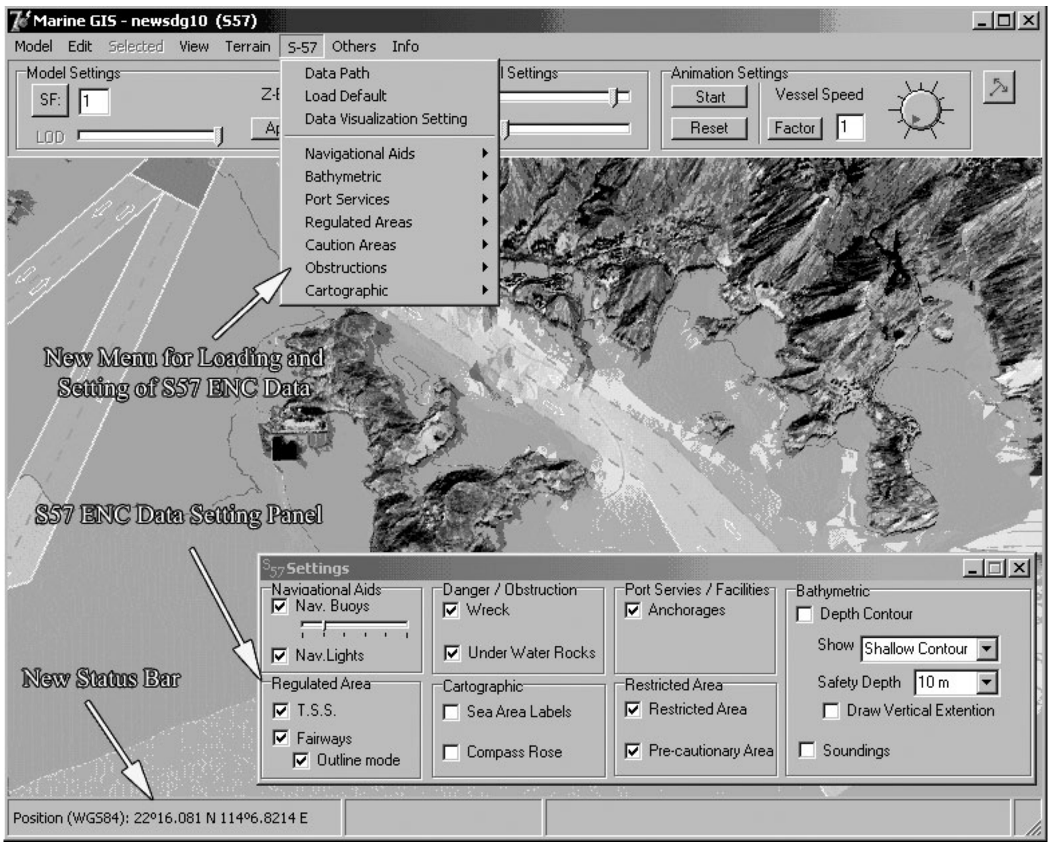

Figure 1. S-57 data menu and S-57 settings dialogue

2.4 Overview of the system

Different features of the Marine GIS are shown on Figures 2-5.

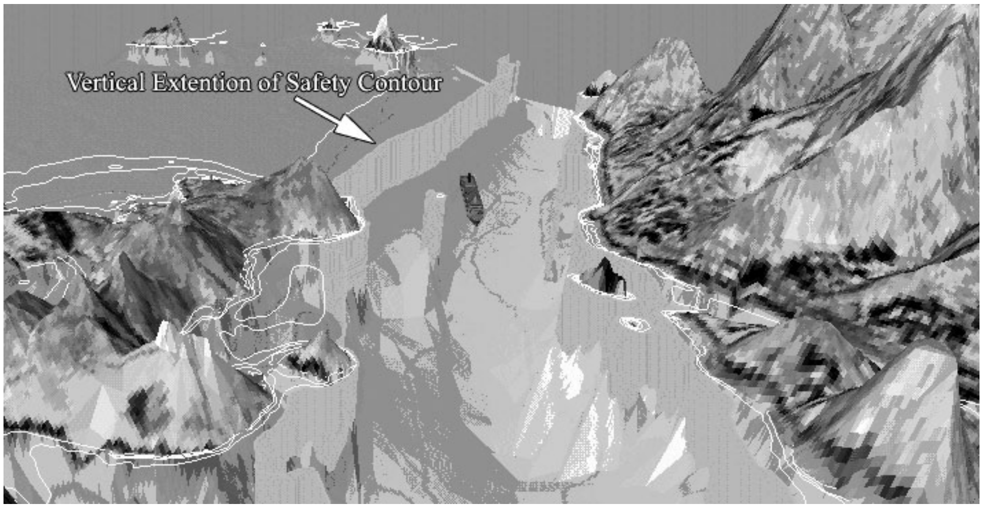

Figure 2. Visualization of safety contour with vertical extension

Safety contours may be displayed along the fairways, and a 3D curtain display emphasizes the safe channel. Fog and night settings may be specified, to indicate the visibility of various lights and buoys under those conditions. Safety contours and control markers may appear illuminated if desired, to aid in the navigation. The result is a functional 3D chart capable of giving a realistic view of the navigation hazards and regulations.

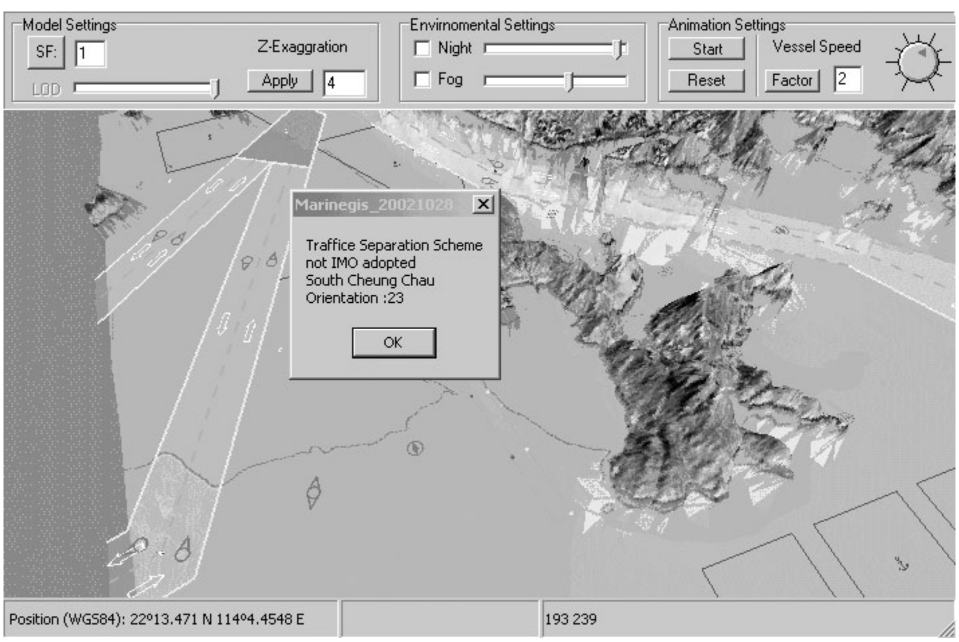

Figure 3. Scene showing the terrain, traffic separation scheme, anchorage area, and other S57 features with the result of query: attributes of traffic separation scheme are displayed

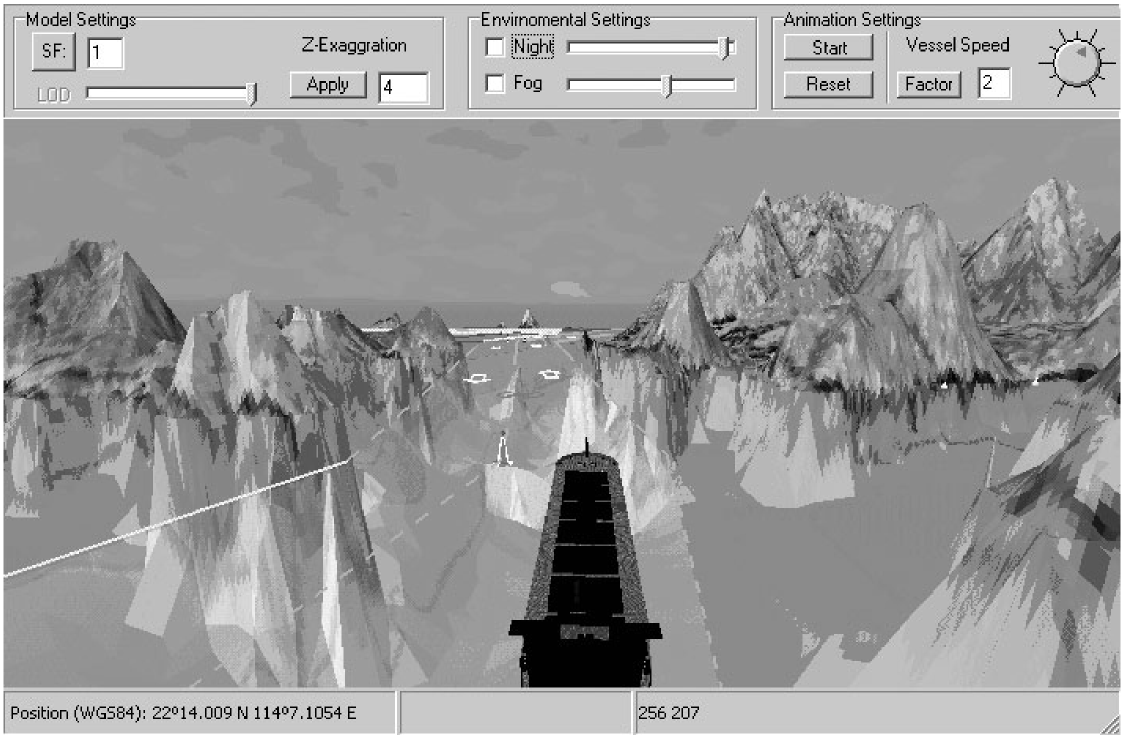

Figure 4. Scene in navigational mode. When animation mode is activated, the viewpoint will follow the movement of the ship model

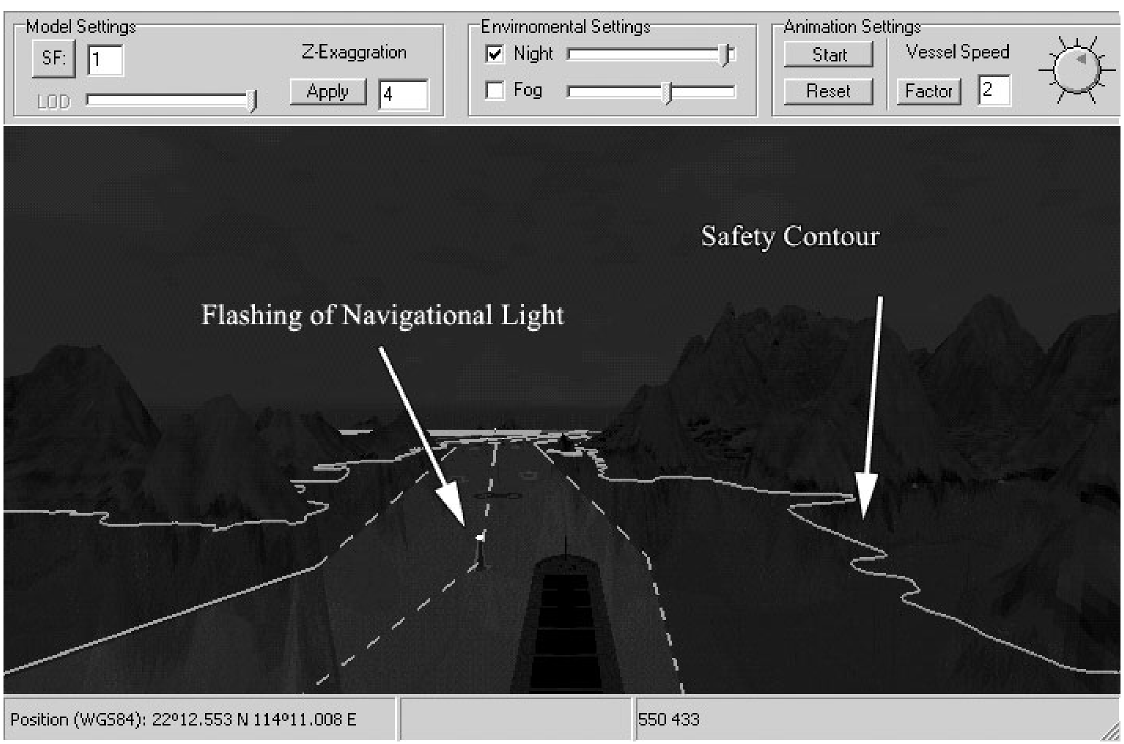

Figure 5. Night scene with navigational lights, safety contour and traffic separation scheme

3. Integration of AIS

Integration of AIS transponder into the Marine GIS was performed in two steps. First an external specialized library for reading AIS messages was designed and implemented using UML modeling tools and the best object-oriented programming practices. Then the library was incorporated into the Marine GIS 3D interface.

The software created allows for real-time tracking and recording of the AIS data, as well as for its later playback for test and simulation purposes. Several safety features related to the AIS specificity were implemented and tested. The integration with the NMEA multiplexer allowed for incorporation of the GPS data of the observer's own position. Figure 6 shows a view of AIS targets moving in the Bristol Channel recorded during field tests in Newport.

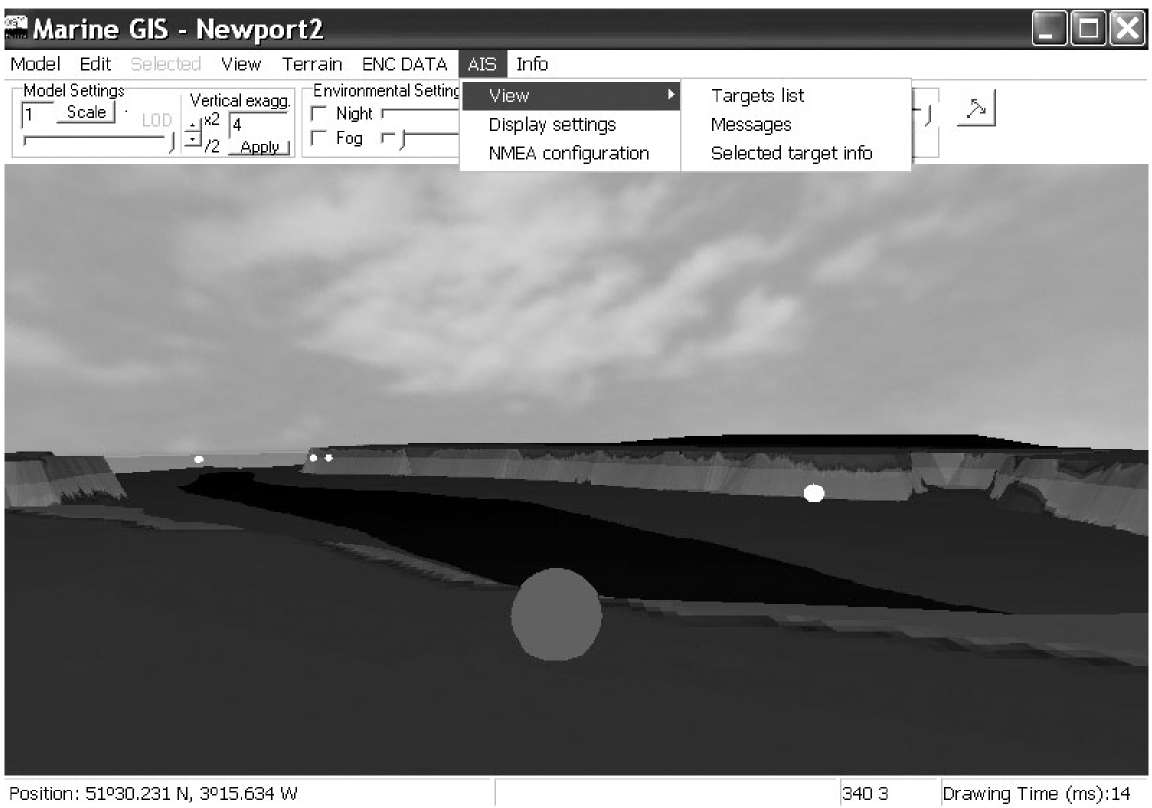

Figure 6. AIS targets on Bristol Channel (distant white spheres) seen from the observer's point of view (the gray sphere in the forefront). The targets sizes are exaggerated as the distance is about 10 NM

4. Acknowledgements

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5. References

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Biography

Rafal Goralski was one of the creators of Marine GIS at the Hong Kong Polytechnic University. For several years he was an industry software development specialist, programmers' team leader and project manager. Currently he is studying for his PhD at the University of Glamorgan under supervision of Professor Christopher Gold.