

THE DEVELOPMENT OF A DYNAMIC GIS FOR MARITIME NAVIGATION SAFETY

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ABSTRACT:

Maritime safety has a huge impact on the world economy and our everyday lives. The vast majority of world cargo is carried by sea by huge container-carriers. Cargo ships carrying hazardous loads pose serious threats to the environment. The disaster and damage caused in the event of major sea collisions can be difficult and costly to deal with. In our research we took a broad look at the problem of maritime safety in order to identify the areas where application of a Marine GIS could lead to the most significant improvement. Then we proposed a new type of GIS system for maritime navigation safety. The system takes advantage of the newest developments in computer graphics and GIS technologies, and is aimed at tackling the main cause of marine accidents – human errors – by providing navigational aid and decision support to mariners.

1. INTRODUCTION

In the last decade many researchers from GIS interested in marine applications have been trying to describe and provide a prototype of a suitable GIS for marine purposes – a Marine GIS (Li and Saxena, 1993; Wright and Goodchild, 1997). Depending on their interests and needs different possible solutions have been described varying from the traditional terrestrial 2D GIS used for marine purposes, electronic charting and navigational aid applications, to the propositions of new real 3D specialized temporal systems for oceanography.

A weak point of many of these was that they did not address the main requirements of the marine realm – multidimensions, uneven distribution and dynamism of data. One effort to address these needs was presented by Gold and Condal (1995) and later by Gold (1999). The authors proposed the use of a locally updateable, self-adapting, kinetic data structure, keeping both the Voronoi diagram and its dual Delaunay triangulation called the “Quad-Edge”. This seemed to fit the need perfectly.

Meanwhile the marine safety problem is becoming more and more important with the constant growth of shipping and pleasure boating. Cargo ships carrying hazardous loads pose serious threats to the environment, as well as to the life and health of the people and animals inhabiting coastal zones. The disaster and damage caused in the event of major sea collision can be difficult and costly to deal with (Ward et al., 1999; Talley, 2005). This also has a huge impact on the world economy where the cost of shipping, clearly related to the level of safety, is a big factor. The increasing number of pleasure boats and the growing density of sea traffic increase the risk of collisions between pleasure boats and cargo ships. The consequences are often fatal.

Studies on the classification and reasons for the marine accidents show that human error is the most common cause of problems (Talley, 2006). To address this researchers like Goulielmos and Tzannatos proposed an information management and decision support system as early as 1997. Since then sea authorities have introduced many standards and

new technologies that support navigation and communication, e.g. ECDIS (IMO, 2004; Ward et al., 1999) and AIS (IMO, 2004). However we still see a lot of points where improvements can be introduced. These include bathymetry data collection and processing, nautical chart production, providing navigational aid software onboard, vessel traffic planning, analysis and monitoring, as well as improving the level of training for mariners and pleasure boats owners.

One particular aspect of maritime safety involves the visualization of the situation in direct proximity 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 is clear that an integration of all these components within a single simple view would improve maritime safety, and that modern navigational aids should take advantage of the latest graphics and GIS technologies. A sufficiently well integrated computer display, able to mimic the real view from the bridge, can be developed at a moderate cost. It 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 a system, and so it would make a cheap but superior alternative to chart plotters used by boats owners today.

2. CREATION OF THE ‘MARINE GIS’

The system we propose is a new type of GIS, based on kinetic data structures, a sophisticated 3D visualization engine and a combination of static and real-time data and intelligent navigation rules. It is targeted specifically for small boat owners and ship navigators, and is aimed at providing navigational aid and decision support superior to today’s ECDIS software, perhaps at a lower cost. We believe that it will be a significant contribution to the problem of maritime safety and will help to minimize the likelihood of human error marine accidents.

The idea of 3D navigational charts was presented by Ford (2002) with conclusion that 3D visualization of chart data had the potential to be an information decision support tool for reducing vessel navigational risks. Our intention is to adapt IHO S-57 Standard Object's and Attributes catalogue for Electronic Navigation Charts (IHO, 2000) for 3D visualization.

Several components are required for such a system. Firstly, an appropriate 3D graphics view of the surrounding land- and sea-scape was needed. A specialized graphical engine using a basic scene-graph structure was implemented. Secondly, the engine had to be populated with the terrain, landscape, buildings and ships appropriate to the geographic location. Thirdly, bathymetry had to be modelled directly from samples of survey soundings, giving a triangulated terrain model of the sea floor. Fourthly models of specific navigational objects (ships, buoys and lighthouses) had to be created. These were developed separately with modelling software and placed at the appropriate locations on the land- or sea-scape. Fifthly, chart information was obtained from ENC data, and new techniques were needed to view this 2D information in 3D. Rights-of-way, anchorages, restricted zones etc. were drawn on the sea surface (Figure 1), and this appears to be comprehensible and effective. Sixthly, to provide real-time data of ships we had to develop a preliminary interface between the 'Marine GIS' and the AIS (Gold and Goralski, 2007) in cooperation with the French Naval Academy (Stroh and Schuldt, 2006).

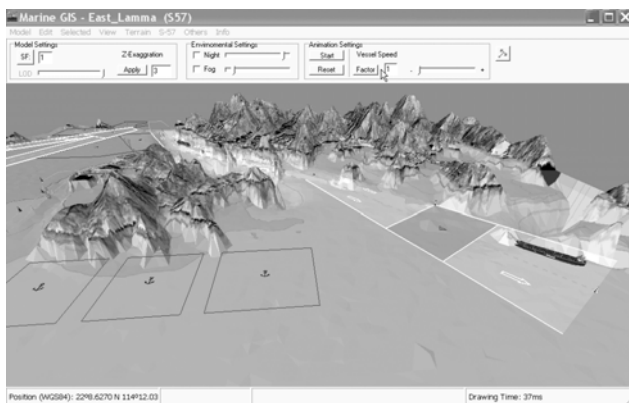


Figure 1. Different S57 navigational features displayed in the general view mode

2.1 The 3D Graphics Engine for Scene Display

The idea behind the system was based on the observation that application of a 3D view in navigational software would be a significant improvement, letting navigators assess the situation precisely in a more natural way. Graphical engines used in today's games were great examples of possibilities and it seemed clear that today's navigational systems should take advantage of these new technologies.

However the graphical engines available on the market were optimized only for display and were not able to maintain spatial relationships and to provide the required GIS features. Hence we had to develop our own Graphical Engine, using the latest object-oriented design.

The development of the graphical system was based on the Graphic Object Tree that manages the spatial relationships

between graphic objects. These objects may be drawable (such as lighthouses, 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 (Figure 2).

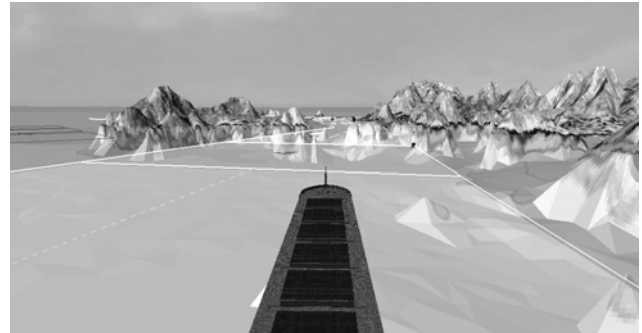


Figure 2. The onboard view of the model

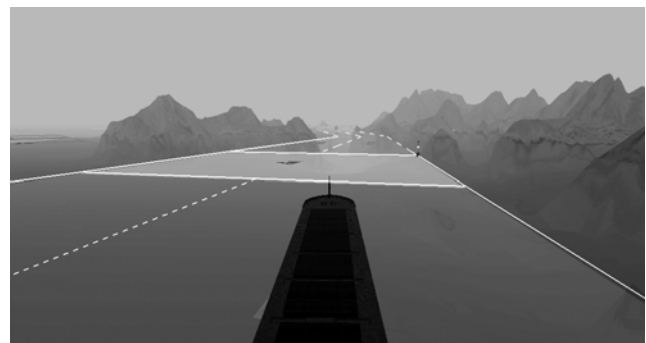


Figure 3. The onboard view with night and fog simulation

The Graphical Engine integrates multiple viewpoints and cameras, and has the capability of performing a simulation of different light and weather conditions, such as night or fog (Figure 3). An important part is the manipulation interface, designed to allow simple performance of typical navigational tasks as well as comprehensive assessment of the displayed scene.

2.2 Kinetic Voronoi Diagram for the Spatial Relationships of Marine Objects

After the development of the Graphical Engine an appropriate data structure to maintain the real-time locations of the ships and other navigational objects had to be developed. We decided to use the "Quad-Edge" structure in which the generators of the Voronoi diagram (VD, Figure 4) represent marine vessels, following the original idea of Gold and Condal (1995) and Gold (1999). As the ships move the positions of points are updated in real-time to reflect the current locations of ships obtained via AIS transponder. The moving-points algorithm (Gold et al., 1999) is used for local updates of the structure.

A landscape model close to the coast also had to be developed, in order to permit reasonable coastline silhouettes (Dakowicz and Gold, 2003), and the bathymetry based on samples of the survey soundings was added. Shoreline points were calculated from the intersection of the triangulated terrain model with the

sea surface. The elevation of the surface may be changed at any time to simulate tides, resulting in recalculation of these points.

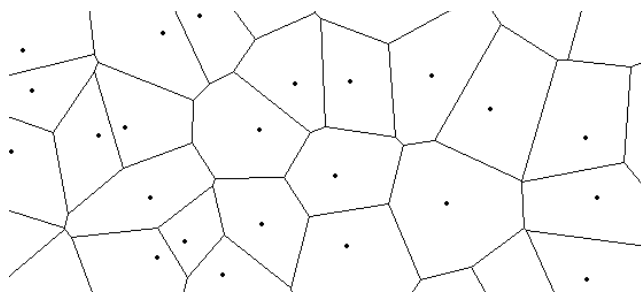


Figure 4. A simple Voronoi diagram

The shoreline points were also incorporated within the kinetic Voronoi diagram layer representing the ships, expressing the neighbourhood relations on the sea surface, and this was used for collision detection and avoidance. The kinetic Voronoi diagram layer of our system is shown on the Figure 5.

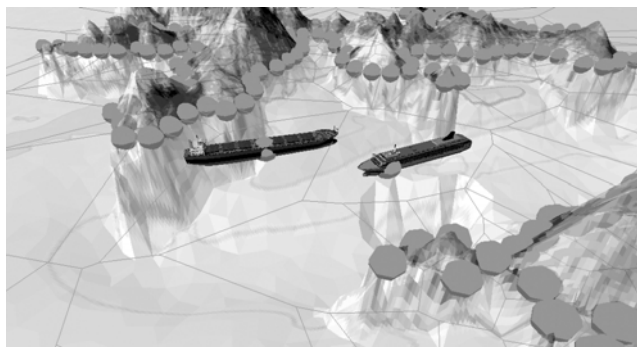


Figure 5. The incorporated kinetic VD for maintenance of spatial relationships and collision detection

2.3 AIS for the Real-Time Vessel Tracking

To provide real-time ship data an interface between the 'Marine GIS' and the AIS has been developed. The integration was performed in two steps. First an external specialized library for reading AIS messages was designed and implemented using UML modelling tools and the best object-oriented programming practices. Then the library was incorporated into the 'Marine GIS' 3D interface.

The library 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 specifically to AIS were implemented and tested. The integration with the NMEA multiplexer allowed for incorporation of the GPS data of the observer's own position.

The system was tested in various areas on the South Wales coast by tracking AIS targets moving in the transponder's range. Data of ships moving in the Bristol Channel were recorded from the coast near Newport for further development of the system in our lab, which is located inland, out of range of AIS transponders. Figure 6 shows a view of AIS targets moving in the Bristol Channel recorded during field tests in Newport.

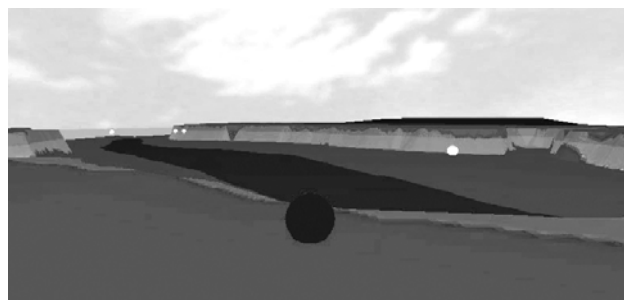


Figure 6. AIS targets (distant white spheres) recorded from the coast location (the dark forefront sphere). The targets are exaggerated, as the distance is over 10NM

3. FUTURE WORK

Although our preliminary results are very promising there are several areas where further development has to be taken. It will cover mainly the following areas:

- Providing open architecture and standards-based data exchange mechanisms – to facilitate use of the Visualization Module for various marine display applications
- Further development of ENC reading capabilities – implementation of new objects from the S-57 Objects Catalogue, and reconstruction of the 3D bathymetry model from native ENC soundings data
- Integration with external intelligent navigation rules systems – to support decision making and reduce human-related errors
- Revision of the user interface and manipulation mechanism – navigational operations must be performed in no more than a few simple steps

As the system is currently in the development phase, its usability and value have yet to be verified. Hence the implementation stage will be followed by comprehensive testing and validation. Tests will be performed onboard real marine vessels of different classes, based on a measurable set of criteria, in cooperation with experienced marine navigators.

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