Scientific Visualization: a Promising Tool for Marine Habitats Management

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Abstract

Enhanced visualization of scientific data can widely improve the understanding of the phenomenon or data being studied. Aiming at the actual demand of scientific management for marine environmental information, the Italian consulting company Underwater Bio-CArtography (UBICA s.r.l.) designed a marine environmental information service system based on GIS and new visualization technologies and software (ArcGIS 10, Surfer 9, Blender, Photo Scene Editor 2, E-On VUE9, Unity, Cinema 4D, 3D Max). This system is developed for data management support. Through the marine environmental data visualization analysis, the system can inquiry, statistics and forecast the marine environmental information, therefore providing fast and intuitive decision support information for the marine environmental management department. UBICA pooled expertise in disciplines including archaeology, underwater exploration & scientific diving, marine robotics and instrumentation, knowledge representation, photogrammetry, virtual reality, and digital data presentation. UBICA’s products allow visualizing the submarine habitats enhancing their peculiarities. This allows educational and outreach experiences that may improve the correct perception of the sea beds. The interactive 3D model gives a correct visualization of the benthic biocoenosis and/or man-made structures and finally allows a suitable and well focused management of the marine environment. The variety of visualization tools developed on the project was more successful with the general public than with the scientists. However, new generations of researcher expressed enthusiasm for these promising tools. The participation of UBICA at the ongoing EU project “Training Network for Monitoring Mediterranean Marine Protected Areas” (MMMPA; FP7-PEOPLE-2011-ITN) will results in a series of best practices and procedures for collecting, storing, and visualizing underwater-biological and/or archaeological data.

1. Introduction

Traditionally developed to describe terrestrial environments, the thematic bionomic cartography techniques, are commonly used to describe the spatial distribution of marine benthic populations.

Paper maps revealed soon their limitations when trying to represent some of the complex models often used to describe the marine ecosystems and their ecological processes, due to their diversified spatial and temporal scales. Bionomic mapping has been considered for decades the primary tool for marine ecosystems analysis and understanding [1]. The development of Geographic Information Systems (GIS) and digital graphics techniques, giving the ability to explore different layers of the map, to zoom in or out, to change the visual appearance of the map, and implementing a wide range of spatial analyses and classification tools, overcame the limitations imposed by traditional paper and
plastic scale models representation and made thematic cartography one of the most useful tools for the coastal zone management (Fig. 1).

Fig.1. Example of bionomic cartography

Through a rapid and effective display of both biotic and abiotic components characterising a region, bionomic mapping can help developing action plans at various levels, from the definition of monitoring programs to integrated coastal management projects (ICZM) [2] [3] [4]. Enhanced visualization of scientific data can widely improve the understanding of the phenomenon or data being studied [5] [6]. For example, in marine navigation the benefits of cartographic 3D visualization systems in support of maritime safety are widely recognised [7]. From educational and management points of view, the bi-dimensional representation is insufficient when trying to describe the spatial distribution of benthic assemblages and ecosystem processes occurring in underwater habitats characterized by steep slopes or complex geomorphology, which is very common for the rocky bottoms. A set of tools for marine habitats characterization and 3D visualization to help their management and increase social awareness towards marine biology was developed. The realised 3D digital cartographic supports are characterized by a realistic data representation and a high level of interactivity.

2. Methods

UBICA’s articulated workflow involves all the traditional cartographic and biological sampling techniques plus tools and methods that belong to the 3D graphic fields and the videogame industry. The result is an innovative 3D visualization support that enhances the perception of the marine environment’s features through highly realistic and interactive data visualization.

2.1 Field data sampling

Biological and geomorphological data sampling is carried out by scientific divers during specific underwater surveys. A wide range of properly geo-referenced marine biology sampling techniques are used to sample the composition and the spatial distribution of the benthic assemblages (Fig. 2). Due
to the high species diversity of many marine environments, not all the species can be represented in the 3D visualization, so it is crucial to choose the focal species to represent [8].

In order to explore a representative portion of the study area, descriptive underwater surveys are carried out along intersecting visual or photo/video transects. The sampling resolution depends on the distance between these transects, which forming a grid over the area, and the clearness of the water during the surveys. The track of these transect are recorded using a DGPS dragged on the surface, therefore the sampled data can be stored in a GIS. Fast and very long transects can be obtained by means of micro video cameras and collimated laser pointers set on underwater scooters. Images and videos are analysed by expert researchers by means of image analysis software. Collected data allow creating a GIS bionomic map of the area, but they also represent the background information for the Further elaborations.

2.2 Seabed morphology reconstruction

3D reconstructions of the seabed morphology are obtained by combining all the existing data, which generally are multi-beam and/or single-beam echo sounder data as well as depths measured directly by scientific divers. The geo-referenced data are processed by powerful contouring, gridding, and 3D surface mapping software that produce digital terrain models based on geostatistical algorithms [9]. The video and photo analysis helps to reconstruct small details and texture of the rocky formations. These high resolution adjustments are done with the powerful sculpting tools now available in 3D modelling software such as Blender and ZBrush. Like in the videogames production pipeline, a highly detailed version of a ‘high poly’ object is modelled and then the details are ‘baked’ to a special type of RGB texture called ‘normal map’, which store information about the high poly geometry in its pixels (Fig. 3). Afterward, a low poly model of the object, with the same topography of the high poly, is modelled and the baked normal map is projected on it; this allows the realtime rendering engine to render all the details of the high poly model on its low poly version. This method highly improves the realtime rendering framerates of the visualization.

Fig.2. Examples of underwater sampling activities.
Another promising technique is the underwater photogrammetry, which first attempts date back to 90’s [10]. This technology appears to be optimal for isolated rocks and for small areas. Innovative approach is based on pictures that report many underwater markers on the rocks and taken by scientific divers at different depths along horizontal transects around the sampling areas. Pictures and information on markers are uploaded to a cloud computing service that calculates and return the 3D model. The results are highly realistic and the photographic footage can also be used to create high quality textures.

2.3 Species 3D modelling
The results of the biological surveys are used to choose the focal species to be modelled in 3D. Like in the modelling of the rocky formations, the workflow consist in a high level of detail model creation from which a normal map is baked and projected on a low poly model. The models are then textured and animated if needed.

2.4 Representation of the population’s distribution
Based on the biological surveys, the populations of focal species (e.g. seagrasses and seaweed meadows, gorgonian forests, protected species, etc.) are positioned in the 3D environment. Depending on the final reproduction scale, some low relief sessile species, characterising benthic assemblages, are integrated in the textures that cover the rocky formation models. 3D models of high relief and focal species are placed according to abundance-distribution statistical models.

2.5 Interactivity and information content
The seabed model and all biological elements are imported in a realtime 3D rendering engine (Unity3D [11]). Here, many other graphic elements and special effects can be added, such as caustic reflections coming from the surface, light intensity, reduced depth of field and turbidity, in order to enhance the realism and/or reproduce variable water conditions and time of day. The user can now interactively navigate through the underwater virtual environment and, thanks to a Graphic User Interface, recall relevant information about biological and ecological aspects (Fig. 4). A standalone multiplatform application is the final output of the described process, which starts from the underwater surveys and passing through several analyses and complex graphical elaborations.
3. Results

The entire described process was developed and applied to a true study case: the “Ponente nel Blu” project, carried out in collaboration with the University of Genoa in 2010. The aims of the project were to characterise and represent the coralligenous assemblages of Capo Berta, Imperia (Ligurian Sea). The sampling sites were located between 40 and 65 meters in depth, beyond the lower bound of the Site of Community Importance (SCI). More than 20% of invertebrate species protected under Annex II of ASPIM protocol were found. Biocoenosis maps and 3D views were reproduced in a book for scuba divers to promote education and underwater tourism of the area. A small portion of the whole study area, the so called “Ariete” site, was completely recreated in the realtime 3D rendering engine. Here, the 3D models of 20 focal species were included and properly positioned (Fig. 5). This virtual reality can be spread to a wide audience through the web, increasing its educational and outreach value. Future developments for an educational use of this support include the porting of such applications on mobile iOS and Android platforms.
References


