3-D Visualization And Standardization Of GIS Elements For Pollution Monitoring Of Water Resources

Kosta Mitreski, Stojan Stevkovski, Danco Davcev
"Sts Cyril and Methodius" University
Skopje, R. Macedonia

Abstract

The old legislation concerning water policy didn't provide a standardized way of integrating our environmental protection objectives. A significant progress in this direction is expected by applying the Water Framework Directive (WFD), together with the guidance document for implementing GIS elements within WFD. In this paper, we will present how the critical pollution sources in the Lake Ohrid can be presented and analysed by using visualization methods. We will also present our approach in adaptation of Web-based GIS for pollution monitoring (WGISPM) of Lake Ohrid to the WFD (case study).The whole project is under construction.

Introduction

The paper is related to the ecological state of Lakes Ohrid and Prespa. The Institute for Computer Science and Informatics at the Faculty of Electrical Engineering from "Sts Cyril and Methodius" University in Skopje in cooperation with the Hydrobiological Institute from Ohrid has been working on ecological state of water resources [1], [2], [3] and [4]. The product of that work was a Web-based Geographic Information System for pollution monitoring of Lake Ohrid [5], [6], [7] and [8]. 2-D and 3-D visualization and analysis of the pollution [9] was provided as well. There have been a number of similar systems developed all over the word [10].

On December 22, 2000, the Water Framework Directive [11] was published as a new challenge in the European water policy. The Directive establishes a framework for the protection of all waters (river basins, inland surface waters, transitional waters, coastal waters and groundwater) in preventing further deterioration of water resources as well as progressive reduction of pollution and preventing pollution in the future. Overall, the Directive aims at achieving good water status for all waters. A working group has been created for dealing specifically with issues related to the implementation of a Geographical Information System (GIS). This working group was named GIS-WG, and its main objective was the development of guidance document [12] for supporting the implementation of the GIS elements of the Water Framework Directive.

The guidance document of the GIS-WG gives a precise Data Model for designing of the database. This serves as a base from which the GIS will be built. The modelling of a software system from requirements to implementation can be provided with the Unified Modelling Language (UML). The UML has a large set of diverse diagrams for representation of software in every aspect and is increasingly being applied for modelling of Geographic Information Systems. The GIS-WG uses a restricted subset of static structure diagrams for representation of the Data Model, and we will use it in the paper for representing our specific Data Model.

The main goal of the paper is to present the standardization in the area of protection of water resources that should take place in our future works. In this paper, in Section 2 we will present the Data Model as defined by the GIS-WG and in Section 3 we will give a case study for the Lake Ohrid. Section 4 will conclude the work.

GIS-WG Data model

The Data Model should be created in such a manner as to satisfy the requirements defined in the Directive. In order to enforce standardization the model is composed of logically divided and related features. According to the GIS-WG recommendation the features given on the map (containing explicit geometry) are presented as classes. The Data Model defined in the guidance document of the GIS-WG is composed of the following features.

Feature

SubBasin

RiverBasin
RiverBasinDistrict
CompetentAuthority

Feature MonitoringStation

SurfaceMonitoringStation
GroundwaterMonitoringStation

Feature WaterBody

GroundWaterBody
SurfaceWaterBody
FreshWaterBody
RiverWaterBody
RiverSegment
LakeWaterBody
LakeSegment
SalineWaterBody
TransitionalWaters
CoastalWaters

Feature

ProtectedArea

Feature

EcoRegion

As shown, the more specific class inherits attributes from the more general class, which means they are related through generalization. Since we are working with lakes, they are defined as LakeWaterBody class and inherit from class FreshWaterBody, which in turn inherits from SurfaceWaterBody. The latter inherits from WaterBody. For a pollution monitoring system to work, we need monitoring stations defined as SurfaceMonitoringStation, which inherits from class MonitoringStations. Fig. 1 shows an UML class diagram, of the GIS for pollution monitoring, and depicts the classes explained with the connections between them.

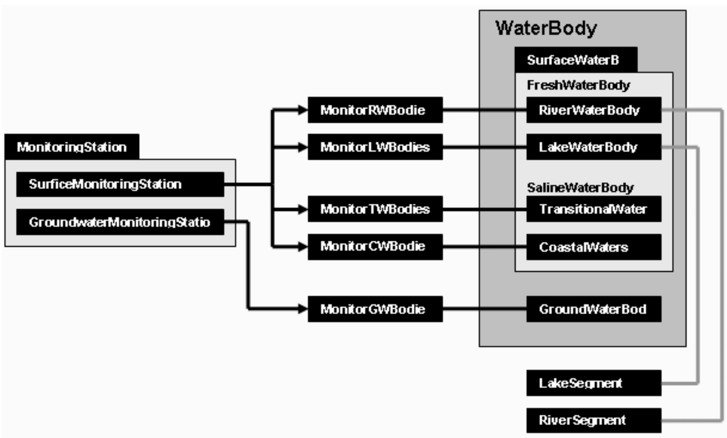

Figure 1. UML class diagram of features composing the Data Model

The classes in a UML diagram become tables in practice. When creating the database, the connections between the classes of the UML diagram, give us the means to relate different tables in the needed manner. The relational database presents a blueprint for the creation of the maps and therefore of the Geographic Information System.

Case study for the Lake Ohrid

The previously developed pollution monitoring system of Lake Ohrid was developed to provide multimedia 2D/3D modelling, visualization and analysis of the Lake Ohrid ecosystem. The measures needed for the analysis were held in several previously determined places (deeps) both for phosphorus and temperature changes and in same time intervals. Every month there were measuring held in following deeps: 0m, 5m, 10m, 30m, 50m, 70m, 100m, 120m, 150m, 200m, 210m, 220m, 230m, 240m, 250m, 260m, 270m. Results of those measurements are placed in separate tables showing an annual review of temperature and phosphorus changes through every month reports.

We have used selected data from pollution monitoring system and ESRI 3D Analyst software for 3-D virtual modelling and visualization. The 3D Analyst provides two types of surfaces models, grids and TINs (triangulated irregular networks), for modelling continuous data. Surfaces can be created from a wide variety of data sources. Triangulating features represented by points, lines, and poligons or from grids can create TINs.

On Fig. 2, 3-D virtual model of phosphorus and temperature for the Lake Ohrid is presented for the period of one month. In the first picture we can see all elements, which are present and used for these analysis. In the centre we have table of temperature changing and phosphorus concentration according to lake deeps. In right upper corner there is TIN model of temperature changing with legend on the left explaining the feature. The TIN model is coloured for better visualisation and understanding. In the bottom half we can see two 3D model of temperature changing and phosphorus concentration in colours and legend by each side for explanation.

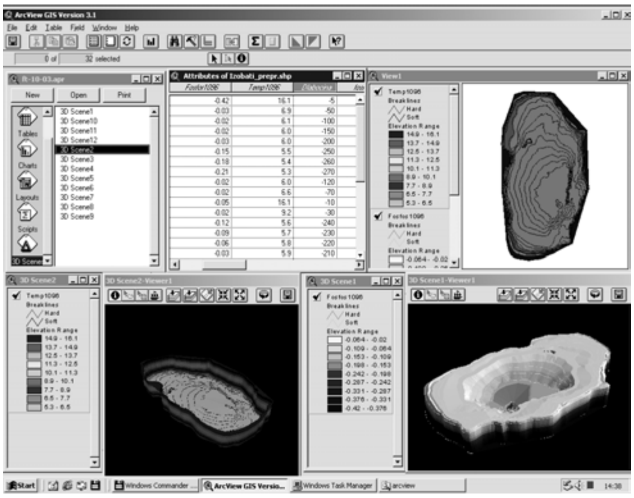

Figure 2. 3-D virtual model for the phosphorus and temperature for the period of one month

These reports are the base of analysis, which was created in ArcView GIS. First we have model of Lake Ohrid consisted of isohipses. Then using temperature and phosphorus concentration chart we created models of equivalent features of Lake Ohrid but now showing temperature changing and phosphorus concentration. For better understanding the nutrient cycles, we created seasonal dynamics of phosphorus concentration and temperature changing. On Fig. 3, 3-D virtual model of phosphorus concentration changing for the period of six months is presented. The virtual model will generate dynamically 3-D graphical presentation from the database for all measured parameters.

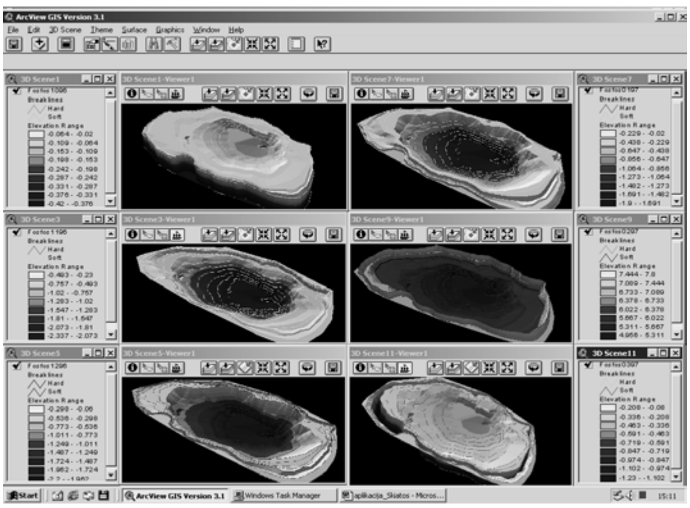

Figure 3. 3-D virtual model for phosphorus for the period of six months

Following the guidance document of the GIS-WG we've started a project for standardization of the GIS elements used in the previously developed Web-based pollution monitoring system of Lake Ohrid. The Case Study for the Lake Ohrid will be extended to include Lake Prespa as well. The geographic position of two lakes is shown on Fig. 4.

Figure 4. The geographic position of the Lakes Ohrid and Prespa

According to GIS-WG recommendation, using UML we performed our analysis and design. In this way, we firstly defined the UML class diagram consisting of eight classes (see Fig. 5). All attributes and functions (methods) are defined in accordance with WFD.

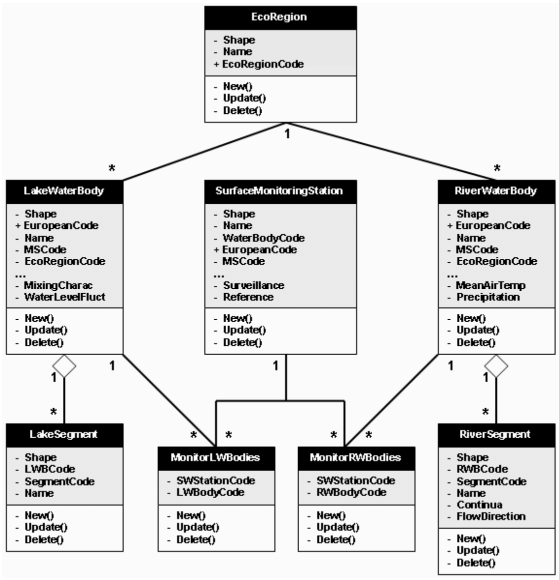

Figure 5. Class diagram

From the Class diagram, the relational scheme of the information system was generated (see Fig. 6).

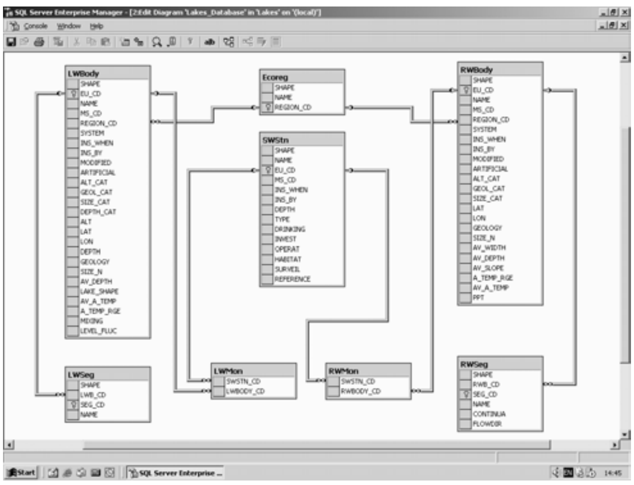

Figure 6. Relational scheme

As can be seen from Fig. 7, there are eight tables connected with corresponding associations. The implementation of the Database was in Microsoft® SQL Server. The pollution monitoring system is Web-based, which gives us the opportunity to access data via the Internet. It is being developed using the .NET technology or more precisely a particular part of this technology: ASP.NET. The Information system is thus given as a service, allowing full mobility of the potential users. One of many possible user-oriented views of the data generated from the Information system can be seen on Fig. 7.

Figure 7. Database Information system view

The maps needed for the GIS are to be made from the database we've created. They are the basic goal of our project and their creation is in progress as it is so for a number of projects across Europe. The GIS-WG has created a timetable for completion of all maps that should help protection of all water resources and for integration of environmental issues.

Conclusion

The solutions for preventing of pollution, enhancing protection and achieving good status of all waters, were dispersed in different water legislation. Their requirements have been reformulated in a new coherent framework called Water Framework Directive. This was done in order to meet modern ecological thinking and for the need of standardization in the field of protection of water resources. In the part of implementation of GIS for water resources, a working group has been founded: GIS-WG. The group prepared a guidance document on how to develop GIS maps to support the Directive. The maps and the Geographic Information Systems developed on them should improve the one we presented in this paper and help us to achieve the environmental objectives – good water status for all waters.

2-D/3-D visualization provides a better and broader presentation of our research results, and easier access to information from any place and at any time.

We have presented some basic elements of the project that should integrate our previous work with this new water environmental protection policy. In this manner we approach step closer to a unified and standardized way of developing WGISPM for water resources and enforce their protection.

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