

MARITIME AWARENESS AND EMERGENCY MANAGEMENT REAL TIME SYSTEM USING REMOTELY ACCESSIBLE GIS TECHNOLOGY

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The paper concerns the concept of the application of the latest achievements in both information technology and remote sensing, including underwater acoustic sensors, for maritime awareness and emergency management supporting in a case of hazard of a different kind, e.g. terrorism, pollution and ecological catastrophes, or natural disasters. The real-time, remotely accessible marine GIS is dedicated for instantaneous integration, processing and multi aspect visualisation, in a form of time variable views and maps, of the data acquired by various types of sensors. The paper presents the prototype application of the marine GIS for remotely accessible, instantaneous detection, localisation and monitoring of sea water pollution aggregations, e.g. oil spills, discharge material plumes etc. The developed system is also capable of performing the instantaneous prediction of the pollutants' behaviour, i.e. the dislocation and spreading of an oil spill, in the nearest future, using the relevant physical models. The system utilises the SQL database for data storage and the SVG language for geographical objects remote presentation, and requires only the WWW browser and SVG viewer on the client side.

INTRODUCTION

Sea and seashore areas in the entire world suffer from hazard of a different kind, e.g. terrorism, pollution and ecological catastrophes, or natural disasters. The problem of pollution detection and appropriate response strategies is one of the most important in this context, due to the continuous absorption by marine ecosystems of many pollutants of different origins, i.e. industrial waste discharges, ships catastrophes, and different kind, such as oil, heavy metals or chemicals. Many of those agents are characterised by great toxicity and cause devastation of the natural environment.

The problem of efficient methods for detection, monitoring, analysis and prediction of pollution in water ecosystems has been of great importance for many years. This is the reason for an extensive research in this area and for development of various techniques using different approaches and equipment. These techniques include:

- direct sampling,
- hydrological measurements using CTD probes,
- remote sensing with the use of electromagnetic waves,
- acoustic methods.

In particular, the acoustic methods seem to be very promising, usually as a preliminary and complementary tool to application of other survey techniques. These methods are non-invasive, faster and less expensive than direct sampling, and when compared with optical techniques, they are capable of penetrating the lower depths more easily. It is known that acoustic methods, being well recognised tool for monitoring marine living resources and seafloor, are also suitable for pollution aggregations monitoring. For instance, typical discharge materials produce acoustic backscatter levels three orders of magnitude above a normal background [1]. Therefore, in the developed system, the backscattered echo signals will be used along with other techniques for detection, localisation and characterisation of pollutant aggregations. For this purpose, the system is capable of integrating and processing the data from different acoustic sensors, namely:

- single beam echosounder signals,
- multidimensional data obtained from sidescan and multibeam sonars.

On the other hand, the huge development in the information technology in last decades has provided the tools for much faster and more efficient access to survey data, allowing their remote, near real-time management, processing and visualisation [2]. This paper presents the concept and the prototype application of the newly developed real-time, remotely accessible marine GIS for water pollution monitoring and emergency management supporting.

1. SYSTEM ARCHITECTURE AND FUNCTIONALITY

The system integrates the data from different sensors and sources and presents the data from the marine region, being currently investigated with respect to presence and behaviour of pollution aggregations, in a form of multiple, time-varying 2^D maps. The system incorporates several functions for acoustic signal and data processing for marine pollutant characterisation, specifically:

- a discontinuity and inhomogeneity detection algorithms for localisation of pollutant plumes and their boundaries,
- the echo features extraction for characterisation of the pollutant's type,
- integration of the data from several acoustic sensors, echogram visualisation and image processing.

For the user, the system provides functionalities which include several features typical for GIS systems, such as:

- map view management basic tools like zooming and panning,

- organisation of map components as a set of separate data layers, where each of the layers contain the objects of the same type, like coastline, depth lines, pollution aggregations,
- easy map object information retrieval,
- user defined thematic views.

The system is fully accessible via the Internet, maintaining its whole functionality for the authorised user. To utilize it, any computer workstation equipped only with the WWW browser and SVG viewer is sufficient.

Besides the near real-time visualisation of pollution aggregations in geographical context using the currently acquired data, the system is also capable of utilizing these data in prediction of the pollution location, its migration and behaviour for a selected time moment in the nearest future.

The system components and relations between them are shown in a form of a diagram in Fig. 1.

The data about the localisation and behaviour of the sea pollution aggregations are being acquired by sensors of a various kind. The Data Integration & Update Module is responsible for an appropriate processing and integration of the pollution data from all sensors, and for instantaneous updating the SQL Spatial Database. It also sends the information about each new data stored in the database to the Dynamic Data Layers Module. The SQL Spatial Database stores the information about both the static layers, e.g. layers with data not expected to change during one session of the system use such as coastlines, ports etc., and the dynamic layers, like those presenting the ships' positions or the movement of pollution aggregations. The application of the standardised, widely used format for the spatial data storage also enables their easy transferring to another systems. The static layers data, along with the WWW pages which host the system, are sent to a client by the WWW Server, which is also able to interpret the PHP language files. The spatial data are sent to a client also in a standardised form, that is in the Scalable Vector Graphics (SVG) language. To provide the client with the changes of dynamic layers data in the near real time, the Dynamic Data Layers Module, written as Java application, runs as an additional component on the server side.

Several system functions were implemented by the software running on the client side in order to decrease the number of Internet connections and tasks to be performed by the server. In spite of this, only the typical WWW browser with SVG viewer plug-in is required on the client side. The SVG map is embedded in the Web page. Additionally, the Java Applet is responsible for communication with the Dynamic Data Layers Module and updating the graphic objects in the SVG window, while the software written in a form of Java Scripts implements the map zooming and panning, layers management, calculations for the pollution aggregation behaviour prediction, customisation of the system views appearance etc.

The sample screenshot presenting the system at work is shown in Fig. 2. At the map, the actual position and shape of a simulated oil spill is visible together with indications of its previous positions as well as the position predicted by the system for a chosen time point in nearest future. As a background, the coastline of the Gulf of Gdańsk and some other details from a nautical map are also visible.

In the presented version of the system, two algorithms were implemented for the oil spill movement prediction procedure, namely:

1. The prediction of an oil spill advection due to the water current and the wind local values.

It is known that the advection is the main mechanism responsible for the spill movement on the water surface [3]. The applied approach utilises the simple relation between the water current velocity and the wind velocity vectors, and the estimated oil spill advection velocity, viz.:

$$\mathbf{v} = \alpha_w \mathbf{v}_w + \alpha_c \mathbf{v}_c, \quad (1)$$

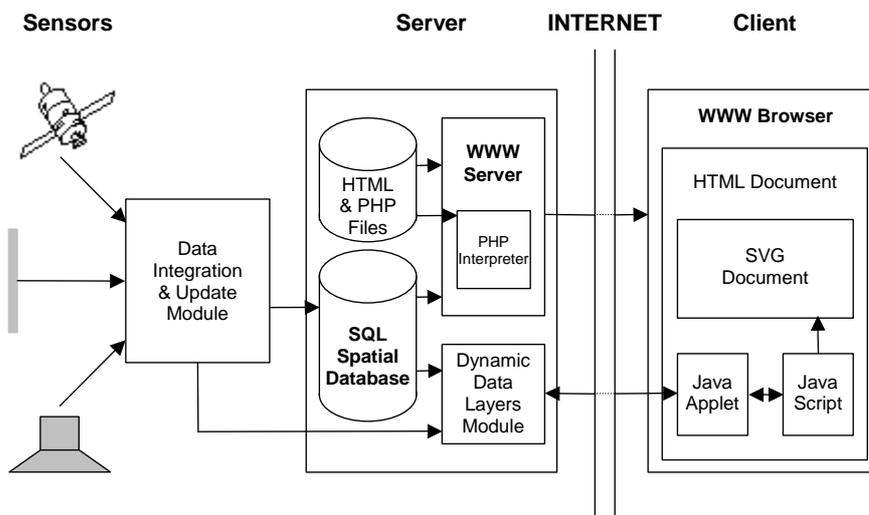


Fig.1 The block diagram of the GIS system components

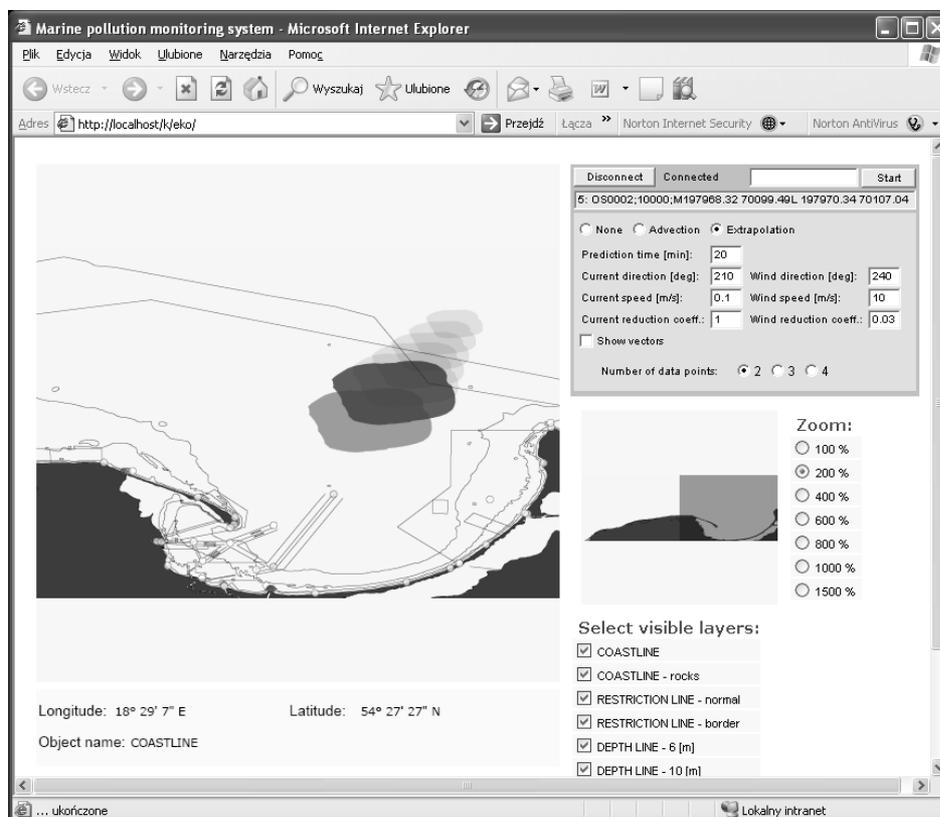


Fig.2 Sample view of the system screen dump, presenting the actual position and shape of an oil spill, and its previous and predicted position, at the background of the Gulf of Gdańsk coastline

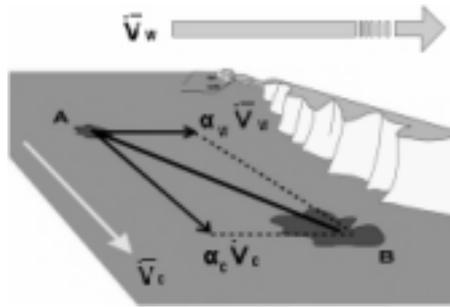


Fig.3 Estimation of an oil spill advection velocity on the sea surface due to water current and wind. See text for explanation of quantities

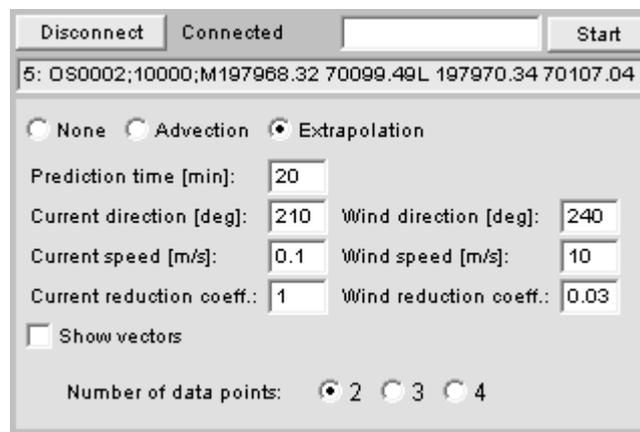


Fig.4 User defined settings regarding the system's prediction of the oil spill behaviour

where:

\mathbf{v} – oil spill advection velocity,

\mathbf{v}_w – wind velocity at the sea surface,

α_w – wind reduction coefficient, which expresses the ratio between a pollutant particles' speed on the sea surface caused by the wind, and the wind speed itself (typically set to 3%),

\mathbf{v}_c – water current velocity,

α_c – water current reduction coefficient (typically set to 100%).

The vector \mathbf{v} calculation is also shown in Fig. 3.

2. The extrapolation of a spill location based on the polynomial approximation using a sequence of known locations from the near past. It may be useful in the case when the data about the local wind and water current are not available.

The enlarged part of a screen with the user defined settings regarding the oil spill behaviour prediction procedure is shown in Fig. 4. The user of the system is able to choose the prediction method and to define a time point in the future for which the prediction of an oil spill location has to be made. For the first prediction method, the user has to provide the values defining speed, direction, and reduction coefficient for both the water current and the wind. For the second prediction method, he can precise the number of previous data points, describing the spill location for several time moments in the near past, to be taken in the extrapolation procedure.

2. CONCLUSIONS

(1) The paper introduces the concept and the prototype application of the newly developed real-time, remotely accessible marine GIS for monitoring water pollution aggregations and prediction of its behaviour. When integrated with sensors providing the current on-line data about the pollution localisation, the system may be a valuable, intelligent support for remote emergency management teams and decision takers. In a further perspective, the system could be extended to work as an aid also in cases of other kinds of emergency related to sea and off-shore regions, i.e. terrorism, natural disasters etc.

(2) The future work should focus on improvement and advancing several features of the system, including the integration with a larger set of sensor types and amelioration of the system performance when employed simultaneously by multiple users. It also should aim at better visualisation including 3^D views, and improvement of the prediction procedure.

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