A PROACTIVE GIS INFRASTRUCTURE FOR ENVIRONMENTAL MONITORING

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ABSTRACT

The impact of oil pollutions on coastal environment, concerns both the economy and the quality of life. The increasing importance of petroleum products and its maritime transportation raised the concern on navigation safety and environmental protection, leading to a major interest in frameworks for remotely detecting oil spill at sea. While many of the approaches have been focused on large oil spills, smaller ones and operational discharges in regional area received fairly less consideration. In this work we present a framework where, in addition to classical remote sensing the information is enriched with data collected in situ thanks to static and mobile sensors and thus leveraging on innovative methods for data correlation and fusion. The proposed GIS infrastructure is an integrated and interoperable system based on advanced sensing capabilities from a variety of electronic sensors along with geo-positioning tools, yet suitable for local authorities and stakeholders.

Keywords: Marine Information System, Oil spill monitoring, Environmental Decision Support Systems, Proactive environmental monitoring, Risk maps

1 INTRODUCTION

Nowadays, the increasing importance of petroleum products and its maritime transportation raised worries about navigation safety and environmental protection, conveying a lot of interest in frameworks for remotely detecting oil spill at sea. The impact of oil pollutions on coastal environment, affects both the economy and the quality of life in those areas. While most approaches have been focused on large oil spills, smaller spills and operational discharges in regional area received fairly less consideration. In this work we present a framework where, in addition to classical remote sensing the information is enriched with data collected in situ thanks to various other sensors and thus operating through innovative methods for data correlation and fusion.

More in detail, we propose a Marine Information System (MIS) integrating multispectral aerial data, SAR satellite processed data, environmental data from in situ monitoring stations (e.g. buoys), dynamic data acquired from in situ mobile sources (e.g. volunteers, Autonomous Underwater Vehicles ...). In addition this MIS is enhanced with proactive capabilities based on a set of environmental decision support services for both, automatic monitoring of the situation through risk factors representation, and notification of events needing consideration from end-users. The automatic analysis of risk maps allows the issue of proactive alerts to the responsible monitoring authorities.

The proposed infrastructure has been demonstrated during extensive test exercises held at the National Marine Park of Zakynthos and at National Park of Tuscany Archipelago in the framework of FP7 Project Argomarine.

2 ARCHITECTURE OF THE MARINE INFORMATION SYSTEM

The design of the MIS has been planned in order to provide an effective and feasible detection and management of marine pollution events, by integrating and analyzing data acquired by a number of heterogeneous monitored resources, used to get useful and relevant information about the controlled areas. The main task of the MIS is to serve as a data fusion engine for integrating information and knowledge from various sources relevant to the marine areas of interest, by means of adequate Information Technology tools. More precisely, the MIS has been conceived as a connected group of subsystems for performing data storage, decision-support, data mining and analysis over data warehouses, as well as a web-GIS portal for the access and usage of products and services available to end-users. Products are herein considered as the marine environmental data acquired by the system or result of their processing; while the services are the processing facilities supplied by the system.

The MIS has been developed following INSPIRE and GMES recommendations (INSPIRE (2007)), regarding in particular the modalities to communicate and interact among systems, and in general to and from the system. Regarding in particular an efficient management of the information flow within the system, needed for guaranteeing interoperability among the different components. Hence the MIS is designed including as a set of specialized subsystems cooperating among each other.

Those independent and re-configurable units guarantee interoperability and the portability of the whole framework, meaning that single units could be re-designed, or its internal components could be modified to fit to specific different domains of application (or case study), without the need to re-design the whole architecture (Pieri et al. (2012)). The MIS architectural design is shown in the following Fig. 1, where the composing units are represented, along with the communication paths that exist and are needed for the MIS to work.

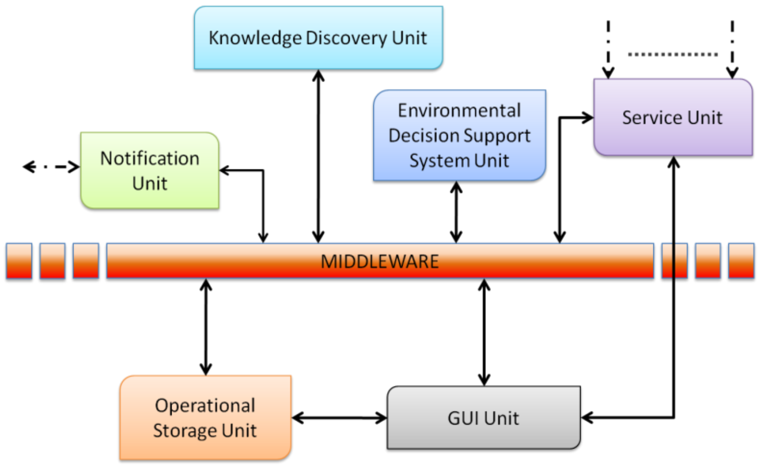

Figure 1. Architectural design of the MIS with modular structure evidenced

The MIS intelligence is represented by the Environmental Decision Support System component (EDSS) which is responsible of the detection and monitoring of pollution accidents by analysing and combining the multisource data coming from the different data acquisition and processing subsystems of the MIS.

The design of the EDSS required understanding of the environmental problem domain and identification of the domain experts and authorities to cooperate with. Special relevance has been put on the identification of the problems which the EDSS could aid to manage or solve, and how the system can intervene and improve the current oil spill detection and management procedures. According to these results, the EDSS has been conceived according to a three levels structure:

1. Data Harvesting and Fusion
2. Diagnosis and/or Prediction
3. Decision Support

According to this conceptual model, and following also the suggestions from Fedra & Winkelbauer (2002), the EDSS has been designed as composed by two main components: the Risk Analysis Model and the Resource Management Service.

In classical quantitative risk assessment, global risk estimation is derived by multiplying the likelihood of occurrence of adverse consequences by the magnitude of each consequence. Extending this principle, we aim at devising a method for the computation of a local risk estimate for each point in a geographical region of interest (see Cocco et al. (2011)). The computed point wise estimates can then be computed and represented in a thematic map of risk for the given region of interest.

Among the data harvested and integrated into the MIS, a selection has been made to extract those parts of information which might be relevant in risk analysis for the control of oil spills and other pollution events. They are related to maritime traffic, oil spill reports from remote sensing, in-situ observations, volunteer reports and local monitoring coverage. Each of these data corresponds to a summand in the overall risk estimation.

3 PROACTIVE SERVICES FOR MARINE MONITORING

A collection of services has been designed for non-stop continuous monitoring of the area of interest. The main focus has been on the optimal dynamic management of monitored and harvested resources and on the provision of proactive services for notification of alerts to end-users.

Each implemented service operates through an intelligent software agent. Those agents work autonomously and are independently reconfigurable to a large extent. Each one fetches data from the MIS and performs a set of preconfigured actions. The MIS is organized with an inner logic which represents the workflow that it is committed to carry out, and it is represented as a condition-action rule. The workflow might include the acquisition of further data or the triggering of external computational methods (e.g. for running simulation or assessing risk again). The service agents activate themselves at regular interval of times (e.g. for harvesting of data from a repository) or they are triggered on demand (e.g. by other agents or upon reception of special requests).

Following this framework, several services have been implemented. Notification services are in charge of analyzing the current situation and of issuing alerts in case some anomalies are detected. In particular, oil spill reports coming from image processing facilities, volunteers' alerts and the computed risk map are continuously monitored by the services. If an oil-spill report from the image processing facilities is found having a high confidence, an alert is immediately generated. In the same vein, if there are a number of volunteer's alerts which might refer to the same pollution event, an alert is generated with different levels of severity. Finally, on the basis of the risk maps, alerts are generated considering both the absolute value of the risk and its trend. With the generation of an alert the service takes care of contacting the most suitable authority selected automatically on the basis of a proximity criterion. Moreover, an example is given by the service for resource management which is in charge of controlling adaptively the sampling frequency of the in situ resources, based on various data from the harvested resources connected this service can automatically change or request additional data from the same or other resources even of different nature in the area of interest for increasing the system knowledge on an occurred event.

4 RESULTS AND DISCUSSION

The proposed systems has been tested in 3 different field tests performed at different times in Zakynthos Marine Park, Greece and in Elba Island, Italy (hosted by National Park of Tuscany Archipelago).

Tests included the acquisition of true data for verifying storage capabilities and near-real time functionalities. Once some interoperability issues were fixed, no problems were found for data integration. Stress tests using dummy data have also been performed for understanding the limits of the platform. On this basis, it can be judged that the system is adequate for managing regional data; in any case the system might be scaled to arbitrarily wide areas. Support for multiple areas is already included and operational. Besides true data, fake data were also feed to the MIS to produce artificial perturbations and thus creating interesting anomalies to be managed by the proactive services. The methods for real-time risk assessment were run automatically at regular time intervals to produce risk maps. The maps were visualized by experienced users (an example of the appearance of the map at the coarse scale is given in Figure 2) as well as stored into a database. By visual inspection, the users found the map to convey meaningful and significant information and regarded it as a useful tool to better focus the attention on the areas that deserve a more accurate monitoring.

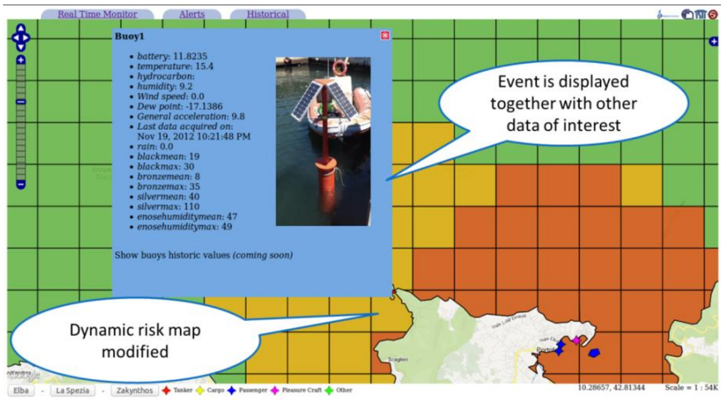

Figure 2. MIS interface showing dynamic risk map modification due to an event generated from an eNose sensor mounted on a buoy and sniffing a spillage

5 CONCLUSIONS

This paper presented an integrated and interoperable system based on advanced sensing capabilities from a variety of electronic sensors along with geo-positioning tools, suitable for local authorities and stakeholders in the monitoring and management of sea and coastal oil pollutions. The implemented MIS integrates various environmental data acquired both in situ and remotely, and it is enhanced with environmental decision support services, aiming at an automatic screening of the real-time situation, a quantitative representation of the risk factors, and most notably a proactive notification of events and suggestion useful in the intervention chain for the management of pollution situations. The architecture of the implemented MIS has been presented, followed by specifications on the methods used for real-time risk estimation and the services realized for environmental monitoring. Finally demonstration of the proposed system has been shown during extensive test exercises held in environmental protected areas in Greece and Italy in the frame of EU-FP7 Project ARGOMARINE.

ACKNOWLEDGMENTS

This paper has been partially supported by FP7 EU Argomarine Project. The authors would like to thank Dr. M. Cocco, coordinator of the project, and Dr. M. D’Acunto for their support in preparing this work.

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