

## **Dolphins' Environment Assessment and Knowledge Management Using a Distributed Instrumentation and Geographic Information System**

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**Abstract**-The purpose of the paper is to report mainly the work developed in the areas of geographic information systems and distributed instrumentation for dolphins' environment assessment. Different solutions for water quality sensing and data communication are considered including independent monitoring nodes and mobile measuring stations associated with ships. The received data from water quality sensors, hydrophones and GPS is wireless transmitted to a host PC where the geographic information system (GIS), data management, and data publishing are implemented. Thus, on-line environment assessment through dynamic web pages is carried out. GIS's database capabilities assure post-processing tasks such as dolphin's sound recognition or water quality data mapping. At the same time, the knowledge about dolphins' environment can be easily organized, formalized and distributed.

### **I. Introduction**

A Geographical Information System (GIS) allows viewing, understanding, questioning, interpreting, and visualizing data in many ways, which reveal relationships, patterns, and trends, and can be used for environment quality assessment related to animal life conditions (e.g. dolphins of the Sado Estuary). Integrating hardware expressed by GPS, multi-parameter water quality measuring units, hydrophones and data transmission units and software associated with instrumentation control, data management and analysis, an optimal designed GIS will assure a better understanding of the Sado Estuary life conditions regarding the requirements associated with dolphins' population. By using different types of devices and systems, including hydrophones, it is possible to collect and analyze the data (especially acoustic signals) associated with dolphins' behavior in a specified region and integrate it in a Geographic Information System [1]. However, in order to guarantee that data is transformed into knowledge, it is necessary that the system will support the information management and information dissemination. Nissen [2] proposed a knowledge management model that supports the creation, organization, formalization and distribution of the knowledge about dolphins' environment.

In our application, water quality assessment includes different parameters such as pH, conductivity, temperature, dissolved oxygen, and turbidity [3][4]. These parameters are measured through field-measuring systems. Underwater acoustic signals are usually sensed using hydrophones that can be also used to acquire specific dolphin' sounds (whistles, clicks and bursts) [5][6] [7].

This paper reports a designed and implemented Geographic Information System developed with a Windows server 2003, SQL server, ASP.net, AJAX and GMAP technologies, that supports the management of the information obtained with a distributed measurement solution expressed by the following measuring units: water quality multisensor probe, underwater acoustic signal acquisition system, global positioning system and wired to wireless bridge that permits to transmit the data to a field processing unit (laptop) that supports IEEE802.11g and 3G/UMTS protocols. The data from the measuring units are received by the laptop and processed using a LabVIEW software. The processing results are uploaded onto the GIS implemented in a land server (supervision center).

### **II. GIS hardware**

Taking into account that the dolphins' population under observation is spread over a large area (Sado Estuary), the Geographic Information System receives the data from a measurement node wireless connected to a field advanced processing and communication unit expressed by a laptop. The measurement nodes (Fig. 1) include: node localization and water quality measuring unit, and underwater acoustic signal measuring unit. The measurement nodes units' description as well as the data communication between the nodes and the advanced processing units expressed by the laptop with Internet access is presented next.

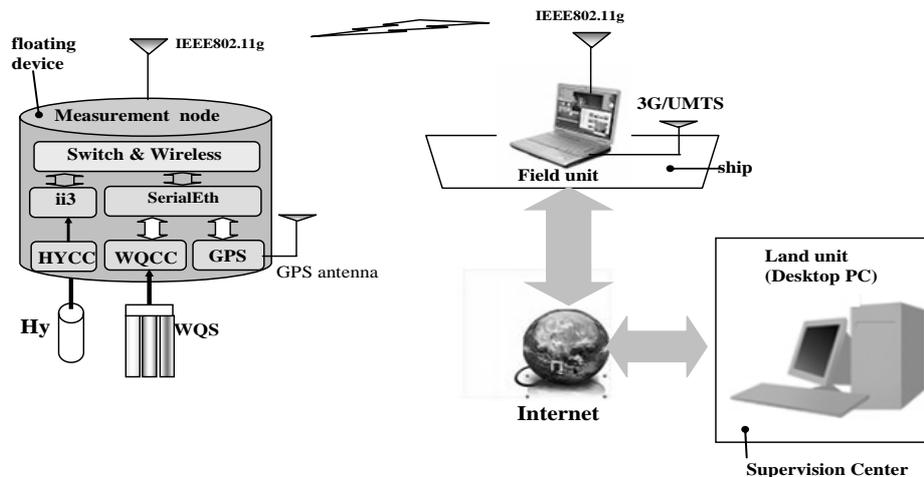


Fig. 1. GIS hardware block diagram (HYCC- hydrophone conditioning circuit, WQS-water quality sensors, WQCC-water quality conditioning circuit, Hy-hydrophone, ii3-audio server, SerialEth – serial to Ethernet bridge, Switch & Wireless – IEEE802.3 switch and IEEE802.3 to IEEE802.11g bridge)

### A. Localization and water quality measuring units

The measurement nodes prototype includes a GPS (Garmin GPSMap75) with RS232 communication capability that provides the information about the measurement node localization on the monitored Sado Estuary area. The localization (e.g. N38°29.429', W008°55,114') information is joined to the water quality parameters values measured using the RS232 compatible Quanta Hydrolab multiparameter measuring system. The measured parameters include: the temperature (T), the conductivity (C), the turbidity (TU) and the pH. Several measurement characteristics of the WQ measurement channel are: accuracy  $\pm 0.2^{\circ}\text{C}$  for temperature,  $\pm 1\%$  of full-scale (FS) for conductivity,  $\pm 0.2$  units for pH and  $\pm 5\%$  of FS for turbidity. Referring to the water quality conditioning circuit (WQCC), it can be mentioned that it is expressed by a SDI-12 to RS232 converter whose output is connected to the RS232 PORT1 of the Netburner RS232 to Ethernet converter where the RS232 PORT2 is connected to the GPS RS232 port.

### B. Underwater acoustic signal measuring unit

To monitor the underwater acoustic sound in the Sado Estuary, the measuring node has an underwater acoustic signal-measuring unit that includes a hydrophone (Cetacean Research S003) with audio preamplifier, which assures an amplified and filtered signal. This signal is applied to the input of an audio server based on VoIP technology that includes an audio input connected to the hydrophone preamplifier. The acquired sound is digitized and transmitted through Ethernet and a wireless bridge to the laptop where de recorded files are uploaded onto the GIS in \*.zip file form.

### C. Wireless data communication

The GIS hardware component is developed in a wireless based architecture. Thus, the measuring node includes a serial to Ethernet converter with web server capabilities, an Ethernet switch and an IEEE802.11g compatible Ethernet to wireless bridge. To assure higher area coverage, high-gain antennas (2.4GHz YAGI Antenna 11.5dBi) are associated with the wireless bridges.

Considering that the measuring nodes are not Internet connection capable, the data from the nodes is transmitted to the advanced processing unit (laptop) that receives the data through Wi-Fi communication, processes the data and uploads the processed data onto the server side using a 3G/UMTS modem (HUAWEI USB 3G UMTS HSDPA modem). Its fast transport rate of 3.6Mbps guarantees smooth Internet connection and online data and audio streaming. Several tests concerning the Wi-Fi transmission range as well as the 3G/UMTS QoS were carried out.

Through mobile Internet connection, the geographic information system (GIS) hosted in a land unit (desktop PC) receives the water quality data, underwater acoustic signal records and field images. Preliminary tests were performed using a Quanta hydrolab multiparameter probe that has temperature, conductivity, turbidity and pH measuring channels, a set of hydrophones (SS03) with preamplifier and a Garmin GPSMap75. Additionally, an audio server ii3 and RS232 to Ethernet bridge is used to implement the measuring node that communicates TCP/IP with the field-measuring unit. The hardware block diagram associated with GIS is presented in Fig. 1.

### III. GIS Software

The developed GIS, called SonicQualSado, associated with dolphins' environment assessment, includes two components: a LabVIEW instrumentation control and a knowledge management. Data logging capabilities were implemented by using Windows server 2003, SQL server, and ASP.net, AJAX, and GMAP technologies.

Referring to the LabVIEW software component, it is based on TCP Read and Write functions associated to Quanta Hydrolab Remote Control and WQ and GPS data reading. Additionally, using ActiveX technology associated with Intercom ii3 remote control, the acoustic flow data acquired by the audio server is loaded in the laptop memory, compressed in \*.arj file and uploaded onto the GIS.

One of the key aspects of the SonicQualSado project is the communication and data transfer between the point of measuring (Sado Estuary), a "server" where the data is stored in a database and a remote terminal to access data. To achieve this goal, a web application has been developed that allows managing data in an integrated and global way.

From GIS, we may access data in a way that allows an easier interpretation, finding relationships, detect patterns and share data in a more understandable way.

The method used to display data was supported by the GIS map. The map enables the visualization of queries to the database. Combining the data, we can get results such as the route of a ship in a given period. These features were implemented using the Google's GMAP API [8] to map the data.

The success of a GIS depends on its database design and therefore the data model should be structured in order to easily retrieve filtered data, being the accuracy of data and the geographical map representation key factors.

In terms of software, the project was developed in ASP.NET 2.0 AJAX 1.0 (C# language), in the Microsoft® Visual Studio 2005 Express Edition platform. The Microsoft® SQL Server 2005 Express Edition was used for database management.

The application data mapping is made using the Google's GMAP technology, accessible on the internet. The code to implement GMAP was done in JavaScript [9]. The GIcon class and GMarker class were used to set a marker distinct from the ones provided by GMAP. The actions that the user can take on the map are captured through listeners. For example, when the user drags with the mouse through the digital map the coordinates are shown.

The application provides a real-time monitor of successive measuring locations by a ship that travels the Sado's estuary. The preview is done in the GMAP by a set of markers (that identify the measurement points) connected by lines. This will give a rough idea of the route followed by the ship.

ASP.NET AJAX [10] is a framework to build web applications. Web applications running almost exclusively on the server side causes the server's overload. This technology provides asynchronous page refresh, not in the full page but only a part of it. This new Microsoft technology incorporates a script library that runs on the client side with ASP.NET 2.0 framework. ASP.NET AJAX extends the JavaScript library to bring standard object-oriented concepts to JavaScript. It brings a formal type declaration system with support for inheritance. This technology enables developers to build applications where much of the processing occurs on the client side using a model that is very similar to the model used in traditional ASP.NET pages.

ScriptManager control manages all ASP.NET AJAX requests through a web page modifying the behavior of the server returns. UpdatePanel control defines a region that must be updated independently of the rest of the page. This makes the application *postback* much less, making interaction with the controls more seamless. This technology was applied in the calendar control area, among others. This control is used in the same page of the map control and avoids constant map update. To make the application more versatile, it is possible to export data to other applications. In particular, a query to the database that filters data based on dates selected by the user may be exported to an XML or Excel file. This is achieved using the *System.Web.HttpResponse* class, which allows sending Http response data to a client and contains

information on the shipment. (see Fig. 2 for an example of the code needed to implement data conversion to Excel file).

```

// Exports to Excel file
protected void ButtonExportExcel_Click(object sender, EventArgs e)
{
    Response.Clear();
    Response.AddHeader("Content-
Disposition", "attachment;filename=MyExcelFile.xls");
    Response.Charset = "";
    Response.ContentType = "application/vnd.ms-excel";
    StringWriter stringWrite = new StringWriter();
    HtmlTextWriter htmlWrite = new HtmlTextWriter(stringWrite);
    GridView1.RenderControl(htmlWrite);
    Response.Write(stringWrite.ToString());
    Response.End();
}
    
```

Fig. 2. The function associated with the export button to an Excel file

#### IV. Results and Discussion

Using the implemented system, several tasks, such as water quality parameter measurement, underwater acoustic signal acquisition and recording, are carried out. The dolphins' observation pictures and the measured data are uploaded onto the GIS, which includes web-publishing capabilities. During field measurement sessions, water quality parameters measured on different locations were recorded. Some results are presented in Table 1.

Table 1. WQ parameters for different measuring locations at different time instances

Date	Time	Lat.	Long.	T (°C)	pH (units)	C (mS/cm)	TU (NTU)
25.06.08	12:01:44	38.29048	-8.91856	18.34	9.23	51.4	8.2
25.06.08	12.36.21	38.49795	-8.89395	21.19	8.82	50.9	33.4
25.06.08	13.31:10	38.51363	-8.90155	19.55	8.68	51.3	73.4

The tests were performed using the prototype of the measurement node Wi-Fi connected to the laptop of the field unit. The implemented node permits to measure an extended number of the WQ parameters including dissolved oxygen, salinity, and ORP. The values are received by the LabVIEW software implemented on the laptop whose front panel is presented in Fig. 3. In the figure one can notice different LabVIEW tab-screens for IP and PORT configuration associated with TCP/IP communication between the laptop and the Netburner RS232-Ethernet bridge. A second tab on the left part of the virtual instrument front panel is expressed by a QuantaHydroLab measurement channel control. It is used to select subset water quality parameters according to the application. The right part of the front panel is designed to display de current values of the measurement parameters.

The GIS application implemented permits to manage the processed data in a web environment. This web-base application supports three types of user profiles: the application management, the project management and the standard user. Just the project manager is allowed to upload data to the database and to operate in a "real time mode". All the users can access the application for data searching and to visualize the ship route. Fig. 4a shows an example of measurement data for a specific location and date. The values obtained from QuantaHydroLab are shown to the user. At the same time, the WQ measurements have associated dolphins' pictures and sounds. Picture and sound tabs (Fig. 4a) are used to get the collected images and the acquired sounds from dolphins, respectively.

The GIS uses a digital map as the main element of the user interface. Not just data is visualized in the digital map, but the map is also used to input data for searching tasks (see Fig 4b). The searching tasks can also be done during predefined periods or by inputting the time information through calendar controls, as it is shown in Fig 5a.

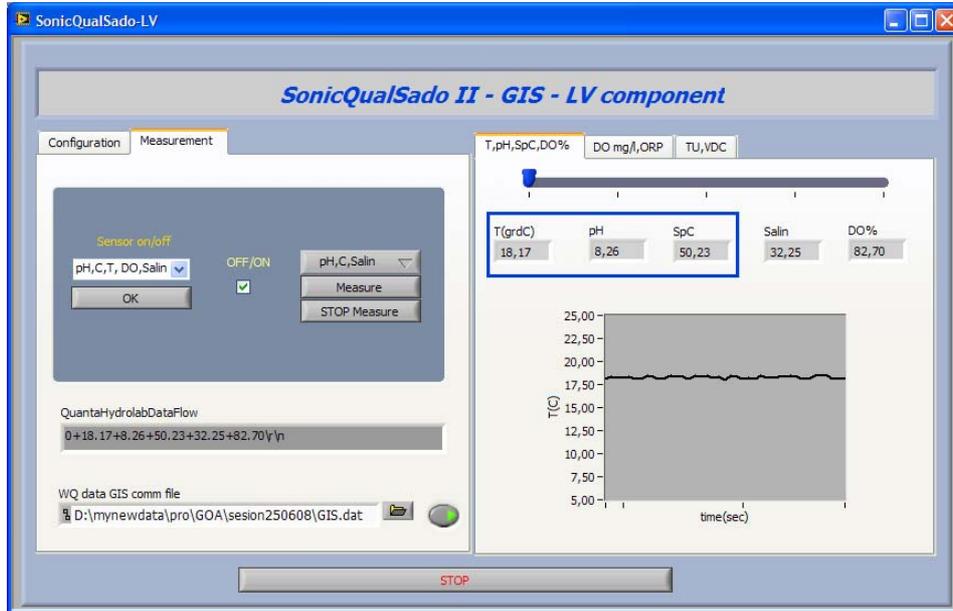
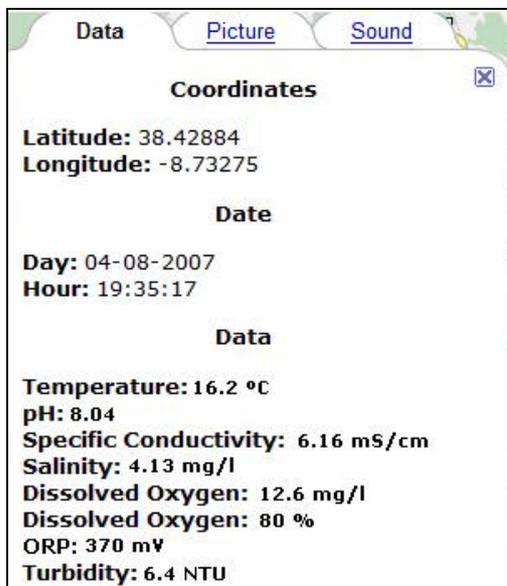
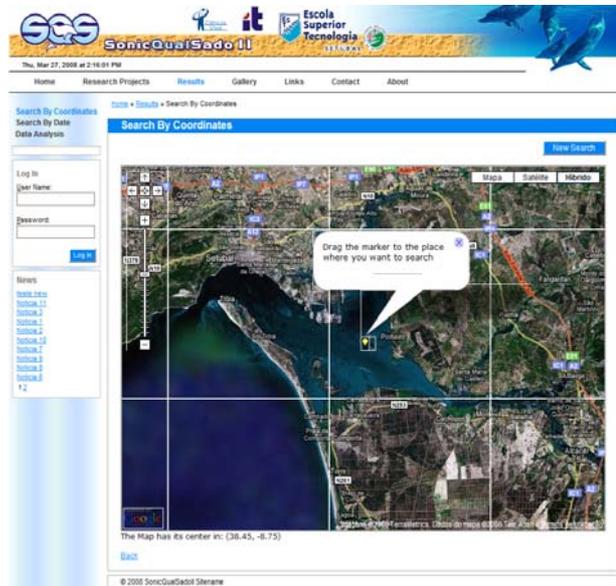


Fig. 3. SonicQualSadoII – GIS LV component – Front Panel

Using the data logging functionalities, the data can be used to express the monitoring trajectories during water quality and underwater sound field measurement sessions (Fig. 5b).



(a)



(b)

Fig. 4. (a) Data frame example in GIS application, (b) Getting data from a field measuring unit by dragging the marker through the map

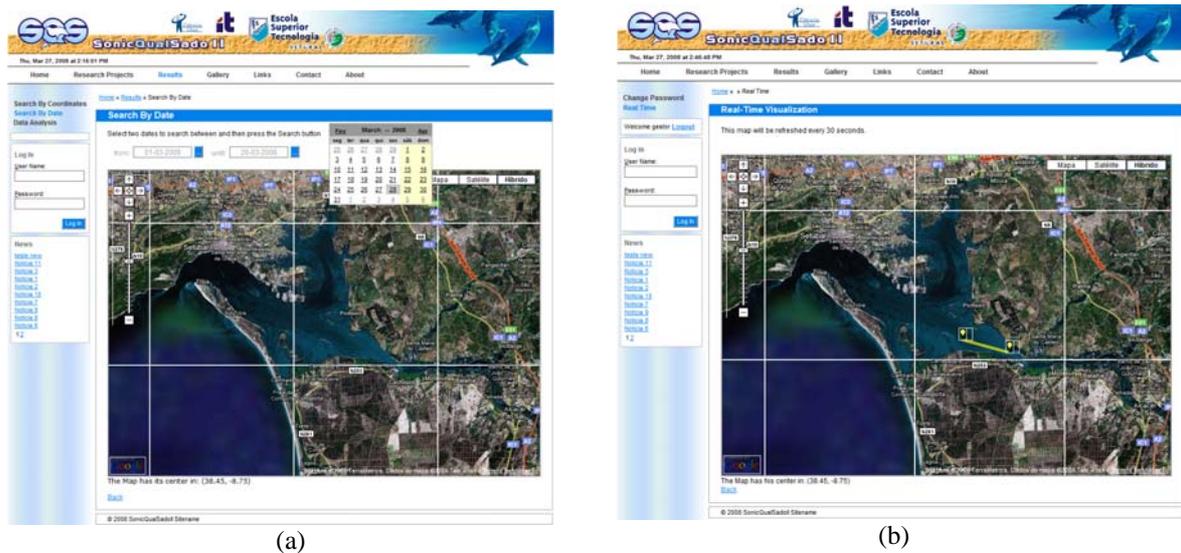


Fig. 5. (a) Update Panel used with the calendar control; (b) Monitoring real-time measurement acquired on a ferryboat that crosses the Sado estuary.

## V. Conclusion

A dolphins' environment assessment based on GIS hardware and software components was developed. The proposed system allows a better management of the field measured data and an improved performance using fixed or moving measurement units. A Geographic Information System was designed and implemented for knowledge management of dolphins' sounds. The measurement system remote control, configuration and data transmission was implemented in LabVIEW graphical programming language. Additional data processing of the data received from measurement nodes was implemented. The system will support the organization and formalization of the knowledge obtained through the environment assessment. This organization and formalization of knowledge is achieved by means of database implementation that supports the importation and exportation of measurement data. The web architecture of the system guarantees the distribution of knowledge, since it allows the searching of information about dolphins' environment remotely from any location.

Future work is related with the characterization and data processing of underwater acoustic signals, using time-frequency distributions, such as Wigner-Ville, to extract sound features and patterns identification.

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