Smart Sensors Monitoring Nodes and GIS for Dolphins' Environment Assessment

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Abstract *– Dolphins' environment assessment is an important challenge able to contribute to the reduction of their mortality especially in regions with a reduced number of individuals such as on the Sado Estuary area. Thus, the purpose of the paper is to report mainly the work developed in the areas of distributed instrumentation and geographic information systems for dolphins' environment assessment using smart sensing nodes. The smart sensing node architecture is expressed by a set of water quality transducers, a low cost hydrophone and a GPS that deliver the informations for an acquisition and wireless communication module mounted on a buoy. The acquired data is wireless (Wi-Fi) transmitted to a laptop PC that is installed in a ship. Using a mobile internet connection (3G/UMTS modem connected to the laptop PC) the data from different sensing nodes are transmitted to a host PC (on land) where a geographic information system for dolphin life assessment (GIS) is implemented. Based on implemented client-server software architecture, on-line monitoring of water quality parameters and underwater sound is performed through dynamic web pages.*

Keywords – smart sensors, water quality, underwater sound, geographic information system

I. INTRODUCTION

A Geographic Information System (GIS) [1] 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). Water quality (WQ) assessment includes the measurement of parameters such as pH, conductivity, temperature and turbidity [2][3]. These parameters are measured using measuring systems with multichannel sensing capabilities such as Quanta Hydrolab and Seabird SBE 25 with RS232 or SDI-12 interfaces or using transducers that deliver analog electric signals, current (4-20mA) or voltage (0-5V).

In order to assure the smart sensor compatibility with IEEE1451 standard, different kinds of memories are included in the systems. Thus, the identification and specific characteristics of the transducer are stored on the Basic TEDS (TEDS- Transducer Electronic Data Sheet). For the particular case of IEEE1451.4 standard for smart transducers the TEDS memory interconnection is described in [4]. Implementations of IEEE1451.4 are reported in literature and the statistics also show that since the IEEE1451.4 standard appeared more than 100 transducers manufacturers have considered this standard as an important bridge between the classical – analog output transducer and smart transducers with, namely, auto-identification and auto-calibration capabilities [5]. However, most manufacturers propose proprietary solutions and the smart sensors standard seems to be applied particularly for force, pressure, and acceleration transducers and less for environment monitoring transducers (air quality and water quality monitoring) or for underwater acoustic signal monitoring.

In order to overcome the limitations of IEEE1451.4 hardware implementation, which requires additional memory associated with the transducer, National Instruments promotes an interesting version for TEDS, the *Virtual TEDS* [6]. Several implementations of IEEE1451.4 and virtual TEDS are referred in the literature and also several results were also presented by the authors [7].

Underwater acoustic signals are usually sensed using hydrophones that can be also used to acquire specific dolphin' sounds (whistles, clicks and bursts). Different signal conditioning circuits such as automatic gain control and active filters are usually associated with hydrophone measuring channels.

The work presents a smart sensor nodes architecture for water quality and underwater acoustic sound monitoring including elements IEEE1451.4 compatible. An important part of the work is related to the design and implementation of a Geographic Information System (GIS) that receives the data from the sensing nodes through a laptop PC installed in a ship. The GIS was developed using software technologies such as Windows server 2003, SQL server, ASP.net, AXAJ and a GMAP technology that supports the management of the obtained information. The data from the sensing nodes are received by the Laptop PC through wireless communication and processed using LabVIEW software. The processed results are automatically uploaded on the GIS implemented in a land server (supervision center). GIS HARDWARE

Taking into account that the dolphins' population under observation is spread over a large area (Sado Estuary), a Geographic Information System was designed to receive the data from smart sensor monitoring nodes that are wireless connected to the field control and processing unit expressed by a aptop PC installed in a ship (Fig. 1).

Fig.1 Smart sensing nodes distribution (SSN1, SSN2, …SSNi) and the field control and processing unit (FCPU) in the Sado Estuary

The smart sensing nodes, described in Fig. 2, include: GPS unit, water quality transducer unit, underwater acoustic signal measuring unit and wireless communication unit.

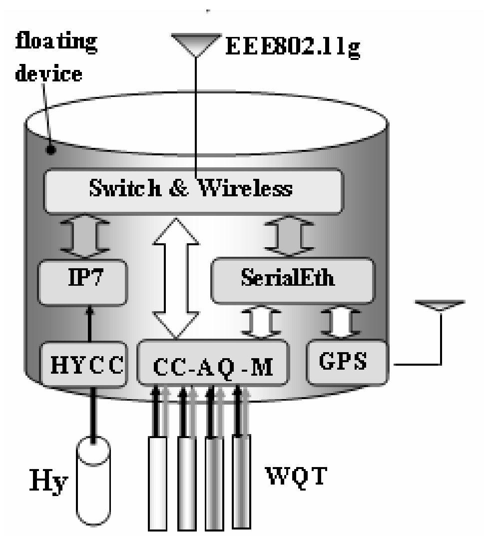

Fig.2 Smart sensing node architecture: Hy – hydrophone, HYCC – hydrophone conditioning circuit, IP7 – IP intercom, WQT – water quality transducers, CC-AQ-M – conditioning, acquisition and memory interfacing module, SerialEth – serial to Ethernet bridge

The GPS unit is represented by Foretrex201 from Garmin with RS232 communication capability that provides the information about the smart sensing node localization on the assessed area, information that is merged to the water quality parameters values measured by a set of transducers from Global Water (WQ101, WQ201, WQ301 and WQ770) that measure the temperature, conductivity, pH and turbidity.

The 4-20mA signals from the WQ sensors are acquired by an acquisition module (AQ) included in uP8930 from Ipsil that has a 16-bit ADC and an Ethernet port connected to the sensing node Switch and Wireless (Wi-Fi) communication block. The transducer identification is based on the Basic TEDS (TEDS – transducer Electronic data sheet) according with the IEEE1451.4 standard. Thus the information for each WQ transducer (see Table 1) is stored in a 1-wire memory (DS2433) associated to each transducer and accessed through a 1-wire MicroLAN Coupler (DS2409) (Fig.3).

Table 1. Implemented Basic TEDS fields.

Components	**Number of Bits**	**Allowable range**
Manufacturer ID	14	17-16381
Model Number	15	0-32767
Version Letter	5	A-Z
Version Number	6	0-63
Serial Number	24	**0-16777215**

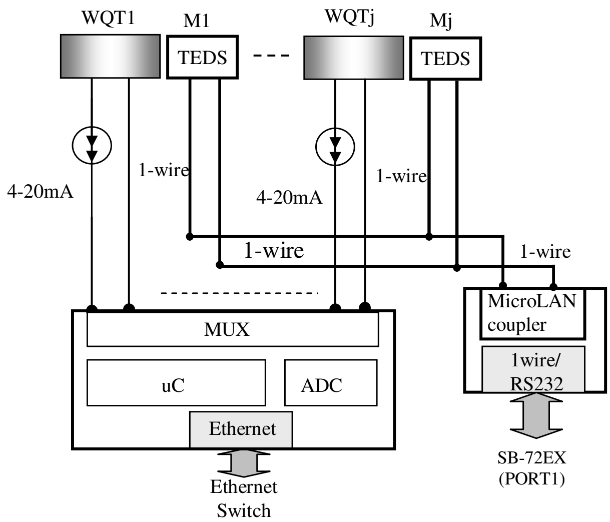

Fig.3 Water Quality Transducer: acquisition and IEEE1451.4 enabling - block diagram

A 1-wire to RS232 protocol converter is used to assure the connection of the 1-wire MicroLAN to the RS232 port of the SB72-EX (high performance Serial-to-Ethernet device) that is followed by an Ethernet/Wi-Fi bridge (D-LINK DWL-G820). Data from the transducers memories (M1, M2 …Mj), which assure the TEDS materialization, are read by the laptop PC and processed to extract the additional information from a transducer database denominated Virtual TEDS.

In order to monitor the underwater acoustic sound in the Sado Estuary, the sensing nodes are equipped with an underwater acoustic signal measuring unit including a hydrophone (Cetacean Research S003, 0.030kHz-30kHz) with audio preamplifier (HYCC). The amplified and filtered signal is applied to the input of IP intercom that uses VoIP technology (IP7).

The data from the SSN_i are received by the field control and processing unit (laptop PC) that presents IEEE803.11g (Wi-Fi) and 3G/UMTS communication capabilities.

Through mobile internet connection, a geographic information system (GIS) hosted in a land unit (desktop PC) receives the water quality data and underwater acoustic signal records.

The implemented measuring nodes can be fixed in critical regions of the monitored region to quickly detect pollution events (chemical or acoustic) that can strong affect the dolphins' population in the Sado Estuary as well as to perform future correlations between the dolphins' communications behavior under different water quality conditions and frequencies composition of the underwater acoustic background.

II. GIS SOFTWARE

The GIS software includes two components: data acquisition and primary processing component and the data management and GIS data representation component. The first component is developed in LabVIEW and is implemented at the field laptop PC level. It is associated with acquisition and current to water quality parameter conversion using the acquired data from the measuring channel. The conversion uses the Basic TEDS information transmitted through 1-wire communication, which permits to select the transducer characteristics from the Virtual TEDS database stored in the laptop PC.

A second software component is implemented in the land computer that receives the processed data from the field through 3G/UMTS Internet connection and performs data logging and advanced processing of the registered acoustic signals. The used software technologies in this case were Windows server 2003, SQL server, and ASP.net, AXAJ, and GMAP.

Regarding data acquisition, the software was developed in LabVIEW using the TCP functions (e.g *TCP open connection*). Additional LabVIEW programming functionalities are used for IP7 control. The listening and *.wav storage control tasks were implemented in LabVIEW using ActiveX technology provided by the iTalk/X full edition that includes properties such as *LocalIP*, *LocalPort*, *SaveMicToFile, ListenMode* and methods such as *GetSocketNumber*, *InitializeAudio, L*istenStart, *ListenStop, CloseAudio* and *CloseConnections*. After acquisition of underwater acoustic sounds for the imposed time interval of 1min, the *.wav files are archived in *.zip form and uploaded on the GIS database implemented in the land PC (server).

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 the ship in a given period. These features were implemented using the Google's GMAP API to map the data.

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.

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

III. RESULTS AND DISCUSSION

Using the implemented system, several tasks, such as water quality parameter measurement, underwater acoustic signal acquisition and recording are carried out.

During field measurement sessions, the water quality parameters measured at different locations are wireless transmitted to the laptop PC that performs the primary processing and automatically uploads the data on the server database installed in a desktop PC localized on land. Several results are presented in Table 2.

Table 2. WQ parameters for different measurement locations at different time instants.

Location	I	II	III
Time	12:01:44	12.36.21	13.31:10
Lat.	38.29048	38.49795	38.51363
Long.	-8.91856	-8.89395	-8.90155
T(°C)	18.34	21.19	9.55
pH (units)	9.23	8.82	8.68
C(mS/cm)	51.4	50.9	51.3
TU(NTU)	8.2	33.4	73.4

The water quality measured values are uploaded on the GIS from time to time and displayed through dynamic pages (Fig. 4), the user being capable to select locations of the map associated with the session and to see the WQ values through additional tabs.

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. Only the project manager is allowed to upload data to the database and to operate in a "real time mode". In Fig. 4 is shown an example of how data of one measurement point is shown to the user. In this example, the measurements have associated dolphins' pictures and sounds. The access to the pictures and to the sound reproduction is made through the picture tab and the sound tab respectively.

The GIS uses a digital map as the main element of the user interface. Not just data is visualized in the map; it is also used to input data for searching tasks, such as searching by date (Fig.5).

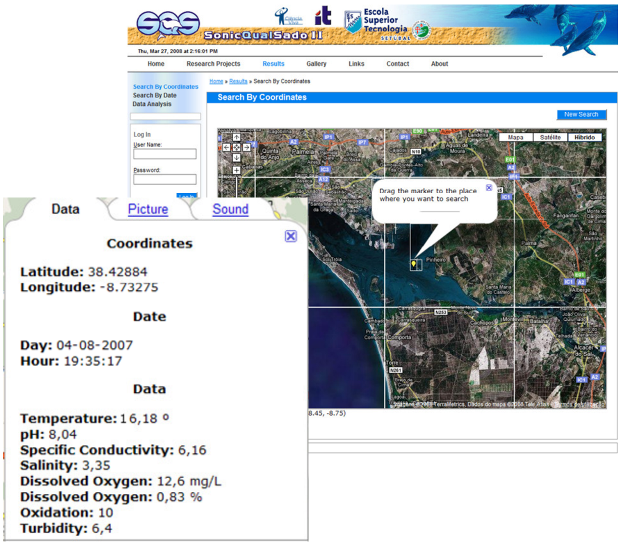

Fig 4 GIS – web GUI including the map with the marker and additional pop-up for data. Picture and sound associated with the selected point of the map.

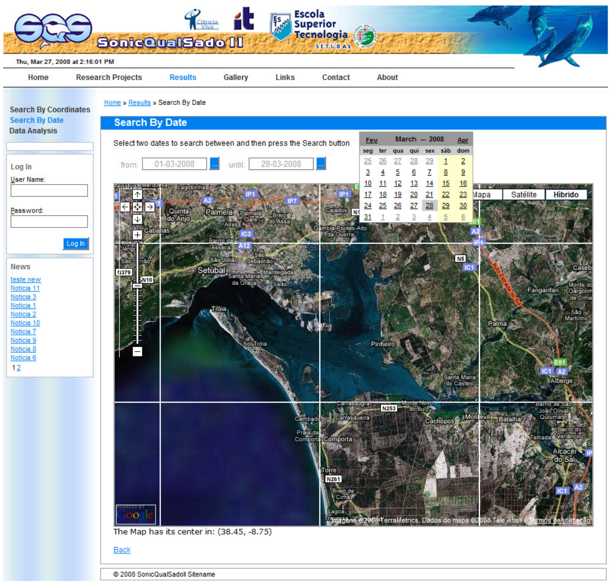

Fig 5 GIS – web GUI - searching of the measured WQ values and sound according by date

Measured values of water quality parameters are associated with the map locations and using the time information, the trajectory of a water quality and underwater acoustic measurement session is displayed on the GIS web – GUI.

IV. CONCLUSION

A GIS that uses a set of IEEE1451.4 compatible smart sensor nodes presenting capabilities such as hydrophone audio signal acquisition associated with underwater acoustic, transducer output signal acquisition and transmission was designed and implemented. Elements of IEEE1451.4 were included in the paper. Referring to software, the article mainly presents a web supported information system that combines software technologies. Dynamic pages are used to present the data from the smart sensors nodes. Different functionalities such as data tabs, data searching, and measurement session trajectory are included in the developed software. An important feature that permits off-line processing is the export data in xml and xls format.

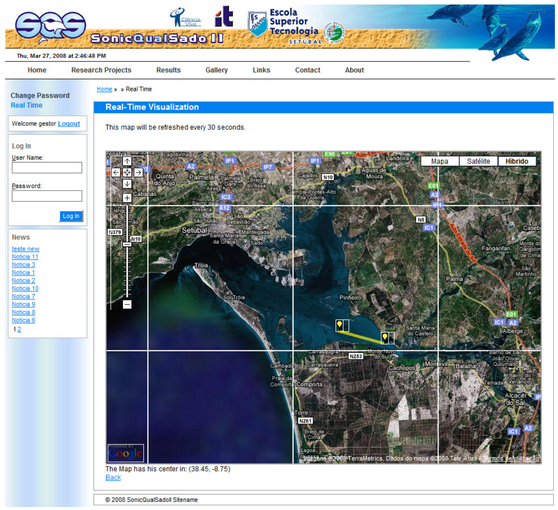

Fig 6 GIS – web GUI including the two points of the measuring session trajectory

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