Real-time Web GIS to monitor marine water quality using wave glider

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Abstract. In the past decade, Malaysia has experienced unprecedented economic development and associated socioeconomic changes. As environmentalists anticipate these changes could have negative impacts on the marine and coastal environment, a comprehensive, continuous and long term marine water quality monitoring programme needs to be strengthened to reflect the government's aggressive mind-set of enhancing its authority in protection, preservation, management and enrichment of vast resources of the ocean. Wave Glider, an autonomous, unmanned marine vehicle provides continuous ocean monitoring at all times and is durable in any weather condition. Geographic Information System (GIS) technology is ideally suited as a tool for the presentation of data derived from continuous monitoring of locations, and used to support and deliver information to environmental managers and the public. Combined with GeoEvent Processor, an extension from ArcGIS for Server, it extends the Web GIS capabilities in providing real-time data from the monitoring activities. Therefore, there is a growing need of Web GIS for easy and fast dissemination, sharing, displaying and processing of spatial information which in turn helps in decision making for various natural resources based applications.

1. Introduction

Alam Sekitar Malaysia Sdn Bhd, or better known as ASMA, has been at the forefront of the nation's environmental monitoring programme since 1993. With a concession spanning the past 20 years with the Department of Environment Malaysia (DOE) for monitoring the nation's air and river water quality, the ocean is the largest and the next frontier for ASMA. Riding on the experience gained from conducting the nation's comprehensive Island Marine Monitoring Programme in 2008, ASMA is also looking forward to provide more value through its latest technology acquisition, the Wave Glider.

Wave Glider is a state-of-the-art marine technology in harvesting oceanic data. It is an autonomous marine surface vehicle that operates only on renewable energy. Wave energy is converted into forward propulsion whilst solar energy powers communication and on- board sensors. Its operation is zero carbon footprint, although a vessel is required for launch and recovery at sea. The Wave Glider is ruggedly built to withstand long durations at sea and harsh oceanic conditions. The speed can go up to 3 knots (kts) depending on the wave intensity and can communicate via cell, satellite and Wi-Fi (depending on the location). Embedded on the platform is a command and control computer that is capable of on-board processing and communication. The units also complements other marine technologies or vessels in providing relevant and vital data for making informed decisions during pollution or exceedance events. Each unit is equipped with on-board sensors to collect 22 in-situ parameters [1]. The unit has an on-board data logger for data safekeeping before new data overwrites the older data when the storage has reached its maximum capacity of approximately 10 gigabytes. The Wave Glider unit is in operation for 24 hours a day, 7 days a week, 365 days per year. Data is collected once every 30 minutes and transmitted once every hour via Iridium satellite to the Wave Glider Management System (WGMS) web. Figure 1 illustrates the 3D layout for the unit. The sensor layout of the unit is reflected in Figure 2.

Figure 1. 3-Dimensional layout of the Wave Glider.

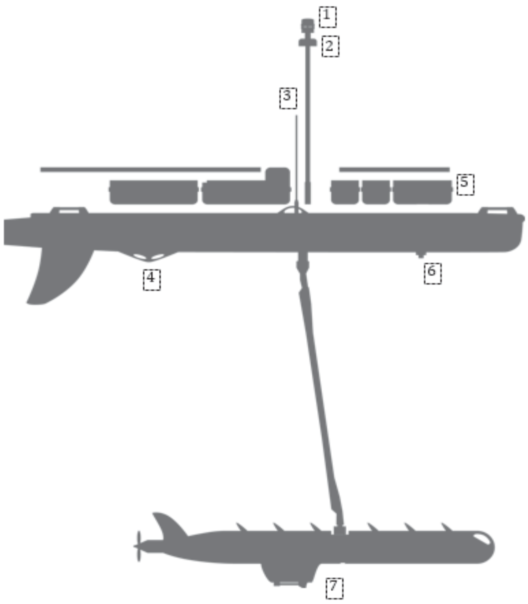
1. Schematic	2. Sensor Detail
	1. Air Temperature, Wind Speed & Direction, Barometric Pressure 2. Wave Height, Wave Direction, Wave Period 3. AIS (Automatic Identification System) 4. Current Direction, Current Speed, 5. Turbidity, pH, Oil – Crude, Oil – Fine, Chlorophyll in vivo, CDOM/FDOM, and Fluorescein dye 6. Water Speed 7. Water Temperature, Dissolved Oxygen, Electrical Conductivity, Salinity, Density

Figure 2. Sensor layout of the Wave Glider.

2. Objectives

The objectives of this project are:

- To continuously monitor marine water quality in real-time basis and provide the data wirelessly to the Web GIS application,
- To function as an early warning system that alerts to any unexpected changes in water quality along its transect routes for indication of exceedance or pollution events through Web GIS,
- To provide long term status and trends data used to determine the changes in water quality conditions and to determine the impact of natural influencing factors (i.e. climate and ocean) on water quality year to year variability via Web GIS Dashboard.

3. Project Area

Round-the-island mission at Bidong Island, Terengganu (5°37'2.57"N, 103° 3'47.17"E), one square kilometre (1km^2) in area and is situated off the coast of Terengganu, Malaysia in the South China Sea. It is the northeast side of Kuala Terengganu city and Merang town. To get to the island, it takes about 40 – 50 min by boat [2].

4. Methodology

4.1 Mission planning

Mission planning was carried out in order to achieve the best possible methodology to execute the mission and meet the desired uptime of collected data. Mission planning began by determining the best possible route for the glider to fulfil the monitoring objectives. The first step in determining the route is by carrying out an Operational Risk Assessment (ORA).

An ORA describes the environmental, political and safety conditions that act as a recommendation of the best practicable route for the units, to ensure the efficiency and reliability of the mission and ultimately to meet the monitoring objectives. Intended coordinates or waypoints of the mission is pre-configured and acknowledged by the satellite. This enables autopilot mode of the operations although dedicated pilots assigned to each unit 24/7 are able to interject the autopilot mode and manoeuvre whenever deemed as necessary. After the necessary interjection, the unit is able to return to its autopilot mode, following the pre-configured waypoints.

4.2 Launch and recovery

A small vessel is required with minimum requirements of 8 m long and installed with a hoisting capability on-board (crane/davit) with minimum Safe Working Load of 500 kg. The small vessel shall bring the Wave Glider off shore up to a point of fulfilling the minimum required depth for it to operate, which in this case is either 8 or 10 m. After a Wave Glider is launched, it will make its way to its first pre-configured coordinate/waypoint and begin data collection (see Figures 3 and 4).

4.3 Piloting

The Wave Glider unit is equipped with physical security features, remote safety watch and alarm to secure against vandalism and theft.

i. Real-time transmission of redundant Global Positioning System (GPS) reports from sensors in real-time
ii. Low visibility
iii. Localized, on-unit labelling
iv. Automatic Identification System (AIS) to autonomously avoid approaching vessels with transponders

The Wave Glider is remotely traced and controlled by dedicated personnel whom are positioned at the Environmental Data Centre (EDC). The WGMS portrays mapping for piloting of the units, where pilots send commands to the units through satellite for instructions and to receive notifications such as the physical or software condition of the unit and to monitor real-time data as the units transmit them. A screenshot of the web-based piloting interface is illustrated in Figure 5.

Figure 3. On-boat preparation before the launch of the Wave Glider.

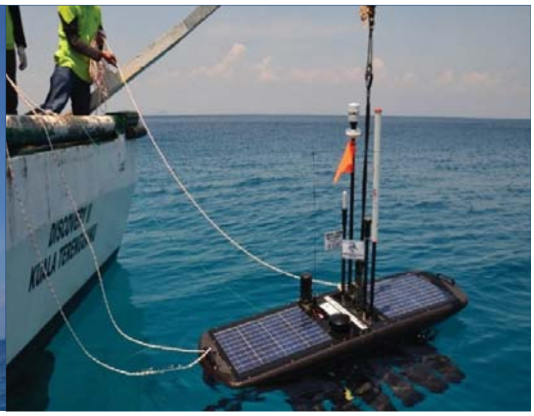


Figure 4. The Wave Glider is ready for launch and begin mission.

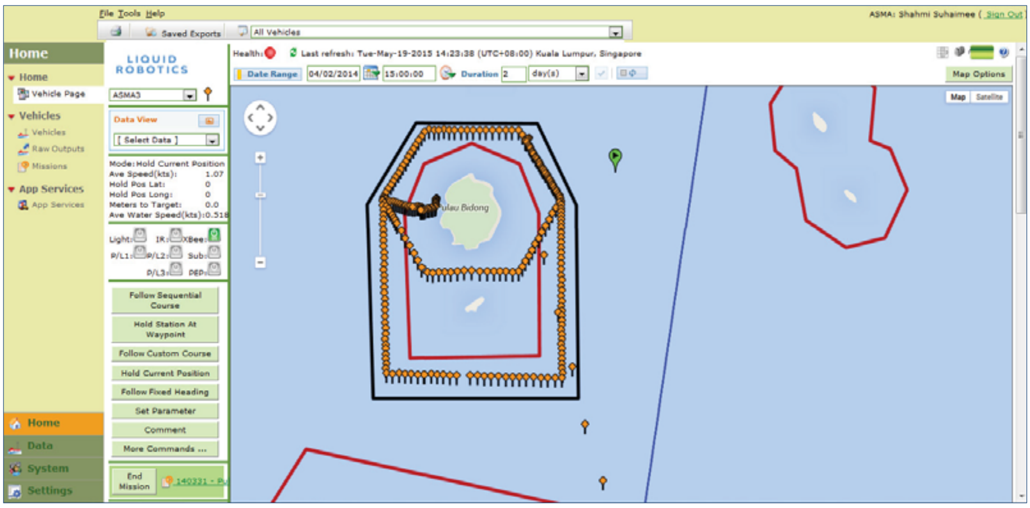


Figure 5. Web based piloting interface that can be viewed on a tablet, laptop and etc. Primary piloting will be at EDC through wireless application.

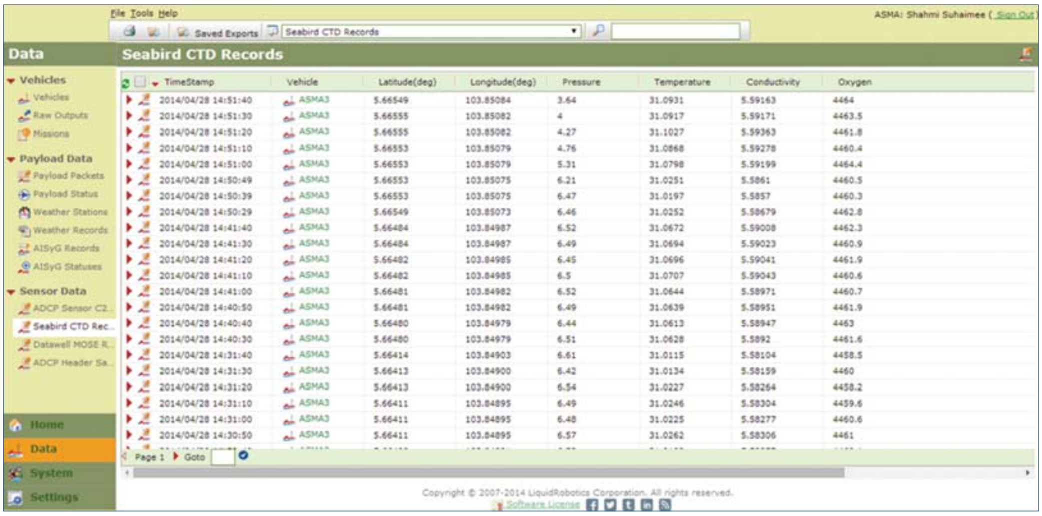


Figure 6. Web based interface to view the real-time data collected by the Wave Glider in tabular format.

4.4 Building Real Time Web Applications Using GeoEvent Processor

Over the past few years interactive mapping or Internet GIS has rapidly developed resulting in the migration of some GIS functionality. By using GeoEvent Processor, it extends the capabilities of ArcGIS for Server by bringing live data from Wave Glider and issuing alerts when specified conditions occur—all in real time. GeoEvent Extension can:

- Stream (push) event data to the FlexViewer via WebSockets,
- Direct event data into feature services hosted on ArcGIS for Server so that maps created will represent the most up-to-date information occurring in the real world,
- View the latest feature status using FlexViewer,
- Filter GeoEvents using spatial or attribute conditions to focus on the most required event data,
- Enable GeoFence to avoided areas during the transection,
- Archive event data within featured services or tables,
- Enrich incoming events with data from a secondary feature service or system file [3].

ArcGIS GeoEvent Manager is used to create and configure service components, as well as design, publish, and manage GeoEvent Services. Input Connectors, Output Connectors and published GeoEvent Services are created in this page. Getting the real-time data into Web Application is done by polling the CSV file from WGMS web. The real-time data is viewed via FlexViewer developed using Flex application builder. ArcGIS Viewer for Flex provides a smart, intuitive framework for viewing and interacting with maps. It is a configurable web application that allows user to easily build user own custom mapping application in just a few minutes, with no programming required. Figure 7 illustrates the process from data collection stage until delivering the information through Web GIS and Mobile Application.

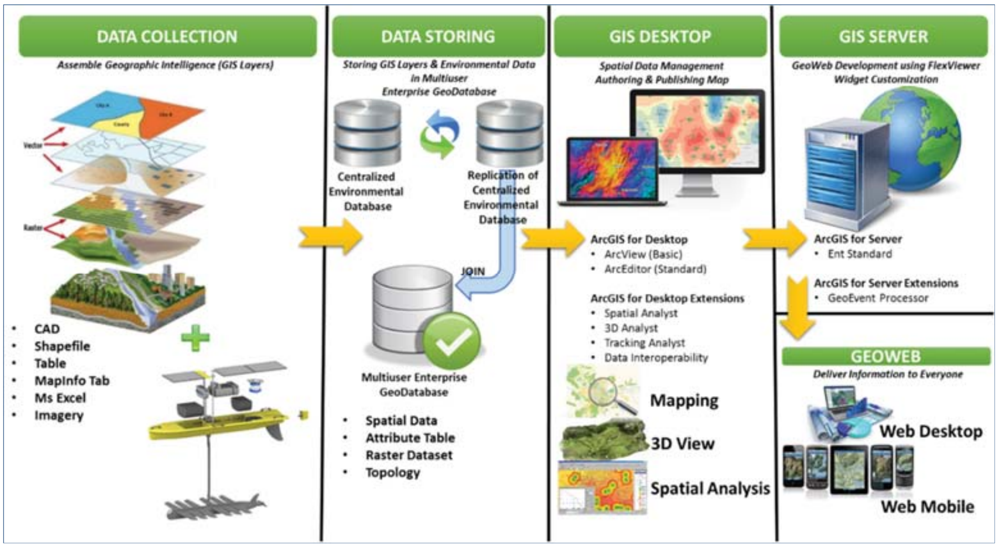


Figure 7. Process in Building Real Time Web Applications Using GeoEvent Processor

This Web GIS has different analysis tools to help the users understand marine water concerns in various areas. This Marine Water Quality Database (MWQDB) contains more than twenty (20) data layers representing various marine water quality themes namely Dissolved Oxygen (DO), Temperature (Temp), pH, Conductivity (Cond) and meteorology data such as Wind Speed, Wind Direction and other parameters. Using the classification capabilities of ArcGIS, the quality of marine water is represented through symbols to show variations on a map that allow visual differentiation, enabling users to easily view the parameters that are exceeding their safe limits, along with their percentage of exceedance. This helps anyone to easily see areas where water quality is exceeding safety limits and by what amount according to the Malaysian standards and best practices. The users can see the results of these calculations as color-coded ranges on a map and easily understand the water quality levels at that particular location.

Figure 8. Colour coded ranges and instantaneous colour schemes for each monitoring locations.

It is easy to understand marine conditions by looking at the dashboard, which includes charts, statistics, summary tables and maps. Users can get access to the updated data in areas where water quality exceeds safety parameters and find complete sample details, parameter variation trends and annual summary of marine water quality status. Water quality changes over time are depicted on intuitive, multilevel, customizable charts that allow users to track marine water quality by years, months or even weeks. They can review and compare the water quality at one or more sites as average annually, monthly or weekly values. Users are also able to identify threshold-violating samples through instantaneous colour schemes and timely automatic alerts on the map.

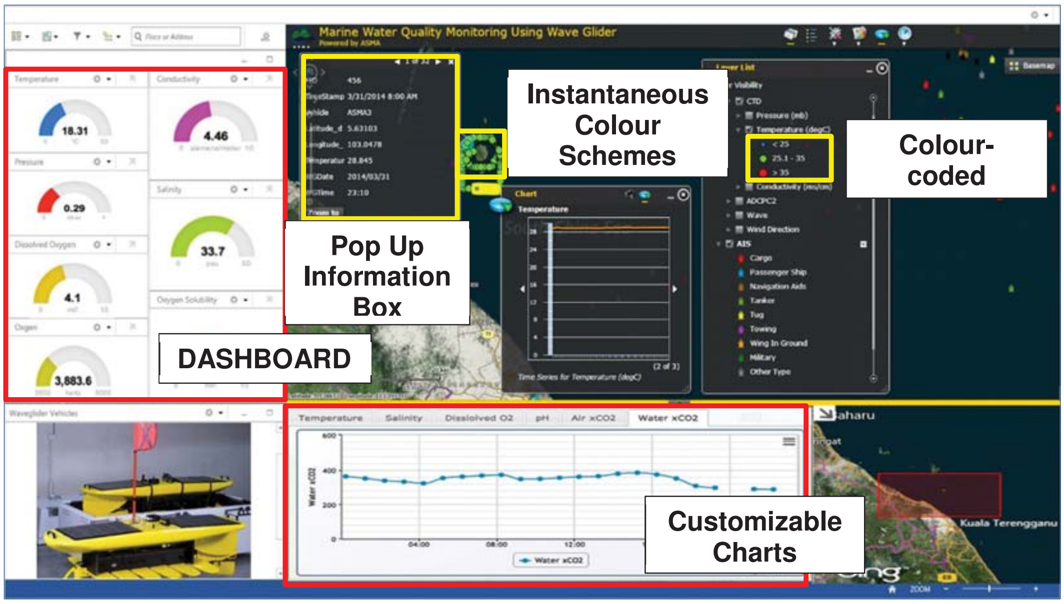


Figure 9. Example of Real-time Web GIS dashboard.

5. Conclusion

The Wave Glider can provide real-time, autonomous, zero-carbon-footprint derived oceanography data - in order for decision and policy makers alike to make more well-informed decisions and even to assist in early warning detection of natural disasters. This platform has many tools to help the users understand marine water condition in various areas. Continuously moving sensors measure temporal and spatial characteristics of surface gradients in water and therefore Wave Glider is a critical feature that ensures corrective actions and response to be taken before potential issues arise in regard of marine water quality.

By using GeoEvent Processor to incorporate the real-time data into Web GIS, it is easier for anyone to analyse the marine water quality data. It shows areas with poor water quality and draws attention to the possible source of environmental violations. Furthermore, by manipulating the different environment map layers, users can make correlations between at-risk water samples and findings with the neighbouring environment. The Web GIS application improves the efficiency dissemination of information to the stakeholders particularly the decision makers. This web helps the staff in managing and analysing relevant data, as well as publishing this information as maps, charts, and reports.

The benefits of having the real-time Web GIS for this monitoring project are:

- Reducing monitoring costs,
- Improving the speed of decision making by supporting the decision-makers with real time information,
- Ability to access by everyone and everywhere over the internet,

- Reducing time and minimizing effort to reach data,
- Ability to produce reports based on user specified parameters.
- GIS classification enables the users to distinguish marine water safety on color-coded maps.

6. References

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