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Keith Gardiner
Dublin Institute of Technology, keith.gardiner@dit.ie

A Rizzini
Dublin Institute of Technology

James Carswell
Dublin Institute of Technology, jcarswell@dit.ie

Michela Bertolotto
University College Dublin

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Keith Gardiner
Dublin Institute of Technology, keith.gardiner@dit.ie

A Rizzini
Dublin Institute of Technology

James D. Carswell
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Michela Bertolotto
University College Dublin

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K. Gardiner[1], A. Rizzini[2], J. Carswell[1], M. Bertolotto[2]

[1]Digital Media Centre
Dublin Institute of Technology
Aungier Street, Dublin 2.
Telephone: 353-1-4023268
Email: keith.gardiner@dit.ie

[2]Dept. of Computer Science
University College Dublin
Belfield, Ireland.
Telephone: 353-1-7162913
Email: michela.bertolotto@ucd.ie

1. Introduction

This paper describes a web-based and Mobile Environmental Management System (MEMS) prototype specifically tailored to perform context-aware queries and updating of spatial datasets. Spatially enabled computing can provide situation aware assistance to both web-based and mobile users by presenting the right information at the right time, place, and situation using context-associated knowledge. Context-associated knowledge is assembled by combining knowledge gained about information accessed in the past with the activities planned by the user, together with other situation dependencies (e.g. location) of these activities. The MEMS datasets are provided by the Canadian Department of Fisheries and Oceans (DFO) and the prototype is customised to the specific needs of the Great Lakes Laboratory for Fisheries and Aquatic Sciences (GLLFAS) Fish Habitat Management Group's requirements for fish species at risk assessment. Currently, freshwater biologists and provincial officers have access to the fisheries database, containing layers of biological information (e.g. spawning sites, weed beds, substrate type, etc.) solely from the office. Delivering this data overlaid on base maps of the Great Lakes region to a spatially enabled hand held device and linking it to each task currently being investigated will allow for mobile GLLFAS biologists and enforcement officers in the field to make informed decisions immediately. This is done to conserve, restore and develop the productive capacity of habitats for recreational, commercial and subsistence fisheries both in the freshwater and marine environments (Minns 1997, Minns, 2001).

Similar research efforts (e.g. Mapster) in this area give researchers critical environmental information about habitats. Briefly, it is designed to provide access to fish and fish habitat related information via a web-based application for Canada to a widely dispersed and diverse group of users (Mapster, 2004). More than 200 datasets from British Columbia and the Yukon Territory are currently accessible. An enhanced version of the interface went online in 2004 that includes data on fish species presence and distribution, marine habitat, administrative boundaries and orthophoto imagery. In contrast to Mapster, the MEMS system has the ability to populate fisheries related datasets in real-time while still in the field based on a users location.

The high-level functionality that GLLFAS biologists envisage for the MEMS prototype includes access to geo-referenced maps and imagery, overlay their positions on the maps, manipulate (e.g. input/edit/query) attribute data in the field while wirelessly connected (where possible) to the office database. Additional functionality to the base MEMS requirements for the developed prototypes are multimedia user annotation capabilities directly on digital images taken in the field, scientific name/common name linking for fish species and other relevant field observations (e.g. vegetation, insect life, etc.).

Another important aspect of the system is the ability to perform real-time queries on the data. Some standard queries include species accumulation curve, which determines when enough of a single species has been sampled, Transect determination, which determines how long a sampling transect is to be, based on certain criterion. In addition, spatial queries such as, district authority notification and containment queries can be processed.

The current "fish species at risk" workflow, whereby scientists enter textual/pictorial information on paper field data sheets is inefficient, has potential for inaccuracies during both initial recording and subsequent data entry phases, and does not facilitate knowledge sharing between staff. Also, different types of information may be stored in different locations and valuable time can often be lost trying to correlate data in order to make decisions. The proposed MEMS system has the following advantages over current practice:

1. Facilitates knowledge sharing and data analysis/synthesis.
2. Supports effective communication between different staff at different physical locations (e.g. scientists in the lab and colleagues in the field).
3. Allows important multimedia data and associated annotations to be combined with text-based records.
4. Saves time and money by reducing paperwork and allows staff to input and access information anywhere at any time without having to return to dedicated access points.
5. Reduces error by reducing latency between collection and data entry, as well as paperwork.

2. Proposed Development

The MEMS system is being developed in two separate stages. Stage 1 includes the development of an initial prototype that is predominantly web-based with simulated mobile aspects. The main objective of this prototype is to demo a workable system to GLLFAS biologists with an evaluation carried out to determine its capabilities, potential, and recommend enhancements. The second stage (Stage 2) of the development considers feedback generated from the Stage 1 evaluation. This stage will develop a second, but fully field-operational, prototype using a PDA and tablet PC.

The prototype is being developed using eSpatials iSmart Suite (eSpatial, 2004). This software is a collection of tools that enables developers to build and deploy spatial applications using a set of standard procedures. It eliminates the need for major pre-requisites that the developers must have in order to fully understand and deploy a full spatial application. These tools offer a high-level development environment which is several time faster than developing the application from a base Java development environment. The three-tier architecture adopted (Figure 1) allows for the development of individual components of the system separately, thus maintaining component independence (Carswell et al. 2004).

The implementation of the system itself is at an early stage. A lengthy process has been used to design the database using the Entity-Relational Model, Logical Design and Normalization rules. The database has been created and the data from the previous system has been successfully migrated into Oracle. The graphical user interface (GUI) is in the early stages and will be rapidly developed to accommodate all the functionality of the system. The system will be developed using the XP programming paradigm or extreme programming approach, which focuses on the modularisation of the functionality.

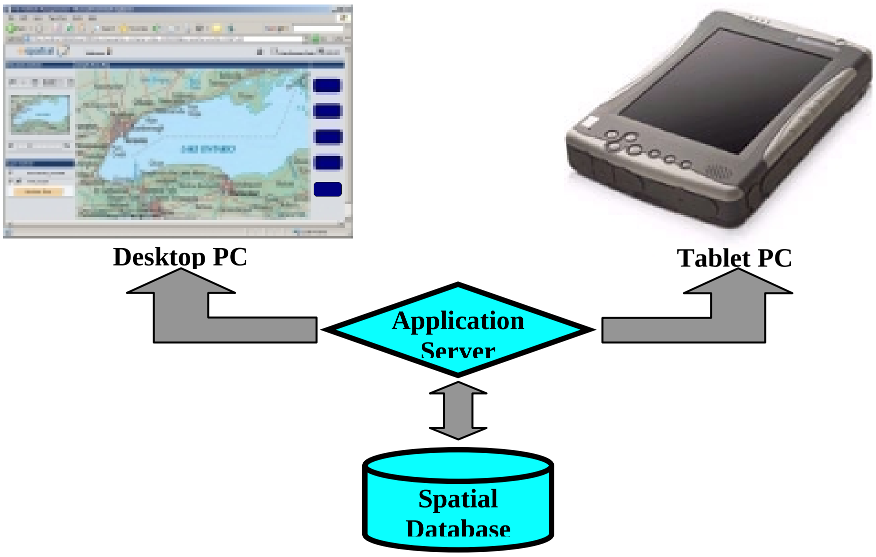

Figure 1. Three-tier Architecture

3. System Architecture

The MEMS prototype relies on a typical three-tier architecture for enterprise information systems, composed of the client layer, application server layer, and the database layer. This architecture focuses on the development of services for a versatile, extendible (J2EE) application server, instead of giving GIS capabilities to a large monolithic application. The communication between the client layer and the database are conducted through the application server layer.

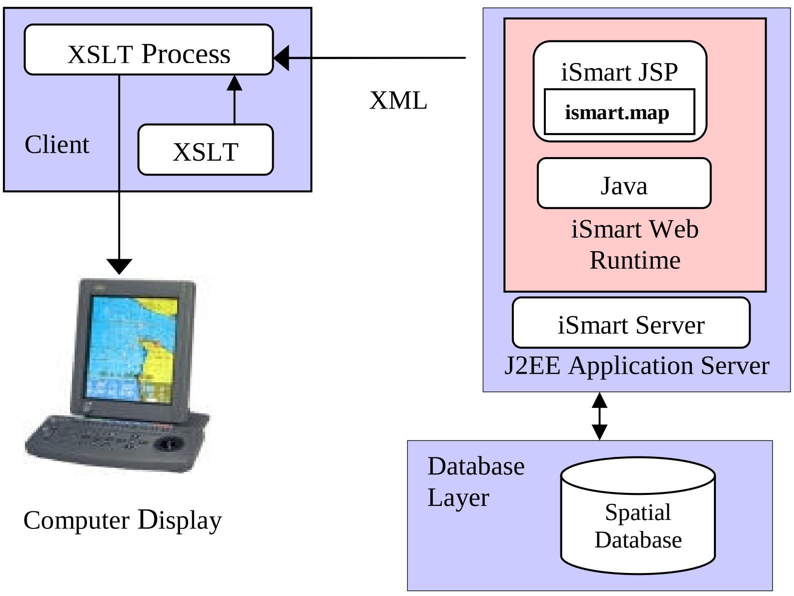

Figure 2: MEMS architecture

The client layer consists of a web-based interface, that enables data-input and analysis functionality to provide biologists with the ability to input, edit and annotate data over the Internet. Initially, as the user navigates in the system, the position and orientation of the user is displayed on a geo-referenced map of the area. This information is used when loading data into the database and for querying the database in real-time. This can be carried out using a Tablet PC or Personal Digital Assistant (PDA) equipped with a Global Positioning System (GPS) receiver that determines the position of the device. The device also has a General Packet Radio Service (GPRS) network connection for requesting and transmitting data to and from the application server. This information is transmitted over a mobile phone network.

The content needs to be scaled down by using a device-specific content adaptation approach to allow for efficient delivery. This is one of the weaker aspects of the system with regards to cost. As the data has to be transmitted using GPRS in the field, this incurs a high cost for the user, so for the system to be feasible, the cost of data transmission will have to fall considerably in the future.

The application server layer of the MEMS system is where all the processing takes place. It acts as the main hub between the client and database layers of the system. This layer of the system consists of a J2EE Application Server, which is made up of two main components, the iSmart web runtime and the iSmart Server (Figure 2). These two components are used to run applications that have been developed using the iSmart Web Designer.

The iSmart Web Runtime is a component of the application server that executes the web application. This component of the system integrates with the iSmart Server to run the application. Within this component there is a Servlet called the iSMARTWebServlet. This Servlet acts as an interceptor to all incoming HTTP requests. This Servlet uses control logic, specified by the developer to decide what actions to take and when, for example, when a button is pressed on the application (Figure 3). The iSmart Server handles all requests made to the application server. The iSmart Server contains all the functions and controls in the application server layer. This layer of the system is also responsible for determining device specific capabilities. Using XML and XSLT, the iSmart Server will adapt all returned content based on the type of device that makes the request. This will be achieved by creating an XML file based on the device request. An XSLT stylesheet is then applied to the XML file to create a device specific output.

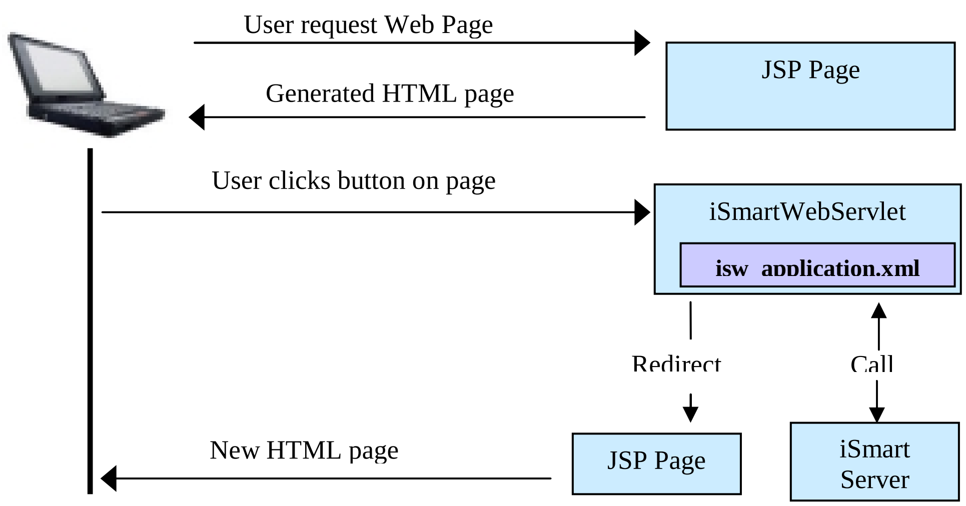

Figure 3: MEMS System Request Scenario

The spatial database layer is responsible for processing all queries, both spatial and transactional. Oracle Spatial is used as the database platform and includes the Spatial Data Option (SDO), a spatial extension to SQL (Rigaux et al, 2002) that enables Spatial Data Types (SDT) to be inserted, stored, manipulated and queried in the database as they are represented in physical space. Also, Oracle Spatial is integrated into the extensible Object Relational Database Management System (ORDBMS), which allows access to the full functionality and security of the underlying DBMS (Lopez, 2003). For stability reasons the server is hosted on a Mandrake Linux Server.

4. Discussion

The architecture for the MEMS system could be modelled in many ways. One such method is remote methods invocation (RMI). RMI offers the advantage of storing executable methods on the server, so the client can execute them remotely. Using the RMI architecture would not have benefited us as much as the distributed workload of the Three-Tier Architecture as it offers a better distribution of processing load, ideal for the development of applications on restricted specification devices such as PDAs, and Tablet PCs. The bulk of the computation is done on the Application Server Layer and Database Server Layer, minimizing as much as possible, the computation on the client layer. The use of the iSmart Suite for developing and deploying the prototype application enables the developers of the system to focus their efforts on the control logic of the application while leaving the low-level deployment to the iSmart Web Application.

The MEMS prototype will be evaluated on a regular basis by the biologists at the DFO where the researchers will use MEMS during regular field sampling sessions. This type of evaluation ensures that MEMS adheres to the functional requirements proposed by the actual system users.

5. Acknowledgements

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Biography

Keith Gardiner received a B.Sc. in Applied Computing from Waterford Institute of Technology (Ireland) in 2001 and a Masters Degree in 2004 from the Dublin Institute of Technology (DIT) where his final thesis proposed innovative techniques of directional querying in spatial databases for mobile applications. Currently he is employed as a Senior Researcher at the DIT Digital Media Centre where his main areas of expertise are the integration of Oracle Spatial with J2EE and Computer Graphics Technologies.