Incorporating Geospatial Information and Animation in a Mobile Web-based Irrigation Management System

Chanon Pansamuth[1] and Sally E. Goldin[2*]

[1]Department of Computer Engineering, King Mongkut's University of Technology Thonburi,

126 Pracha Uthit Road, Bangmod 10140 Bangkok THAILAND;

E-mail:chanonpsm@gmail.com

[2] Department of Computer Engineering, King Mongkut's University of Technology Thonburi,

126 Pracha Uthit Road, Bangmod 10140 Bangkok THAILAND;
E-mail: sally@cpe.kmutt.ac.th

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ABSTRACT: Water resources are very important for agriculture in Thailand. Many irrigation projects have been built to provide improved systems for using water resources efficiently. Irrigation officials in Thailand currently use a special offline application to compute irrigation water requirements. However, farmers lack access to information from the management application, so they do not understand the irrigation plans and sometimes do not follow them. In our research we have designed and implemented a mobile web application to provide farmers with information about irrigation plans and outcomes. We have extended the currently used mathematical model for calculating irrigation requirements and integrated that model with a simulation that calculates the amount of water delivered to each section of canal system, using geographic information about irrigation canal structure, location and connectivity. We have also created a simple spatial dynamic visualization capability for displaying simulation results. Our application can help the farmers to monitor the water situation in order to understand and follow water management plans. It also allows them easy access to irrigation data while they are in their fields. Our special purpose GIS application is designed for use in the Nam Oon irrigation project but the software can easily be adapted to other irrigation systems. It allows farmers to optimize the water delivered to their fields and hopefully, to improve agricultural productivity.

1. INTRODUCTION

Water resources are very important in Thailand. Management techniques have been implemented to support water use activities. Many infrastructure projects have been built in appropriate areas with different functions, such as storage, distribution and transmission. Agriculture is the first target of water resources development planning strategies, since 67% of water consumption in Thailand involves this sector. Many irrigation projects have been established around the country, not only to serve farming operations, but also to improve the livelihood of people.

The Nam Oon irrigation project was constructed in the northeast of Thailand in 1967 to decrease damage from drought and develop the rural areas in the Lam Nam Oon basin. An additional target of project was to increase agriculture production in this area. To manage water in this reservoir, the Royal Irrigation Department (RID) presently uses an application developed by Louis Berger International Inc. (1986) called Water Requirement Calculation (WATERCAL). WATERCAL can predict water demand and plan the dispensing of water to crop fields. However, this application was designed to represent data in text form only. It cannot presently use geographical information in its calculation or to display its results. WATERCAL also calculates requirements at a fairly coarse level of granularity, namely canal sections, rather than individual fields. The staff of the Department of Water Allocation gives knowledge about using water efficiently to farmers in this irrigation service area but some farmers do not follow the water distribution plan and do not control flows as directed. They do not open and close gates in ditches as the plan requires. This negatively affects other farmers who receive water in same canal section.

Geospatial technologies can improve the irrigation system effectiveness. The operation of irrigation systems depends on the location of canals, gates and fields, and the connectivity between them. Integrating spatial information into irrigation management software can help irrigation planners reduce time of operation and create more detailed and more realistic water use plans.

The number of mobile devices in Thailand (NBTC, 2011) is increasing at a rapid rate. Currently, mobile phone penetration is greater than 100% (meaning that some people have more than one phone). Smart phones are very popular and are available for under US$100. Although the capabilities of mobile devices vary, almost all have a micro-browser implemented in a portable device environment. Moreover, wireless broadband technology on mobile phone such as WiFi, 3G and 4G is improving high speed data transmission which provides easy access to information anywhere.

Communication is at the heart of management. Managers must be able to communicate both the plans and the expected outcomes to the users (farmers) who are supposed to benefit from the irrigation system. Data visualization provides a way to represent information clearly and effectively. The work described in this paper combines the benefits of mobile devices and geospatial data analysis. We present a mobile web-based irrigation management system prototype. The aim of the web-mapping function is to support interaction between irrigation project managers and farmers by using visualization.

2. MOBILE SPATIAL TECHNOLOGY

Geographic Information Systems (GIS) use computational tools to manage spatial data. Spatial data is information that is provided with corresponding geographic location, for example, the elevation above sea level at each position, or the types of soil found at different locations. Geo-spatial technologies have been applied on mobile device with differences in functional usage. Dong et al. (2010) researched and implemented a mobile GIS to manage forest resources, running on a mobile device and communicating with wireless technology. The software is intended to extend the device utility into forest field surveys for monitoring fires, land and water resources. A mobile GIS system has also been implemented for real estate development (He et al., 2008) to collect information about and monitor land resources. The application separates database into spatial information and a monitoring database. Mobile inspection system is a line inspection application based on J2ME that is intended to audit line power (Zhao et al., 2012). This project used a GIS server to generate the data in an SVG document. The J2ME platform was used to reduce memory requirements on the mobile device and increase efficiency of data transmission.

Geographic Information Systems (GIS) have also been integrated with irrigation management systems. Mobile technology is evolving to solve irrigation problems in India (Rao et al., 2009), where researchers are using Short Message Service (SMS) technology to improve agricultural productivity. In another study (Lin et al., 2006) a Personal Digital Assistant (PDA) was integrated with a spatial application to support field investigation in an irrigation system.

The World Wide Web Consortium (W3C) has defined a standard vector image format based on XML, called Scalable Vector Graphics (SVG) (W3C, 2001). SVG provides components for creating and editing graphic elements. W3C (2001) provides a standard language to manipulate SVG within HTML and XML documents. Document Object Model (DOM) is cross platform application programming interface (API). With capability of DOM, SVG can be used to support visualization on modern web-browsers. The browser can render SVG directly within the markup language. Michael et al. (2011) created a JavaScript facility called D3, which provides methods to operate on DOM objects to support fast and easy represent data visualization on websites.

3. SYSTEM DESIGN

We call our mobile irrigation planning and visualization system "Water in Your Pocket". The architecture of the system is shown in Figure 1. The system is separated into two parts, the mobile web client and the server. The server side has water requirement and simulation water distribution modules. The results of calculations are stored in the database. The mobile client side sends a data request to the server. In response, the server queries the database to retrieve both irrigation simulation results and geo-spatial data. All of the query information is restructured to XML format and sent back to mobile client side.

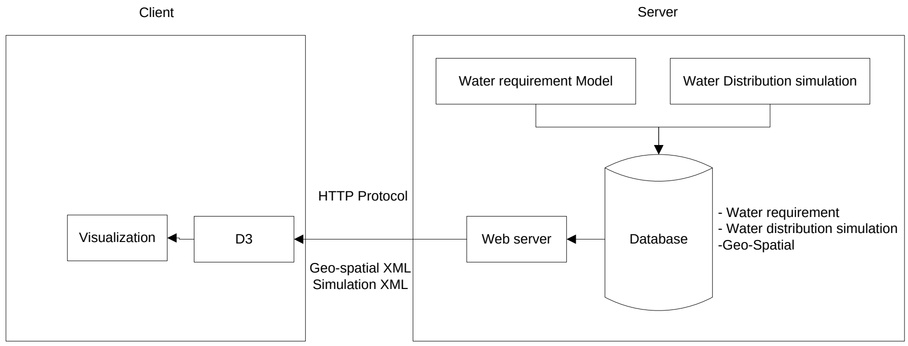

Figure 1, Mobile-web based irrigation architecture

3.1 Database design

The database underlying our system is implemented using the open source PostgreSQL system, version 9.1(PostgreSQL, 2011). The database is divided into three main parts: irrigation management data, simulation parameters and results, and geo-spatial data.

3.1.1 Irrigation management database

To run the irrigation requirements model, the database includes crop calendar data, field areas, weather information and crop water consumption parameters. Water requirement calculations are divided by canal section. Each section has a specific ID which links it to location data via a feature ID in the geo-spatial database.

3.1.2 Water distribution simulation database

The water distribution simulation database stores parameters for a simulation run, and corresponding results. The parameters include date and time, initial amount of water to dispense, season (wet or dry), and the configuration of gates (open/closed) for each day. The results are organized by canal section and save the amount of water received each day and a value indicating the degree to which that water satisfies the calculated water requirement (over or under). The simulation results also include information on connectivity between canal sections (that is, the network topology).

3.1.3 Geospatial database

The spatial data are organized as features, nodes and points. The feature table stores a foreign key that links to the logical canal section or water gate. The node table associates points with features and provides ordinal information. The point table stores UTM coordinates of individual points in the irrigation structure.

3.2 Server side

3.2.1 Water requirement model

Each type of plant consumes a different amount of water in order to grow. Crop water requirements and rainfall are the main components that are considered in order to evaluate amount of water demand in an irrigation system. To calculate irrigation water requirements, evapotranspiration or consumption of water is the primary factor to consider. Our water requirement model is implemented based on Doorenbos and Pruitt (1977). Our implementation includes the potential to allocate water to different fields based on their crop patterns.

3.2.2 Water distribution simulation model

The irrigation infrastructure of Nam Oon irrigation system consists of main canals, farm turnout and check dams. Canals are divided into sections by check dams. We simulate distribution of water in canal sections based on a breadth-first network traversal algorithm (Cormen et al., 2009). Each canal subsection and farm turnout constitutes a vertex in the network. Edges are defined based on physical connectivity, that is, the geographic layout of the irrigation system. The distribution simulation is run day by day in a week. On each day, individual water gates can be specified as open or closed.

Traversal begins from the dam outlet into the main canal, with a specified overall amount of water to be dispensed each day. Water will be delivered to each section based on the section's maximum capacity, but limited by the amount available from its parent vertex. As water passes through each canal section, the overall amount is also reduced to simulate conveyance loss due to evaporation and absorption.

Each canal section has a water requirement which is calculated from water requirement model. By comparing the amount of water delivered by the simulation to the required amount, we can evaluate the "goodness" of a particular irrigation plan.

3.2.3 Web server

The XML format consists with a geographic section and simulation section. The geographic section encodes feature, node and point attributes to provide the necessary data for visualizing the canal layout. The simulation layer has attributes such as day, canal section ID, amount of water delivered, and water required.

3.2.4 Data transmission

The mobile client interacts with the server using the HTTP protocol. We use a GET request to ask for information from the server side. The server returns both geospatial data and simulation results in XML format. The XML data will be separated and restructured into JavaScript objects by the client.

3.3 Client side

3.3.1 Visualization

The mapping consists of three layers: irrigation zones, canal system and irrigation gates. We use SVG path structures to represent graphic elements on HTML page. Geo-spatial data is transformed to SVG graphic using D3. Each path element has attribute commands to build the graphic object. Tag of path which generate by D3 is **<*path* > *M L***; **M** is move to origin point and **L** is line to next point.

We display the simulation results one day at a time, using different colors to indicate the water level in each canal section. An empty canal section is shown as gray. As the amount of water in a canal section increases, up to the calculated requirement, the color of the section will become a deeper and purer blue. If the amount of water delivered (according to the simulation) exceeds the calculated requirement (thus wasting water), the section turns red. By observing the color changes from day to day, the user can see the success (or failure) of the irrigation plan represented by the simulation.

The user should be able to zoom the visualization so that he can see his own fields, and also pause, rewind, slow or speed up the animation.

4. RESULTS

4.1 Work completed

The server side development component of this research has been essentially completed. The water requirement model can calculate crop water requirements under different assumptions. The distribution simulation module can calculate water dispensed day by day during cultivation season. All of database design elements are implemented. The XML generator module can query information and send the response the client side.

We currently have a prototype of the visualization application running on a mobile simulator (Opera, 2011) as shown in Figure2. Canal section is shown as line graphic on the mobile screen.

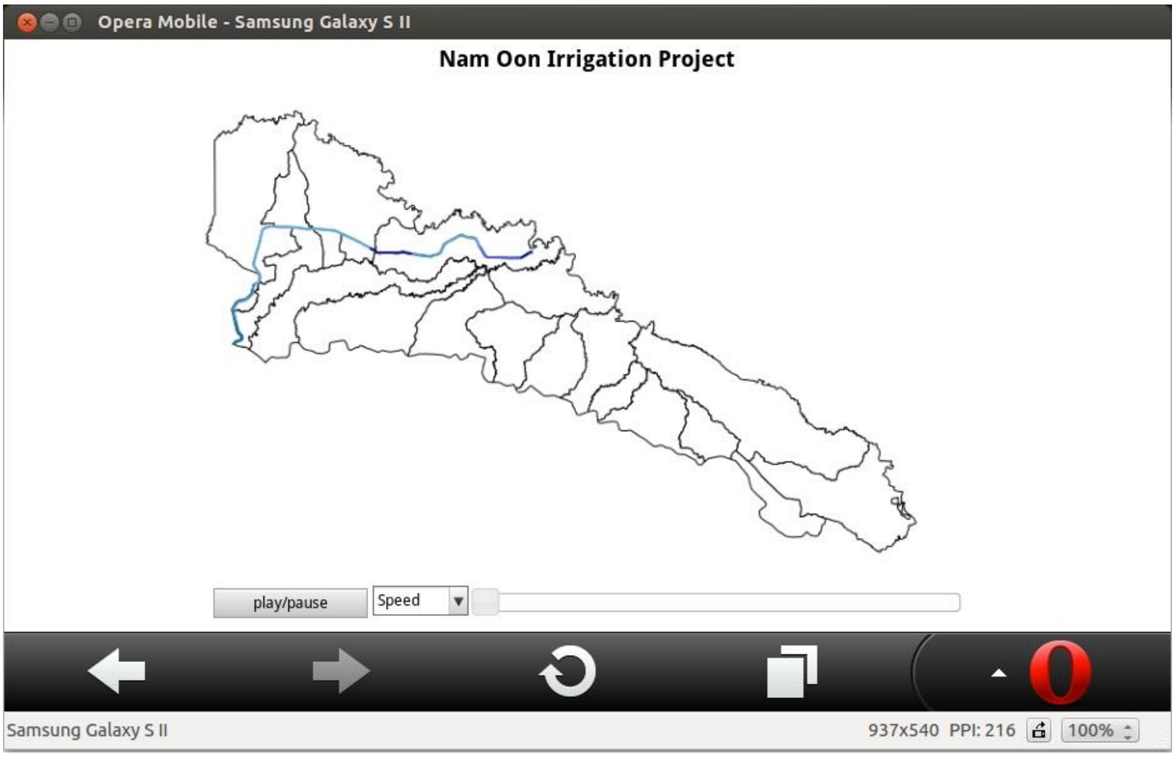

Figure 2, Mobile-web base irrigation prototypes on open mobile-browser

4.2 Work in progress

We are currently working on development of the client side visualization. XML data received from the server can be unpacked into JavaScript format. The data visualization component uses simple SVG graphics to render the geographic part of the XML using the D3 library. We have implemented the animation using changing colors from day to day of the simulation to represent different water levels.

We use JavaScript combined with the jQuery UI (jQuery UI, 2013) to design THE interactive components on the page. Basic animation of water delivery is implemented using standard JavaScript. We increase its capability by providing the user with more control animation such as play, pause and animation speed controls. We have also implemented a zooming function in application.

4.3 Future work

We will also undertake an evaluation by providing the application to water managers and farmers in the Nam Oon basin, and surveying the utility of the application and the users' satisfaction.

5. CONCLUSION

This paper presents an application that can help the farmers to monitor the water situation in order to understand and follow water management plans prepared by irrigation managers. It also allows farmers easy access to irrigation data while they are in their fields.

By implementing the system using a mobile browser, we take advantage of the popularity and convenience of mobile devices. We also minimize platform differences, so the application can be used on any smart phone, regardless of the operating system. We use geospatial information to drive the simulation as well as to make the visualization easier to understand. Our application can help fill the gap in communication between farmers and irrigation officials and thus improve both productivity and satisfaction.

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