Developing a new Dock Information System

The USACE has developed & implemented a new process for collecting data on NPIs

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This paper describes the design, development, and early implementation efforts for a new computerized system to collect, organize, and transfer data pertaining to piers, wharves, docks and terminals (i.e. Navigational Point of Interest – NPI) in support of maritime transportation. This data has been collected and managed for over 80 years in the Corps' Port Series Reports.

As the demand for more timely, detailed and accurate information relating to port facilities has grown in the past decade, the Corps has in turn revised its approach to data collection using a new, more dynamic and continuous system in the Master Docks Plus database. A web-based application that uses a three-tier architecture was developed to perform functions such as: 1) search for a dock, 2) view dock information, 3) update dock information, 4) edit dock information, 5) save dock information, 6) transfer updated information to USACE, and 7) automatically receive regular updates from the USACE. This system was tested to evaluate the functionality of the application and also to gather users' input to fine-tune the web application.

Introduction & background

The system described herein was developed in response to a recent initiative undertaken by the US Army Corps of Engineers (USACE) to update the methodology used to assemble and maintain timely and accurate data for the nation's dock facilities. According to the Navigation Data Center (NDC), current methods for data collection use a combination of personal site inspection by qualified engineering personnel, direct interviews with terminal operators, and detailed reviews of port facility plans, charts, maps, aerial photography, directories, and other media [1].

While current methods yield highly accurate and detailed information at the time of collection, they also require a significant expenditure of the NDC's time and resources. The process also takes several years to complete a single cycle of the total US inventory of dock facilities and their attributes. The growth in maritime commerce, and the resulting growth of ports to meet increasing demand, has led to a situation where the accuracy of information on dock facilities declines significantly over time after data have been collected and reported. This information must be as current as possible if it is to be of significant use in transportation decision-making [1].

As a result, the Corps contracted with the University of Toledo's Geographic Information Science and Applied Geographics (GISAG) Center to work toward developing a new process for collecting dock facility data that minimizes the need for site visits, reduces the time spent during a site visit, and assures more continuous data input into the Master Docks Plus (MDP) database. This effort also included a pilot program to collect data locally in the Toledo region, using the newly developed protocols in the area formerly known as Port Series 44.

Specifically, this project involves exploring a number of approaches to data collection that include geographic information system (GIS) and remote sensing data acquisition, direct web-based data entry, and new ways for contacting and working with terminal operators in the data acquisition process. This paper's focus is mainly on the web entry approach, where individual dock and terminal operators are given the opportunity to enter the data directly into the registry themselves without any intermediaries and with limited need for site visits by Corps personnel. The data collection/testing phase of this project emphasized this direct data entry approach by dock and terminal operators.

A significant portion of the project efforts dealt with the design of the data collection subsystem, as pre-collection activity is one of the most crucial steps in developing any data collection process [3, 4]. Furthermore, the design stage was devoted to developing a process utilizing current technology to minimize time and effort and to ensure that the data gathered are accurate and current [4]. The resulting system was a browser-based web application acting as an interface for collecting data (i.e., collecting new data or updating existing data). It also includes an exclusive interface to notify and pass the collected data to the USACE at the Navigation Data Center (NDC). All data collected are stored and managed at the Toledo site. Changes are transferred to the USACE NDC for acknowledgement and verification before the *Master Docks Plus* database is updated (see Figure 1). In addition, any updates made from sources other than the Toledo site to the NDC can be transferred back and incorporated to the maritime database residing at Toledo's end. The website can then display filtered information presenting non-sensitive information to the general public regarding dock facilities; it also displays detailed information of a specific dock based on search criteria (e.g., state, city, commodity, etc.).

This web-based dock information system (DIS) application is an easy-to-use, secure, and efficient tool for the USACE to keep track of all the NPI (Navigation Points of Interest) and

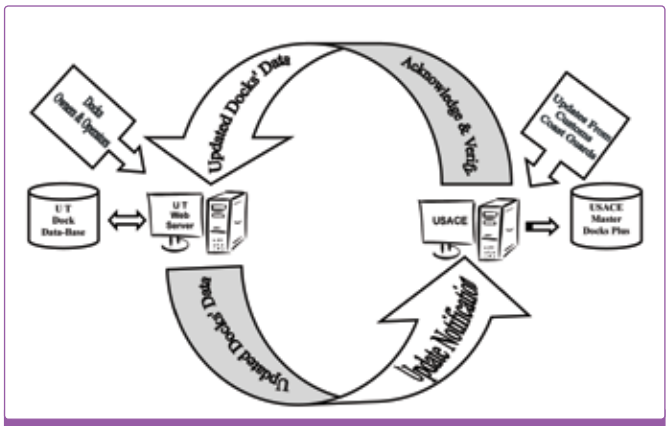

Figure 1. The dock update process.

the periodic changes occurring in the dock information. The outcome of this pilot project, if proven to be successful, can be expanded to encompass all docks in the US. This prototype system is currently limited to implementation and testing in the Great Lakes region.

Methodology

The development of this data collection system is geared toward devising a distributed system that is scalable, feasible, and sustainable. This section outlines the development process of the DIS system that uses a traditional life-cycle approach to identify, model, and document the data requirements. It also describes the application of a simple three-tired client-server type architecture that is a successful and popular approach to web application development [5]. Futthermore, it describes the web interfaces that use current web technology (Web 2.0), thereby providing flexibility in design, developing a rich user interface, and supporting different programming tools. Added to this system is the use of an *ASP.Net* framework to access and represent data in a secured fashion. Finally, the data are stored and managed using *MS SQL Server*, which resides on a data server hosted and managed by the University of Toledo. Five key processes are further discussed in the following sections regarding the design of the system. These include:

- Systems Life-cycle model
- Three-Tier architecture
- Web Development tool
- The Maritime Database
- Development of the Web Interface.

Life-Cycle

In the development of a web application, the understanding of the business logic is vital, but so too is the planning of the associated technical activity [6]. Figure 2 illustrates the life-cycle model used for the development of this application.

The process of identifying *Web Application Requirements* is focused on the users and defines the nature of the information exchanged. Since this web application is designed for universal access, a process of identifying users' requirements and the nature of their interaction with the database must be established. Two different types of users were identified, one being the general user who will have read-only access to the data. The other user type is the dock owners/operators who will have both read-only access to all the dock data and write access to their own dock facility data after valid authentication.

In the *Application Design & Development*, the structural view of the application is mapped to the data repository. The visual design, which is of great importance in any web application, is planned into a set of content-independent visual specifications. The navigational views are arranged into sets of access elements in the data repository.

Prototyping & Testing involves a simplified but complete version of the web application for users to have hands-on experience with the system. Feedback, comments, and suggestions are the key outcomes expected from users during this stage. Members of the project team maintain a log in their interactions with users (i.e., the dock owners and operators) to monitor the effectiveness of the system. In addition, system developers monitor for minor bugs and problems with the system and make the necessary repairs. This stage of the process was completed locally at the Port of Toledo.

Finally, *Implementation & Maintenance* enables the project team to replace the current version of the database with the most recent data obtained from the USACE *Master Docks Plus* database. From the Toledo end, data that are sent to the USACE NDC are used to update the *Master Docks Plus* database after the acknowledgement and verification process. In return, the USACE will periodically send the entire contents of the MDP database to Toledo for storage in the Great Lakes Maritime Research Information Clearinghouse (GLMRIC).

Architecture

This web application uses the three-tier system architecture (see Figure 3), where all three layers operate independently on different parts of an interconnected system. By using the three-tier architecture, the application logic is removed from the user tier and is executed on a web application tier. This module is situated between the user interface and the data storage system. The architecture enables the development of client-server applications and also helps to integrate various web tools and protocols for better performance and security [5].

The three-tier application framework (see Figure 4) is comprised of one or more users in the User Tier, the web application in the Web Application Tier, and the data in the Database Tier. The user tier consists of the user-side application logic and web graphic user interface (GUI) components along with several processes such as 'search dock', 'view dock information', 'update dock information', 'edit dock information' and 'save dock information.' The web application tier consists of the server side application logic, the database connectivity object, the data store object, and several data manipulation processes such as data retrieval, data view, data update, data edit, data save, the 'notify USACE' process, and the acknowledge/verify process. The database tier consists of several components that include an SQL interpreter, query evaluator, data access, and libraries to communicate with the DBMS.

As shown in the schematic in Figure 4, users are connected to the web application server to exchange both process calls and data, while the web application is connected to the database

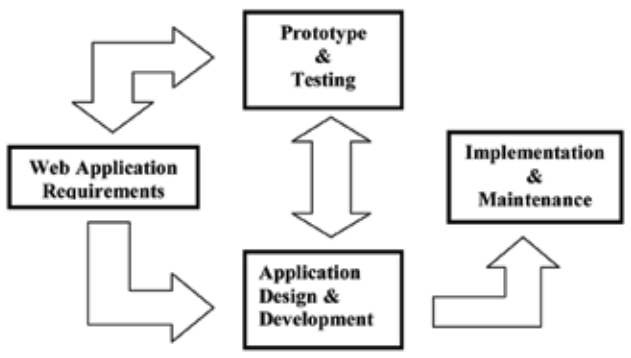

Figure 2. Web application life-cycle.

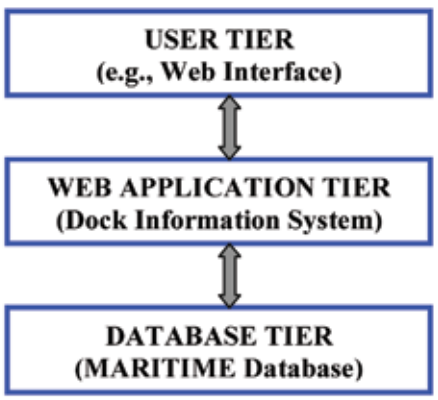

Figure 3. Three-Tier Architecture.

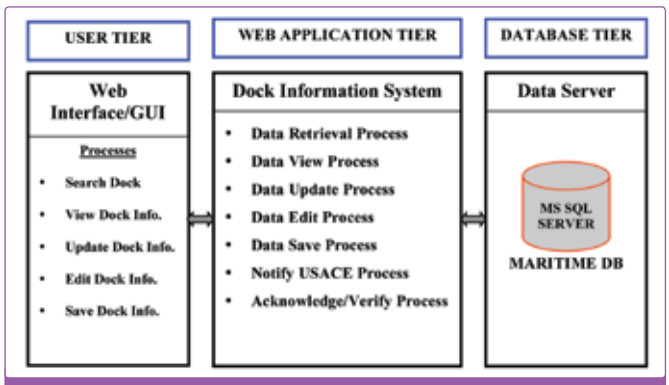

Figure 4. Three-tier application framework.

server in order to exchange database-related calls. The data are maintained in the form of data objects within the user and application tiers. The application tier also maintains a set of objects containing data for the users. As the application tier takes data from the format that is specific to the database server, it transforms them into the format that is specific to the data objects (and vice versa). The user tier is comprised of processes expected to perform one or more functions, such as 1) search for a dock, 2) view dock information, 3) update dock information, 4) edit dock information, and 5) save dock information. Any executed process will trigger sets of functions and procedures to be executed at the web server level or the data server level.

Web development tools

Visual Web Developer Express Edition was the primary tool used in construction of the web interface using the Web 2.0 standards – standards that are now becoming mainstream [7]. This Integrated Development Environment (IDE) offered by Microsoft, Inc. supports the *ASP.NET* framework along with *C#, JavaScript, CSS* style, and *AJAX*-enabled applications in the development processes since it provides less waiting and more control for the user [8]. This web application is hosted on two servers, a *Windows IIS* web server and an *MS SQL* Database server, which is administered by the University of Toledo's IT department. This web application provides primitives for the execution of asynchronous requests as well as updating page structure and content. Since this application consists of a single page, all of the elements on that page are updated in response to callbacks activated asynchronously by the user or by a server message.

The Maritime DB Database.

The database management system (DBMS) residing at and administered by The University of Toledo has an *MS SQL* server managing the Maritime DB database, and is currently in operation. The Maritime DB database is the exact replica of the *Master Docks Plus* database used by the USACE to store the NPI information. The Entity Relationship model (ERM) (see Figure 5) shows the conceptual data model of the Maritime DB Database.

In total, 11 main tables are used to store relevant information about the dock, as shown below:

- USACE_NAVIGATION_UNIT
- USACE_SERVICE
- USACE ADDRESS
- USACE_OPERATOR_OWNER
- USACE_COMMODITY
- USACE_WATERWAY_LOCATION
- USACE_LAND_TRANSPORTATION
- USACE_CONTACT
- USACE_PHYSICAL_LAYOUT
- SERVICE MASTER
- USACE_NAVIGATION_UNIT_ALIAS

The attribute NAV_UNIT_GUID is the common identifier in the entire Maritime DB to identify a dock's information. The UNLOC_GUID attribute also serves as a unique identifier.

Web interface

The web interface (see Figure 5) for this application was designed with the three basic designing constructs in mind, namely, usability, aesthetics, and functionality [9]. Users' technical capabilities were also considered when designing the interface.

Figure 5. The web application interface.

Easy step-by-step methods were devised to perform any task, and wherever possible, they were devised to give users the option to reduce the amount of typing while they are editing or updating their dock information. Every *ASP.NET* web control was assigned tool tips explaining the purpose of that control or any data attribute. Multi-view panels are used to show grouping of web controls and content. Views inside Multi-view panels were used and users can toggle between them. Users can interact with only one view at a time, thus providing a compartmentalized view of the entire data structure. Since HTTP is a stateless protocol, session variables are used to hold the user's navigation status as they navigate through the web page during the update or edit processes. A detailed users' guide is also published in PDF format and is made available to every user to further assist them while using the web application.

Dock update process

This is a new process developed with the objective of maintaining current and accurate data. The process described here uses current technology to provide users with easy access to data sources where they can update their information. This updated information is then made available to the USACE in an automated fashion to minimize human error. The data transfer from the UT's Maritime DB to the USACE's *Master Docks Plus* database is not only acknowledged but also checked and verified by the USACE personnel before updating their *Master Docks Plus* database, so as to avoid any transfer of bad or erroneous data. This process also ensures that any bad data transferred to the USACE will not reside in UT's Maritime DB. The new process also checks for repeated updates made by a dock owner/operator on a specific dock. When the process finds repeated updates, the most recent update is tagged to the previous update not verified by the USACE; this reduces the number of updates that the USACE has to verify. The process also aids in synchronizing both the *Master Docks Plus* database and the Maritime DB in real time, not only by transferring updated or new information to the USACE, but by also acquiring updated and new information from the USACE. The dock update process is divided into four sub-processes, and include:

a) User Edit/Update information process

b) USACE notification process

c) USACE acknowledge and verification process

d) Data Turn-Around process.

Figure 6. The docks page.

Users require an Internet connection to access the website (http://maritime.utoledo.edu). The 'Docks' tab of the website displays information about all the docks present around the Great Lakes region. Separate individual user names and passwords are made available for each dock facility. This feature allows the users to edit or insert information for their particular facility only. Upon authorization, users can review their information and make changes to it. The information displayed on the 'DOCK' page is categorized into Profile, Corporate, Functions, Features, Snaps, and My Account (Figure 6).

The Profile tab has general information about the dock facility such as the dock name, address, purpose, port association, and so on. The *Corporate* tab contains details about owners and operators and their relevant contact information. The *Functions* tab contains the commodity and service details for a particular dock. The *Features* tab displays the physical characteristics of the dock facility, while *Snaps* contains aerial pictures of the NPI and also allows the user to upload more pictures or to remove unwanted pictures. On the *My Account* tab, the user can edit their password information; however, this feature can only be accessed after a user logs into the system.

Once the user has edited/updated their dock information, a notification is sent out to USACE (five different personnel), an alert in the form of an email that contains the GUID information of the dock facility that was edited or updated and the web URL (http://maritime.utoledo.edu/USACE.aspx) to view the changes made. The USACE has exclusive access to this web page. Repeated updates to a single NPI that are made by users prior to the verification of earlier updates by USACE personnel can be tagged to the earlier update, and are then shown as one update. This minimizes the number of updates that are made to a single dock facility, thereby reducing the workload of the USACE personnel. The edited information is color-coded to enable the USACE personnel to easily identify any changes made. At this point, the USACE personnel can furnish recognition of the dock update by clicking the 'Acknowledge' button, which in turn alerts the system to send a series of email alerts announcing that this update has been acknowledged by USACE personnel. If the dock update contains new information – such as a new operator, commodity, or service, SQL queries are displayed in a pop-up box along with an email to USACE personnel containing these queries in addition to the other email alerts. These queries can be copied off the pop-up box or from the email and pasted in Oracle SQL for execution. When executed, these queries provide a unique ID for the new information, which in turn enable USACE personnel to capture the unique ID for the new information and feed it back to the Maritime DB in the verification process to update the Maritime DB. This step provides a quick and convenient turnaround for the update of information.

Once the data have been acknowledged, USACE personnel have the option to 'Update data before verification' or 'Accept updates.' If USACE personnel find the data to be incorrect, they have the option to rectify the updated data. If the USACE finds that the data are correct, they can accept the data 'as-is', and update the record with no further changes. This series of alerts in the form of emails are then sent out along with the changes in data in the form of SQL queries, which in turn are used by the USACE to update their *Master Docks Plus* database. In addition, the data is also updated in the Maritime DB if the USACE personnel make changes to any information in the dock update during this verification process.

In addition, any update made to the *Master Docks Plus* database by personnel from USACE regional offices, the US Coast Guard, US Customs, or any related agency can be made available to UT's Maritime DB via a text file sent periodically via FTP. The text file contains SQL queries that are automatically read and executed, ensuring that the updates made to the *Master Docks Plus* database

by USACE personnel are reflected in the UT's maritime DB, thereby synchronizing both the databases. As mentioned earlier, this new dock update process, which is in the form of a web application, needs to be tested further on a larger geographical region to evaluate its performance and also to gather a wider population of users' input.

Data acquisition with GIS and remote sensing methods

Finally, the project team explored new approaches for data acquisition using alternative tools such as GIS and remote sensing techniques, digital imagery, and photo overlays. The initial objective in adapting these techniques to the project were focused on refining dock locations in lat/lon coordinates, to identify and measure dock and slip dimensions, to identify dock and terminal equipment, and to establish highway and rail connections to each dock facility. Digital orthophotos of port facilities were obtained from various sources (e.g., Google Maps, Bing), and georectified to lat/lon within ESRI's *ArcGIS* software. These images were then overlayed with rail and highway network shapefiles to align landside transportation facilities with the dock locations.

Dock lat/lon locations were easily obtained and revised dock points were added to the MD+ database. Landside transportation connections were also readily obtainable. In contrast, slip dimensions and dock dimensions were not as easily obtainable for new docks or reconstructed docks, due to a lack of availability of current images. The project team therefore recommends this technique for refining dock locations and for identifying highway and rail connections, but recommends additional study that requires site visits and interviews with owner/operators for measuring the dimensions of dock and slip dimensions, and for identifying the cargo-handling equipment at the dock facility. Otherwise, these latter data items are best obtained through the web portal.

Conclusion

The principal focus of this project was to develop and test a new process for data collection using an automated system for the Corps *Master Docks Plus* database. The overall idea of the new process is to collect data and transfer it to the Corps so that they can update their *Master Docks Plus* database. This process also incorporates a turn-around data transfer, where updates made at the Corps' *Master Docks Plus* database will be made available to UT's Maritime DB at their site.

The data collection system described here was developed to minimize the Corps' time and resources needed to collect data on these facilities. A three-tier application architecture was used in developing the data collection system which consists of a *user tier*, a *web application tier*, and *database tier*. This web application uses Web 2.0 (a second-generation web standard), *ASP.Net*, and *AJAX* to translate the data collection process. All three layers operate independently on different parts of an interconnected system. By using the three-tier architecture, the application logic is removed from the user tier and is executed on a web application tier. Users are connected to the web application server to exchange both process calls and data, and the web application in turn is connected to the database server in order to exchange database-related calls. The data are maintained in the form of data objects within the user and application tiers. The application tier also maintains a set of objects containing data for the users, and plays the role of taking data from the format specific to the database server and transforming them into the format of data objects, and vice versa.

As the system was initially tested by USACE personnel, it was refined and improved in response to user comments and observations. USACE responded favorably to the functionality and appearance of the data entry page. Overall, the web-based application performed smoothly, with minimal problems. In some cases, however, the application was found to run quite slowly, most likely due to a slow Internet connection, heavy Internet traffic, or a firewall on the users' side.

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ABOUT THE ORGANISATION

The **U.S. Army Corps of Engineers** (USACE) has approximately 34,000 dedicated civilians and soldiers delivering engineering services to customers in more than 90 countries worldwide. With environmental sustainability as a guiding principle, its disciplined Corps team works to strengthen the USA's security by building and maintaining the country's infrastructure and providing military facilities where its service members train, work and live.

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