Providing Driving Directions during Reconstruction of a Complex Urban Interchange

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Abstract
The Marquette Interchange is a complex interstate highway interchange in downtown Milwaukee. Due to traffic volumes greater than expected, the current interchange has exceeded its useful life and will be reconstructed over the next several years. CH2M HILL and ESRI have developed the "Map It" tool - a custom WebGIS application using ArcGIS Server to provide web-based mapping, routing, and driving directions to the public via the Internet. This paper summarizes the development of this application including project history, technical approach, lessons learned, and future plans.

Introduction
The Marquette Interchange in downtown Milwaukee links I-94, I-43, and I-794, and provides primary access for commuters, commercial traffic, and others to the Milwaukee central business district, lakefront, or destinations beyond the city. The interchange, which was opened to traffic in 1968, today handles twice the volume of traffic originally expected and suffers from significant deterioration, posing safety hazards and inconveniences to the traveling public.

The Wisconsin Department of Transportation (WisDOT) engaged Milwaukee Transportation Partners (MTP), a joint venture between CH2M HILL and HNTB, to evaluate the interchange and provide recommendations for reconstructing the system to improve traffic flow, increase safety, and reduce congestion. WisDOT and MTP are nearing completion of the design and construction has commenced.

A key concern was the potential impact on the community and visitors to Milwaukee during reconstruction. Construction is scheduled to extend over a four to five year period, beginning in mid to late 2004 and nearing completion by late 2008. The community has expressed a need for easy-to-understand information on the traffic limitations and construction activities at any given date. Additionally, the project team foresaw the need for a tool to assist travelers from out of town to successfully drive through the interchange reconstruction and reach their destination. This need called for a customized Geographic Information System (GIS) application that would provide driving directions the general public that incorporated latest available construction condition information. Such a tool would allow travelers through the interchange area to avoid routes that are closed to traffic due to construction activities. This tool is referred to as the Marquette MapIt tool.

Purpose of Tool
The MapIt tool is one of several tools developed by the Marquette Interchange Project team to provide timely and useful information to the public during construction. As part of public outreach efforts, traditional media campaigns were developed, as was a web site to

inform motorists on reconstruction activities. The web site has several tools to aid motorists traveling through the interchange.

One such tool was developed to communicate current traffic conditions in the interchange area, using data feeds from the WisDOT Traffic Operations Center. Current travel speeds, messages displayed on variable message signs, and warnings about incidents are all communicated to the public through this web tool to aid motorists planning to travel through the interchange area to select a route based on current traffic information.

A second tool, the traffic bug, was developed for commuters who travel through the interchange area. The bug is an application that can be downloaded and installed on a user's computer. Users can set preferences to monitor traffic in a specific portion of the construction zone and receive alerts when an incident occurs or travel speeds decrease under a threshold.

The objective for the Marquette MapIt tool was different from that of the other web components intended to aid travelers through the interchange area. The other tools provided through the web site focused on regular commuters familiar with routes through the interchange area. The Marquette MapIt tool was intended to serve a different population with the aim of:

- Assisting travelers who are not familiar with the Milwaukee area (not daily commuters)

- Assisting local businesses

- Helping event planners for conventions or lakefront festivals obtain information on future available routes through the interchange area

A set of design requirements was assembled to guide the development of the Marquette MapIt tool.

- Available to the public over the Internet.

- Provide dynamic navigation instructions in the form of a map and text driving directions.

- Allow users to enter a destination address in the downtown Milwaukee area and obtain navigation instructions to that destination when traveling from the North, South, or West of the interchange area.

- Allow users to enter an origin address in the downtown Milwaukee area and obtain navigation instructions from the origin to a destination North, South, or West of the interchange area.

- Allow users to enter the time period of travel such that navigation instructions reflect construction conditions during that period and only open routes would be returned.

- Provide formatted, printable driving directions.

- Intuitive interface allowing users to navigate the site and enter data to obtain required navigation instructions with minimal direction or help documentation.

Technical Approach

The Marquette MapIt tool's architecture has evolved as technology has evolved. The original approach crafted in 2002 involved the use of ESRI ArcIMS as the platform for Marquette MapIt. Ultimately, the combination of project schedule changes and advances in ESRI technology resulted in the selection of ArcGIS Server 9.0 as the platform for Marquette MapIt.

ESRI worked closely with CH2M HILL to develop an ArcIMS architecture to meet the requirements of Marquette MapIt. An ArcIMS web site was proposed to obtain user input. This input would be processed by code linking the ArcIMS web site with ArcGIS, taking advantage of available ArcGIS functions to determine a route and return driving directions. A custom DLL was proposed to perform this function. The custom code would then return the driving direction text and mapped output to the web site. This approach required a high degree of customization, linking ArcIMS with ArcGIS to take advantage of available ArcGIS functionality. This approach also involved licensing issues since linking ArcIMS with ArcGIS was not standard and exposed the functionality of ArcGIS to multiple users. ArcIMS was considered very stable and the project team had extensive experience developing with ArcIMS and was comfortable with the approach developed.

In fall 2003, the project team was prepared to proceed with development of Marquette MapIt. At that time ArcGIS 9.0 was in development, including ArcGIS Server, a potential alternate platform for Marquette MapIt. An evaluation of ArcGIS versus ArcIMS as the Marquette MapIt tool platform was conducted. The evaluation addressed concerns of the project team and WisDOT, particularly the stability of an early release of the product and cost implications. The team was also concerned with integrating with the rest of the web site the Marquette MapIt tool running on this platform.

There were many advantages of using ArcGIS Server for Marquette MapIt. The primary advantage was complete access to all ArcGIS functionality, including path finding. Additionally, ArcGIS offered more flexibility and scalability for future application modifications or expansion. This was particularly important since the site was anticipated to be active for a four to five year time period. Adopting the appropriate platform from the start that would more readily support future functionality enhancements was a significant driver toward the selection of ArcGIS Server.

ESRI also provided assurances that the product was stable, even in pre-release form. Extensive testing of ArcGIS Server had been ongoing with good results. Hosting the Marquette MapIt Tool and ArcGIS server on a separate server computer could mitigate the risk to the rest of the web site.

ArcGIS Server was selected as the platform for the Marquette MapIt tool based on the results of this evaluation. Two custom DLLs developed in Visual Basic and Visual C++ were still required to provide driving directions, however, the flexibility and scalability this solution provided over the duration of the project provided adequate incentive to use

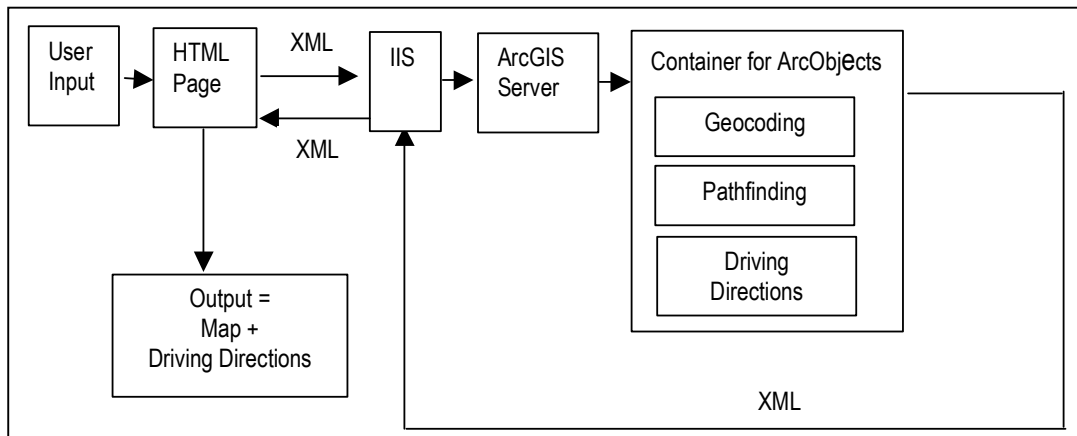ArcGIS Server. Figure 1 illustrates how the ArcGIS Server based Marquette MapIt tool would operate.

Figure 1 - Application Design

Marquette MapIt Application
Data was assembled to support the Marquette MapIt GIS application. Three main types of data were required:

- Cartographic data

- Routing networks

- Construction schedules

Base map data such as streets, railroads, and major water features were obtained and symbolized in an ArcMap document to serve as the backdrop for mapped routes returned with the driving directions. Major downtown Milwaukee landmarks were also identified and included in the ArcMap document. All data was converted into ESRI Personal Geodatabase feature classes.

A street network with appropriate integrity to support routing and adequate attribution to support geocoding was also required. Street data was obtained from available sources with address information to support geocoding. The street layer was updated to reflect changes to the road system. Additionally, road links were added to represent the new interstate system and local road system in the reconstruction area. All links were coded with the anticipated speed limit that would apply to the link. From this master street network with all existing and future roadway links included, a master Geometric Network was created, weighted by travel time, the combination of speed limit and link length.

Projected construction schedule data was obtained and compiled. The schedule was aggregated so that a road link was identified as either open or closed for monthly intervals for the immediate three months and then fiscal quarters thereafter. It was assumed that if a roadway link was projected to be closed at any time during the time period then the link would be identified as closed for the entire time period. This assumption was made to ensure a valid, open route, would be returned even though a better route might be available. No network changes were made if lanes were closed, only if the road segment or

ramp was closed to traffic completely. The quarterly time period was selected as the time interval when selecting a travel period farther than three months in the future since confidence in the projected construction schedule was lower the farther out the projection was made. It was intended that during construction the schedule information would be updated as changes in the project schedule occurred so that the most accurate information was available to users planning a route through the interchange area.

Once schedule information was added to the master road network, a separate road network and geometric network was created for each time period. The geometric network for each time period included only those road links that were open during the entire time period so that only routes over road links open to traffic would be returned to the user. The geometric networks were created using travel time as the weight. Two-way links were coded with a FROM-TO and a TO-FROM travel time allowing routing in both directions along the link.

ArcGIS Server was installed and configured to support the Marquette MapIt application. A MapServer was created from the existing ArcGIS Map Document (.mxd) and a GeocodeServer was created using the previously described road network.

ESRI, teamed with CH2M HILL, performed the initial development of both the web services using the ArcGIS Server API and the web application, or user interface. The web services code was written in VB.NET and tied together ArcGIS Server, ArcObjects, and two custom DLLs. The two DLLs performed routing and created driving directions written in Visual Basic and C++ respectively.

The web application was written primarily using ASP.NET. The application was organized using three tabs: two tabs for collecting user input depending on whether the user desired directions heading into or away from downtown Milwaukee and the third tab to displayed map and driving directions. Figure 2 shows the BETA version of the Marquette MapIt interface. Users can enter their starting location, North, South or West of the interchange area, and then enter a destination in the downtown Milwaukee area. The user can either select a pre-defined location from a pick-list or enter an address. The user is then prompted to enter the time period during which they will be traveling.

Once the user clicks the "Get Driving Directions" button, the information entered by the user on the web application is passed to the web service. The web service geocodes the downtown Milwaukee location and determines the route between the trip start and end points. The web service then returns a map of the route and driving directions to the web application. A separate web page was developed presenting the driving directions and map on a formatted page that can be printed.

Lessons Learned and Future Plans
The Marquette MapIt application is currently in the BETA stage of development. Application performance is still being evaluated and final impressions of the platform are still being formed. There have been lessons learned even in the short time this development environment has been utilized for Marquette MapIt.

- Working with ESRI proved to be an effective method of mitigating risks of commencing development using pre-release version of ArcGIS Server.
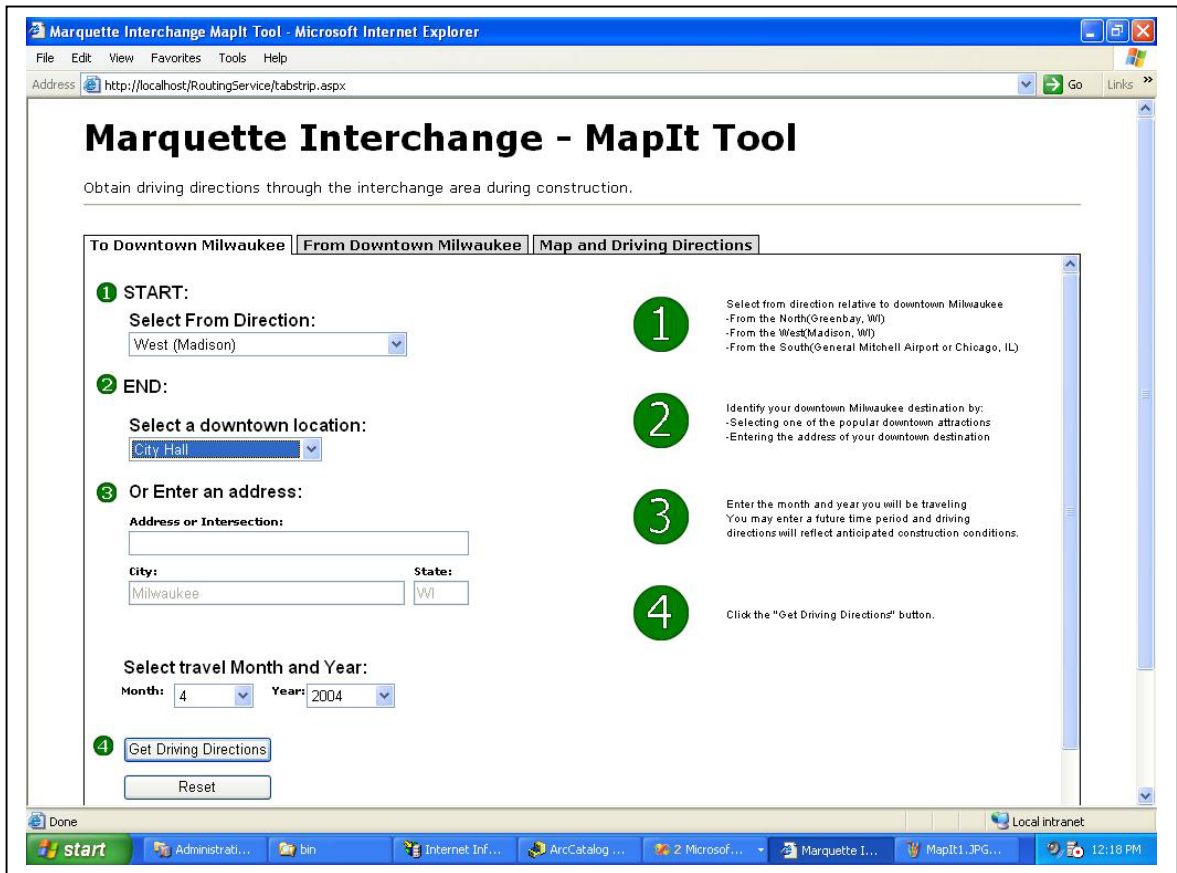
Figure 2 - Web Application Interface

- The use of pre-release ArcGIS server during beta development proved successful. Only minor code revisions were needed once the final 9.0 ArcGIS Server product was installed.

- The use of ArcGIS Server in a distributed configuration requires fast and reliable network connectivity. Currently all ArcGIS Server components reside on a single server for the production site to ensure adequate performance.

- ESRI has provided a very useful and effective set of .NET Tools in the ArcGIS Server Application Developer's Framework.

During BETA release of the Marquette MapIt tool, project team members will provide feedback on the tool and suggest improvements.   The full Marquette Interchange web site, including the MapIt application, is scheduled for release to the public in October 2004.

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