LRRB
Local Operational Research Assistance Program (OPERA) for Local Transportation Groups
Field Report

This report must include the underlined subject areas and supporting resources (i.e. photos, graphs, charts, etc.). The OPERA program will use this information in an annual report that will be shared with other local agencies within the state. We request that a short 5-10 minute demo or presentation be shared at the Spring Maintenance Training Expo.

Date: Oct. 1, 2010

Project Title: Implementation of USNG Field Marker Design and Maintenance System

Project Number:

Agency: City of Saint Paul, Department of Public Works

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Problem: Being able to locate a point on the Earth's surface is a function which every level of Government is intimately involved with every day. Over time many different systems have evolved to specify a location. The long list includes street addresses, many differing X-Y coordinate systems, public land survey descriptions, and Lat-Long coordinates to name a few. Most every agency developed references to infrastructure pretty much independently of surrounding or even overlapping agencies. Even within individual agencies different reference systems may exist for the same things. Public Safety agencies may use property addresses to locate a fire hydrant, while Public Works departments may use an X-Y coordinate to locate the same hydrant. The difficulties in translating from one system to another are obvious, particularly in an emergency response situation

There is a tremendous amount of public infrastructure devoted to providing location information. Consider the number of street signs, address numbers, trail markers, etc., which currently exist. All of these markings are familiar to those who know the geography of a given area, but they are far less meaningful to someone who doesn't "know" the area. To provide an interoperable location system for first responders, the Federal Government has established the use of the US National Grid (USNG) system as a standard. Although USNG locations can be determined from GPS receivers or paper maps, there are virtually no USNG based field markings (signs) which reference the USNG location.

A secondary issue which is being researched by this project is the ability to encode data into a field marker. The ability to convey a quantity of information in traditional signage is typically limited by physical size and language considerations. By encoding the information directly, or by providing an electronic link to the information, it is possible to provide a potentially large amount of embedded information on the field marker.

The problem which this project investigates is the methodology and equipment necessary to accomplish these goals:

- Inexpensively mark infrastructure in the field with USNG location and other data
- Record the geo-location of the field marker that was placed in a database.

- Create a proof of concept application to create a USNG field marker with machine readable information embedded in the marker.

Solution: The solution developed to accomplish the goals above utilizes the three key technologies listed below:

- Moderately priced “smart” phones as the primary hardware device
- “QR” codes to encode the USNG location and other information
- Open source software development

The first key technology is the rapid advance in cell phone capabilities which have led to the widespread use of so called “smart” phones. Smart phones are typically equipped with a camera, GPS capability, and the ability run an application. This makes them a very affordable platform upon which to build an application to obtain a USNG location and drive a printer to create a field marker. Smart phones also provide an application platform to read and utilize the USNG field marking through.

The means for the phone to read the field marking is the second key technology involved in the solution. The field markers were created using a technology known as “QR Code” or 2D bar coding (http://en.wikipedia.org/wiki/QR_Code). The QR code is readable by most any cellular phone handset built with an embedded camera. The appropriate, and in most cases free, QR reader software can be easily installed on the phone. The QR technology allows for encoding USNG information as well as other data such as a URL, piece of text, phone number or SMS content.

The final key technology is the use of open source software to develop the applications and integrate the various functions. Open source software provides for a low to no cost development environment. Applications developed using open source can in turn be distributed freely to end users thus lowering barriers to adoption and use.

Two basic products were developed using the key technologies.

- A portable marker generating system for use in the field
- A marker reading application for end users.

Procedure: The first step in this project was to create a detailed list of requirements to achieve the project goals. The requirements identified were:

Hardware & Data Service:

- Low cost & readily available
- Handheld device with Integrated GPS, web browsing capabilities and a method for running web services in a standalone or local fashion.
- Able to support future expansion of capabilities.
- Mobile printing capability via wireless connection.
- Mobile data service to support the selected hardware

Software:

- Field marker creation application
    - View current location on a map
    - Create markers
    - Capture field marker location points for syncing to a master database
- Master database
- Aggregate collected data.
- Integration with an existing GIS (NOTE: It is assumed that a suitable GIS system is already in place and integration with the master database is possible.)

- A GPS to USNG coordinate conversion application for the handheld device.
- A QR Code generator.
- A method for wireless printing over a wireless network.
- A cellular data connection for transfer of data to and from the field.

Potential hardware components were researched for a best fit for the desired capabilities. The hardware platform selected was the Nokia N900 Cell Phone (http://maemo.nokia.com/n900/). In general this phone includes the following features:

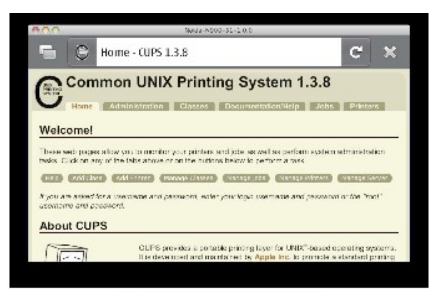
- Linux operating system
- Integrated GPS
- Integrated Bluetooth (for printer communication)
- Multi-threaded processing capabilities. (more than one process can run at the same time.)
- T-Mobile GSM service plan.

The mobile printer selected for the project was a Hewlett Packard H470 Bluetooth enabled Portable Printer.

The software components developed for this project were primarily created from components available in the open source software arena. This makes the applications cheaper to develop and removes any proprietary intellectual property restrictions. The components used in this project were:

Software Packages

- Maemo operating system (Native Nokia phone OS)
- CHROOT (Easy Debian). http://wiki.maemo.org/Easy_Debian
- Apache Web server
- Mapserver (Mapping engine)
- GeoMoose (User Interface to Mapserver)
- OpenLayers (Mapping Library)
- PERL / GD
- QR CODE generator
- Python
- “GPS Coordinate” to “U. S. National Grid” conversion.
- User web interface for previewing of QRCODE.
- Common Unix Printing System (CUPS). http://www.cups.org/
- Print server



CUPS web configuration page

Using the software development tools and environments listed above, the following applications were developed and configured for use on the handset:

- A GPS data capture routine for field device.
- A syncing program able to communicate the field captured data to a central database.
- A centralized service that publishes where markers have been applied and represents them on a map.

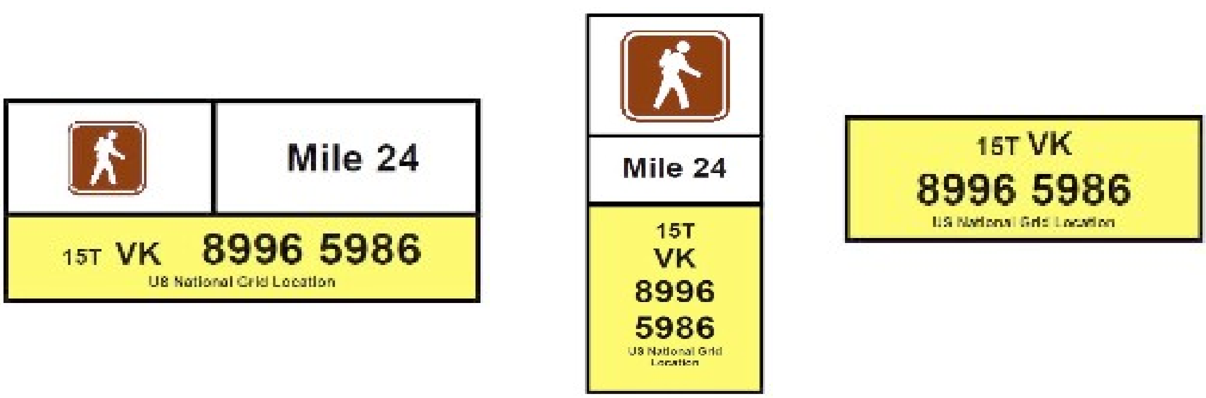
- A map based marker placement tool (additional buttons) for the smart phone based, auto tracking map visualizer for use in tracking the placement of markers in the field.
- A routine for printing over Bluetooth, from the cell phone to the Bluetooth enabled printer(s)
- Printing templates for generation of markers.
- Print tool for printing to a portable printer.

Project objectives:

- Leverage the GPS reading/recording toolsets developed for the OPERA AVL project to display and print the USNG markers in the field and provide a Geo-locating feature to each marker placed.
- Install and configure a QR Code generator for the Linux based cell phone, that can embed a QRCODE into the Field Marker.
- Evaluate implementation process of placing USNG markers in the field, including the signage substrate / backing material and longevity of markers.
- Partner with other agencies to promote the USNG marker concepts, and describe their benefits.

Results: Much research has already been applied to the idea of building a USNG marker system. The mechanics and related specifications for building such a system are therefore fairly straightforward, especially with respect to specifications about the look and feel of the markers. This project was intended as a means of taking these marker specifications and augmenting them where needed, as well as applying them to field operations. Enhancements to the specifications as a result of this project have already been incorporated into the US National Grid location marker proposal: http://www.mngeo.state.mn.us/committee/emprep/download/USNG/USNG_location_marker_proposal.html

Some examples of the proposed markers:



A primary focus of the project was in applying the configuration and output parameters of the printed Markers from the handset. Each component of the system was implemented as a standalone service. While this produces a more complex “application” consisting of multiple individual services, the benefits afforded in the resulting flexibility for adding and removing functional components cannot be overstated.

What Worked:

Setting up the individual services and foundational software stack worked fairly well across the board.

Because the Linux OS environment was already familiar to the development team, most aspects of the configuration and programming had few problems.

The field testing of the devices will reveal usability factors both good and bad. These results will be added to this report at the end of field testing.

What didn't work:

There were various issues related to the phone manufacturers implementation of the Linux OS which caused some early software development and installation headaches. Once these issues were identified and workarounds were developed, the rest of the project proceeded without undue difficulty.

Making sure the printer is active and functioning over the Bluetooth connection can be problematic for the first time user. The process typically takes a few seconds to startup during which time users may not know if it is working or not.

Recommendations:

There needs to be more work put into evaluation above and beyond this project related to user feedback and enhancements to the user experience.

There were other optional pieces of hardware that were initially identified which were either more expensive or required more time to implement than what was eventually chosen and implemented here.

Since these other optional hardware systems ended up as designs that included configuration of multiple components. As well as adding on software and networking processes that would quickly eat up all development resources. Choosing the Nokia N900 with all of it's embedded hardware was easily justified by the hardware requirements.

An public outreach effort related to USNG awareness as well as the flexible nature of the system should be implemented. The marker system could be applied to many marker types of tasks besides USNG markers. Public Infrastructure maintenance management aspects come to mind.

Evaluation of process:

Success for this project was identified as being able to use the equipment & software at a field location to:

- See the current GPS derived location on a map.
- Present the location to the user in a map view for verification.
- Upon verification, record the location in the database.
- Generate a QR coded field marker containing the USNG location.
- Print the marker with a mobile printer connected to the handheld device via Bluetooth.
- Read the field produced marker using the handheld device to retrieve the data encoded in the QR code.

Return on Investment:

The flexibility of the resulting system allows for many possible uses of this system of components for field related tasks, such as:

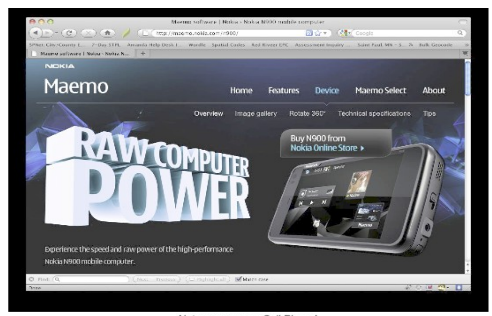
- Printing of markers or tags of most any size or color depending on media and portable printer capabilities used
- Collection of location specific data for archiving.
- The automatic transfer of collected data and new service from a master service to the field using the cellular data connection.
- AVL GPS/ Tracking processes, for mobile assets such as vehicles and / or personnel.
- Field captured photography (the N900 handset has an integrated 5mp camera with dual LED flash) which can be geo-referenced and tagged with the marker placed in the field.
- 2D QR Code application beyond the USNG.

Implementation: Each of the field devices uses much of the same software stack as a centralized, master service to reduce long term management and configuration costs. The user interface software being used is GeoMoose: http://geomoose.org/ . This mapping interface has been enhanced to allow recording of point locations corresponding to field locations of placed markers.

The software stack is all open-source. The costs of implementation are significantly reduced while retaining a very high level of flexibility with regard to modifications and operational tuning of developed software.

Status:

Currently:



Not your average Cell Phone!

Field hardware devices have been researched and identified for portability. Using a Nokia N900 smart phone allows for most of the hardware components to be integrated together into a single unit.

The design of these handsets and the fact that they are Linux based allows for a high degree of flexibility when considering the development tools that are available.

Installing and augmenting the open source software project GeoMoose allowed the development team to use familiar tools to display a map for geo-location of the field markers as they were placed.

The mapping visualizer has been restyled for the small form factor as well as receiving some display modifications targeted at simplification and automation of the marker generation and location recording tasks.

A recent addition to the USNG Marker system is for the optional inclusion of a QR Code. A QR Code can be used to embed information like a name, Web URL, ID number, address or other information, up to 4000 characters. This information can then be read by most camera enabled cell phones with the appropriate software enabled.

By including a USNG coordinate value in the QR Code in a USNG marker, a user can be directed to additional information from either within the QR Code itself and/or over a cell connection to a web based service. This allows for a very high level of accuracy in pin-pointing a Users location either for their use or for emergency dispatching.

A QR Code generator was installed on the handset. The QR Code generator accepts various parameters such as the message to embed into the output image. This output can be resized based on the parameters for printing variously sized markers.

The printing output pipeline is very flexible and can be easily changed to include different configurations of the output for both black and white as well as color output.

With a QR Code reader, this QR Code can be read to reveal its secret message.

A starting point for obtaining QR Code readers (there are many others) can be found here:

http://www.beetagg.com/

http://reader.kaywa.com/en

There are obvious applications here for a geo-location marking system such as the USNG. Embedding the location into these QR Coded images that are attached to stationary objects in the field allows for a portable and machine readable method for finding a location as well as embedding other pertinent information in the code related to that location.

Ongoing:

Research into appropriate print media which is weatherproof to an acceptable level is in process. A few types of media have been identified for use by the system and testing is progressing currently along these lines.

Testing also progresses with streamlining of the syncing process to remove as many possible problems related to the transfer of data between the handset and a master service. The end goal is to make the systems as easy to use in the field as possible.

Field usage of the system is being documented and a follow up report will be written detailing the field usage and describing the automation processes.

Future:

The central server syncing components will be very similar to the syncing software on each of the field devices. This will simplify and speed up the development process as well as reduce the number of components required to set up the system from end to end. An optional approach here might be in treating the handset fleet of hardware as a peer-to-peer network, where each of the devices backs up each of the other devices when a network is available. A system for registering the devices would still be needed, either by manually coding the list into each device, or by using a single service, either a master service, or one of the handsets, as the keeper of the communication list for the fleet.

Adding in layer management tools related to remote access (to/from a central server) for online mapping data when connected to the network. This would insure that the geodata related to the field placement of markers is available for later reuse and analysis as well as making the information available to other field enabled handsets for viewing in a mapping environment.

More work is needed regarding what types of information should be included in the QR CODE for the USNG markers, most proably from the perspective of the marker owning or originating organization.

Standardizing the content of the codes generated will affect their long term usability as well as to their general acceptability for field use, especially in the realm of emergency preparedness and response.

Some potential enhancements to the project:

- Attaching additional file types and information to a geospatial marker location, such as:
    - A digital photograph, or many of them.
    - A digital document of form filled out by the user denoting additional information about the marker placed in the field.
- Application of the system to other field placement processes.
- Adding gesture controls to the mapping interface controls and tighter integration of the marker generation with the mapping interface.
- More effort applied to the mapping cartography to add in some pleasing elements to the way the maps and markers look in the map view.

Partnering agencies have been identified to test the system in the field. Two Counties in northern Minnesota have expressed interest in using the system as a test for marking trails. Initial meetings are scheduled for November. More information on these events as they happen. Update will be posted to the City of Saint Paul web site at: http://pwultra5.ci.stpaul.mn.us/OPERA/

Total Duration of Project: Development of the system with follow up year of testing and evaluation in the field.

Project End Date: July 2011

Approximate Cost of Entire Project: $10,000

Total OPERA Funds used for project: $5,000

Send and Email a completed report with pictures to: Mindy Carlson, CTS - 200 TSB, 511 Washington Ave. SE, Mpls. MN 55455, email carlson@umn.edu**.** For questions about this report please contact Mindy Carlson at 612-625-1813.