VISUALIZATION OF FAILED HIGHWAY ASSETS THROUGH GEO-CODED PICTURES IN GOOGLE EARTH AND GOOGLE MAPS

Jesús M. de la Garza, Vecellio Professor, chema@vt.edu
Department of Civil and Environmental Engineering, Virginia Tech, Blacksburg, Virginia, USA
Ignaci Roca, Former Graduate Research Assistant, igiroca@vt.edu
Jennifer Sparrow, Director, Emerging Technologies and New Ventures, sparrow@vt.edu
Innovation Space, Virginia Tech, Blacksburg, VA 24061

ABSTRACT

The Virginia Department of Transportation (VDOT) has adopted an innovative highway asset management program known as Performance-Based Road Maintenance. Under the Virginia Tech-VDOT Partnership for Highway Maintenance Monitoring Programs, Virginia Tech's Center for Highway Asset Management Programs provides independent assessment and technical leadership to support innovations in highway maintenance contracting and asset management practices. In the past, VDOT's only way of checking a failed asset item was to go out to the field. This was very time consuming, especially if the assets were numerous or far apart. Moreover, it was often difficult to locate a specific asset item failure in a given segment. In other cases, finding the failure was impossible, since the condition of some asset items can change in a short span of time. This paper presents the development of a comprehensive system to display pictures of failed asset items. The major contribution of this system is to provide VDOT a tool to check any failed asset item from any computer with an Internet connection, eliminating the need to go out to the field and visit each individual site. The proposed technologies and processes were implemented as a pilot project in the Staunton South 2009 Maintenance Rating Program Evaluation. Results from the pilot project were used to evaluate how the system can enhance current highway asset management practices.

Keywords: Highway Asset Management, Highway Maintenance, Performance-based Maintenance

1. INTRODUCTION

Maintenance of public transportation routes remains a top priority for federal, state, and local governments. The Virginia Department of Transportation (VDOT) has adopted an innovative highway asset management program in which a desired outcome is specified. This differs from the traditional approach, in which a material, method, or technique was specified. VDOT was one of the first agencies in the nation to implement this new approach. This approach, known as Performance-Based Road Maintenance (PBRM), has produced significant benefits in the maintenance of public roadway systems (Piñero 2003).

Virginia Tech and VDOT established the VT-VDOT Partnership for Highway Maintenance Monitoring Programs. Under this partnership, Virginia Tech's Center for Highway Asset Management ProgramS (CHAMPS) provides independent assessment and technical leadership to support innovations in highway maintenance contracting and asset management practices (CHAMPS 2009).

An integral part of this independent assessment involves data collection performed by trained crews on the interstate highways all across the state. Through a subcontract with CHAMPS, Anderson & Associates, Inc. (A&A), an engineering and design firm, provides the manpower to staff the crews which inspect the condition of the various highway assets. According to certain performance criteria previously established in VDOT's maintenance contracts, asset items can either pass or fail. At CHAMPS, all the information regarding the condition assessment of all the assets is analyzed. A report is then provided to VDOT showing the extent to which a maintenance contractor has achieved the performance targets.

In the past, VDOT's only way of checking a failed asset item was to go out to the field. This was very time consuming, especially if the assets were numerous or far apart. Moreover, it was often difficult to locate a specific asset item failure in a given segment. In other cases, finding the failure was impossible, since the condition of some asset items can change in a short span of time. These problems were addressed by developing a comprehensive system to display pictures of failed asset items. As illustrated in Figure 1, this was done by implementing the technologies of web-mapping applications, geo-coded pictures, and databases to create a tool for highway asset management. This gave VDOT a tool to check any failed asset item from any computer with an Internet connection, eliminating the need to go out to the field and visit each individual site. It also promises to be of great help in a situation where a maintenance contractor challenges the failure of an asset item that can change with time, by providing an actual 'snapshot in time' of the condition of the asset item at the time the asset was assessed. This system allows VDOT and other end users to query a database of every failed asset item in a given project or number of projects, display the failures in their actual location in a map, and look at a picture of the failed asset item.

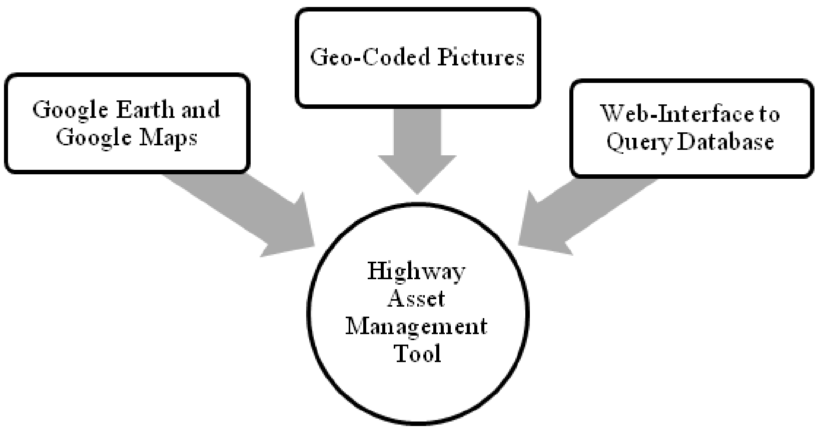

Figure 1. Technologies used in development of tool.

2. GOOGLE EARTH AND GOOGLE MAPS

In recent years, major web search engine providers such as Google and MSN, have developed a variety of geographic search interfaces such as Google Earth and MSN Virtual Earth. These online geo-informatics services have significantly increased the general public interest in geography and satellite imagery. Satellite imagery has become a part of the mainstream, as it has been made accessible to millions of people thanks to online services like Google Earth. There has been a great shift in the accessibility to geographic information. With the advent of these dedicated geographic interfaces, the general public now has access to information that was only available to experts not too long ago (Boulos 2005). Web-based map services and virtual globe applications such as Google Earth make it possible for everyone to use and explore graphical information in ways that were not possible in the recent past (Graupmann and Shenckel 2006).

Google Earth is a virtual globe, map and geographic information program. It maps the Earth by the superimposition of images of the Earth's surface. Google Earth can be seen as a GIS (Geographic Information System) itself. This free-of-charge, 3D (three-dimensional) desktop application offers the general public access to a wealth of geographic information; it provides access to a rich array of datasets including aerial imagery, roads, administrative boundaries and photographs (Slingsby et al. 2008). One of the most powerful features of Google Earth is that it allows users to add their own data. Google Earth utilizes Keyhole Markup Language (KML) to manage and store 3D geospatial data (Boulos 2005, Slingsby et al. 2008). KML is an Extensible Markup Language (XML) dialect used to describe the data so that it may be interpreted and plotted in Google Earth. KML can be used to model geographic features for display in Google Earth. KML can also be used to share data with other Google Earth users. The combination of Google Earth and KML allows the user to explore and interact with the data to a greater level of detail.

Google Maps is another free web mapping service application and technology provided by Google that powers many map-based services. Google Maps provides users with street maps, a route planner, an urban business locator, and driving directions. Google Maps has its roots in XML, which makes it possible for users to produce their own custom annotated maps and import their own GPS data. Images and video can be linked to the map to create interactive multimedia maps (Boulos 2005). In addition, Google Maps can read KML, the same file format that Google Earth uses to manage geographic data. This gives users the option of using Google Maps to view data created with Google Earth. Users can also embed Google Maps in their own web pages.

3. GEO-CODED PICTURES

Geo-coding, also known as geo-tagging, is the process of adding geographical identification metadata to various media such as photographs, video, or websites. These geospatial metadata usually consist of latitude and longitude coordinates. Geo-coding makes it easier for users to find information that is specific to a certain geographic location.

Pictures that are associated with a geographical location are known as geo-coded pictures. In most picture files (e.g. JPEG file format) the geo-tag information is embedded in the metadata. When geo-coded pictures are displayed, the picture can be placed onto a map to view the location from where the picture was taken. There are various methods of geo-coding photographs. This can be done in an automated way by utilizing a camera with a built-in GPS receiver. This is the easiest way of geo-coding a picture.

4. WEB PAGES AND DATABASES

Web pages rely on databases to store the data for many applications. MySQL is a relational database management system which runs as a server and provides users with access to various databases. A relational database management system is a database management system that is based on the relational model. This means that the data is stored in the form of tables, and the relationships among the data are stored in the same way. MySQL is commonly used by free software projects that require a full-featured database management system, as is the case with many web applications. The use of MySQL in web applications is closely linked to the popularity of PHP (originally stood for Personal Home Page). PHP is often used in conjunction with MySQL. PHP is a scripting language originally designed for producing dynamic web pages. Nowadays, PHP is widely used for web development since it can be embedded into HTML. It usually runs on a web server, takes PHP code as input, and creates web pages as output.

5. SYSTEM DESIGN AND SET-UP

This section presents a detailed description of the methodologies that were pursued to design and set-up the system to display pictures of failed asset items. The purpose of the work presented in this section was to design the system in the best way possible before implementation in the pilot project.

The first step was to determine the optimal technology to use to take the geo-coded pictures. The analysis focused on selecting the best camera with a built-in GPS. A market analysis was performed to better understand the cameras that were available. Because this is a very new technology, there are not many manufacturers that offer cameras with built-in GPS. However, one of the most important camera manufacturers, Ricoh, has included this technology into one camera in their line of products. The Ricoh Caplio 500SE has many features that made it a great candidate for the specific application in this system: (1) it has geo-coding capabilities; (2) it has long battery life, which is an important factor considering the crews will be out on the field all day long, and cannot recharge the batteries; (3) it is specifically tailored to perform in harsh outdoor conditions, so it is resistant to water, to impact, and to dust; and (4) it has a memo function, which is very useful to input data on the field in a simple, easy, and fast manner.

The next step was to determine the optimal technology to use to process the picture files with the attached metadata. This metadata is not visible in the picture itself, but is recognized by special software programs. For this project the Ricoh Data Manager software, which accompanies the Ricoh Caplio 500SE camera, was used. The main functionality of the Ricoh Data Manager is to extract the metadata in each picture file and convert it into usable information. For our system, this information includes Segment Number, Latitude and Longitude, B2 Distress Code, Date and Time, and Crew Number. In addition, when processing the picture files with this software, it is possible to imprint the pictures with certain data. This means that the data will be written onto the picture, and become a part of the picture itself. Figure 2 provides an example of a picture with a data imprint, which includes Segment Number, Latitude and Longitude, B2 Code, and Date and Time. So, in the case that the picture file is misplaced, or the related metadata information is lost, the data imprint ensures that the data will never be completely lost.

The third step was to determine the optimal technology to use to host the picture files. Because the system handles high-resolution pictures, this required the hosting location to possess a large storage capacity. The estimated required storage capacity for any given project was around 2 GB (Giga Bytes). It was decided to make use of the CHAMPS FTP (File Transfer Protocol) site to host the pictures. This site is used to manipulate, share, and exchange files over the Internet. It is particularly useful for handling large files, and constitutes a relatively secure method of data storage.

The last component was to determine the optimal technology to use in the system to display the pictures of failed asset items. For the specific application in this project, it was suitable to use Google Earth and Google Maps as GIS platforms. These two Google products were the best way of sharing and disseminating information because they both are available for free, they run on inexpensive hardware, and they can be embedded in a webpage.

6. WEB-INTERFACE

In order to provide a user-friendly web interface to query the database of pictures of failed assets, this project involved close collaboration with the Enterprise GIS Research and Development Administration (EGRDA) at Virginia Tech. Because special technical expertise was required to develop the web interface, this collaborative effort ensured that the end product was in accordance with the highest professional standards.

The initial intent was to develop a web interface that would allow VDOT to query a database of all the failed asset items, display the search results in the form of a table, and then download the search results to view in Google Earth. However, this initial idea grew into a more dynamic and robust application, which provided the end-user with added features and functionalities. The web interface evolved into a comprehensive web-mapping application. This interactive web-mapping application was titled “Visualization of Failed Asset Items.” This application has a very user-friendly and intuitive interface. The main features that allow the user to search the database of failures include: (1) an embedded Google Map which displays the selected portion of interstate highway, and (2) data input boxes in the left pane which allow the user to construct a query. With this tool, VDOT is able to query the database and immediately see the search results displayed in their actual geographic location in an embedded Google Map. The search results are also displayed in a table, and the user has the option to download the results to view in Google Earth. Furthermore, an option was enabled to allow the user to download the table of results as an MS Excel spreadsheet. This gave the user great flexibility in viewing the results, with a total of four different ways of exploring the data through (1) the table of results, (2) the embedded Google Map, (3) the spreadsheet in MS Excel, and (4) Google Earth.

Figure 2. Example of data imprint in a picture.

In technical terms, the application developed is a Google Maps-based site that uses PHP to query a MySQL database on the backend and then delivers the results in XML, KML, HTML, and TXT format to the frontend interface. This means that the raw data is stored in a MySQL database. When the user selects parameters in the data input boxes in the left pane, he/she is building an SQL query. When the search is submitted, a request is sent to query the database. The request is sent in the form of PHP code. After the database is queried, the results are delivered, again through PHP code, in the four formats mentioned. The XML results are responsible for displaying the search results in the embedded Google Map. The resulting KML file can be downloaded and used to view the results in Google Earth. The HTML results are responsible for displaying the results in the table. Finally, the TXT file can be downloaded to view the results as a spreadsheet in MS Excel. Every time a new query is submitted, the results in all four formats are refreshed. The flow of information in the query process is illustrated in Figure 3. The step-by-step process to perform a search using the web-mapping application is detailed in the flowchart presented in Figure 4.

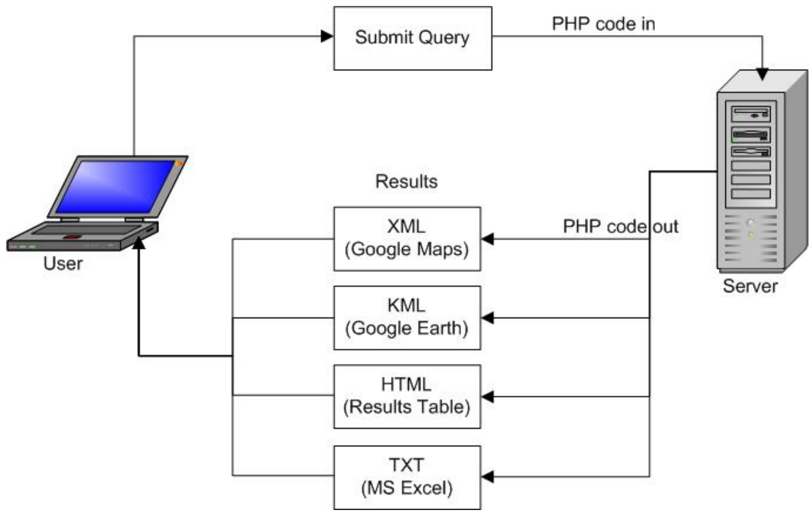

Figure 3. Flow of information in the querying process.

Another important aspect of the inner workings of the web-application is that it uses Javascript. Javascript is an integrated component of the web browser, and it has allowed the development of enhanced user interfaces and dynamic websites such as this one. Javascript is what allows the application to update the information every time the user submits a new query without having to reload the whole page. It does this by submitting an AJAX (Asynchronous Javascript and XML) request. With AJAX, the web application can query the database and retrieve the data asynchronously in the background, without interfering with the display of the page.

7. PILOT PROJECT

The system was implemented in the manner of a pilot project in the Staunton South 2009 Maintenance Rating Program (MRP) Evaluation. This proved to be really advantageous, because the system was tested in its actual application in a real-life situation. The Staunton South 2009 MRP Evaluation was selected by VDOT to serve as the testing bed for the system. The scope of the project involved the evaluation of a portion of two interstates: Route I-64 (from mile marker 0.0 to 56.7) and Route I-81 (from mile marker 174.3 to 237.5). Anderson & Associates (A&A) performed the data collection. The inspections were performed in the Spring of 2009. Table 1 presents the total number of tenth-of-a-mile sites that were inspected during the data collection process. Table 2 details the various asset items that were inspected by the crews. They are categorized by asset groups.

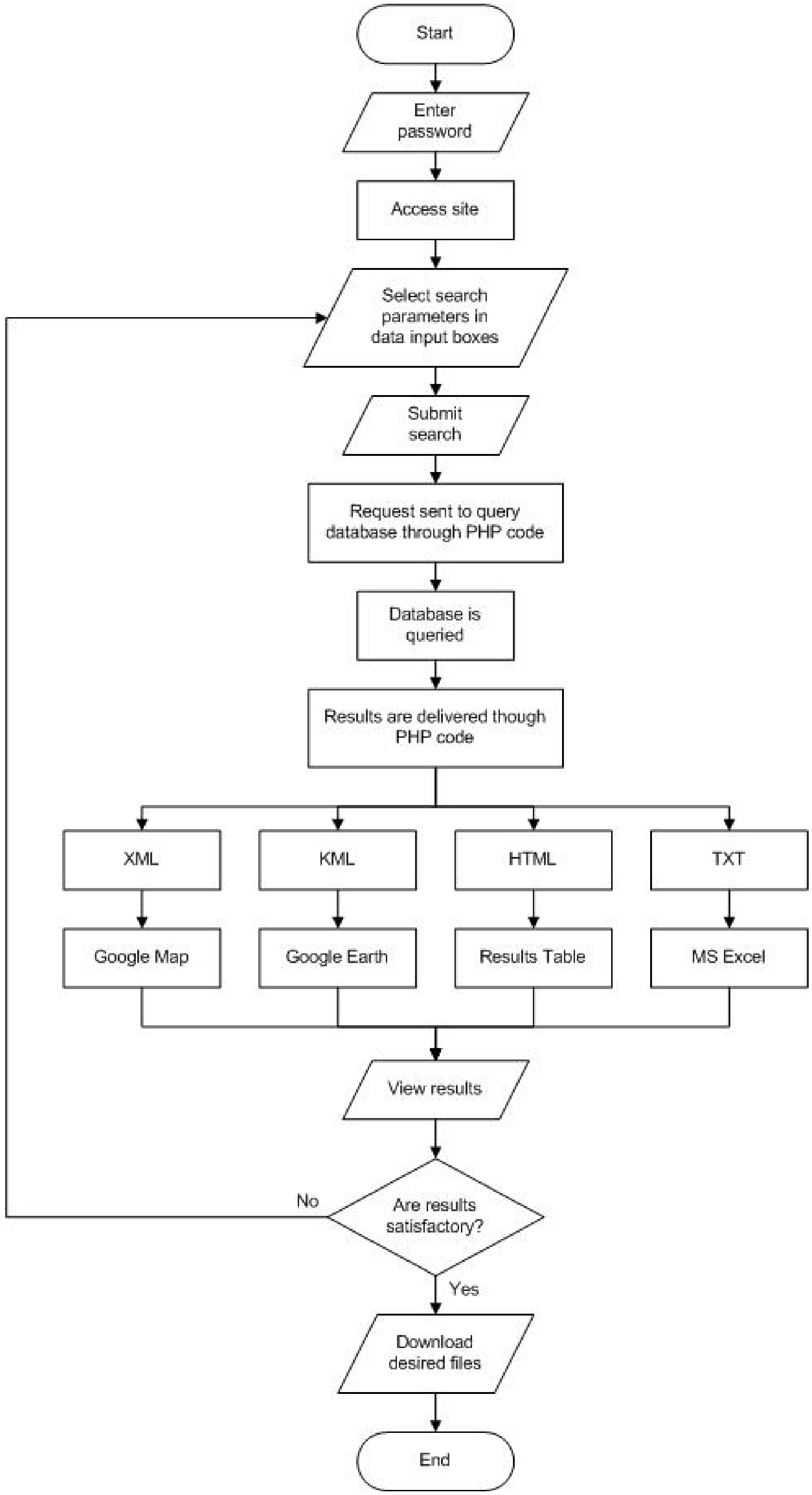

Figure 4. Step-by-step process to perform a search.

Data collection for the Staunton South project started in mid-April and lasted four weeks. The data collection crews from A&A submitted a total of four installments of picture files, one at the end of each week of inspection, for a total of 1131 files. Table 3 presents a breakdown of the number of picture files submitted each week by the crews.

During the pilot project, the data collection crews uploaded the picture files through the FTP site. At CHAMPS, the files were downloaded with the FTP site and then processed with the Ricoh Data Manager. Each file was renamed with a descriptive and unique file name following a naming convention. In addition, every picture was imprinted with its particular Segment Number, Latitude and Longitude, B2 Code, and Date and Time. Following this, the pictures were uploaded to their permanent storage location in the FTP site. A database consisting of all the asset item failures was created. Each failure in the database was linked to a picture stored in the FTP site.

Table 1. Sites inspected during Staunton South 2009 MRP (de la Garza 2009).

Route	Section	Sites Inspected	Percentages
I-64	Mainline	844	46.1%
	Ramps	50	2.7%
I-81	Mainline	872	47.6%
	Ramps	65	3.5%
TOTAL		1831	100%

All the processes ran very smoothly during the pilot project, due primarily to the thorough work performed during the planning stage of the project. There were, however, a couple of rough spots that are worth mentioning. The main issue, which is of great importance, concerns the actual capturing of the pictures out on the field. A substantial amount of the pictures submitted each week did not contain GPS coordinates. From Table 3 we can observe that 18% of the total number of 1131 pictures captured did not register GPS coordinates. This means that the GPS unit on the camera was not able to acquire a good lock on the GPS signal. A GPS device usually needs the signal of 3 to 5 satellites to register the coordinates accurately. For this reason, at certain times in some remote locations it might be hard to get a good signal. In future projects, this issue needs to be addressed to drive the percentage of pictures without coordinates to a much lower number.

It was also found that having to take pictures during data collection was responsible for a 40% reduction in productivity from the crews. On other projects that did not require taking pictures, each two-man crew inspected an average of 50 tenth-of-a-mile segments per 8-hour-day. On the Staunton South inspection, this dropped to just 30 segments per day. The two most time consuming processes were: (1) the manual input of data such as Segment Number and B2 Distress Code for each picture; and (2) getting a lock on the GPS signal. This information has to be taken into account for a future implementation of this technology. For example, an automated data input process would have a significant effect in reducing the time required to take the pictures. Also, the use of external GPS devices to serve the purpose of back-up when the camera cannot get a good signal could reduce the time the crews spend waiting for a signal and would also help reduce the amount of pictures that do not register coordinates.

After the pilot project, the cumulative database containing all the available data was loaded into the web-mapping application. The different features of the application were tested to ensure they were working properly. The following screenshots present a sample search that was done for the Staunton South 2009 project with the following search parameters: Asset Group = Roadside, Asset Item = Debris and Roadkill & Slopes, and B2 Distress Code = ALL. Figure 5 shows the results after the search is submitted. It also shows the highlighted selections in the boxes in the left pane that were used to construct the query. Figure 6 shows how the picture of a failed asset item is displayed by clicking on the orange icon in the embedded Google Map. By clicking on the image, you can display it at full resolution in another window. This is demonstrated in Figure 7.

Table 2. Assets inspected during Staunton South 2009 MRP (de la Garza 2009).

Roadway	Shoulders	Bridge
Paved Lanes – Asphalt	Paved Shoulders	Deck
Paved Lanes – Concrete	Unpaved Shoulders	Superstructure
		Substructure
		Slope & Channel Protection
Roadside	**Drainage**	**Traffic**
Grass	Pipes & Culverts (≤36 sq ft)	Signals & Signs
Debris & Roadkill	Pipes & Culverts (>36 sq ft)	Lighting
Landscaping	Paved Ditches	Guardrail
Brush & Tree Control	Unpaved Ditches	Impact Attenuators
Concrete Barrier	Under/Edge Drains	Object Markers/Delineators
Sound Barrier	Strom Drains/Drop Inlets	Pavement Messages
Slopes	Curb & Gutter	Pavement Markings
Fence	Storm Water Mgmt Pond	Pavement Markers
Retaining Walls		Crossovers
Illegal Signs & Structures		
Weep Holes		
Graffiti		

Table 3. Picture files submitted each week.

Week #	Submitted	With GPS	Without GPS	% Without GPS
1	196	141	55	28%
2	368	319	49	13%
3	508	407	101	20%
4	59	57	2	3%
TOTAL	1131	924	207	18%

The primary use of the web-application was for viewing and verifying assets that had failed the evaluation inspection. Secondary uses included: (1) quality assurance for MRP reviews, (2) verification of assets prior to applying contractor disincentives, and (3) training of data collection crews. These three uses are perfect examples of how the system succeeded in adding value to current highway asset management practices.

8. CONCLUSIONS

This paper presented a comprehensive system to display pictures of failed asset items. Through the use of a web interface, VDOT and other end users are now be able to: (1) query a database of every failed asset item in a given project, (2) display the failures in their actual location in a map, and (3) examine a high-resolution picture of every failed asset item. This gives VDOT a tool to check any failed asset item from any computer with an Internet connection, eliminating the need to go out on the field and visit each individual site. With the use of this system, maintenance officials will significantly reduce the countless hours spent driving across the state searching for a few assets to verify their condition. This represents a great savings in terms of time, but also a cost savings in terms of labor hours of maintenance officials. Another source of cost savings that could derive from this system is the ability to apply monetary penalties on the contractors for poor performance.

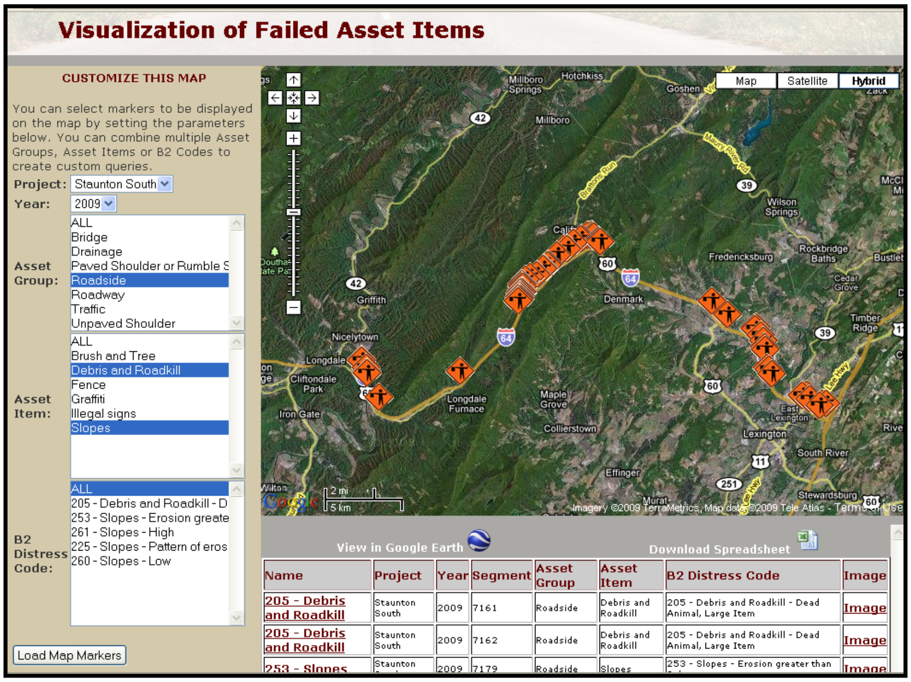

Figure 5. Display of search results in Google Map.

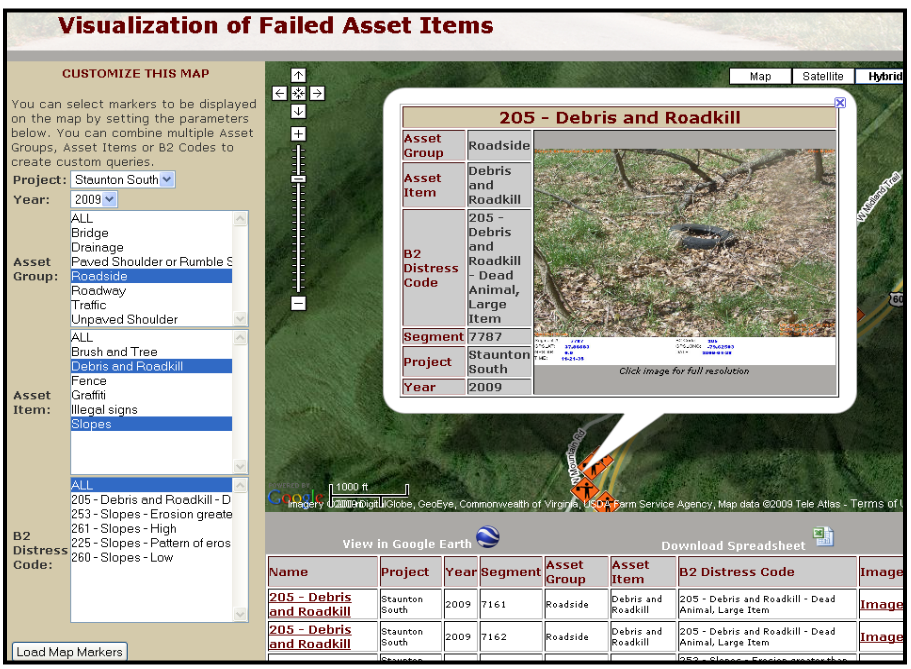

Figure 6. Display of the picture of a failed asset item.

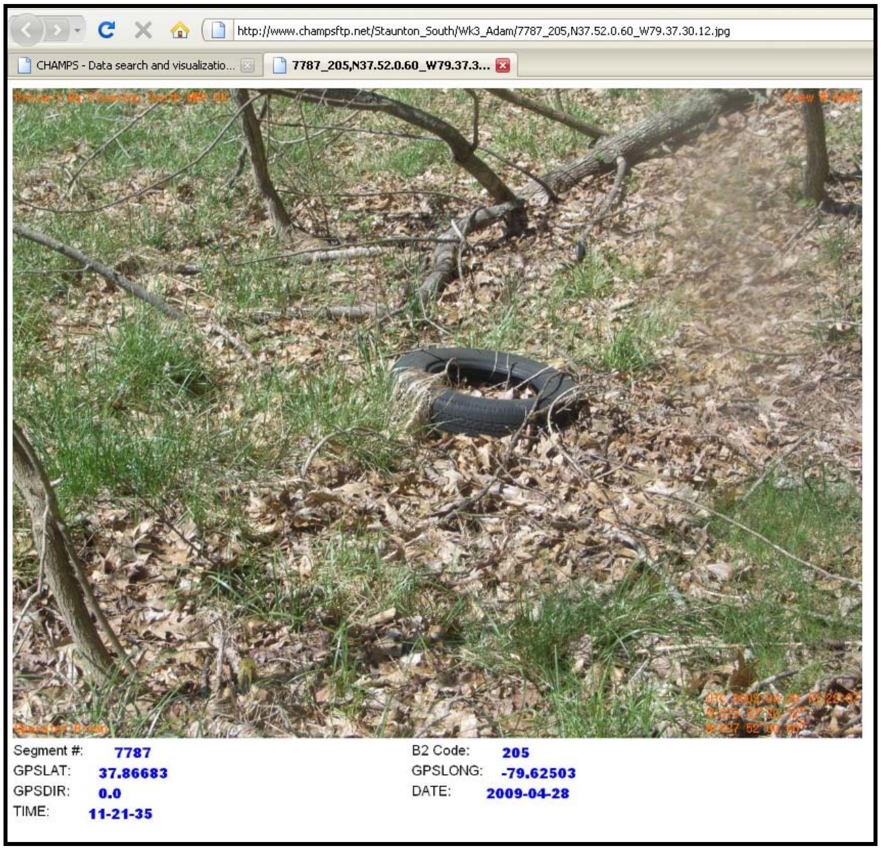

Figure 7. Full resolution picture in a new window or tab.

ACKNOWLEDGMENTS

This research was funded by the Virginia Department of Transportation. Any views, opinions, and findings presented in the paper are those of the authors and do not necessarily reflect the views of VDOT.

REFERENCES

Boulos, M. (2005). "Web GIS in practice III: creating a simple interactive map of England's Strategic Health Authorities using Google Maps API, Google Earth KML, and MSN Virtual Earth Map Control." *Int. J. Health Geogr*. 2005, 4(22). <http://www.ij-health geographics.com/content/4/1/22>

Center for Highway Asset Management ProgramS (CHAMPS) Website. (2009). <http://www. champs.eng. vt.edu>

de la Garza, J.M. (2009). "Spring 2009 Staunton South Turnkey Asset Maintenance Services Evaluation – Final Results." Report submitted to VDOT June 2009. Blacksburg, VA.

Graupmann, J. and Schenkel, R. (2006). "GeoSphereSearch: Context-Aware Geographic Web Search." In *Proceedings of the 3rd Workshop on Geographic Information Retrieval* held at The 29th Annual International ACM SIGIR Conference, Seattle, WA, USA.

Piñero, J.C. (2003). "A Framework for Monitoring Performance-Based Road Maintenance." Doctor of Philosophy Thesis. Virginia Polytechnic Institute and State University, Blacksburg, VA.

Slingsby, A., Dykes, J., Wood, J., Foote, M., and Blom, M. (2008). "The Visual Exploration of Insurance Data in Google Earth." In *Proceedings of Geographical Information Systems Research UK (GISRUK) (Manchester, UK, 2007),* 24-32. <http://www.willisresearchnetwork.com/Documents/WRN _GoogleEarth_Paper_FINAL.pdf >