Integrating GIS and Real-Time Vehicle Tracking for County Emergency Response

Gretchen Baldus, Jay Kim
Collier County Government
Naples, Florida

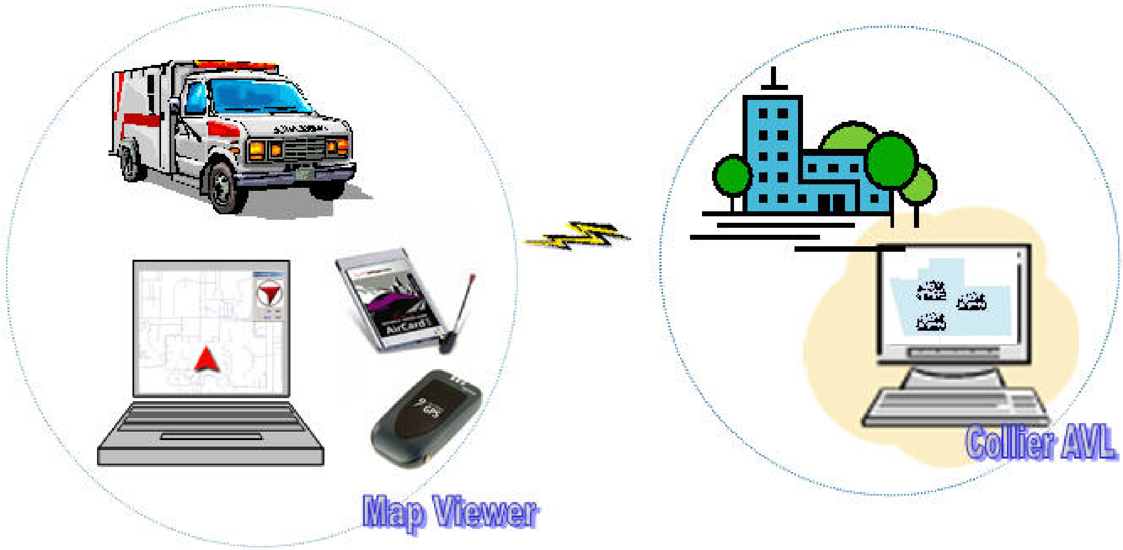
Abstract -- *The Collier County Emergency Medical Services serves the largest county in Florida with a land area of 2,030 square miles—the majority of which is covered by vast areas of rural farmland, state preserves, and Everglades National Park. Furthermore, in addition to its 276,000 year-round residents, Naples experiences a large influx of seasonal residents and tourists who are potentially unfamiliar with the area—often problematic when reporting emergencies. Response time is therefore critical to ensuring quality medical services for Collier County citizens.*

The new AVL system provides a tool for monitoring all deployed vehicles, including 1 helicopter, in real-time. The in-vehicle map viewer allows drivers to enter an incident's address, graphically display it, and simultaneously upload live location data to headquarters. Meanwhile the AVL component at headquarters visually displays each vehicle's location and destination. Furthermore, an error capturing function during the geocoding process enables GIS staff to update address data.

1. Introduction

1.1. Background

The EMS provides 24-hour first response advanced life support (ALS) for this entire region and has a fleet of 22 ALS ambulances, 3 ALS engines and 1 helicopter. Prior to installation of the Automated Vehicle Location system (AVL), all communications between the vehicle operators and the EMS Center were conducted using radios and cellular phones. Drivers were therefore required to report their location to the Center every 15 minutes for dispatchers to adequately monitor their vehicles' routes and manage incident response. This method proved increasingly unreliable and forced Center staff to manually plot locations and depend on often outdated paper maps for routing information.



The central GIS operations lie within the Information Technology Department of Collier County and provide the GIS infrastructure and system support to numerous GIS users throughout the organization. It is staffed by a GIS Manager, and three Programmer/Analysts. This group is responsible for the centralized coordination and management of the GIS licensing and infrastructure; data publishing, documentation, and maintenance; technical support for users; and providing application development to the County departments who lack the resources to develop their own. Therefore, when the EMS department needed assistance in improving their process for locating and tracking their vehicles and incident locations, they came to the GIS group for development of a custom application.

The AVL system was designed to accomplish four primary objectives: 1) increase frequency of vehicle location reporting to near real-time; 2) install GPS in each vehicle to enable continuous tracking for the benefit of both center staff and drivers; 3) provide navigational features for vehicle operators including destination location, vehicle heading, remaining distance to destination, and direction to destination; and 4) provide database administrators with periodic or real-time data update and error capturing. The added benefit to the system includes providing EMS staff with a simple desktop viewer application loaded with compressed 6” aerial imagery and other base layers for quickly locating addresses, intersections, or coordinates on a county map. This was a vast improvement over the paper maps previously used. Also, as additional user-specific information is added, such as fire hydrants and school floor plan documents, the system will benefit other departments like the nine fire districts located throughout the county. A third indirect benefit is therefore a result of the adaptability of the system: other agencies are realizing the value of the system and coordinating efforts with the County to develop the product further, resulting in increased communication and cooperation among agencies.

1.2. Motivating Factors

The initial motivation behind the AVL system was two-fold: 1) EMS issued a request for an incident reporting tool, and 2) the department was currently monitoring their vehicle locations by requiring periodic checks via radios and cellular phones – an unreliable method that increased response times. To comply with the first request, the GIS/IT group designed a map viewer application that allowed staff to quickly and accurately locate addresses, intersections, and latitude/longitude coordinates on a map – the method of input depending on how an accident location was reported. With the development of the viewer component, it was evident that it could serve an additional purpose: besides providing an incident locator and reference tool, the viewer could run on a laptop or tablet PC within each EMS vehicle and while using a GPS receiver with a wireless connection to a remote server, the driver's location could be tracked in real-time. The viewer component then serves to feed live location data to a server at the central office, while the AVL component at the central office provides staff a visual display of all the vehicle locations and their current destinations.

Secondary motivating factors that influenced the overall design of the system included the need for the most current data available as part of the map viewer. The MapObjects application the GIS/IT group developed opens a window displaying all the street centerlines with labels and the county boundary; moreover, the application can access the data directly on the SDE server, enabling the system to be updated with the most current information at the click of a button. In addition, the 1 meter and 6 inch aerial imagery were added as optional background layers.

And finally, a motive related to the vehicle tracking request was EMS's requirement to more easily document and analyze the daily routes followed by their vehicles. This could readily be accomplished by extracting the log files that are continuously sent to the server containing the coordinate information from the GPS.

2. System Development

The primary objective of the system was to provide the EMS Department with a tool for monitoring all deployed EMS vehicles and for better managing the dispatch operations, thereby improving response times. Previously all vehicles were tracked using radios or cellular phones, which often led to inaccurate location reporting, severe lag times, and the inability to account for all vehicles simultaneously. The solution to this problem consists of the system's two components: the AVL application which resides on one or more desktops at the central office, and the map viewer which is installed in each of the rover vehicles.

2.1. AVL

On the AVL side, each vehicle is assigned a vehicle ID which is prominently displayed on the application window, with graphics to represent the destination of each vehicle and its projected track. The user must first choose the Setting button to browse to the location of the log file on the server, which will be populated by the roving map viewer applications (Figure 1). The refresh data rate must also be set, and optimal results have been achieved by setting the AVL application to a refresh rate of two seconds. Additional features include tools to zoom in, zoom out, pan, and view the aerial imagery as a background layer (Figure 2).

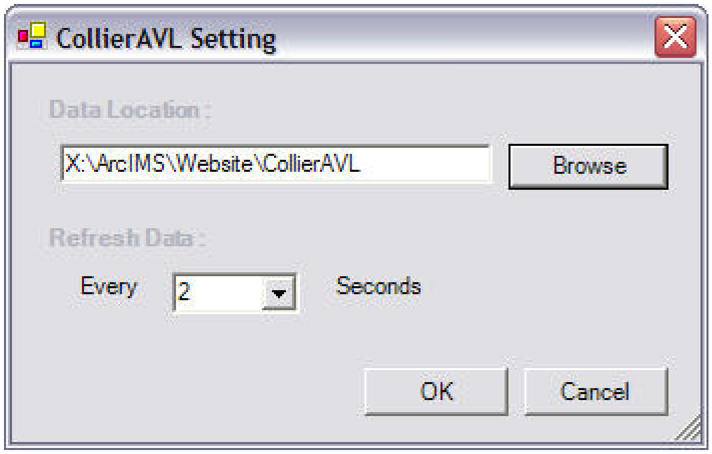


Figure 1. The AVL dialog for specifying the location of the vehicle log files and refresh rate.

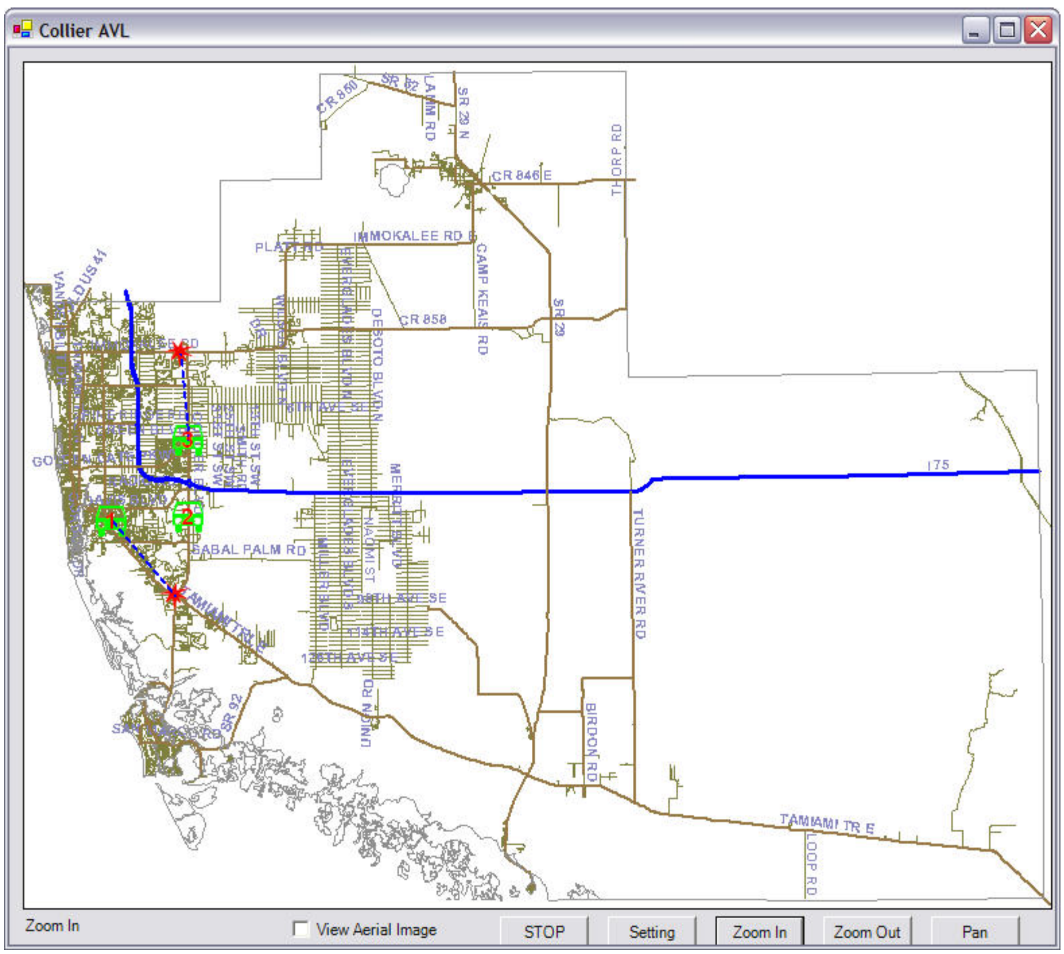


Figure 2. The AVL component to the system, showing the display of 3 vehicles and the destinations for vehicles 1 and 3.

On the vehicle operator's end, the map viewer component was designed to provide a dual purpose function: a reference tool for quickly locating a destination based on an address, intersection, or latitude/longitude coordinate, and to display valuable navigational features for reference while en route. These features include a large arrow indicating the direction to the destination, the distance remaining to the destination, current miles per hour, and a point symbol representing the destination location. (Figure 4). The driver also sets the data update rate, or the rate at which coordinate information is uploaded to the server (Figure 3). The information is sent using a CDMA PC card, primarily because this technology was already in-house; we had, however, tested the GSM PC card as well and found that virtually any communication protocol can be used given the small size of the data. In the testing phase, 5 second intervals proved satisfactory. The coordinate information is then stored in log files on the server (Table 1).

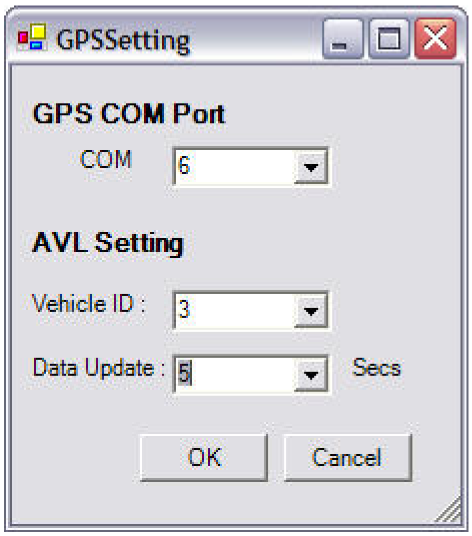


Figure 3. The GPS connectivity dialog on the map viewer application.

```
5,406344,653238,0,0,6/1/2004 4:58:13 PM,2
5,406367,653595,0,0,6/1/2004 4:59:14 PM,2
5,406362,653707,0,0,6/1/2004 4:59:19 PM,2
5,406356,653812,0,0,6/1/2004 4:59:24 PM,2
5,406347,653901,0,0,6/1/2004 4:59:29 PM,2
5,406271,653909,0,0,6/1/2004 4:59:34 PM,2
5,406162,653899,0,0,6/1/2004 4:59:39 PM,2
5,406049,653889,0,0,6/1/2004 4:59:44 PM,2
5,405936,653885,0,0,6/1/2004 4:59:49 PM,2
5,405845,653884,0,0,6/1/2004 4:59:54 PM,2
5,405766,653893,0,0,6/1/2004 4:59:59 PM,2
5,405639,653894,0,0,6/1/2004 5:00:04 PM,2
5,405499,653892,0,0,6/1/2004 5:00:09 PM,2
5,405380,653859,0,0,6/1/2004 5:00:14 PM,2
5,405340,653783,0,0,6/1/2004 5:00:19 PM,2
5,405281,653773,0,0,6/1/2004 5:00:24 PM,2
5,405181,653775,0,0,6/1/2004 5:00:29 PM,2
5,405130,653831,0,0,6/1/2004 5:00:34 PM,2
```

Table 1. Sample log file stored on the server.

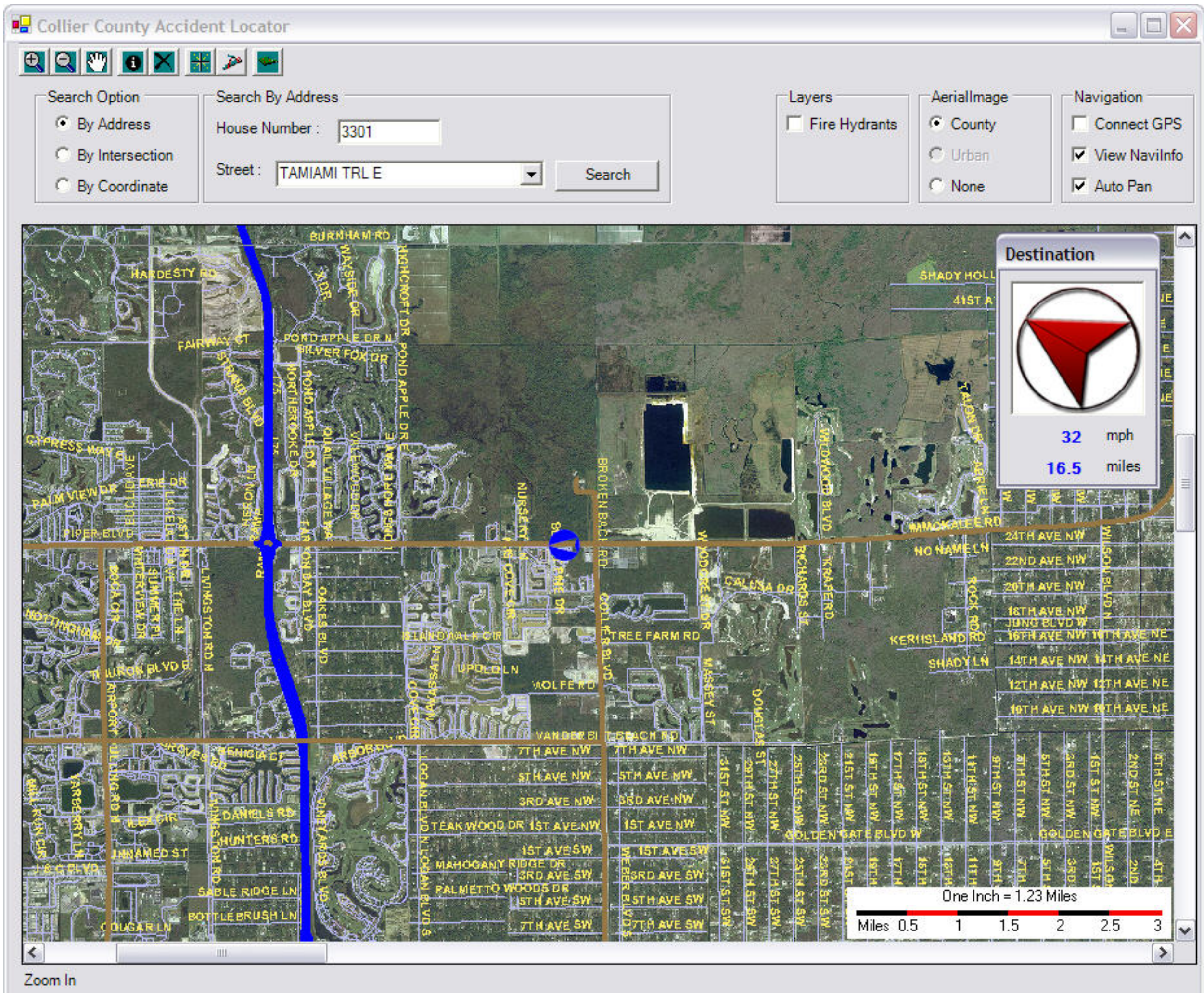


Figure 4. The Map Viewer showing the navigational aids and address search options.

2.2. Incident Locator

This application was also designed to improve the process by which incident reporting is managed. Prior to activation of the system the staff had to locate incidents on a paper map – which in itself was time-consuming and error-prone – but also proved difficult when locations were received in varying formats such as latitude / longitude coordinates. Embedded in the functionality was the ability to search for a location by entering either a street address, intersection, or coordinate. The coordinates could be in WGS84 latitude/longitude or NAD83 Florida State Plane East.

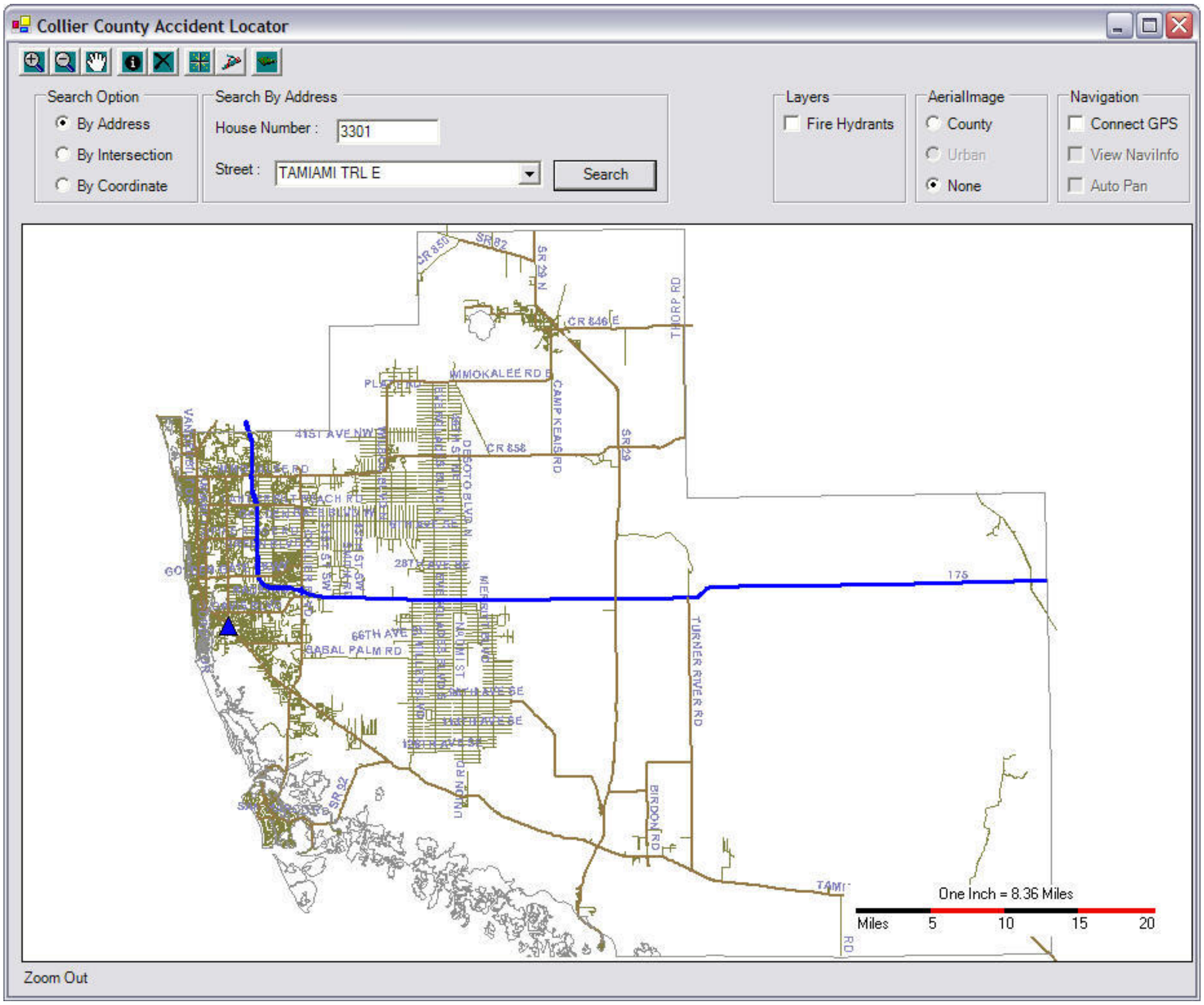


Figure 5. The Map Viewer component to the system, showing the address search function.

For the street addresses, a drop-down menu was provided with which to select the desired street in order to avoid typographical errors. (Figure 5). The viewer would then zoom to the desired location and display a symbol. Other navigational tools were added including Zoom In, Zoom Out, Pan, and Location. The Location button allowed the user to click anywhere on the map and the lat/long coordinates for that location would be displayed in decimal degrees.

2.3. Additional Benefits

2.3.1. Capturing Geocoding Errors

During the map viewer development process the GIS/IT group recognized the benefit of adding an error capturing function. With various users routinely entering street addresses, two types of errors would inevitably occur: either the user would enter a non-existent address, or the street centerline dataset would contain an incorrect address range and the address would not be found. In order to flag these errors and ensure they are promptly resolved in the data, a function was implemented where the user simply clicks a button and a log of all the reported errors are copied to the server. In a later version of the application, a frequency setting was added whereby the user can choose to send the error report either when the button is clicked, or in real-time. In that instance, every time an error is encountered the report is automatically uploaded to the server. These features have allowed the GIS staff to maintain currency and accuracy in the data, as well as assure the user that all errors will be resolved.

2.3.2. Emergency Management Data Development

After evaluation of the system by outside emergency response agencies, a second unexpected benefit was realized: the reprioritization of data development efforts. Plans are now underway for completing the fire hydrant feature dataset, which will greatly improve the usability of the map viewer for the fire departments. They claim to expect significant reductions in response time if the hydrant locations are visible as an overlay on the aerial imagery.

We are also adding the ability to view the floor plans for all area schools. After a user types in the street address for a school, a button becomes visible which pops open a window displaying any available drawing files of plans, aerial images of the school and its vicinity, and other relevant documents. (Figure 6).

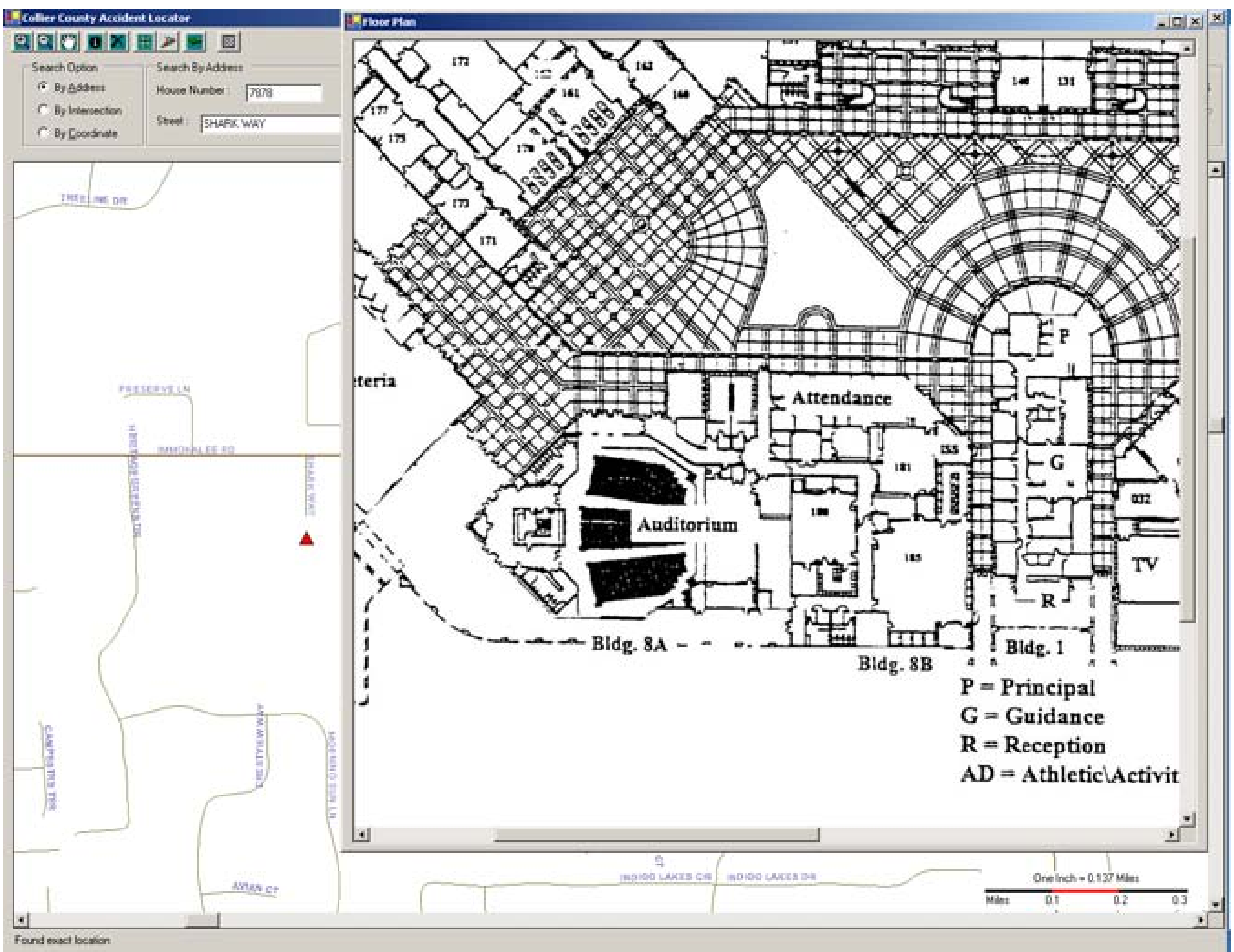


Figure 6. The Map Viewer component to the system, showing the address search function.

2.4. Hardware /Software /Data

2.4.1. Hardware

- Laptop or Tablet PC located in the vehicle to collect GPS coordinates and transmit this information on a regular interval to a server via a cellular modem.
- GPS unit that is attached to the laptop or tablet PC via USB.
- PC wireless card (cellular modem) that is connected to the laptop or tablet PC. The County has a contract for a vendor to provide the hardware and services at fixed rates. Monthly charges do apply.
- A server is used to collect the incoming data from the field units and store it in a database. Standard file transfer protocol is used as the data being transmitted only contains coordinates, date stamp and a non-descriptive vehicle identification that does not compromise the safety and security of the field personnel. A web server is then used to publish the data via an intranet to desktop computers.

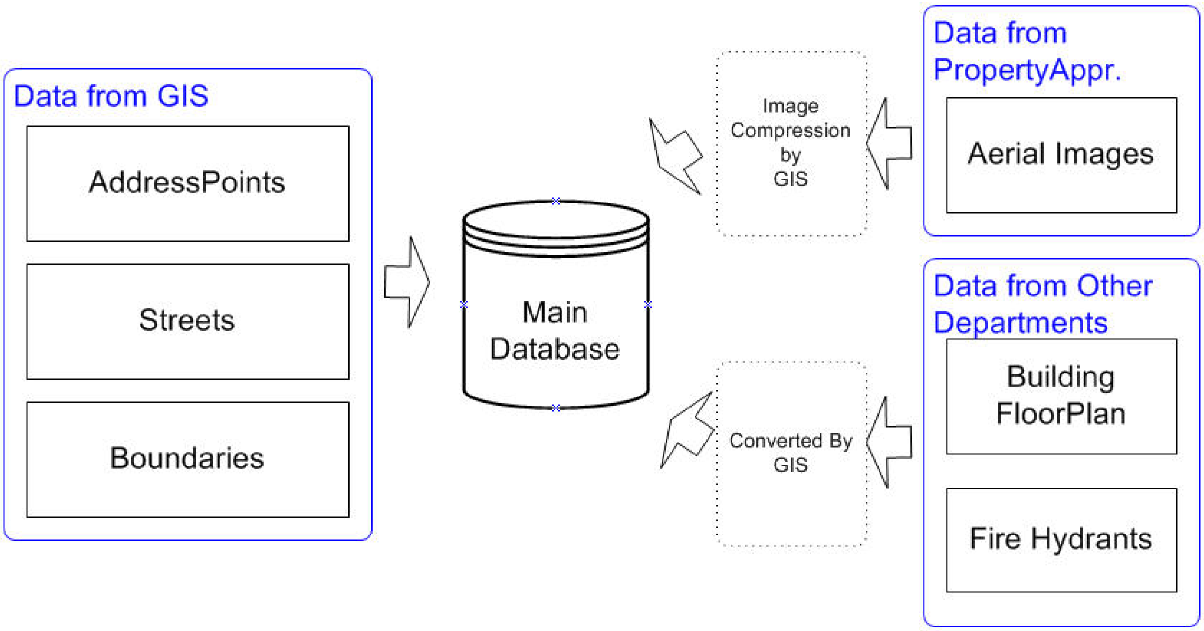
2.4.2 Software

- The system was written using ESRI Map Objects and Microsoft Visual Basic.Net. In addition to the custom application, a plug-in is used for the aerial imagery that has been compressed using ER Mapper software. The compression software was necessary to mosaic the imagery and establish a compression ratio that works for the field units.
- The server performs three functions: receiving location data, data storage, and a secondary Web application for AVL information. The data capture process was originally built using Macromedia ColdFusion and has been redeveloped as a .NET Web service. The data are stored in ArcSDE with Microsoft SQL Server. The secondary .NET Web application displays the current locations of all remote vehicles and uses ArcIMS for the map display.

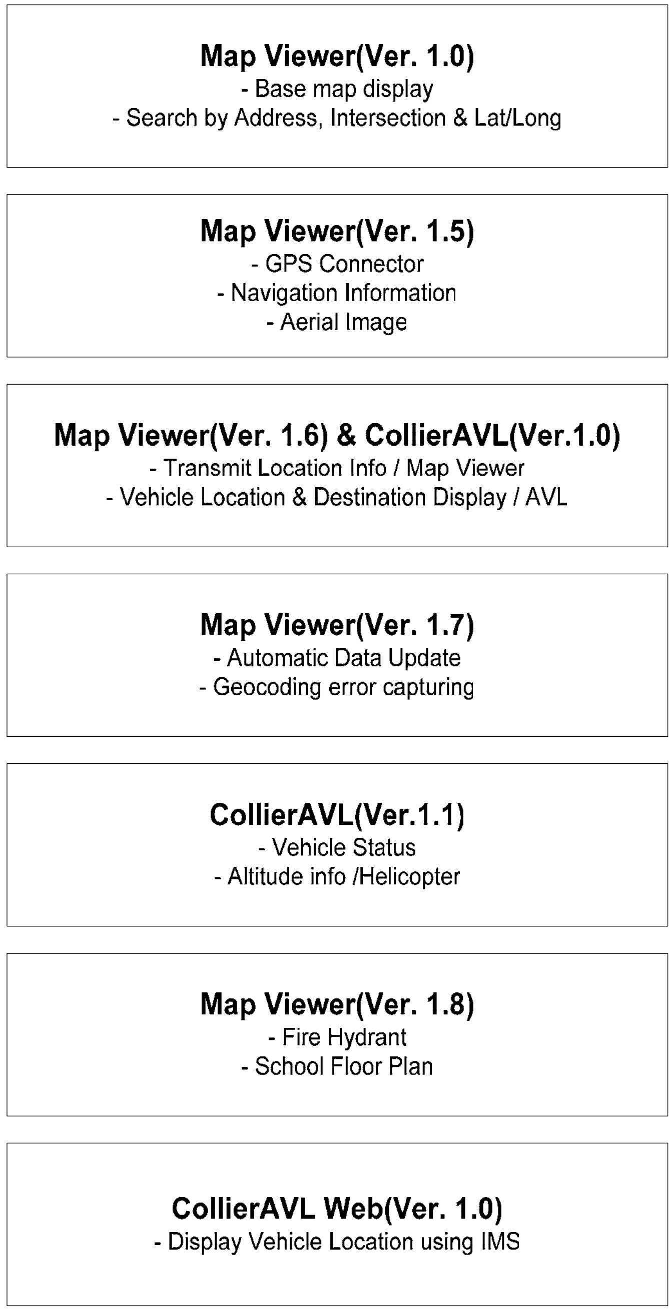
2.4.3. Data Improvement

- The system is using data stored within an enterprise geodatabase running ESRI ArcSDE with Microsoft SQL Server. Address points and street centerlines with address ranges are used for geocoding and map display.
- Data updates are set up to automatically occur when the laptop or tablet PC is attached to the network. The program will check for whether new data are available, and the user will be prompted to choose whether to download the new data. The data are extracted from the ArcSDE server and placed on the local computer as shapefiles.
- Two aerial imagery files, 6 inch and 1 meter resolution, are loaded during the initial install of the program and are stored in ECW format. The two files are required as one covers the urban area while the other covers the entire county.

- The system also collects information about what addresses were searched for but not found within the database. These missing or unknown addresses are then automatically reported back to GIS staff so research can be done to further enhance our addressing databases.



2.5. Development History



3. Conclusions

What differentiates this system is largely the cost of implementation and the ability to integrate this system with our enterprise GIS goals. The cost of the system was minimal as the emergency medical vehicles were already assigned laptop or tablet computers with cellular modems. The only hardware costs were for a portable GPS unit. Staff resources were all full-time employees assigned to GIS development and deployment.

Beyond the ability of the system to save lives by providing better information to emergency response personnel, is the ability of the system to automatically give feedback to the GIS team in regards to omitted or erroneous addressing data. This is important as addressing data is one of the core data sets necessary for implementing an enterprise GIS within county government.

The system takes advantage of new technology that has trimmed costs, and in testing has performed better than anticipated. The new GPS units and cellular modems were continually able to provide data that only had a 4 to 7 second delay time. The system seems to perform optimally with a 7 second delay as this represents a 5 second GPS data update interval on the roving vehicle and a 2 second delay in sending the data to the server and seeing the results on a desktop computer in the office. Factors that allowed an improved response time included the ability to capture GPS data on a tablet PC and then transmit that data on an existing cellular modem service. Prior to implementation of the system, the EMS center relied on the vehicle drivers to phone in a report of their location every 15 minutes. Using the system, the center can now monitor all vehicle locations on one desktop application with refresh rates of 4 – 7 seconds.

Already, the potential is enormous for this system in a wide variety of applications: from tracking individual firefighters who are battling a brush fire in the Everglades, to outfitting Public Utility personnel making routine service calls. Virtually any task that requires a fieldwork crew and the supervising personnel to monitor them could benefit from the system. And as the number of users and successes increase, more will recognize the value in the system and initiate new deployments.

Although the system is directly used by EMS staff and, in the near future, by other emergency response offices, the system ultimately serves all the citizens of Collier County. They are the end users of the services EMS provides and because the system improves EMS's ability to manage their fleet and respond to incidents more quickly, increasing the likelihood that lives will be saved, the citizens are therefore better served.

Author Information:

Gretchen Baldus
Sr. GIS Programmer/Analyst
Information Technology
Collier County Government
3301 East Tamiami Trail, H-209
Naples, FL 34112
Ph. 239-417-6040
Fax 239-530-6344
GretchenBaldus@colliergov.net

Jay Kim
Sr. GIS Programmer/Analyst
Information Technology
Collier County Government
3301 East Tamiami Trail, H-209
Naples, FL 34112
Ph. 239-417-6017
Fax 239-530-6323
JayKim@colliergov.net