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AUTONOMY AND VISUALIZATION ENHANCEMENT FOR SITUATIONAL AWARENESS

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ABSTRACT

In the Tank Automotive Research Development and Engineering Center (TARDEC) Phase II SBIR "Autonomy and Visualization Enhancement for Situational Awareness" (AVESA) program, Robotic Research, LLC has developed a camera-based intelligence and reconnaissance tool to address the needs of warfighters on the battlefield. The RR-Flashback system developed under this program provides a hardware and software solution that captures, time tags, and geo-references panoramic imagery, along with a spatiotemporal imagery database for use in mission planning, intelligence analysis, and detecting changes in the environment.

INTRODUCTION

Military operations in urban areas mean facing constantly changing hazardous conditions. Having advanced intelligence in the area of operation increases the preparedness the warfighters when a mission begins. Often times, the routes being traveled have been traversed many times before (such as in mine clearing operations or supply convoys). However, there is currently no method to easily review and analyze data (imagery, annotations) from past missions.

Missions often require small teams to quickly navigate remote sites over extended periods of time. Operators that are familiar with a route can recall past objects of interest locations and recognize changes in the environment, but new operators do not have access to the same information, even if fellow soldiers have traversed the same route. An intuitive and systematic method for storing and accessing information such as images of routes on previous days or marked object of interest events would reduce the threat of territory unfamiliar to the soldier and supplement the intelligence collected in a given area.

Enhanced situational awareness yields significant tactical advantages for combatants. DARPA recently released a call for technologies that improve situational awareness for dismounted squads. They specifically seek "geolocation technologies, particularly for global positioning system (GPS)-denied areas" [1]. Systems that can collect location-tagged information about surroundings would give a significant edge for vehicles and dismounts whose decisions and intelligence would benefit from enhanced situational awareness.

SYSTEM OVERVIEW

In order to address the shortcomings in a-priori situational awareness noted in the introduction, Robotic Research, LLC has developed, under a Tank Automotive Research Development and Engineering Center (TARDEC) Phase II

SBIR ("Autonomy and Visualization Enhancement for Situational Awareness" (AVESA)), a camera-based intelligence and reconnaissance tool to address the needs of warfighters on the battlefield. The RR-Flashback system developed under this program provides a hardware and software solution that captures, time tags, and geo-references panoramic imagery, along with a spatiotemporal imagery database for use in mission planning, intelligence analysis, and detecting changes in the environment.

The goal of the RR-Flashback system is to capture and geo-reference imagery passively during daily operations. The system provides tools for storing, reviewing, and analyzing captured data post mission. The data is stored in a database and indexed for fast search. Searches can be based on a wide range of criteria, such as location, time, vehicle id, and/or keywords. RR-Flashback provides a graphical user interface that allows a user to view the data from the current mission, and/or compare imagery from past missions to perform reconnaissance and detect changes in the environment.

A system diagram is shown in Figure 1. When returning to base, a fleet of vehicles, each equipped with a stand-alone RR-Flashback Camera Module, wirelessly transfer the geo-referenced imagery collected during the day to a central database. Once the data has been loaded into the database, the RR-Flashback Viewer can be used to review the data.

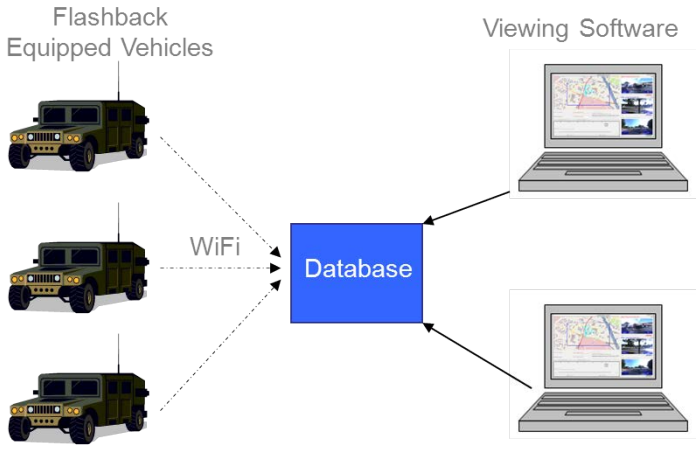

Figure 1: System diagram of AVESA RR-Flashback system. Vehicles are equipped with a RR-Flashback Camera Module which collects and geo-references imagery. The data is wirelessly transferred to a database and accessed using the RR-Flashback Database Viewer software.

RR-FLASHBACK CAMERA MODULE

The RR-Flashback Camera Module is a standalone camera system that collects and geo-locates 360° imagery passively during normal, daily operations (Figure 2).

Figure 2: RR-Flashback Camera Module prototype

The system consists of five 1.3MP cameras, an on-board GPS and inertial based navigation system, an ARM embedded computer, a hard drive, and an 802.11 WiFi module. Images from each camera are collected at one to two frames per second, and can be stitched to create a panoramic view around the vehicle (Figure 3). The hardware was designed to be relatively inexpensive for deployment on large fleets of vehicles. Additionally, the system was designed to be self-contained and hands-off. That is, the vehicle operator does not need training to use the system. The system records whenever the vehicle is powered on and wirelessly syncs data with the database when the vehicle returns to the base of operations.

Figure 3: Example panoramic image captured with RR-Flashback Camera Module

Web Interface for Status Monitoring

One of the major challenges in the development and testing of a new system is monitoring the statuses and

outputs of various pieces of hardware and software. The RR Flashback Camera Module web interface was developed to overcome this challenge. It can communicate in real time the states of cameras, stream the current camera imagery, stream and plot the navigation data, send relevant commands to the system, and configure options (e.g., camera frame rate).

The status monitor webpage for the cameras represents the state of each camera using a color coded graphical interface (Figure 4). The five semi-circular shapes on the outside of the decagon represent the five cameras. If the cameras are on and working, the color is green; if there is an error, the color will switch to red and an error message will be displayed. Clicking on a valid camera will bring up a live stream of the requested image data.

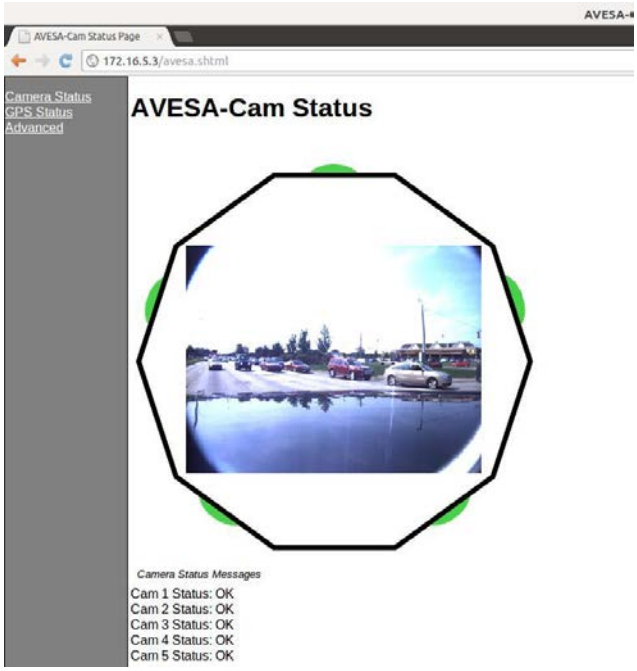

Figure 4: The status webpage for the RR-Flashback Camera Module web interface displays the current status of each camera and allows the user to stream the camera images in real-time.

The GPS Status page (Figure 5) updates based on the live GPS stream. It displays the latitude, longitude, and altitude, and plots the current location on top of a map display. This page displays both aerial imagery and OpenStreetMap data.

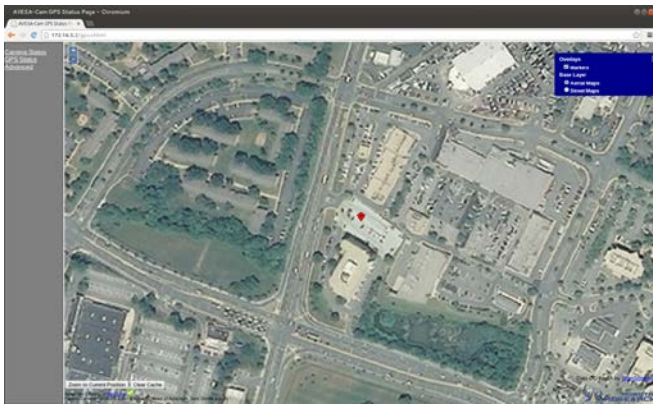

Figure 5: Screenshot of the GPS Status page. The aerial imagery is selected in this example.

A communications module on the RR-Flashback Camera Module system receives and transmits messages between the webpage and the on-board software. Communications from the website are performed using web sockets. The communications module parses these messages and sends the required actions to the camera module software using the Neutral Messaging Language (NML). The RR-Flashback Camera Module software also uses NML to communicate back to the communication module, which interprets these messages and send out commands to the web interface using web sockets. This communication module enables a set of simple commands to be sent, such as sending commands to the software to restart or sending a reboot command to the computer.

RR-FLASHBACK DATABASE

Storage and Search

The RR-Flashback Database stores and searches the data collected by the camera module. Robotic Research has developed a search server and related tools to maintain an efficiently searchable index of collected data. The system uses a combination of spatial and temporal indexes at varying scales to answer search queries that may include time, distance, vehicle id, or keywords. For example, a potential query could be translated as “What did this vehicle see within 10 km of point 39N,77W last week?”

When a client sends such a query to a search server, the server uses its query optimizer to determine the best search strategy for the constraints given. The presence and breadth of certain parameters help determine which type of index the server should employ.

The server returns a result set in which it lists each collection or 10-minute unit it found (depending on the

result format the client requested). When asked for collections, it lists each collection's important data, including vehicle ID, tags, and start time, and when the client requests 10-minute units, the server lists each unit's start time as well as its sequential number within the collection and all of the data that would be returned for the corresponding collection. Start time and vehicle ID make up the unique key with which the client may identify a collection and fetch its raw data. If the client requires, the server will also include a summary of the unit or collection, consisting of a list of time-stamped points at a specified resolution.

Mission Review and Analysis

The RR-Flashback Database Viewer graphical user interface (Figure 6) allows a user to query the database, download the desired data, and display the results. The user can select a region on the map to search for all collections in the database that exist inside that bounding box. Additional search parameters can be specified, such as a time range or keyword(s) of interest. The resulting collections that match all of the search criteria are plotted on the map, as well as on a zoom-able timeline (Figure 7). The user can select collections to download and display by selecting regions on the timeline. Up to three data sets can be compared simultaneously. The ability to recall geo-referenced imagery, combined with the ability to compare this imagery over time will allow the end user, prior to or during a mission, to detect natural (e.g., disturbed earth, holes) and artificial (e.g., boxes, cars) changes in the environment. This technology can be used to detect patterns, track people or vehicles of interest, and can provide more actionable intelligence. It can be utilized on manned or unmanned vehicles for a variety of uses.

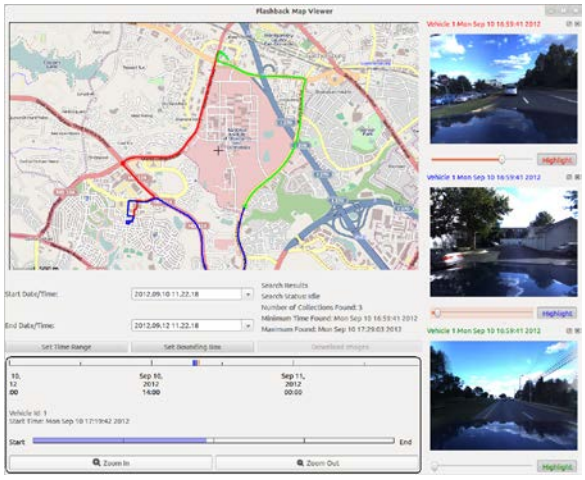

Figure 6: RR-Flashback Database Viewer can display up to three data collections simultaneously.

The Database Viewer stitches and displays the panoramic imagery. The user can pan, tilt, and zoom in on the imagery to explore the scene. By clicking on a map, the viewer "teleports" to that specific location in each dataset being compared. To reduce operator load, overlapping datasets can be "locked" together; that is, the camera views are forced to the same location and manipulating one image will manipulate all of the locked images. This allows the user to quickly and easily navigate multiple datasets and is useful for detecting changes in the environment.

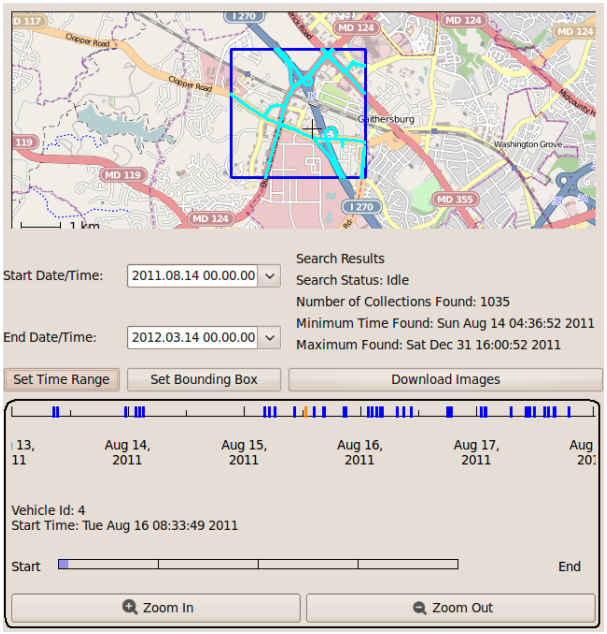

Figure 7: RR-Flashback Database Viewer map interface. The results of the database query are plotted both on a map and on a timeline.

REFERENCES

[1] "DARPA seeks technology to radically improve dismounted squad situational awareness, communication effectiveness." (2013, May 15). *DARPA Information* [Online]. Available: http://www.darpa.mil/NewsEvents/Releases/2013/05/15.aspx

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