Situational Awareness and Visual Analytics for Emergency Response and Training

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Abstract—Many emergency response units are currently faced with restrictive budgets which prohibit their use of technology both in training and in real-world situations. Our work focuses on creating an affordable, mobile, state-of-the-art emergency response test-bed through the integration of low-cost, commercially available products. We have developed a command, control, communications, surveillance and reconnaissance system that will allow small-unit exercises to be tracked and recorded for evaluation purposes. Our system can be used for military and first responder training providing the nexus for decision making through the use of computational models, advanced technology, situational awareness and command and control. During a training session, data is streamed back to a central repository allowing commanders to evaluate their squads in a live action setting and assess their effectiveness in an after-action review. In order to effectively analyze this data, an interactive visualization system has been designed in which commanders can track personnel movement, view surveillance feeds, listen to radio traffic, and fast-forward/rewind event sequences. This system provides both 2-D and 3-D views of the environment while showing previously traveled paths, responder orientation and activity level. Both stationary and personnel-worn mobile camera video feeds may be displayed, as well as the associated radio traffic.

I. INTRODUCTION

Most large-scale emergency operation center systems and tools are designed only to coordinate support and provide basic information for first responders and decision makers during a disaster. The next generation of systems needs to be a true visual analytics environment that supports planning, prediction, detection, mitigation, monitoring, and crisis management. This comprehensive environment requires integrated visual and traditional systematic analysis of massive data, including improved strategies for exploratory visual analysis, hypothesis testing and user-specific presentation of relevant information as a basis for actionable decision making. To this end, we have developed a new system incorporating the principles of visual analytics into a command and control environment for enhanced situational awareness.

Visual analytics is defined as the science of analytical reasoning facilitated by interactive visual interfaces [1]. Our work facilitates the visual analytics framework by providing a command and control environment from which first responders may analyze real-time training scenarios and provide interactive feedback to participants. Our work integrates data from multiple sources into a seamless environment for tracking in-field personnel in an urban environment. Furthermore, this work needs to be available on displays with varying modalities to allow operatives both in the field and at the command center access to relevant data.

As such, this work employs the use of both desktop PCs and mobile devices such as PDAs and cell-phones. Images of our application running on mobile devices can be seen in Figure 1. Currently, our work has focused on emergency response training in our local testbed facility. Our testbed consists of integrated video (stationary and active) surveillance and GPS to GPS-denied tracking. Our most recent training session consisted of an active shooter in a school scenario. In this scenario, our deployed visual analytics tool was used to direct participants in the scenario, as well as provide feedback during after-action review.

Fig. 1. Our system running on mobile devices: Smartphone (left) OQO 02 device (right).

II. RELATED WORK

The primary thrust of this work is to create visual analytics tools for the enhancement of situational awareness. As such, relevant related work can be classified into two areas: visualization of sensor data and visual analytics on mobile devices.

A. Visualization of sensor data

In monitoring first responders for in-field training scenarios and real-world incidents, timely and accurate visualization of sensor data is a crucial component of situational awareness. Fan and Biagioni [2] described approaches to process and
interpret data gathered by sensor networks for geographic information systems. These approaches combine database management technology, geographic information systems, web development technology, and human computer interactive design to visualize the data gathered by wireless sensor networks. Koo et al. [3] designed software to analyze multi-sensor data for pipeline inspection of gas transmission. The information gathered by sensors is parsed and converted before it is saved in a database. Gunnarsson et al. [4] introduced a mobile augmented reality prototype for visual inspection of hidden structures on mobile devices using data collected from a mobile wireless sensor network. Pattath et al. [5] implemented an interactive visual analytic system to visualize sensor network data on PDAs.

B. Visual analytics on mobile devices

While the visualization of sensor data is a crucial component, our work specifically focuses on the presentation and analysis of data on handheld devices. Such an application is different from visual analytics on common desktop systems because of the restricted display space and computing resources of mobile devices. Furthermore, we also focus on simplified views for enhanced situational awareness. While much work on visualization on mobile devices has focused on 3D rendering, 2D graphics and visualization can be just as efficient in the case of information visualization. In fact, there are many applications that utilize 2D capabilities of mobile devices in fields such as geographic information systems [6], [7], entertainment, education, business, and industry. Moreover, OpenVG [8] and Mobile 2D Graphics (M2G) are boosting the development of 2D applications that are scalable across any screen size.

Further work on visualization on mobile devices extends their capabilities from a visualization tool to a visual analytics tool. Sanfilipa et al. [9] introduced InfoStar [10], an adaptive visual analytics platform for mobile devices. Their work was demonstrated at Super Computing 2004 (SC2004) providing information such as maps, schedules, exhibitor lists, and visual exploration tools to conference attendees. Similarly, the work by Pattath et al. [5] provided a visual analytic tool for the visualization of network and sensor data gathered from Purdue Ross-Ade Stadium during football games. Finally, Herrero et al. [11] presented an intrusion detection system for visual analysis of high-volume network traffic data streams on mobile devices.

III. SYSTEM DESIGN

Figure 2 shows the abstraction of our system structure. Our system integrates commodity hardware products into a real-time tracking and surveillance module for use in emergency response training. We primarily focus on the utilization of various types of datasets such as images/videos, 3D models, sensor data, and radio traffic. Wearable components in the system were chosen based on factors of weight, size and cost in order to accommodate first responders in the field.

An initial visual analytics system was designed for a command center position in which the training evaluator, or dispatcher, could track personnel in the field. This initial tool was then ported to a mobile application and tailored for the use of in-field personnel. This conversion involved determining the appropriate representation of the data for rapid, in-field cognition on a small-screen mobile device. The data created for desktop systems could not be used for mobile devices without further preprocessing because of the limits of mobile devices in terms of memory, bandwidth, and screen resolution.

Our mobile visual analytics tool consists of a 2D/3D visualization component which shows personnel-related information, situational and static scene-related information, integrated multi-media playback functionality for personnel outfitted with cameras, and fast-forward/rewind capability for reviewing events.
C. Database

Both the tracking and video data are stored in a database to provide for after-action review of a training session. Challenges addressed include retrieving and storing session data client-side while maintaining interactivity, effective utilization of network bandwidth, and the real-time reconstruction of continuous-time activity from discrete stored events. All video and position information is temporarily stored locally on the participant’s wearable computer. In the event of network loss, information is pushed to the database once a network connection is re-established. All information is stored on the wearable computer, which can hold over two hours worth of session data.

Prior to each session, personnel are assigned equipment, and the database must capture this relational information. Figure 3 shows a screenshot of the entity relationship interface. Here we show the initialization of a session. The upper left box shows all previously created sessions. An event coordinator can go back and modify entity relationships in a previously recorded session if mistakes occur. Participants’ names are entered into the database and found in the middle box on the screen. Known equipment and past participants are already populated into the list of choices so that the event coordinator can quickly assign agents to their given devices, or add new agents and equipment as necessary. Stationary camera positions can be assigned at each session, allowing users of our facility to modify the setup for their specific needs.

D. Visual Analytics

Once a session begins, the database pulls and stores all data from both the sensor networks and video networks. Our visual analytics tool pulls data directly from the tracking and video components to prevent data delays, and displays this data on the corresponding 2D or 3D model of the building. In after-action review, all data is pulled from the database.

The display capability has been tailored to the responders and their roles, and provides a succinct, quickly understood summary of relevant information extracted from all information acquired. System capabilities include the rewinding and fast-forwarding of a session, model displays in both a 2D and 3D environment, path tracking of multiple agents, and camera view selection.

Figure 4 (Left) shows the initial screen for the visual analytics software. Users may pick from any previously recorded session for playback. If there is an active session currently running, that sessions name will appear at the top of the list as assigned from the interface shown in Figure 3. Note the control bar on the left. Users have the option of playing the radio traffic associated with the session. Agent movement can be fast forward or rewind. The ‘+’ and ‘-’ buttons can be used to speed up or slow down the rate of play; however, the associated video playback is currently limited to 1x speed.

In Figure 4 (Middle) we show the normal viewing mode of our interface. Users can see a 2D overview of a building floorplan. Agents are shown as either circles or directional arrowheads (when directional information is available). The third shape represents the position of all stationary cameras within the building. Also visible is a colored line trailing behind each agent’s glyph. This line represents the path traveled by the agent, helping commanders better assess the movements of their agents.

In Figure 4 (Right) we show the 3D viewing mode of our interface. Depending on the level of detail of the building model, texture information could be displayed as well as relevant height information, providing commanders with more details on their surroundings. Again in the 3D mode, the agent’s previously traveled path can also be seen.

Video traffic associated with the stationary cameras and headmounted displays on the agents can be retrieved by left-clicking on an agent’s glyph. The video may be turned off by again clicking on the glyph. If the user chooses to fast forward or rewind in the program, the open videos will also rewind to the associated points. All video, radio and tracking data are time synched for proper playback.

IV. FIRST RESPONDER CASE STUDY

Currently, our system is deployed at a decommissioned local elementary school near Purdue University. The floorplan can be seen in Figure 5. To assess the capabilities of our system, we have conducted a live shooter in the school scenario in which a group of personnel were instructed to search the building.

Each member of the response team was outfitted as seen in Figure 6. Each member is given a head-mounted camera, two tracking tags, one positioned on the head, and GPS tag positioned on the fanny pack. The fanny pack at the waist consists of the portable OQO 02 device that is used for video-processing and recording as well as for mobile visualization, see Figure 1 (Right). Figure 7 shows a screen capture of a live session. Here we show multiple video displays from both mobile and stationary cameras.
Fig. 4. From left to right: session selection (Left), agents path being tracked in a 2D model (Middle), 3D view (Right).

Fig. 5. Floorplan of our training area.

V. CONCLUSION

This work demonstrates the applicability of a mobile visual analytics system in a command and control environment. We have successfully utilized low-cost components in the creation of a real-time tracking and video surveillance network. Our visual analytics tools could be ported to other areas where asset monitoring through location and video is necessary. In the future, we plan to extend this work, modifying our tracking system for quick deployment in areas where no pre-existing wireless network structures exist. We also plan to implement video tracking algorithms that will send alerts to our visual analytics system when an entity (known or unknown) enters the cameras viewing area, as well as add wearable system components that will monitor the health status of first responders.

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REFERENCES


