Data Fusion in Disaster Response

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1 Introduction

Imagine a gourmet chef preparing a steak. To be successful, she must be acutely aware of every aspect of the cut, including its color, feel, smell, and even the sound it makes while it sizzles. Her brain receives messages about these individual attributes from her sensory organs, but the combined understanding of all this information at once is what enables her to determine when the steak is done.

This is the idea behind data fusion; information from multiple sources can be leveraged to provide novel insights greater than the sum of their parts. Through the UAV Autonomous Control Search and Rescue project for Tufts University, Team Mahogany is using data fusion methods to provide disaster responders with the tools they need to rapidly and effectively assess unfamiliar and dangerous situations.

2 Background

2.1 Past Applications

Multisensor data fusion has been employed in a variety of spaces over the last few decades. In its infancy, it was primarily utilized for threat detection, vehicle guidance systems, and other military purposes [1]. In recent years, however, rapid advances in sensing technology, computation power, and digital signal processing have made this technique more accessible and relevant in other applications, such as facial recognition, security systems, and computer vision [4].

A 2011 survey of the state of intelligent transportation system technology identified that data fusion is helping to address a variety of challenges in that area, including advanced driver assistance, automatic incident detection, and traffic forecasting [7]. This has implications for driverless cars, smart traffic control systems, and adaptive transportation networks. Our team seeks to apply the same methods on a smaller, simpler scale to enable rapid, informed decisions in the context of disaster response.

2.2 Previous Work

In Tufts' own Simulation Research Laboratory, Dr. Karen Panetta's team designs detection and recognition systems, with a focus on humanitarian work. These endeavors rely on image processing methods such as edge detection and color correction, as well as data fusion. A 2012 effort produced a novel algorithm to fuse images for contextual enhancement [8]. More recent work includes detection algorithms for facial or object recognition systems and advanced image enhancement techniques.

In support of the Lab, Senior Capstone Project Team Mahogany developed a portable data collection and transmission system for disaster responders. This project incorporates GPS, visual, and radiation data, with the critical challenge of presenting the images and readings gathered effectively and concisely to the user. By investing in such a solution, the Lab is expanding its scope of expertise on data fusion technology and initiating the exploration of new applications for its cutting-edge detection and recognition algorithms.

3 Project

3.1 Implementation

The data collection system, including a camera, radiation detection system, and GPS chip is attached to an autonomous vehicle, such as a UAV. The information gathered by the sensors is transmitted via radio to a laptop running the data processing and user interface software.

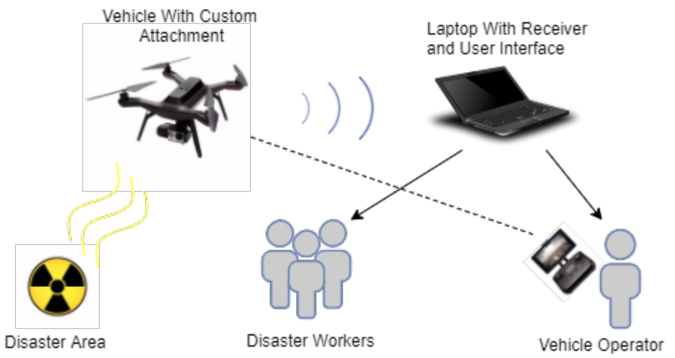

Figure 1: Top-Level System Diagram

The UI incorporates the transmitted data to generate a map of the scene. The location is determined by the GPS coordinates, and the hazard level is determined by the radiation measurement in counts per minute (CPM). The UI also leverages street map tiles in tandem with the collected images to provide context for the GPS and CPM readings.

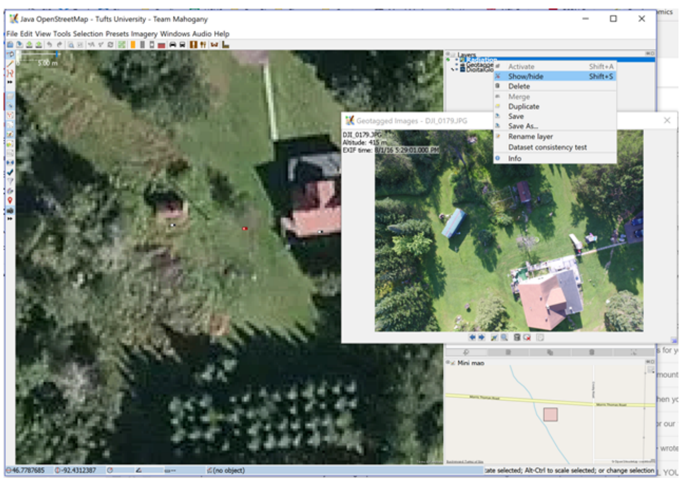

Figure 2: User Interface

3.2 Challenges

To effectively employ data fusion methods, one must first obtain the data. Spurious, imperfect or missing information can negatively impact the model in a variety of ways. For example, a simple connectivity problem can cause packet loss, which translates to holes in the map. A potentially more severe problem occurs in radiation measurement. Post processing cannot rectify an inaccurate reading on the radiation detection module, so it is critical that care is taken when collecting the data. Otherwise, the UI could identify a potentially dangerous area as safe.

4 Future Work

4.1 Disaster Response

This project barely scratches the surface of how data fusion technology can improve the effectiveness of disaster response teams. Even without upgrading the sensor capability of the data collection system, the UI could better visualize the scene by intelligently "stitching" together collected images. This improvement could be accomplished through feature-based image registration, much like the panorama setting on a smartphone camera. This works by first detecting features such as edges, contours, line intersections, and corners to establish Control Points. Images with similar features are matched and transformed for alignment, with the goal of minimizing the differences in overlapping pixels [9].

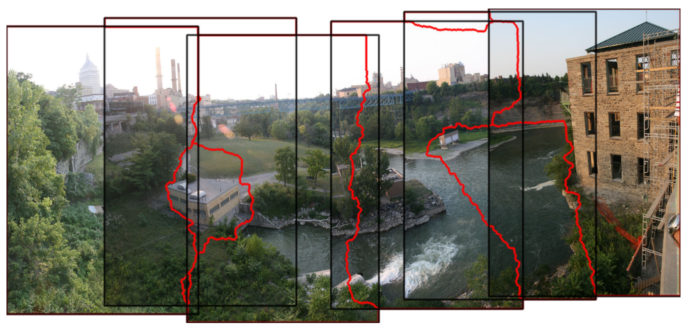

Figure 3: Feature-Based Image Registration
(https://en.wikipedia.org/wiki/Image_stitching)

Of course, to really extend the capability of data fusion in this context, we simply have to collect more data. A thermal camera in the data collection system could enable more interesting features, such as the ability to automatically highlight targets of interest such as survivors. A 2004 effort improved facial recognition capability by fusing visual and thermal data [2]. Similar techniques could be used in conjunction with the Lab's state-of-the-art detection and recognition algorithms to provide a more attractive and feature-rich solution.

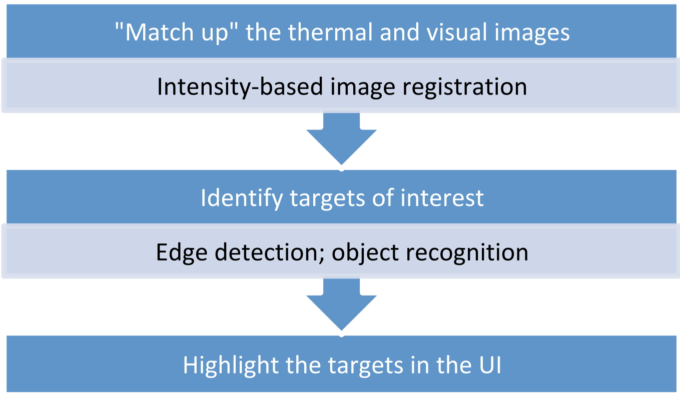

Figure 4: Process Description to Incorporate Thermal Data

4.2 Other Applications

Beyond disaster response, multisensor data fusion is becoming more and more relevant in a wide range of applications, including industrial control, autonomous robotics, and military tracking [6]. The recent explosion in the field of machine learning, coupled with advanced data fusion techniques, inspires and enables new, intelligent systems with the potential to transform the human-computer interface.

5 Conclusion

In support of the UAV Autonomous Control Search and Rescue Project for Tufts University, Team Mahogany developed a data collection and delivery system for disaster responders. This project utilized data fusion methods to produce an informative, real-time visualization of the scene. More advanced algorithms can be used in the future to extend recognition capability, provided accurate sensing systems and reliable networks.

6 References

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