Smart and Connected Firefighting System Design

Aura Rose Jensen-Curtis, Vinh Nguyen, Manish Bhattarai, Ramiro Jordan, Manel Martinez Ramon
Department of Electrical and Computer Engineering,
University of New Mexico

Abstract

Firefighting is a dynamic activity, in which numerous operations occur simultaneously. Maintaining situational awareness (i.e., knowledge of current conditions and activities at the scene) is critical to the accurate decision-making necessary for a firefighter's safe and successful navigation of a fire environment. Conversely, the disorientation caused by hazards such as smoke and extreme heat can lead to injury or even fatality. The firefighter's life and the lives of those needing rescue are reliant on accurate decisions during scene navigation. Advancements in technology can now assist and improve this decision-making process.

Firefighters often carry various sensors in their personal equipment, such as infrared cameras, gas sensors, and microphones, and improved data processing techniques can mine this data more effectively. The aim of this research is to design and build an embedded platform that can process the captured thermal imagery and return that processed information via wireless streaming. This platform will deploy already developed deep learning models that analyze the input data in real time. These algorithms effectively exploit the images gathered from the infrared camera by using a trained deep Convolutional Neural Network (CNN) system to identify, classify, and track objects of interest. Furthermore, the system is capable of performing human recognition and posture detection to deduce a victim's condition and guide firefighters accordingly, which can assist in prioritizing victims by urgency. Processed information is relayed back to the firefighter via an augmented reality platform that enables them to visualize the results of the analyzed inputs and draws their attention to objects of interest, such as doors and windows otherwise invisible through smoke and flames. This visualization also provides localized information related to those objects.

Project Overview

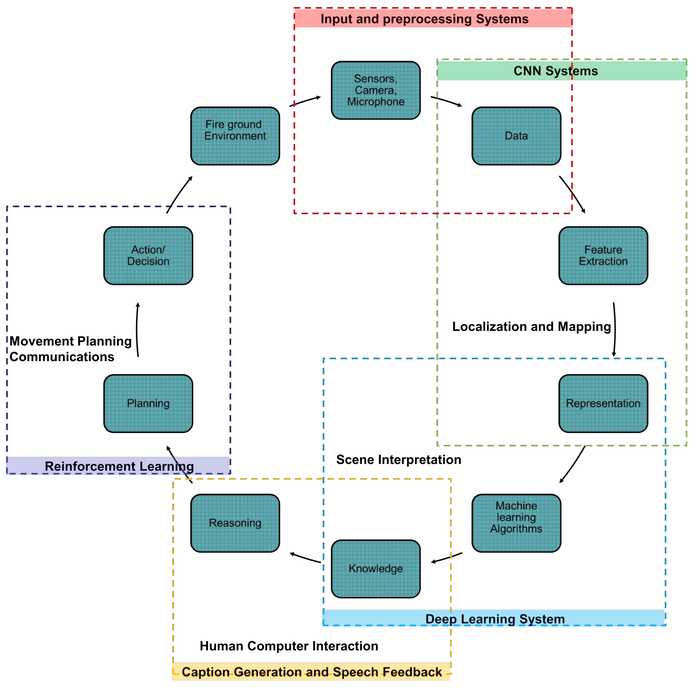
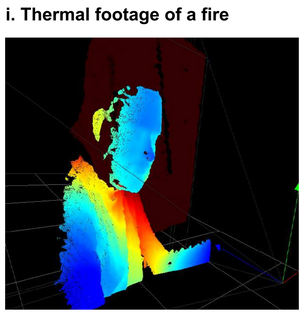


Figure 1. Overview of Embedded System Integrated into Smart and Connected Firefighting System.

Datasets

i. Thermal footage of a fire

ii. Thermal footage of a firefighter exiting through a window



iii. Depth map of a human subject

iii. Point cloud of a person in a room

Figure 2. Different types of datasets acquired by multiple cameras. Footage corresponding to i and ii are acquired by the FLIR One, whereas iii and iv are acquired by the Intel RealSense camera

System Architecture

Embedded System Overview

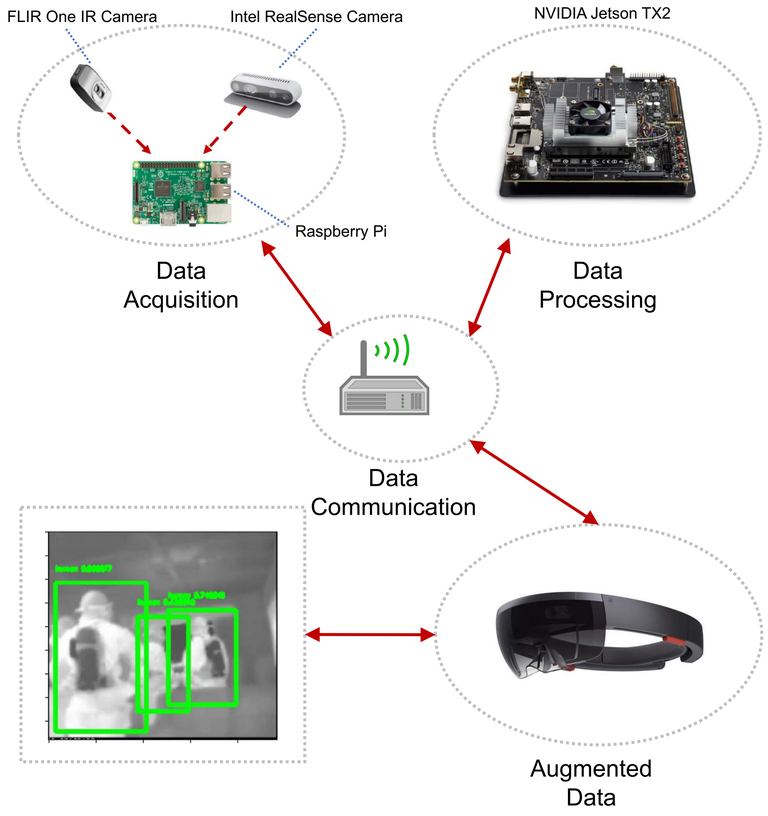


Figure 3. System Overview Showing Interactions between Components

System Deployment

Figure 4. Illustration of System Deployed as Part of a Firefighter's Gear The embedded system is demonstrated as part of the firefighter's integrated gear.

System Description

Data Acquisition

Data is acquired using live recordings of thermal, RGB, and depth datasets with FLIR imaging and Intel Real Sense Cameras. The cameras are mounted on the firefighter's helmet to provide real-time imaging

Data Communication

Using a Raspberry Pi, the dataset is communicated wirelessly across devices through a secured Wi-Fi Network. The wireless feed carries the data from the sensors to the embedded computation board for processing, and then carries the processed information to the HoloLens for the augmented information.

Data Processing with Deep Learning

Deep learning models are deployed into the Jetson TX2 to process the camera-acquired dataset received from the Raspberry Pi. The information processed is object detection, object tracking, instance segmentation, and scene description.

Information Augmentation

The processed information is relayed back to the HoloLens to augment the firefighters vision and improve their situational awareness.

Results

Object detection and Tracking

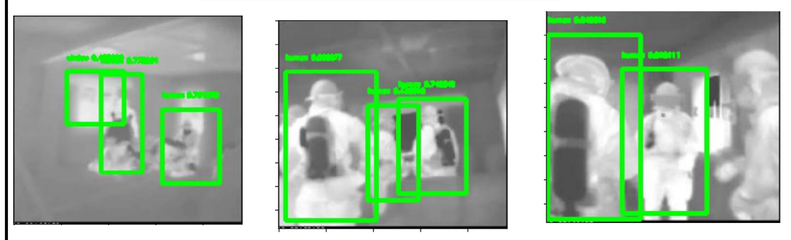


Figure 5. Demonstration of object detection and tracking implemented with Faster RCNN. The green boxes bind the object of interest. The label on top infers corresponding object and detection probability. Selected objects of interest include firefighters and civilians, doors, windows, and ladders.

Object instance Segmentation

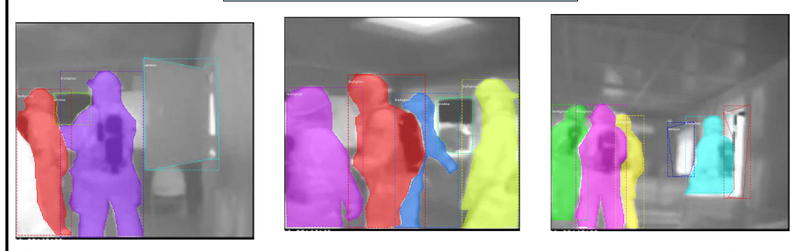


Figure 6. Demonstration of object instance segmentation implemented with Mask RCNN. Every instance of significant object is enclosed with different mask . The instances for firefighter are shaded with distinct colors. Doors and windows are shaded with instance boundaries. This information will be used to define states for reinforcement learning in path planning and navigation.

Scene Description

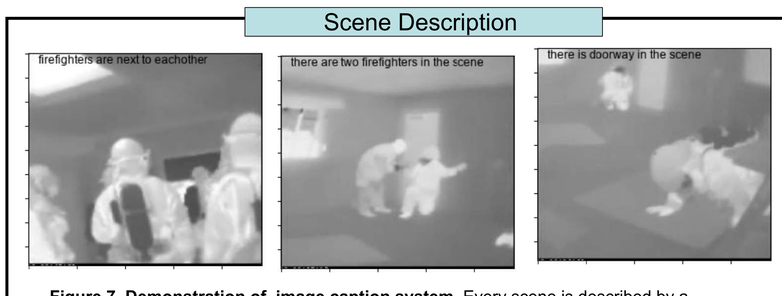


Figure 7. Demonstration of image caption system. Every scene is described by a relevant sentence as shown in the images.

Scene Reconstruction (Work In progress)

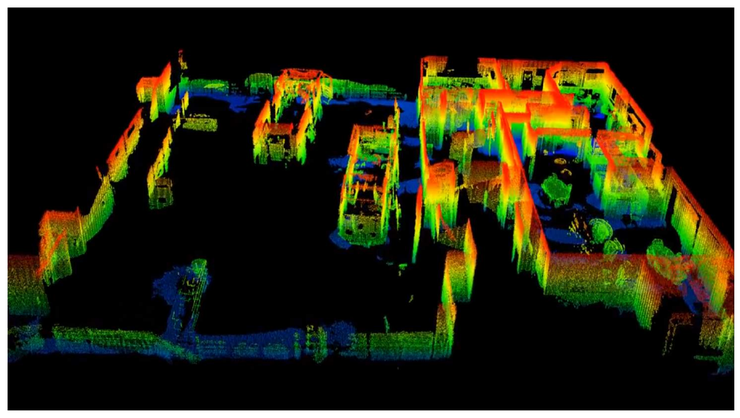


Figure 8. Reconstruction of a room based on point cloud dataset and infrared dataset.

Conclusion and Future Work

We have created an automated system that is capable of real-time object detection and recognition using data gathered on site. The algorithms developed by our team are able to provide detailed analyses of the surroundings. The improvements made to the firefighter's ability to maintain a constant and consistent situational awareness also greatly improves their ability to correctly interpret surroundings, maximizing rescue efficiency and effectiveness.

Our next steps will focus on fusing the data collected from different cameras to form a 3D map of the building. The data will form the foundation of a new AI system that assists the firefighters with path planning through cataloging of doors, windows, and paths clear of fire.

ACKNOWLEDGEMENT AND REFERENCES:

This work was funded by NSF grant 1637092. *We would like to thank the UNM Center for Advanced Research Computing, supported in part by the National Science Foundation, for providing the {high performance computing, large-scale storage, visualization} resources used in this work.*

1) He, Kaiming, et al. "Mask r-cnn." *Computer Vision (ICCV), 2017 IEEE International Conference on*. IEEE, 2017.
2) Ren, Shaoqing, et al. "Faster r-cnn: Towards real-time object detection with region proposal networks." *Advances in neural information processing systems*. 2015.
3) Xu, Kelvin, et al. "Show, attend and tell: Neural image caption generation with visual attention." *International conference on machine learning*. 2015.
4) Mnih, Volodymyr, et al. "Human-level control through deep reinforcement learning." *Nature* 518.7540 (2015): 529.
5) Shah, Shital, et al. "Airsim: High-fidelity visual and physical simulation for autonomous vehicles." *Field and service robotics*. Springer, Cham, 2018.