See through Smoke: Real-time Scene Perception and Navigation on Smart Firefighter Helmet

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I. Introduction

Firefighting is still one of the most dangerous jobs. Due to the smoke and darkness in a fireground, firefighters often experience severe visual degradation and face extreme difficulty to understand the environment, locate victims and navigate themselves. For efficient and safe firefighting under visual degradation, we designed a prototype of a firefighter helmet equipped with emerging miniaturised sensors such as Longwave Infrared (LWIR) thermal cameras and mmWave radars, to realize robust sensing in extreme dark or smoke-filled environments. The design and sensor layout can be seen in Fig. 1 (a). Furthermore, effective embedded AI algorithms are proposed and deployed to allow our helmet to perform two essential tasks and drastically reduce the cognitive load of firefighters.

The helmet's first task is navigation which helps firefighters localise themselves in unfamiliar environments. The second is scene perception including human detection and pose estimation, to help firefighters recognize victims and their actions. All the computation can be real-time on an embedded system with a power-efficient, lightweight and compact form factor.

II. Methods and Results

Our proposed real-time scene perception system uses a thermal camera and low-cost mmWave radar coupled with several deep neural network models to accurately and robustly sense humans, including human detection, human pose estimation, and human activity recognition. The model fuses radar measurements and thermal images and features a YOLO-based [1] human detection network and GCN-based [2] activity recognition network.

Fig. 1 (b) shows our detection network fusing thermal images and mmWave radar point clouds to output the location and distance of humans under challenging visual degradation. Fig. 1 (c) shows lab testbed data examples and corresponding human pose estimation results.

Our navigation algorithm on the helmet leverages measurements from multiple mmWave radars and an IMU. The computation for the helmet runs an implementation of our milliEgo [3] algorithm in real-time and outputs a 6-degree-of-freedom movement trajectory of the helmet that can help locate the firefighters.

Fig. 1 (d) showcases the real-time navigation results in smoke-filled fire simulation at the Scottish Fire and Rescue Service (SFRS) training facility. In the test, two firefighters are exploring the building, with the trailing firefighter wearing our helmet.

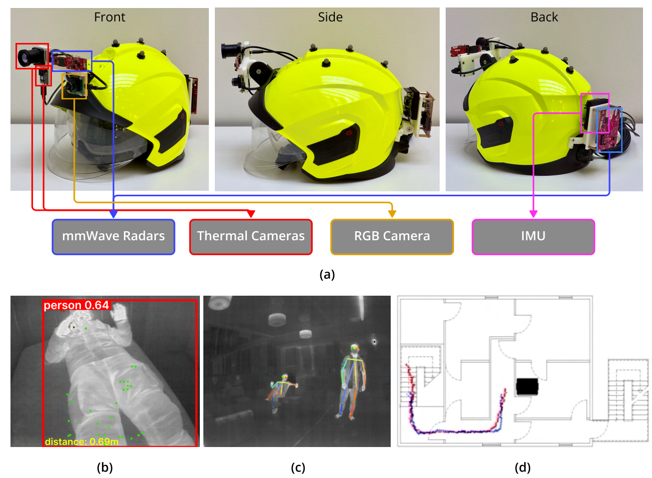

Fig. 1: (a) The design of our smart helmet platform with annotations of sensors. (b) Human detection and (d) navigaion trajectory results in smoke-filled firefighting drill environments. (c) Human pose estimation results in lab environments.

III. Conclusion

In conclusion, we designed a prototype of a smart firefighter helmet that performs scene perception and navigation tasks in visual-degraded environments. The helmet aims to aid firefighters in performing life-saving tasks in real firegrounds safely and efficiently. We have tested the helmet in smoke-filled fire simulations and generated satisfactory results in human detection, human pose estimation and real-time navigation.

References

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