A Drone-based Automatic Indoor Firefighting System

Department of Electrical and Computer Engineering, Lafayette College
Khaknazar Shyntassov, Prof. Jon Wallace, Prof. Yih-Choung Yu

Abstract

The ongoing rise of residential fire cases and associated property damage suggests the ineffectiveness of current firefighting solutions. This research proposes an unmanned aerial vehicle (UAV) based firefighting system that detects and locates the indoor fire ignition source and extinguishes it instantly using a small drone. A method is developed that consists of the following steps: 1) fire detection using video-based machine learning methods, 2) fire localization using stereoscopic vision, and 3) automated navigation of the drone from its base station to the fire using pre-stored paths combined with the detected fire location. Two object detection algorithms are compared (Haar cascade and YOLOv3) and the most effective one is further assessed for the detection of indoor fires. Methods for extinguishing a fire from a drone are discussed. The efficiency of the proposed method is evaluated through experiments with a DJI Tello drone.

Background

- In recent years, annual reports, released by the U.S. Fire Administration, show that residential fire statistics keep hitting new anti-records [1].
- The number of federal drone flights for outdoor firefighting purposes has grown exponentially in the span of eight years, underscoring their benefits in providing safety and accurate information to firefighters [2].

- These drone-based systems help firefighters on the ground to identify wildfire affected areas by recording video from cameras equipped with thermal-infrared sensors or even extinguish the fires.

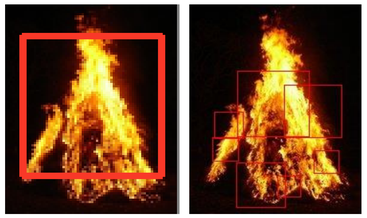
System's operating principle

Fire | Stereo camera detects and locates the fire | Drone moves to the fire and extinguishes it

System description

A. Fire detection algorithm

- Two machine learning approaches were compared: the Haar cascade classifier method and the YOLOv3 object detection algorithm.
- Intersection over union (IoU) metric has shown that YOLOv3 algorithm is more effective than Haar method in fire detection.



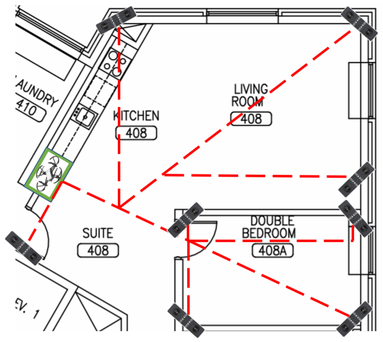
YOLOv3 output HAAR output

- Unlike YOLOv3 algorithm, the Haar cascade method provides a segmented detection result having multiple bounding boxes (see figure on the left).

B. Fire location algorithm

- Existing approach [3] of using stereoscopic cameras to identify distance was implemented and further developed to calculate projected distance and azimuth angle between camera and fire.
- Both distance and angle were calculated based on coordinates of the left and right bounding boxes generated by the fire detection algorithm.

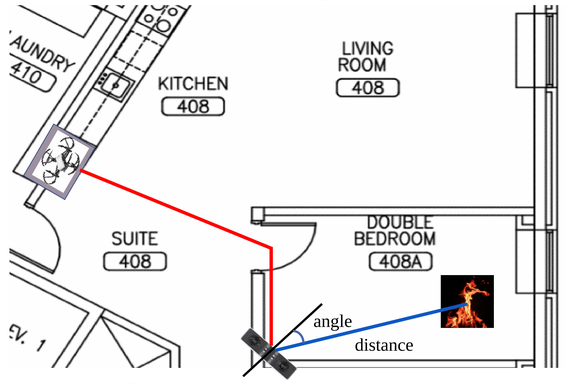
C. Drone control



- Drone's path consists of 2 paths: established path (that runs from the base station to the camera) and dependent path (that runs from the camera to the fire).
- Drone moves according to the established path based on the stereo camera's location.
- Fire location algorithm sends distance and angle measurements to the drone, which, in turn, moves to a target point and extinguishes the fire, using DJI Tello Python library's commands.
- Possible configuration of stereo cameras in the testing residence, as well as established paths, are shown as red dashed lines on the figure above.

Results

- Overall average response time of the system is **2 minutes and 20 seconds**. This time includes 1 minute and 3 seconds for fire detection and localization and 1 minute and 17 seconds for the drone's movement to the detected fire.
- During testing it was noticed that even though the fire's location was usually determined accurately, the drone missed the target by about **5-10 cm** and **1-3 degrees** in low lighting conditions
- The use of two paths instead of a single direct path means a waste of time and the drone's battery. We expect that developing direct navigation algorithms would further reduce response time of the drone-based system.



Testing location's plan.
Red line: established path. Blue line: dependent path

Discussion and Future Work

Importance

- Less water damage compared to water sprinkling systems.
- Especially efficient in houses that are remotely located, where firefighters need longer time to respond.
- Drone extinguishes small flames without turning into major fire.

Improvements

- Our system currently is limited to areas without any obstacles. More advanced home automation systems coupled with object avoidance algorithms could overcome these issues.
- The system is unable to distinguish between real fire and pictures of fire. IR and smoke sensors could be employed to improve detection robustness and ensure that only real fires are detected.
- To ensure drone's safety, we plan to incorporate IR sensors on a drone to identify dangerous areas impacted by fire and avoid them.

References

[1] "Residential Building Fire Trends (2009-2018)," National Fire Data Center, Mar. 2020. [Online]. Available: https://www.usfa.fema.gov/downloads/pdf/statistics/res_bldg_fire_estimates.pdf.
[2] A. L. D. / News21, "Drones equipped with infrared cameras monitor wildfires across the West," *Cronkite News - Arizona PBS*, Jul. 19, 2019. https://cronkitenews.azpbs.org/2019/07/19/wildfire-drones.
[3] J. Mrovlje and D. Vrančić, "Distance measuring based on stereoscopic pictures," in *9th International PhD Workshop on Systems and Control: Young Generation Viewpoint*, Izola, Slovenia, Oct. 2008, pp. 1–6.