A Camera-Based Automatic Wildfire Detection and Monitoring System

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BACKGROUND
Wildfires burned over 4 million acres during 2020 in California alone, obliterating communities and devastating families [1]. Due to climate change and more frequent droughts these fires are occurring in exponentially more areas, requiring more robust fire detection methods than anytime before. Current monitoring systems use numerous cameras to look over large areas of land, such as AlertWildfire [2], but these cameras are mainly used to observe fires currently in progress, rather than proactively search for fires at all times. This lack of constant monitoring leaves the door open for developing automatic detection methods.

WILDFIRE DETECTION AND MONITORING SYSTEM
System Design: The monitoring system consists of multiple devices distributed over large areas and connected to a central web server. Each device is housed in a weatherproof enclosure with a camera that can rotate panoramically to take pictures and monitor its surroundings. A microcomputer running an artificial intelligence algorithm automatically detects fires if they present in the pictures. After processing, fire images are uploaded to a database and web server, where the images are able to be reviewed by users and monitoring personnel.

Machine Learning: For the artificial intelligence algorithm, we chose YOLOv5s (You Only Look Once) due to its high accuracy and efficiency based on our previous research [3]. We created a dataset based on a fire-smoke detection dataset [4] and a landscape dataset [5]. A Python program was used to randomly select 2000 fire images and 2000 non-fire/landscape images for training, and 200 fire images and 200 non-fire/landscape images for validation. We trained the network and validated the model. The validation images were then processed by the detector. Based on how many fires and non-fires the detector correctly labeled, the F1-score which is a measure of an algorithm’s accuracy for a dataset was calculated. An F1-score of 1 means that all fires and non-fires were correctly identified. Fig. 2 shows the F1-score of the trained model running on a microcomputer (Raspberry Pi 4). The score reached a peak of 0.928.

EXPERIMENT RESULTS
The real-world experiment of the system started with the detection of controlled fires. The system was first put at 5 feet from a fire source. In this setting, the fire takes up about 14% of the total area of the image taken. 10 pictures were automatically captured in a sequence by the system. Then we moved the camera back to 15 feet where the fire takes up about 2.8% of the total area of the image and another 10 pictures were taken. We repeated this process until the system was 65 feet away from the fire source. The experiment has been conducted in both lowlight and nighttime conditions. Fig. 5 is an example of the detection results of one of the images captured during the test. The green annotation boxes were marked by the detector and show the locations of the detected fires.

CONCLUSION
Our research and tests prove that artificial intelligence used in automatic wildfire detection systems is certainly possible in real-world situations. The system design can be scaled to a large amount of distributed systems to survey a very large scale of landscapes. This system of proactive monitoring will improve our ecological sustainability by finding fires more quickly before they have a chance to devastate local communities and contribute more to global warming, which would continue this destructive cycle of fires.

FUTURE WORK
With these first prototypes developed, the next steps would be a refinement of the current systems and preparation for scaling the system to include many more devices. Further field tests should also be done to check the viability of this device with fires at much larger distances.

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References