

Drone Based Fire Detection System Based on Convolutional Neural Network

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Abstract: Open fires are happening more and more throughout Malaysia. It is either intentional or accidental fire. The most dangerous is an accidental fire because it may not be detected by anyone until it becomes large. Detecting a fire is not an easy task. People may not see an ongoing fire because it may be too far away, or the fire may be too small. The objective of this project is to build a fire detection system. Fire detecting systems are developed to ensure more accurate fire detection. To ensure accurate fire detection, this project uses a waterfall methodology. This project uses drones as a tool to help with fire detection. Using a Convolutional Neural Network (CNN), this project implements the use of the PyTorch framework in detecting fires. The testing was done with a distance of 2 meters from the fire and a height of 2 meter from the ground. Edited images were used and uploaded to the system. Accuracy results of 80% can ensure accurate fire detection. To evaluate the system, edited fire images are used to ensure the accuracy of the system. Therefore, CNN is a good tool for detecting fires.

Keywords: Fire Detection System, Convolutional Neural Network, Drones, Image Processing, Waterfall Methodology.



1. Introduction

Fires can be considered safe when properly managed and handled with care. However, when a fire grows out of control and becomes unmanageable, it can no longer be classified as safe. Although dangerous, fire plays an important role in everyday life. It provides essential heat for survival and plays an important role in cooking food. For example, in areas like Siberia, extreme cold is a challenge, people rely on fire to keep themselves warm. Although fire carries risks, it serves as an important resource for human well-being when used responsibly.

Convolutional Neural Network (CNN) can detect deformations or abnormalities, and it can also be employed for detecting diseases in rice crops. A diseased leaf which has a different colour texture and dimension than a healthy rice leaf provides an opportunity to perform image analysis using a CNN network and to collect information on inconsistency among the pixels of the entire leaf [1]. This approach makes disease detection more accessible and efficient.

Drones have become increasingly useful across industries, from industrial applications to surveillance. Unmanned aircraft (UA), commonly known as drones, are aircraft without a human pilot on board [2]. The autonomous nature of drones eliminates the need for human presence during operations. It allows navigation to run more safely when in challenging or inaccessible environments. These aircraft have been known for their use in the military field, where they are used for intelligence, reconnaissance, and surveillance (ISR) [3]. This reinforces the claim that drones are the optimal choice for surveillance purposes.

Approaching an open flame is dangerous, and locating an open flame in the forest poses significant challenges. Early detection and rapid response by firefighters are essential to ensure that forest fires are quickly extinguished and cause minimal economic damage and loss of life [4]. A quick response can save many lives while minimizing the unnecessary spread of fire and helping to reduce fire-related losses and damage. Indoors is more prone to fire or even spreading, places where fires often occur in the house, such as sockets, wires, fireplaces, etc., are easily blocked by other objects, such as tables, chairs, and beds [5]. This helps in reducing possible losses.

Image processing involves analysis or manipulation. Digital image processing is the use of algorithms and mathematical models to process and analyze digital images [6]. The algorithm systematically examines all potential elements in the image to identify the presence of fire. After detecting a fire, a warning message is displayed on the system screen. This image processing is used in traffic management. Image processing techniques can be used to redirect traffic [7]. This significantly increases the speed of fire detection.

The idea of developing a firefighting system based on Convolutional Neural Networks using drones existed because, the most common cause of death in fire-related incidents is neurogenic shock, also known as burn shock respiratory complications, are also a major cause of early death, accounting for 34-45% of fire-related deaths, depending on the age of the person. Multi-organ failure is responsible for around 25% of all burn deaths, whilst sepsis accounts for around 14% [8]. Fire-related incidents will be minimized or potentially eliminated.

2. Literature Review

2.1. Drone

Drone is an unmanned aircraft (UA), commonly known as drones, are aircraft without human pilots aboard [2]. No human is needed to be physically in the drone for it to be piloted. As the nature of the drone to be small, there is no need of big space to store it. Surveillance is hard to be done if the area of coverage is huge. Search and rescue (SAR) have been a human-intensive task so far, but recent technological advancements can make it autonomous. Using drone surveillance with a recent computer vision technology can increase the number of humans saved at the time of disaster [4]. This shown the efficiency of using drone to do surveillance. Figure 1 shows the illustration schematic of UAV fire detection.

- Surveillance Drone

Surveillance drones find extensive application in military operations and search and rescue missions. They are particularly valued for their ability to accomplish high-speed, long-range tasks that often involve hazardous conditions, relieving humans of dangerous duties. Drones were first used by military forces. Therefore, the drone warfare concept is not new. For years, they were used to carry out reconnaissance, target infrastructure and attack people. The U.S. in particular has used

drones extensively to kill militants and destroy physical targets [9]. Utilizing drones in search and rescue operations significantly enhances the ability to locate and track victims, leading to faster and more effective rescue efforts. Search and rescue (SAR) have been a human-intensive task so far, but recent technological advancements can make it autonomous. Using drone surveillance with recent computer vision technology can increase the number of humans saved at the time of disaster [10]. Thus means, drone played a huge role in ensure safety of all humanity. Figure 2 shows the surveillance drone.

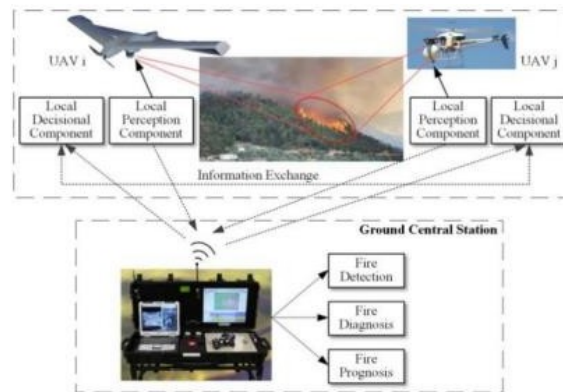


Figure 1. Schematic of UAV Fire Detection



Figure 2. Surveillance Drone

- Agriculture Drone

The vitality and sustainability of agriculture play a paramount role in providing the essential food sources for humanity, ensuring the continuity of life itself. Accurate soil data, which can be collected with agricultural sensors spaced at the half-variogram range, is crucial information for precision agriculture. Drones offer a unique advantage over other existing methods to sample data from soil sensors because of the high density of sensors required to gather spatially granular data to capture soil variability [11], Precision agriculture offers a pathway to increase crop yield while reducing water consumption, carbon footprint, and chemicals leaching into groundwater [11]. This means that drones could assist humans in ensuring consistent food production. Figure 3 shows the agriculture drone.



Figure 3. Agriculture Drone

2.2. Image Processing

In image processing applications, one often needs to detect the presence of a target at any position in an image. This is a combined detection or localization problem [12]. Image processing is used to either detect certain subject or to predict what is going to happen. Different techniques are used to satisfy certain task. For example, a landslide can be detected before it happens. The development and propagation of surface cracks are important indicators of future landslides [13].

- Object Detection

Object detection is a computer vision technique that allows to identify an image or a video. This technique will take each pixel of the image or video and process it. It uses Convolutional Neural Network (CNN) to identify and tell what the object is. These new events and activities have raised new challenges and issues, including uninhabitable crowd organizing and control. In such scenarios, it is important to ensure a high level of safety, management, and security which indeed requires careful study of the size of the crowds [14]. By this mean, an object detection can be used to detect a human to increase the security. So, for surveillance purposes, this technique can be used to detect any danger that eminent to happen. Figure 4 shows how the object detection work and Figure 5 shows how CNN and object detection work.

- Image Analysis

Image analysis works by extracting meaningful information from an image by involving processing an image into its own fundamental components. Each of the image will be process and be identified by using different degree of black and white shade to see the intensity of the fire and thickness of the smoke. Deep learning methods for image analysis are attracting increasing interest for application in a wide range of different research fields [15]. This means, image analysis could be used in many fields. Figure 6 shows image processing flowchart and Figure 7 shows the thickness of smoke.

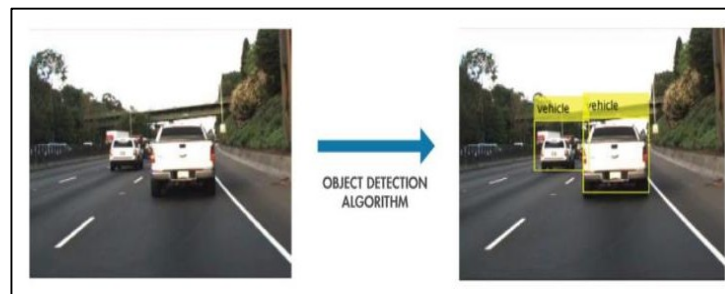


Figure 4. How Object Detection Work

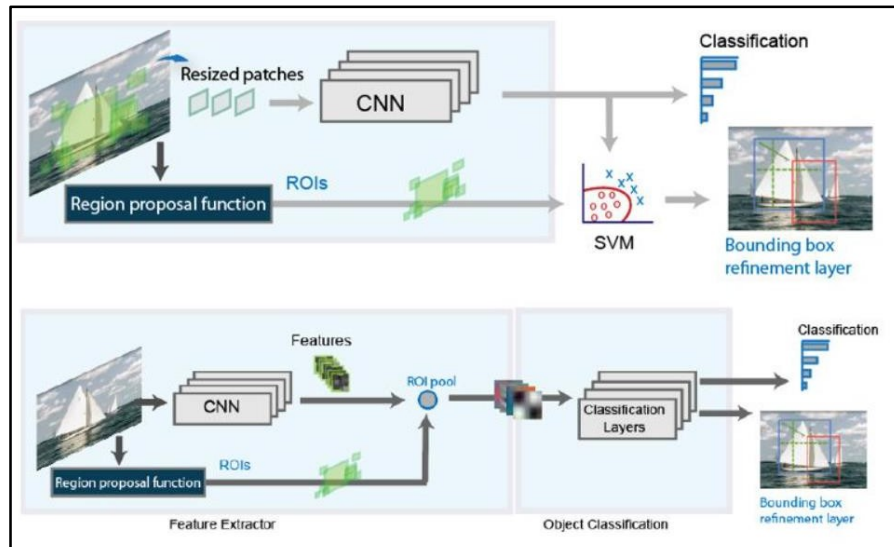


Figure 5. CNN and Object Detection Work

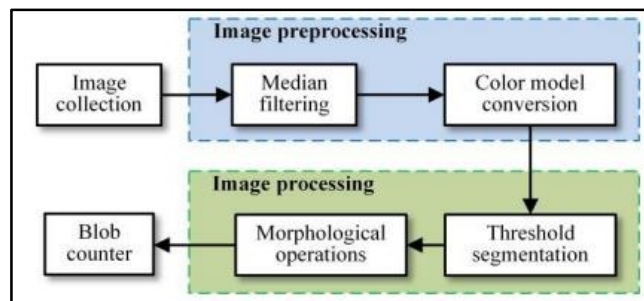


Figure 6. Image Processing Flowchart

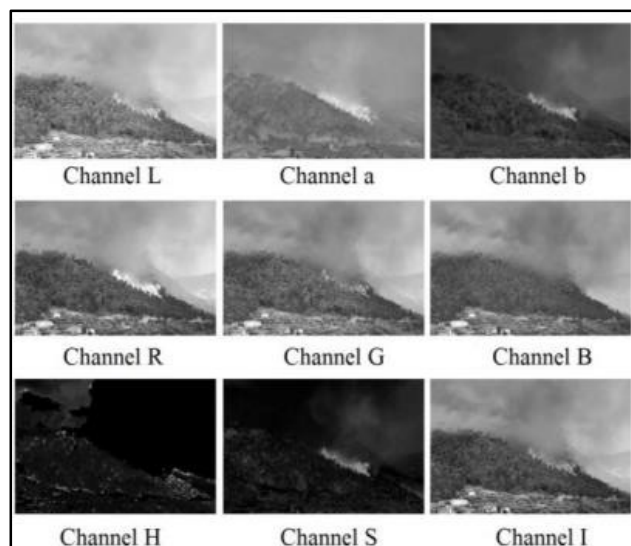


Figure 7. Thickness of the Smokes

By using image taken by the UAV, the position of the fire can be easily detected and predicted. The proposed strategy can successfully achieve the goals of fire detection and tracking based on the real-time images collected by UAV [16]. This means that image analysis works well with UAV. Figure 8 shows fire position detection.



Figure 8. Fire Position Detected

3. Methodology

3.1. System Design for drone-based fire detection system based on Convolutional Neural Network

This research uses drone, IR sensor and a camera. IR sensors were used in the early detection of fires. Then drone is used if fire is detected. An image was first uploaded to the system. Then, the system processes the image and then output the confidence score. If the system detects fire or smoke, the alert button is pressed. A warning message is sent to the user's phone.

3.2. System Development for fire detection system based on Convolutional Neural Network

The Waterfall model was deemed suitable for the research due to its clear and well- defined requirements, providing a structured approach particularly beneficial for lacking extensive experience. Many SDLC model good in a paper but practically it is not suited [17]. The Waterfall model was completed sequentially, adhering to five distinct phases: requirement analysis, design, implementation, testing, and maintenance. Each phase is well defined and sequentially performed tasks [17].

Figure 9 shows the waterfall models.

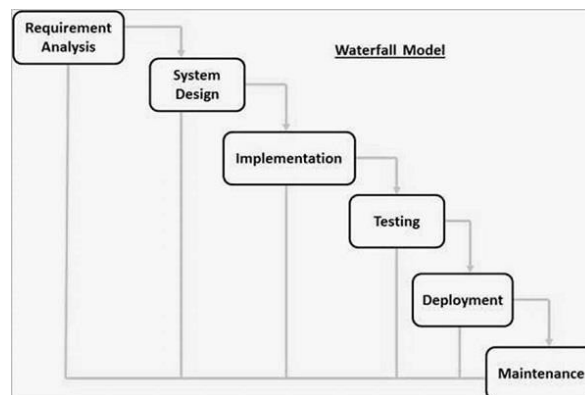


Figure 9. Waterfall Model Design

3.3. Evaluation of the Accuracy of fire detection System Based on Convolutional Neural Network

A series of real-world tests will be conducted to thoroughly evaluate the system's reliability and performance in practical scenarios. In the event of substantial test failures, the system will undergo iterative retraining, utilizing advanced machine learning techniques, until satisfactory results are achieved.

The primary measure of success will be the drone's ability to detect. If the drone demonstrates the capability to detect fires, the test will be deemed a resounding success. These dimensions cover all four crucial elements of assessment, ensuring a comprehensive evaluation of the system's capabilities. Figure 10 shows propose evaluation of CNN accuracy.

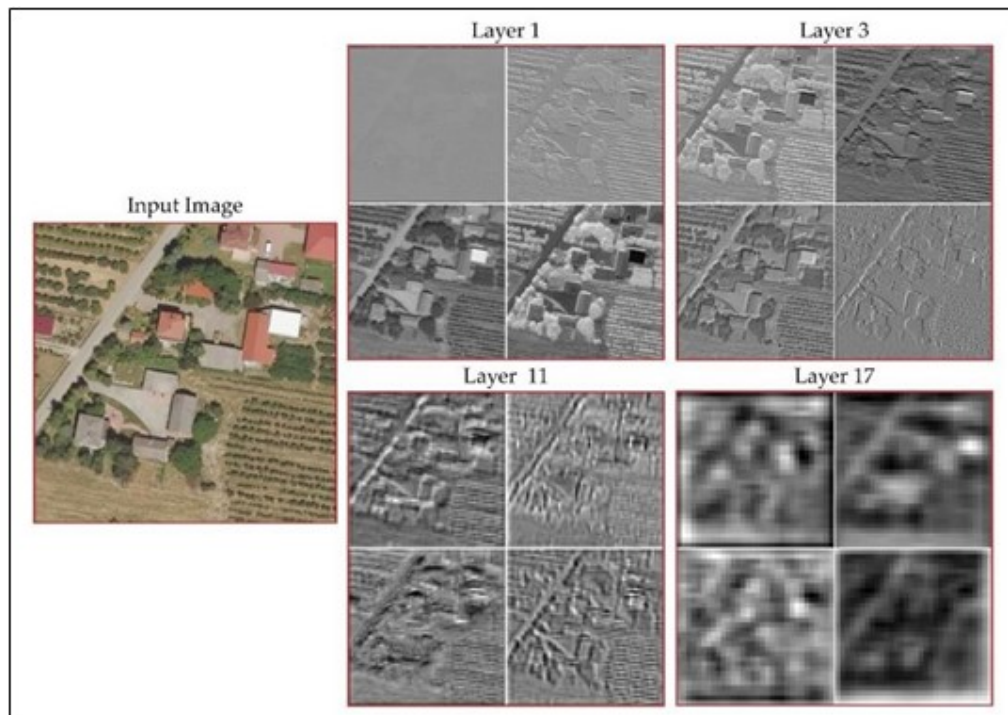


Figure 10. Propose Evaluation of CNN Accuracy [18]

3.4. System Architecture

By harnessing the agility of drones, they were utilized to assist IR sensors in spotting and detecting small fires. The drones were flown at an approximate height of 2 meters, scanning the surroundings for any signs of fire. By using infrared cameras, early detection was done and before the drone were deployed for further investigation.

The captured images by the drone were then transmitted to a computer for processing. An advanced Image processing algorithm were be employed for fire detection, promptly notifying researchers of any fire incidents. If a fire was detected, a fire alert message was sent to user smartphone. If a smoke was detected, a smoke alert message was sent to user smartphone.

In the event that no fire is detected, an alert message indicating "no fire detected" will be displayed, indicating no further action is required. Through this cutting-edge approach, the drone system will play a pivotal role in enhancing fire detection, ensuring swift and effective responses to potential fire hazards.

Figure 11 shows the architecture design while Figure 12 shows the diagram of CNN architecture.

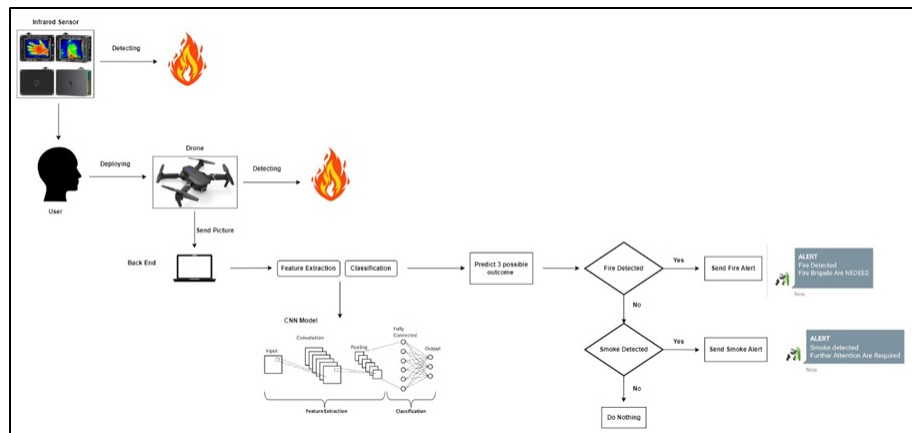


Figure 11. Architecture Design

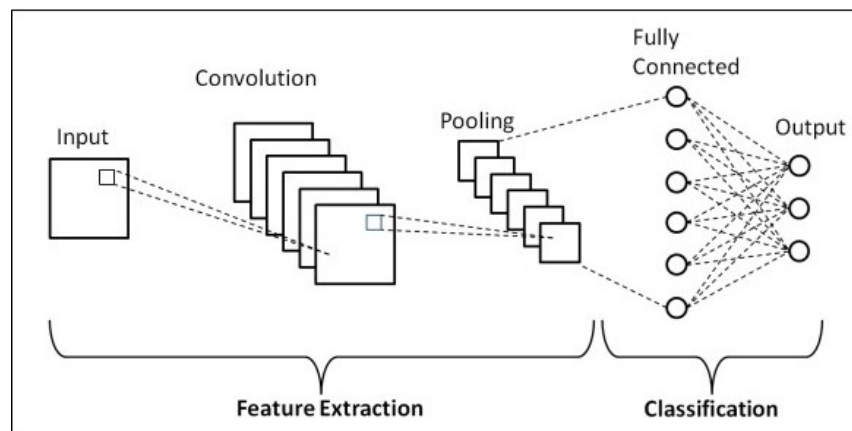


Figure 12. Diagram of CNN Architecture

4. Finding and Discussion

The system was gone through a series of testing to evaluate the accuracy of confidence score. This test was done with a distance of 2 meters from the fire and a height of 2 meters from the ground. By using edited image, the image was then uploaded to the system and the accuracy score were evaluated. Blurred out image, blurred and flip image, mono image and hibiscus filter image were used for this testing. All of this image were taken using drone and later edited.

- (1) Blurred Image
 A fire image with 60% of blurriness was uploaded to the system. A confidence score of 0.8696 was achieved in this testing. Figure 13 shows the fire image with 60% blurriness.
- (2) Blur and Flip Image
 A fire image with 60% of blurriness was uploaded to the system. A confidence score of 0.8576 was achieved in this testing. Figure 14 shows the flip fire image with 60% blurriness.
- (3) Mono Filter Image
 A fire image with mono filter was uploaded to the system. A confidence score of 0.8422 was achieved in this testing. Figure 15 shows the mono filter image.
- (4) Hibiscus Filter Image
 A fire image with mono filter was uploaded to the system. A confidence score of 0.8123 was achieved in this testing. Figure 16 shows the hibiscus filter image.

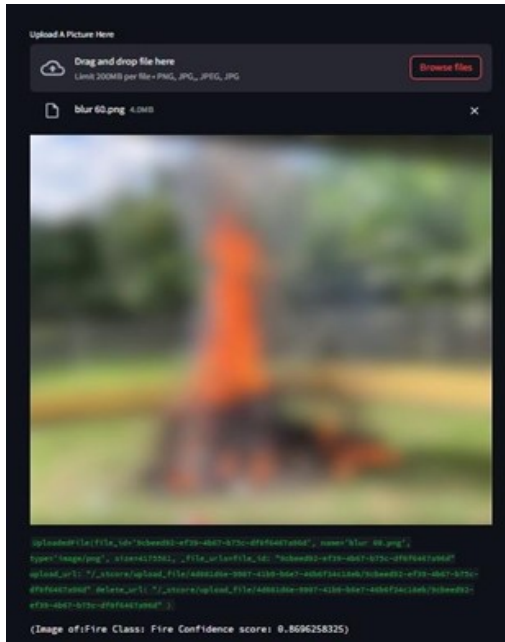


Figure 13. Fire image with 60% Blurriness



Figure 14. Flip Fire image with 60% Blurriness



Figure 15. Mono Filter Image



Figure 16. Hibiscus Filter Image

Based on the confidence score achieved above, the system had achieved a satisfactory level of confidence. Even in the mono filter, the system managed to detect the evidence of fire existence in the image.

5. Conclusion

This research successfully developed a drone-based fire detection system that employs Convolutional Neural Networks (CNN) to enhance early fire detection. By integrating infrared sensors and advanced image processing techniques, the system demonstrates a commendable accuracy rate of 80%, enabling prompt alerts to users via their smartphones when fire or smoke is detected. This innovative approach not only increases the reliability of fire detection in challenging environments but also enhances overall safety measures, illustrating the potential of combining drone technology with machine learning in fire management strategies.

Despite the promising results, the research identifies several gaps that could limit the system's effectiveness in diverse real-world scenarios. The reliance on edited images during testing may not fully represent the complexities of detecting fires in uncontrolled environments. Additionally, the system's performance in varying weather conditions, such as rain or fog, remains unexamined. Furthermore, the current implementation focuses primarily on small fires; hence, its capability to detect larger, rapidly spreading fires requires further exploration. Addressing these gaps is crucial for optimizing the system's performance and ensuring its practical applicability in various fire scenarios.

Future research should aim to expand the testing parameters to include a broader range of environmental conditions and fire sizes. Implementing real-time data collection from various locations will provide valuable insights into the system's adaptability and robustness. Additionally, exploring advanced machine learning algorithms beyond CNNs could enhance detection accuracy and speed. Incorporating other sensor technologies, such as thermal imaging and gas sensors, may further improve fire detection capabilities. Lastly, investigating the integration of this system with existing firefighting infrastructure could lead to more effective emergency response strategies, ultimately saving lives and reducing property damage.

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