TEKNOFEST

HAVACILIK, UZAY VE TEKNOLOJİ FESTİVALİ

İNSANLIK YARARINA TEKNOLOJİ YARIŞMASI
PROJE DETAY RAPORU

PROJE ADI:

Forest Fire Management and Detection using AI

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1. PROJECT DESCRIPTION

In recent years, forest fires have increased, causing huge losses in forests and lives. This contributed to an increase in the importance of early fire detection.

More specifically Turkey has an environment characterized by green forests, in addition to hot summer in some areas that may affect forests and help in the occurrence of fires, as happened in the past years, where the environmental losses were great. A system that helps in the early detection of fires automatically and helps in the management of firefighting may contribute to reduce losses in the coming years. The traditional fire detection technologies are not suitable for large spaces. Our project aims to detect forest fires and reduce the losses in a contributory way depending mainly on AI techniques. That's why we chose this idea as a graduation project at Harran University, Computer Engineering Department. First, we did a research that included most of the research and projects in this field, and we made a comparison between the methods and tools used in these researches, then we made a full technical study of the project. We designed a project that contains three subsystems, first is the AI subsystem that helps detect fires early by using neural networks and deep learning to increase detection accuracy without using traditional fire detection technologies. This sub system also is used to detect fake reports by using Bayesian network. The second subsystem is a mobile application that is developed to allow people to report a fire and also receive a notification when a fire happens around them. The third subsystem is an interactive map that helps simplify and accelerate firefighting by collecting important data needed for the firefighting (like weather situations) and displaying it on an interactive map to control the process of fighting fires in a professional way.

2. DEFINING THE PROBLEM SITUATION

Forest fires are increasing annually in the summer, and because forests are very important in our lives and survival, it was necessary to develop a project that helps in combating forest fire disasters to avoid forest loss. One of the best ways to deal with forest fires is by detecting fire early. The problem can be divided into:

1. The speed of detecting fires: When we searched in this field, we found that the best and first way to fight fires is early detection. We found many methods like:
    a. Traditional methods such as heat and smoke sensors, but it's not suitable for the forest, it costs a lot, and it's too hard to be implemented.
    b. Putting cameras that cover the forests and monitoring them continuously by a human cadre, which means a large number of watchers.
    c. Image processing are also unsuitable because of the difficulty in determining the characteristics of fire and smoke images.
    d. Deep learning to analyze forest monitoring videos and images and automatically detect fire and smoke. We have studied and implemented this solution.
2. Receiving fake reports which consumes the energy of firefighting teams.
3. Managing the process of fighting forest fires: The field monitoring of fires is not easy, especially when several fires occur, and because of the importance of this process in fighting fires, it was necessary to help simplify the process.
4. Not taking advantage of people to report the fire: Forest fires cause losses of lives because there is no way to warn people and allow them to report nearby fires quickly.

3. THE SOLUTION

Our main goal was to create a project that provides real assistance to be used in our lives, we had decided to solve the previous problem described by developing a project that would help solve the problem of forest fires, especially in Turkey.

We designed and built an integrated system that helps in the early detection of fires, allows humans to submit fire reports directly to be analyzed and verified using AI, and finally provides a platform that provides information and tools for managing forest fire disasters.

The solution can be detailed as follows:

- First, the problem of slow and late fire detection: After studying the problem and the existing solutions, we found that it is possible to rely on AI techniques through the use of deep learning algorithms to analyze and monitor videos and images to detect fires and send the necessary warnings. After the theoretical study of algorithms in this field, we prepared and collected the necessary data for the training and testing process, and finally compared the results between the different structures. Thus, finding an automatic solution for the problem of slow fire detection.
- Secondly, the problem of continuous monitoring and ease of reporting: it can be solved by taking advantage of electricity and communication towers or the turbines that expanded in mountains and forests especially in Turkey. So, it’s kind of easy to place cameras that constantly scan the forests. Also, we can rely on drones to scan the forests. Finally, we provided a mobile application that allows people to report fires directly and quickly. These reports are sent from various sources to the detection fire system to analyze them using artificial intelligent.
- The problem of false reports that may be submitted by humans or even sometimes from the AI system (even if the rate of occurrence is too small) is also solved by analyzing the incoming report depending on some factors using Bayesian network technology, which is one of the AI techniques that depend on some factors have been studied. This network is used to give the probability of being a real report, and thus give priority to the report.
- Finally, we provided a platform that contains fire data and reports with an interactive map that collects and displays all the information necessary for disaster management. Also, it has been provided with some tools for planning and management. This map can be developed in the future to show more information.

Thus, the system was designed to be integrated, starting from effectively detecting the fire with low cost, to managing the firefighting process by giving a complete image as possible for the situation. In addition, trying to reduce losses by alerting people early to do the necessary things. The integrity and flexibility of the project structure increase the importance of the project as it's an effective solution to the problem of forest fire disasters.

Because using the traditional methods or human monitoring are ineffective solutions or partially solve the problem. We believe that if we keep developing and supporting this project until it is implemented, it will help significantly and directly reduce material and human losses, especially with the lack of projects in this field, especially those that achieve the goals we plan. Therefore, our forest and land will remain green.

4. THE METHOD

4.1. The Study and Research Method

The research started by reading researches that talk about the ways of detecting fire, and there were several ways founded. We decided to use deep learning to detect fire.

In this field, there are many neural network architectures that detect objects, and these architectures have been developed over time. New architectures vary in speed, accuracy, training time, and more. We chose several architectures with quick results and good accuracy to train them to detect fire and smoke. some of these architectures have been tested in some researches to detect fire and smoke, and some are not.

Later we studied the best way to prepare the data that the neural network should be trained on, how to adjust the architecture of the neural network to match the detection of fire and smoke, and finally training the neural network and reading the results correctly to choose the best architecture for our project.

Later, as the project allows people to provide a fire report (by taking an image of the fire and sending it to the system to be verified), there was a need to start looking at how to avoid false reports, and it has been found that using a Bayesian network is useful in these cases.

It has been studied how to build the Bayesian network depending on a number of factors that are useful in determining the status of the report. Some factors have been chosen such as the current season and weather, the location of the fire and the susceptibility of the area to fire, etc... In addition to the result of the AI system verification and the number of reports sent on the fire. Depending on the above factors and the Bayesian network, the correctness of the report can be given, thus at least avoiding giving priority to false reports.

4.2. Solution Details

4.2.1. System Overview

The system aims primarily to fight forest fires through early detection. The inputs from the cameras and the reports sent by the mobile users are checked using AI system. Then the results that may indicate a fire will be shown on an interactive map. The map shows fire alarms and the weather conditions that may affect fires. The system also helps reduce losses by alerting people nearby fires through a mobile application after the manager confirms a fire.

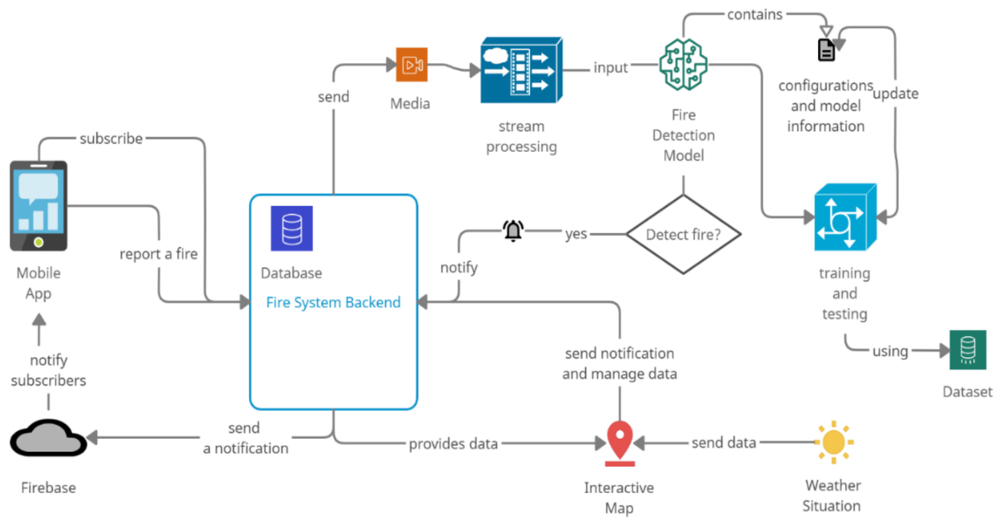


Figure 1 System overview

4.2.2. Design Considerations

This project is designed to be expandable. It's divided into three main blocks that each block can work separately to achieve the greatest possible benefit. We followed the Agile software development method. Also, during the design and implementation, we followed the points:

1. **Reliability:** Our purpose is to make the system runs with no problems or bugs.
2. **Reusability**: The project should be in three subsystems, each useable separately.
3. **Flexibility**: We considered the design patterns, and work with the rules of clean code.
4. **Maintainability**, we added debugging tools and a log to cover the main sections' errors.
5. **Usability**, the project should be simple and functional at the same time.

4.2.3. System Architecture

The infrastructure of our project consists of three sub-systems:

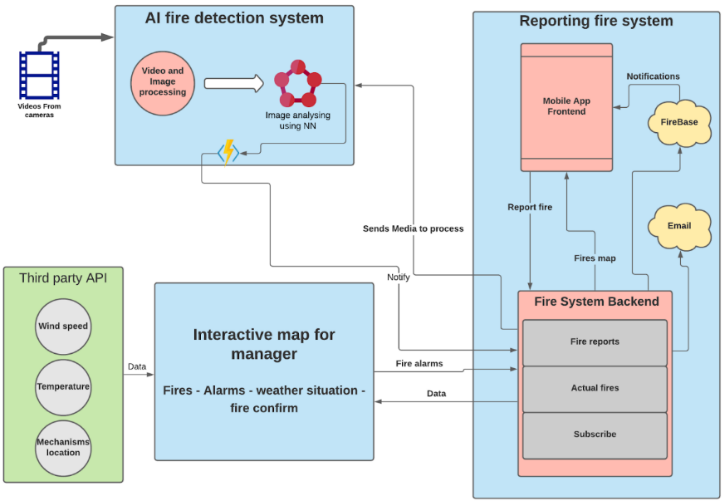


Figure 2 System architecture

4.2.3.1. Artificial intelligence fire detection system

This system relies on the computer vision technology that is used for object detection on images. It's main responsibility detecting and locating the instances of fires and smokes within the images. When the AI system detects a fire or smoke, it sends a notification to the map system. In the model preparation stage, we trained an object detection model to detect a fire or smoke in the input image. The steps of preparation:

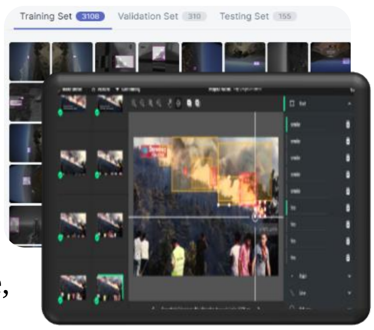
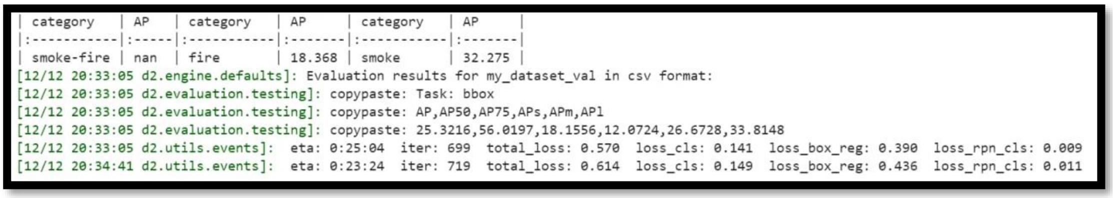


Figure 3 Prepearing the data set

- First, we collected images from the internet by manual searching, taking images from videos, and using some ready data set.
- Doing annotation to the collected data. Image annotation is the process of labeling images of a dataset to train a machine learning model. We used more than 3 thousand hand-labeled images with 2 categories (fire, smoke).
- Doing Image augmentation and resizing for the dataset. Image augmentation is a technique of altering the existing data to create some more data for the model training process.
- Dividing the dataset images into three divides: training, test, and validation set.
- Convert the labels data to a JSON COCO format so it's more efficient on use.

- Start training the model using that labeled dataset. We tried several models and chose the most efficient for the project (faster RCNN).
- After got a good result from the training we used the pre-trained model.



```
| category   | AP    | category   | AP     | category   | AP     |
|:-----------|:------|:-----------|:-------|:-----------|:-------|
| smoke-fire | nan   | fire       | 18.368 | smoke      | 32.275 |
[12/12 20:33:05 d2.engine.defaults]: Evaluation results for my_dataset_val in csv format:
[12/12 20:33:05 d2.evaluation.testing]: copypaste: Task: bbox
[12/12 20:33:05 d2.evaluation.testing]: copypaste: AP,AP50,AP75,APs,APm,APl
[12/12 20:33:05 d2.evaluation.testing]: copypaste: 25.3216,56.0197,18.1556,12.0724,26.6728,33.8148
[12/12 20:33:05 d2.utils.events]:  eta: 0:25:04  iter: 699  total_loss: 0.570  loss_cls: 0.141  loss_box_reg: 0.390  loss_rpn_cls: 0.009
[12/12 20:34:41 d2.utils.events]:  eta: 0:23:24  iter: 719  total_loss: 0.614  loss_cls: 0.149  loss_box_reg: 0.436  loss_rpn_cls: 0.011
```

Figure 4 Images from training

- We faced several problems during training, including the lack of a suitable data set for training, and the project needs huge data, in addition, the images must be diverse and include many special cases for detecting fire and smoke. For example, we had difficulty making the network differentiate between clouds and smoke, as well as car lights and fires at night, so we re-set the dataset several times, and it also requires some professionalism in identifying fires and smoke to give the training correct results.
- The network has been trained for more than 100 000 iterations and 10 epochs using Google Collab, but due to the limited use we could not fully show the results as shown in the Figure 5 Training Results. The error decreased clearly after 10 000 iterations of training, and decreased more when reaching 100 000.
- Later, we got very good results in detecting smoke and fire in the images.

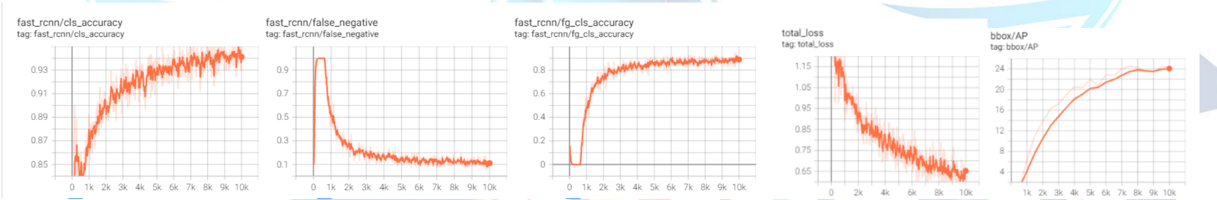


Figure 5 Training Results after 10 000 iterations

The processing flow in AI system is:

- When the component receives a video or image, it converts the video to frames and resizes the images to be compatible with the object detection pre-trained model, and for high performance the system developed to test one frame out of every 10 frames.
- The object detection pre-trained model takes images and tries to detect fires or smokes.
- If a fire or smoke is detected the component will send a notification to the backend component containing the needed details.

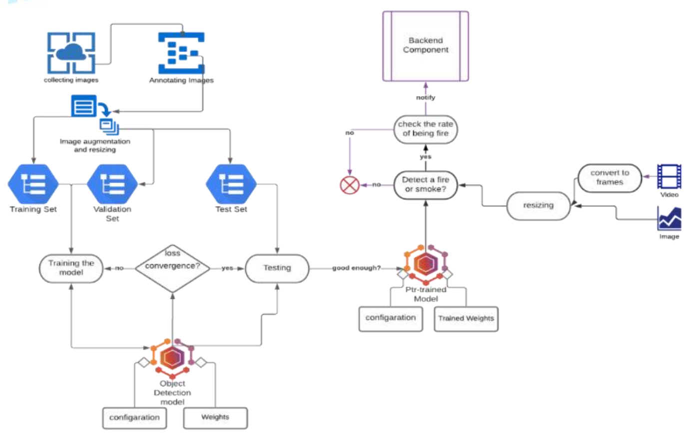


Figure 6 The AI Processing Flow

- We have built a Bayesian network that works to give a priority to reports according to several factors that contribute to determine the validity of the report. The network gave results that are very close to reality, as the Table 1 shows.

	AreaPro	Season	Tree Density	Tree Type	Report Acc	Report Number	Alarm	
							certain	rare
1	Med	spring	High	rare	high	1	0.78	0.21
2	rare	summer	med	med	med	10	0.825	0.174
3	high	winter	High	high	rare	5	0.41	0.58
4	rare	winter	rare	rare	high	1	0.57	0.42
5	rare	winter	rare	rare	high	10	0.81	0.19
6	Med	spring	med	med	med	5	0.71	0.29
7	-	-	-	-	high	1	0.67	0.33
8	Rare	winter	rare	rare	rare	1	0.15	0.85
9	High	summer	High	high	high	0	0.43	0.57
10	High	summer	High	high	high	1	0.8	0.2
11	High	summer	High	high	rare	1	0.51	0.49
12	Rare	winter	rare	rare	rare	10	0.42	0.58
13	-	-	-	-	med	5	0.75	0.25
14	Med	summer	med	med	high	5	0.82	0.18

Table 1 Bayesian network Test Results

4.2.3.2. *Reporting fire system*

It contains the mobile application interface and application backend, after the user logs in via the phone number, the user can report a fire by locating it and attaching an image, then the system sends the image to the AI fire detection system for verification. This part also sends warning notifications to users who are near a fire via Firebase or by email.

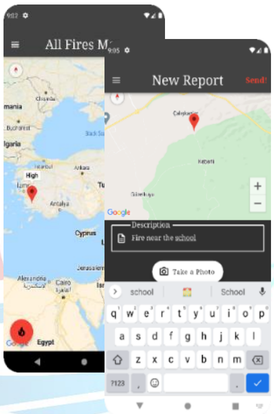


Figure 7 The mobile application

4.2.3.3. *Interactive map*

The map shows the details of the fire received from the AI fire detection system. This map provides an effective management of reducing fire damage by giving a general picture of the situation while showing the weather conditions that helps predict fire spread and allows the manager to plan through the tools in addition to sending the notifications to the fire reporting system after confirming fire and specific a degree of danger.

The manager can also control the cameras connected to the system, and check the fires and reports directly and quickly.

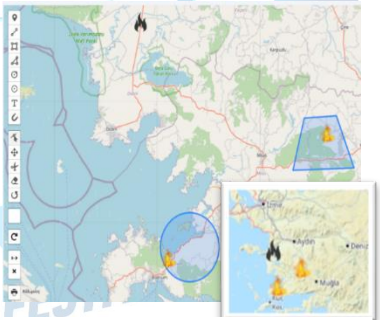


Figure 8 The interactive map

Figure 9 The interactive map showing weather situations and fire reports.

4.2.4. State transition diagrams

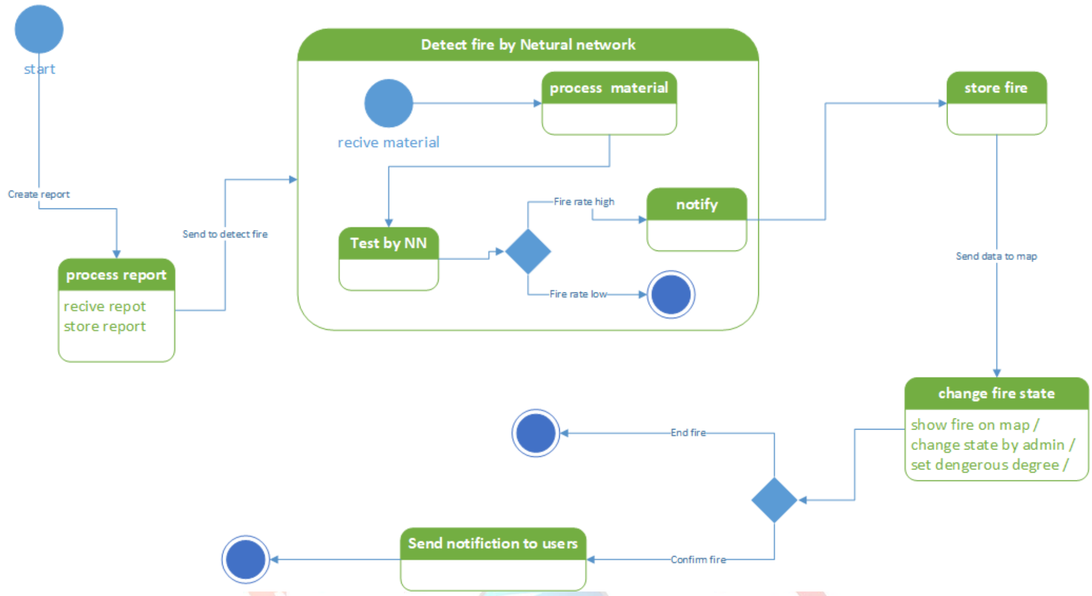


Figure 10 State diagram of the system

The process flow in main steps:

- The system getting a report from the user, stores the reports, and sends media to the AI system.
- The AI system may also continually receive data from cameras or Drones.
- Then the AI system will process and test the received media to detect fire, if the fire rate is low, the state of the system will end.
- Then the media will be analyzed to check the truth.
- The manager can change the fire status, set the degree of danger, and send notifications to the users near fire.

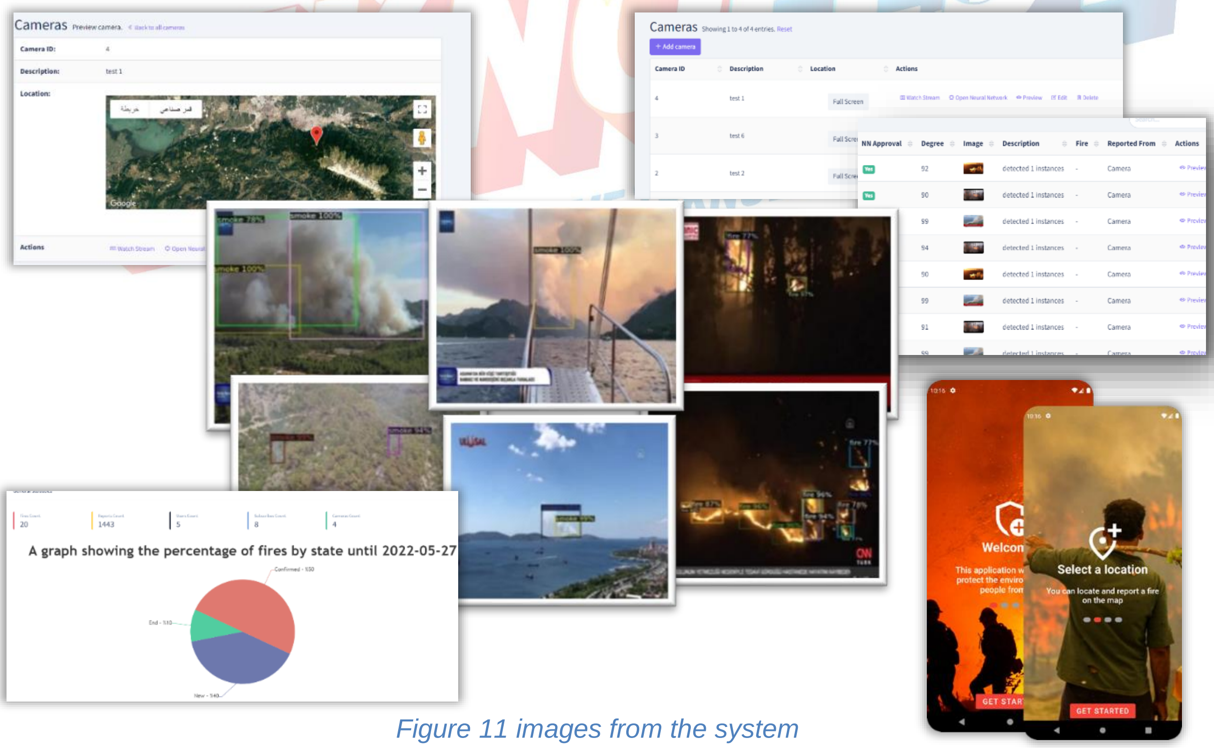


Figure 11 images from the system

5. Innovative Aspect

There are many projects that detects fires and sends alerts, part of them rely on image processing or sensors, but we think our project will add the following points:

1. Focusing on neural networks and deep learning to increase detection accuracy.
2. Increasing the speed and accuracy of a fire report.
3. Integrating camera reports with user reports.
4. Improving and simplifying the process of fire management process by providing an interactive map that could be linked with several external data to give a complete image of the firefighting process.
5. Determining the probability of a fire to avoid fake reports using Bayesian networks.
6. Alerting people near the fireplaces.
7. Being Developed into subsystems provides flexibility and reusability. For example, the fire detection system can be used separately with Drones with no need for other systems.

6. Applicability

The project can be used effectively by officials for forest fires. Thus, to implement the project, we need a network of cameras that cover and survey the forests continuously according to the following points:

1. The installation locations: Cameras can be placed on wind turbines located on mountains, electric and communication towers, or drones that scans forests.
2. Camera type: Many types are available to cover large areas (+50 km) with high accuracy and feature 360-degree coverage. These cameras need more research to determine the best types, noting the possibility of using solar energy to power the cameras.
3. Image processing and transfer: As mentioned, the detection system has been developed as an independent subsystem, so images can be transferred in one of three ways:
    a) Full Transfer: Using the available communication network to transfer images continuously to the central system and processing them.
    b) Decentralized processing: through a network of servers, each server is responsible for processing camera images within a specific area and sending the results to the central system.
    c) Embedded processing: adding an embedded processor (Raspberry pi) to each camera is the best way. The embedded processor detects fire or smoke and sends the result to the central system instead of images and videos. This way will save a lot of data transfer, and it is very effective in drones.

The system can be applied in decentralized processing (minicomputer) because the platform and the detection system do not require very high specifications. The system has been tested on medium-performance devices and the results were accurate and fast. But it is preferable to use processors that contain a GPU to ensure faster performance in terms of image processing.

The project can be converted to commercial use after developing it to monitor huge facilities or laboratories, especially places that cannot be covered by traditional ways like sensors.

7. Estimated Cost and Project Time Planning

The implementation of the project is divided into two parts:

1. Preparing the software system, which consists of three sub-systems.
2. Implementing the project realistically and determining the needed cameras, their installation locations, and the communication methods.

The first part is the most important part of the project. The system has been studied and analyzed, and then divided into sub-systems. For each sub-system, detailed technical research has been done after reviewing the available studies.

The research and design phase took about three months. After that, the phase of implementation, experimentation, and improvement of the system has been begun, which took six months and passed in 5 stages.

Today we have a semi-integrated software system that has been tested in different cases. Thus, it can be said that the first part is ready for use, and there is a plan to add more improvements and developments that will be mentioned later in this section.

The second part is related to studies on the cameras and processors that can be used. Costs vary according to the required specifications. For example, it can be said that the cost of a camera is between 1000$ to 5000$, depending on the needed coverage area, the communication method, power source, etc... The mini processor's (Raspberry pi) cost starts from $200, depending on the required brand and type. When the required cameras and the communication system between cameras and the system are provided, the system can start working as a beta version.

There are periodic expenses (the cost of internet connection and electric power) but with a lower cost compared to traditional methods because the cameras cover large areas. Traditional methods require a large network of sensors and cover small areas, each sensor needs a connection and electrical power. Therefore, this method is applicable in large areas such as forests, and according to the comparison we made, this solution is an economical solution compared to other solutions.

Several global projects offer similar ideas like detecting fires using artificial intelligence, but our project is distinguished by providing an analyzing system to determine the false alarms, an interactive map, and a mobile application that can be used by people.

We aim to improve the software system through the following points:

1. Increasing the performance of the neural network in some cases such as the ones we solved (the difference between clouds and smoke or small fire and orange lights at nights) and continuing the training in new cases as we expect to have more special cases in the future.
2. Improving the analyzing system to determine the false alarms by obtaining statistical data from an official source.
3. Adding more tools to the interactive map, such as the live locations of the mechanisms that fight the fire, predicting the spread of the fire, and determining the location of the fire more accurately based on the locations of the warming cameras.

8. Target Audience of the Project Idea (Users)

We depend on forests for our survival, from the air we breathe to the wood we use. The forest helps us breathe, keep the earth cool, nearly half of the earth's known species live in forests, and more a lot. A system that helps in the early detection of fires automatically and helps in the management of firefighting may contribute to reducing losses in the coming years. So, this work can be used by:

- Departments responsible for forests, especially those responsible for protecting the forests or predicting the occurrence of fires, and even workers in receiving fires reports.
- Normal people to report fires quickly and directly.
- People who live or work nearby forests to receive alarms about fires and save their lives.
- In addition, the AI system can be used in drones responsible for monitoring forests.

9. Risks

Since we have completed the design and implementation of the software system, achieving the goals we were planning, we can say that there are no major risks for now, except for the stage of further testing and improvements, especially on the neural network architecture in the special cases (like ones that depend on the camera type).

There are risks in the performance of the neural network. We tested the neural network on a processor with two cores and 4 GB of RAM. The results were very good (with accuracy above 98% after compressing the images and the fire was detected within about a third of a second per image). But it is better to use better processors and don't compress the image resolution because it affects the accuracy of the results. So, if good processors (with GPU) are used, this risk can be addressed.

There are risks of false alarms, especially with the acceptance of reports from humans, and this risk can be addressed by increasing the statistics and factors in the system of ignoring false alarms.

During the implementation of the project, the following risks may appear to us:

1- The inability to import the needed cameras from outside the country, and it's expected to be solved through the government official.

2- Testing special cases while implementation: We may need more time to continue training the network on the special cases that may appear while testing a specific type of camera in a particular place. The training can be accelerated by using fast computing devices which are available in universities in research centers.

3- If an area isn't covered by the internet, the plan is to use point to point wireless bridge that are available and reach tens of kilometers.

	The Probability		
	Very low	Moderate	High
Low risk		Detecting fire on special cases	
Moderate risk	Processor performance		
High risk		Availability of cameras and internet	

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