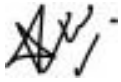
UNIVERSITY OF CENTRAL ASIA

School of Art and Sciences
Department of Computer Science
B.Sc. in Computer Science
COMP 4811: Final Year Project-1

Title:	Detecting forest fires using machine learning techniques and creating an alert system.	
Project author:	Azra Nisar	
Supervisor:	Dr. Muhammad Fayaz	
Co-supervisor (if applicable): (If none, remove this row)	Dr. Azmat Hussain	
Main subject Area(s):	Machine learning, mobile app development, image processing	
Keywords:	Fire detection, app development, machine learning, image processing	
Project type:	Software and hardware development, machine learning	
Methodologies:	Waterfall and iterative method	
Short project description:	This project aims to resolve one of the global concerns named “forest fires” by developing an alert system for fire recognition using machine learning techniques. Moreover, the objective of the project is to build a user-friendly interface that fire extinguishing companies and general people can use. Dynamic mathematical models will be used to predict the fires.	

Project Aim and Objective(s):	Aim: This project aims at training a machine learning model on an image dataset collected from an online source which can recognize the fire in an image and developing an alert system to speed up the process of fire extinguishing, which can be enhanced and monetized and used by the fire extinguishing companies, by generating an alert that notifies the fire extinguishing companies. My project achieves the following objectives: Objectives: 1. Create an alert system in the form of web application or mobile app to notify the relevant personals about fire. 2. Train a deep learning model for fire recognition to increase accuracy and decrease technical risks of misclassification. 3. This project aims to acquire minimum 80% of accuracy for the classification model. 4. To employ classification models to classify fire, no fire, smoke, and no smoke images from the dataset. 5. To use dynamic mathematical models to predict the forest fires.
Equipment and critical resources required:	High quality image dataset and a high-speed laptop
Recommended pre-requisites / Knowledge required and Supporting 3rd Year Study units:	Mobile app development Machine learning and image processing Python(streamlit)
Foreseeable Ethical issues and how these will be tackled (if applicable):	None
Copyright note: (specify copyrights)	It is acknowledged that the Department of Computer Science at the University of Central Asia is responsible for all outcomes, designs, or patents resulting from the student's project.

Expected outcomes:	1. A complete alert system to notify the relevant fire extinguishing companies after detecting fire. 2. A user-friendly interface for the users.
Expected deliverables: **Note**: Project Proposal and report must be signed by author, supervisor(s) and department chair.	a) Project Proposal: (original file + pdf) soft copy + hard copy b) Project Report: (original file + pdf) soft copy + hard copy c) Presentation (original + pdf) d) GitHub repository as downloaded zip file e) Supervisor(s) review f) External expert review g) Plagiarism report h) Product (installation file, link to deployed website)
Estimated Budget in USD:	300$
Language support:	**English** Russian Kyrgyz Tajik Kazakh
GitHub repository[1] link:	https://github.com/eatandcod/FYP
Programming language(s):	Python, java
Framework (if applicable):	I will be using java or Python frameworks to create the UI of my project. For instance, Tkinter, Kivy, or Spring.
External libraries:	Keras, open cv, streamlit, NumPy, pandas, scikit-learn, Matplotlib

Note: Proposal which lacks signatures are rejected as it lacks legal power.

Submission date : ___23____/ ___October_____/ 2023

Important: This page is used for department purposes only and must filled by faculty only.

Department committee approval:

Approve

Dr. Ayman Aljarbouh (signature) :

Chair of Computer Science department

Date : 25 / 10 / 2023

NOTE: This document is evolving. It will be subjected to revisions with a view to help the current and future students learn and enjoy more from their FYP experience. If you think of relevant points, welcome to let me know and I'll add in your observations. A completed project proposal can simply be cut and pasted into your report later.

Contents

Project Description

Forest fire is a burning fire in an area covered with trees which is challenging to control and spreads at a fast pace (Cambridge reference, n.d.). Global warming and forest fire are profoundly interconnected. For instance, global warming results in forest fire due to the rising temperature and the heat of forest fire eventually contributes to global warming. Therefore, their relationship forms a positive feedback loop. Apart from global warming, human activities are equally responsible for the forest fire. According to University of California's fire ecologist fires sparked due to human activities are more extreme because they spread faster and kills a greater number of trees than the ones caused by lightning or nature (Joosse, 2020). For instance, human prone fires spread at a speed of 1.8km per day which is twice as fast as lightning induced fires. The number of forest fire has increased drastically in the past few years and its impacts have amused everyone indeed. According to a research study conducted by the university of Maryland, forest fires have resulted in a loss of three million more hectares of trees compared to 2001 which equals an area of roughly Belgium's size (MacCarthy et al., 2023). It is not only the fire that leads to global problems, but wildfire smoke also has hazardous impacts on the environment. The smoke contains harmful air pollutants such as ozone, NO2, PM2.5, and hydrocarbons which results in air pollution eventually (WHO, n.d.). The carbon released from wildfires is a huge contributor to global warming and climate change.

Wildfires affect everyone equally regardless of where we live therefore, my research and project will address this respective issue. The research will help in analyzing and finding trends in forest fires and detecting their occurrences using various machine learning techniques. Furthermore, this project aims to predict forest fires using dynamic mathematical models.

Keywords: Machine learning, forest fire, user interface, dataset, mathematical models

Literature Survey

Forests cover a wide range of area on earth, and with an increase in global warming and climate change forests conservation has become a major concern. Unfortunately, due to natural causes and human activities forest fires are increasing at a fast pace thus affecting the whole ecosystem. Uncontrollable flames caused an estimated 4,225,000 km2 of land to burn between 2002 and 2016 (Abdusalomov et al., 2023). Some of the main natural causes of forest fires are lightning, volcanos, dry weather, and wind while smoking and cooking are human activities that contribute to wildfires. Amusingly 90% of the forest fires are caused by human activities (Abdusalomov et al., 2023).

Machine learning techniques have been widely used in forest fire prediction and detection. Fire detection systems based on machine learning rely on manually extracting visible information from photos. These features solely focus on the superficial aspects of the flame, which may result in data loss when manually extracted. Deep learning algorithms, unlike machine learning algorithms, can automatically extract and learn complex feature representations (Sathishkumar et al., 2023).

CNNs have significantly improved performance in a variety of computer-based vision applications, including visual identification and image categorization. Many researchers have employed CNN (convolution neural network) based wildfires detection using unmanned aerial vehicle dataset (Sathishkumar et al., 2023). Convolutional Neural Networks (CNN) are a sort of Artificial Intelligence (AI) technique that has been demonstrated to perform better than cutting-edge approaches in image classification and other computer vision applications, but their training time may be prohibitive, furthermore, when there is an insufficient dataset, a pre-trained CNN may underperform (Seydi et al., 2022).

Most of the fire detection research have used YOLOv2 (you only look once) CNN for both outdoor and indoor fire scenarios. (YOLO) is a deep learning model for object detection; YOLOv2 is the next version that has been upgraded to address YOLO's shortcomings, namely the inability to accurately locate and mark the region of interest in images and the lower recall rate when compared to other region-oriented algorithms. Increasing the architecture's effectiveness as a result.

According to a research study, automatic fire detection can be classified into three types: aerial, ground, and borne detection. The ground-based systems use numerous gazing black and white video cameras in fire detection, which detect smoke and compare it to natural smoke (Rajan et al., 2022). The key advantage of employing this technology is the great temporal and spatial resolution, thus, making it easier to detect. However, these techniques still come with some demerits therefore, it is vital to use a mechanism which can detect the fire as early as possible.

Mathematical models have been useful to predict the spread rate of fire. There are mainly three types of mathematical models which include empirical, semi empirical, and theoretical models. Theoretical approaches to understanding fire dynamics involve applying the principles of combustion, fluid dynamics, and heat transfer. These approaches necessitate incorporating numerous parameters into the computational equations. The resulting equations are typically complex, complicating their practical application, particularly in real-world scenarios in developing nations. Furthermore, confirming the accuracy of these models is challenging, given the diverse and large-scale nature of wildland fires (Karouni et al., 2021). Empirical models are built upon statistical correlations derived from observed data and past studies on wildland fires. Their application is generally confined to scenarios that closely resemble the tested conditions. Meanwhile, semi-empirical models combine basic physical principles with data obtained from experiments to enhance their applicability (Beer, 2012).

The Rothermel Model, renowned for its effectiveness both in practical scenarios and theoretical applications, remains a cornerstone in contemporary fire behavior modeling. Its integration into various advanced modeling techniques, including remote sensing, finite difference methods, finite element analysis, neural networks, and cellular automata, highlights its fundamental role. However, the model's complexity, characterized by the need for 24 distinct parameters, renders its implementation quite costly.

$$R = \frac{I_R \xi (1 + \phi_w + \phi_s)}{\rho_b \varepsilon Q_{ig}}$$

Fig.1. Rothermel speed formula

Rothermel model to determine the spread rate of a forest fire comes under semi empirical model, where the value of some parameters can be found via experiments. Therefore, this model has been classified as a complex model.

Similar applications comparison table:

Below is an app comparison table, which compares different fire detection apps based on their features.

Table.1 apps comparison table

Applications / Features	Firesmoke detection app	Firealarm inspection app	DRYAD	Fireangel connected app	Smoke detector inspection app	Nimbus	Your app	Total
Push notifications		☑	☑	☑	☑		☑	5
Detect both smoke and fire	☑		☑				☑	3
Using mathematical models							☑	1
send daily inspection reports		☑				☑	☑	3
Classifies the fire as severe, mild, and moderate							☑	1

Links to applications

Fire smoke detection app (https://store.azena.com/shop/p/A_00104000)

Fire alarm inspection app (https://axonator.com/micro-app-store/fire-alarm-inspection-app)

DRYAD (https://www.dryad.net/)

Fireangel connected app (https://www.fireangel.co.uk/home/product/app/)

Smoke detector inspection app (https://www.fulcrumapp.com/apps/smoke-detector-inspection/)

Nimbus (https://www.blazequel.com/videos/nimbus-fire-alarm-weekly-test-app/)

Unique Feature of my app

One of the features which makes my app unique is using mathematical models to predict the forest fires. Mathematical models are highly efficient in prediction related projects.

Technical specification of the project:

Table 2 and table 3 below contain the technical specifications of my project. Table 2 has functional requirements while Table 3 depicts the non-functional requitements of the project.

Table 2. Functional requirements:

Functional requirement No.	Functional Requirement
FR 1	Preprocessing the images and their acquisition
FR 2	Algorithm for fire detection
FR 3	Real-time monitoring of the respective area
FR 4	Notifications and alerts

1. **Preprocessing the images and their acquisition**

1.1. Description:

Images should be acquired from multiple sources, such as cameras or drones, then preprocessed to improve quality. Images can be acquired from open sources such as Kaggle.

1.2. Acceptance Criteria:

To improve the quality of the images, image processing techniques have been applied.

Images are obtained from multiple sources.

2. **Algorithm for Fire detection**

2.1. Description:

A machine learning algorithm will be used to create a model for fire detection.

2.2. Acceptance Criteria:

The algorithm can detect fire in photos with high accuracy.

The false positive rate is less than a predefined threshold.

3. **Real-time monitoring of the respective area**

3.1. Description:

The system should offer real-time forest monitoring via cameras.

3.2. Acceptance Criteria:

Notifications and alerts should be sent out frequently regarding the fire status.

When a fire is detected, notifications are sent in real time.

4. **Notifications and alerts**

4.1. Description:

When a fire is detected, notify the appropriate authorities and stakeholders.

4.2. Acceptance Criteria:

Predefined contacts, such as emergency services and forest management, receive alerts.

Notifications indicate the location and severity of the fire.

Table 3. Non-functional requirements:

Non-functional requirement No.	Non-Functional Requirement Description
NFR 1	Performance
NFR 2	Reliability
NFR 3	Security
NFR 4	Availability

1. **Performance**

1.1. Description:

Under varying workloads, the entire system should respond quickly and accurately.

1.2. Acceptance criteria:

Within 2 seconds, the system must process image data.

The system should be able to handle 100 concurrent requests without degrading performance.

2. **Reliability**

2.1. Description:

The system should be up and running 99.9% of the time.

2.2. Acceptance Criteria:

In a year, the system encounters no more than 0.1% downtime.

3. **Security**

3.1. Description:

Maintain data privacy and secure the system against illicit access.

3.2. Acceptance Criteria:

During transmission and storage, data is encrypted.

Unauthorized entry is prevented by access control methods.

4. **Availability**

4.1. Description:

The system must be accessible and running 24/7.

4.2. Acceptance Criteria:

The system must have at least 99.9% uptime during a specific period, such as a year.

Project Budget Estimation

Below is the project budget estimation table for my project, it shows how the 300$ budget will be utilized to make the project a success.

Table 4: Project Budget estimation

Category	*Description*	*Quantity*	*Unit price*	*Total cost*	*% Of Budget*
Deployment	1TB external hard disk	10 months	$ 100	$ 100	33.3%
Plagiarism report	Two times document check payment with plagiarism checker[2]	2 times	$ 35	$ 70	23%
equipment	16GB RAM	1	$90	$90	30%
Online course(streamlit)	Making the UI of the app using streamlit	1	$20	$20	6.66%
Unexpected expenses	Unforeseen expenses	1	$20	$20	6.66%
Total Budget Cost Estimate = $300					

[2] https://www.scribbr.com/plagiarism-checker/

Project plan and schedule:

The table below shows the important milestones to be covered to successfully complete the project in a certain time frame.

Table 5. project plan and schedule

Milestones

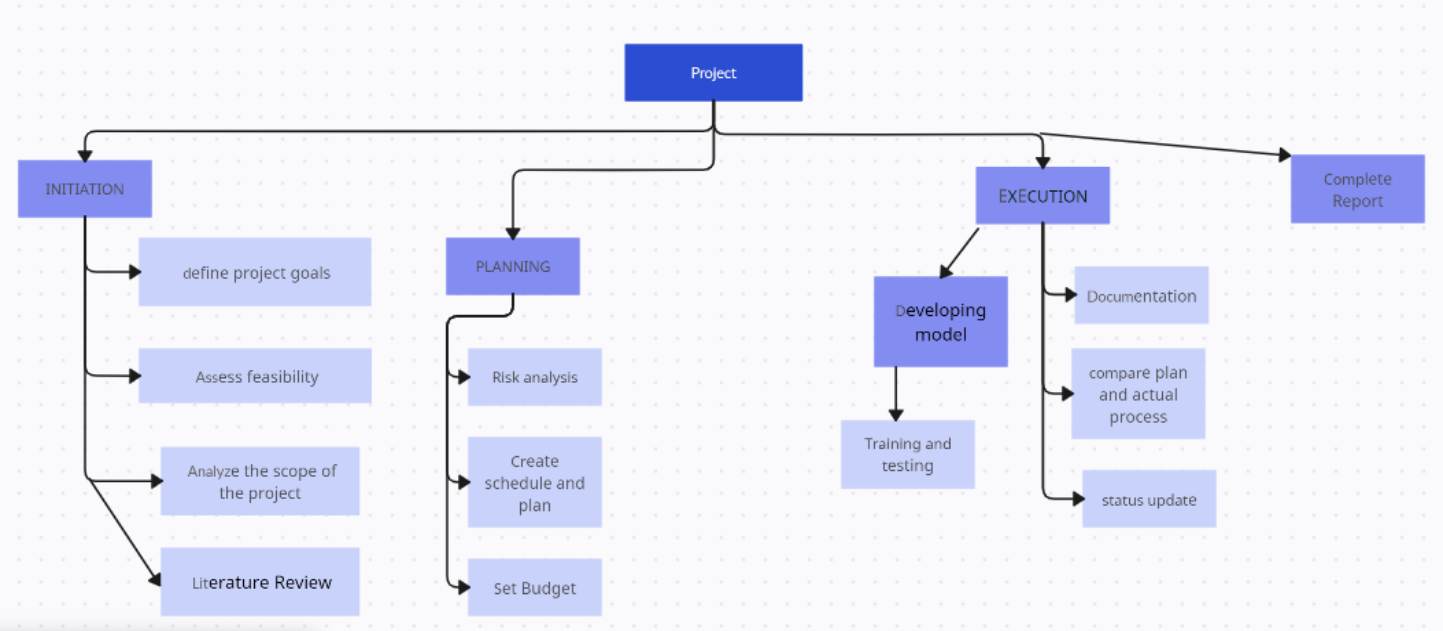
S/N	WEEK	To be done	MILESTONE	OUTCOMES
1	2 Weeks	22/10/23	Project initiation and planning	Clear objectives and scope of the project.
2	4-6 Weeks	30/11/23	Dataset acquisition and preparation	Collect project related dataset such as drone or satellite images.
3	2 Weeks	14/12/23	Cleaning, labelling, and annotating the data	Will get a clear picture of the dataset, because the outliers will be removed.
4	2 Weeks	2/01/24	Model selection and development	Selecting the relevant and appropriate machine learning model.
5	4 Weeks	2/02/2024	Model training	The model will be trained based on the final dataset.
6	4 Weeks	3/03/2024	Testing and validating the model	Analyze the performance of the model using various datasets.
7	2 Weeks	28/03/24	Deploying the model	Deploying the model at UCA
8	3 Weeks	20/04/24	Documentation	Write a report based on the whole project.
9	1 Weeks	30/04/24	Revision	Revising the whole project and the documentation.

Work Breakdown structure (WBS)

The figure below shows the work breakdown structure of my project. The whole project has been divided into four main stages such as initiation, planning, execution, and documentation.

The figure has been added to support my project milestones.

Fig.1 WBS



Gantt Chart

Below is the Gantt Chart that specifies the tasks and their expected date of start and completion.

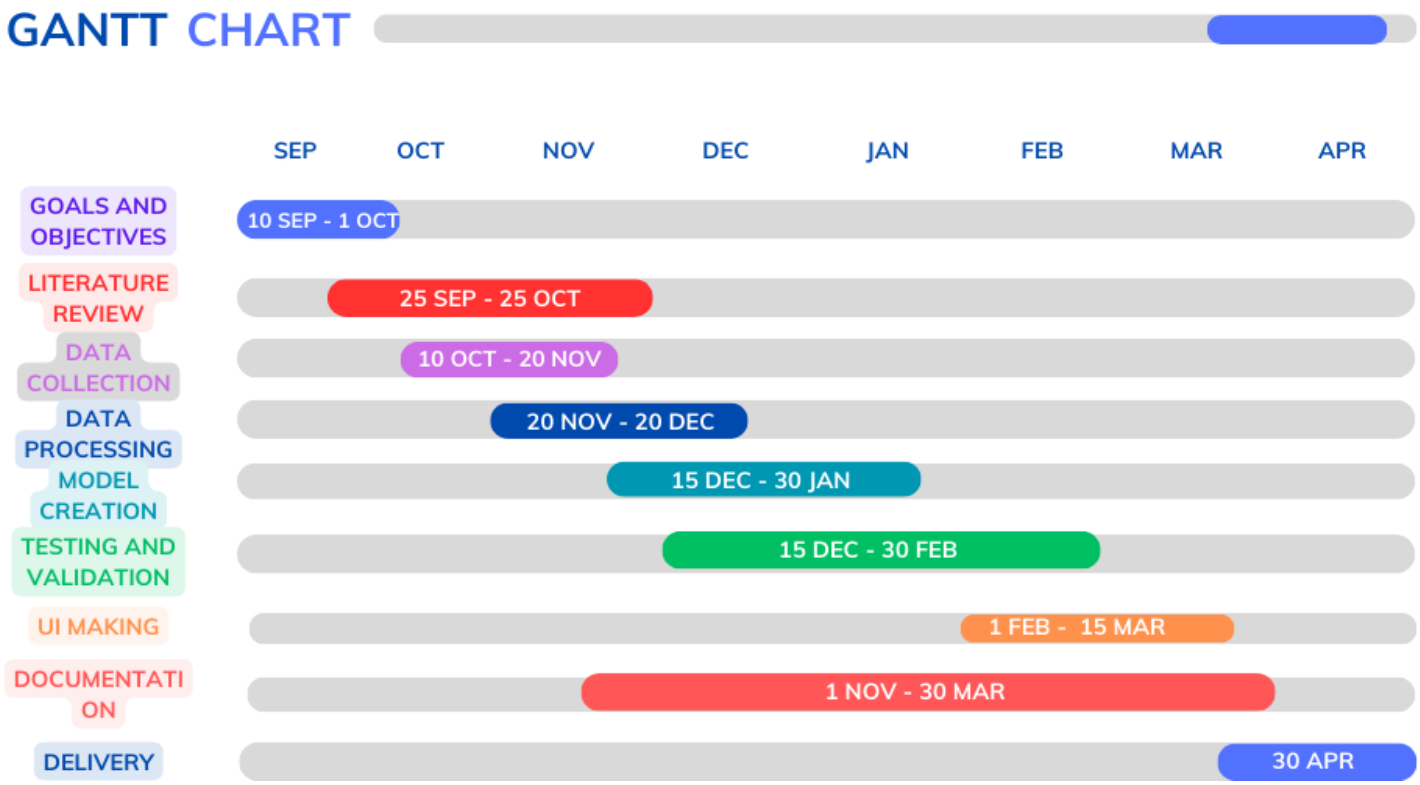


Figure 2. Gantt Chart

Risk management plan:

Risks are indeed part of any project either it's a small scale or a big scale. Table 6 shows the expected risks that I may face while carrying out my project.

Table 6. Risk Assessment Table

Risks		Likelihood (1-3)	Consequence (1-5)	Overall Risk (1-15)	Risk Level
1	unbalance dataset	1	4	10	Major
2	Model Sturdiness	2	4	11	Major
3	Model Fairness	3	5	13	Severe
4	Equipment malfunctioning	1	1	1	insignificant

Four main risks

1. **The quality and quantity of data (Balance Data)**

1.1. Description

Training data is one of the most vital aspects of a machine learning trained model. The dataset should be unbiased and sufficient to have accurate predictions and results. Having a balanced dataset is equally important to avoid false results. For instance, having more fire pictures than non-fire pictures lead to inaccurate results.

1.2. Solution

Will get the dataset from a reliable and a legitimate source. The images present in the dataset should be of good quality and updated. Fire images, non-fire images, and smoke images should be of equal number.

2. **Model Sturdiness and adaptability**

2.1. Description

Over fitness occurs when a model works perfectly for a certain data set and doesn't perform well on a new dataset. Overfitted models are indeed not efficient for fire detecting models.

2.2. Solution

To avoid overfitted model, I will frequently retrain the model on fresh dataset.

3. **Model Fairness and Biasness**

3.1. Description

Models can never be 100% accurate because they are trained using a certain data. The data might not be well balance and updated which makes the model biased.

3.2. Solution

To have an unbiased model, I will take updated and balanced dataset of images. I will acquire data from multiple sources and then compile them to make my final dataset.

4. Equipment Malfunctioning

4.1. Description

The equipment that I am using such as my laptop may malfunction due to various reasons such as some software or hardware issues.

4.2. Solution

There are multiple PCs in the CS lab and library of UCA that I can use to work.

Business Benefits

Business benefits of the project:

The business benefits of the project focused on analyzing and predicting forest fires using machine learning and dynamic mathematical models are multifaceted, extending from economic gains to corporate social responsibility:

- *Risk management and management*

  Businesses in sectors like insurance, agriculture, and real estate can significantly reduce risks and financial losses associated with forest fires by implementing predictive models that allow for better planning and quicker response.

- *Resource Allocation*

  Efficiently predicting forest fires enables governments and firefighting units to optimally allocate resources, thus saving costs associated with emergency responses and reducing the economic impact of fires.

- *Benefits for the Insurance Industry*

  For insurance companies, improved prediction models mean more accurate risk assessment, which can lead to more tailored insurance packages and premiums, potentially increasing profitability.

- *Real Estate and land value protection*

  Real estate developers and investors can use insights from this project to protect their assets and invest in safer areas, preserving property values and investor confidence.

- *Tourism and recreation*

  For businesses in the tourism sector, better management of forest fire risks can protect natural attractions and ensure the continuity of tourism revenues.

- *Regulatory Compliance*

  For businesses with operations in fire-prone areas, advanced prediction capabilities can help in maintaining compliance with environmental regulations and avoiding fines or sanctions.

- *New markets and innovation*

  Technology firms can utilize the findings to develop innovative products, such as early warning systems and firefighting drones, opening up new markets and revenue streams.

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