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Development of an IoT-Based Fire Recognition Using Artificial Intelligence

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Abstract— *This paper presents the development of an IoT-based Fire Recognition using Artificial Intelligence. One of the most ubiquitous causes of worldwide deforestation and devastation of wildlife is fire. Disasters caused by fire in various residential homes, commercial and industrial locations are major concern because huge damage of infrastructure as well as human lives is always recorded. Early detection of the fire to protect valuable lives and properties is required. This research is geared towards developing an early fire recognition system capable of giving warning report in order to prevent fire incidence in the environment. The system was divided into hardware and software. The IoT hardware part of the system was carefully designed, considering all the sensors, actuators and controllers for the detection of the early fire. The computer vision was deployed to filter information from the fire images captured for early fire recognition. A sensor camera is used to monitor the environment in case of smoke or early fire, capture the image and processed using machine learning. A pre-trained Google model deployed to confirm the presence of a fire outbreak. The confirmation triggers an alarm, sends image via telegram bot to the personnel on duty and activates fire suppression process. The personnel use smart phone to view the incidence via configured telegram app. The prototype system was built and tested with good results*.

Keywords— *IoT, Fire Recognition, Artificial Intelligence, water pump, bylnk technology, Google model, fire extinguisher*.

I. INTRODUCTION

Fire accidents in buildings, market, organization, supermarket, industries, fuel stations etc. have become increasingly frequent due to bad economy, careless and jobless hunters in Nigeria. Fire recognition has attracted considerable attention from researchers due to its potential to cause significant harm to both lives and property in a short span. Over the past decade, numerous applications and systems related to the Internet of Things (IoT) have been developed to enhance surveillance and safeguarding of property. A recent solution for fire detection involves utilizing Internet of Things (IoT) devices that are equipped with cameras for surveillance purposes. These IoT devices can either process the captured videos of their surroundings themselves or transmit the data to the cloud for processing, especially when the detection algorithm requires significant computational resources. However, there is a drawback associated with using the cloud. Specifically, relying on cloud-based processing can introduce security risks that might compromise the privacy of a location, either through hacking or unauthorized access to the footage stored on the cloud [1]. It is crucial to ensure that accurate, swift, and potentially portable fire detection solutions are easily accessible to the general public at affordable prices. Various research efforts have been made to create efficient and reasonably priced fire detection systems, but they have achieved different levels of success. Nonetheless, many of these systems exhibit a compromise between performance and model size, which determines the system's suitability for installation on portable devices.

Fire serves both as a valuable resource for humanity and the environment, and simultaneously, it stands as one of the most destructive and deadly natural disasters. While fire accidents occur infrequently, their impact can be profoundly devastating. Timely recognition of a fire is crucial in preventing further harm and safeguarding lives. Hence, guiding individuals within a building to exit safely during a fire incident is of paramount importance.

II. REVIEWED WORKS

In [2], an IoT-Based Fuzzy Approximation Prediction Model aimed at early fire detection to enhance public safety and control in local urban markets was developed. Their study introduced a fuzzy model designed to improve early fire detection and control as a fundamental contribution to the application of fuzzy systems in computer and engineering sciences. A real-time monitoring and fire detection system utilizing the Internet of Things (IoT) and cloud-based drones was developed as part of a growing field of research in smart cities and smart infrastructure as in [3]. Unmanned Aerial Vehicles (UAVs) and wireless sensor networks were employed to detect fires at an early stage, thus preventing potentially severe fire accidents. Fuzzy Logic Algorithm-GSM IoT-Based Fire Fighting Robot was presented [4]. The system utilized an IR sensor to detect fires and transmit this information to a microcontroller. The microcontroller was programmed with a fuzzy logic algorithm designed to facilitate fire detection and control the movement of the nozzle head on the Fire Fighting Robot. In [5], an IoT-based Security System for Fire Monitoring and Prevention in Tanzanian Industries was developed. Their work involved an in-depth exploration of existing fire monitoring and prevention systems, followed by the design and development of an innovative security system aimed at early fire monitoring and prevention within Tanzanian industries. This system harnessed emerging technologies like Wireless Sensor Networks (WSN) and the Internet of Things (IoT).

In [6], An IoT-Based Fire analysis and Manipulation System using Decision Trees and Fuzzy Inference was developed. They focused on creating a smart fire manipulation

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system that could respond based on flame detection. The goal was to enable the implementation of a system that promotes the intelligent development of societies. An IoT-based system for the early detection of forest fires using the Multi-Layer Perceptron (MLP) and the Advanced Relative Operating Characteristic (AROC) method was presented in [7]. The researchers identified certain limitations in existing methods, such as false alerts, delayed notifications, and issues with network coverage. Their model achieved an impressive accuracy rate of 90%, surpassing the performance of fuzzy logic and average consensus algorithms, and thereby enhancing the reliability and effectiveness of early forest fire detection.

III. DESIGN METHOD

The System composed of hardware, cloud-based model and mobile app. Bottom-up design approach was used to implement the IoT hardware and agile methodology deployed for the model and mobile app. The complete diagram of the system is shown in fig. 1.

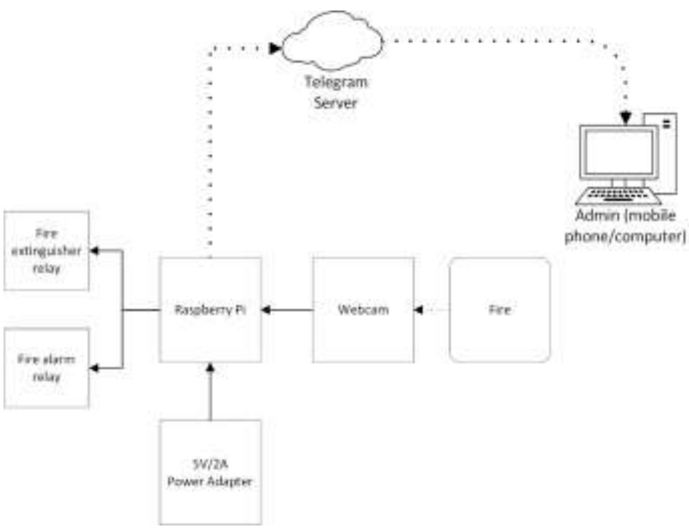

Fig.1: Block diagram of IoT-Based Fire Recognition System

A. IoT Hardware System

The IoT hardware unit comprises of power supply, input, control, and output units.

Power Supply: the power supplies provides +5V DC to the raspberry Pi board for its operation.

Sensor: the smoke sensor used to detect smoke in the environment and send signal to the controller for necessary action.

ESP 32 cam: is used as an input device to the system to capture the fire image from the surrounding. The image is then processed using the program installed before it is sent to the cloud for identification.

Control unit: This unit controls the activities of the system. It uses raspberry Pi model 3B+ to achieve it. The control unit works under the control of program and gives command to all other peripheral devices connected to the system.

16 x 2 Liquid Crystal Display (LCD): the device is used to display information processed by the controller to the user like monitoring, fire detected during operation.

B. System circuit diagram

The circuit diagram of the system consists of power supply module, buzzer, 12v DC connector jack, LEDs, soft push switch, resistors etc. and interfaces to other modules such as Raspberry PI, and LCD shown in fig.2.

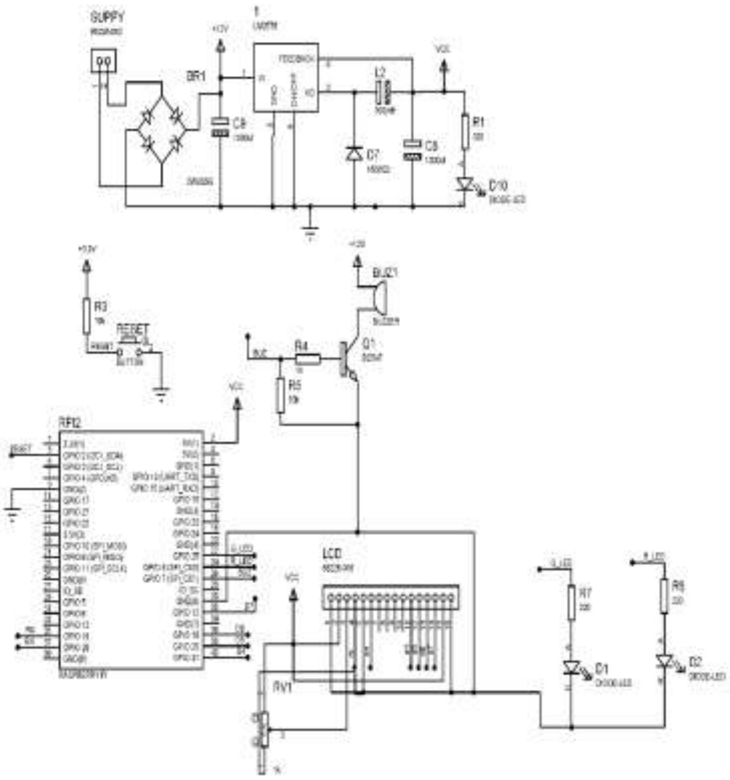

Fig.2. System Circuit diagram

The printed circuit board of the system is shown in fig.3

Fig.3. System Printed circuit board

C. IoT Prototype System and its operations

Once the switch of the system is depressed, the raspberry Pi boots with its green power indicator ON and its green status LED flahing. As the raspberry Pi boots, it loads the program embeded in the its memory for the operation of the system. The LCD in turn displays information which helps the user understand the onging activities. During boot up, the LCD displays initilizing which indicates that the system is trying to

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connects to availble wifi, recognises the camera and loads the google cloud application credentials. Upon recognising the camera, the LCD displays system monitoring. At this point the system begins to monitor the evironment through the sensor feed and camera. When sensed smoke, the ESp32 cam takes the picture of the images and sends to the cloud server where the trained model processes and predict the image. Upon the recogntion of a fire image, an alarm and water pump are activated. The pump sprinkle water to the detected fire until it goes off. Once the fire threat is put off, the alarm, the pump, go off and the system goes back to its monitoring mode and the process continues (fig.4).

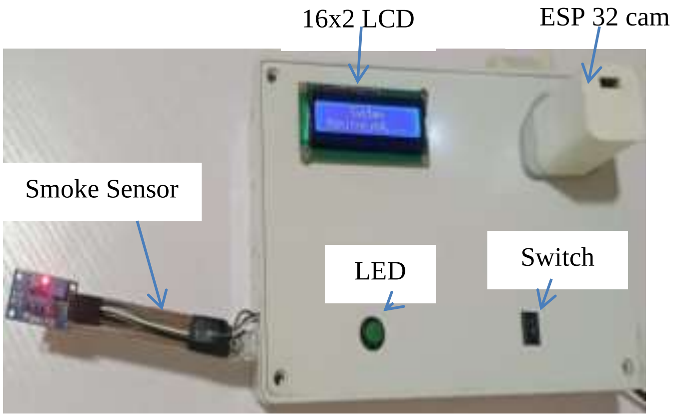

Fig.4. the smoke detection and fire recognition system

D. System Algorithm and Flow chart

The following algorithm is used by the system to monitor, detect, alert and activate pump:

Step1: Start and activate WI-FI and connect to the Router/Hotspot
Step 2: Read from sensor and camera
Step 3: is motion detected?
Step 4: Yes, capture image and send to the Google cloud for processing and go to step 6
Step 5: No, go back to step 2
Step 6: Google Cloud process the image and check if hazard is detected
Step 7: If yes, trigger alarm, send SMS and active water pump and goto step 9
Step 8: if No, delete the image and go back to step 2
Step 9: delete image and check if the fire is off
Step 10: yes, go to step 2.
Step 11: No, goto step 7
Step 12: Stop

The system flowchart is shown in fig.5.

E. Google Platform

The Google cloud platform is configured based on the block diagram shown in fig.6.

The raspberry PI sends the captured image to the Google cloud. The image is stored in the Google cloud bucket. At this point, the hyper parameter tuning is done and the algorithm re-trained for prediction. After training, the model is deployed and tested for prediction.

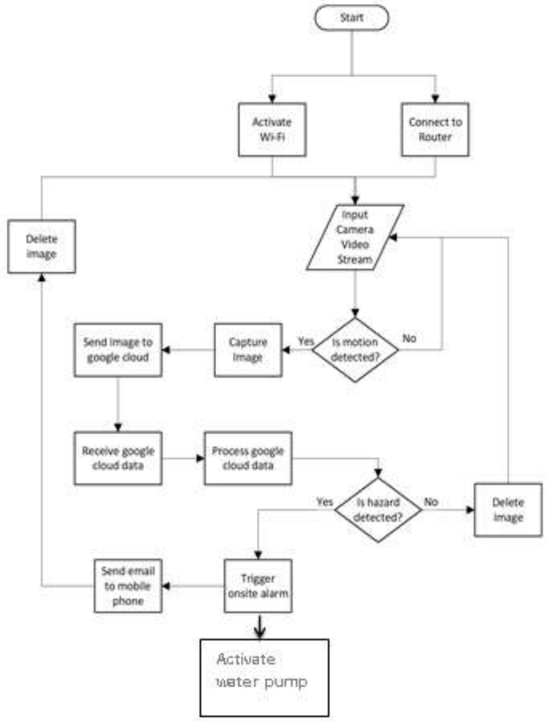

Fig.5. the system flowchart

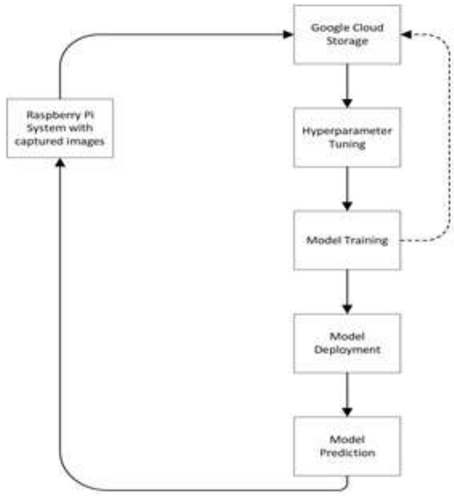

Fig.6. Block diagram of Google cloud prediction processes

Prediction Process involves retrieval of stored images from the Google bucket for further processing. The system performs hyper parameter tuning to find the optimal parameters for learning algorithm. Then, training the algorithms to learn fire images for accurate predictions is carried out and the model prediction analyzes performed on real time images and predicts the image.

IV. RESULTS OBTAINED

The system was setup and tested in order to measure the accuracy of the system. Two main types of threat were used to run these tests; picture of a fire and actual fire using a gas lighter and paper set on fire. Both objects were used to simulate a fire outbreak.

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A. *Image Detection Test*

The system is powered ON to test its accuracy. A lighter was lit and placed in front of the camera. The camera detected an object, snaps the image, and sends to the raspberry pi which processed and sent to the Google cloud for further processing. The following conditions were used for fire hazard detection during testing:

i. Recognition in a well-lit environment when object is at a close distance (<100cm)
ii. Recognition in a well-lit environment when object is at mid distance (100cm<x<500cm)
iii. Recognition in a well-lit environment when object is at a far distance (>500cm)
iv. Recognition in a dark environment when object is at a close distance (<100cm)
v. Recognition in a dark environment when object is at a mid-distance (100cm<x<500cm)
vi. Recognition in a dark environment when object is at a far distance (>500cm)
vii. False positives in a well-lit environment
viii. False positives in a dark environment

B. *Telegram bot Test*

In order to view the detected image, telegram bot was configured and used as shown in fig.7. The results obtained are as follows:

i. A = Recognition in a well-lit environment when object is at a close distance
ii. B = Recognition in a well-lit environment when object is at mid distance
iii. C = Recognition in a well-lit environment when object is at a far distance
iv. D = Recognition in a dark environment when object is at a close distance
v. E = Recognition in a dark environment when object is at a mid-distance
vi. F = Recognition in a dark environment when object is at a far distance
vii. G = False positives in a well-lit environment
viii. H = False positives in a dark environment

Fig.7: Image detection test

C. *Hardware test*

Voltage Test: The V_{out} and ground pins were tested using digital multi-meter to ensure that it supplies the power required, that is 5V and 0V for good functionality.

Continuity Test: After components are soldered to the Vero board, a meter which is set to continuity is used to check if the cables are continuous and also to see if there is any short circuiting in the system.

Camera Test: The brightness and quality of the raspberry camera was tested in various room light conditions to ensure accurate when hazard is detected. The results varied in different brightness levels. The testing result obtained is shown in fig.8

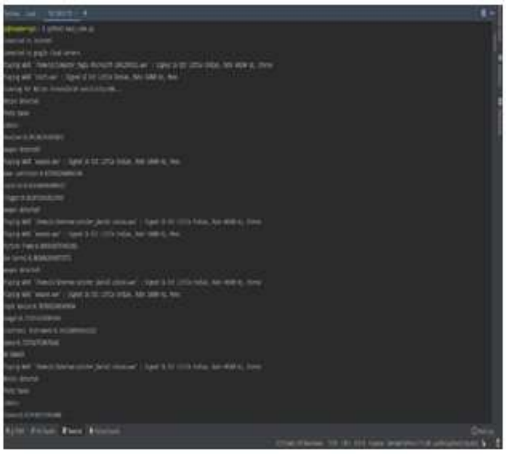

Fig.8: The System response during testing

The percentage accuracy for various conditions of test conducted is shown in table 1.

Table 1: Success rate of fire detection system

S/N	Test Condition	No. of Accuracy	No. of Failure	Percentage Success (%)
	Recognition in a well-lit environment when object is at a close distance	145	5	96.67
2	Recognition in a well-lit environment when object is at mid distance	144	6	96.00
3	Recognition in a well lit environment when object is at a far distance	140	10	93.33
4	Recognition in a dark environment when object is at a close distance	146	4	97.33
5	Recognition in a dark environment when object is at a mid-distance	144	6	96.00
6	Recognition in a dark environment when object is at a far distance	135	15	90.00
7	False positives in a well-lit environment	150	0	100.00
8	False positives in a dark environment	150	0	100.00

V. CONCLUSION

Cloud-based hazard detection using image processing for home security has been successfully implemented on the

Raspberry Pi Single Board Computer. This system can be further industrialized and made to work in companies as their means of security to detect and classify situations that could pose a threat. Furthermore, it can be used to securely log the data goings-on in a particular place at a specific time. From the tests and the results carried out, it can be deduced that the hazard detection performed best in well-lit scenarios and scenarios in close proximity to the camera. The response time of this module is relatively fast.

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