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# Long Range (LoRa) and Alert Network System for Forest Fire Prediction

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**Abstract:** Forest fires are a regular occurrence throughout the year with an increasing intensity in the summer and fall periods. Forest fires pose a significant threat to ecosystems, property and human lives. Early detection and rapid response are critical to mitigate the devastating effects of these fires. This article presents a Long Range (LoRa) Alert Network System designed for the early prediction and timely notification of forest fires. The system leverages LoRa technology to create a robust and cost-effective wireless communication network in remote forested areas. These fires primarily stem from various natural and environmental phenomena and natural disasters. The timely dissemination of forest fire alerts was hampered, resulting in delays in fire management. In order to address this issue, efforts were made to enhance the capability for prompt forest fire detection. The challenges predominantly revolve around forested regions where data communication infrastructure is deficient. In the event of a forest fire, there exists a network barrier that impedes information transmission. Consequently, forest fire detection systems leveraging Mesh LoRa networks and image processing networks have been devised. An integrated module within the LoRa/GPS HAT has been explored as a potential solution to the fire predicament. The Flame Sensor Module, functioning as a fire detection sensor component, and the LoRa/GPS HAT, serving as a hardware medium for radio frequency data transmission communication, have been employed. The interconnection of these devices within a network facilitates the development of a prototype fire detection system. Combining a Flame Sensor Module with a LoRa/GPS HAT is indeed a viable approach to creating a prototype fire detection and alert system. By combining the Flame Sensor Module with the LoRa/GPS HAT, a scalable and cost-effective fire detection and alert system appropriate for distant and wooded locations with limited traditional communication infrastructure is created. This system can play a crucial role in early fire detection, potentially reducing the severity of forest fires and protecting both natural resources and human lives.

**Key words:** Early forest fire detection, LoRaWAN, sensor network, unmanned aerial vehicles, drone.

## Introduction

For the underlying timberland fire identification, a productive and robust vision-based smoke recognition calculation is required. Forest fires, while often destructive, play significant ecological and environmental roles that are important for maintaining the health and balance of forest ecosystems. It’s important to note that while forest fires have ecological importance, uncontrolled and human-caused wildfires can have devastating consequences, including loss of life, property and natural resources. Therefore, managing and preventing wildfires remains a significant challenge, and efforts are made to strike a balance between the ecological benefits and the need to protect human interests and safety. While timberland fires pose a

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significant challenge to both human safety and the natural ecosystem, their uncontrolled spread can have a profound impact on extensive areas. Response time plays a crucial role in determining the effectiveness of forest fire containment efforts. Conversely, extensive research has been conducted on photoelectric or ionisation-based smoke detectors. These sensors, however, are constrained by their operation as point sensors in space, rendering them unsuitable for monitoring larger areas, such as early forest fire detection. The limitations of current smoke detectors have spurred investigations into vision-based smoke detection methods. This study introduces a fire detection and alert system based on LoRa (Long Range) communication and image processing techniques. In this system, a well-defined environment is continuously monitored 24×7, and users are alerted in the event of any critical situation. This monitoring is achieved through the use of a NodeMCU and a variety of sensors and detectors capable of sensing various physical parameters that may escalate during a fire incident. Arduino, an Internet of Things (IoT) based controller board, is employed to constantly monitor two key parameters: temperature and the presence of smoke. A wildfire is characterised as a highly energetic and uncontrollable fire that inflicts severe damage on both the natural environment and human resources. Upon ignition, it rapidly propagates throughout the forest, leading to extensive devastation.

Another researcher by the name of Kaushik Ghosh introduced a project titled 'Detection and Reporting of Forest Fires via Deployment of Three-Dimensional Multi-Sink Wireless Sensor Networks.' Forest fires represent a recurrent phenomenon during the summer months worldwide in 2018, necessitating the adoption of a robust forest fire detection methodology to assess fire propagation and mitigate associated losses. In this study, we have initiated an energy-efficient forest fire detection method and reporting mechanism by leveraging the three-dimensional spatial positioning of multi-sink wireless sensor networks. This methodology can be employed in event-driven, time-driven, or a proposed hybrid operational mode. The results of our proposed approach have been compared with the three-dimensional variants of well-established routing protocols for sensor networks. Our approach draws upon techniques within the domains of Wireless Sensor Networks, Forest Fire Dynamics, Fermat Point Localisation, Energy Efficiency Optimisation, and Network Lifetime Extension.

In 2018, Guilherme Borba Neumann and Markus Endler introduced a project titled "Smart Forests: Fire Detection Service," which elucidates the concept of "Smart Forests" originating from the Internet of Things (IoT). Smart Forests entail the utilisation of remote sensing within specific forest regions to gather environmental data. A primary objective of Smart Forests is the early detection of wildfires. Traditional monitoring technology for this purpose typically necessitates intricate and costly sensor systems, an extensive network infrastructure, and centralised processing capabilities for the analysis of data collected from numerous sensors. The primary objective of this undertaking is to propose an Edge Computing solution by leveraging the concept of "Mobile Hubs" (M-Hubs). These M-Hubs integrate various techniques encompassing Forestry, Temperature Sensing, Fire Detection, Humidity Monitoring, Server Infrastructure, and Edge Computing, among others.

Jayaram and Muralidharan (2019) introduced a novel paradigm for a Forest Fire Alerting System utilising IoT and GPS coordinates. In our dynamic contemporary world, it becomes imperative to fortify the ecological domain. The globe is witnessing numerous instances of both anthropogenic and natural disasters. Among these, forest conflagrations represent a formidable environmental catastrophe. Once ignited within a densely wooded area, a forest fire manifests a vigorous and extensive propagation, inflicting significant devastation upon the forest ecosystem. The fire's proliferation results in the destruction of arboreal and herbaceous vegetation, particularly exacerbated by escalating arid conditions within the forest region. Curtailing such occurrences of forest fires becomes imperative for the preservation of biodiversity and the ecological equilibrium within these wooded habitats.

A new generation of methods for the initial identification and prevention of forest fires has been made possible by the ongoing advancement of knowledge and communication technology. In recent years, networks of cameras, sensors, and even satellite-based systems have been developed and deployed for use. The direct involvement of humans in the forest fire detection process has been significantly decreased as a consequence of these resolutions. This system operates through the use of LoRA technology and Image Processing Technique, which supports networking, real-time analytics, reporting, and other functions such as geolocation. A specific environment is monitored 24 hours a day, seven days a week, and the user is notified in the event of a catastrophic scenario. This objective can be achieved through the integration of a NodeMCU microcontroller and a suite of sensors designed to detect various physical parameters that may exhibit abnormal behaviour in the event of a fire-related incident. Specifically, we continuously monitor two critical parameters: temperature using an LM35 temperature sensor, and the presence of smoke through an MQ6 gas sensor. In the event of sensor malfunctions or improper configuration, electronic surveillance cameras are deployed as a failsafe mechanism. These surveillance devices encompass a diverse array of technologies, including Closed-Circuit Television (CCTV) systems, wireless camera networks, and even Unmanned Aerial Vehicles (UAVs).

## Early Forest Fire Detection Using LoraWAN Sensor Networks and Devices

Due to their long-range communication potential, the Long Range (LoRa) digital wireless communication technology and other LoraWAN networks are particularly well suited for sensor and telemetry applications. These networks are ideal for many new applications due to their increased range, such as the detection of forest fires, environmental sensing, and long-term research on air quality. By reaching a range of more than 15 kilometres in the suburbs and more than 2 kilometres in congested urban areas. Figure 1 depicts the operation of the LoRa module.

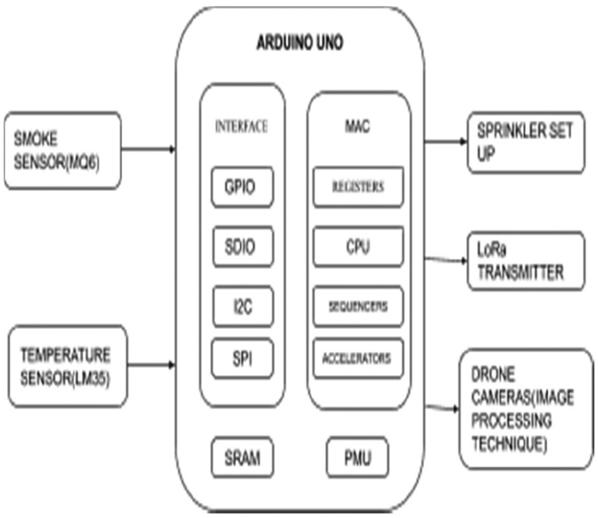


**Figure 1: Working of LoRa module.**

The schematic depicting the transmitter and receiver modules in Figure 2 illustrates an Arduino serving as the core component of the overall system. The Arduino is the central hub to which all other elements are interconnected, as delineated in the provided diagram. The system incorporates three distinct sensors: a temperature sensor, a smoke sensor, and a Passive Infrared (PIR) sensor. These sensors are responsible for the continuous monitoring of two critical parameters: temperature levels and the presence of smoke.

To monitor ambient temperature, an LM35 temperature sensor is employed. To detect the presence of carbon-based gases, an MQ6 gas sensor is utilised, exhibiting the capability to identify and quantify such gases. Additionally, a Passive Infrared (PIR) sensor is incorporated to ascertain human presence. In the event of fire detection, an automated sprinkler system equipped with fire-suppressant agents is activated to extinguish the flames. Simultaneously, a notification is dispatched to authorised personnel for prompt supplementary response.

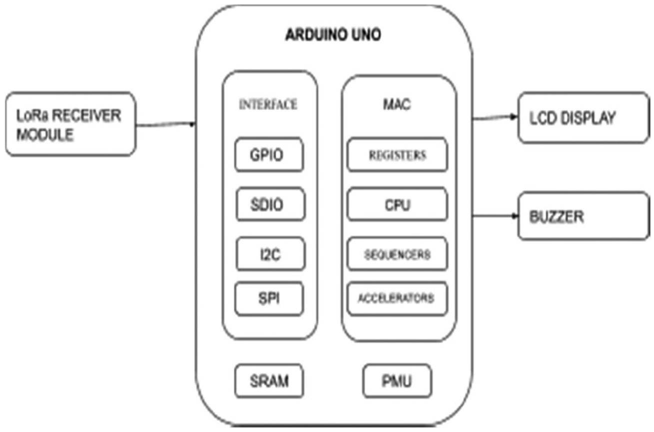


**Figure 2: Block diagram of the transmitter module and receiver module.**

## Early Forest Fire Detection Using Image Processing Technique

The opportunity to use automated flying vehicles (UAVs) against forest fires rather than directed airplanes was made possible by the present advancements in their development. Different types of UAVs were deployed throughout the year and malfunctioned as a result of early forest fire recognition (Figure 3).

Our initial approach involves the identification of the spectral characteristics associated with fire, typically dominated by a reddish hue. Subsequently, we employ Sobel edge detection on the initial image frame, which has been freshly acquired, to delineate the contours of the fire while filtering out edges with gradient magnitudes below a threshold of 100. Following this, we execute a segmentation process that integrates the outcomes of the aforementioned first and second methodologies to effectively partition the

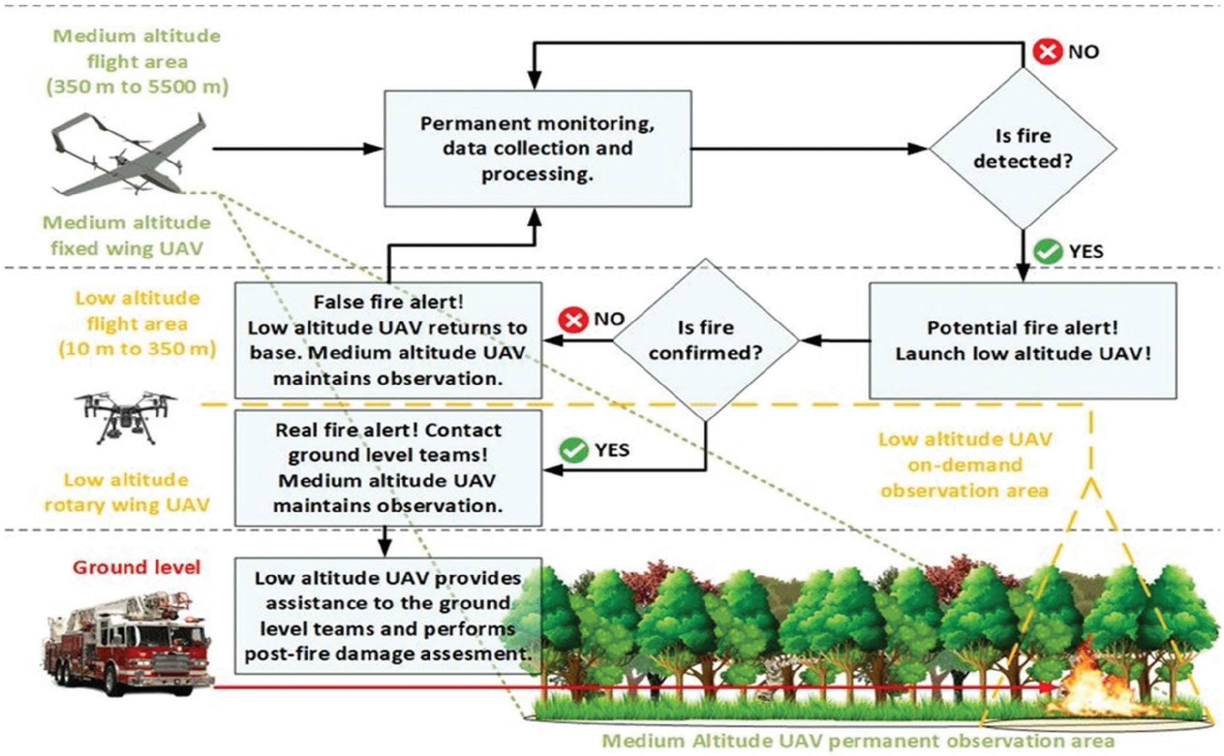


**Figure 3: Early forest fire detection system conceptual model using both fixed-wing and rotary-wing UAVs.**

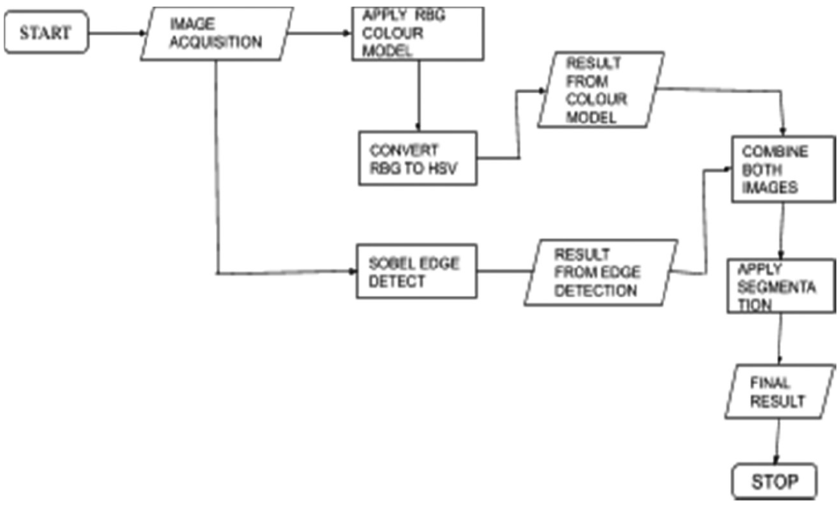


**Figure 4: Flowchart of algorithm.**

Region of Interest (ROI) pertaining to the fire from the surrounding background. For a more comprehensive understanding of the algorithm, please refer to Figure 4, which provides a detailed explanation.

### Image Acquisition

Image acquisition is a fundamental process for generating high-quality visual data. It involves the utilisation of an image sensor and the requisite signal digitisation capability. The image sensor employed in this context can take the form of either a monochromatic or colour television camera, which captures a complete image of the target area at a frequency of 1/30 second. Alternatively, a line-scan camera may be employed, which captures a single line of the image at a specific moment in time, necessitating synchronisation with the object's motion along the line. Scanners, in particular, are instrumental in producing two-dimensional images. To facilitate integration into digital systems, an analog-to-digital (A2D) converter is employed to convert the camera's output or that of other imaging devices into a digital format. The output must remain exclusively in digital form. The characteristics of the sensor and the resulting image are intrinsically linked to the specific application at hand.

**Image Enhancement**

Image enhancement is one of the least complicated, easiest, and most intriguing areas of sophisticated image processing. In general, the major goal of these enhancement procedures is to bring out all of the subtleties that have been secured or to highlight certain aspects of an image.

**Image Restoration**

Image restoration pertains to a domain concerned with ameliorating the visual fidelity of an image. In contrast to enhancement, which possesses a subjective nature, image restoration is characterised by objectivity, where restoration methodologies are typically rooted in mathematical or probabilistic models of image degradation. Enhancement, conversely, hinges on human subjective preferences regarding what constitutes a "desirable" enhancement outcome. For instance, contrast adjustment is deemed an enhancement technique as it primarily seeks to offer pleasing visual attributes to the observer, while the elimination of image blur through the application of a deblurring function is considered a restoration technique.

**Colour Image Processing**

Two major factors influence the use of shading in image processing. To begin, shade is an excellent descriptor that typically helps item identification and extraction from a scene. Second, individuals can distinguish a large variety of shading hues and forces, as opposed to just approximately two dozen dark shades. This next component is extremely important in manual image inspection.

**Segmentation**

Segmentation methodology involves the partitioning of an image into its constituent regions or objects. In the realm of digital image processing, autonomous segmentation stands out as one of the most challenging tasks. Employing a rudimentary segmentation approach significantly advances the process of successfully addressing imaging problems requiring the individual identification of objects. Conversely, the utilisation of weak or unpredictable segmentation algorithms almost invariably guarantees eventual failure. In essence, the higher the precision achieved in segmentation, the greater the likelihood of successful object recognition.

Digital images are formally defined as two-dimensional functions, denoted as $f(x, y)$, where $x$ and $y$ represent spatial (planar) coordinates. The magnitude of $f$ at any given pair of coordinates $(x, y)$ is referred to as the intensity or grayscale value of the image at that particular point. The field of digital image processing pertains to the manipulation and analysis of digital images using a digital computer. A digital image consists of a finite number of components, each possessing a specific location and value. These components are referred to as picture elements, image elements, pels, or pixels, with "pixel" being the most commonly used term.

**Image Compression**

Advanced image compression addresses the challenge of reducing the data required to represent a digital image. The fundamental principle behind the compression process involves the elimination of redundant information. From a mathematical standpoint, this entails transforming a 2D pixel array into a statistically uncorrelated data set. The concept of data redundancy is not abstract but rather a quantifiable mathematical entity. In the event that n1 and n2 signify the quantity of data conveying units in two informational indexes that speak to similar data, the relative information repetition DR of the principal informational collection (the one described by n1) can be characterised as,

$$R = 1 - \frac{1}{R}$$

where RC is called as compression ratio. It is defined as

$$C = \frac{n_1}{Rn_2}$$

In the field of image compression, three fundamental types of information redundancies are identified and exploited: Coding redundancy, spatial redundancy, and psycho-visual redundancy. Image compression is achieved through the reduction or elimination of one or more of these redundancies. Image compression primarily finds applications in image transmission and storage. Applications for image transmission include broadcast television, remote sensing via satellite, aerial, radar, or sonar platforms, video conferencing, computer networking, and facsimile transmission. Picture stockpiling is required most usually for training (Figure 3).

## Conclusions

The main strategies for avoiding unfathomable catastrophes are early warning and prompt action in the event of a fire outbreak. Thus, swift and forceful recognition and obstruction of the flames are the most fundamental goals in fire perception. When the origin of the fire is identified and you keep in mind that it is still in its early stages, it is much easier to put it out. Information on the spread of fire is like manner significantly gainful for dealing with the fire in all of its stages. Considering this information, the firefighting crew might be directed to put out the fire before it causes social heritage objections and to put it out completely. In this manuscript, we have expeditiously introduced two novel methodologies for the early detection of fires in wooded areas, encompassing their inherent attributes and fundamental components. We have propounded a fire detection algorithm grounded in image processing techniques. The algorithm leverages the RGB colour model to discern the chromatic characteristics of the fire, primarily emphasising the intensity of the red component (R). The fire's propagation is ascertained through Sobel edge detection. Ultimately, a colour-based segmentation technique was applied, predicated on the outcomes derived from the initial and secondary methodologies, to delineate the Region of Interest (ROI) corresponding to the fire. The algorithm exhibits commendable efficacy, particularly during instances of wildfire outbreaks. LoRa (short for long range) is a spread range tweak strategy derived from trill spread range (CSS) innovation" by Semtech. It is a remote adjustment innovation with low force utilisation and successful long-extend ability. It can accomplish a range of up to 15 km while expending next to no power (100 mW consistent RF yield @3.3V, in light of Semtech SX1276), and it is planned explicitly for M2M and IoT networks.

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