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Early fire hazard risk management model in urban environments : Leveraging optimized deep learning techniques

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Abstract

The rapid growth of IoT technology has revolutionized smart city applications, improving societal functionalities. This integration offers real-time applications for predicting crime events, monitoring environmental conditions, and managing health. However, current IoT-based smart city implementations face challenges in technological capacity and skill readiness. To address this, they propose a framework combining RNN with ALO to predict fire hazard risks early. IoT sensor devices are deployed across smart cities to monitor environmental conditions like drought code, temperature, and humidity. Data is securely stored in Firebase for processing with MATLAB. The model's effectiveness is validated against conventional methods, demonstrating superior accuracy and minimal

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errors. This framework addresses technological challenges and offers promising outcomes in predicting and mitigating fire hazards through advanced data analysis.

Subject Classification: *68T07.*

Keywords: *Internet of Things, Smart city, Management sciences, Urban environments, Drought code, Temperature, Smoke, Flame, Relative humidity, Fuel moisture, Duff moisture code, Fire hazard.*

I. Introduction

Fire accidents are on the rise, posing serious threats due to urbanization and population growth in smart cities [1]. IoT technology aims to enhance efficiency and security in smart city environments but faces challenges like limited storage and processing capabilities [2-4]. Sensors are the foundation of conventional fire detection systems and may produce false alarms. Infrared or ultraviolet detectors are effective but can be disrupted by environmental factors [5]. While satellite remote sensing detects large-scale fires, it struggles with early-stage detection [6-8]. Densely populated urban areas face unpredictable risks, necessitating early fire detection systems. Smart city developments include IoT integration in waste management and smart building systems [9]. However, there's a critical need to predict and respond to fire outbreaks, especially wildfires, to mitigate disasters. The subsequent sections review existing works, present the problem statement and system model, detail the proposed methodology, analyze the platform, and conclude with future scope [10-13].

II. Problem statement and system model

Figure 1 demonstrates the model for IoT-based smart cities, emphasizing their role in improving urban life quality [14]. Smart cities prioritize security and resilient infrastructure to tackle environmental

Figure 1

System model for IoT-based smart cities

challenges like pollution, weather variations, and chemical exposure. With the rise of high-rise buildings, fire safety becomes crucial to prevent material and human losses [15-17]. Climate change exacerbates fire risks, increasing the occurrence of tragic incidents.

Timely response to fire hazards is critical in smart cities due to heightened urban activities and traffic [18-20]. Delayed interventions can worsen the situation. However, existing fire protection systems often struggle to meet the rigorous standards for smart city fire safety, leading to a research focus on early detection and mitigation of fire hazards.

III. Proposed methodology

This section provides a full explanation of the proposed RNN-ALO framework, which is displayed in Figure 2. The developed model consists of five steps such as IoT device deployment, cloud storage system, data receptor, sensed dataset and prediction model. Here, the IoT device is the important component to sense the various environmental properties like Flame, smoke, temperature, relative humidity (RH), duff moisture code, fine fuel moisture code, and drought code. Here, the IoT sensors are connected through the cloud storage system. Moreover, the Firebase cloud storage system is used to store the sensed data.

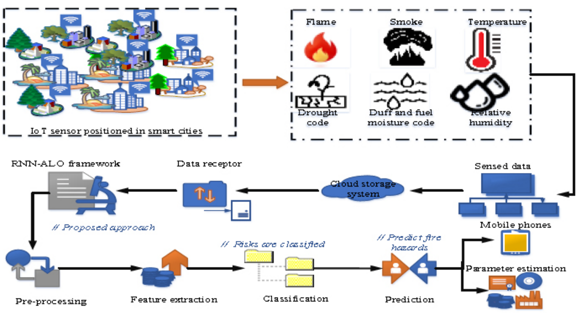

Figure 2

Proposed model

Then, the data receptor is used to process the further processing for extracting the relevant information using a heuristic strategy. Finally, based on the proposed model can efficiently detect the fire hazard from the sensed information. The key purpose of this study is to create a structural design for the prediction of fire risks across smart cities. Moreover, the silent features of the developed RNN-ALO early fire prediction model are mentioned as follows, fire prediction using IoT and optimization techniques. Then collect the several real-time environmental conditions and validate the fire risk events using optimization techniques. Finally, an alert signal or warning message is sent back to the mobile nodes.

- Sensor deployment
- Cloud storage system
- Workflow RNN
- Process of ALO

IV. Result and discussion

The developed technique implementation is done in MATLAB framework and the efficacy of the suggested model is to prove the efficiency. Moreover, the method predicts the fire hazard risk from the collected dataset. Therefore, the recommended testing module is to improve the classification accuracy of the entire system. For, the implementation Kaggle dataset was collected to predict the fire hazards. The main motive of this work is to predict the early fire risk caution prediction model for evaluating the accurate locations of fire in smart cities with the help of sensed data. Moreover, the simulation parameters are enclosed in Table 1. Figures 3, 4, and 5 show the training accuracy, humidity and flame values. Figures 6, 7, 8, 9 and 10 show the smoke value, drought code, drought moisture code, temperature value, and fine fuel moisture code.

Table 1

Simulation parameters

Sr. No	Parameters	Values
1	Input dimension	9
2	Output dimension	5
3	Learning optimizer	ALO
4	Initial weight	[0,1]
5	Internal layer unit	LSTM unit
6	Initial bias	Nil
7	Error function	Cross entropy

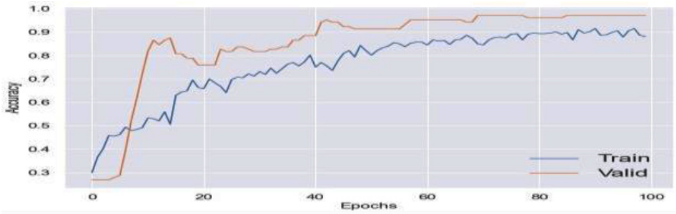

Figure 3

Training and validation accuracy

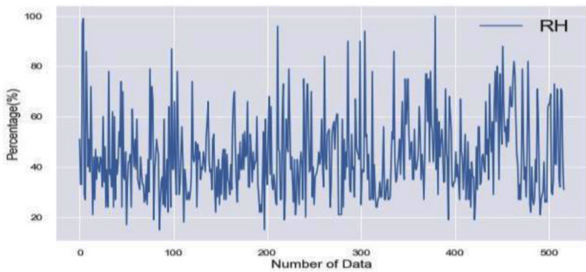

Figure 4

Relative humidity

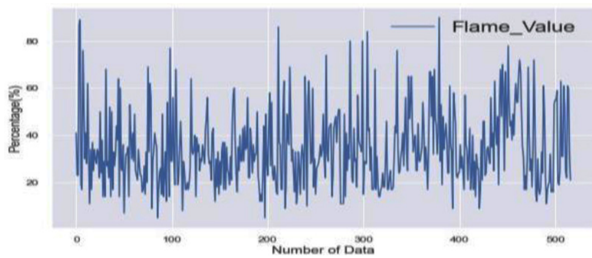

Figure 5

Flame values

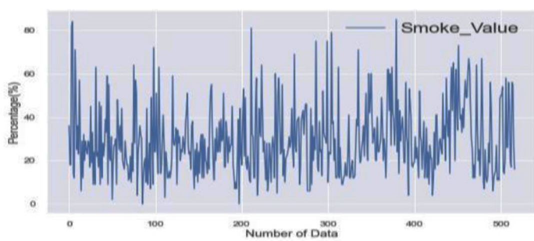

Figure 6

Smoke values

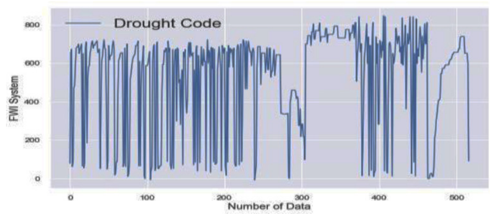

Figure 7

Drought code

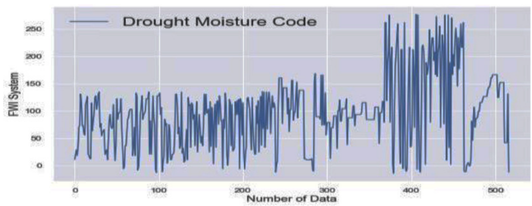

Figure 8

Drought moisture code

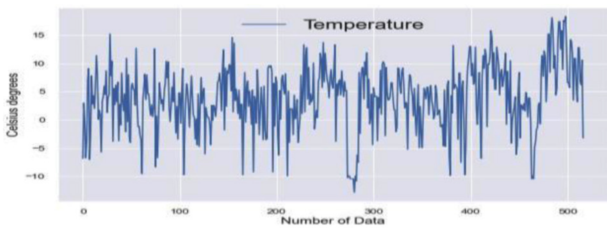

Figure 9

Temperature value

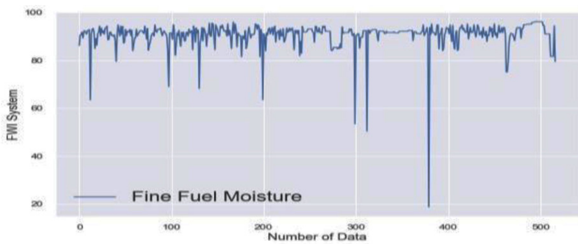

Figure 10

Fine fuel moisture code

- **Performance comparison**

Figures 11, 12, 13 and 14 show the overall performance of the proposed system.

- **Accuracy**

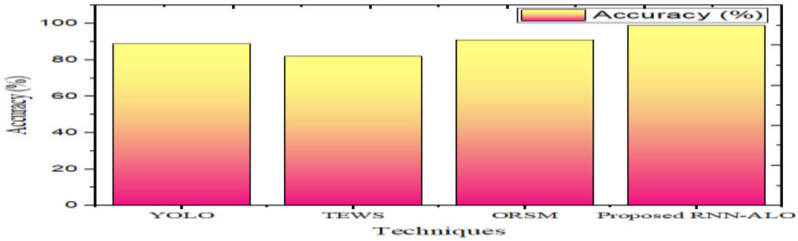

Figure 11

Performance comparison of accuracy

- **True positive rate**

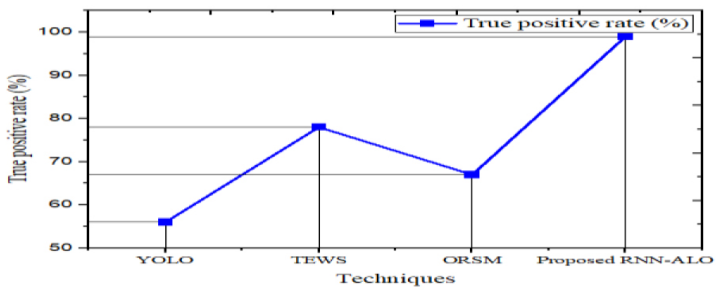

Figure 12

Performance comparison of true positive rate

- **False positive rate**

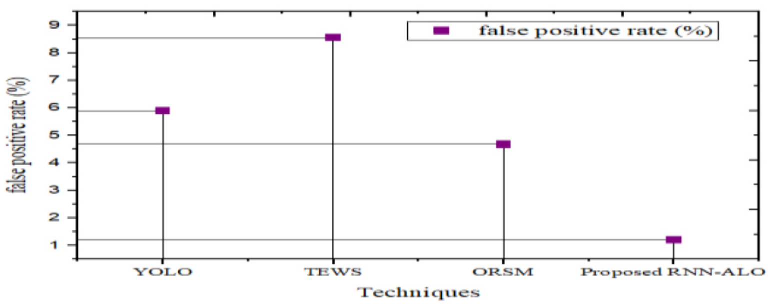

Figure 13

Comparison performance of false positive rate

- **Error rate**

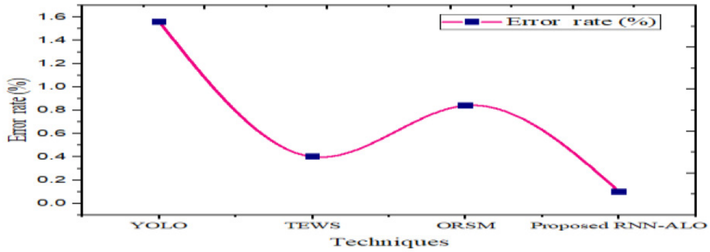

Figure 14

Comparison performance of error rate

- **Discussion**

The propped design achieves a very strong interaction module and sensors through the application for exploring, separating, and collecting the detected data for independent direction. The design gives a uniform answer for the recognition of a fire occasion in the beginning phase utilizing sensors and IoT. The simulation outcomes for the key metrics are compared with conventional models. Table 2 shows the overall performance of the system.

Table 2

Overall performance

Sr.no	Techniques	Accuracy	TPR	FPR	Error rate
1	YOLO	89	56	5.89	1.56
2	TEWS	82	78	8.56	0.4
3	ORSM	91	67	4.67	0.84
4	Proposed RNN-ALO	99	99	1.2	0.1

V. Conclusion

Globally, concerns over fire hazards persist, driving research into early prediction methods. Existing approaches face challenges in achieving accurate predictions. This article introduces the RNN-ALO model, deploying sensor devices in smart cities to gather real-time fire risk data. Developed using Matlab, the model shows significant improvement, with an 8 to 10% increase in prediction accuracy compared to existing methods. These results highlight the model's effectiveness in enhancing early fire hazard predictions.

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