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AN INTELLIGENT MODEL FOR PREDICTING FIRE RISK IN RESIDENTIAL HOUSEHOLDS BASED ON ARTIFICIAL INTELLIGENCE

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Abstract: Residential fires remain a major threat to human life, property, and public safety. Most conventional fire safety systems are designed to detect fire after ignition, limiting their preventive capabilities. This study proposes an intelligent model for predicting fire risk in residential households based on artificial intelligence. The model integrates data from temperature, smoke, gas, humidity, and electrical sensors to assess fire hazards before ignition occurs. By analyzing multiple risk indicators simultaneously, the proposed approach enables early warning, supports preventive measures, and contributes to reducing fire-related losses. The study highlights the practical potential of artificial intelligence in strengthening residential fire safety and emergency management.

Keywords: artificial intelligence, fire risk prediction, residential safety, smart sensors, emergency management, fire prevention.

1. Introduction

Fire incidents in residential buildings continue to pose serious challenges to emergency management agencies worldwide. Every year, thousands of people lose their lives, suffer injuries, or experience significant property damage because of preventable fires. In many cases, fires occur due to electrical faults, gas leaks, overheating appliances, human negligence, or the absence of early warning mechanisms (National Fire Protection Association, 2024).

Traditional fire alarm systems are effective in detecting smoke or heat after a fire has already started. However, they rarely provide information about hazardous conditions that exist before ignition. As a result, emergency response often begins only after damage has occurred (Kim & Lee, 2021).

Recent advances in artificial intelligence, sensor technologies, and data analytics have created opportunities to shift from reactive fire response to proactive fire prevention. Artificial intelligence systems are capable of processing large amounts of data, identifying hidden patterns, and recognizing conditions associated with increased fire risk (Li et al., 2024).

From the perspective of emergency management, the ability to predict fire hazards before ignition is significantly more valuable than detecting a fire after it has already developed. Early prediction allows homeowners, emergency services, and local authorities to take preventive actions and eliminate dangerous conditions before they result in disasters.

The purpose of this study is to develop an intelligent model capable of predicting fire risks in residential households using environmental and technical indicators. The proposed model is intended to support practical fire prevention efforts, improve public safety, and strengthen emergency preparedness.

2. Literature Review

The concept of predictive fire safety has gained increasing attention in recent years. Traditional fire protection systems mainly rely on smoke detectors, heat sensors, and manual inspections. While

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these technologies play an important role in fire detection, they are generally activated only after hazardous conditions have already developed (Kim & Lee, 2021).

Researchers have increasingly explored the use of artificial intelligence for risk assessment and early warning systems. According to Wang et al. (2023), machine learning algorithms can identify relationships among multiple risk factors that are often difficult for human operators to recognize. This capability enables more accurate prediction of hazardous situations.

Li et al. (2024) emphasized that intelligent monitoring systems can significantly improve preventive fire safety by continuously analyzing environmental and technical parameters. Their study demonstrated that integrating sensor networks with predictive algorithms reduces response times and enhances decision-making processes.

Despite these advancements, many existing systems focus on industrial facilities, commercial buildings, or smart-city infrastructure. Comparatively little attention has been devoted to practical and affordable fire risk prediction solutions for ordinary residential households, particularly in developing countries.

Therefore, there remains a need for an intelligent, cost-effective, and user-friendly model capable of predicting fire risks in residential environments before ignition occurs.

3. Practical Causes of Residential Fires

Analysis of fire incident reports shows that most residential fires are not caused by extraordinary circumstances but by common everyday situations.

One of the most frequent causes is electrical overloading. For example, a household may connect multiple high-power appliances such as electric heaters, air conditioners, washing machines, and electric kettles to a single circuit. Continuous overloading increases conductor temperature and gradually damages insulation materials, creating conditions favorable for fire ignition (National Fire Protection Association, 2024).

Another common cause is aging electrical wiring. In many residential buildings, wiring systems installed decades ago remain in operation despite increased energy consumption. As insulation deteriorates over time, the probability of short circuits and electrical arcing increases significantly (International Electrotechnical Commission, 2023).

Gas leakage also represents a major fire hazard. A minor leak from a cooking appliance may remain unnoticed for hours. If an ignition source is introduced, a fire or explosion may occur.

Human negligence remains another critical factor. Leaving electrical appliances unattended, charging devices overnight under unsafe conditions, or failing to repair damaged wiring can substantially increase fire risks (Garcia & Torres, 2022).

These examples demonstrate that many residential fires develop gradually through the accumulation of risk factors rather than through sudden unpredictable events.

4. Proposed Intelligent Fire Risk Prediction Model

The proposed model is designed to identify dangerous conditions before ignition occurs. Rather than waiting for smoke or flames to appear, the system continuously evaluates risk indicators and estimates the probability of fire occurrence.

The model consists of four interconnected components:

4.1 Data Collection Layer

Information is collected from sensors installed within the household, including:

- Temperature sensors;
- Smoke sensors;
- Gas leakage detectors;
- Humidity sensors;

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- Electrical current sensors;
- Voltage monitoring devices.

4.2 Data Processing Layer

Collected data are filtered and standardized to remove noise and improve analytical accuracy. This process ensures that abnormal readings do not generate unnecessary warnings.

4.3 Risk Assessment Layer

The system evaluates multiple indicators simultaneously. For instance:

- Rising electrical current;
- Increasing conductor temperature;
- Detection of gas leakage;
- Unusual smoke concentrations.

Each factor receives a weighted score based on its contribution to fire risk.

The overall Fire Risk Score (FRS) can be expressed as:

FRS = (0.30 × Electrical Load) + (0.25 × Temperature) + (0.20 × Gas Level) + (0.15 × Smoke Level) + (0.10 × Humidity Factor)

The resulting score is used to classify risk levels from Very Low to Critical.

4.4 Decision Support Layer

If the predicted risk exceeds predefined thresholds, the system automatically generates warnings and recommends preventive actions.

Examples include:

- Disconnect overloaded appliances;
- Inspect electrical wiring;
- Ventilate rooms with elevated gas concentrations;
- Contact emergency services when necessary.

5. Potential Benefits for Emergency Management

The proposed model offers several practical advantages.

First, it shifts fire safety efforts from reactive response to proactive prevention. Emergency services often arrive after a fire has already caused damage. Predictive systems help reduce the likelihood of such incidents occurring in the first place (Singh et al., 2023).

Second, the model improves resource allocation. Emergency management organizations can identify neighborhoods or residential areas with elevated fire risks and prioritize inspections accordingly.

Third, homeowners receive clear and understandable warnings. Rather than presenting complex technical information, the system translates sensor data into practical recommendations.

Finally, widespread implementation could reduce economic losses, injuries, and fatalities associated with residential fires.

6. Strategies for Practical Implementation

For successful implementation, the proposed system should be introduced gradually through cooperation among emergency management agencies, local governments, utility providers, and technology companies.

Several practical measures are recommended:

1. Installation of low-cost sensor packages in residential buildings.
2. Integration of fire-risk monitoring into smart-home platforms.
3. Development of mobile applications for household risk notifications.
4. Public awareness campaigns on fire prevention and electrical safety.
5. Pilot projects in high-risk residential districts.

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In Uzbekistan, such initiatives could be implemented through collaborative programs involving the Ministry of Emergency Situations, local authorities, and educational institutions.

7. Results and Expected Impact

The expected outcomes of implementing the proposed model include:

- Earlier identification of hazardous conditions;
- Reduction in residential fire incidents;
- Improved emergency preparedness;
- More efficient use of fire safety resources;
- Increased public awareness regarding fire prevention.

The model is particularly suitable for modern smart-home environments and can be expanded as part of future smart-city fire safety systems.

8. Conclusion

Residential fires remain a significant threat to public safety, particularly when caused by preventable factors such as electrical faults, gas leaks, and human negligence. Traditional fire detection systems provide valuable protection but generally operate after hazardous conditions have already developed.

This study proposed an intelligent fire risk prediction model based on artificial intelligence and sensor technologies. By continuously monitoring environmental and technical indicators, the model enables early identification of dangerous conditions and supports preventive intervention before ignition occurs.

The proposed approach has the potential to improve residential fire safety, strengthen emergency management capabilities, and contribute to the development of safer and more resilient communities. Future research should focus on real-world pilot implementation, integration with smart-home systems, and validation using large-scale residential datasets.

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