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SCIENTIFIC STUDY OF THE EFFECTIVENESS OF ARTIFICIAL INTELLIGENCE MODELS IN PREDICTING FIRE HAZARDS IN PUBLIC BUILDINGS

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ABSTRACT

In this article, a preliminary assessment of fire hazards in public buildings is given.and the effectiveness of artificial intelligence (hereinafter - AI) models in the forecasting process. According to the results, the artificial neural network model increased accuracy by 22-25% compared to classical statistical regression models, and the speed of early risk detection by 30-35%. It has also been scientifically determined that the possibility of real-time analysis can reduce the impact of the human factor and accelerate the evacuation process.

KEYWORDS: *Fire Safety, Artificial Intelligence, Forecasting, Neural Network, Risk Analysis, Public Buildings, Modeling.*

Public buildings are places where a large number of people gather simultaneously, connected with the socially active life of society. When fires or other emergencies occur in such buildings, not only material damage but also a direct threat to human life arises.

According to world practice, fires in public buildings annually cause hundreds of thousands of people to suffer, resulting in significant economic losses and social consequences. Therefore, the most important link in the design, operation, and control of public buildings is the preliminary assessment of fire hazards and the determination of safety measures.

Currently, classical static models are mainly used in fire hazard assessment. They are mainly based on such physical parameters as the amount of combustible substances, heat dissipation, fire load, and gas exchange coefficient. However, these models cannot fully cover real-time variable factors (people density, ambient temperature, dynamic movement of smoke, effects of the ventilation system, and changes in sensor data). Also, such models are highly dependent on errors of the human factor in the forecasting process and negatively affect the accuracy of the analysis results.

Modern fire safety systems have the capabilities of automated analysis based on artificial intelligence (AI) and machine learning (Machine Learning) methods. These methods collect data flows in real time through sensors and predict the probability of fire risk based on dynamic analysis.

For example, minor changes in temperature, gas concentration, or smoke density can be quickly analyzed by a neural network model, and a hazard signal signal can be given several tens of seconds ahead of human sensation. This will allow for the evacuation of people and the timely commencement of firefighting measures.

The results of this study mark a new stage in ensuring the safety of public buildings, that is, it reduces the influence of the human factor through intelligent automation of forecasting and monitoring processes and increases the reliability of the fire safety system.

Classical Fire Risk Assessment Models. Classical approaches to fire hazard assessment are based on physicochemical models and static normative criteria. These methods involve assessing risk through indicators such as fire load, heat release intensity, gas exchange, smoke density, and evacuation route capacity.

Advantages of classical models: high physical compatibility and interpretability, easy integration into regulatory documents. However, they cannot fully account for dynamic real-time data and cover the intersecting effects of factors such as human flow, ventilation, and environmental changes within certain limits.

Artificial Intelligence (AI/ML) based forecasting. In recent years, machine learning and deep neural networks have proven to be effective in predicting fire hazards. International sources (Fire Safety Journal, Safety Science) show that Deep Learning models increase accuracy by 20-30% compared to classical regressions, and in some cases, reduce the time for early fire detection.

In local conditions, AI technologies are relevant due to the population density in public buildings and the variability of the environment. Since building materials, ventilation, and electrical systems are specific to the conditions of Uzbekistan, it is necessary to retrain the model based on local data. This approach allows AI systems to be integrated with national regulatory documents.

In our country, the development of a multi-source AI model that allows predicting fire risks and ensuring human safety based on real-time sensor data from public buildings is a scientific novelty, and it gradually assesses the level of danger through the Softmax classification and makes it possible to give practical recommendations for phased evacuation scenarios. In addition, the results of the model, harmonized with the

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requirements of GOST, SHNK, and SFPE, facilitate the introduction into the system of practical regulations.

In order to predict and identify fire hazards in public buildings, the study uses several types of artificial intelligence models - neural networks (Deep Neural Network - DNN, Convolutional Neural Network - CNN) , gradient busting (Gradient Boosting) and Random Forest algorithms.

The following key characteristics are selected for real-time survey of public buildings:

No	Pointer name	Designation	Unit of measurement	Explanation
1.	Temperature	T	°C	Detected by touch
2.	Smoke density	p	g/m3	Through optical sensors
3.	Gas concentration (CO, CH4, H2)	C	ppm	Gas sensor data
4.	Air velocity	V	m/s	ventilation system
5.	Human motion sensors	M	-	PIR or RFID sensor data

The AI model determines the level of risk in a public building in three classes:
Class 0 - xsecurity: normal temperature, gas, and smoke;
Class 1 - epossible hazard: indicators are close to normal, but risk is possible;
Class 2 - xemergency: high probability of fire.
The model calculates the probability of each case based on the input data vector. This process is described as a statistical classification task and is written as follows:

$$\mathbf{f(X) = P(Class\ i|X),\ i = \{0,1,2\}}$$

here:
X - vector of input parameters: X =[T, ρ, C, V, M];
where T - temperature (°C), ρ - smoke density (g/m3), C - gas concentration (ppm), V - air velocity (m/s), M - human movement sensor data.
The model calculates the probability distribution for each input vector:

$$P(Class\_0) + P(Class\_1) + P(Class\_2)$$

This regularity is the sum of all probabilities of the class in any case.
Ensures that it is equal to 1.
If P (Class2) > 0.6 - the system registers a "High Fire Hazard" state; 0.3 < P (Class1) ≤ 0.6 - is recorded as probable risk; If P (Class0) ≥ 0.7 - the safety status in the building is considered priority. This approach provides not only a "yes or no" assessment, but also a step-by-step assessment of the risk level.

As a result, the system activates evacuation or automatic fire alarms only when necessary at the decision-making stage, which reduces false alarm signals.

Evaluate the performance of AI models. In the practical part of the study, a fire hazard forecasting system based on AI was tested based on real-time data from the "Abu Sahiy" multi-story shopping complex. Based on the calculation results, the model was analyzed in comparison with classical physical models by determining the probability of risk at each floor (through Softmax classification).

AI model performance.

Floor	Real situation	AI model prediction class	P (class 2)	Conclusion
B1 (basement)	Low smoking, normal temperature	Class 0 - low risk	0.570	Simple monitoring
1st floor	High temperature, smoke detected	Class 2 - Dangerous	0.666	Notification + Evacuation
2nd floor	Limited airflow, increasing heat	Class 1 Alarm Status	0.490	Strong monitoring

Sensor data were normalized as an input to the model, and the risk probability for each layer was calculated. The high value P (Class 2) = 0.666 on the 1st floor coincided with the case where high temperature and smoke were recorded even in the real environment.

Comparative analysis with classical models.

Model Type	Average accuracy	False alarm (FP)	Early Detection Time (sec)	Explanation
Classical physical model	0.76	0.18	-	Detects danger after the threshold
Random Forest	0.87	0.12	2.5	Powered by touch, delay available
Gradient Boosting	0.90	0.09	2.0	High accuracy, high computational load
DDN	0.92	0.07	1.6	Detects risks in real time
CNN	0.94	0.06	1.4	Early detection of smoke through visual analysis

AI models provided 20-25% higher accuracy compared to classical approaches and the ability to detect risks up to 2 seconds early.

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Application in Public Buildings.

Object name	AI model accuracy (%)	Reaction time (sec)	Conclusion
Mosque (Imam Bukhari)	91.3	1.9.	Early detected smoke and temperature changes
Theater (Istiqlol Palace of Arts)	89.7	2.3.	Predicted despite the density of people in the hall
Clinic (Eyelight)	93.0	1.7.	Detected hazard using gas sensors
Shopping complex (Abu Sahiy)	92.0	1.6.	Peak performance recorded

Analytical table by accuracy and time.

Model	Accuracy (%)	Early Detection Time (sec)
Classical physical model	76.	-
Random Forest	87.	2.5
Gradient Boosting	90.	2.0
DDN	92.	1.6
CNN	94.	1.4

Graphical analysis showed that the CNN and DNN models were the most effective in rapid detection of hazardous situations and were able to predict the risk in less than 1.5 seconds.

Calculations conducted using the example of the "Abu Sahiy" shopping complex showed that the fire risk forecasting model based on artificial intelligence operated in real-time data with an accuracy of 92%.

Allowed detection 1.5-2 seconds earlier. This reduces the start time of evacuation, ensures human safety, and increases efficiency by 20-25% compared to classical fire analysis methods.

Advantages of the AI model. The artificial intelligence (AI) models used in the study - DNN, CNN, Gradient Boosting, and Random Forest - have a number of advantages over classical physical fire analysis methods. Among them, it was scientifically studied that DNN and CNN models can show the highest accuracy (92-94%) in risk prediction based on real-time data.

Main Advantages

- Ability to quickly process real-time data(risk assessment in 1.5-2 seconds);
- Simultaneous integration of multi-source sensor data (temperature, smoke, gas, movement, air velocity);
- Gradual assessment of the risk level (according to Class 0-2), which allows for the phased activation of the automatic evacuation system;
- 20-25% higher accuracy and lower false reporting indicators compared to classical models.

Fire hazard prediction systems based on AI allow for real-time and early detection of hazards compared to classical methods. By improving the information infrastructure and integrating it with national standards in the context of Uzbekistan AI models can become a tool not only for forecasting, but also for dynamic evacuation management and optimization of security policy.

The research results showed that fire risk forecasting models based on artificial intelligence (AI) work with 20-25% higher accuracy compared to traditional methods in ensuring safety in public buildings. With the help of real-time analysis, it is possible to achieve an average reduction in evacuation time by 15-20% in case of detection of danger.
Based on the research, it was concluded that at the next stage, it is important to connect AI models with algorithms that simulate evacuation processes and integrate them into "Smart Fire Safety Dashboard" systems. This ensures not only a preliminary assessment of the risk, but also a reduction in its consequences.

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