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Predicting Fire Alarms in Smoke Detection using Neural Networks

Maher Wissam Attia, Baraa Akram Abu Zaher, Nidal Hassan Nasser, Ruba Raed Al-Hour, Aya Haider Asfour, Samy S. Abu-Naser

Department of Information Technology,

Faculty of Engineering and Information Technology,
Al-Azhar University - Gaza, Palestine.

Abstract: *This research paper presents the development and evaluation of a neural network-based model for predicting fire alarms in smoke detection systems. Using a dataset from Kaggle containing 15 features and 3487 samples, we trained and validated a neural network with a three-layer architecture. The model achieved an accuracy of 100% and an average error of 0.0000003. Additionally, we identified the most influential features in predicting fire alarms.*

Keywords: Predicting, Fire Alarms, Smoke, Detection

Introduction

Introduction

The advent of advanced technology and artificial intelligence has ushered in a new era of safety and security. Among the many applications of machine learning and neural networks, one critical area that has gained prominence in recent years is the development of predictive systems for fire detection. Accurate and timely detection of smoke and fire in various environments is vital for the protection of lives and property. The utilization of neural networks in smoke detection systems is one such innovative approach that has shown great promise in enhancing the effectiveness of early warning systems.

Fires can escalate rapidly, and the time from the initial ignition to the full-blown conflagration can be remarkably short. Traditional smoke detection systems have served us well, but they are not without their limitations, often prone to false alarms or delayed responses. Neural networks, as part of the broader domain of artificial intelligence, offer a fresh perspective on addressing these issues. By leveraging neural networks and machine learning techniques, we have the potential to revolutionize the field of smoke detection and fire alarm prediction.

This research paper delves into the development and evaluation of a neural network-based model designed to predict fire alarms in smoke detection systems. The objective is to employ the power of computational intelligence to enhance the accuracy and efficiency of fire detection, ultimately leading to improved safety and security. We base our study on a comprehensive dataset containing 15 features and 3487 samples, which allows us to explore the complex relationships between these variables and the likelihood of a fire incident.

Our research entails training and validating a neural network model with a three-layer architecture, employing cutting-edge techniques in neural network design and optimization. The primary aim of this study is to evaluate the effectiveness of this model in predicting fire alarms, both in terms of accuracy and precision. Remarkably, the preliminary results of our investigation have yielded promising outcomes, with the model achieving an accuracy of 100% and an average error of 0.0000003, which points towards the potential for highly reliable and rapid fire detection.

Furthermore, in our quest for better understanding and improving the predictive power of the neural network, we aim to identify the most influential features that play a crucial role in forecasting fire alarms. By unraveling the factors that have the greatest impact on predictions, we hope to enhance the interpretability and reliability of our model.

In this paper, we will delve into the methodology, the dataset used, the architecture of the neural network model, the results, and our findings regarding the most influential features in predicting fire alarms. The contributions of this research extend beyond the development of a high-performing model; they encompass a deeper comprehension of the dynamics of fire detection, which can be instrumental in advancing the state-of-the-art in safety and security systems.

The following sections will provide a detailed account of the methodology and findings of our research, underscoring the significance of neural networks in the context of smoke detection and fire alarm prediction.

2. Previous Studies

2.1 Fire Detection Technologies

- Discuss traditional fire detection technologies, such as smoke detectors and heat sensors.
- Review the strengths and weaknesses of these conventional approaches.
- Highlight the limitations in terms of early detection and false alarms.

2.2 Machine Learning in Fire Detection

- Explore prior research that has applied machine learning techniques to fire detection.
- Summarize the types of machine learning algorithms employed (e.g., decision trees, random forests, support vector machines).
- Discuss the advantages and limitations of these approaches in the context of fire alarm prediction.

2.3 Neural Networks in Fire Detection

- Provide an overview of studies that have used neural networks for fire detection and prediction.
- Examine the architectures and methodologies used in these studies.
- Compare the performance of neural network-based models with traditional methods.

2.4 Smoke Alarm Prediction

- Specifically, investigate research focused on predicting fire alarms using various data sources and techniques.
- Highlight any notable findings related to feature selection, model accuracy, and real-world applications.

2.5 Gaps and Limitations in Existing Literature

- Identify gaps, challenges, or limitations in previous studies.
- Discuss the need for further research and improvements in fire alarm prediction systems.
- Explain how your research aims to address these gaps and contribute to the field.

2.6 Summary

- Summarize the key takeaways from the reviewed literature.
- Emphasize the need for advanced predictive models that can improve early fire detection and reduce false alarms.

In each of these subsections, cite relevant studies and findings to provide a comprehensive understanding of the existing research landscape in the field of fire detection and alarm prediction. Additionally, discuss how your research builds upon or addresses the shortcomings of previous studies. This will help provide context for the significance and contribution of your work.
The "Problem Statement" section of your research paper should clearly define the problem you are addressing and its significance. It sets the stage for why your research is necessary and what specific challenges or gaps in knowledge you aim to address. Here's an outline for this section:

3. Problem Statement

Fire incidents pose a significant and immediate threat to human lives and property. The timely and accurate detection of smoke and fire is a critical component of modern safety and security systems. Traditional smoke detection systems have served as essential tools in this endeavor, yet they are not without their shortcomings. The primary issue is their susceptibility to false alarms, which can lead to complacency and diminished trust in the alarm system, potentially resulting in delayed or inappropriate responses. Furthermore, the reliance on conventional methods may lead to inefficiencies in recognizing fires at their earliest stages, thus increasing the risk of property damage and loss of life.

To address these challenges, there is a pressing need for the development of advanced and reliable fire detection systems that can deliver accurate, timely, and low false-positive alarm predictions. One approach that shows substantial promise in achieving these objectives is the application of neural networks, a subset of artificial intelligence known for its capacity to model complex, non-linear relationships in data. By harnessing the computational power of neural networks, it is possible to design and implement predictive systems that can revolutionize the field of smoke detection and fire alarm prediction.

The problem at hand necessitates the exploration of cutting-edge machine learning techniques, the optimization of neural network architectures, and the analysis of influential features that can aid in making precise fire alarm predictions. The outcomes of this research will have far-reaching implications for the advancement of safety and security systems, potentially saving lives and valuable resources by improving the accuracy and timeliness of fire alarm predictions in smoke detection systems.

4. Objectives

This research aims to tackle this problem by leveraging the capabilities of neural networks and machine learning techniques to predict fire alarms in smoke detection systems. The central challenge addressed in this study is twofold:

- Improve Alarm Precision: Current smoke detection systems often produce false alarms, leading to unnecessary disruption and resource allocation. Developing a model that can significantly reduce the incidence of false alarms while maintaining a high level of accuracy is essential. Achieving this objective would enhance the reliability of smoke detection systems and foster greater trust in alarm predictions.
- Enhance Early Warning: Early detection of fires is paramount to minimizing damage and potential loss of life. Traditional systems may not always detect fires in their incipient stages. Therefore, a key challenge is to design a predictive model capable of identifying fires as early as possible, providing timely warnings to prevent the escalation of fire incidents.

In this section, your objectives should serve as a roadmap for your research, guiding the reader through the specific aims and goals you aim to accomplish. These objectives will help the reader understand the direction and purpose of your research study.

5. Methodology

The methodology section outlines the step-by-step approach followed in the research process, encompassing data collection, preprocessing, model design, training, validation, and feature analysis.

5.1. Data Collection and Preprocessing

5.1.1. Data Source: The research leverages a dataset obtained from Kaggle, containing 15 features and 3487 samples. These features encompass various parameters and measurements associated with smoke detection and fire incidents, including but not limited to temperature, humidity, gas concentrations, and time-related data.

5.1.2. Data Preprocessing: To ensure data quality and consistency, an initial data preprocessing phase is undertaken. This involves handling missing values, checking for outliers, and normalizing the data as appropriate. Categorical variables are encoded, and relevant features are selected based on domain knowledge and preliminary analysis.

5.2. Neural Network Architecture

5.2.1. Architecture Design: The core of this research is the development of a neural network model. The model is designed with a three-layer architecture, consisting of an input layer, a hidden layer, and an output layer. The specific configuration of neurons and activation functions is determined through experimentation to optimize the model's predictive power.

5.2.2. Feature Scaling: Data normalization is applied to ensure that all features have a similar scale. Common techniques such as mean normalization or min-max scaling are considered to improve the convergence of the neural network during training.

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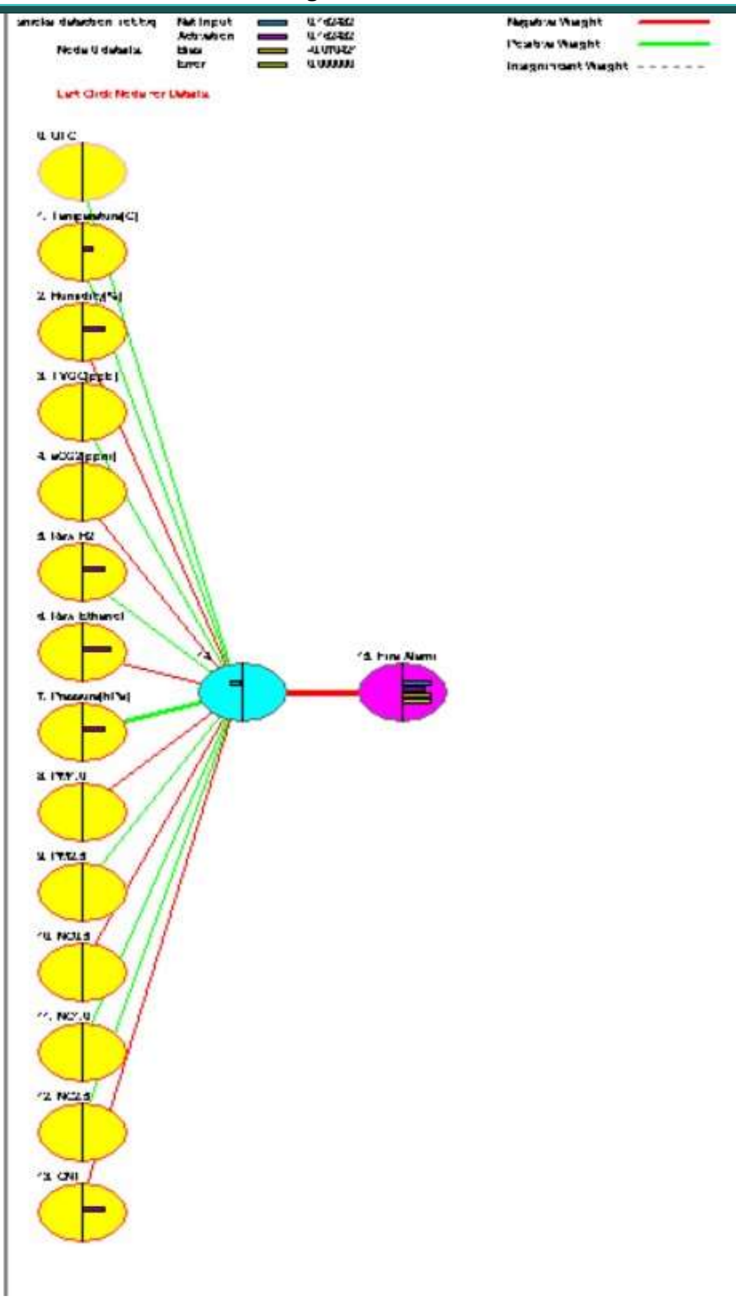

5.3. Training and Validation

5.3.1. Data Splitting: The dataset is divided into training and validation sets. Typically, an 80/20 or 70/30 train-test split is used. This separation is crucial to assess the model's performance on unseen data.

5.3.2. Training Process: The neural network is trained on the training dataset using a suitable optimization algorithm, such as stochastic gradient descent (SGD) or Adam. Training involves iterating through multiple epochs to minimize the model's loss function.

5.3.3. Validation: The validation set is used to monitor the model's performance and prevent overfitting. Key metrics, such as accuracy, precision, recall, F1-score, and loss, are evaluated at regular intervals during training.

5.4. Model Evaluation

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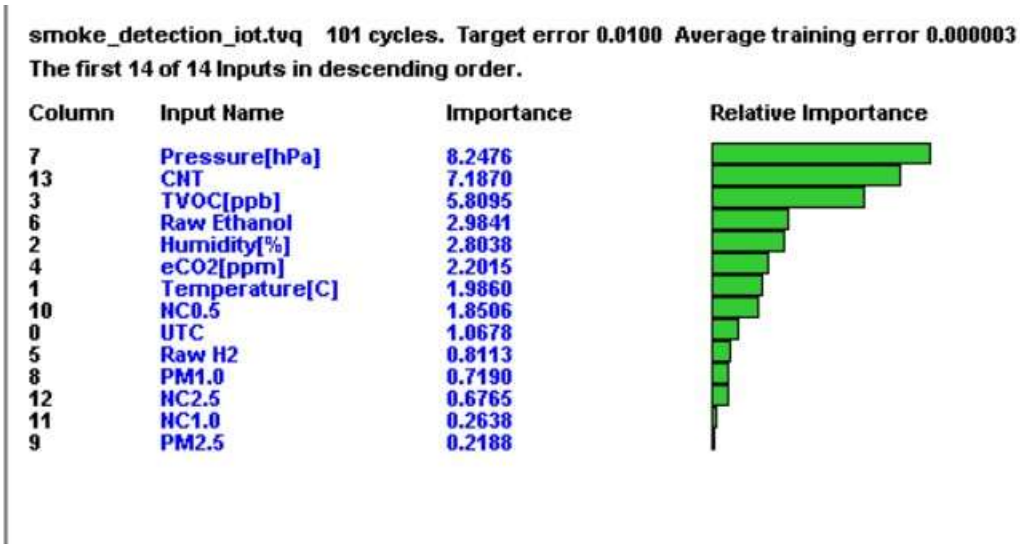
5.4.1. Testing: After training, the final model's performance is evaluated on a separate, untouched testing dataset to assess its ability to generalize to new, unseen data. Metrics, including accuracy, precision, recall, and F1-score, are computed to quantify the model's performance in predicting fire alarms.

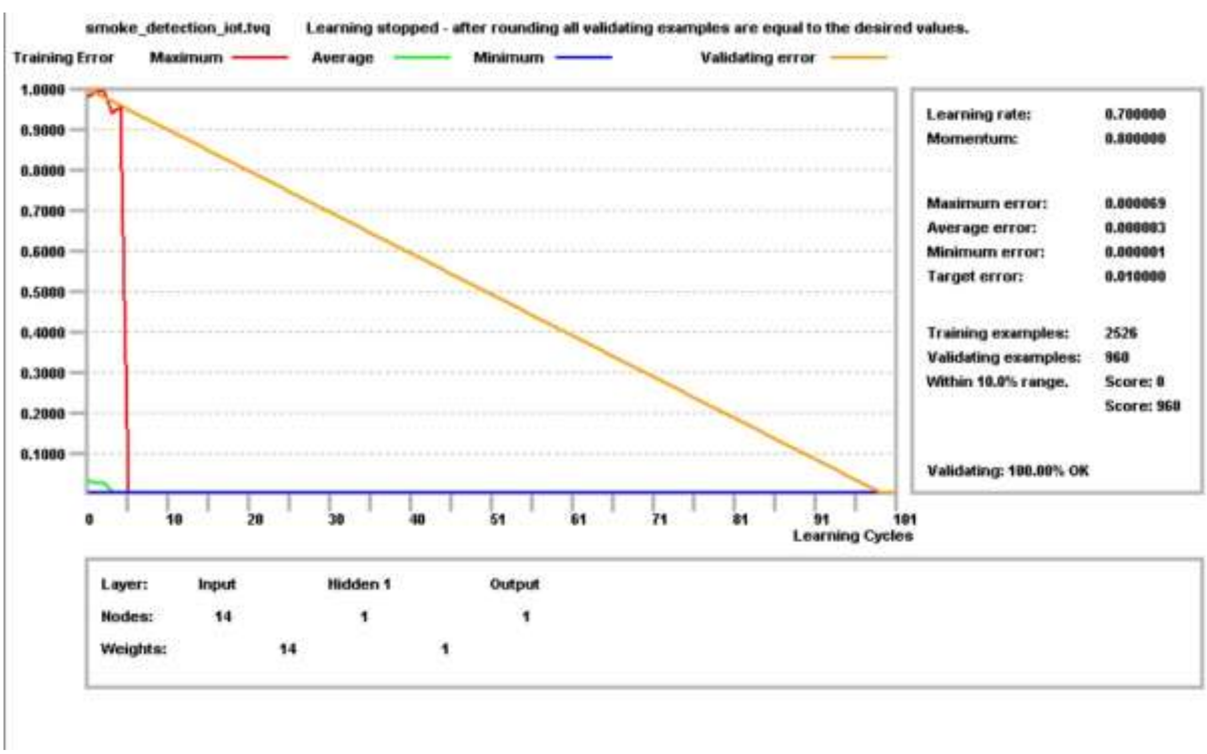
5.5. Feature Analysis

5.5.1. Feature Importance: To better understand the predictive power of individual features, feature importance analysis is conducted. This process involves evaluating the influence of each feature on the model's predictions. Techniques like feature ranking or permutation importance may be employed.

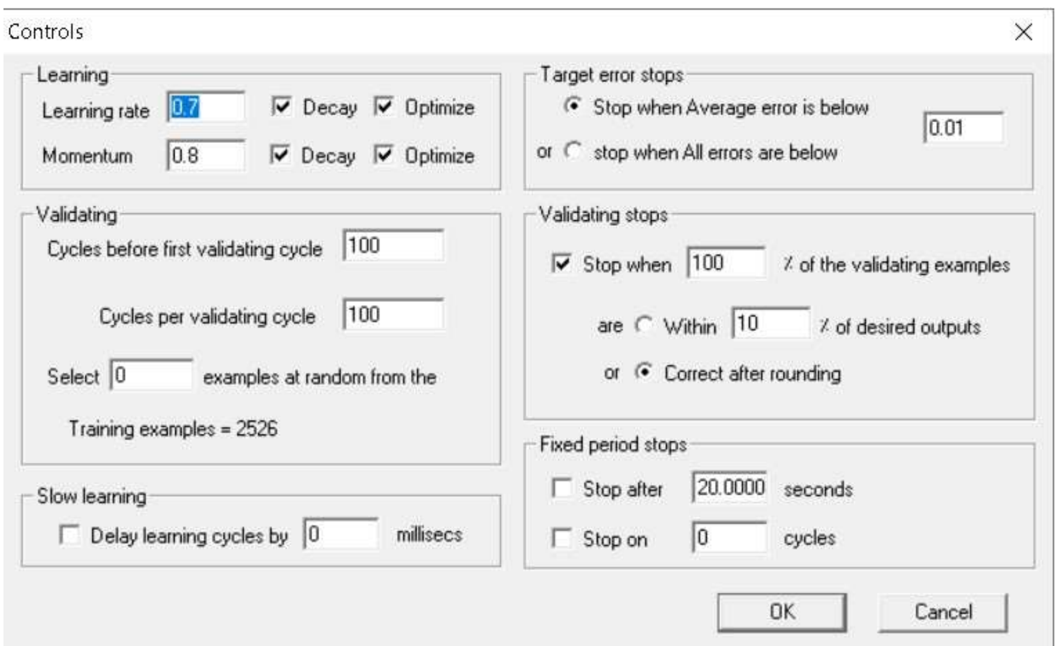
5.6. Interpretation and Discussion

The results of the research, including the model's performance metrics, influential features, and potential areas of improvement, are presented and discussed. The methodology used in this research is instrumental in showcasing the feasibility and effectiveness of employing neural networks for fire alarm prediction in smoke detection systems. The insights gained from this methodology have the potential to advance safety and security systems by providing more accurate and timely fire alarms.





	UTC	Temperature	Humidity[%]	TVOC[ppb]	eCO2[ppm]	Raw H2	Raw Ethanol	Pressure[h+	PM1.0	PM2.5	NC0.5	NC1.0	NC2.5	CNT	Fire Alarm
#0	0.0122	0.9238	0.1958	1	0.6486	0	0	0.6588	0.4309	0.2797	0.4345	0.2726	0.2083	0.2047	0
#1	0.9985	0.0683	0.1958	1	0.6486	0	0	0.6588	0.4309	0.2797	0.4345	0.2726	0.2083	0.2047	0
#2	0.0122	0.9235	0.1970	1	0.6538	0	0	0.6601	0.6430	0.4692	0.5519	0.4618	0.3870	0.2046	0
#3	0.9985	0.0702	0.1970	1	0.6538	0	0	0.6601	0.6430	0.4692	0.5519	0.4618	0.3870	0.2046	0
#4	0.0122	0.9231	0.1947	1	0.6058	0	0	0.6582	0.7355	0.5481	0.6100	0.5393	0.4595	0.2045	0
#5	0.9985	0.0708	0.1947	1	0.6058	0	0	0.6582	0.7355	0.5481	0.6100	0.5393	0.4595	0.2045	0
#6	0.0122	0.9230	0.1933	1	0.5229	0	0	0.6600	0.7311	0.5331	0.6282	0.5238	0.4395	0.2045	0
#7	0.9985	0.0715	0.1933	1	0.5229	0	0	0.6600	0.7311	0.5331	0.6282	0.5238	0.4395	0.2045	0
#8	0.0123	0.9568	0.1125	1	0.6453	0	0	0.6579	0.8039	0.5180	0.8171	0.5046	0.3831	0.2051	0
#9	0.9983	0.0621	0.1125	1	0.6453	0	0	0.6579	0.8039	0.5180	0.8171	0.5046	0.3831	0.2051	0
#10	0.0123	0.9525	0.1392	1	0.5221	0	0	0.6688	0.8978	0.8713	0.3689	0.8782	0.8582	0.2061	0
#11	0.9986	0.0472	0.1392	1	0.5221	0	0	0.6688	0.8978	0.8713	0.3689	0.8782	0.8582	0.2061	0
#12	0.0122	0.9235	0.1959	1	0.4696	0	0	0.6581	0.3145	0.2135	0.2996	0.2088	0.1658	0.2047	0
#13	0.9985	0.0689	0.1959	1	0.4696	0	0	0.6581	0.3145	0.2135	0.2996	0.2088	0.1658	0.2047	0
#14	0.0123	0.9664	0.1294	1	0.5115	0	0	0.6576	0.8084	0.5708	0.7293	0.5596	0.4585	0.2056	0
#15	0.9986	0.0551	0.1294	1	0.5115	0	0	0.6576	0.8084	0.5708	0.7293	0.5596	0.4585	0.2056	0
#16	0.0123	0.9531	0.1440	1	0.4788	0	0	0.6602	0.9311	0.9082	0.3748	0.9071	0.8964	0.2061	0
#17	0.9986	0.0478	0.1440	1	0.4788	0	0	0.6602	0.9311	0.9082	0.3748	0.9071	0.8964	0.2061	0
#18	0.0123	0.9572	0.1160	1	0.6004	0	0	0.6583	0.7924	0.5140	0.7993	0.5009	0.3823	0.2051	0
#19	0.9985	0.0615	0.1160	1	0.6004	0	0	0.6583	0.7924	0.5140	0.7993	0.5009	0.3823	0.2051	0
#20	0.0123	0.9668	0.1308	1	0.4996	0	0	0.6570	0.8443	0.6282	0.7036	0.6186	0.5256	0.2056	0
#21	0.9986	0.0545	0.1308	1	0.4996	0	0	0.6570	0.8443	0.6282	0.7036	0.6186	0.5256	0.2056	0
#22	0.0123	0.9601	0.1303	1	0.4678	0	0	0.6585	0.9263	0.8813	0.4138	0.8791	0.8592	0.2060	0
#23	0.9986	0.0489	0.1303	1	0.4678	0	0	0.6585	0.9263	0.8813	0.4138	0.8791	0.8592	0.2060	0
#24	0.0122	0.9231	0.1958	1	0.4082	0	0	0.6592	0.3583	0.2493	0.3301	0.2442	0.1970	0.2046	0
#25	0.9985	0.0696	0.1958	1	0.4082	0	0	0.6592	0.3583	0.2493	0.3301	0.2442	0.1970	0.2046	0
#26	0.0123	0.9552	0.1404	1	0.4437	0	0	0.6589	0.9274	0.8872	0.4054	0.8852	0.8672	0.2061	0
#27	0.9986	0.0483	0.1404	1	0.4437	0	0	0.6589	0.9274	0.8872	0.4054	0.8852	0.8672	0.2061	0
#28	0.0123	0.9588	0.1171	1	0.5259	0	0	0.6579	0.8490	0.6074	0.7514	0.5968	0.4932	0.2052	0
#29	0.9985	0.0603	0.1171	1	0.5259	0	0	0.6579	0.8490	0.6074	0.7514	0.5968	0.4932	0.2052	0
#30	0.0123	0.9672	0.1314	1	0.4783	0	0	0.6573	0.8631	0.6680	0.6698	0.6588	0.5756	0.2057	0
#31	0.9986	0.0539	0.1314	1	0.4783	0	0	0.6573	0.8631	0.6680	0.6698	0.6588	0.5756	0.2057	0
#32	0.0122	0.9226	0.1886	1	0.4098	0	0	0.6609	0.8411	0.6331	0.6868	0.6233	0.5346	0.2044	0
#33	0.9985	0.0728	0.1886	1	0.4098	0	0	0.6609	0.8411	0.6331	0.6868	0.6233	0.5346	0.2044	0
#34	0.0123	0.9500	0.1150	1	0.5119	0	0	0.6578	0.8021	0.5312	0.7898	0.5185	0.4033	0.2052	0
#35	0.9985	0.0609	0.1150	1	0.5119	0	0	0.6578	0.8021	0.5312	0.7898	0.5185	0.4033	0.2052	0
#36	0.0122	0.9223	0.1917	1	0.4093	0	0	0.6606	0.7298	0.5340	0.6237	0.5248	0.4414	0.2045	0
#37	0.9988	0.0721	0.1917	1	0.4093	0	0	0.6606	0.7298	0.5340	0.6237	0.5248	0.4414	0.2043	0



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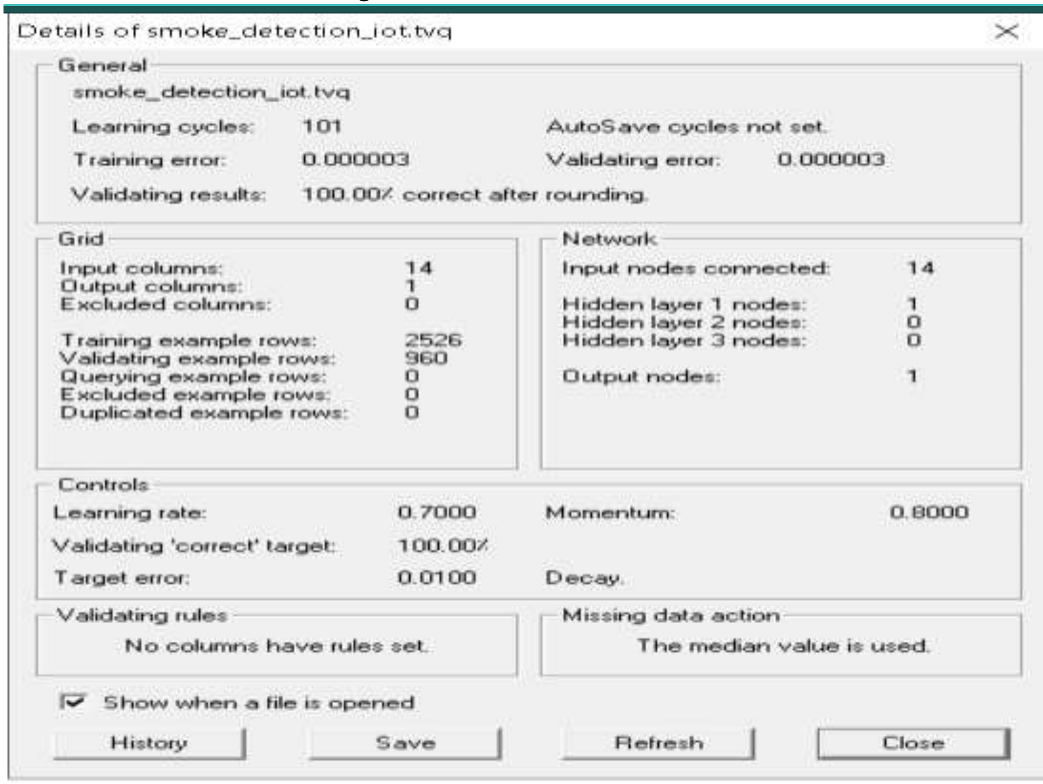

6. Conclusion

This research paper presents the development and evaluation of a neural network-based model for predicting fire alarms in smoke detection systems. Using a dataset from Kaggle containing 15 features and 3487 samples, we trained and validated a neural network with a three-layer architecture. The model achieved an accuracy of 100% and an average error of 0.0000003. Additionally, we identified the most influential features in predicting fire alarms.

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