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NETWORK INTRUSION DETECTION MODEL BASED ON CONVOLUTIONAL NEURAL NETWORKS AND TABULAR DATA CONVERTED INTO IMAGES

Abstract. The **object of the study** is the process of identifying the state of a computer systems and network. The **subject** of the study are the methods of identifying the state of computer systems and networks. The **purpose** of this paper is to improve the quality of detecting intrusions into computer networks. The UNSW-NB 15 set, which contains information about the normal functioning of the network and during synthetic intrusions, was used as input. Deep neural networks (DL), their advantages and problems in big data processing are considered. It was found that deep neural networks when processing tabular data require their transformation. Modern methods of tabular data transformation were studied. **The results obtained.** A method of converting tabular data into an image is proposed. The method converts each object of a separate class from a set of tabular data into an image by mapping the attribute values onto a two-dimensional plane. The method was implemented programmatically using the GOOGLE COLAB cloud service based on Jupyter Notebook. **Conclusions.** It was found that the use of the proposed conversion method of tabular data into an image made it possible to use a classification model based on the CNN neural network and increase the quality of detection of intrusions into computer networks up to 4%.

Keywords: intrusion detection systems, computer networks, machine learning, deep neural networks, tabular data conversion.

Introduction

Despite significant progress in the field of cyber security, today there is a need for continuous improvement of methods and technologies used to monitor and identify intrusions into computer networks [1].

Network traffic represents a complex set of data transmitted across a network. Its characteristics are determined by the interaction of numerous factors, including the properties of devices, software, the data itself, and the network. This forms the key features that characterize the traffic.

- **Hardware components:** The device type, technical specifications (processor, RAM), operating system, and network adapters significantly impact the nature of the generated traffic.

- **Software:** The use of different applications, their functionality, versions, and interaction protocols shape the characteristics of the traffic.

- **Data:** The type of data (text, images, video), its volume, and transmission frequency directly affect the network load.

- **Network infrastructure:** Bandwidth of channels, transmission delays, quality of service, and network topology determine the data transmission capabilities.

The set of features characterizing network traffic is flexible and can be adapted to specific analysis tasks. For example, when studying cyber threats, attributes related to attacks, such as type, source, and target are added to the traditional set of features. This approach allows for the creation of a detailed traffic profile but also increases its dimensionality. A large number of features complicates the process of training machine learning models, as it requires more computational resources and time. The presence of high-dimensional data introduces the problem of computational complexity, which can make training machine learning models slower and more expensive.

Today, models based on deep neural networks are the most popular for big data processing [2–4]. Neural networks are typically associated with image and text processing. However, they can also be successfully applied to tabular data, though this requires transforming the data first [5].

The purpose of this work is to develop a method of transforming tabular data into images and using deep neural networks to improve the quality of intrusion detection in computer networks.

1. Approaches and methods

Deep neural networks (DL) have a unique ability to autonomously discover and learn hidden patterns in data, forming internal representations of information. This feature makes them a powerful tool for solving complex problems such as image recognition, natural language processing, and speech signal analysis. Their ability to automatically identify abstract representations allows deep learning models to effectively adapt to new tasks and generalize acquired knowledge to new data. In many tasks, especially with large amounts of data, neural networks demonstrate higher accuracy compared to traditional machine learning methods like linear regression or decision trees. Additionally, deep neural networks can detect complex nonlinear relationships between data features, which is particularly useful for tabular data with many interactions between variables.

Due to these properties of deep neural networks, numerous attempts have been made to apply them to various types of tabular data [6].

Converting raw data into images is one of approach to applying DL to tabular data [7].

For example, Taehoon Kim et al. in his work [8] uses dimensionality reduction algorithms such as t-SNE, UMAP, PCA, and others to convert tabular data into grayscale images, which are then combined into a color image.

Sharma A. et al. [9] also proposes a method called DeepInsight, which involves arranging similar or

3. Convert the list into a NumPy array, resulting in a four-dimensional array that can be fed into the neural network.

4. Also, load the class labels that were previously saved in a separate dataset.

5. Split the data into training and testing datasets.

The combination of the two previously developed algorithms forms a method for transforming tabular data

into images, which are then used as input data for the model.

Since the IGTD method for converting tabular data into images showed the best results in previous studies, we will compare its results with those of the proposed method.

Fig. 2 shows an object of the Normal class transformed into an image using the IGTD method.

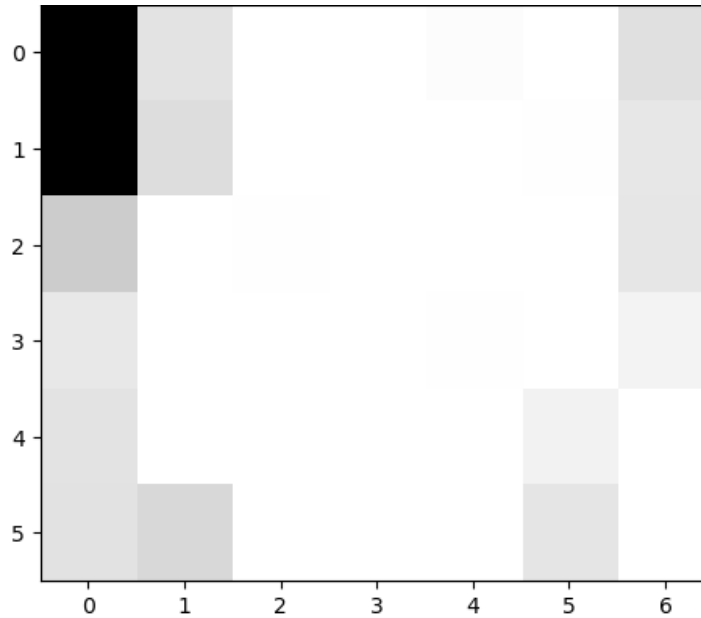


Fig. 2. An object of the Normal class transformed into an image using the IGTD method

For comparative analysis, a Convolutional Neural Network (CNN) model was constructed. The UNSW-NB15 dataset, which was converted from tabular data into images, was used as the input data. The model's

performance was assessed using metrics such as Accuracy, F-1 Score, Precision, Recall, Training Time, and Recognition Time. The test results are presented in Table 1.

Table 1 – Results of multiclass classification of the dataset converted into images using the IGTD method and the proposed method

Transformation method	Model of classifier	Accuracy, %	F1-score, %	Precision, %	Recall, %	Training time, s	Recognition time, s
IGTD	CNN	83.21	83.35	84.9	81.66	680.2	10.45
Proposed method	CNN	86.89	87.06	88.02	85.59	669.3	10.62

As shown in Table 2, using the proposed method for converting tabular data into images enabled the construction of a classification model based on a CNN and improved classification quality by up to 4%.

Conclusions

This work investigates the effectiveness of using modern deep neural network models for intrusion detection in computer networks.

Deep neural networks are among the most popular methods for analyzing big data. Typically, neural network models are used for processing images and texts. For handling tabular data, these models require a transformation of the input data.

The research analyzed various data conversion approaches. It was found that the most effective technique for converting tabular data into images is the

"Image Generator for Tabular Data" (IGTD). However, the quality of the model remains insufficient.

To improve model quality, a method for converting tabular data into images has been proposed. Initially, images are created for each object in the form of two-dimensional line plots, where features are represented on the x-axis and their values on the y-axis. The images are then converted into a three-dimensional array, and a list of objects is formed. This list is converted into a NumPy array, resulting in a four-dimensional array that can be fed into the neural network.

The proposed method was implemented using the GOOGLE COLAB cloud service based on Jupyter Notebook. An intrusion detection model for computer networks based on a Convolutional Neural Network (CNN) was developed. The model also includes a block for converting the input data into images.

In this work, the UNSW-NB15 dataset is used as the source data. This dataset was developed by the Cyber Range laboratory of the Australian Centre for Cyber Security (ACCS) and contains information about normal network operations as well as synthetic intrusions.

For comparative analysis, the input data was converted into images using both the proposed method and the IGTD method.

Using the proposed method for converting tabular data into images enabled the application of a CNN-based classification model and improved classification quality by up to 4%.

Future research will focus on augmenting the input data with synthetic features and evaluating their impact on model performance.

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Модель виявлення вторгнень у комп'ютерну мережу на основі згорткових нейронних мереж та табличних даних, перетворених на зображення

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Анотація. Об'єктом дослідження є процес ідентифікації стану комп'ютерної системи та мережі. Предметом дослідження є методи ідентифікації стану комп'ютерних систем і мереж. Метою даної роботи є підвищення якості виявлення вторгнень в комп'ютерні мережі. В якості вхідних даних використовувався набір UNSW-NB 15, який містить інформацію про нормальне функціонування мережі та під час синтетичних вторгнень. Розглянуто глибокі нейронні мережі (DL), їх переваги та проблеми в обробці великих даних. Виявлено, що глибокі нейронні мережі при обробці табличних даних потребують їх трансформації. Досліджено сучасні методи трансформації табличних даних. **Отримано такі результати.** Запропоновано метод перетворення табличних даних в зображення. Метод перетворює кожен об'єкт окремого класу з набору табличних даних на зображення шляхом відображення значень атрибутів на двовимірну площину. Метод реалізовано програмно за допомогою хмарного сервісу GOOGLE COLAB на базі Jupyter Notebook. **Висновки.** Встановлено, що використання запропонованого методу перетворення табличних даних в зображення дозволило використати модель класифікації на основі нейронної мережі CNN та підвищити якість виявлення вторгнень у комп'ютерні мережі до 4%.

Ключові слова: системи виявлення вторгнень, комп'ютерні мережі, машинне навчання, глибокі нейронні мережі, перетворення табличних даних.