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MuDeLA: multi-level deep learning approach for intrusion detection systems

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ABSTRACT

In recent years, deep learning techniques have achieved significant results in several fields, like computer vision, speech recognition, bioinformatics, medical image analysis, and natural language processing. On the other hand, deep learning for intrusion detection has been widely used, particularly the implementation of convolutional neural networks (CNN), multilayer perceptron (MLP), and autoencoders (AE) to classify normal and abnormal. In this article, we propose a multi-level deep learning approach (MuDeLA) for intrusion detection systems (IDS). The MuDeLA is based on CNN and MLP to enhance the performance of detecting attacks in the IDS. The MuDeLA is evaluated by using various well-known benchmark datasets like KDDCup'99, NSL-KDD, and UNSW-NB15 in order to expand the comparison with different related work results. The outcomes show that the proposed MuDeLA achieves high efficiency for multiclass classification compared with the other methods, where the accuracy reaches 95.55% for KDDCup'99, 88.12% for NSL-KDD, and 90.52% for UNSW-NB15.

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Intrusion detection system; multilevel learning model; deep learning; convolution neural network; multilayer perceptron

1. Introduction

Nowadays, the massive increase in network attacks is a crucial issue in the field of cyber security due to the widespread use of networks and Internet services by institutions and commercial companies in their activities. The IDSs are one of the important elements of the security infrastructure for network and computer systems [1,2]. The most popular categories of IDS are misuse and anomaly [1,3,4]: misuse IDS can competently detect known attacks with low false alarm rates, but it fails to detect unknown attacks that are not included in the signatures in the database. An anomaly IDS distinguishes deviations from normal behavior by building a model of normal categories. Therefore, anomaly IDS can detect unknown attacks (new attacks), but with a high false alarm rate. Many techniques have been used to develop and improve the IDS, such as statistical-based, knowledge-based, and machine learning techniques [5–10]. Among the most popular and widely used techniques are SVM [11] and ELM, which rely heavily in their work on the concept of a neural network.

1.1. Motivation

Since the number of intrusion detection systems (IDSs) based on deep learning techniques has grown in recent years, these techniques are derived from neural networks such as AE, LSTM (long short-term memory), CNN, and RNN (recurrent neural network) [12–18]. However, some deep learning approaches take a long time to be trained and produce test results, like LSTM [19]. On the other hand, due to the development of attacks, which are becoming more complex, some researchers have tended to use multi-level methods in the building of their IDS models [20–22]. Some methods use the same technique many times as a multi-level, while others use different techniques. These methods showed high performance in detecting attacks.

1.2. Contributions

This paper gives the following contributions.

(i) A multi-level deep learning approach (MuDeLA) for intrusion detection systems (IDS) is proposed. In order to improve the effectiveness of the IDS, the MuDeLA optimizes the performance of the CNN and the MLP.
(ii) The MuDeLA is evaluated by using various well-known benchmark datasets like KDDCup'99, NSL-KDD, and UNSW-NB15 using the Python programing language. The results of the proposed MuDeLA are compared with those of CNN, MLP, ResNet 50 [23], GoogLeNet [23], CNN-BiLSTM [24], BAT-MC [25], and DAE+DNN [26] to show the effectiveness of the MuDeLA.

1.3. Paper layout

This article is structured as follows. Section 2 demonstrates the related works. In Section 3, the proposed MuDeLA is presented in more detail. The performance evaluation of the MuDeLA is shown in Section 4. In Section 5, the conclusion and future works are illustrated.

2. Related works

This section investigates several previously published works for IDS. CNN and MLP are promising deep learning techniques that can be used in a variety of fields, particularly medical and pattern recognition [27]. A convolutional neural network (CNN) is an expansion of the feed-forward neural network (FFN). The first studies that used CNN were image processing with convolutional 2D layers, pooling 2D layers, and fully connected layers. After that, CNN used a process of natural language with a convolution 1D layer, a pooling 1D layer, and a fully connected [28]. Recently, many studies have used

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