MACHINE LEARNING APPLIED TO NETWORKING

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ABSTRACT

Recently, machine learning has been used in all possible fields of science and engineering. These have been the key infrastructure to provide efficient computational resources for automatic processing. Computer networks can also benefit from this technology. This article focuses on the application of neural networks in networking.

KEYWORDS: Deep Learning, Machine Learning, Networking, Flow Network, Traffic, QoS, OSPF

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1. INTRODUCTION

The rapid development of communication networks, and their different types of implementation such as wired or wireless networks, as well as their varied repertoire of applications, such as secure networks, multimedia networks, among others, has led to much more complex network systems configurations, these configurations must be dynamic and scalable, in order to meet the needs of information transfer safely and efficiently. In addition, these networks require a management system and constant maintenance due to repeated and constant changes in the network, the incorporation of artificial intelligence in this type of network, can improve their efficiency and performance as well as network traffic control in order to guarantee the quality of service (QoS), transfer of packages with the most efficient routes, rapid network convergence, intruder detection, traffic prediction, among others.

There are several techniques and machine learning algorithms (ML), which can be described by the work cycle shown in figure 1. These algorithms are used for both supervised and unsupervised learning, and can be applied to networking depending on the purpose of the application you want to make. In this document the current development of artificial intelligence in networks will be shown.

2. MACHINE LEARNING (ML)

The latest advances in machine learning, such as Deep Learning (DL), learning transfer and adverse generative networks (AGN) provide potential for research and application to different types of systems, such as networks, for this field it has been noted that "Deep learning" has a better efficiency to learn network traffic control [1].

Workflow for ML network application (MLN) (Figure 1), can be described as:

A. Problem Formulation

Since the implementation of a system based on ML requires a high computational cost, it is necessary to correctly formulate the problem, and so that it can be classified into a category of machine learning, such as sorting,

grouping, decision-making, among others.

B. Data collection

The data is taken depending on the problem to be solved, among types of data here are: metrics, bandwidth, transfer rate, packet size, among others.

Figure 1: Basic workflow of a neural network¹⁸.

C. Data Analysis

In this step we extract the main network characteristics that can help us solve the problem, the data must be standardized, discretized and the data that does not add value to the solution must be deleted.

D. Building the Model

An appropriate base model must be selected depending on the size of the data and typical network characteristics, in order to initiate training and start-up.

E. Validating the Model

This is an important step in MLN workflow, during this process a cross validation must be carried out in order to evaluate model performance.

Deep Learning is one of the most important branches of machine learning, within which the multiple layer structure must be highlighted, among others [2]. Next, we will show different architectures developed using deep learning.

3. DEEP LEARNING ARCHITECTURES

Depending on the use of the architecture, it can be classified as generative, discriminative and hybrid. Generative architecture is characterized by having high order correlation properties in the input data, for synthesis purposes. Discriminative architecture is used for recognition and classification purposes and hybrid architecture is used for discrimination tasks aided by the results of a generative process [2].

- Convolutional Neural Networks (CNNs): Consist of a discriminative architecture [3], in which the input consists of a vector and is transformed by a number of hidden layers which are formed by neurons, these neurons are totally connected by the front and back layers.
- Recurrent Neural Networks (RNNs): Consist of a generative architecture [4]; its main characteristic is having a long input data sequence.

- Stacked Autoencoder: networks without supervision and prior training, used for data compression.

4. DEEP LEARNING IN NETWORKING

Deep learning architectures and algorithms have helped traffic control networks, because it has been possible to predict network traffic and routes, in order to make intelligent decisions to define reserved bandwidth at different times.

Algorithms most used for networking are gradient stochastic descendant and greedy layer - wise training, which can be easily implemented with low latency processors hardware. With this it has been possible to develop SDR (Software Defined Routers), which have a high capacity to process packets.

5. APPLICATIONS

Several applications have been developed that use deep learning for networking. Next we will address applications in wireless sensor networks, traffic classification, flow prediction, among others.

A. Deep Learning in Wireless Sensor Networks

These types of systems require a small number of examples for training, these systems are mostly by low cost and low power consumption autonomous nodes, which collect different types of information, such as temperature, pressure, sound levels (acoustics) among other data types.

B. Traffic Classification

Neural networks are intended to improve the performance of the traffic classification used within a network, as well as the quality of service and detection of intruders [5] [6] [7]. The system input is commonly: the time interval between packet arrivals, size of packets, among others.

Studies have been conducted using a Bayes Naive classifier (supervised learning algorithm) whose classification approach is based on event probability applied to an environment with changing traffic characteristics; in this investigation [5], the learning was based on the data of:

- Interval of arrival between packets
- Variation of length between packets
- IP packet length

Subsequently, two types of ET and non-ET traffic were used, which are traffics outside and within the interest class, different window sizes were used for training, in each one an N amount of packages was used. Figure 2 shows the results of the simulation, where M is the number of lost packets and a recovery percentage is taken depending on the times the system does not correspond.

Figure 2: Recovery and precision with the use of Naive Bayes [5].

C. Prediction of network flow

This is another of the important areas in network traffic control, from which several deep learning applications have been developed. The network traffic flow is defined by the sequence of packets, video and audio content, among others. In order to manage the limit of network resources, the use of SDNs to program routers is appropriate. Several techniques have been developed in order to establish this prediction [8] [9] [10].

6. ROUTING WITH DEEP LEARNING

In addition the many applications that have been made with the use of artificial intelligence, it should be noted that the routing area with artificial intelligence facilitates control of intelligent traffic, and is quite a boom today, since traffic control is essential for quality of service (QoS), especially in multimedia networks.

Traditional routing protocols, are based on the metric values to obtain the fastest transmission route, in addition, the methods used tend to have problems due to the slow convergence, which is critical for changes in networks, which tend to be dynamic; this can cause congestion in the net [11].

Due to this, different methods have been investigated using machine learning to find routes intelligently, efficiently and with great speed [12] [13] [14] [15] [16]. In fact, the performance of computer networks has been evaluated using Deep Learning [18], where simulations are carried out in order to compare the use of deep learning with the traditional routing protocols; different results have been obtained, as can be observed in figure 3.

Figure 3: Performance comparison between OSPF and Deep Learning [1].

Comparisons have also been made within the routing with deep learning, using different layers in the neural network and compared to the number of nodes in the system; these results can be seen in table I.

Table I: Comparison of different structures with deep learning

$MSE(10^{-5})$ \ layers \ nodes	4	5	6
14	2.157	2.224	2.232
16	2.15	2.223	2.229
18	2.15	2.218	2.224
20	2.159	2.212	2.225

Where it can be highlighted that the mean square error (MSE) does not vary significantly, although the fewer layers of the neural network, the error will be relatively smaller, indicating that 4 layers are sufficient for data training.

In Figure 2, it can be noted that the generation of packets dedicated to routing in OSPF is much greater; this is because in OSPF, continuous transmission of routing tables to neighboring routers is necessary, while with deep learning it is sufficient only to transmit the traffic patterns of the edge routers to achieve an accuracy of 95%. Internal router patterns are established arbitrarily in the implementation phase. With deep learning packages destination routes are evaluated much faster than with OSPF [1].

7. TRAFFIC PREDICTION AND CLASSIFICATION

In the field of networking, traffic prediction and classification are currently the fields with more research, because in this may allow us to solve various problems of network congestion.

If you can estimate the volume of dynamic traffic in the networks, you can benefit in congestion control, resource management, routing and streaming control. There are currently two research directions; analysis of time series and network tomography, which differ depending on whether direct observations are made to the network or not.

Traffic classification matches the network applications and protocols with the corresponding traffic flows. Traditional methods of traffic classification include the port-based approach and the payload-based approach. It has been proven that the port-based approach is not effective because of unfixed or reused port assignments, while the payload based approach solves the privacy problems caused by deep packet inspection, which may even fail in the presence encrypted traffic [18].

8. CONCLUSIONS

The use of machine learning has been very involved in several fields of computer science, such as facial recognition, signal processing, classification, robotics, among others. Although the application of artificial intelligence in networking, has not been researched in depth, it has been noted that this can help solve the problems of traditional networks because their performance and efficiency is much higher, up to at least 95% ¹.

It has been shown that to classify traffic in real time, the best method is to use classifiers with statistical methods, which after being in their development stage can work in networks with dynamic traffic 5.

Numerous problems are still open and we shed light on the opportunities that require a greater research effort, both from the point of view of networks and well as automatic learning.

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