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Application of machine learning in wireless communication

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Abstract. With the rapid development of wireless communication technology, people have put forward higher requirements for the speed and quality of data transmission in wireless communication while enjoying a convenient life. Wireless communication systems are expected to be combined with artificial intelligence to meet these requirements. Machine learning (ML) can rely on different algorithms to process data without explicit programming. It can also optimize wireless systems by solving complex problems that traditional mathematics cannot solve. This paper briefly introduces wireless communication, machine learning, and the necessity of combining machine learning. The potential and applications of machine learning in various aspects of wireless communication, such as channel estimation, spectrum allocation, adaptive interference suppression, etc., are listed. The paper also introduces the various conveniences that machine learning in wireless communication brings to people in practical applications and the potential hazards that improper applications may bring.

Keywords: Wireless Communication, Machine Learning, Application Situation.

1. Introduction

Since the launch of the first generation of wireless communication systems, wireless technology has evolved from supporting basic coverage to meeting more advanced needs, where algorithm design enhancements for network, mobility management, resource management, and localization are also essential [1]. However, current wireless communication technologies face many challenges, such as limited spectrum resources, interference affecting network performance, and multi-path propagation. As an essential enabling technology of artificial intelligence, machine learning has been successfully applied in computer vision and many other fields. Machine learning lets computers learn and extract patterns from the data and automatically improve and optimize the algorithm to realize intelligent decision-making and automatic task processing [2]. The basic principle is to remove the characteristics and rules of the data by analyzing and learning a large amount of data.

Machine learning can be divided into three main types: supervised machine learning, unsupervised machine learning, and reinforcement machine learning [3]. Supervised learning refers to letting the machine learning algorithm learn the relationship between the input and the output through the information in the training data set and its corresponding output. Unsupervised learning lets machine

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learning algorithms automatically discover and learn the internal structure and rules of the data from the data without the annotated result [4]. Reinforcement learning is learning optimal behavior through interaction with the environment. Machine learning algorithms constantly improve and optimize behavioral strategies to maximize cumulative rewards through trial and error and reward mechanisms. Machine learning overcomes the disadvantages of traditional networking, resource management, mobility management, and localization algorithms. It provides new ideas and methods to solve the above problems, which have been applied in wireless communication. It has the following advantages. First, machine learning can learn helpful information from the input data, which helps to improve the network performance. Second, machine learning-based networks, resource management, and mobility management algorithms can adapt well to the dynamic environment [5]. Third, machine learning can help achieve network self-organization. For example, with multi-agent reinforcement learning, each node in the network can self-optimize its transmission power and sub-channel allocation. Finally, machine learning can quickly solve a new problem involving transfer learning.

However, machine learning also faces some challenges, including difficulties in data collection and annotation, the complexity of the algorithms, and the consumption of computational resources. Addressing these challenges requires more exploration and innovation in theoretical research and engineering practice.

2. Overview of Wireless Communication and Machine Learning

2.1. Wireless Communications

Wireless communication refers to a communication method that utilizes the propagation of electromagnetic wave signals in free space for information transmission and exchange. Due to wireless communication breaking through, the constraints of wired communication on the fixed geographical location of the receiving and transmitting ends have dramatically expanded the scope of people's communication and activities. With the development of wireless communication technology, people have begun to regard personal communication as the highest goal: using any terminal, anytime, anywhere, to communicate with anyone of any kind - speech, data, and images.

According to the different communication equipment, content, and communication methods, wireless communication networks can be divided into cellular mobile communication systems, cluster scheduling mobile communication systems, satellite communication systems, radio paging systems, infrared and ultraviolet communication systems, and broadband wireless access systems. Cellular mobile communication and wireless broadband access systems are the most used systems [1].

The current applications of cellular mobile communication systems are 4G (the fourth-generation mobile communication system) and 5G systems (the fifth-generation mobile communication system). 4G takes Multiple-Input Multiple-Output, and Orthogonal Frequency Division Multiple Access as the core technology. 5G extends the supported traditional Enhance Mobile Broadband business scenarios to massive Machine Type of Communication scenarios and ultra-Reliable and Low Latency Communication scenarios based on massive Multiple-Input Multiple-Output, millimeter-wave transmission, and multiple connectivity [2]. Wireless local area network (WLAN) refers to the communication between network devices through wireless channels, achieving mobility, personalization, and broadband communication.

2.2. Machine Learning

Based on experience accumulation, people can make effective decisions and judgments about new situations. ML is based on this concept, which can improve the system's performance through computational means and experience. Machine learning mainly studies "learning algorithms, " which generate models from computer data. After learning algorithms and summarizing the empirical data, computers can create models based on these data. The model can provide corresponding judgments without explicit programming when facing new situations.

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According to the classification of learning methods, machine learning can generally be divided into Supervised learning, Unsupervised learning, and Reinforcement learning. Its standard methods include decision trees, neural network learning, support vector machine, Bayesian classifier, Ensemble learning, clustering, etc. Because machine learning can comprehensively approach any nonlinear system in a complex environment by extracting data features through training and has good robustness and fault tolerance, in recent years, machine learning has been widely used in multimedia, medicine, and other fields, as well as communication.

2.3. Overview of machine learning in wireless communication

With the rapid development of wireless communication technology, it faces many challenges. The networks have become increasingly complex. Also, the overall performance requirements of wireless communication systems are becoming higher, and the electromagnetic propagation environment and technology application scenarios are becoming more complex. Moreover, many models and solutions have been accumulated in the wireless communication technology field, and most of the structural components are clear and descriptive. Therefore, integrating machine learning technology with wireless communication is undoubtedly a necessary solution., based on machine learning's ability to deal with large-scale complex nonlinear system problems.

For example, it can be applied to deal with multipath effects and inter-symbol interference problems in channel equalization; It can be used to handle the situation of multiple access interference in code division multiple access wireless communication systems in multiuser monitoring; It can be applied to parameter adjustment of intelligent demodulators to improve their demodulation performance; It can be used to predict network status to achieve high dynamic channel allocation.

3. Abstract Application of Machine Learning in Communication

With the rapid development of wireless communication technology, the application of machine learning in the field of wireless communication is also getting more and more attention. The following reviews the application of machine learning in wireless communications and discusses its potential for future wireless communications technology developments.

Channel estimation is one of the critical problems in wireless communication. Traditional channel estimation methods usually rely on mathematical models and signal processing algorithms; however, they are often difficult to accurately estimate channel states due to the complex wireless channel environment and rapidly changing signal properties. Machine learning can automatically build channel estimation models by analyzing and learning the existing data to achieve more efficient and accurate channel estimation. There have been many related studies, such as the channel estimation methods based on support vector regression and the deep learning-based channel estimation methods [6].

Spectrum resources are limited, and the rational utilization of spectrum resources in wireless communication is crucial. Traditional spectrum allocation methods are often based on static rules and experience and fail to adapt to the dynamically changing network environment. Machine learning methods can learn and optimize many spectra using data to realize an intelligent spectrum allocation strategy and improve spectrum utilization efficiency.

In wireless communication systems, interference is one of the critical factors affecting performance. The interference suppression technology is designed to reduce the impact of interference on communication quality. Machine learning methods can realize adaptive interference suppression strategies by learning interference models and optimization algorithms. For example, the deep learning model can identify and locate the interference sources using real-time observation data and take corresponding inhibition measures [7].

A wireless communication network needs effective resource management and scheduling to ensure service quality and network performance. Wireless resource management is another vital link in the wireless communication system, which mainly involves allocating and scheduling frequency spectrum, power, bandwidth, and other resources. Traditional network management algorithms are usually based on static rules and optimization models, which cannot adapt to complex and changeable network

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environments. Machine learning methods can realize intelligent network management and scheduling strategies by learning the network state and the user behavior mode and improving the efficiency and performance of the network. There have been many related studies, such as the wireless resource management method based on reinforcement learning [8].

With the popularization and development of wireless communication technology, the problem of wireless network security is also getting more and more attention. Machine learning can realize more efficient and accurate network security monitoring and early warning through analyzing and learning a large amount of network data[9]. There have been many related studies, such as intrusion detection methods based on deep learning and malicious code detection method based on support vector machines.

Due to the proliferation of smart devices and intelligent applications such as augmented reality, virtual reality, ubiquitous social networks, and the Internet of Things, wireless communication systems have experienced tremendous data traffic growth over the past few years. In the face of the explosive data demand, the future wireless network introduces the cache mode to shorten the latency and reduce the transmission burden of the backhaul. In recent years, many excellent researchers have adopted machine-learning techniques to manage cache resources and have achieved great success—for example, a distributed cache update scheme based on joint utility and policy estimation of reinforcement learning.

4. Practical Application of Machine Learning in Communication

As already known, machine learning is the way of computer programs and AI digest information and make decisions or complete goals more accurately and precisely. Machine learning is essential nowadays. Breakthroughs in machine learning are quickly changing our world. Learning from a vast database could make a more robust AI.

As network system has already been highly developed, wireless communication can send vast amounts of data for the TB-level usage of machine learning [10]. This means that machine learning can be more efficient than before and can fulfill most of the usual use of this technology only by wireless communication.

One of this technology's most essential combinations is reducing interference and helping data transportation reserve as much as possible. Using the deep learning model, devices can identify and locate the interference sources using real-time observation and take corresponding inhibition methods. For instance, microphones in a computer can reduce noise by learning the sound wave law of noise and human speaking, then create a particular function to delete the background noise soundtrack.

Traffic problems can be solved by machine learning [11]. Navigation systems can make better decisions by learning the regular pattern of different places, such as avoiding often crowded roads. It predicts traffic conditions in two ways: whether traffic is clear, slow driving, or severe congestion: the vehicle's real-time location comes from the mapping app and sensors, and the average time over the past few days co-occurs. The system can be more reliable in estimating and reacting after being fed big data by everyone who uses this system. It takes user information and sends it back to its database to improve performance [12].

Another practical use is in the network society management area. By sending data, not only by developers but also lots of authentic expressions in social networking sites through wireless ways, machine learning can be used in filtrating rubbish e-mails and messages. It can delete nasty comments by AI manager. Robots can help reduce pollution in a network environment by learning keywords and advertising or fraud models.

Machine learning can also be used in commercial environments. The very classic example is the advertisements and recommendations. Whenever we search for a particular product on an online shopping platform, we receive an ad for the same effect while surfing the Internet on a browser, and this is because of machine learning. These platforms use various machine learning algorithms to understand users' interests and show products based on their interests.

However, machine learning may be used in crime as well. Synthetic images can be used in spreading fake news. AI-based face images can cheat people on social network platforms. Criminals using a facial image of a relative of someone to get money is very usual these days. The problem is, how can the

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governments of different countries unite to control the use of machine learning to prevent high-tech crime from happening again?

We are in the era of breakthroughs in AI: more complex neural networks accompanied by valid language training data. The main problems new machine learning algorithms face are more complex, and the application fields of machine learning have developed from breadth to depth, which puts higher requirements for model training and application. Robots and AI face more complex work, not playing chess anymore, but chatting with people or learning to work. With the development of artificial intelligence, the theoretical basis of von Neumann-style finite state machines is becoming increasingly difficult to cope with the requirements of the number of layers in the current neural network, which poses challenges to machine learning. There are two breakthroughs in machine learning in the future, one is the improvement of algorithms, and the other is the improvement of computing power. The future may be unpredictable; maybe there is a new technology we could never consider!

5. Conclusion

In this paper, we put our sights on application forms of machine learning in wireless communicational backgrounds. First, we defined machine learning and wireless communication and recently introduced their progress in practical use. After we analyzed the synchronous development of these two technologies, machine learning, and wireless communication, and provides, we also presented the method of combining machine learning and wireless communication, providing several forms of utilization in different fields. The basic structure of the cooperation of this two technology is to let machines learn from significant data transformed by wireless communication. Specifically, we list methods from channel estimation, spectrum allocation, and interference inhibition to mathematical problems and management of network society in real life. We provide an overview of machine learning exploitation in nowadays wireless communication settings. Machine learning can be more efficient by backing significant data transformation wireless. We also list the primary practical use of machine learning in the wireless background—network society management (delete nasty comments, for example) and navigation system. Last but not least, we spread our attention to the legal and morality level to review the control of this technology in criminal and commercial usage.

It's clear that the application of these two combined technology is handy and can make extraordinary use of either of them only. As communication becomes more efficient (for instance, 5G technology, optical fiber satellite communication), extensive data transport in wireless ways can be the stable and incomparable support. However, we should also be careful of control of this technology. Governments should make laws to ban the illegal use of this technology to reduce the loss of fortune.

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