Nick Tipton

Brandon Saunders

ITS 2140

2 December 2022

Artificial Intelligence and Machine Learning – The 5th Generation Network (5G)

Introduction

The implementation of 5th generation (5G) networks is the next generation for mobile communications. Artificial Intelligence (AI), Machine Learning (ML), and 5G, the history of each, and the combination of them today will be defined and stated. For AI to be successful with this combination of Machine Learning, it relies on the infrastructure and the large amounts of data that 5G provides. AI improves 5G over time from the beginning to the end. Machine Learning brings the algorithms needed for 5G networks to work as efficiently as possible. AI is the first area of concentration discussed and defined.

Artificial Intelligence

Artificial Intelligence (AI) is the widespread branch of the computer sciences concerned with creating machines that are smart enough to have the capability to perform tasks that otherwise requires the intelligence of humans. AI has multiple approaches in interdisciplinary science; deep and machine learning are creating a complete change in every sector due to the advancements within the tech industry. Machine Learning (ML), the subset of AI, refers to the ability of computer programs to adapt and learn from new data automatically without the assistance of any humans. The principle of Artificial Intelligence is based upon human intelligence being mimicked by machines and executing the simplicity and the complex tasks, “to develop machine systems toward the

same intelligence as a human mind" ([3], p.5). Strong Artificial Intelligence is the categorization of AI that handles the more complex tasks and is most like human-like tasks. There are complications with these tasks that require programmed machines for "it is used to solve complex problems automatically and undependably from human intervention" ([3], p.4). The programs are derived from the developing project systems provided with the characteristic of intellectual capabilities found in humans; to discover meaning, to learn from experience, the ability to reason, and to generalize. As Machine Learning is mentioned alongside AI, ML will follow.

Machine Learning

Machine Learning (ML) as defined before, is in close relation to Artificial Intelligence "which is a subset of AI technology that learns patterns from empirical data" ([2]). How these machines learn is done in three phases: training, validation, and application. Training refers to correct behaviors analyzed with some representation of the recently learned information being stored, a set of rules to follow. The validation phase sounds exactly as it seems, the checking of rules and additional testing to ensure correctness. The final phase of the application is being used to respond to newly introduced sceneries and situations. The method that a computer trains, without the programming of every situation, explicitly will learn from its inputs. Essentially, ML is the programming for all mature Artificial Intelligence. The machines, if something correct is given once, will always be correct in the future. The same theory goes for something if given incorrect once, and then it will always be incorrect. In radio networks, ML is used "within the wireless network environment and learn how to adapt its actions as a communication device" ([1]). Without Machine Learning, AI would not be able to

continue to learn no matter the amount of intelligence that is gathered and implemented. Machine Learning varies from traditional devices as ML devices continuously act and think about the data intake. Where Traditional devices require programming-set rules to follow and act based upon those rules given. This disables non-learning devices from being able to adapt to mistakes or even changes. Going towards a newly introduced technology application, the 5th generation of telecommunication technology is the third area of concentration.

5th Generation Network

The 5th Generation (5G) is the newest and latest version of wireless global networks. Following the 1G, 2G, 3G, and 4G networks, 5G networks are designed to connect virtually every corner and every person including objects and machines as well as devices in the Internet of Things (IoT). The GSMA Intelligence portrays 5G as having two views "the hyper-connected vision and the next-generation radio access technology" ([5], p.2). This global network is built upon three improved communications capabilities: connectivity, adaptability, and capacity. The first of the improvements is connectivity, which refers to what and who has the availability to connect and utilize wireless communications. Infrastructure, users, hotspots, drones, cellular, vehicular mobiles, and direct connectivity are different functions of connectivity. The following is adaptability, which refers to the change the network goes through to thrive and endure challenges. Having resilience, environmental awareness, and being autonomous have improved significantly. The last improvement seen in the 5th generation is with the capacity significantly higher than before. The high capacity is about mm-Wave bands, modulation schemas, network densification, and multiple antennas being used. All mobile networks

utilize Radio Access Networks and Core Networks, which in turn are the two main components. The Radio Access Network is the facility that connects the users and the wireless devices to the Core Network. To provide a continuous connection, small cells need to be used in clusters as the mm-Wave frequencies have short ranges. The use of more antennas comes from the MIMO (multiple input, multiple outputs) antennas that have multiple connections that are sending and receiving data more simultaneously. The Massive MIMO is "one of the foundations of 5G technology" ([5], p.2). The Core Network is the exchange that mobile and data networks go through. Voice, connections to the Internet, and data are manageable exchanges. Network Slicing is the segmentation of a network used for separating particular industries. Another part of the Core Network is Network Function Virtualization (NVF), which is essential to enable agility and speed efficiency. Since Artificial Intelligence, Machine Learning, and 5G have been introduced and defined, the timeline history of AI follows.

History - Artificial Intelligence

In the 1950's the beginning of modern Artificial Intelligence was summoned. Alan Turing, a mathematician, and computer scientist is the creator of the Turing Test, which simply tests machines' intelligence behavior that is equivalent to that of humans and "could be turned into a general-purpose problem-solving machine" ([1], p.11). How these test works are simple, it involves the same set of questions given by a human evaluator to a machine and another human. To pass the Turing test, the evaluator must distinguish a difference between both the human and machine answers. In 1955, the term 'Artificial Intelligence is coined by John McCarthy, a computer scientist, who defined the term as "the science and engineering of making intelligent machines". Ten years later in

1965, a natural language program called Eliza, is created which handles dialogue. The 1980s brought Edward Feigenbaum's expert system emulating the decisions of human experts. From 1997-2014, different computer programs accomplished many feats such as defeating a world chess player, autonomous vacuum, self-driving car, winning Jeopardy, and personal assistants with speech recognition. Ian Goodfellow, a computer scientist, and machine-learning director, 2014 creates Generative Adversarial Networks (GAN). Generative Adversarial Networks are generative modeling while using convolutional neural networks and "can generate an infinite number of similar samples based on a given dataset" ([2], p.8). The subset of AI known as Machine Learning follows a different historical timeline.

History - Machine Learning

In 1943, Walter Pitts, a mathematician, and Warren McCulloh, a neurophysiologist, created a model of a neural network with an electrical circuit. Arthur Samuel creates a learning computer program, which learns to play a game of checkers in 1952. The first artificial neural network was designed by Frank Rosenblatt in 1958 to recognize shapes and patterns. One year later in 1959, Bernard Widrow and Marcian Hoff created ADELINE and MADELINE; neural networks to detect patterns of binary and eliminate echo on phone lines. In 1982, the suggestion of bidirectional lines from John Hopfield to create a network was introduced. Machine Learning would shift from knowledge to data-driven in the 1990s. From the 2000s-2010s, deep learning leads to widely used software service use and Support-Vector Clustering. The final dive into history is on the 5th generation network specifically known as 5G.

History - 5th Generation Network

The Americans and Europeans were the first to use 1G in communication devices. The first cell phone to be introduced with this network occurred in the 1980s with analog voice. Currently, the noise was a mystery to solve between communication devices. The early 1990s brought 2G with the introduction of digital voice. The main difference between 1G to 2G was "radio signals that 1G networks are analog, while 2G networks are digital" ([4], p.58). The noise issue was now manageable for the devices. In the digital format, data is digitally encrypted to ensure the intended receiver has access. Japan introduced 3G first and brought along mobile data within the early 2000s. The 3rd generation came with "2100 Hz and bandwidth 15-20 MHz" ([4], p.61) enhancing the clarity of conversations. Data rates were higher and are the main difference between 3G and 2G. The 2010s came with the 4th generation and the mobile broadband era. Increased data speeds and upload speeds capped over 50 megabits per second while download speeds capped over 100 megabits per second. More security, more encryption, and less latency were improvements in the 4G (LTE) networks. Utilizing all the previous generations, 5G can provide overall greater connectivity. The 5th generation is built upon the improvements between the previous generations of telecommunication technology. Now that all the basics have been covered from the introduction to the history, now AI, ML, and 5G come together as one.

Today

The 5th generation is the most current network and "5G is the next-generation mobile communication technology that aims to offer better network capacity and data rates compared with the previous LTE technology" ([2], p.29). Artificial Intelligence has techniques aside from Machine Learning implemented in 5G. The first is Supervised

Learning which creates predictions dependent on patterns that have been learned. These are used to clarify the connection between giving information and yield to deduct the essential capacity. The next technique of AI is Unsupervised Learning, which evaluates and “finds similarities between input values and a similar group of data into clusters” ([3]). There is zero input and output data in Reinforcement Learning, the learning culminates through experience depending on an experimentation model to figure out how to acquire a prize. Deep Learning is a subset of Machine Learning, which learns from unsupervised data that is unstructured having the ability to do this by mimicking human minds. A final technique of Artificial Intelligence is Natural Language Processing (NLP) which enables the interaction of computers and humans; NLP deciphers, understands, and can make sense of all valuable humans. Massive MIMO (mMIMO), network and latency optimization, and quality of experience are ways that AI impacts 5G. Many antennas are needed for 5G to work properly; the mMIMO requires numerous antennas that are higher than those of the previous generations of networks. Network and latency optimization is achieved from the reduction of radio resources in the transition of information. The quality of experience is analyzed with how big data analyzing finds user influence factors by unsupervised machine learning. Machine Learning uses algorithms to schedule resources in advance based on historical data to reduce global latency. “Congestion control ensures network stability, fair resource utilization, and acceptable packet loss ratio” ([2], p.10), and without the control, there is the possibility of network delay and resources not being fully utilized. Quality of Service in network communications is the delay, packet loss, and bandwidth. These ML algorithms decrease the amount of delay, abide by the traffic Quality of Service requirements, and maximize the throughput. The

ML algorithm for network resource management is the cycle of overseeing and allotting the accessible assets for the systems administration measure; when requirements are fully met, network resource management is efficient. As the idea of Artificial Intelligence, Machine Learning, and 5G have been introduced, historicized, and brought together a recap summarizes the findings.

Conclusion

Artificial Intelligence (AI) is the widespread branch of the computer sciences concerned with creating machines that are smart enough to have the capability to perform tasks that otherwise requires the intelligence of humans. Machine Learning (ML) is in close relation to Artificial Intelligence as a subset of AI. Artificial intelligence improves the 5th generation of telecommunication technology with the help of Machine Learning. Machine Learning contains the algorithms needed for 5G networks to work efficiently. By managing and operating the 5G networks, AI and ML develop and learn according to user needs within the Internet of Things devices. Therefore, Artificial Intelligence, Machine Learning, 5G, the history of each, and the combination of them today have been discussed, stated, and defined.

Addendum

The Concepts Behind the Network – LTE (4G) vs. 5G

LTE

The fourth generation network known as LTE is the previous and still current network in most areas. 4G focuses on favorable performance and capabilities; referring to download speeds reaching 100 Mbps that are as good as HD video quality. Straightforward interoperability and trouble-free roaming are with service personalization, which holds different terminals having autonomously widespread service. The concept of effusive coupled services deals with the freedom of choice for 4G users by enabling the connectivity to hold up email, web browsing, video streaming, and many others from any application. The interface is user-friendly and projects spontaneous and visual devices in comparison to text-based menu systems as well as an improved GPS service that can locate individuals. LTE networks can expand and scale according to the number of services and customers utilizing the cellular network. The final concept of LTE refers to the indispensable applications of disaster management and how quickly the communication structure can be re-established in hours instead of days or weeks with transmissions that are wired.

5G

The fifth generation of telecommunication networks is the newly introduced and ever-expanding form of communication. The 5G networks focus on the MAC and physical layers that characterize wireless technology. This shows how it is based upon Open Wireless Architecture in the MAC and physical layers of the mobile network. The network layer also is in close relation to an Internet Protocol layer that today has zero

rivals. Specific to 5G, Mobile IP has each terminal as a Foreign Agent that addresses and utilizes the Care of Address for the network. All radio interfaces, even with unusual IP addresses will be upheld under the CoA and mobile IP. Address translation also is upheld to dissimilar Lower Network IP addresses from the Upper network address and vice versa. The concept of Open Transport protocol (OTA) refers to how networks are differentiated from a wired network based on the transport layer basis. TCP amendments are projected for wireless networks to retransmit destroyed parts over the like wirelessly. Based upon the Open Transport Protocol (OTP), mobile networks are enabled to transport protocols belonging to explicit wireless technologies that the base stations have initiated. The final concept of 5G communications is within the application layer. The assortment of networks is held below the Quality-of-Service administration with the applications. The mobile terminals store extensive information in databases like an agreement of services. Algorithms in the process of the systems in mobile terminals complete these. IPv6 rids of Network Address Translation by the number of IP addresses mounted. The entire IP center network progression refers to the superior data rates and the speed of mobile wireless users, which is the survival strength of the Internet.

Work Cited

[1] Luo, Fa-Long. "*Machine Learning for Future Wireless Communications*." *Google Books*, Google, 2020, www.google.com/books/edition/Machine_Learning_for_Future_Wireless_Com/GFTGDwAAQBAJ?hl=en&gbpv=0.

[2] Ridwan, M. A., et al. Applications of Machine Learning in Networking: A Survey of Current Issues and Future Challenges*:* 2021, ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=9388670

[3] AZZAOUI, ABIR EL, et al. *Block5GIntell: Blockchain for AI-Enabled 5G Networks*, 2020, ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=9159573.

[4] Shukla, Sapna., et al. "Journal of Engineering, Computers & Applied Sciences - Comparative Study of 1G, 2G, 3G and 4G." Research Gate - Blue Ocean Journals, 2013. https://www.researchgate.net/profile/SbalaMurugan/publication/328304840_JECA_Ap_2013_-_FEM_-_Published/links/5bc55d5a299bf17a1c55692d/JEC-AS-Ap-2013FEM-Published.pdf#page=57

[5] Paudel, Prabesh, and Abhi Bhattarai. "5G Telecommunication Technology: History, Overview, Requirements and Use Case Scenario in Context of Nepal." Research Gate, 2018.

https://www.researchgate.net/publication/325250893_5G_Telecommunication_Technology_History_Overview_Requirements_and_Use_Case_Scenario_in_Context_of_Nepal

Other Sources

"What Is 5G: Everything You Need to Know About 5G: 5G FAQ." *Qualcomm*, 12 Feb. 2021, www.qualcomm.com/5g/what-is-5g#:~:text=A%3A%205G%20is%20the%205th,machines%2C%20objects%2C%20and%20devices

Gilbert, Mazin, et al. "AI/ML Track." *IEEE 5G World Forum WF5G*, 2020, IEEE-wf-5g.org/ai-ml-track/#:~:text=AI%2FML%20is%20being%20used,on%20chatbots%2C%20recommender%20systems%2C%20and.

A., Khalid. "The Concept of Fifth Generation (5G) Mobile Technology." *Communications on Applied Electronics*, vol. 2, no. 8, 2015., doi:10.5120/cae2015651853.