Emerging Trends in Artificial Intelligence and Machine Learning: Historical and State-of-the-Art Perspectives

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ABSTRACT

The growing importance and relevance of artificial intelligence (AI) in every field of human endeavor ranging from business, healthcare, education, agriculture, bioinformatic, cybersecurity, military, etc., is on the increase. Since the start of the 21st century, many businesses have realized that artificial intelligence and machine learning will increase the potential at which people will do their businesses. This is why businesses and organizations such as Google, Facebook, Amazon, etc., are investing heavily in these areas especially with the advent of Big data regime, so that they can stay ahead of their competitors. The application and use of Artificial intelligence have become so important that one cannot but discuss it. AI has become more popular these days due largely to increased data volumes, advanced algorithms, and improvements in computing powers and storage. AI makes it possible for machines to learn from experience, adjust to new inputs and perform human-like tasks such as chess-playing, robotics used in war zones and manufacturing processes, self-driving cars, all of which rely on deep learning and natural language processing where computers are trained to accomplish specific tasks by processing large amounts of data and recognizing patterns in the data. This paper discusses the emerging trends in artificial intelligence (AI) and Machine learning by tracing the history their histories and state-of-the-art of the two concepts. It also discusses other concepts such as deep learning, machine learning, facial recognition, privacy policy, AI-enabled and embedded chips, cloud especially cloud AI, brainware and improved data analysis.

Keywords: Artificial Intelligence, machine learning, deep learning, cloud computing, brainware.

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1. INTRODUCTION

The growing importance and relevance of artificial intelligence (AI) in every field of human endeavor ranging from business, healthcare, education, agriculture, bioinformatic, cybersecurity, military, etc., is on the increase [1] [2]. The application and use of Artificial intelligence have become so important that one cannot but discuss it. AI has become more popular these days due largely to increased data volumes, advanced algorithms, and improvements in computing powers and storage. AI makes it possible for machines to learn from experience, adjust to new inputs and perform human-like tasks such as chess-playing, robotics used in war zones and manufacturing processes, self-driving (autonomous) cars, all of which rely on deep learning and natural

language processing where computers are trained to accomplish specific tasks by processing large amounts of data and recognizing patterns in the data [3].

Artificial Intelligence (AI) is defined as any technique that enables computers to mimic human intelligence using logic, if-then rules, decision trees, and machine learning (including deep learning) [4]. Machine Learning (ML) is a subset of AI that includes abstract statistical techniques that enable machines to improve at tasks with experience. The category includes deep learning [5]. Deep Learning is the subset of machine learning composed of algorithms that permit software to train itself to perform tasks like speech and image recognition, exposing multi-layered neural networks to vast amount of data [6]. The relationship between these concepts is shown in figure 1.

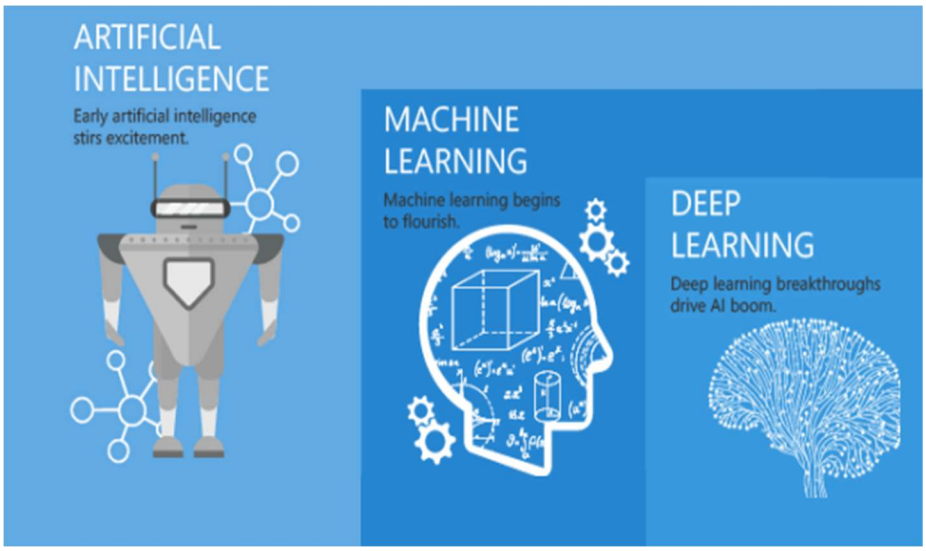

Fig. 1: Relationship between Artificial Intelligence, Machine Learning, and Deep Learning
Source: Kumar, S. (2018)

The term machine learning was coined by Arthur Samuel in 1959 while working at International Business Management (IBM) [7][8]. Prior to this time, in the Pre – 1940's, there were lots of mathematical theorems in statistics underpinning modern machine learning. Among these are the works of Thomas Bayes (Bayes Theorem) in 1812, which defines the probability of an event based on prior knowledge, the least squares of conditions that might be related to it, which was developed by Adrien – Marie Legendre for data fitting in 1905, and Adrey Markov who developed the Markov Chains in 1913 for analysis techniques. These techniques are all fundamental to modern day artificial intelligence and machine learning. In the late 1940s the concept of stored program computers that holds instructions (programs) in the same memory used for data were developed. These computers include EDVAC, and Mark 1 both developed in 1949, EDVAC in 1951 [9].

In 1950, Alan Turing published Computing Machinery and Intelligence with the question "Can machine think?" This paper was one of the first attempt to describe how 'artificial' intelligence could be developed based on the power of computers. Turing's paper proposed the "imitation game", a test game to determine whether a computer is intelligent by asking a person to distinguish between a human and a computer when communicating with both of them through typed messages [10].

In 1951, Marvin Minsky and Dean Edmonds **[12]** built the first artificial neural network – a computer-based simulation of the organic brains work. In 1952, Arthur Samuel at IBM laboratory started working on some of the first machine learning programs by creating programs checker player. However, it was in 1959 that Arthur Samuel finally coined the name 'Machine Learning.' In 1957, Frank Resenblatt invented the perceptron while working at the Cornell Aeronautical Laboratory. The invention of the perception generated great excitement and was widely used in the media at the time. In 1967, the nearest neighbor algorithm was created, allowing computers to begin using basic pattern recognition. The nearest neighbor algorithm was used to map a route for traveling salesmen, starting at a random city but ensuring that all cities are visited during a short tour [13][14].

In 1970, Seppor Linnainmaa publishes the general method for automatic differentiation (AD) of discrete connected networks of nested differentiable functions which is similar to the concept of present day back – propagation. In 1979, students at Stanford University developed a Cart which was able to navigate and avoid obstacles in a room, and in 1980, the concept of Neocognition was proposed by Kenihiko Fukushima. Neocognition is a type of artificial neural network (ANN). The concept of neocognition later inspired researchers in the area of convolutional neural networks (CNNs) [15]. Gerald Dejon in 1981 introduced the concept of Explanation Based Learning (EBL), in which a computer was able to analyze training data and creates a general rule it can follow by discarding unimportant data. In 1985, Terry Sejnowski invented NETalk, a program that learns to pronounce words the same way a baby does. In 1989, Q – learning was used to greatly improve the practicality and feasibility of reinforcement learning. In 1989, Ancelis Inc. releases Evolver, the first software package to commercialize the use of genetic algorithms on personal computers. This marked the beginning of commercialization of machine learning on personal computers [16][17].

In 1990s works on AI and machine learning shifted from a knowledge – driven approach to a data – driven approach. Scientists begin to create programs for computer to analyze large amounts of data and draw conclusion – or "learn" – from the results. In 1992, Gerald Tesauro developed TD – Gammon, a computer backgammon program that uses an artificial neural network (ANN) trained using temporal – difference learning. In 1995, the Support Vector machines (SVMs) was developed. SVMs are supervised machine learning algorithms for analyzing data used for classification and regression analysis. In 1997, IBM developed the IBM Deep Blue a chess – playing computer was able to beat the world champion in a chess competition. In 1998, at AT & T Laboratories, a team of researchers developed MNIST database, a dataset comprising a mix of handwritten digits, a digit recognition which was later used for good accuracy in detecting handwritten postcodes from the US Postal Service. The software used back – propagation, a neutral network model for optimizing learning by feeding "training data" with correct output into the neural network [18].

2. ARTIFICIAL INTELLIGENCE (AI) AND MACHINE LEARNING (ML) IN THE 21ST CENTURY

Since the start of the 21st century, many businesses have realized that artificial intelligence and machine learning will increase the potential at which people will do their businesses. This is why businesses and organizations such as Google, Facebook, Amazon, etc., are investing heavily in these areas especially with the advent of Big data regime, so that they can stay ahead of their competitors. In 2006, Netfix released a software that use machine learning to beat Netfix's own recommendation software's accuracy in predicting a user's rating for a film. Also, in 2006, Geoffrey Hiton coined the term Deep Learning to explain new algorithms that let computers "see" and distinguish objects and text in images and videos. In 2009, ImageNet, a large visual database envisioned by Fei – Fei Li from Stanford University was created. Fei – Fei Li realized that the best machine learning algorithms would not work well for real world data [19][20].

Today, ImageNet has been regarded by many AI and many machine learning researches as the catalyst for the AI boom in the 21st century. In 2012, the Google Brain team, led by Andrew Ng and Jeff Dean, developed a neural network that learns to recognize cats by watching unlabeled images. Thus this deep neural network focused mainly on pattern detection in images and video. The Google Brain was able to use Google's resources, which made it incomparable to much smaller neural networks. It was later used to detect objects in YouTube videos. Also, in 2012, the use of Graphical Processing Unit (GPU) and Convoluted Neural Networks (CNNs) in machine learning was used by AlexNet to win ImageNet competition by a large margin. They also created ReLU, an activation function that greatly improves efficiency of CNNs. GPUs are Graphical Processing Units that have about 200 times more processors per chip than CPUs. They are very important in the world of machine learning.[21].

In 2014, Deep Neural Network was created by Facebook, it is a tool used for face recognition called DeepFace. According to them, DeepFace can recognize people with the same precision as a human can. In that same year, DeepMind, a company bought by Google, is capable of playing basic video games to the same levels as humans [22]. In 2015, Amazon Machine Learning Platform, a part of Amazon Web Services, showed how most big companies want to get involved in machine learning. According to them, machine learning drives many of their internal systems, from regularly used services such as search recommendations and Alexa, to more experimental ones like Prime Air and Amazon Go. U–net was created in 2015. It is a CNN architecture that specialized in biomedical image segmentation. It used an equal amount of upsampling and downsampling layers as well as skipng of connections. In 2016, it was able to beat a professional at the game Go, which is considered to be one of the world's most difficult board game. Computer Go program to bear an unhandicapped professional player used combination of machine learning and tree search technique. It was later improved as Alpha Zero and then in 2017 to chess and more two – player game with Alpha Zero [23].

Also, in 2016, natural language processing gives life to a digital personal shopper. The North face became the first retailer to use IBM Watson's natural language processing in a mobile application. The Expert Personal Shopper helps consumers find what they are searching for through conversation just as human sales representative would. In 2018, Generative Adversorial Networks (GAN), a type of unsupervised deep learning system implemented as two competing neural networks was produced. In GAN, one network, the generator, creates take data that looks exactly like the real data set, while the other, the discriminator ingests real and synthetic data. Thus each network improves, thus enabling the pair to learn the entire distribution of the given data sets. In 2018, deep learning theory was used to explain the principle of deep neural networks and how it works by trying to mimic the human brain and their ability to "learn" from images, audio, and text-data. Deep learning also enables greater development and use by providing insight into optimal network design and architecture choices, while providing increased transparency for safety – critical or regulatory applications.

The concept of capsule networks was also proposed in 2018. Capsule network is a new type of deep neural network. It is used to process visual information in a similar way to human brain, thereby, maintaining hierarchical relationships. This a huge leap from convolutional neural networks which fails to take into account important spatial hierarchies between simple and complex objects, resulting in mis-classification and a high error rate. Another major development in AI and machine learning is the concept of deep reinforcement learning, (DRL) a technique which combines reinforcement learning with deep neural networks to learn by interacting with the environment. Deep reinforcement is a type of neural network that learns by interacting with the environment through observation, actions, and reward. Deep reinforcement learning has been used to learn gaming strategies such as Atari, Go, and AlphaGo program that beat a human champion.

DRL is the most general purpose among all learning techniques and has been used in most business applications. It requires less data the other learning techniques. Also, it can be trained via simulation, thus eliminating the need for labeled data completely. Another major technological breakthrough of machine learning in 2018 is the concept of Lean and Augmented Learning (LADL). LADL is a combination of techniques that enable a model to learn from less data or synthetic data. The biggest challenge in machine learning, deep learning in particular, is the availability of large volumes of labeled data to train the system. Two major techniques are used to address this challenge: 1) synthesizing new data, and 2) transferring a model trained for one task or domain to another. Techniques such as transfer learning (i.e., transferring the insights learned from one task/domain to another) or one – shot learning (i.e., transfer Learning taken to the extreme with learning occurring with just one or no relevant examples) making them "learn data" learning technique. Similarly, synthesizing new data through simulations or interpolations helps obtain more data, thereby augmenting existing data to improve learning. Using these techniques, it is possible to address a wider variety of problems that especially those with less historical data [23].

Probabilistic Programming, a high – level language that makes it easy for developers to define probability models is another major technological breakthrough in 2018. Probabilistic programming is a high – lever programming language that more easily enables a developer to design probability models and then automatically "Solve" these models. Probabilistic programming languages make it possible to reuse model liberaries, support interactive modeling and formal verification, and provide the abstraction layer necessary to foster generic, efficient inference in universal model classes. Probabilistic programming languages have the ability to accommodate the uncertain and incomplete information that is very common in the business domain. Hybrid Learning Models, an approach that combines different types of deep neural \ networks with probabilistic approaches to model uncertainty is one of the highlights in machine learning in 2018.

In hybrid learning models, different deep neural networks such as generative adversarial network (GANs) or deep reinforcement learning (DRL) have shown great promise in terms of their performance and widespread application with different types of data. However, deep learning models do not model uncertainty, the way Bayesian, or probabilistic approaches do. Hybrid learning models combines the two approaches to leverage the strengths of each. Some examples of hybrid models are Bayesian deep learning, Bayesian GANs, and Bayesian conditional GANs. Hybrid learning models make it possible to expand the variety of business problems to include deep learning with uncertainty. Thus can help business owners achieve better performance and explain ability of models, which in turn could encourage more widespread adoption. Another major breakthrough in machine learning in 2018 is the concept of automated machine learning, a technique for automating the standard workflow of machine learning.

Developing machine learning models is time consuming and expert driven workflow, which includes data preparation, feature selection, model or technique selection, training, and tuning. Automated Machine Learning (Auto ML) aims to automate the workflow using a number of different statistical and deep learning techniques. Auto ML is part of what is seen as a democratization of AI tools, enabling business users to develop machine learning models without a deep programming background which will help speed up the time required for data scientists to create models [24]. Digital Twin, a virtual model used for facilitating detailed analysis and monitoring of physical or psychological systems was another milestone achievement in the development of machine learning in 2018. The concept of the digital twin originated in the industrial world where it has been widely used to analyze and monitor things like windmill farms or industrial systems.

With agent – based modeling (i.e. computational models for simulating the actions and interactions of autonomous agents) and system dynamics (a computer – aided approach to policy analysis and design), digital twins are being applied to nonphysical objects and processes including predicting customer behavior. Digital twins can help spar the development and broader adoption of the internet of things (IoTs), providing a way to predictable diagnosis and maintain IoT systems [25].

Explainable Artificial Intelligence (Explainable AI), a machine learning technique that produce more explainable models while maintaining high performance was another major breakthrough in the development of machine learning in 2018. Today, there are scores of machine learning algorithms in use that sense, think, and act in a variety of applications. Yet many of these algorithms are considered as "black boxes" offering little or no insight into how they reached their outcome. Explainable AI is a movement to develop machine learning techniques that produce more explanations to models while maintaining prediction accuracy. AI that is explainable, provable, and transparent will be critical to establishing trust in the technology and will encourage wider adoption of machine learning techniques. Enterprises will adopt explainable AI as a requirement or best practice before embarking on widespread deployment of AI, while governments may make explainable AI a regulatory requirement in the future.

2.1 New Trends in Artificial Intelligence and Machine Learning

In recent times, artificial intelligence and machine learning have deeply involved in a number of groundbreaking researches and discoveries in many areas. These include facial recognition, security and privacy policies, AI-enabled chips, cloud maturity, deep learning, etc.

Facial Recognition

Facial recognition is a technology that enables the recognition of human faces and detects facial features and expressions. This technology helps to identify or verify a person from a digital image or a video frame from video. It does this by creating a template of someone's image as shown in figure 2. Facial recognition helps capture the picture of a person by creating an image or template

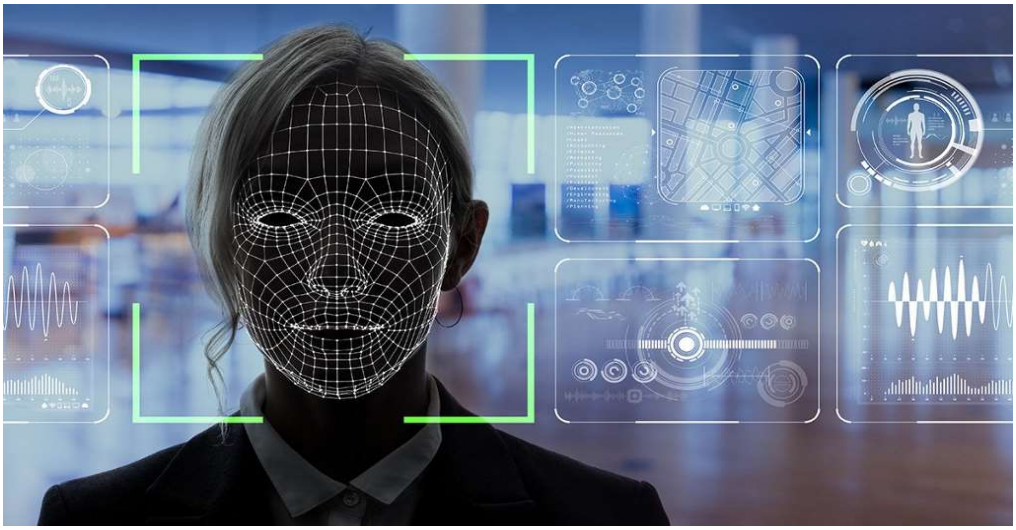

Fig. 3: Facial Recognition, Source: [26]

Improved Cyber Security and Privacy Policy

Artificial intelligence and machine learning have greatly improved cybersecurity and privacy policies of businesses and organizations in recent time through the automation of complex processes that detect cyber-attacks and cyber-crimes and other security breaches. This is made possible as a result of improved incident monitoring of cyber criminals. With improved incident monitoring, speed of detection and the resulting monitoring are very crucial to mitigating damages that may caused by these cyber criminals. Figure 3 shows a typical example of privacy policy of an organization.

Fig. 3: Privacy Policy, Source: [27]

Thus artificial intelligence and machine learning provides automated responses to various forms of cyber-attacks without human intervention. Artificial intelligence and machine learning will also provide countermeasures to reduce the incidence of counterfeiting for both online and physical commerce to spot incidence of face and adulterated products.

3. CONVERGENCE OF ARTIFICIAL INTELLIGENCE (AI) AND INTERNET OF THINGS (IOTS)

There convergence of AI and IoTs in recent time. Presently, AI and IoTs are very important research areas and virtually every technology is embedded with AI and IoTs software. AI and IoTs have met at the edge of computing layer and have converged. AI and Machine learning are already used for root cause analysis for automatic detection of device problems by advanced learning machine models and neural networks are being used for speech synthesis. They are also used for analyzing video frames, time-series data and unstructured data from IoTs devices. The collaboration is expected to leverage the use of distributed systems in the near future [28].

AI-Enabled Chips

Artificial Intelligence (AI) depends on specialized processors. Applications such as speech recognition and natural language processing (NLP) requires high processor speeds. Ordinary central processing units (CPUs) cannot run these high-speed AI applications. They require AI-enabled chips that are very robust and fast to be able to perform optimally and efficiently. These specialized chips are now being produced by International Business Management (IBM) and Intel by optimizing them to deal with specific applications that require high processor speed. Figure 4 shows an example of AI-Enabled Chips [29].

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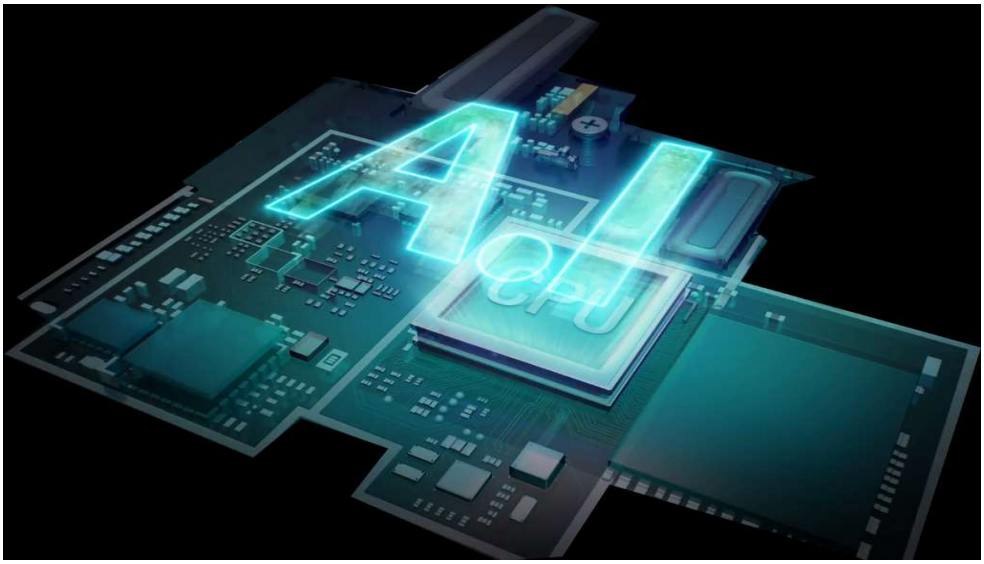

Fig. 4: AI-Enabled Chips

Improved Data Analysis

We live in the era of big data. The amount of data collected on daily basis in businesses worldwide is massive. These data need to be proper analyses and interpretation to guide manager and business executives make proper decisions as it concerns their businesses. Emerging AI and machine learning trends have made it possible and easier for large organizations to collect, store and analyze these data. During the process of data analysis, massive computation and patterns determined and recognized on the data and recommendations for the most relevant data. From the patterns discovered, such data provide information for reuse and business prediction in future analysis and management purposes [29].

Cloud Maturity

Amazon EC2 C5/C5d and M5/M5d instances are built on the Nitro system. This is a collection of AWS-built hardware and software components that enable high performance, high availability, high security, and bare metal capabilities to eliminate virtualization overhead. Based on these enhancements, Nitro system EBS-optimized bandwidth has increased significantly from 9Gbps for C5/C5d and 10Gbps for M5M5d respectively to 14Gbps. Other metrics have also increased considerably. This performance increase enables a user to speed up the parts that are workflows dependent on EBS-optimized instance performance thereby saving costs and users are now able to handle unplanned tasks in EBS-optimized instance demand without major impacts on user's application performance. Figure 5 shows a typical Google cloud AI. It is built on AI tensor process technology [30].

Fig. 5: Google Cloud AI
Source: Cloud TPU, https://cloud.google.com/tpu/

Machine learning has produced business and research breakthroughs ranging from network security to medical diagnoses. Today, Tensor Processing Unit (TPU) are built to make sure that everyone is able to achieve similar breakthroughs. Cloud TPU is the custom-designed machine learning ASIC that powers Google products like Translate, Photos, Search, Assistant, and Gmail. Here's how you can put the TPU and machine learning to work to increase speed and scalability.

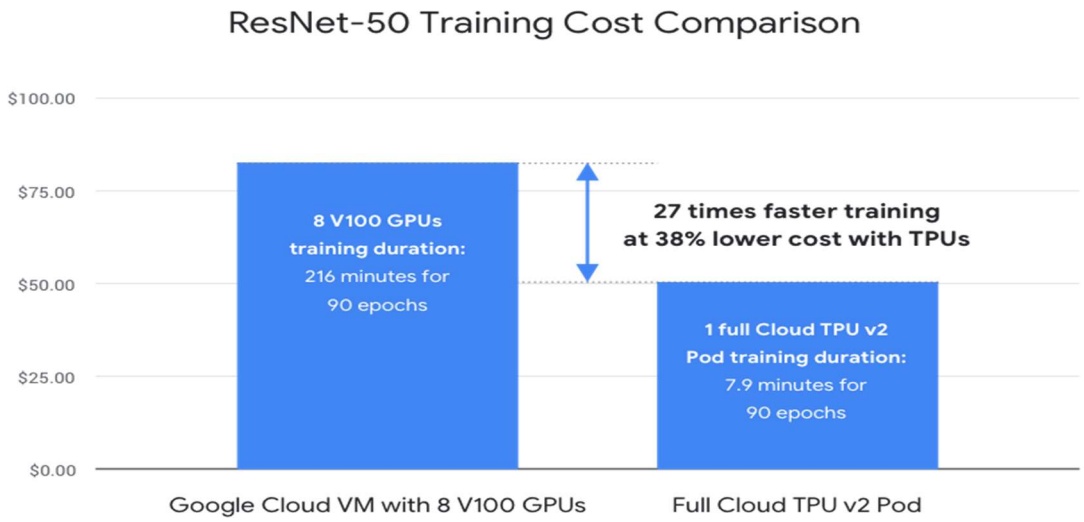

Fig. 6: Google Cloud Virtual Machine
Source: Cloud TPU

Figure 6 shows the Google Cloud Virtual Machine with 8 V100 GPUs versus 1 full Cloud TPU v2 Pod. With the Google Cloud Virtual Machine with 8 V100 GPUs, it can be seen that the training performance is 27 times faster and a much lower training costs of 38% reduction. The implication is that it will become cheaper and affordable foe companies and small organizations to adopt cloud computing more and its deployment and adoption has made it cheaper thus making AI to become customers friendly and machine learning user friendly.

4. MACHINE LEARNING AND DEEP LEARNING

Deep Learning is the subset of machine learning composed of algorithms that permit software to train itself to perform tasks like speech and image recognition, exposing multi-layered neural networks to vast amount of data. Figure 2 shows the diagram of how deep learning works. With the introduction of the concepts such as artificial intelligence, machine learning and deep learning, there virtual agents in company's websites which now responds to customer's need. These agents provide human-like customized help to clients. These virtual agents rely on AI systems to provide answers to customer's frequently asked questions using the concept of machine learning and deep learning. The answers to these questions are used to predict future conversations and market trends.

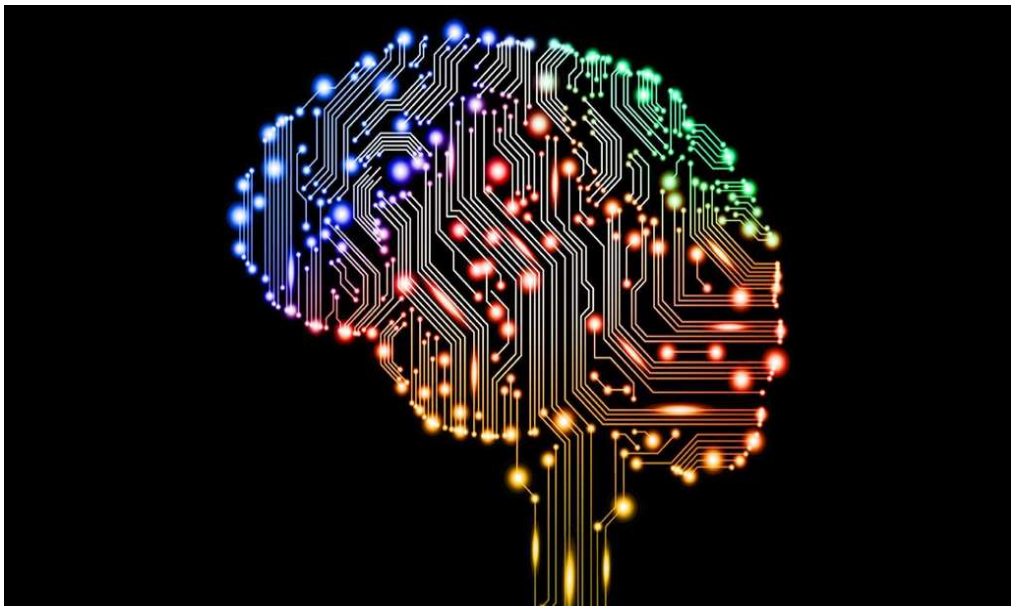

Fig. 7: Deep Learning

Figure 7 shows an example of a deep learning. Deep learning help customer to be able to understand and predict business patterns more reliably. With machine learning and deep learning, customers companies now assign repetitive customer service tasks to virtual agents which has helped to reduce the costs of doing businesses drastically. Also, machine learning and deep learning are expected to increase the rate innovation and enable virtual agents to perform better in terms of query handling, customer service, better performance, costs reduction, etc.

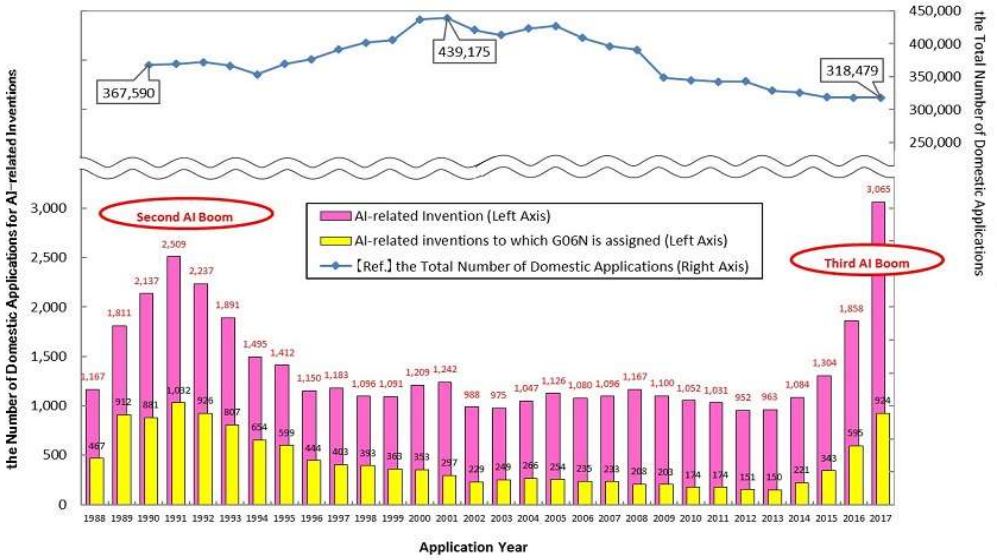

Fig. 8: AI-related inventions (1988-2017)
Source: Burgar [31]

Figure 8 shows the graph of AI-related inventions between 1988 to 2017. There was the second AI boom in 1991 and again in 2017 during which time there was drastic increase in the number of domestic applications of AI related inventions.

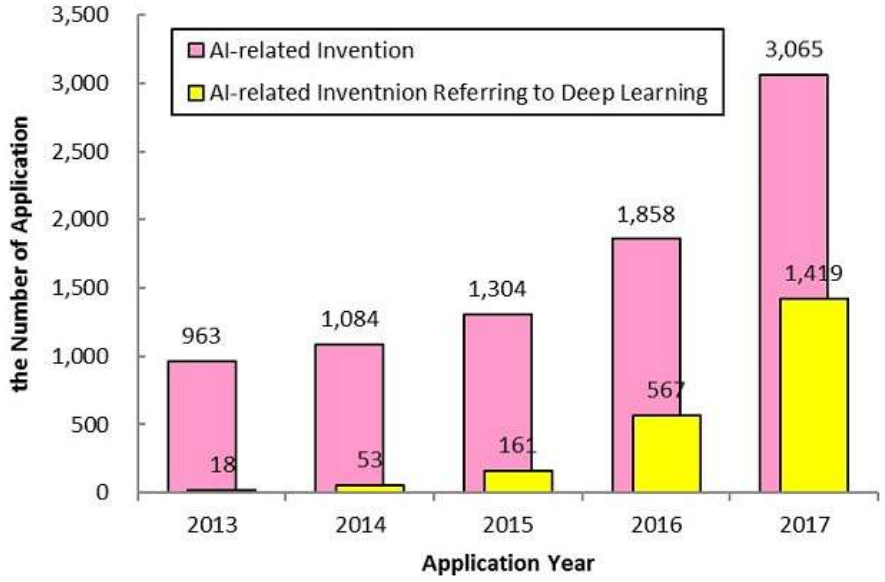

Fig. 9: AI-related inventions (2013-2017)
Source: Burgar [31]

Figure 9 shows the actual number of these applications and their years. It can be seen that there was a gradual rise of domestic applications of AI-enabled or AI-related inventions from 963 in 2013 to 1, 858 in 2016 and a drastic increase in 2019. Also, in deep learning, there was a drastic increase from 2014 to 2017 and the trend is expected to continue due to the importance of artificial intelligence, machine learning and deep learning in businesses and organizations due to global interest in these fields.

5. CONCLUSION

In recent years, there has been a growing trend in AI of attention from policy makers, universities, researchers, corporations, media, and the public. Driven by advances in big data and computing power, breakthroughs in AI and machine learning research and technology seem to happen about on daily basis. The growing importance and relevance of artificial intelligence (AI) in every field of human endeavor ranging from business, healthcare, education, agriculture, bioinformatic, cybersecurity, military, etc., is on the increase. Since the start of the 21st century, many businesses have realized that artificial intelligence and machine learning will increase the potential at which people will do their businesses. This is why businesses and organizations such as Google, Facebook, Amazon, etc., are investing heavily in these areas especially with the advent of Big data regime, so that they can stay ahead of their competitors. The application and use of Artificial intelligence have become so important that one cannot but discuss it.

AI has become more popular these days due largely to increased data volumes, advanced algorithms, and improvements in computing powers and storage. AI makes it possible for machines to learn from experience, adjust to new inputs and perform human-like tasks such as chess-playing, robotics used in war zones and manufacturing processes, self-driving cars, all of which rely on deep learning and natural language processing where computers are trained to accomplish specific tasks by processing large amounts of data and recognizing patterns in the data. This paper discusses the emerging trends in artificial intelligence (AI) and Machine learning by tracing the history their histories and state-of-the-art of the two concepts. It also discusses other concepts such as deep learning, machine learning, facial recognition, privacy policy, AI-enabled and embedded chips, cloud especially cloud AI, brainware, etc.

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