Artificial Intelligence and Deep Learning in Video Games A Brief Review

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***Abstract*—Artificial Intelligence has been used in many fields since the term was coined six decades ago. Artificial Intelligence in video games was introduced with Atari 2600's early titles such as 'Computer Space' and 'Pong' and has come a long way since. However, it has become expected of developers to have flawless AI which is as human-like as possible. Neural Networks are allowing AI systems to become smarter and used in ways such as OpenAI does with their game-playing bots. Many game-playing Neural Networks use reinforcement learning to train as it allows for more efficient training for larger games where the number of possible positions and combinations of game mechanics are extremely large. This paper provides an introductory literature review of these core fields of research as they applied within a video game context.**

Keywords-artificial intelligence; deep learning; video games; neural networks

I. Introduction

Artificial Intelligence (AI) or Machine Intelligence is a system that attempts to mimic the characteristics of the human thought process in order to make its own decisions/learn/think without human intervention. When most people think of intelligent machines they immediately think of robots from science fiction, however in this paper we will be looking at the history of AI, how AI is used in video games, and how deep learning can be used to make more 'intelligent' machines and improve the AI experience in video gaming. John McCarthy coined the term 'Artificial Intelligence in 1956, however the principles were first developed around 1950 by Alan Turing and the famous Turing test, as stated by Smith, McGuire, Huang and Yang [1]. AI in video games was first seen in early Atari games such as Pong and Space Invaders, although they were very basic systems. In recent AI research progression, we have seen computers equipped with deep learning algorithms take down some of the world's best DotA 2 players. The possibilities of future Artificial Intelligence and Deep learning are endless, and the robots depicted in Sci-Fi classics may not be too fictional in the near future. Future research into Machine Learning, according to scholars, will result in Neural Nets being able to train autonomously which will lead to larger number of 'self-thinking' machines. Many sources on the matter state in the near future machines will be used to train professional players as they will soon surpass them.

II. History of Artificial Intelligence and the Turing Test

The authors in [1] suggest that John McCarthy is known for coining the term 'Artificial Intelligence' at an academic conference in 1956. McCarthy defined the conference proposal as "The study is to proceed on the basis of the conjecture that every aspect of learning or any other feature of intelligence can in principle be so precisely described that a machine can be made to simulate it. An attempt will be made to find how to make machines use language, form abstractions and concepts, solve kinds of problems now reserved for humans, and improve themselves" [2]. The study in [1] states that the AI hasn't seen any sort of rapid progression since its initial studies, due to its complex nature and overblown expectations in the field. This is mainly due to lack of motivation (especially in video games). Future age robots and smart houses are usually the kinds of thing that come to mind when you ask someone what they think Artificial Intelligence is. While this could be the reality someday, we are still far from an AI machine that could be mistaken for a human (physically and logically).

While McCarthy coined the term, the credit for conceiving the idea of AI is awarded to Alan Turing with his paper "Computing Machinery and intelligence" [1]. Turing's paper, as outlined by the author of [3], poses the question to the reader "Can machines think?", which is regarded as the birth of AI. Hodges [3] studies the philosophical view of the all-important question as well as objections the field may have (e.g. The Mathematical Objection). Turing is known for developing the Turing Test (aka The Imitation game), a long-term benchmark for AI developers, in which they attempt to imitate a human in a series of tests, with the ultimate goal of being mistaken for a human [3].

The test includes a computer, a human controller, and a judge (usually an expert in psychology or speech). In Hugh Loebner's annual competition, the judge is separated from both the computer and human controller. The judge has a conversation with each both the human and the computer for five minutes in order to figure out which of the participants is the human, as described by Mohn [4]. Marcus [5] is very sceptical about a 'winner', who in 2014 managed to convince roughly a third of the judges by taking on the persona of a 13-year-old boy. The computer won by completely avoiding answering the questions in a proper manner and instead reduced to sarcasm. After the Turing Test was technically defeated, Marcus [5] dedicated himself to developing a more

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modern test, that would focus on watching and evaluating a variety of videos, alongside former President of the International Joint Conferences on Artificial Intelligence Organisation (IJCAI), Francesca Rossi. Pavlus' article [6] outlines 4 tests that could possibly be labelled the 'new' Turing Tests: Winograd Schema Challenge (simple schema tests that challenges common sense of the machine), Standardised Testing for Machines (a testing system similar to what a primary school child would sit), Physically Embodied Turing Test (A set of tests which a robot would build a structure and a creative challenge using toys such as building blocks), and I-Athlon (a test in which the machine will listen to an audio file or watch a video and summarize them).

III. ARTIFICIAL INTELLIGENCE IN GAMES

Today, we see Artificial Intelligence as a staple for a good video game. According to Xu [7]. The first video games were created without AI due to them being overly simple and being designed to be competition between two or more people. Xu [7] continued to say that AI wasn't really introduced into the video game world until 'Computer Space' was released on the Atari in 1970. Designers continued to create more complex AI in order to convince players to keep putting coins into arcade machines. The first video games were designed for two players to play against each other, however, AI development enabled designers to create a computer-generated enemy, thus allowing single person play. The most notable game to do this, and is still played today, was Pong.

There is no argument that Artificial Intelligence in video games has come a long way in terms of functionality and human-like capabilities, but is it yet as advanced as it could be? The authors in [8],[9] argue that video game developers of latter years have primarily been focusing on making games graphically perfect and realistic, to keep up with competitors and to meet today's demand, as customers expect the game to look and feel spotless. Thus, developers are putting more resources into the graphical engine and leaving less for the AI in order to boost sales and create a loyal fan base. The authors of [1] also outline three other major reasons for the lack of video game AI advancement.

Firstly, studies conducted in [1] blames lack of CPU power and resources. This is a constant (and will remain) as other areas of game development, such as graphics, will continue to become more advanced, thus needing a higher level of CPU power, and in turn leaving less room for AI advancement. However, since the development of more powerful GPU's (Graphic Processing Unit), the weight has shifted almost entirely off the CPU, and we may see developers take advantage of this in the near future [8], [10]. Secondly, a lack of understanding of advanced AI techniques can also be blamed, as an excellent understanding of AI programming and its capabilities is needed in order to create a believable system. Thirdly and more unlikely, is the true unknown long-term effect of using neural networks or other non-deterministic methods in terms of completely breaking the game. Although studies in [8] are 17 years old, these arguments are still relevant today as the level of advancement has remained constant.

In the current profile of AI in gaming, users are not particularly interested in using it as a determinant when choosing whether or not to purchase a game. However, Hruska and Nareyek [9], [10] have found that a video game's AI rarely affects it's selling power in a positive way, only in a negative way when it receives bad reviews. Both studies go on to say that gamers definitely value a good AI system, but the only AI that stands out, is the systems that have very poor performance. Narayek [10] also found that developers and publishers, rather that developing a consistently good AI, will instead focus on more unexpected and innovative areas of more complex AI procedures, that will 'wow' the audience, but not provide any real functionality to the game (for example, creating more realistic townsfolk in an RPG rather than smarter enemies).

IV. AI METHODOLOGIES

Artificial Intelligence and machine learning can fall into two categories: supervised and unsupervised learning. As described in [11], supervised learning is when the output is known by the supervisor and the training data is labelled as such. Supervised learning contains methods such as decision trees and classification, which, as the name suggests, classifies data into meaningful categories [12]. This form of artificial intelligence/ machine learning is used continuously through game development.

The authors in [11] state that in unsupervised learning, data is not labelled, and the output is not known. Unsupervised learning, as outlined in [13], contains methods that are usually interested in input patterns and the meaning of these patterns. The data that is gathered, in unsupervised learning, is grouped with similar data, in which it is easier to identify patterns. This is called clustering [14].

Reinforcement learning is a hybrid technique that most people will be familiar with, whether its Pavlov's dogs or first-hand training with a pet. The general idea of Reinforcement Learning or teaching is to reward or discipline something or someone after they perform a desired or undesired action. However, in relation to machine learning, Reinforcement Learning is machine learning by interaction in which the learner is reinforced according to which action they take in a specific situation [15], [16]. Therefore, the machine learns the best possible action to take in a certain situation.

Neural Networks are a form of Artificial Intelligence algorithm that have a greater capacity to mimic how the actual human brain works. Zahedi [16] states that a Neural Network consists of layers (input, output, sometimes hidden layers), nodes (each layer contains nodes), connections (connection between nodes, connections start at the input layer, to the hidden layer, and then to the output layer), weight (nodes can contain different weights which have different impact on the network), and the node's net input (how the strength of the connection between two nodes effects the output of other nodes connected to it). Gurney [17] states that Neural Networks work by receiving a weighted input to the input layer nodes; a number from 0-1, the input layer then passes the information onto the hidden layers which activate if the weighting from the previous layer is similar to that of its own. When the signal reaches the output layer, it will hopefully contain the desired output. Gurney [17] explains Neural Networks as a sequence of switches that activate if the input is similar to that which it desires. This is very similar to how neurons work in the brain (hence the name); the Dendrites receive impulse through the synapse, which passes the information to the cell body, which then processes the information, passes the information on to the Axon through an electrical impulse that is in turn passed onto another neuron, as described by Stahl [18].

Convolutional Neural Networks (CNN) are a type of multi-layer network that are designed to be used with images and videos [19]. CNN's attempt to use the space between pixels of an image or video as information that is inputted into the Neural Network [19],[20]. According to Stutz [20], CNN's work by convolving an initial input through trainable filters and biases to produce feature maps. These feature maps then group pixels and are added, weighted and combined with a bias, which are filtered again various times until it knows what is in the section of an image [21]. Gupta [21] outlines that the general goal of the CNN is to extract features within an image and are mostly used in handwriting recognition.

Recurrent Neural Networks (RNN) are similar to the tradition Neural Net, however, they contain an added layer called a 'delay' layer which loops in multiple iterations inside the hidden layers [22]. These types of Networks are usually used in, again, handwriting recognition and speech recognition.

There are many AI methodologies and topologies that are used for creating the perfect machine. Deep learning algorithms such as Neural Networks are also used in creating 'players' of famous video games in order to complete the game or rival human players. Video games provide an excellent testing field for developing AI as there are no boundaries or consequences.

V. MACHINES PLAYING GAMES

The authors state in [23] that video games are widely used for testing out new and different mixtures of AI algorithms and techniques due to their complexity, nondeterminism, and limited input. According to Togelius [24], it is immensely cheaper to develop and test AI in a created environment with thousands of instances, than to build robots and have them do thousands of tests. Kahn [25] states that when designing software for real world uses, such as selfdriving cars, it is much easier to just train the AI through a driving computer game rather than risk damaging the hardware and injuring people. In a recent Forbes article [26], Olson states that partnerships with leading companies such as Google's DeepMind (known for its AlphaGo program) and Unity Technologies, can take AI methodologies such as deep-reinforcement learning to the next level, and this case, Unity's environment created AI that can tackle more real-life problems such as self-driving cars and 3D navigation. AI that can play video games may also assist developers in the future by running a machine in testing phases to find bugs and improve the quality of the gameplay overall.

According to Yannakakis and Togelius [27], One of the first big milestones in AI playing video games was IBM's Deep Blue in 1997 when it defeated Chess world champion Garry Kasparov using a Minimax algorithm, evaluation functions, and harnessing the power of a supercomputer. AlphaGo, DeepMind's AI program dedicated to the ancient Chinese game Go, was able to defeat some of Go's top ranked players in 2016, 9 years after taking down chess by defeating its champion. In Koch's AlphaGo review [28], he declares an end of an era as the last of the traditional board games was defeated. It is a fair declaration that Go is considered slightly harder than chess as there are more possible positions, strategies, and hours needed to master it. Koch [28] states that this milestone shows how powerful a combination of supervised learning, reinforcement learning, and deep neural networks can be through playing hundreds of thousands of games against itself simultaneously. AlphaGo's latest work, AlphaGo Zero, completely skips the supervised learning steps of the AI training and starts off with playing itself using a neural net trained by self-play reinforcement learning, according to the AlphaGo Zero Team [29].

DeepMind Technologies was able to train machines to play classic Atari 2600 games through reinforcement learning and a CNN, with the goal of creating a single Neural Network that can play any Atari 2600 game, according to the authors of [30]. Seven of the classics were initially completed faster than any human had before, this attracted attention to the field as it was rapidly progressing the first thought capabilities and scope of the Neural Network. Since the first games were initially defeated, new algorithms such as the Asynchronous Advantage Actor Critic (A3C) algorithm defined in [31], allowed more games to be completed or maintain a very high average score in a much shorter time. The A3C algorithm allows multiple instances using multiple CPU threads on a single machine which can use different exploration policies whilst training to maximise the efficiency of the whole process [28], [31]. DeepMind state in [31] that running multiple instances using different CPU threads means that using a 16 core CPU is completely viable and much less expensive compared to the earlier AlphaGo 2 step method across multiple machines which needed 48 CPUs and 8 GPUs, as explained in [28].

OpenAI's DotA 2 team, OpenAI Five, is proof of how far machines can go at playing video games on an extreme level. DotA 2 is the sequel of the popular Warcraft 3 mod, Defence of the Ancients, and is now developed by Valve. This game pits two teams of five against each other with the goal of destroying each other's ancient (base structure). The Game contains over 100 playable characters and hundreds of in-game items to purchase, meaning the possible combination of character and item builds are almost endless. The OpenAI bots are trained using Reinforcement learning and using methods such as the A3C algorithm in which they play games against each other, initially 1v1, for a total of 180 years of game time everyday [32], [33]. Tsukayama states in [33] that a solo bot was able to outplay professionals in a 1v1 context at The International 7 (TI7), Esports largest prize pool annual tournament, with general ease. The next big step was to defeat a team in a 5v5 setting, and they did just that against a team of ex-pros, casters, and semi-pros, which were ranked in the 99.95th percentile of skill, according to Quach [34]. With OpenAI Five destroying all human opponents in its path, OpenAI decided to put on two show matches at TI8 against organised professionals who were competing, paiN Gaming and Big God. In OpenAI's blogpost about the results of the event [35], they stated that the competition was much stronger compared to anything it had faced before, hence the loss against both teams. However, it is also stated in [35] that the games both took longer than their averages so far and put up a very good fight, leaving everyone impressed.

OpenAI state in [35] that they will keep developing their systems after the results of TI8 and continue to advance AI to perform better in, and out of, DotA. In a matter of 21 years, AI was able to progress from defeating the best players in the world at Chess to competing in the biggest Esports tournaments in the world. The complexity of traditional games such as chess to an ever-complexing game such as DotA 2 is incomparable due to the sheer amount of combinations possible in such a huge game that takes even the amateur players thousands of hours to become competent.

VI. Conclusion and Future Research

The capabilities of Deep Learning and Machine Learning in general, as far as we can predict, are limitless. Chollet [36] predicts that Neural Networks will no longer be engineered by humans, but by systems that will access a library of subroutines which are evolved by other models that have endless amounts of data. Whereas Dhar [37] believes the next step for Deep Learning relates to mimicking human "common sense", such as making connections and hard decisions. In terms of game related advancement, studies in [8] suggest that NPCs, dynamic storylines, and harder opponents will be the result of AI research. This will allow for an overall better game experience for players, which is what developers are always aiming for. OpenAI states [35] that after the defeat at TI8 their research will continue to work on developing a better team for OpenAI Five and return next year to hopefully defeat the strongest team at the annual event.

Deep Learning and AI in general, has evolved at a relatively steady pace and hasn't really taken any major leaps and bounds until recently, according to the authors in [1], [8], [9]. Marcus [5] and Pavlus [6] outline how they believe that the Turing Test, as described by the authors in [3], is now outdated, and are working on new benchmarks to test the advancement of intelligent machines. Neural Networks are allowing machines to learn more information and illicit human-like responses in a shorter time as explored in [20], [21]. Sources such as [26], [36], [37] believe that the advancement of Machine Learning will continue full steam ahead, as tech masterminds such as Elon Musk are investing in extensive research such as his not-forprofit company OpenAI. OpenAI states in [35] they will continue to work on intelligent machines in, and out of, the DotA 2 scene and as a company they stand for the ethical development of AI and its responsible use. Video game AI in its current state is largely leaving users dissatisfied, as the authors in [9], [10] state, users are much better at noticing bad AI in games and leaving bad reviews, whereas good AI is expected of the game. Although there is a lot of caution in developing AI after the success of dystopian novels and films such as 'I, Robot', Companies such as OpenAI are dedicated to developing smart machines that will not bring our race to an end. Dickson [38] states that AI shown in dystopian literature will not become evident for a very long time, if ever, due to the sheer amount of data needed for AI to function, the limited tasks that AI can focus on, and not having a human brain that can apply outside knowledge to processes such as video games.

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