Faculty of International Economics and Administration

Computer Science Department

Course Project

E-Sports

Research Project

Artificial Intelligence as a turning point in the evolution of the video games

Submitted by: Elis Fikri Mehmed

F№ 213110003

2022

Contents

Abstract

A video game is an electronic program, created for entertainment, based on the interaction between one or more people and an electronic device called a console that runs the video game. These video games' complexity can range from a few lines of code to several years of a project involving a large number of programmers. Many developers of these video games ask themselves, what will define their game? what will make different their games from others? All of them were developing their graphics, but the difference in graphics between one game and another has reached a very minimal point, so the solution for this need was the constant advances that Artificial Intelligence has had. Therefore, this project will be briefly presented the history of artificial intelligence in video games from the beginning, defining the most relevant AI used in video games to explain the most important points to take into account when the artificial intelligence of a video game is being developed.

Introduction

In the past, video games were implemented using the same classic techniques and generating the same gameplay, this was due to the absence of more powerful technologies.

Currently, we have new technologies and more powerful devices allowing video game developers to create more powerful engines applicable to non-player characters (NPC), which allow more information and a broader speed to process this artificial intelligence, and therefore an improved artificial intelligence.

Artificial intelligence is the branch of computer science, that deals with building intelligent agents, which can be able to think intelligently like humans, can be able to solve, and evolve by themselves.

Developers must focus on this artificial intelligence to improve game experiences and difficulties, providing a greater challenge to users at the time of playing, putting the NPC characters at a higher level being able to simulate the movements and decision making of a human user thanks to the development of artificial intelligence focused on behaviors of the characters and game scenarios.

That's why Artificial Intelligence has become one of the most important when studying or criticizing a video game.

With the advances made in recent years, notable changes can be observed in the gameplay of some video games, where enemies (NPC) with greater "intelligence" and aggressiveness are observed, with which they can execute a greater variety of actions to be able to neutralize the user player, such as switching from a weapon or grenade in a matter of seconds, recognizing alterations in the game scenarios, such as noises that the user can make. All these actions represent a real challenge for video game lovers and it was widely accepted within the community Gamer.

Objectives

General Objectives

Study the application of artificial intelligence for the development of more complex video games.

Specific Objectives

- ➤ Construct a line of evolution of video games based on technical characteristics and playability.

- ➤ Study the artificial intelligence techniques within video games.

- ➤ Analyze how the integration of artificial intelligence is taking place in the world of video games and what is its potential within that field

Methodology

To carry out this project, it was used a methodology of generic research, for its development previous planning was carried out in which the possible topics of the project were estimated, as well as the final choice and its communication to the tutor. It has proceeded with a search of primary sources of information from which to extract minimum and basic content to the subject. Similarly, it has been seen several video games to determine and understand the content of them, that lately were used for this project.

In addition, the final section of the project includes the bibliography and sources of information used in this project.

Theoretical framework

1. Artificial Intelligence applied to video games

Artificial Intelligence is a part of computer science, where algorithms are developed (sequence of instructions that represent a solution model to a certain problem) and is raised to design intelligent systems, which are applied to technological machines (computer, cell phones, robots, etc.) to represent the capacities that the human being possesses, with this technology the machines are given the power of reason on their own.

In video games, these algorithms are implemented to generate a game experience different from what is used to. The challenges imposed by a virtual world are increased, thus leading the user to experience games where he is more involved, making the game more logical to determine the success obtained within the game.

1.1. Classical Artificial Intelligence

They are the first AI techniques developed and applied in video games, such as:

1.1.1. Zero-sum games, Minimax algorithm

This algorithm looks for all the possible moves and the answers that can be given (see figure 1), until reaching its maximum state level, once it is reached, it evaluates the game board, where if the action is good is given a positive value, or opposite it would be a negative value, this algorithm responds with the best move that it can give, because it assumes that the player is also making his best moves. This technique is applied in games where two players are involved, the interactions that occur are known as the zero-sum game because the sum of the points of each result is equal to zero.
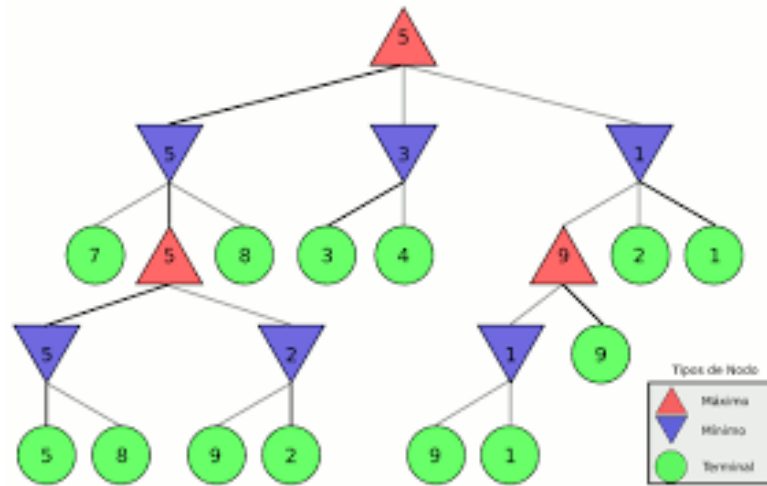
Figure 1. Minimax algorithm

In the algorithm, one player is called the maximizer, and the other player is a minimizer. The maximizer works to get the highest score, while the minimizer tries to get the lowest score by trying to counter moves. Examples of such games are chess, poker, checkers, and tic-tac-toe.

1.1.2. Pathfinding algorithm

The Pathfinding algorithm is capable to search an existing path between an initial node and an end node of a graph, at the moment of the search. This takes into account the distance and the difficulty of the territory, which in this case will give as a response the most optimal path. The root of this algorithm is associated with the evolution of video games because they are the most practical applications in this environment. With the pathfinding technique, the target can bypass obstacles to carry from one point to another (points A and B).

The main function of this algorithm is the exploration of the paths that can be given, starting from an origin vertex, which is connected to other vertices, which are inside the graph (Figure 2), if one of these vertices passes through a negative edge, it can cut the path and the algorithm can exclude them from the search. This is one of the first AI techniques in video games, thanks to this, games like Pac-Man have had success in the markets since the dynamics of this game is used the pathfinding algorithm. Pacman can move and at the same time can avoid the obstacles that prevent him to meet his goal.
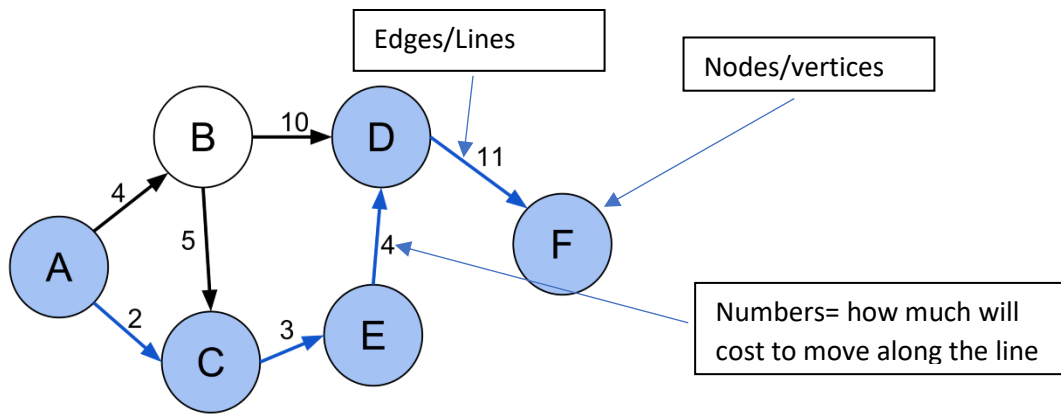
Figure 2. Pathfinding Algorithm

1.1.3. Intelligent agents

An intelligent agent is a program or software which perceives (or observes or senses) its environment through sensors, thinks intelligently, and acts upon that environment through its actuators (Figure 3).
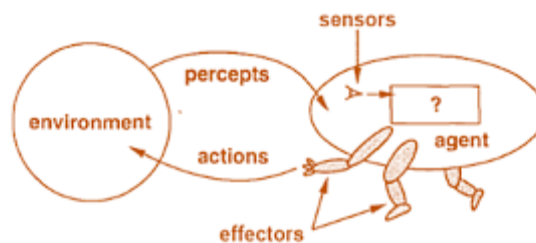

Figure 3. Intelligent agent

Any agent carries 3 key tasks continuously in an infinite loop (or cycle) they are "sense, think and act" or "perception-action". This technique is one of the most used within virtual environments and we can see it in NPC characters (characters controlled by AI), which provide greater dynamism to the scenarios of play. In shooter games like Call of Duty, Battlefield, etc. the NPC characters are depending on the intelligent agent technique to perform their movements like shooting, throwing grenades, talk, all this happens, thanks to this algorithm. This technique can have several degrees of difficulty, depending on the model chosen (easy, normal, difficult, legendary), this goes to the judgment and the ability of the player.

1.1.4. A finite-state machine (FSM)

Video games are finite-state machines. A finite-state machine describes how the software works. The idea is that it is presently one state, an action is performed and you move into another state. In particular, each state is made of various data, then when an action happens, that data is changed moving into another state.

Only a single state can be active at the same time, so the machine must transition from one state to another to perform different actions (Figure 4).
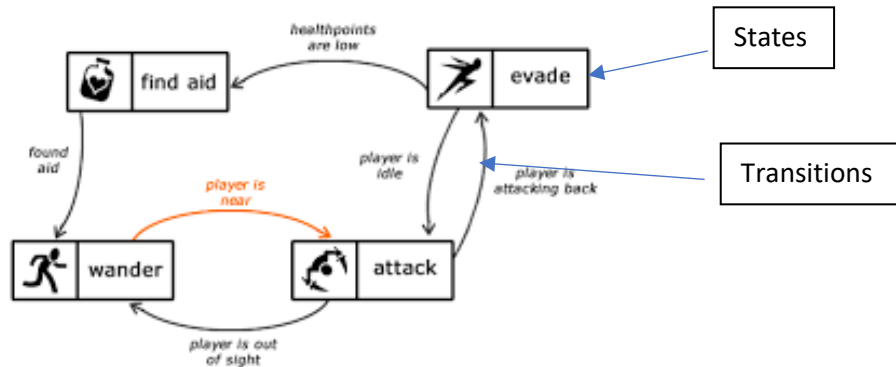

Figure 4. Fine state machine

FSM is commonly used to organize and represent an execution flow, which is useful to implement AI in games. The "brain" of an enemy, for instance, can be implemented using FSM: every state represents an action, such as *attack or evade.*

FSM technique can be combined with intelligent agents and simulate realistic actions with faster reactions, which improves the experience within these scenarios. And if to this we sum a mode of a legendary game, the NPCs can act like a person (regarding the game actions), giving the impression that two real people are facing each other.

1.1.5. Genetic algorithms

A genetic algorithm is a heuristic search algorithm used to solve search and optimization problems. This algorithm is a subset of evolutionary algorithms, which are used in the computation.
In video games, GA`s main function is to find the individuals who best perform their duties (tasks) and use them to create new individuals with better adaptation (this means, that are better performing the tasks than the previous individual), see (Figure 5).
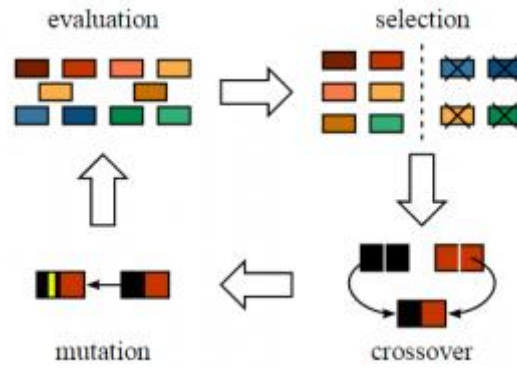
Figure 5. Genetic algorithm

These techniques are applied in video games with complicated territories and we can see them in games like Word of Warcraft, the GA is used in NPC characters that transit through each of their maps, and during their journey, they must face obstacles.

1.1.6. Monte Carlo Tree Search

In computer science, Monte Carlo tree search (MCTS) is a heuristic search algorithm for some type of decision processes, most notably those employed in software that plays board games such as chess and shogi, bridge and poker, as well as turn-based strategy video games such as Total Implementation of War: Rome 2.

Monte Carlo Tree search work on four phases: tree traversal, node expansion, rollout phase, and backpropagation phase (see Figure 6).
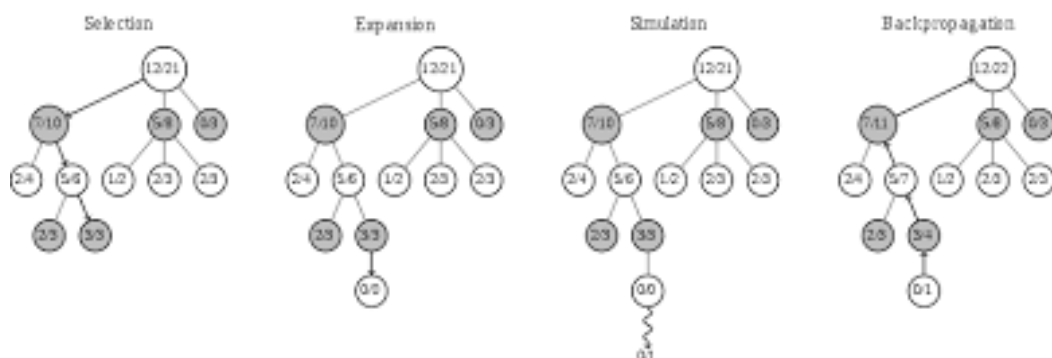

Figure 6. Genetic algorithm

1.2.Modern artificial intelligence applied to video games

In recent years, modern AI techniques are developed of greater complexity than the classic techniques and they have more advanced AI, but still, modern artificial intelligence needs the collaboration of the classic algorithm for better performance in the tasks. This combination has achieved great success and more realistic simulations of human thought.

Some of these modern AI techniques are:

1.2.1. Machine learning

Machine learning is an AI discipline and can create intelligent systems which are learning itself automatically, this means that they identify patterns of complexity within the volume of data assigned to them, where the algorithm reviews these patterns and can predict future behavior. These systems can imitate human intelligence, thanks to the training, and achieve "knowledge" with higher success (see Figure 7) because are learning from the new events that occur during their training.
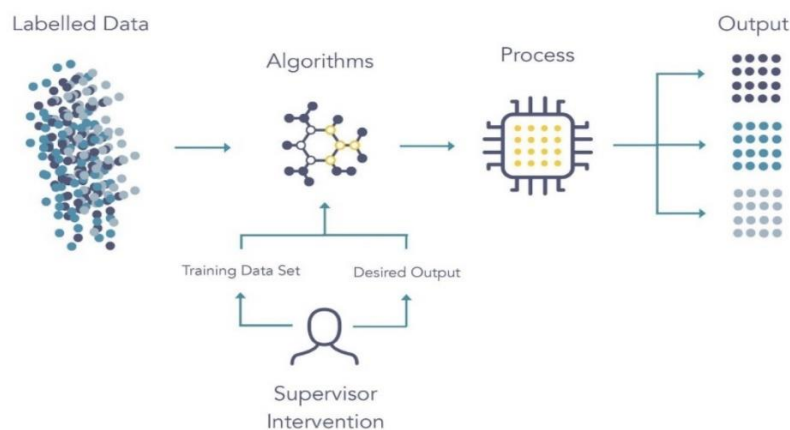
Figure 7. Machine learning

Machine learning can learn and anticipate behaviors, this algorithm uses artificial neural networks, which are supplied with a volume of data for their learning so they can resolve some specific problem. This technique has multiple uses, ranging from the most generalized as a facial recognition system to more specialized uses such as being able to generate medical diagnoses.

In the field of video games, there is an intelligent system known as AlphaGo (developed by Google) that makes use of this AI technique (artificial neural networks) and it is capable of "imagining" worlds never seen before and projecting them. To analyze the countless data and human behavior variables, for a person takes a lot of time, this AI does it in a matter of seconds.

Machine learning technology is making significant changes to the game difficulties within the game scenarios since these have changed the way of playing the NPCs of each virtual world, so these characters already can execute more successful strategies and movements according to the move made by the player. This has achieved that the rates of difficulty are increased and therefore video games become more attractive to people, more interactive and more realistic, engaging players to execute new strategies and greater concentration.

1.2.2. Deep learning

Deep learning is another modern AI technique, which carries out Machine Learning processes using artificial neural networks, which are made up of hierarchical levels (see Figure 8). At the first level of the hierarchy, what is learned is something basic and simple, the information obtained is sent to the next level to be combined with new information, giving as a result data of greater complexity than in the previous level and sends it to the next level, and so on.
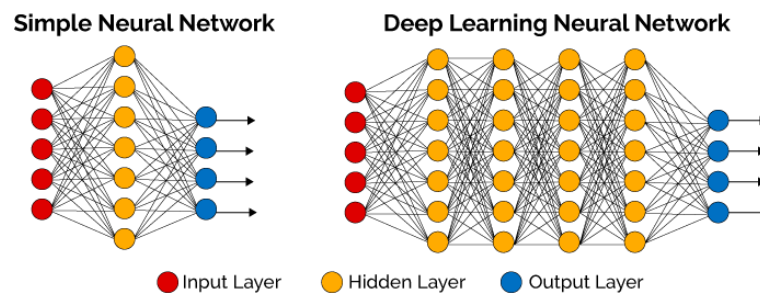

Figure 8. Deep learning

The main difference between machine learning and deep learning is that in machine learning, you have to guide the machine in each of the phases of the process so that it learns, through practice, to identify what we want automatically. Conversely, in deep learning, the machine learns by itself with each new input of information it receives.

Augmented reality games or virtual reality games are becoming more and more possible due to deep learning algorithms that allow us to bring the outside world to the coded world that the machine can understand.

1.2.3. Artificial neural networks

Artificial neural networks are computer systems capable of imitating the capabilities of biological systems, thanks to the fact that are composed of many simple elements that are interconnected with each other. The artificial neural networks can classify input patterns and at the same time generalize them, their learning takes place through supervised training and once it is completed it can be used in real-time.

The artificial neurons that compose these networks are represented as follows (see Figure 8). In the case of these neurons, the sum of the inputs is multiplied by the associated weight, this is to determine the "nerve impulse" that will receive, the given results are processed inside the neuron with the help of an activation function, which is returning an output value, in the same way as the human brain (see Figure 9).

The artificial neural networks during their training are adjusting constantly the weight of the inputs of all the neurons that compose it, in this way, each of the output responses that are given, are more adjusted to the real data.
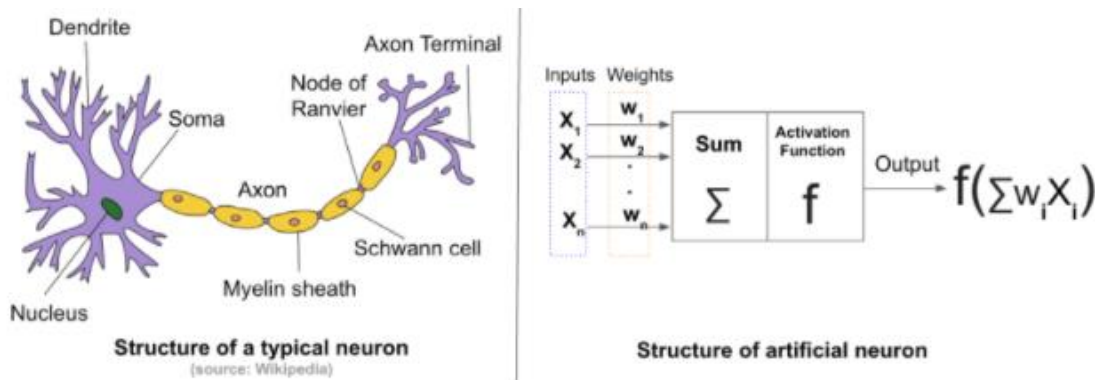
Figure 9. Artificial Neural Network

These artificial neural networks are being used in the field of video games for the creation of intelligent systems capable to win games against the best players in the world, one example of this is the OpenAI, an AI who won a duel in the game of Dota 2 (see Figure 10) against a team of 5 professional players (team OG). Why these intelligent systems are better and better is thanks to the training and learning from the defeats in the games. This technique makes video games more attractive because the NPCs are showing their best results.

Figure 10. Elon Musk`s OpenAI used in the Dota2 video game won

a duel against the best players (OG) in the international tournament 201

This algorithm was born thanks to the combination of artificial neural techniques and genetic algorithms, where the neural networks are in charge to define the inputs and the outputs, and the genetic algorithms define the weight of each neuron. This technique is linked to evolutionary computation, which focuses his studies on the creation of algorithms based on the principles of the biological evolution made up of different layers (input, hidden, and output) in which it is stored the information of the individuals under study (see Figure 11). Here we can observe functions such as natural selection, genetic inheritance, and mutation.
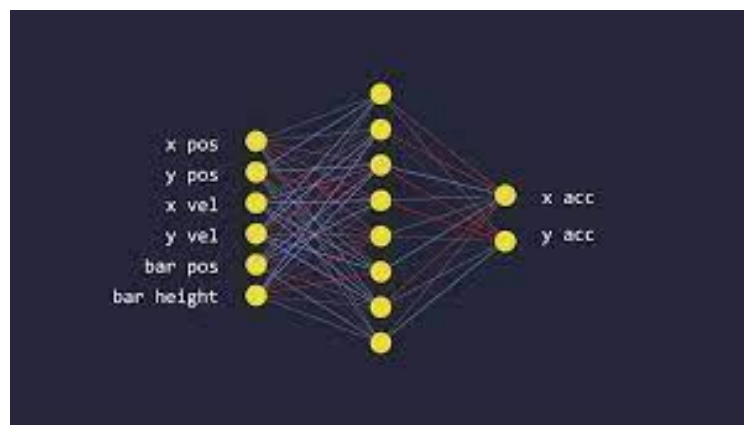
Figure 11. AI Neural Network

History of Evolution of Artificial Intelligence and its application in video games

The first video game in history has been considered the Noughts and Crosses, also known as OXO, which was developed by Alexander S. Douglas in 1952. This game was a tic-tac-toe simulator where the player plays against the computer.

OXO game was programmed for the ESDAC computer and only worked for this computer, which used a telephone dial as control and, as output, an oscilloscope screen.

Six years later in 1958, William Higinbotham created the world`s second video game – Tennis for Two, a game that simulates a table tennis match. Tennis for Two consisted of an oscilloscope that acted as a screen and that is offered a side view of the playing court (which was divided by a net). The players had a control that included a button to hit the ball and a wheel to control its direction. The logic of the game was

composed of a series of operational amplifiers that controlled the trajectory of the ball whether or not it touched the ground, if it touched the net, etc., all this thanks to a program, which calculated the trajectory that could catch the ball when it was hit by the player.

In addition, Tennis for Two, unlike OXO, offered better dynamics and a multiplayer system.

Later, in 1962, Steven Russell, a student at the Institute of Technology of Massachusetts developed a computer game using vector graphics which he gave the name Spacewar.

This video game was designed for two players who faced each other in a battle between two spaceships, who had to destroy each other without getting caught by the gravitational force of a star.

Spacewar was developed for a computer called PDP-1. The game required 100 000 calculations per second to control the movement of ships, gravity, user controls, the relative positions of the background stars, and the "attractor" star and send the monitor 20 000 points per second to refresh the screen with user movements.

Today there is only one functional PDP-1 computer in the museum of Computer History in California and you can still play Spacewar.

In 1966, was launched the video game called fox and Hounds, created by Ralph Baer, Albert Maricon, and Ted Dabney.

With this project, video games have entered the homes thanks to the consoles, that could be connected to TV screens. The prototype of this project included games like Ping-Pong, Voleibol, and shooting game. This is the time when the idea for the famous Magnavox Odyssey console surged and, in 1971 started to be produced. This console was launched on the market in 1972, the pack of sale consisted of a console, a couple of controls, and six cartridges or cassettes that stored twelve games.

Later, in 1971, Nolan Bushnell began marketing Computer Space, which was the first coin-operated video game. Computer Space is a version of Spacewar with the difference that is designed for arcade machines that were functioning by inserting coins.

The Computer Space was a video game implemented entirely in hardware, it was a digital system that was based on three boards connected to a common bus and a General Electric CRT monitor that showed the interface machine graphics.

The machine was produced in series but had an irregular success.

In 1972, the video game Space Invaders was presented, it was the first game that kills Martians. Space Invaders was developed by Toshihiro Nishikado and It was designed for arcade game machines. Thanks to the gameplay offered the game was a total success.

During that time, in these video games, the animations become better and better, providing a greater experience. Numerous technological advances were already being

implemented, where microprocessors and memory chips stood out. Video games are kept in continuous evolution.

In 1980, the Pac-Man went one of the most popular in the entire history of video games. Toru Iwatani has created the widely known arcade game. This game was developed by maze search algorithms.

After 1985, video games were more popular and people were inclined more to home consoles that's why Nintendo launched one of the most popular consoles on the market at that time, the NES, this console had a CPU: 6508 at 1.79Mhz, RAM: 2 kilobytes, VIDEO RAM: 2 KYLOBYTES, Graphics: 16 simultaneous colors, adding to this the NES also had a large repertoire of games (more than 500).

Super Mario Bros was one of the video games on the NES console that captivated people. This game marked an important point in history, since it offers a great variety of graphics, and each game scenario had its difficulty.

Later, at the beginning of the '90s, the famous generation "16-bit generation" would arrive, which brings with it a great technical evolution in video games, with this gives way to new more sophisticated consoles, such as Master System, the Mega Drive, the Super Nintendo or Super NES, etc.

In the field of PC video games, environments are worked three dimensional, due to this 2D, 3D, and 4D games begin to emerge games like Virtual Racing, Doom, and Wolfenstein.

This time was known as the "Golden age of video games" or "The war of the consoles". Due to the advancement from 8 bits to 16 bits, taking the Super Nintendo console as an example, very unusual and innovative hardware was implemented and it had a quite efficient processor which had implemented the so-called support chips, to provide better video and sound processing. The architect of this console allowed technological advances since it allowed their game cartridges to implement support chips, in this way the games needed fewer megabytes.

Another iconic game to compete with Super Mario was Sonic, which was created by the Sega franchise.

In the same decade of 90`s the markets began to give a great acceptance of 3D video games and quickly became very popular, thanks to the so-called "32 bites" and "64 bites" generation.

The video game market was dominated by Sega Saturn, PlayStation, and Nintendo 64 consoles.

 PlayStation would become the console best selling in world markets. This console has provided sophisticated software for these times, it had a CD-ROM drive, two inputs for the controls, a parallel port and a serial port located on the back, power input, and two memory slots, the players would move from a 2D platform to a platform with 3D animations.

 By the end of the decade of the 90s, the PlayStation consoles would become an icon for the fans of these virtual worlds. Taking as a reference the famous Resident Evil

game saga, which is a series of Survival Horror categories and also achieved great success in the market.

Another console that made history at that time was Nintendo`s Game Boy. Game boy was a portable console that offered a very good game experience to its users, thanks to the fact that its games were the same as those offered on the home consoles.

One of the games that made an impact with its arrival was Tetris. Despite the simplicity of the game, it has captured the attention of many computer enthusiasts, since in its first developments this game was for computer platforms.

On the other hand, PC games were very popular like FPS (First Person Shooting), RTS (Real-Time Strategy), an MMORPG (Massive Multiplayer Online Role-Playing Games).

In the MMORPG games, it could be seen that many players were met in a single scenario, with game modes such as PVP (Player vs Player) or PVM (Player vs Machine).

One of the most outstanding games in this category was WOW (World Of Warcraft), one of the most popular online games, even today its versions continue to be improved.

World of Warcraft is a real-time massively multiplayer role-playing game. Later, in the year 2000, the 128-bit generation would arrive, for this year Sony launches the PlayStation2 and Sega launches another console called Dreamcast Drivers 2000, with a wide variety of games such as Football, shooting games, adventure games, driving, fighting, etc. Some of them were: Twisted Metal, Rayman, Dragon Ball, etc.

Subsequently, in 2004 important technical advances arrived in this industry, so this time new portable consoles arose such as Nintendo DS and PSP (PlayStation Portable) and they have offered a variety of games like God of War, CallDuty, Grand Theft Auto, Metal Gear Solid, etc.

Consequently, from the year 2005 onwards, video games began to have a new objective, which would be to make the user feel inside the game, that was, how to recreate a virtual reality, for these new consoles were launched with new technical characteristics which provided a scenario with increased realism and greater user experience.

How much AI is used within video games currently

Artificial intelligence is considered today as the point of technological innovation. The advances that were made thanks to AI have shown the world machines that surpass human beings. AI in video games (Google DeepMind), questions and answers games (IBM Watson Computer), a robot interacting with humans in real-time (Robot Sophia), and this is just the beginning of the advances that can be made in AI. In video games, its application has become the point of innovation for the new games that will come on the market, because they are already implementing techniques such as machine learning, artificial neurons, intelligent systems that are capable of creating a game from scratch, with scenarios, stories, people, that exceed human imagination, an example of this is the AI system called Angelina machine.

The AI implemented in the past in video games was based on techniques such as Minimax Algorithm, Decision Making, Pathfinding Algorithm, Decision Making, Pathfinding Algorithm, Intelligent Agents, Finite State Machines, Neural Networks, Genetic Algorithms, and Evolutionary Networks, these techniques currently continue to be part of the development of video games.

Thanks to these first AI algorithms, more advanced techniques are available now, with which video games are experiencing a diversity of changes, intending to achieve higher level realism, both in its graphics (remastering) and its gameplay.

The latest AI techniques that have been used to generate games like BattleFields 1 have already are demonstrating that AI can contribute to the development of new video games, where its focus will be the generation of more realistic scenarios, that are generated through the actions that players execute when playing, all this information is saved so later the intelligent system learns to play based on this data, in this way the NPC (non-player characters) will be able to execute actions with higher realism and even surpass human playability, which would become more challenge for the players.

Some of the latest AI techniques used in the development of video games are DeepFake, Angelina AI, and AlphaZero.

DeepFake is an AI capable of replacing one person`s face with another, for this it uses the neural artificial networks specially designed for image processing (photos), where the AI reduces the photo and turns it into an abstract image, then performs the process inversely, the abstract image is converted into a photograph. This procedure is carried out thousands of times until achieving a result with the greatest possible realism, this is something innovative in games.

The AI not only contributes to the generation of realistic behavior in NPC but now, artificial intelligence is capable to create video games from scratch, as we mentioned previously, the AI Angelina. This intelligent system uses neural artificial networks designed for the processing of virtual scenarios, it is enough to give it some parameters of land and she will do the rest of the work. With this AI new scenarios

can be developed, and that is precisely what the users want, games that immerse them in epic virtual games.

On the other hand, AlphaZero is an intelligent system developed by the company DeepMind in 2014, that has human intuition which makes it different from the other intelligent systems, and is that it doesn`t need the knowledge of human supervision for its training. This AI is promising since was able to beat Stockfish 2017 the best chess player. This AI has intuition, creativity, risk-taking, and much more.

Artificial intelligence is gaining autonomy due to the improvements that are constantly given, since on some occasions the AI has been able to make decisions freely, a clear example of this occurred in a video game EVE Online, the AI applied in this game "got out of control" and unleashed an intense battle between three different fleets of the game, where there was no human participation. In such video games, the application of AI techniques in the NPC characters is equipping them with the ability to start wars for the control of territories, based on automatic learning, they are taking high participation and the benefits for the game are notable. Because the experience and the levels of the games are higher now, the difficulties are rising now, simulating human thought to the point that in some games the AI has outperformed a person`s game.

On the other hand, currently, AI is being used to master classic games that have fascinated the world at that time, and bring them back to "life", classics like Doom, Final Fantasy, and Legends Of Zelda, showing fascinating results and thanks to these AI the remastering is done automatically in a matter of hours through the use of artificial neural networks.

Another AI used in games like StarCraft 2 is the technique acquired by Google, DeepMind, to learn to play to the point of being able to win games against human players. DeepMind system is being fed with a volume of data created by collecting (real repetitions) of professional games, this is mixed with one neural network that is responsible for creating new players, then the neural network simply makes battle each other testing different game strategies, discarding the strategies that don`t work and stays with those that work. This system has a week of training, during this learning period DeepMind played it has an equivalent of 200 years of games given between humans.

On the other hand, any intelligent system during its trial period may have various behavior problems, the AI techniques that are implemented in the development of video games, are techniques that already passed their trial period and can be presented in the markets. All these techniques completely changed the way of thinking of video game developers, where they realized that the innovativeness of a game doesn`t go on its graphics, and what makes games attractive are the challenges and difficulties that it delivers to their players. Depending on the service you want to deliver, video games continue to have a promising future which has become the proving ground of AI, and it is the first technology field that experiences the new developments in it.

Conclusions

Artificial intelligence has been present in the development of video games since a long time ago, when OXO (the first video game in history) was released, AI was being implemented.

Over time, video games have undergone significant changes to improve the game scenarios that are delivered to the users of this industry.

The evolution of artificial intelligence was slow but its application was very important in video games. In the past, the developers of video games used AI more to improve the graphic part of the video game than the gameplay, because the point of innovation in video games for that time was its graphic part, this was only until a while longer forward, because the improvements in graphics would reach a point where all the video games would have the same visual attributes.

It is at this point, that video game developers began to look for a new point that marks the difference between the diverse classification of video games.

From this time artificial intelligence begins to gain strength within this great industry, due to the significant contribution that it gave to the playability part of digital games. In my opinion, the contribution that AI has made to the development of video games has been the key to having scenarios like the ones we know today.

Today in the video game industry it is extremely important to develop the most promising game scenarios that deliver to their users' gameplay that impose greater difficulties. In some cases it has been observed that these intelligent systems have been able to surpass the game of a real user, thanks to AI techniques such as Machine Learning, which is based on autonomous learning, taking as a reference the learning game data made by human players, thanks to this they have been able to generate more realistic gameplay, something that is being asked a lot by the gamer community. Artificial intelligence at the moment is giving a total turn to the world of video games since typical video games didn`t offer gameplay with a good degree of difficulty, although this evolution also occurs thanks to the capabilities of the hardware currently available.

Right now, the point of focus for game development is the implementation of AI techniques that go hand to hand with Big Data, which is the source of intelligence, developed by these intelligent systems.

Players like the new era of video games, which are being developed thanks to the touch given by AI technologies, are exploring new digital worlds, with new stories to tell and new obstacles to overcome.

Bibliography

1. Harbing Lou, Shannon McArdel, (25.08.2017), AI in Video Games: Toward a More intelligent Game.

   https://sitn.hms.harvard.edu/flash/2017/ai-video-games-toward-intelligent-game/

2. Adnan O. M Abuassba, (June 2020), Recent Research on AI in Games.

   https://www.researchgate.net/publication/343244745_Recent_Research_on_AI_in_Games

3. Abdennour El Rhalibi, (January 2009), Artificial intelligence for Computer games

   https://www.researchgate.net/publication/220061084_Artificial_Intelligence_for_Computer_Games

4. Bruno Bouzy, Tistan Cazenave, Vincent Corruble, Olivier Teytaud, (January 2021), Artificial Intelligence for games.

   https://hal.archives-ouvertes.fr/hal-03118174/document

5. Rachel Kowert, The Video Game Debate: Unravelling the Physical, Social and Psychological. https://books.google.se/books?id=z-FzCgAAQBAJ&lpg=PT7&ots=s4E8z_2hi6&dq=oxo%20video%20games%20research%20paper&hl=bg&pg=PP1#v=onepage&q=oxo%20video%20games%20research%20paper&f=false

6. Spyridon Samothrakis, Diego Perez Liebana, (August 2015), Neuroevolution for General Video Game Playing https://www.researchgate.net/publication/308863022_Neuroevolution_for_General_Video_Game_Playing

7. T. Bullen and M. Katchabaw, Using genetic algorithms to evolve character behaviors in modern video games. https://www.csd.uwo.ca/~mkatchab/pubs/gameonna2008_unreal.pdf

8. Fabio Aioli & Claudio Enrico Palazzi, Enhancing Artificial Intelligence in Games by Learning the Opponent`s Playing Style. https://link.springer.com/chapter/10.1007/978-0-387-09701-5_1