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The Use of Genetic Algorithms for the Development of Intelligent Video Game Opponents using AI

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***Abstarct* - When playing a video game, what aspects enhance the experience for the player? How can we guarantee that each and every game we play will be entertaining and engaging? This study primarily focuses on these two aspects. Many factors contribute to a player's enjoyment of video games, but in predator/prey games, player strategy and conduct are of the utmost importance. Determining what makes an opponent's moves "interesting" requires some introspection into the psychological aspects of the game and the development of a mathematical formula grounded on real-world facts. Using this paradigm, neural-network opponent controls may be implemented in dynamic game scenarios that restrict the length of time agents can communicate with each other, promoting cooperation in space. Investigations on beneficial team practices are underway due to the difficulty of the predator job. The objective is to outperform the opponent, therefore basic neural controls are used in off-line learning approaches to make initial decisions. Then, these example controls are transformed into interesting opponents using online learning techniques, i.e., while playing. To evaluate the efficacy of online education, we use two predator-prey games and a battery of tests including various computer player techniques. It demonstrates that regardless of the complexity of the game field or changes to the player or original opponent's controller, it functions identically on both test beds for both games. The interest metric is compared to people's ratings of how much they love a game in an informal poll. In order to gauge the level of interest in a test-bed game, a sizable sample of players were asked to assess their experiences with the game. After that, the players' scores were compared to the proposed interest measure. It turns out that players' ratings of their own enjoyment of a game are compatible with the attention metric.Finally, the approach and strategy proposals are evaluated according to their practicality, adaptability, and feasibility. It also considers the player's own strategy and other variables that impact the player's satisfaction. Future directions are considered and proposed based on the work detailed here.**

Keywords - Artificial Intelligence, Algorithm, Games, Metric, Player, Video Game.

1. INTRODUCTION

At this point in time, the entertainment sector is significantly impacted by video games played on computers. Imagine the amount of money and research that might be produced if games were more appealing (or less intriguing). Just think about it. According to Russell and Norvig (1995), artificial intelligence (AI) will profit from the continuous need for games that are both greater in quality and more entertaining. There is also the possibility that increased computer power may make it possible to bring back expensive artificial intelligence methods that were previously inaccessible in video games. It is possible to generate intelligent figures with the assistance of approaches that include machine learning. It is possible that characters that are able to communicate with one another and form teams can significantly improve the overall gaming experience and provide players a great deal of delight.

A. *Motivation*

The video game business has had a remarkable amount of growth over the course of the last ten years. According to the most recent information that is currently available from the Entertainment Software Association, the amount of money that American consumers spent on video games in 2004 was $7.6 billion, which is a 31% increase from 1996. In the United States of America, video games are now the most popular form of entertainment or recreation. In addition to this, they are among the most prosperous industries in the United Kingdom. Computer games, in contrast to other types of entertainment, enable players to develop emotional relationships with the characters and do not need a significant financial input on their part. There is little question that the increasing popularity of these items may be attributed, at least in part, to the fact that the people who will be purchasing them are getting more diversified in terms of age and socioeconomic position. Several different hypotheses have an impact on the description and categorization of video games played on computers.

Organizing them according to the category. A hypothetical virtual world that has all of this electronic entertainment is logged into by the participant so that they may take part. The capabilities of these virtual worlds in terms of multimedia have seen significant development over the course of the last twenty years. These worlds have progressed from having two-dimensional surfaces that are flat to having surfaces that are more detailed and lifelike. This level of visual quality has been the major focus of attention for game makers, and it is partly responsible for the rapid spike in popularity that the games have experienced. As a consequence of this, realistic game settings have progressed to the point where it is essential to make incremental changes (Champandard, 2004). Despite the fact that the majority of the development team's focus has been on the beauty of the landscapes, the behavior of non-player characters (NPCs) has also been given a significant amount of thought. In order to regulate non-player characters (NPCs), the vast majority of games continue to

depend on finite-state or fuzzy-state machines and plain written rules, as stated by Woodcock (2001). As seen by the increasing popularity of multi-player games, people want more possibilities to interact with one other and sharper opponents, among other things. This desire is reflected in the proliferation of these games. In order to satisfy this desire, cutting-edge artificial intelligence methods may be used to create avatars, which are characters that are both intelligent and fascinating. These avatars have the potential to improve the whole gaming experience (Funge, 2004). There is a possibility that in the near future, more powerful computers would make it possible to create revolutionary artificial intelligence methods such as machine learning, which would be suitable for use in video games. These techniques would be expensive.

According to Fogel et al. (2004), a large gaming community that is always looking for more realistic, demanding, and substantial entertainment will find that playing against clever and engaged opponents is more fun. In spite of this, it is still challenging to determine which parts of a game make players happy given the current degree of artificial intelligence in games. As a consequence of this, it is not evident how to make games that are fun. In this area of study, the vast majority of academic and industrial research is flawed because there is a deficiency of data.

In this dissertation, the two primary issues that are discussed are (1) the creation of effective tools that may provide the player with autonomous entertainment and (2) the provision of qualitative and quantitative metrics to evaluate the level of satisfaction that a game provides. As a result, our primary objective is to get an understanding of the components that contribute to the enjoyment of players in the here and now, as well as the processes that are involved in the production of enjoyable games. Before we are able to accomplish our goals, we need to fulfill a few criteria, which are presented in the following paragraphs. Taking this into consideration, we want to improve the quality of this kind of digital entertainment.

B. Game Properties

The study of advantageous behaviors in multi-player systems (including settings and video games) is a topic that is receiving a lot of attention from academics. The development of bots for these systems can need a significant amount of time and a great deal of repetition. This challenge is made much more difficult by the fact that it needs study into a multi-agent system that is not just unexpected but also dynamic. The fact that bots interact with one another in a garbled and flawed way adds an additional layer of complexity to the situation. In light of this, there is a dearth of information on the complexity of controllers that are necessary for autonomous virtual agents to successfully complete certain tasks when it comes to the development of controllers for such scenarios. A learning system that is capable of doing anything like to that is difficult, and the design of the system is something that we do not know very much about.
Within the context of our research, the experimental settings that we use are video games that only have two dimensions.

Studying emergent cooperation in a multi-agent setting (i.e., with several opponents).

In the context of artificial intelligence discourse, implicit, fragmented, and inactive data are the building blocks. The criteria of the animat technique (Meyer and Guillot, 1994) served as the basis for our conclusion. These rules establish the groundwork for ensuring that non-player characters in video games behave in a manner that is consistent with reality (Champandard, 2004).
Agents are now being explored for their ability to do tasks that solely demand spatial coordination.

We are mainly working on the creation of these gaming settings in order to determine whether or not the agents are capable of constructing complex and cooperative opponent behaviors. The duties that they are required to perform and the language that they are required to utilize are being taken into consideration by us. After that, we will investigate the ways in which these decisions could affect the pleasure that the user derives from playing the game.
This collection of games, which is referred to as the predator/prey type, has all of these natural elements among its components. When it comes to our study, predator-prey games are an excellent starting point because of the special traits that they possess.
It is possible that you will purposefully reduce the significance of the environment in these games in order to pay attention to the activities of the players. Due to the fact that it is necessary for hunting behaviors to be successful, the degree to which the activities are coordinated is now being investigated. Additionally, the management of the learning process is simplified by the use of online communication. To repeat, in order to investigate the potential of interactive online learning to inspire constructive acts, predator-prey games are an appropriate starting point to consider. In spite of the fact that other game types, such as first-person shooters, have aspects that are analogous to those of predator/prey games, these games are often chosen because of how simple it is to create and coordinate them.
Not to mention the fact that our studies are carried out on personal computers, and not on any specific website. A single central processing unit (CPU) is responsible for handling the game's real-time graphics as well as all of the background computing operations. As a result of this decision, competitors in the field of online education will have a more difficult time implementing fast modifications and working with a significant number of processing resources. According to Woodcock (2001), a single central processing unit (CPU) should be more than sufficient to run even the most complex artificial intelligence system. As a result, this choice is still a good one.

2. LITERATURE REVIEW

Wikipedia, an online encyclopaedia, defines a game as a pleasurable activity that involves at least two participants and is distinguished by (a) an aim that the players try to attain and (b) a code of conduct that specifies their powers and restrictions. In other words, a game is a game. On the other

hand, games may also be used as a method of education or simulation, despite the fact that its primary purpose is to provide entertainment.

To put it another way, a computer game is a notion that has its origins in the real world. It is a combination of a computer-controlled virtual environment and player involvement, with the goal of achieving specified goals. This is the reason why the article does not explore conventional board games or card games that are played online. These extra features are also incorporated in the several computer games that were evaluated, which are as follows: It is not possible to play them online. (2) They are played on personal computers, and each central processing unit (CPU) has its own limitations.

The development of physical things that are capable of thinking and emotion, in a manner analogous to that of robots, is one of the many fundamental goals of artificial intelligence. This purpose may be accomplished, as stated by Brooks (1990), by first performing early research studies in the physical environment, and then proceeding to conduct more advanced research that makes use of computer models to support decision-making. In contrast, Etzioni (1993) argues that it is possible to pursue both of these courses of action concurrently. Furthermore, according to Funge (2004), computer games are perfect for merging artificial intelligence research into intricate virtual worlds that have the potential to produce large money. This is because computer games are good for game development.

The graphical technology that is used in video games has gone a long way over the course of the fourth quarter of a century. Beginning with simple two-dimensional designs and progressing to complex virtual worlds that are powered by strong physics engines (Bourg, 2001; Terzopoulos et al., 1994), as well as beginning with simple character models and progressing to very realistic characters. For artificial intelligence, the vast majority of computer games continue to depend on rule-based finite and fuzzy state machines (Cass, 2002). On the other hand, more sophisticated technologies like as machine learning are still in the early stages of development. All of these allegations are reinforced by the fact that new games are being found that employ the same idea, which has been around for twenty years, but with graphics engines that are completely different from one another (Woodcock, 2001).

Back in the middle of the 1990s, there was a trend towards developing video games with more advanced artificial intelligence. At that point in time, the computer game business had reached a plateau; manufacturing costs were increasing, and the majority of games were just copy copies of various other games. Crawford (1994, 1996) state that "the games have more internal detail, bigger worlds, and more complexity, but the basic designs have not changed in the last ten years." This statement is based on the fact that the games have become more sophisticated. However, according to "the graphics, animations, and sound are better."

On the other hand, as a result of the current surge in popularity of online multiplayer games, people may be relying more and more on opponents who are more clever. To add insult to injury, this illustrates that challenging opponents have the potential to improve the whole gaming experience for the player as well as the game itself. Additionally, intelligent and well-suited game characters may be developed via the use of methods that include machine learning (Champandard, 2004). Therefore, the desire to compete with intelligent opponents is the fundamental motivator for adding artificial intelligence methods such as machine learning and internet communication into the design of video games. The research conducted by Fogel et al. (2004) indicates that players spend an average of 2.01 hours, which is equivalent to 3.7 days per week, looking for new and interesting games. The argument presented in Rep (2002) is that this desire ought to be fostered in some fashion. According to Michael van Lent and John Laird (1999), you will want an artificial intelligence engine in order to bring about the creation of game characters that are simple to construct, lifelike, responsive, and flexible. The author Nareyek (2002) makes the observation that playing video games on a computer takes a certain degree of knowledge.

The gaming industry has just recently started to have a better understanding of the potential financial effect that artificial intelligence technologies may have on the items it produces. Boon claims that the most prevalent criticism from players is that the game is too short. This is the case since the game is too short. On the other hand, Boon believes that creators shouldn't be concerned with making games longer; rather, they should focus on making games more interesting and accessible to a wider audience.

It is unfortunate that the creators placed a higher priority on the game's visual quality than they did on the creation of intelligent enemies. In the not too distant future, we predict a "AI revolution" in the video gaming industry. People will have a need for more interesting games, and as the speed of computers continues to increase, this desire will be fulfilled. According to Molynoeux (2001), the God video game Black & White, which was developed by Lionhead Studios and Electronic Arts in 2003, was an early example of a game that included variable character models. From the computer game Creatures, which was released in the late 1990s, the idea for "Black & White" was conceived. Within the context of this game (Cliff and Grand, 1999), the player takes control of an organism that is capable of learning, remembering, and forming connections via the application of Artificial Life concepts. Implementation of powerful machine learning algorithms is the next step that makes the most logical sense. The use of these techniques has the ability to convince individuals that the intellect is comparable to that of humans (Woodcock, 2001; Champandard, 2004; Funge, 2004).

A. *AI in Computer Games Methodology*

The methods that were used in order to achieve the objectives of the thesis are described in depth in this part. This is mostly due to the rapid rise of great video games, which depend in part on unique group behaviors produced by relatively basic command structures. The bulk of them arise from the introduction of these games. When we use this as a starting point, we define and try out in a prototype a two-dimensional, multi-agent, computer game-inspired virtual world the learning strategies that will bring us to where we want to go.

B. *Mastering Teamwork in Competitive Video Games*

The major purpose of two-dimensional computer games is to convince all of the adversaries to work together. Players have a greater appreciation for the game when they collaborate with one another since it raises the intellect of the other player. Therefore, it is essential that participants coordinate their efforts for the whole of the tournament.
Techniques of learning that are supervised (also known as "learning by samples") and unsupervised (also known as "learning by rewards") are used in order to develop cooperative behaviors shown by individuals. To what extent this is possible is contingent upon the existence of a learnable near-optimal spatial cooperative behavior.

C. The Power of Rewards in Learning

Within this part, a comprehensive description is provided of the two evolutionary computation off-line learning strategies that were used in the research that was conducted for this thesis. The fact that agents are encouraged to behave in a certain manner when they continuously display high levels of similarity and performance is something that they all have in common. Two instances of this kind of learning that has been produced via the process of evolution are a generational genetic algorithm and a modified Univariate Marginal Distribution for Continuous Domains (UMDAc) (Holland, 1975; González et al., 2002). Both of these examples may be found across the literature.

D. *Generational Genetic Algorithm (GGA*)

Using an evaluation function that is "endogenous" to the agents' actions in the world, it uses a genetic algorithm that is passed down through generations to decide whether a behavior is rewarded or penalized according to the agents' duties. This is accomplished via the use of an evaluation function. It is possible that the problem might be solved by intelligent agents that are able to recognize this behavior.
It is the behavior of such entities that is governed by neural networks that have formed over the course of time. The purpose of this section is to demonstrate how to modify the link weights of the neural network as it grows.

It is possible for us to have an understanding of the genetic approach that was used here. The genetic material of every living organism carries information on the degree to which its neural network is connected to other networks. In most cases, the configuration of neural networks involves picking Np at random from a pool of Np resources. The significant computational expenditure is the reason why this statistic is maintained at a low level. The link weights of the initial real values are selected at random from a uniform distribution that spreads from -5 to 5 and includes all possible values. After then, for the generations who came after then:

Step 1:, you will need to generate an N-copy of each and every agent that is part of the population. Here, N refers to the total number of agents that are present in the gaming environment. After being included into the game, these N copies are subjected to an assessment phase, often known as an ep. It is possible for us to analyze the performance of each agent in real time with the assistance of the data that is supplied by this review.

Step 2: we assign a ranking to each person i by making use of a group fitness function fi. According to the content of the review, one of the most important aspects is to support N identical solutions that are capable of working together to achieve the desired behavior. In a setting that is consistent, the creation of positive behaviors within a team takes place.

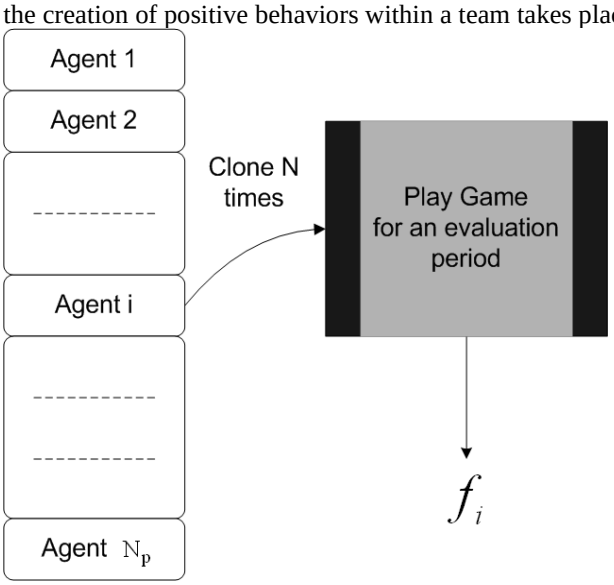


Figure 1: GGA: clonal evaluation of agents.

Step 3 In a pure elitist selection process, only the optimal Ns percent of solutions are allowed to breed, and the individuals that make up the intermediate population are chosen at random.
Step 4 It is necessary for each parent to clone an equal number of offspring in order to guarantee that the population will reach Np members. Both the traditional (Syswerda, 1989) and alternative (Montana and Davis, 1989) crossover operators have been tried and tested, but they have not proved successful. The reasoning behind this is that techniques of distributed knowledge representation, such as neural networks, are hampered by the use of crossover operators. To restate, it is quite plausible that successful neural network children would go on to fail as a result of crossover (Yao, 1999).
Step 5 When it comes to the genome of a progeny, the chance of each gene (connection weight) being modified is quite low. The revised link weight value is chosen once again using a random number generator that is uniform in its distribution.

The procedure is considered to have reached its conclusion when either the optimum agent has been found or a certain number of generations T have successfully passed. When agents are evaluated using fi combined with short modeling times (ep), the amount of computing work that is needed is reduced. The purpose of this evaluation function is to offer an approximation of the performance of the characters in a

significant exercise. It has been shown that increasing the number of ep simulation steps leads to an improvement in the accuracy of the bots' performance modeling. The capacity of the GGA technique to maintain an acceptable balance between predicting results and exerting an adequate degree of effort is a crucial component of the strategy.

3. PAC-MAN

As was seen in the last chapter, the OLL technique may be used to construct Dead End games that are both enjoyable and challenging. If the suggested method had been evaluated in a different predator/prey situation, it would be more relevant and helpful in a wider variety of circumstances. Pac-Man is one of the best examples of this kind of computer game, and we use it to illustrate how the online learning system can capture the interest of players and keep it over the whole of the game. In a similar manner, the actions of the characters who are not the players are constantly monitored. OLL is very adaptable and strong in terms of its processing power and architecture; it is able to handle a wide variety of player strategies across a vast array of demanding game levels.

In this section, we go further into the subject matter by investigating the potential of the online learning approach that has been presented to develop engaging video games on a variety of different levels. The first factor is the overall idea of the game; the second factor is the environment, namely the amount of detail and organization of the stage; the third factor is the conduct of other players at the beginning of the game; and the fourth factor is the player's skill level. The results of these studies provide evidence that supports our premise that the online learning system that we have presented may be used to get a wide variety of fun predator/prey games. This is true regardless of the kind of game, the degree of difficulty, the beginning conduct of the opponents, or the identity of the player. In addition to this, they provide evidence that the approach may be generalized in those directions.

The Pac-Man Game

A modified version of Namco's original Pac-Man serves as the foundation for the games that are being covered here. The player, who goes under the name PacMan, is tasked with consuming every pellet that occurs in a level that is reminiscent of a maze while also avoiding four Ghosts. It is the conclusion of the game when PacMan uses up all of the pellets in a level or when he is vanquished by a Ghost. Every single one of the five players starts the game from the identical location in this scenario.
In comparison to the commercial versions of the game, the basic version of the game is missing a few elements, such as the ability to collect power tablets. When the participants are not committed in the game, these components do not contribute anything to the "interesting" element of the game. This is something that has been confirmed by players of both the original game and the upgraded version.

In light of this, we examine the Pac-Man video game from the perspective of the Ghosts, focusing on how the new behaviors they exhibit could help to improve the overall experience.

Pac-Man, a two-dimensional, multi-agent, predator/prey, grid-motion game, is an excellent illustration of a computer game that has unique characteristics. There are a number of obstacles and stairs that make up the "gaming field," often known as the stage. The level is already aware of the dimensions of the labyrinth as well as its architectural design. The stage that was used for these studies was a 19x29 grid labyrinth that had routes that were 1 grid cell wide (for an illustration of this stage, please refer to Figure 1(a)).

Figure 2(a) is a representation of the Pac-Man video game, which has four things that seem to be ghosts and Pac-Man himself as a white circle. Additionally, there are wall blocks that have a dark gray color, and the pellets are represented by black circles.

Considering that there are no dead ends and that Pac-Man travels twice as rapidly as Ghosts do, it is impossible for a single Ghost to complete the task of killing Pac-Man. Due to the fact that PacMan is faster than any Ghost, vanquishing him will need a concerted effort from a large number of Ghost packs working together. When considering ghosts, it is important to bear in mind that they are able to move through solid things. Therefore, it is conceivable for a large number of Ghosts to take up residence in the same grid cell inside the game.

Following is an explanation of how the Pac-Man gaming simulation works. When it comes to the playing field, there is a considerable gap between Pac-Man and Ghosts. Following that, on each successive stage of the imulation,the following takes place:

There is a similarity between Ghosts and Pac-Man in the sense that both of them take in information from their surroundings.

Because the Ghost provides a mobility choice for each step of the simulation, Pac-Man has the potential to ove twice asapidly as the Ghost. Pac-Man, on the other hand, has the option of moving every other step of the simulation.

Following the conclusion of a game (for example, when all of the pellets have been used up, when Pac-Man passes away, or when the simulation step hits a specific huge number), a new game starts from the same starting locations as the previous one.

It is possible to keep track of information such as the amount of pellets consumed, the amount of time needed to simulate killing Pac-Man, and the number of Ghost visits to each grid cell.

Stages

We will try to put the online learning mechanism through its paces by creating fascinating Pac-Man games over levels of varying difficulty and, more specifically, stages with diverse topologies. This will be done in a manner similar to the Dead End game.

Complexity

We need a suitable metric to quantify this stage attribute so we can differentiate across stages of varying complexity. This assessment is

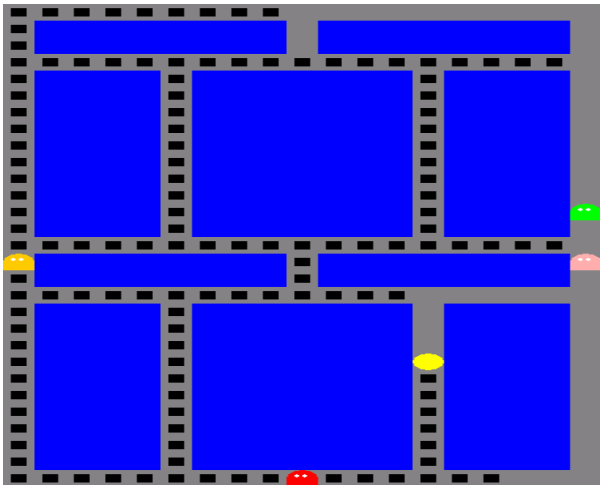
$$C = \frac{1}{E\{L\}} \qquad (6.1)$$

A measure of the level's difficulty is denoted by the letter C, while the average length of the stage's corridors is denoted by the letter E. The term "corridor" refers to the passageway that links two entrances on stage.
The average length of a stage's corridors has an inverse connection with the difficulty level, as represented by equation (6.1), which states that this relationship exists. The level gets less difficult to complete as the average hallway length is increased because it becomes easier for the Ghosts to obstruct PacMan, which in turn makes the level more difficult.

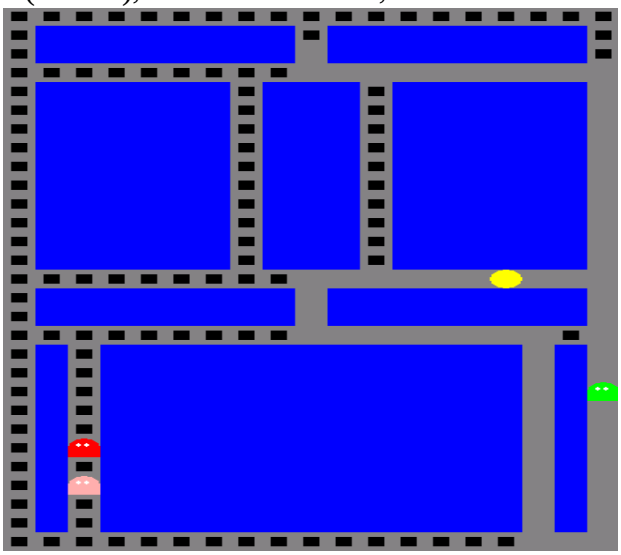
In this inquiry, there were four different techniques that were used, and they are shown in Figure 2. There are four different difficulty levels, with Easy A having a difficulty of 0.16, Easy B having a difficulty of 0.22, Normal having a difficulty of 0.22, and Hard having a difficulty of 0.98. In addition, the Hard level is the most difficult Pac-Man stage for the Ghosts to travel since it adheres to the game regulations in a very stringent manner. This means that walls surround blocks, tunnels are one grid square wide, there are no dead ends, and cells cannot be bigger than 19 by 29.

Topology

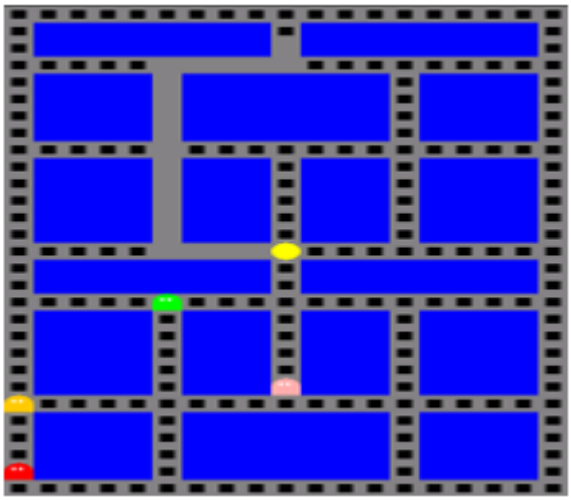
The layouts, or the configurations of the blocks on the stage, might be different from one level to the next, despite the fact that all of the levels have the same difficulty level (6.1). Despite the fact that the stages in Easy A and Easy B (refer to Figure 2) are not topologically similar to one another, they require the same amount of effort.



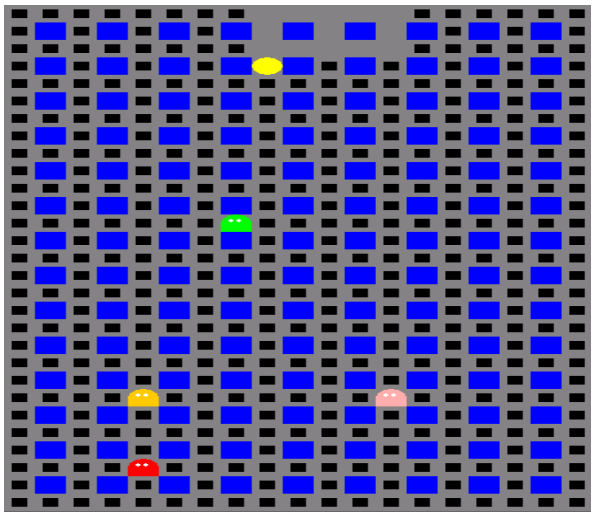
(a) Easy A



(b) Easy B



(c)Normal



(d) Hard

Figure 4.1: Every one of Pac-Man's four levels.

CONCLUSIONS

Both the question of how to measure the satisfaction that video game players experience and the question of whether artificial intelligence systems may be able to do so are the primary research issues that are being investigated in this thesis. The sort of game, which was composed of predators and prey, was the first component that led to the resolution of both problems. In order to put our results to the test, we developed two different games that include predators and prey.

As a result of our research and findings about these games, we were able to determine what aspects of them made them particularly entertaining to play and how to oppose the strategies used by our rivals. It is our opinion that the most fun feature of computer games is not the visuals, the plot, or the genre, but rather the interaction between players and opponents. This is the primary reason why we like playing computer games. Through the application of this fundamental idea, we were able to devise a technique for determining the degree to which predator-prey games provide amusement in real time. This quantity is influenced by three different factors of entertainment: the right level of difficulty, the variety of actions that opponents may do, and the variety of sites where opponents can be found.

The second hypothesis that we have is that players will find what they are doing more engaging when their opponents work together. Through the process of learning how to complete tasks without being connected to the internet, we were able to show that cooperative behaviors may operate effectively in the virtual environment of the FlatLand prototype. In order to effectively produce accurate implicit and partial sense in artificial situations, we made use of the animat technique, which was first established by Meyer and Guillot in the year 1994. The findings of this world suggest that computers are capable of working together efficiently even in environments with minimal sensory input, and that unsupervised mutation-based learning techniques are preferable than supervised ones in terms of dependability and performance. The method used by ECWAS was likewise, the same test bench in order to develop controls that were able to perform with the smallest size that was achievable.

As a result of the constraints of the processing capacity of personal computer games, more advanced learning techniques were created in order to speed up the process of real-time learning. Consequently, in Chapter 8, we investigated the part that the person plays in the creation of some kind of entertainment. An OLL system that is more robust and equipped with a reliable player modeling tool seems to be more successful at fast developing the entertaining games that players seek, according to research that has been conducted for this purpose. When focusing on the concepts that are discussed in this chapter, it is possible to make computer games more interesting and enjoyable for players.

The process of making changes to the controller of one's opponent in real time. In light of the fact that this is a novel approach to merging cutting-edge AI approaches with social psychology and the study of human-machine interaction in video gaming systems, it has a great deal of potential.

The research that is given in this dissertation lends support to three theories that are in direct opposition to one another: Human players have shown, in accordance with the first premise, that changes in the conduct of opponents are the most important differentiator between games that provide differing degrees of pleasure. Additionally, they reached a consensus on the interest meter that was presented. In accordance with the findings of the second hypothesis, helpful behavior is present and continues to be present when the game is fun. In the third place, learning in real-time has the potential to enhance the gaming experience on computers. This is shown by the ability of the OLL mechanism to modify and improve the game over the course of time.

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