A REPORT

ON

GAME THEORY AND ITS APPLICATIONS IN ARTIFICIAL INTELLIGENCE

BY

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UNDER
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CS F266

STUDY PROJECT

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Sagar Agarwal

Signature of the Student

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CHAPTER 1

GLOSSARY

1.1 TERMS

1. **Backward induction**
   It looks for the best move at the end of the game and from there tracks back in time for the resultant moves. At every instance player is informed about the future move.

2. **General Knowledge**
   If every player knows everything and that ever other player knows everything as well.

3. **Dominating strategy**
   If this strategy gives the best pay off every time it is used

4. **Extensive game**
   Describes a tree for how the game has to be played with the knowledge and the moves.

5. **Game**
   Definition of strategic planned situation.

6. **Game theory**
   Formal study of planned decision making.

7. **Nash equilibrium**
   Lists down every strategy available to the players in that particular game.

8. **Payoff**
   Payoff is the number, also known as utility, that describes the desirability of an outcome to the player, for whichever reason.

9. **Player**
   Agent who makes up the decisions at a given time.

10. **Rationality**
    It is assumed that rationality is a given fact, and a payer is known as rational if he makes the move for the best pay-off.

11. **Strategy**
    Player has the complete plan for the whole game from beforehand.

CHAPTER 2

INTRODUCTION

2.1 WHAT IS GAME THEORY?

It is detail-oriented study of conflict and cooperation. The concepts of game theory apply whenever there are several players whose ideas may or may not be dependent on each other. This can be put into use for various aspects in life such as analyzing, formulating, structuring and understanding strategic scenarios.

2.1.1 HISTORY

The earliest evidence of a formal game-theoretic study is of a duopoly by Antoine Cournot in 1838. The mathematician Emile Borel proposed a formal theory of games back in 1921, which was mastered by mathematician John von Neumann in 1928 in the “theory of parlor games.”

In 1950, John Nash proved that finite games will always have an equilibrium point, at which all players make actions that are best for the given their opponents’ choices. This main concept of non-cooperative game theory had been a focal point of analyzing since then.

By the end of the 1990s, a high-profile application of game theory had been the designed for auctions.

2.1.2 OBJECTIVES

- ✓ Game theory is the study of modeling the strategic interaction between many players in a situation containing set of rules and outcomes.
- ✓ The basic assumption that underlines the theory are that decision-makers follow well-defined exogenous points (they are rational) and take into consideration their knowledge or expectations of another decision-makers' performance (they reason strategically).

2.1.3 ASSUMPTIONS OF GAME THEORY

- ✓ Assumes one player can use more than one given strategy.
- ✓ Assumes pre-defined outcomes are available.
- ✓ Assumes overall outcome after each player is done with its moves would be zero.
- ✓ Assumes that each player in the game is aware about the rules and what the outcome of the game would be in the end.

- ✓ Assumes rational decisions need to be made by players in order to win.

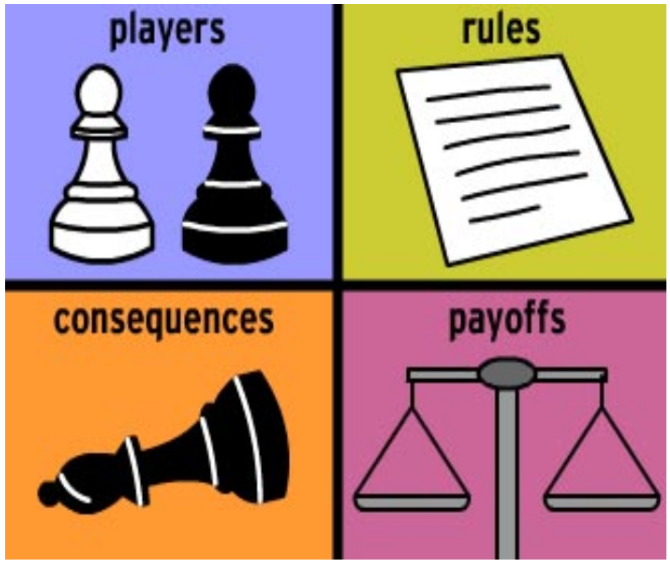


Figure 2.1 – Game Theory

2.1.4 STRUCTURE OF THE GAME

Game theory is built on the concept of strategy and payoffs. Strategy shows an action that a player makes when he is challenged to solve a particular problem. On the other hand, payoff refers to the result of the strategy used by the player. For example, two players are playing coin flipping game.

In this game, one person tosses the coin, and the other person calls for head or tail. In case, the caller's prediction about the coin is correct, then they get the coin. However, in case the caller's prediction is wrong, then they lose the coin and the other player takes the coin.

Figure 2.2 - Toss

Therefore, in this scenario, the caller's prediction of head or tail can be regarded as the strategy and the payoff would be the outcome of coin flipping, which shows that either caller takes the coin or toss takes the coin. In this coin game, the outcome or payoff depends on the caller as he/she predicted which side of coin. However, in other games, the payoff might depend on more than just one player.

2.1.5 PAYOFFS AND STRATEGIES

Assume two competing organizations, ABC and XYZ, decided to increase their profits by changing the prices of manufactured products. In this case, it can be assumed that both the organizations are expected to adopt two strategies. Either to increase the price level of the product or keep the prices on the same level as before.

Figure 2.3 – Chess Move

As per the above strategies, there could be four possible combinations of strategies, which are listed below:

i. Both ABC and XYZ did increase the price of their products.

ii. Only ABC increases the price of its product, while XYZ did not make any changes in the price level.

iii. Only XYZ has increases its prices, while ABC keeps constant price level.

iv. Both ABC and XYZ keep the same price of their product as it was before.

CHAPTER 3

DEFINITION OF GAMES

3.1 FORMAL DEFINITION

3.1.1 DECISION PROBLEM

The subject of study in game theory is the game, which is the formal model of an interactive scenario. It typically involves several players; the game with just one player is usually called a decision problem. The formal definition says out the players, their preferences, their information and the strategic actions available to them.

3.1.2 THE COOPERATIVE GAME

The coalitional (or cooperative) game is a high-level description that specifies only what payoffs each potential group, or coalition, can obtain by the cooperation of its members. What is not made public is the process by which the coalition forms. For example, the players may be several parties from parliament. Each party has got different strength, based upon the number of seats occupied by party members. The game tells which coalitions of parties will form a majority, but does not delineate, as an example, the negotiation process through which an agreement to vote.

3.1.3 THE NON-COOPERATIVE GAME

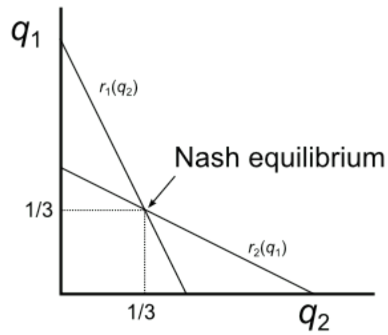
- ✓ The Non-cooperative game theory deals with the analysis of strategic choices.
- ✓ The structure of non-cooperative game theory is of the details of the ordering and timing of players' choices are crucial to predicting the outcome of a game.
- ✓ Contradicting the Nash's cooperative model, a non-cooperative model of bargaining would bring a specific process in which it is pre-written rule as to who gets to make the offer at a given time.
- ✓ The term "no cooperative" means that the branch of game theory explicitly models the process of players making choices for their own interest.

3.1.4 EXTENSIVE FORM GAMES

The extensive form, also known as the game tree, is more detail oriented than the strategic form of a game. It is the complete description of how the game will be played over time. It includes the order in which players will perform actions, information that the players have at the time when they must take those actions, and the times at which any uncertainty in the situation will be resolved.

3.1.5 NASH'S MODEL

Nash coined the solution to the games saying, regardless of what one person may or may not do, the other player will still pick what is the best in his favor. We will further see an example of Nash equilibrium in the following chapter, where two strategies are given and both players pick only one strategy when they do not know about the move of the other person. Later, when they are informed about the moves, they still pick the same strategy.



Graph 3.1 – Nash Equilibrium

CHAPTER 4

DOMINANCE

4.1 ABOUT DOMINANCE

Figure 4.1 - Dominance

4.1.1 DEFINITION

Since all players are expected to be rational, they made choices which result in the result they prefer most, provided what their opponents make. During extreme cases, a player may have two strategies A and B so that, given any combination of strategies of the other player, the final resulting from A is better than the result from B. Then strategy A is said to dominate over strategy B. The rational player would never choose to play a dominated strategy. In few games, examination of which strategies are dominated results in the conclusion that rational players can only choose one of the strategies. The following example illustrates this idea**.**

4.1.2 PRISONER'S DILEMMA

In this game, two criminals have been arrested, and each is kept in solitary confinement with no means of communicating with one another. The police do not have the evidence to convict the pair, hence they offer each prisoner with the opportunity to either betray the other by testifying against the crime committed or cooperate by remaining silent.

Figure 4.2 - Prison

If both the criminals decide to deceive each other then they both are sentenced to eight years in the prison. If Prisoner 1 decides to betray Prisoner B, but the latter choses to stay quiet, then Prisoner A is set free and Prisoner B gets ten years of jail term, or vice versa. If they both opt to remain silent, then they both get only a year in the prison. Nash model would be better if both of them decide to deceive each other even though mutual decision may be better, but if one criminal choses mutual cooperation but the other does not, the former will suffer.

		PRISONER 2	
		Confess	Lie
PRISONER 1	Confess	-8 , -8	0 , -10
	Lie	-10 , 0	-1 , -1

Table 4.1 – Prisoners' Dilemma

4.1.3 APPLYING IN REAL LIFE

We can take an example of the project courses students take under various faculties, and if we ask them to pick a grade they would like to receive at the end of their submission. There are few prerequisite conditions with every grade and every student shall be informed about it beforehand, but they cannot discuss the same with their peers for mutual benefit, they have to tell what they want independent of what his/her friend may want.

4.1.4 CONDITIONS

- ✓ If both people pick A, both will get B-
- ✓ If both people pick B, both will get B+
- ✓ If one picks A and the other B, the A picker gets an A and the B picker gets a C

		Student 2	
		A	B
Student 1	A	B-, B-	A, C
	B	C, A	B+, B+

Table 4.2 - Grades

4.1.5 ADVANTAGES

- ✓ Modern Game Theory is important for:
  - Understanding rivalry among existing competitors.
  - Understanding how to deal with the threat of entry.
- ✓ Game Theory is a formal technique that gives insight into competitive interactions in which all players are assumed to be strategic and helps us think about the problem of “what I should do depends on what you should do, but I know that what you should do depends on what I do”.

It has a logic that guides and disciplines our intuition.

4.1.6 NASH EQUILIBRIUM

John Nash, an American mathematician coined the concept of this equilibrium and since then it has become one of the most important topics of research. The sole idea being irrespective of the other person’s move, pick the strategy best for your resulting outcome, that is the payoff.

The main idea of Nash equilibrium is much more generic. A Nash equilibrium suggests a strategy for each player that the player could not improve upon unilaterally, that is, given that the other participants follow the recommendation.

Since every other person is also rational, it is reasonable for each player to expect their opponents to use the recommendation as well.

Let us take an example of game between Charles and Martin. They are offered two strategies, 1 and 2. Strategy 1 suggests you either take $10 and Strategy 2 is to lose $10. Now logically both the players will want to opt for Strategy 1. Let us inform Charles about Martin's strategy or vice versa, we will notice that neither of the player wants to move from their original strategy. Therefore, we notice that regardless of what the other person does, their moves don't change. In this case Strategy 1 represents Nash Equilibrium.

CHAPTER 5

MIXED STRATEGIES AND EXTENSIVE GAMES

5.1 MIXED STRATEGIES

Assume that a consumer purchased a license for a software package, agreeing to certain restrictions with its usage. The consumer can choose to violate these rules. The vendor would want to verify that the consumer is abiding by this agreement but doing so requires inspections that are costly. If the vendor does inspect and finds the consumer cheating, the vendor will demand a huge penalty payment for the noncompliance.

- ✓ Player I is the vendor and Player II is the consumer
- ✓ If I does not inspect but the consumer is cheating he gets -10. If the consumer is complying, the nobody gets anything.
- ✓ If I inspects and the consumer is complying, then he gets a -1. But if the consumer is cheating the, II gets a -90 and vendor that is Player I gets -six.

I \ II	*comply* →	*cheat*
Don't inspect	0 0	10 −10
↑ *Inspect*	0 −1	−90 −6

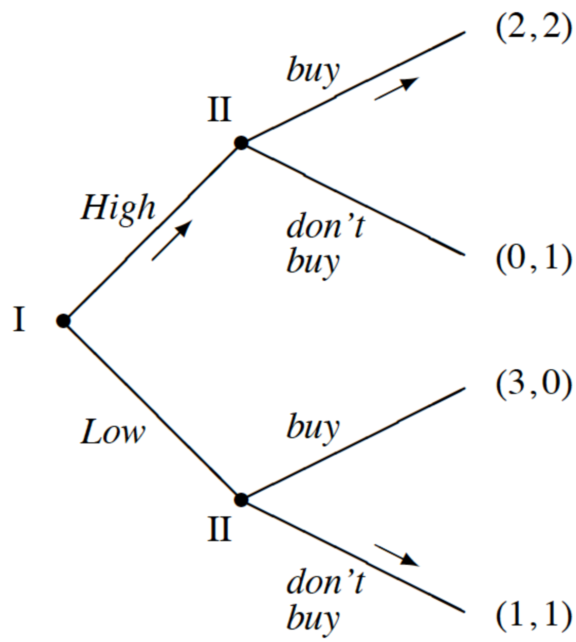
Table 5.1 – Mixed Strategies

5.2 EXTENSIVE GAMES WITH IMPERFECT INFORMATION

Usually, player does not always have full access to all the information that is relevant to their choices. Extensive games with imperfect information model is the one in which information is available to the players when they make a move. Modeling and evaluating strategic information with precision is one of the strengths of game theory. John Harsanyi's pioneering work in this area was recognized in the 1994 Nobel awards.

5.3 EXTENSIVE GAMES WITH PERFECT INFORMATION

Games in strategic form do not have a temporal component. In the game which is in strategic form, the players can pick their strategies simultaneously, without knowing the moves of the other player. This is the more detailed model of a game tree, also called as the game in extensive form, describes interactions where the players can over time be aware about the actions of others. This section deals with games of perfect information. In the extensive game with perfect information, every player at any point is aware of the previous choices of made by other players. Furthermore, only one player can move at a time, so that there is no simultaneous move.



. Quality choice game where player I *commits* to *High* or *Low* quality, and player II can react accordingly. The arrows indicate the optimal moves as determined by backward induction.

Figure 5.1 – Extensive Games

5.3.1 ZERO SUM GAMES

In this type of game, the net resulting sum of every participant must be zero. That is one player wins only if one player loses, for instance in the case of chess or rock, paper and scissors. The net resultant outcome in the end has to always be zero regardless of whatever moves that were made during the game. The game ends with victory of one player at the cost of defeat of all the other players.

Figure 5.2 – Zero Sum Games

The most common game example of a Zero-Sum Game, is the one of poker where the players have 4 choices – stay in, sell out, announce and cede along with combinations of the same. Player I can be either dealt with strong or weak hand, which the Player II has no knowledge about. Now Player I can announce even though he may have weak hand, this is called "bluffing". This game basically shows the total sum in each payoffs combination remains 16, and the gain of one person reflects the loss of the other player. Player I's bluff can either make the other player sell out or stay in, both of which only increases his gain.

I \ II	*stay in*	←	*sell out*
Announce	8 8		4 12
Cede	6 10		10 6

Table 5.2 - Poker

CHAPTER 6

ARTIFICIAL INTELLIGENCE

6.1 HISTORY

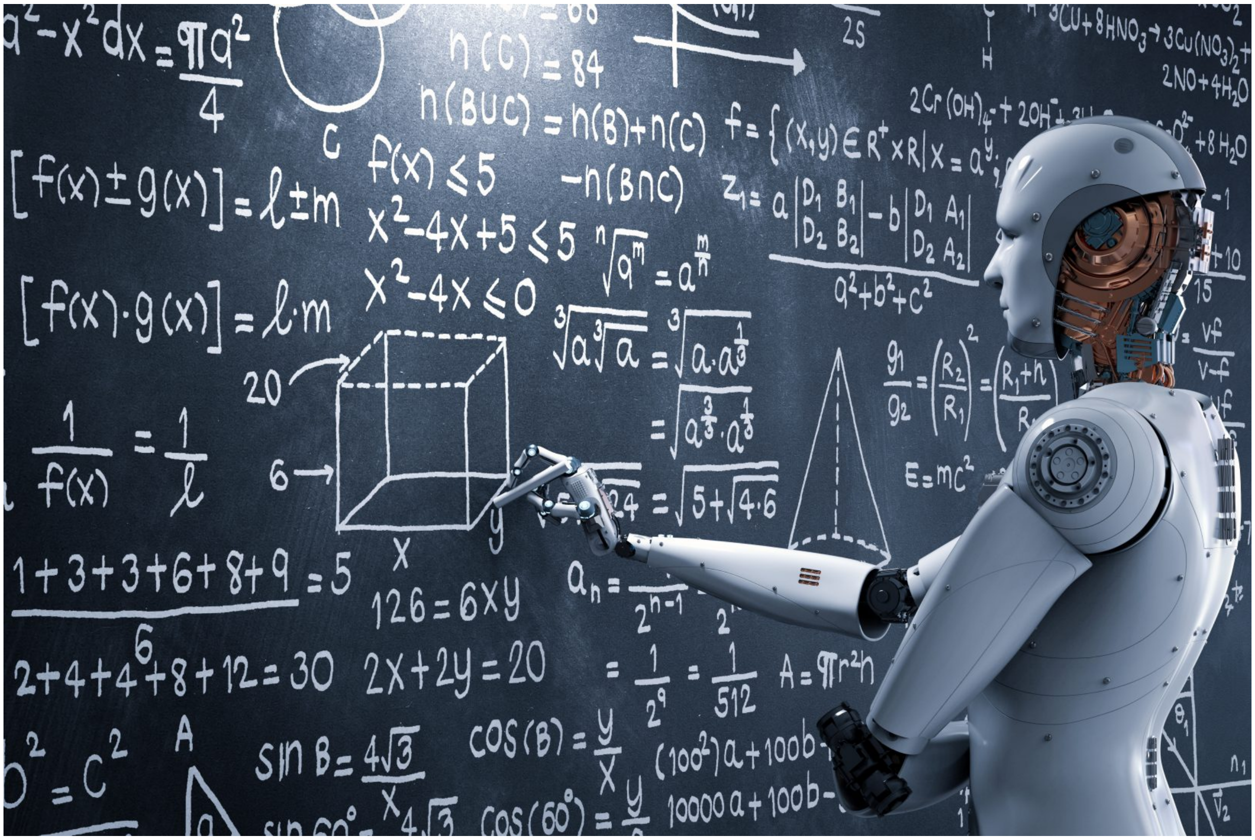


Figure 6.1 – AI

6.1.1 WHAT IS ARTIFICIAL INTELLIGENCE?

AI (artificial intelligence) is the simulation of human intelligence processes by machines, especially computer systems. These processes include learning (the acquisition of information and rules for using the information), reasoning (using the rules to reach approximate or definite conclusions) and self-correction. Particular applications of AI include expert systems, speech recognition and machine vision.

6.1.2 TYPES OF ARTIFICIAL INTELLIGENCE

The first classifies AI systems as either weak AI or strong AI. Weak AI, also known as narrow AI, is an AI system that is designed and trained for a particular task. Virtual personal assistants, such as Apple's Siri, are a form of weak AI.

Strong AI, also known as artificial general intelligence, is an AI system with generalized human cognitive abilities so that when presented with an unfamiliar task, it has enough intelligence to find a solution. The Turing Test, developed by mathematician Alan Turing in 1950, is a method used to determine if a computer can actually think like a human, although the method is controversial.

6.1.3 FURTHER CLASSIFICATION

- ✓ **Reactive Machines:** Deep Blue, the Chess Program developed by IBM which defeated Garry Kasparov back in 1990s. The program had no past memory but could identify pieces on the board and predict.
- ✓ **Limited Memory:** They use past experiences to influence future decisions. Some of the autonomous vehicles are the example of this category since observations are not stored permanently but only for the time being.

- ✓ **Theory of mind:** being a psychology term, refers to the fact that everybody whether machine or human has their own beliefs that can influence their decision making majorly. This kind of robots do not exist yet though.

- ✓ **Self-awareness:** in this final category, the AI robots have self-awareness, and consciousness. They can infer how others are feeing and make decision based on that. Even this kind of machines do not exist yet.

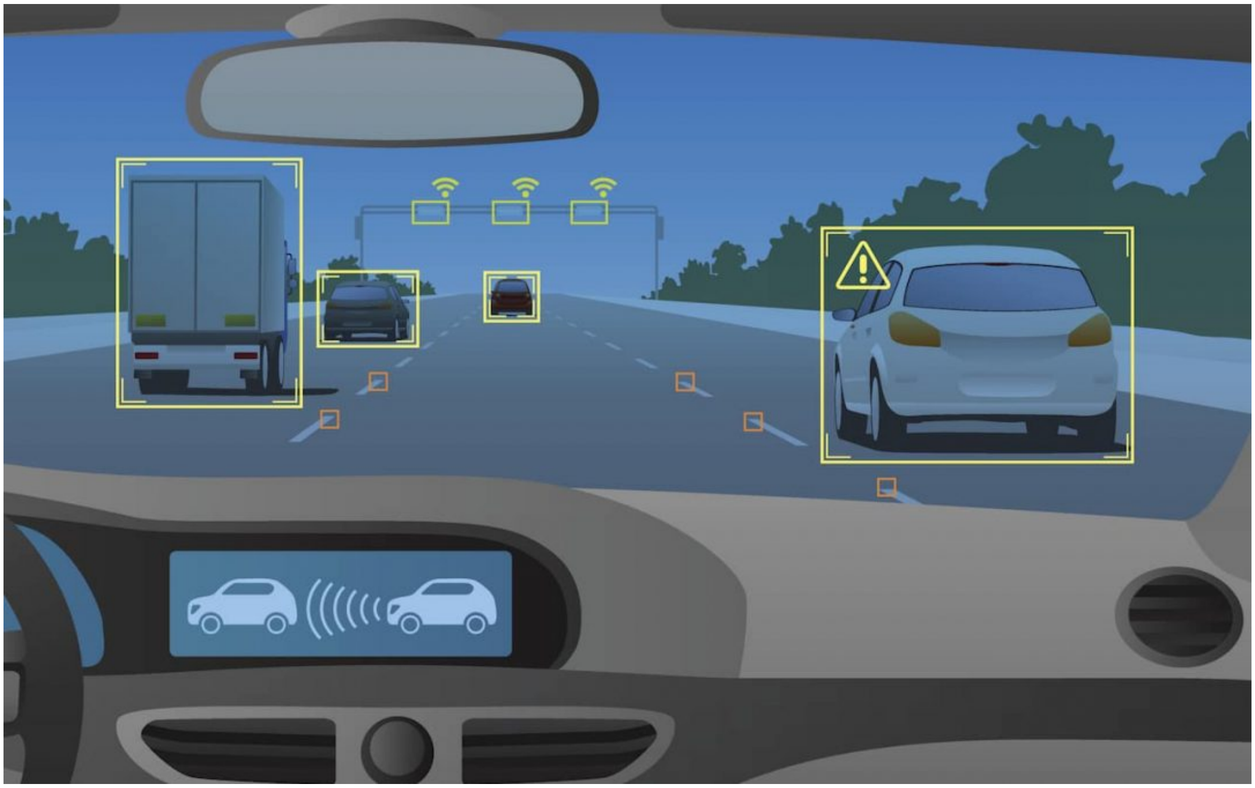


Figure 6.2 – Smart Car

6.1.4 FUTURE OF ARTIFICIAL INTELLIGENCE

- ✓ Deep Mind by Google
- ✓ Advanced Siri
- ✓ Deep Learning.
- ✓ Machine Learning and Machine Vision.
- ✓ Pro-active decision making.
- ✓ Directly pay to either device or person.
- ✓ Digital wallet will let you pay and buy from any device be it laptops, handheld PDAs or mobile phones or tablets.
- ✓ Online apps will allow you to compare shopping rates at any internet point. This will enable true monetary transparency and control over consumers.
- ✓ You can schedule your payments and receive invoice as per your convenience whenever you have access to the internet.
- ✓ AI will become single access finances portal for medicines, insurance claims, motor vehicle registrations, loan and mortgage, investing money etc.
- ✓ It will also store calendars, to-do list, notes, diaries, reminders etc. that can be accessed from any device with same account and internet connection.
- ✓ It will enable the merchant to prompt the buyer at equal intervals of time to make the purchases and in case there is something purchased at loan, then he can remind the buyer to pay the require installments.

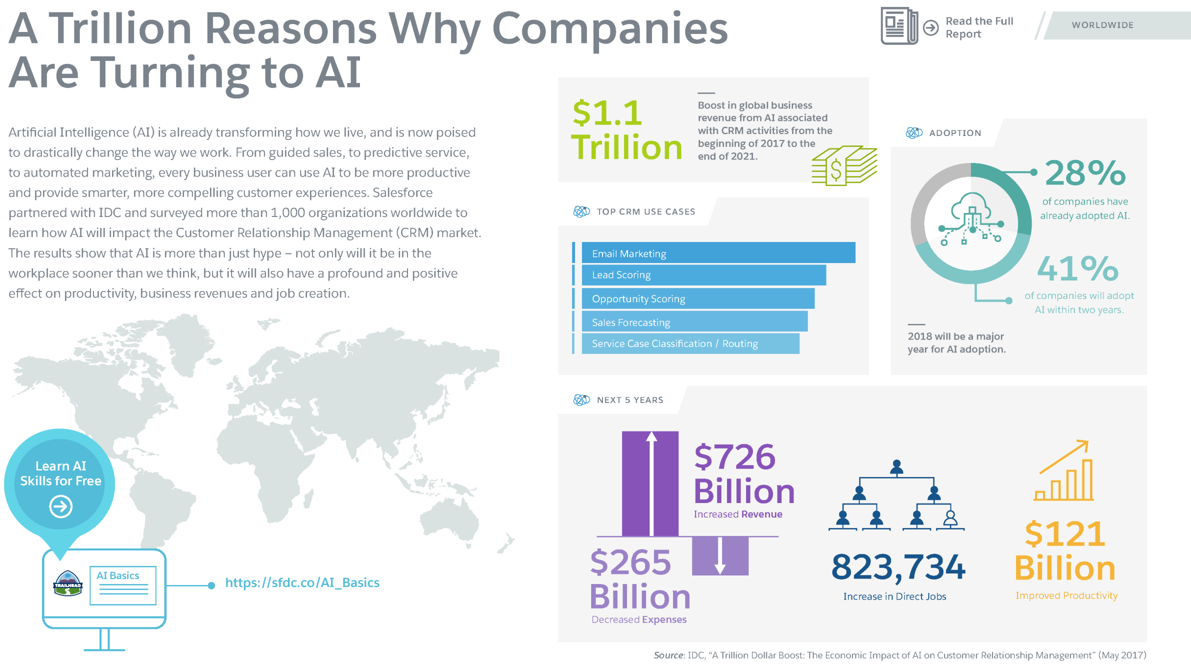
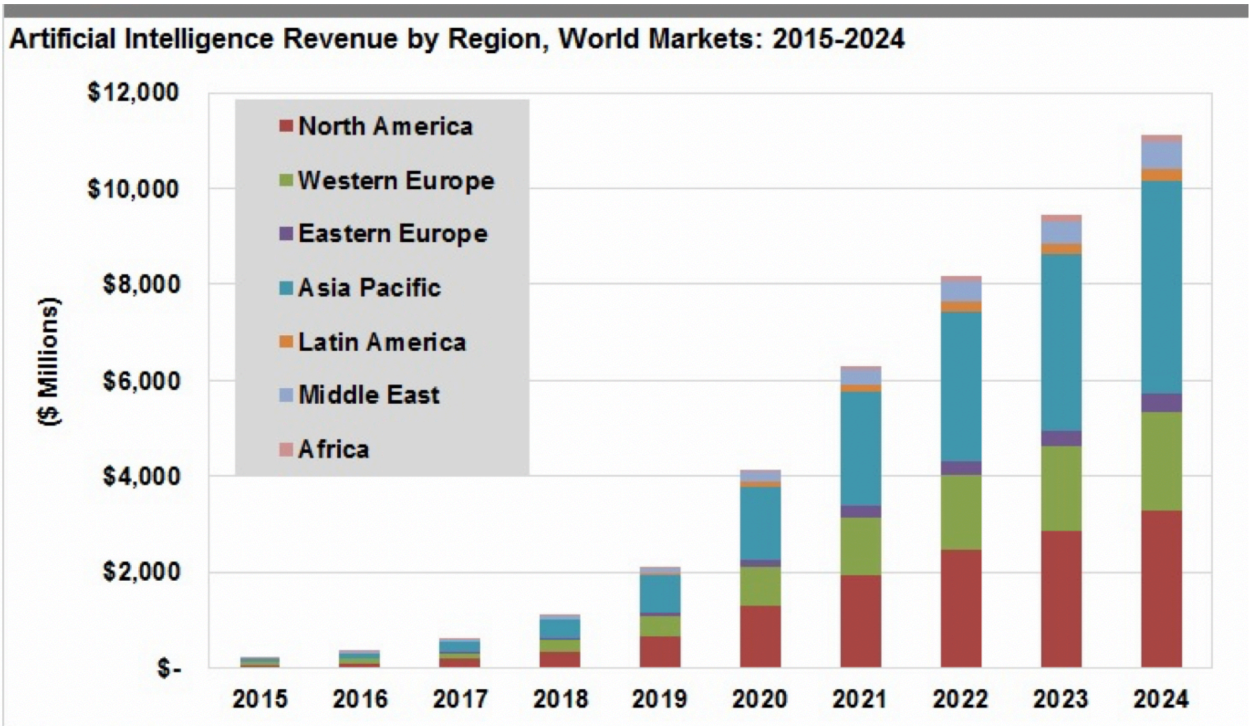


Figure 6.3 – Why AI

CHAPTER 7

AI APPICATIONS

7.1 ARTIFICIAL INTELLIGENCE REVENUE



Grpah 7.1 - Revenue

7.1.1 HEALTHCARE

How about we take a glance at each of the healthcare and as to how AI and self-learning machines are helping make operations etc. easier and helping doctors in solving the diseases and finding cure to already existing illness.

- ✓ Patient outcomes and decreasing costs
- ✓ Patient data and hypothesis
- ✓ IBM WATSON – healthcare tech
- ✓ Schedule and follow-up appointments
- ✓ Virtual health assistant apps for basic feedback

7.1.2 BUSINESS

Robotics is being applied and used in highly repetitive tasks that are usually performed by humans. Machine learning codes and algorithms are being put in use for data analysis and data sorting and on how to serve their customer better. Chatbots are incorporated into sites for immediate customer service.

7.1.3 EDUCATION

Technically, an educational institution is business engaged in the sale of educational services. But, AI can judge students and adapt to what they require at their convenient pace to ensure they're on right track with their peers. AI and machine learning can be put in place of teachers which is a backdrop to their jobs.

7.1.4 FINANCE

Artificial intelligence can be applied to professional applications, like taxations, investors, crypto currency to help financial institutions build up. They can accumulate personal details and advice on which investment would be beneficial for the party along with best tax advices. These apps are also playing an important part on trading in the Wall Street.

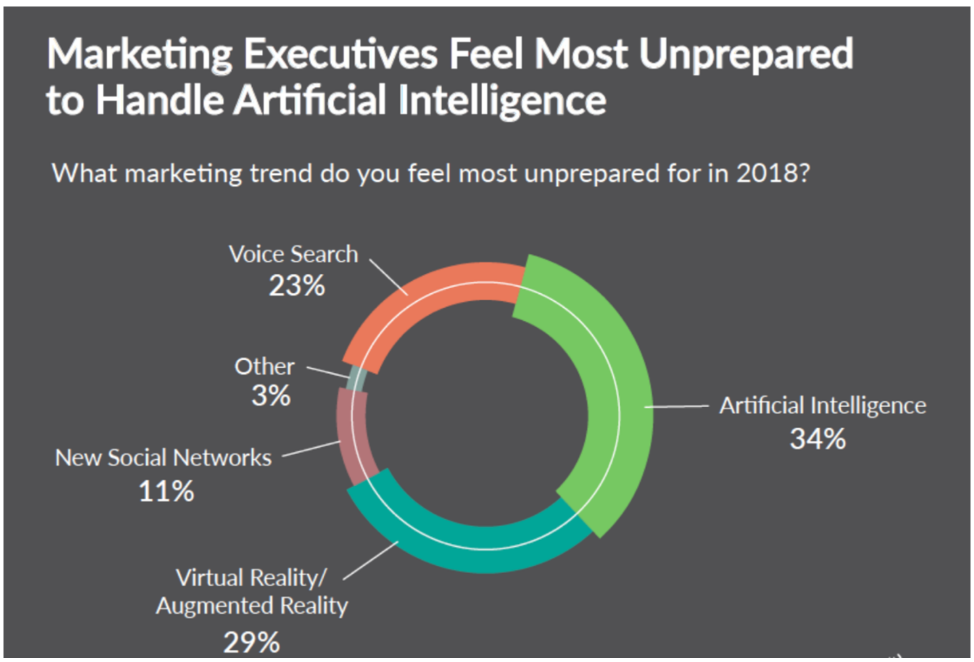


Figure 7.1 – AI Statistics

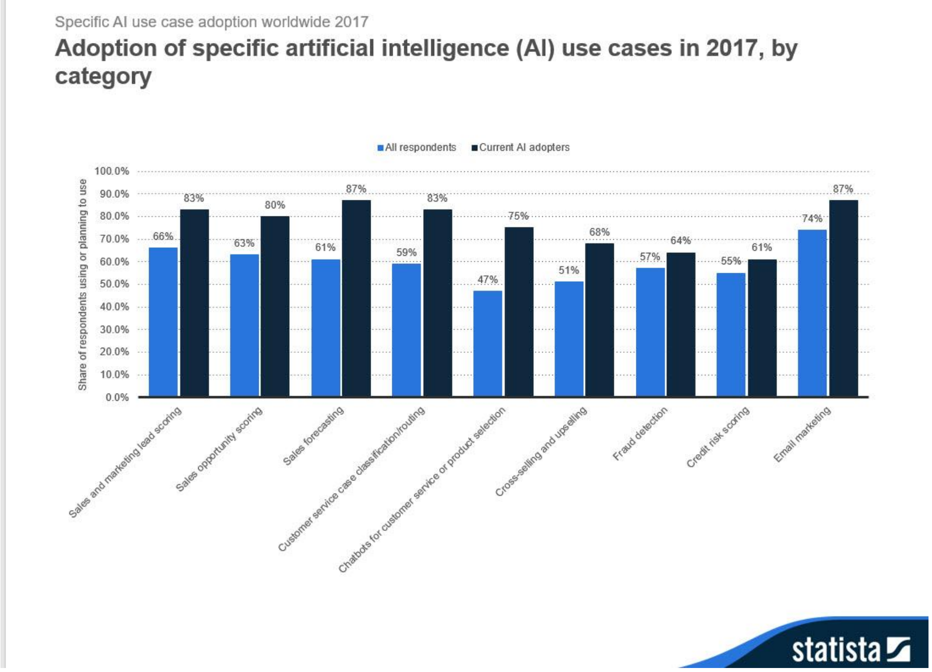
7.1.5 LAW

The discovering processes, shuffling through documents and advices have always fascinated humans. Automating this whole procedure will not only save cost but increase productivity.

Startups are making apps that can have the question and answer session along with examining the testimonies and the facts provided by the clients and their lawyers.

7.1.6 MANUFACTURING

integrating robots with the work flow has been at the front of every industry lately. They can be incorporated to perform single tasks and can enhance human work along with overall productivity. The graph below shows the adoption of AI in various fields for production.



Grpah 7.2 – Adoption of AI

CHAPTER 8

DESIGN AND TYPES OF GAMES

8.1 Participant Design

Game theory can be incorporated for optimizing the decision of the player for producing max utility**.**

8.2 Mechanism Design

This mainly focuses on making a game for an audience of intelligent people. Auctions being an important example of this design.

8.3 Single-Move Games

This game is played without the knowledge of what the other player is going to move in the future. For example, stock purchasing in the share market.

8.4 Repeated Games

These types of games challenges players with the same choice but multiple times, and each time the player seems to have knowledge of the previous move that they made.

8.5 Sequential Games

They model the environment with new and various new states coming with every new scenario. Chess being an example of this category.

CHAPTER 9

INCORPORATING KNOWLEDGE

9.1 TIC TAC TOE

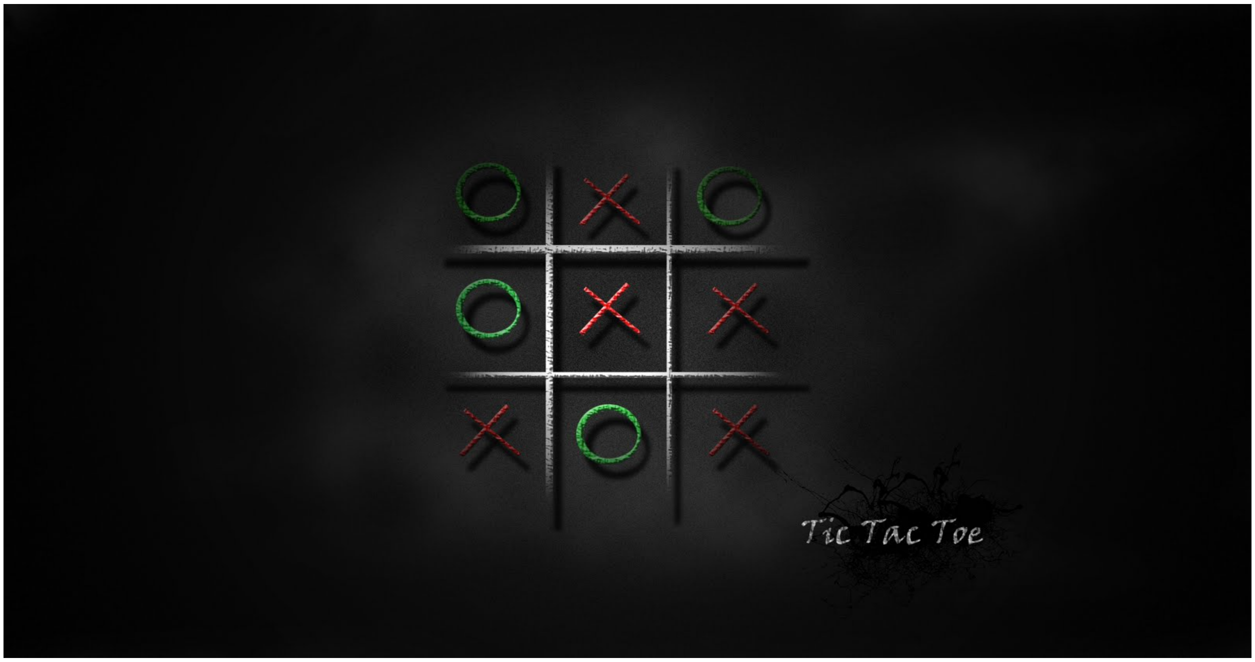


Figure 9.1 – Tic Tac Toe

9.2 VARIOUS CONDITIONS

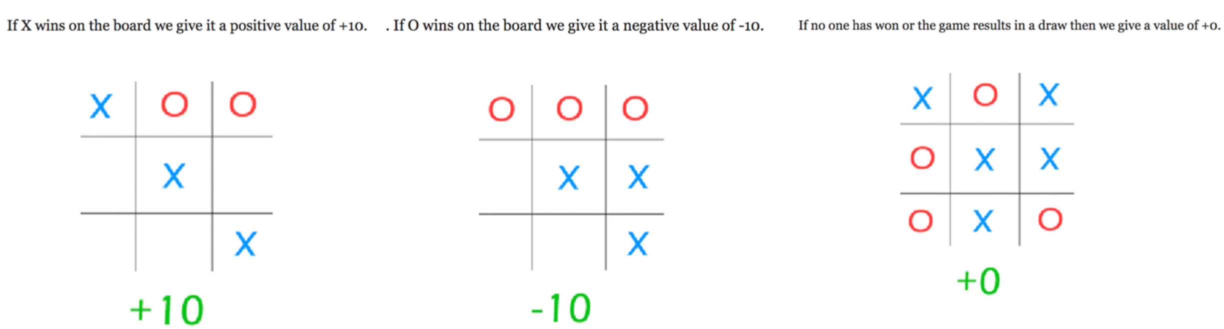


Figure 9.2 - Conditions

9.3 PLAYING AS THE AI

We could have chosen any positive / negative value other than 10.

If we represent our board as a 3×3 2D character matrix, like char board [3][3]; then we have to check each row, each column and the diagonals to check if either of the players have gotten 3 in a row.

1. We design a game where we play as the AI and the moves are in respect to X on the board.
2. Considering the various conditions given above, we need to make sure that we win the game in the fastest possible manner.

9.4 CHECKING ROWS AND COLUMNS FOR VICTORY

Checking for Rows for X or O victory.

```
for (int row = 0; row<3; row++)
{
    if (b[row][0]==b[row][1] && b[row][1]==b[row][2])
    {
        if (b[row][0]=='x')
           return +10;
        else if (b[row][0]=='o')
           return -10;
    }
}
```

Checking for Columns for X or O victory.

```
for (int col = 0; col<3; col++)
{
    if (b[0][col]==b[1][col] && b[1][col]==b[2][col])
    {
        if (b[0][col]=='x')
            return +10;
        else if (b[0][col]=='o')
            return -10;
    }
}
```

9.5 FINDING THE BEST MOVE

- A new function called **findBestMove()**
- This function evaluates all the available moves using **minimax()**
- Returns the best move the maximizer can make.

The pseudocode is as follows:

```
function findBestMove(board):
    bestMove = NULL
    for each move in board :
        if current move is better than bestMove
            bestMove = current move
    return bestMove
```

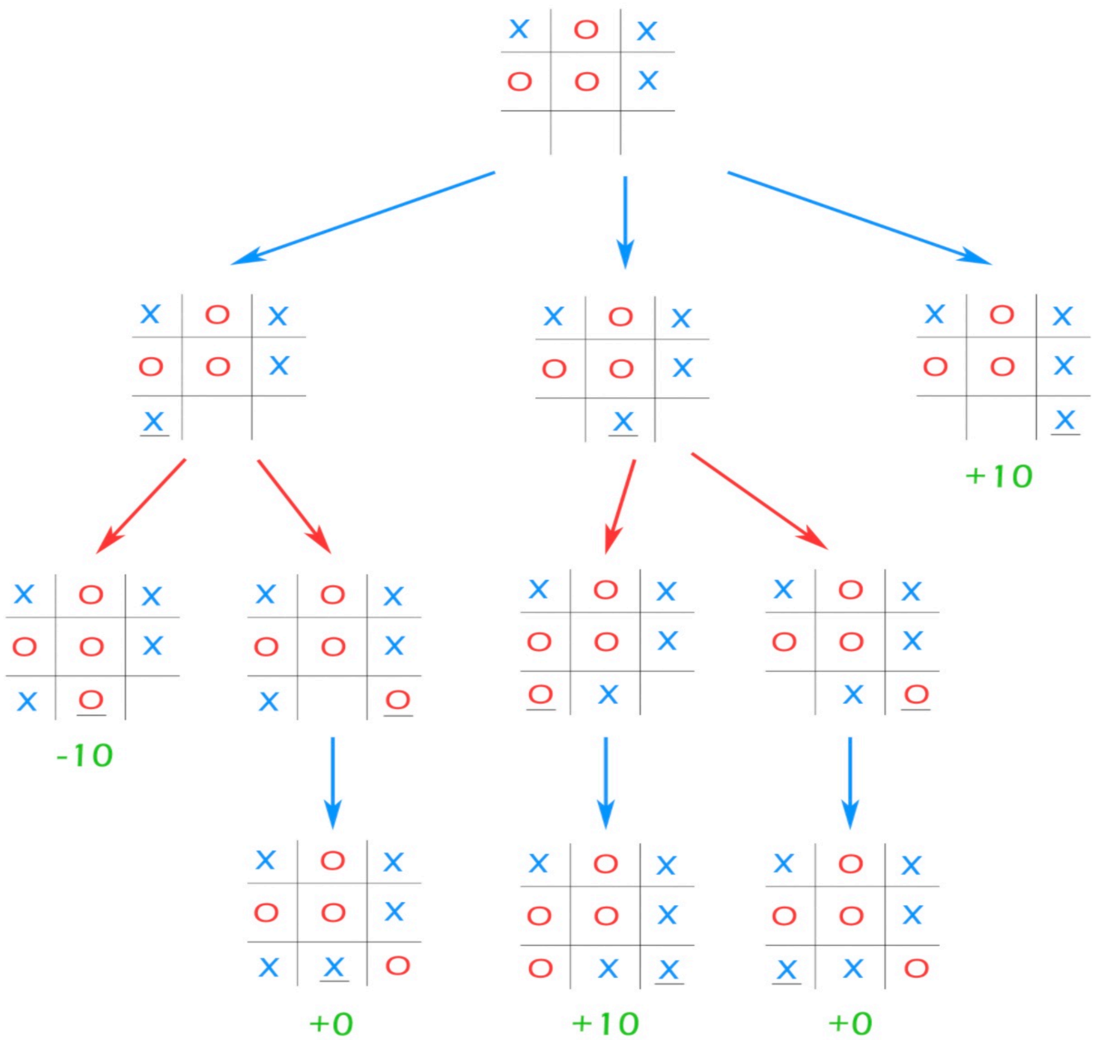


Figure 9.3 - Moves

9.6 MAKING OUR AI SMARTER

✓ Assume that there are 2 possible ways for X to win the game from a give board state.

Move **A** : X can win in 2 move
Move **B** : X can win in 4 moves

✓ Our evaluation function will return a value of +10 for both moves **A** and **B**. Even though the move **A** is better because it ensures a faster victory, our AI may choose **B** sometimes.

Move **A** will have a value of +10 – 2 = 8
Move **B** will have a value of +10 – 4 = 6

9.7 CHECKING FOR GAME OVER STATE

- If the game is over and no moves left we use **isMovesLeft()** function
- The function checks whether a move is available or not and returns true or false respectively.

Pseudocode is as follows :

```
function isMovesLeft(board):
    for each cell in board:
        if current cell is empty:
            return true
    return false
```

CHAPTER 10

CONCLUSION AND FUTURE SCOPE

10.1CONCLUSION

Games have always been one of the most important areas in the success of Artificial Intelligence and machine learning. Chess, Jeopardy, GO and lately Poker are few games that can be manipulated for good by AI systems using recent technological developments. From this perspective, it is justified to say that Artificial Intelligence is really tied to the progress in Game Theory.

10.2FUTURE SCOPE

The project report has the necessary details and information about the mentioned objectives that need to be looked in while deciding to incorporate Game Theory to the progress of Artificial Intelligence. It also tells us about all the factors that one needs to consider in future for making decisions by autonomous machines efficient with respect to mutual benefits.
Everything that can affect the future along with its feasibility analysis is explained in a detailed manner in this report.

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