



Background Intelligence for Games: A Survey

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Abstract

Artificial Intelligence and Game Theory are the two mature concepts at different paths which are connected and linked with each other. In past 50 years game theory and AI are two new concepts for research, comes from the same base. This research shows that the both concepts are deeply connected to one another and this research is trying to fill the gap between both game theory and AI. In this paper we will also discuss about the types of game theory and also on the issues in representation, reasoning and learning.

Keywords: Game Theory, Artificial Intelligence, Nash Equilibrium, Competitive ratio, Game

Introduction

Many founder as student and professors, starting different research by generating some other new concepts and many other audacious experiment of widening mathematical and economical reasoning in the early 50s which were very beneficial and effective [1-2]. Game theory and AI, both have elemental and broad connection between them but now, after 50 years, these both concepts taken diverse paths. Examining on connections of both may give momentous beneficence to both the areas. Also about the game theory types and how game theory can be applied in AI and also discuss about the three elemental points which are representation, learning and reasoning and also give some points on these [3,21,22].

History

Game Theory is a branch of mathematics with some previously defined rules and regulation which is used for the interactions between different players. Jon Von Neumann is known as the father of Game Theory as he published is paper on game theory in 1928 but seven years before him in 1921 Emile Borel published many papers on game theory, he envisioned that this theory can be used in economic and military applications.[23] Von Neumann gave strict formulation so he is known as its father. It is developed in economics in beginning but now it is an interdisciplinary area of study. In case of AI and deep learning GT is important to

facilitate some of necessary efficiencies needed in multi agent environment where different AI program need to collaborate or complete as in to achieve a target [4,24,25].

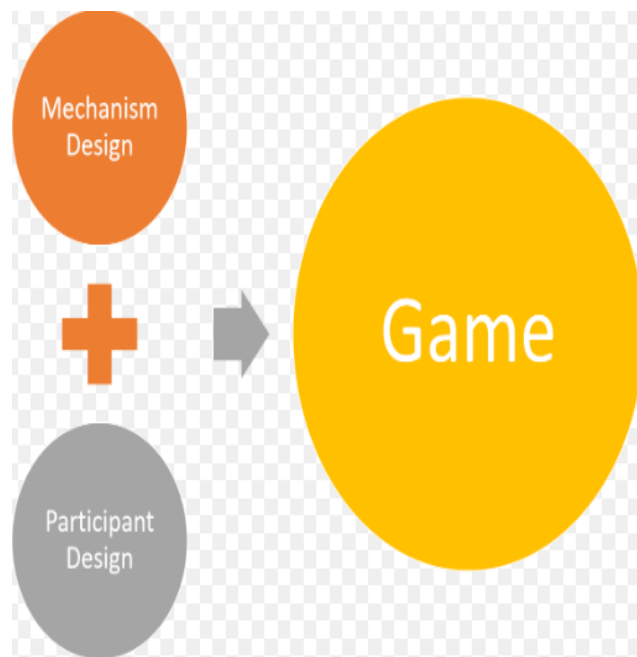


Figure 1. Game Theory

AI was invented by Herbert Simon and Allen Newell in December, 1955. They develop the Logic Theorist which was the first artificial intelligence program and the AI and after that many program and things get invented based on AI and many papers published on this concept as research [5].

Artificial Intelligence

AI is a broad branch of computer science related to building smart machines which is able to perform task which need human intelligence and smartness. It guides to the imitation of intelligence of human being in automobiles or gadgets that are computed to anticipate as humans and their actions [6,26,27]. It is intelligence described by machines which is look like the intelligence present in humans and animals which include knowledge and impressibility. This concept can also use for a machine which shows the characteristics linked with a human brain like learning and problem solving. Its main ability is its rationalization and ability of taking steps which give a chance of getting a particular goal target. Machine learning is a subdivision of artificial intelligence, which tells about the approach of immediately learning in computer programs [7,39].

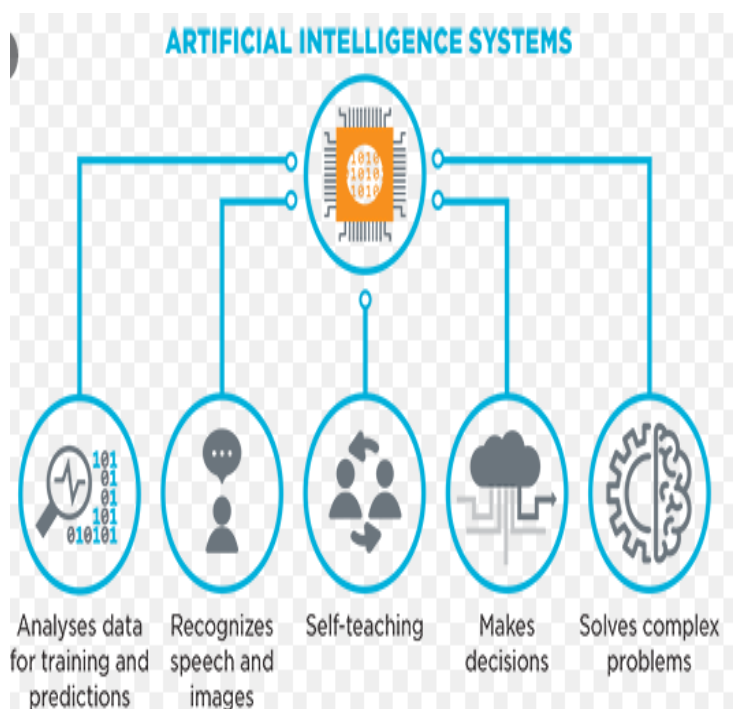


Figure 2. Artificial Intelligence

There are many application of AI. In mostly sector and industries AI and other technologies are used.[28] It is also used and tested in healthcare section for the treatments and making drugs and medicines used for curing diseases and also in the operating wards. It includes computers which are used to play chess and self-driving cars used in financial industry where it is used for banking and finance.[29]

Weak AI is the type which is designed body to carry out one specific job e.g. Amazon's Alexa, Apple's Siri, etc [8]. Strong AI systems are the type in which human like structures perform many tasks as human being.[30]

Game Theory

The study of mathematical mode of negotiation, conflict and cooperation between individual, organization and government is called game theory.[38] Its direct uses are in contract theory, economics, sociology and psychology.[31] This concept is also used in different sectors of study to know that why a person made a selected choice and how that have it affect others. It also contains studies of connection between person or a group as humans use various technologies to get their desired targets. Game theory is a science of strategy whose focus is on game, which shows that it is a model who serves the interaction among players (or rational players) [9]. Game also gives the identification to players and strategies of playing games and how these strategies affect the results. It is still a young and developing area of science in which many researches are possible further. There are different types of game theory which are discussed further in the next topic of this paper.



Figure 3. Terms used in game theory

Types of Game Theory

There are five different types of Game Theory which are as follows-

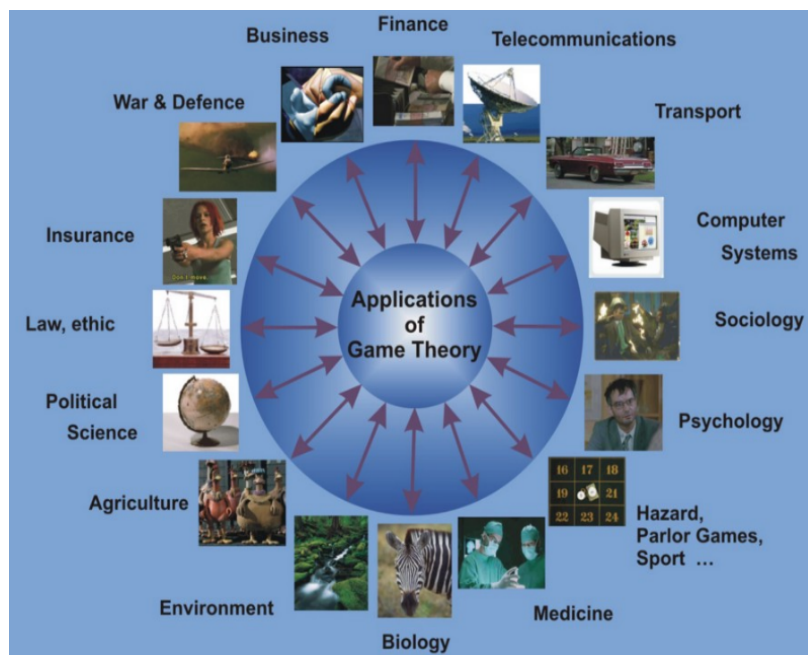


Figure 4. Applications of game theory



Figure 5. Types of Game Theory

- i.** Cooperative vs Non-cooperative games- The game where players can setup their union to inflate their probability of victory in the game is called cooperative games (e.g. negotiation).
The game in which players cannot form their union is called non-cooperative games (e.g. wars).[32]
- ii.** Symmetric vs Asymmetric games- The game in which players have the same target and their victory depends on their strategies is called symmetric games (e.g. chess).[40]
The game in which players have different or contradictory targets is called asymmetric game (e.g. prisoner's dilemma) [10].
- iii.** Perfect vs Imperfect Information games- The game in which all the participants can see the moves of other participants is called perfect information game (e.g. ludo).[33]
The game in which the moves of other participant are unseen or secret is called imperfect information game (e.g. card games).
- iv.** Simultaneous vs sequential games- The game in which various participants take action all at once are called simultaneous game (e.g. rock-paper-scissor).[34]
The game in which every participant knows the former actions of other participants is called sequential game (e.g. board games).
- v.** Zero-Sum vs Non-Zero Sum games- The game in which a participant profit is loss to other participant in the game is called zero-sum game (e.g. poker) [11].

The game in which multiple participants can take advantage of the profit of another participant is called non-zero sum game (e.g. monopoly) [12].

Game Theory in Artificial Intelligence

Game Theory is a very important concept for Artificial Intelligence model when we have to compose and design the model. Game Theory has its power in artificial intelligence, and to understand importance of game theory in artificial intelligence we have to know the basic of

game theory which we had discussed earlier.[35] Now, game theory is an important element in making and forming AI models today as game models are becoming popular day by day [13]. Mostly it is becoming popular in the multi-agent system which is used within a game model for interconnection with other agents. Game Theory is used to promote the abilities of multi-agent system needs to implement various programs in artificial intelligence for interaction to get the target. Multiple agents get connected to one another in gaming dimensions in reinforcement learning whose aim is to get victory without changing other variables. Multiple agents are able to conclude and collude in gaming dimensions to manage a work very accurately and efficiently. [36]Game Theory is also getting used in artificial intelligence in various sectors from cyber security to healthcare diagnosis and has capability of real world problem solving. Game theory is one of the main concepts in artificial intelligence skills that every artificial intelligence engineer needs to have in ordnance [14]. Game theory can be practiced in various extent of artificial intelligence:

1. Multi-agent artificial intelligence systems
2. Imitation and Reinforcement Learning
3. Adversary training in Generative Adversarial Networks (GANs).

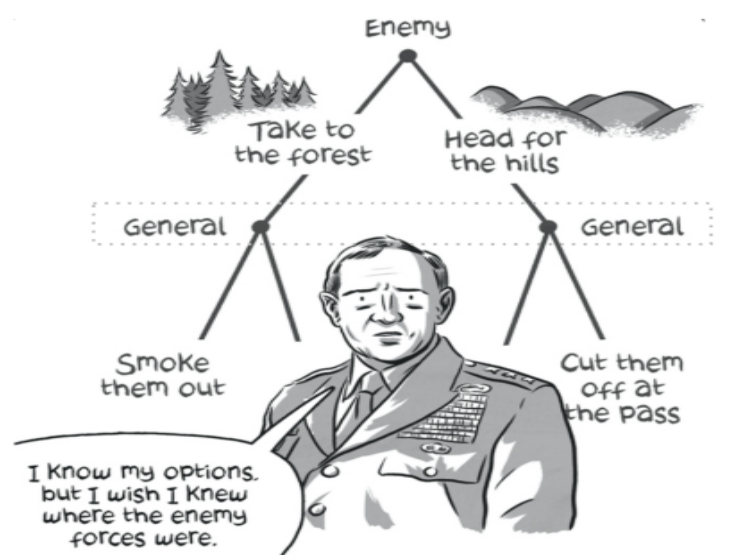


Figure 6. Game theory in Artificial intelligence

Representation, Reasoning and Learning

Both concepts are handled by “intelligent” agents. By applying different reasoning and learning techniques, agents can collaborate with each other and try to enhance their performance [15]. The points given below are elemental to both concepts-

- Reasoning about distributed systems-** Act in artificial intelligence examine obligations for distributed environments, computational constraints etc. Act in game theory examine communication between agents which are based on rational constraints (where agents pursue their own concern). Reasoning is essential priority for both as it is assimilating the two communication constraints as well as rationality constraints [16]. To achieve a particular behavior there are two hurdles which have to be conquered:

- **Rationality-** Agents can scam about their estimation.
- **Communication bounds-** Communication with estimation of agents become infeasible for each subset and communication bound is number of possible subset of source which might be very big.

It has two theorems:

- Theorem 1- When set B is a partition of set R, where $v_i(d) = \max_{b \in B, b \subseteq d} v_i(b)$ (b) is an equilibrium of the Clarke mechanism.[41]
- Theorem 2- Let set $B = \{A_1, \dots, A_k\}$ be a partition of R into k non empty sets of maximum size $\beta(B)$. (That is, $\beta(B) = \max\{|A_1|, \dots, |A_k|\}$.) Then

$$R_B \leq \beta(B) \cdot \phi(k),$$

where, $\phi(k) = \max_{j=1 \dots k} \min\{j, k/j\}$.

$j = 1 \dots k$

ii. Learning- Learning is an elemental case/point for both these concepts. Game theory asserts learning as a descriptive medium which explain the development of Nash equilibrium. Working on reinforcement learning in artificial intelligence asserts a way, and also deal with algorithms which get high payoff in unusual environment which lies on feedback. This type of learning scheme is elemental for both the topics. The algorithm which deals with optimal behavior is very effective. It is a broad issue in both the concepts [17]. Working on reinforcement learning various attentions by both the topics researchers and scholars and theorists of game. It provides the justification for the concept of Nash equilibrium which is concentrated for long period of time. A duo of strategies, for each participant, like deviation by other participant is irrational considering other participants to be in its strategies is called Nash equilibrium [18]. Its objective is providing the rules of learning to agent which gives high probability and more payoffs after some sort of time.

It has a theorem:

- Theorem 3- Given a game G, and $\epsilon > 0$, $0 < \delta < 1$, there exists a number T, polynomial in $1/\epsilon$, $1/\delta$, $|G|$, after which R_{\max} will have the property that for every $t \geq T$, the average payoff obtained by the agent is ϵ close to the probabilistic maximin value of G, with a probability of failure of at most δ .

iii. Representation- It is a central concept between both the topics as all the modelling agents are centered all around the representation [19]. It is the criteria of classical decision which includes competitive analysis, approach of maximization and level of safety (which is bad case). Agent is seen as maximizer of utility in game theory/economics. An elemental problem among economist is the ability of agent modelling's maximization of utility. It is the common or conventional path in game theory and a prominent way in the current artificial intelligence. This is the outlook as decision maker for agent modelling who are trying to upgrading their payoffs.[37]

It has a theorem:

- Theorem 4- Closure under unions is a sound and complete axiomatization for the competitive-ratio decision criterion, in any given binary choice problem

These three elemental topics are the necessary topics by which we can relate both game theory and artificial intelligence and these topics also show the interconnection between both the concepts [20].

Conclusion

In this paper, we have discussed about the artificial intelligence, game theory and how they both are connected with each other and relate with one another. Game theory and artificial intelligence are the two mature and vast concepts which give a lead to many researches and researchers also show their many uses to us. Game theory is related to mathematical formulation and artificial intelligence is related to building smart machine and to build a machine artificial intelligence needs game theory this is the way by which both are interconnected to each other. This paper also discuss about the type of game theory and their means.

The connection between both the concepts consist 3 parts which are following

1. Viewing use of computational settings by re-visiting game-theoretic and economic ways/paths.
2. For game-theoretic paths, it deals with computational issues.
3. To produce new theories for non-cooperative multi-agent systems, we combine game-theoretic paths and artificial intelligence paths.

This work cannot be completed by one group, these work need alliance or participation between computer scientists and artificial intelligence researchers. This participation and cooperation will lead to remarkable contribution in science and technology.

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