ALGORITHMIC GAME THEORY 2011/2012

PROJECT ASSIGNMENT: REVIEW

GAME THEORY AND VIDEO GAME, A NEW APPROACH OF GAME THEORY TO ANALYZE AND CONCEIVE GAME SYSTEMS

INTRODUCTION:

This review aims at analyzing the relevance of the article “Game theory and Video Game, a New Approach of Game Theory to Analyze and Conceive Game Systems”. Both the relevance from a game design perspective and from a game theory view are addressed.

ARTICLE DATA:

Authors: Stéphane Natkin And Emmanuel Guardiola

Date of publication: January 2005

Appeared in: CGAMES'05, Int. Conf. on Computer Games, Angoulame, France, pp.166-170,

ARTICLE RESUME:

The authors borrow from the tools of game theory to improve the design of video games. They first give an introduction both on game design, with a few words on previous studies, and on game theory, presenting the main concepts that will be borrowed: payoff matrices and dominant strategies.

The authors list the peculiarities of the joint use of game theory and game design, explaining how they intend to use payoff matrices and what assumptions are to be made. They focus on single player games, with the game logic as one of the actors.

In the second section, an action scene of a game is taken as a case study and the concepts explained in the previous section are applied to it. They define both the actions of the actors and the payoffs of the matrices through observation of the gameplay.

Using the payoff matrices, the authors analyze the gameplay, applying the concept of dominant strategy. Authors point out the pros and the cons of this approach, then conclude with observations on the possible uses of this method.

FORMAL ANALYSIS:

The article contains a few typos, especially with plurals, which may be due to the non-English nationality of the authors. Some concepts are not explained with due accuracy, it is therefore sometimes hard to follow the discussion, especially in the first section. However, the authors make many examples and thus what can be hard to understand from their definition can be made easier through them.

Example of formal corrections:

*"In academicals researches the game design is **studied** on a high level by Espen Aarseth and the DIAC team of the ITU of Copenhagen."*

*"Develops new **tools** to analyze and conceive game **systems** by using Petri **networks**"*

IN-DEPTH ARTICLE ANALYSIS

ABSTRACT

The premises of the work are well explained in the abstract. The authors aim to use game theory inside the field of game design. Two possible uses are mentioned: using game theory to *understand* the gameplay or to *build* the gameplay, but this distinction is not well explored in the rest of the article, as the focus was only on the first use. Authors also already mention that seeing actual video games from a game theory perspective has some flaws, something that will be made clear throughout the rest of the article.

SECTION 1: INTRODUCTION

In this first section, the purpose of the article is presented. The authors want to give an introduction to what game design is and what game theory is.

The authors give a small definition of *game design* and present the figure of the *game designer*. The authors also mention that the game design field is very broad and it does not include just videogames. This initial definition is useful to understand the goals of the authors, which are concerned with the creation of interesting *gameplay*.

It is not clear from the introduction, but the focus on game design highlights one of the main discrepancies between game theory and game design: the fact that one of the actors, the game AI, is not concerned with its own benefit, but instead is concerned with providing the player with an enjoyable experience and a correct amount of challenge.

On a side note, this same fact creates friction between classic academic artificial intelligence and videogame artificial intelligence, showing once again how the field of game design and development has its own, different, rules.

Video game creation and research

A brief *previous work* section is written here. The section is short and the references are little. I would have expected a stronger discussion on previous theories, since the field of game design is so big and many works have been published, especially in the last ten years.

The authors distinguish between *ludologic* and *narrativist* approaches in game design. It must be said that the debate on this distinction was fiercer at the start of the century, but now many researchers agree on a combination of the two. This is documented in the book Rules of Play, which is also one of the references of the article.

The authors introduce the limit of previous works: *"the exclusion of the resulting tools to create gameplay ... with all the difficulty and balancing stakes"*. This sentence is somewhat unclear, but I think the authors want to point out the lack of tools for mechanically designing games, where up to then (and still up to today!) game design is more like a form of art-craft than a precise science. I can share this concern with the author, and I too think that the field is in need of more accurate tools.

Basics of game theory

I feel this introduction on game theory is good enough for the scope of the article. The last sentence, however, where the authors mention that game theory is not usually used alongside other branches of mathematics, seems out of context for their purposes.

Typical game

The authors mention the two basic forms of games in game theory: trees and matrices. They choose to use matrices as, as also mentioned in Rules of Play, trees are not well suited for the representation of real games, as even the simplest game (think Tic-Tac-Toe) requires a tree with a high number of nodes.

It must be noted, however, that Salen and Zimmerman do not suggest using matrices either! This is due to the fact that games are *dynamic systems*, and as such their state keeps changing after each action, spawning dozens of new possibilities. In order to explore the whole *space of possibility* of a game, a static representation such as a tree or a payoff matrix is not well suited. Hence, the use of game theory for game design must be limited to small and incomplete parts of the game. A better representation of a game would be that of a state-machine, or a petri network (and the authors acknowledged this as well), or even better a model of a dynamic system, akin to those used in system theory. This is due to the need for games to be experienced, or at least simulated, in order to explore the intricacy of their workings and thus define whether the gameplay is good or not.

The authors restrict further their discussion by considering only two-player games. They present the example of a two-player, simultaneous choice game with perfect and incomplete information.

The authors also provide definitions of classic concepts in game theory such as *zero-sum games, dominant strategies, mixed strategies* and *Nash equilibrium.* The definitions, although heavily summarized, are useful as a brief introduction to the nomenclature of game theory. However, as will be seen later, only the concept of dominant strategy is used in the article, while the others are mentioned without any further discussion. These should be removed altogether, or they should be included in the study.

Video game creation and Game Theory

The authors present the characteristics of games seen from a game theory perspective. This part is quite useful to understand the differences and similarities between game design and game theory. Let us explore and discuss the chosen characteristics:

- **The notion of *strategy* is similar in the two fields.** In game design, with strategy we refer to the series of decisions that the player will do during the whole game, what is in some games also called *macro-management*. The same concept is present in game theory.
  This is a valid point made by the authors.
- **The payoffs of the matrices must be unknown.** It is not clear from the paragraph to whom they should be unknown, however. The fourth characteristic, however, points out that the player must not know the matrices. Thus, in this paragraph the authors speak about the designer.

What the authors may mean is that the payoffs of the matrixes are *variables* for the game designer, as they must be carefully designed to provide an optimal experience. This is true and is quite interesting as we thus move from classic game theory, where one is concerned with determining the actions of the actors given a game, to the actual creation of games, something that is more akin to *mechanism design*. (Further discussed in a later section.)

- **The goal is not to find an equilibrium, but a *winning strategy for the human player that is hard to find.*** This third point is really valid and quite interesting, as it explains a big difference in the *purpose* of the game. In game theory, an equilibrium is what is sought after. This is because the actors are supposed to progress towards the equilibrium and, as such, knowing what equilibrium will be reached is important. Think, as an example, of a competitor on the market who wants to determine how the market will move.
  As defined, an equilibrium is a point in the payoff matrices where the actors will converge. It is not hard to imagine that an equilibrium would be an uninteresting result for gameplay. The game would keep converging towards the same point, the same outcome, whatever the player does. Tic-Tac-Toc is a classic example of a game with a dominant strategy. Once the game has been played a few times, an intelligent player will always know that the only possible outcome will be a tie, and thus never play again. What players need in a game is to continuously move from a point to another, exploring a wide space of possibility. This fact adds once again to the idea that games are a dynamic system.
- **The game decision tree must be really vast and impossible to fully decipher and analyze for the player.** This point is not well explained in the article, but it is interesting. What they mean is that the player *must* have imperfect or uncertain information, such as unknown or unreliable payoffs values. This is true of many games, which usually sport some kind of probability distribution (like most role playing games) or hidden information (walls, fog, remaining life points). However, not all games do! As an example, puzzle games usually present all the information to the player, as well as strategy games. What makes these games compelling is the fact that the sheer complexity of the single puzzle or of the strategy game interrelations between units makes the player unable to understand the game wholly and thus present an illusion of *imperfect* information. This *uncertainty of the outcome* is needed for a game to be interesting, it is easy to imagine that a game which has the same predictable outcome every time would not be played.
  Last but not least, and this is a point that I think the authors should have made, there is some kind of information that must never be imperfect, nor hidden. That is the outcome of any game action, which must be meaningful and discernible (see Rules of Play for a valid discussion on the topic).

The authors then consider a case study. It is important to note that due to the inherent complexity of games, as shown by the fourth point in the previous list, the authors have decided to focus on a *sub-game*, as in a model of just one small part of a real game. This is a good choice, as the same discussion can be made for all sub-games inside a game, in order to potentially provide a good design tool for the whole game experience. We observe, however, that it is not easy, and may also be impossible, to determine a closed sub-games with no influence from other parts of the game. This approach thus reveals to be quite theoretic.

SECTION 2: CASE STUDY: NINJA GAIDEN - THE GAME

In this second section, game theory is applied to the potential design of a sub-system, the combat between the player and three enemies in a famous commercial game: Ninja Gaiden.

The authors make the assumption that the player is in a state of *"tactical exploitation",* which means, although it is not properly explained in the article, that he now knows the outcomes of his actions and their consequences, i.e. he has a good idea of the payoffs.

The data collected by authors is in the form of a video sequence and actual gameplay. It is not reported exactly how many sessions have been done, which would have been helpful in gauging the relevance of the study.

Building the matrix

The authors apply game theory to the chosen sub-section of the video game. They define a two-player payoff matrix, with the human player actions on one hand, and the strategy of the game system (which will be designed) on the other. Interestingly, the game is not given any payoff and as such is considered passive to the strategy of the player. A better idea would be to use this information to build an artificial intelligence for the enemies.

Human player's strategies entries

For the human player's entries, the authors decided to refer to the physical buttons the player is going to press. Since we are analyzing a fast-paced action game, the player is going to press many buttons every second, requiring an almost instantaneous choice at each decision node.

The table provides a good summary of the actions performed by the player and can be used by the reader to imagine the situation.

Game system player strategies entries

The authors declare their choice to include all game elements that can induce changes in the player's strategy. They then choose to focus on the formation of the enemies in the scene and on the position of the player among different *detection zones.* As the authors show, just by including the formation and the player's position in the zones, the analysis of the design using payoff matrices becomes really complex. In fact, the authors create one payoff matrix for each position of the player, resulting basically in a three-dimensional matrix.

By doing so, however, they basically contradict themselves. Indeed, there are many elements that can induce strategy changes, of which the enemy formation and the detection zones are just a couple of elements. If we were to add others elements in order to take into account everything that can change the player's strategies, such as his avatar's health and power, his ammo, his skills, his current equipped weapon, his knowledge of the next sections, the enemies' current health and so on, it would be even clearer that the approach is too *'static'* for the purpose. Once again, we see that a dynamic approach should be preferred. Note also that the behavior of the enemies, as usually done in such games, follows a finite state machine, hinting again at the dynamic nature of the game.

Defining the payoff values

In this section, the payoff values of the chosen matrices are determined. The authors make an interesting point in considering as the payoff unit the in-game money of the player, the *yellow aura*, stripping down the situation to its basic resource management part. The authors then proceed to determine the yellow aura value of each element of the sub-game.

However, by doing so they make a further simplification. For example, they assume that at any time the player may convert his yellow aura into health, which is not possible in such a game. Another example lays in the determination of the yellow aura value of an enemy. The authors make a simple statement: since an enemy drops 100 yellow aura on his death, and since it takes 4 hits to kill the enemy, each hit is worth +25 yellow aura. As good as it sounds, this logic is however naïve. What if the player had really low life? What if he managed to hit the enemy three times, before having to flee? Then each of his hits would net +0 yellow aura. Once again, we see that the dynamics of the game system are too complex for such a simple model.

From a matrix to another

The authors reiterate the division of the space into zones (which is a bit redundant at this point). Then, recognizing that the model is too simple, the authors introduce other variables, such as the fire shield or the equipped weapon, but stating that they are minor compared to the positional variable. I think that these variables should have been introduced in the previous section and should have had an important part in the determination of correct payoff matrices.

Even using the simplest model, the resulting matrices are 9, each with 11 rows and 4 columns. A total of 396 different cells for just one of the countless enemy encounters of the game, overly simplified too! The resulting game (from a game theory perspective) is thus quite complex and far from what the theories were made for.

An interesting fact is also stated: the player is not free to move from one matrix to any other, but must follow a precise path. This, again, makes the payoff matrices not analyzable with classic game theory, since no constraint on the movement between different actions are considered.

SECTION 3: ANALYSING THE GAMEPLAY USING THE GAME THEORY MATRICES

In this section, the authors make an analysis of the gameplay from a game theory perspective using the matrices that have been built previously.

The good accumulation of payoffs problematic

The authors analyze the first matrix, showing that a dominant strategy is present: blocking until an opening permits the shooting of arrows. However, the very authors point out that the player is not likely to use this dominant strategy, due to other variables such as the limited amount of arrows. I would like to add that there are other variables that can influence this decision: such as the pace of the game, since blocking and shooting arrows is quite slow and not so fun compared to running into the enemies and slashing them to death! The authors even admit that the matrices alone are not sufficient and that the payoffs themselves are subject to interpretation (should we consider the payoffs when one enemy is killed? Or three enemies? Or the level is completed?). As a result, the method looks like having too many weak points to be useful.

However, the authors conclude this section saying that the matrices are *a good tool to measure the depth of gameplay*. I must point out that a two-dimensional matrix showing the combinations of actions and states of the game does not look like the best way to show that a game has depth, i.e. a lot of choices. What would be more interesting is a representation of the *dimensions* of choice of the game, basically the *space of possibility*. As we know, however, this would result in a huge representation, hence once again we return to the problem of the dynamics of the game.

To further prove the point that the method is not suited for game design, using the values written in table 1 we can find what would look like a bad strategy in game theory, but is used often in the actual game. Let's say that the player is in the Visible zone, thus the dominant strategy would be to use the bow. Why would the player ever use the fire shield, since by using it he would lose the amount of 20 enemies killed in yellow aura? In fact, the fire shield is often used during the game, since it gives a buff to the player allowing him to more easily avoid death.

Learning in game

The authors at last try to assign a place to these payoff matrices by introducing the concept of *learning curve*. Their thesis is that the payoff matrices can be a good tool to determine the difference between subsequent sections in the game, in order to give the player new challenges by reordering and modifying payoffs. While this can be possible, it seems to me that the tool would be too clumsy to use, keeping the same weak points as mentioned before.

SECTION 4: CONCLUSION

After concluding by affirming that game theory can be an useful tool for game desig the authors mention possible future work.

The authors mention analyzing other games. This would be really helpful to assess the validity of the study, as there are different genres of games (such as real-time strategy games) that would probably benefit more from payoff matrices and the study of strategies. After all, an action game is quite far from the theoretical examples of game theory.

The authors mention again the concept of designing a new game system using the tools described. As this was also mentioned in the abstract, it is surprising that there was no further discussion about the differences in using payoff matrices to understand games or using it to build. I think time constraints are to blame for this.

At last, they explain the possibility to use the payoff matrices to build an artificial intelligence in the game. This would be interesting, and probably the tools would be more useful for that purpose. A paper exploring this path would be interesting and would probably achieve better results.

The authors themselves mention creating a *dynamic model of the player*, which once again reminds us of the nature of games.

REFERENCES COMMENTARY

The reference section is consistent, showing that this article builds upon a bibliography of 14 previous works. However, a good number of the referenced articles were written by the reviewed article's authors and may thus constitute just a form of "self-advertisement".

Most of the references come from the game theory fields, with notable inclusions of famous books as well as less-known works. A few references point to other applications of game theory ("The evolution of cooperation") or to the application of different methods to game design (Petri nets).

From a game theory perspective, on the other hand, the article is not well-versed and misses critical references, showing once again that the field of game theory has been just scratched on the surface.

- *Aarseth, E. 2004. "Genre trouble : narrativism and the art of simulation", in First person. N. Wardrip-Fruin. and P. Harrigan, eds. The MIT Press, Cambridge.*

I cannot find the article, but from the title I can gather that the topic is the debate on the nature of games, whether they should be considered as narrative or as simulation. The same topic is addressed in another referenced article: *Simulation versus Narrative from G. Frasca.*

- *Axelrod, R. 1985. The evolution of cooperation, Basid books.*

This is the only reference to an application of game theory in the bibliography. The book it references tries to explain how game theory can be used to explain the evolution of social cooperation in the human being. Refer to http://en.wikipedia.org/wiki/Evolution_of_cooperation#Social_Darwinism for an introduction to the book.

- *Byrne, E. 2005. Game Level Design, Charles River Media, Hingham.*

A book on game level design, i.e. the design of the sections and environments inside of which the player will freely move and experience the game.

(NDA: The book looks like a good read and I just added it to my to-read list!)

- *Frasca, G. 2003. "Simulation versus Narrative"- in The Video Game Theory Reader. M.J.P. Wolf. and B. Perron., Eds. Routledge, New York.*

A really interesting read on game design, this article is a good testimony of the young state of the field. The author addresses the debate on games as narrative against games as simulation, propending for the latter as a more accurate definition on games. I too agree with the author and his thesis is also supported by many other important authors in the field.

- *Guerrier, B. 2002. La théorie des jeux, Ed Economica, Paris.*

I cannot find the article and, even then, I think I wouldn't be able to understand it thoroughly due to the language.

- *Juul, J. 2004. "Working with the Player's Repertoire", Imagina 04, Young researcher winning price.*

I cannot find the article, but I found a few slides from the same author. The author addresses still open questions in the game design field. With "player's repertoire", the author points to the fact that player like to learn new skills while playing, and as such the concept is tied to the *learning curve* mentioned in the reviewed article.

An interesting work from the same author: http://ocw.mit.edu/courses/comparative-media-studies/cms-608-game-design-spring-2008/lecture-notes/MITCMS_608s08_lec04.pdf

- *Koster, R. 2005. Theory of fun for game design, Paraglyph Press,Scottsdale*.

This book has become a classic in game design studies and is a required as well as a pleasurable read. Ralph Koster, a game designer, writes about what motivates us to play, exploring his theories accompanying them with funny drawings and small thoughts.

- *Natkin, S., C. Le Prado, V. Gal and L. Vega. 2002. "Quelques aspects de l'économie du jeu vidéo, in Journées d'études" in jeu etsocialisation , Eclos des télécommunication, Paris.*

- *Natkin, S. 2004. Jeux video et media au XXI siècle, Ed Vuibert,*

- *Ponsard, J-P. 1977. Logique de la négociation et théorie des jeux, Les Editions d'Organisation, Paris.*

Other French articles. I did not consider them.

- *Rollins A. and D. Morris, 2000. Game Architecture and Design, Coriolis*

A book on game design and development. I am looking to get get a copy of it.

- *Rollins A. and E.Adams. 2003. Andrew Rollings and Ernest Adams on Game Design, New Riders, Indianapolis.*

A famous book on game design by two important designers, Adams in particular is known for his work in Bullfrog Production, a now dead software house that created a few jewels in the eighties.

- *Salen K and E. Zimmerman. 2004. Rule of Play : Game Design Fundamentals, MIT press, London.*

The book that any game design enthusiast should read and cherish, Rules of Play analyzes games from dozens of different views and try to give answers to the many questions that this young field keeps proposing. The authors speak of games in terms of their Rules, Play and Culture aspects and provide many useful insights on the difficult art of game design. Last but not least, the authors provide an astonishing set of references for game design readers.

The book also has a whole chapter dedicated to game theory and its applications in game design.

I must report that the correct title is "Rules of Play", with the plural. A misspell or a sign of a fake reference inclusion?

- *Vega, L. and S. Natkin, 2003. "A petri net model for the analysis of the ordering of actions in computer games" ,in proceeding of the GAME ON 2003, London.*

This article, similar to the reviewed article, takes a well-known and useful technique born from a different field (in this case, computer science) to use in game design.

It must be noted that the article was written by one of the authors of the reviewed one.

- *Ninja Gaiden, 2004, Team Ninja developer, Tecmo/MicrosoftPublisher.*

Just this one game is referenced inside the work. It is surprising that the game comes from the developers of Tecmo, given that one of the author works for a well-known game publisher. Nonetheless, the game has been acclaimed by the critics both for its technical accomplishment and its game design. The game is known for its sheer difficulty and is thus a good candidate for the analysis of player's strategies, given that the game is targeted to the so-called 'hard-core' gamer, the kind of gamer that carefully hones his strategies. However, the fast paced action may be not the best choice, while a strategy game such as Age of Empires would have been a better choice for analysis thru game theory.

DISCUSSION: GAME DESIGN

From a game design perspective, the proposed tools seem too clumsy and limited to be useful in practice. The authors themselves mention the many differences between the fields of game theory and design and we can summarize them here:

- Game theory deals with simplified models of reality and its results are based on many assumptions, which are rarely fulfilled in such a complex system as a video game.
- Video games, as all games, are dynamic in nature. These dynamics are hardly represented by a fixed matrix like the authors try to do.
- The game has many variables that must be taken into account and that can induce changes in its outcome. Since a game will try to be as varied as possible, it would be too hard for game theory methods to encompass it. This is clear in the impossibility to achieve an extensive form of even the simplest game.
- The game system is considered as one of the actors, but its aim is not to maximize his gain, hence many concepts of game theory cannot be used, such as equilibrium concepts.
- The player may be constrained in his available actions at different times, resulting in the impossibility for a matrix to represent his choices, if not continuously changing the matrix (as the authors try to do).

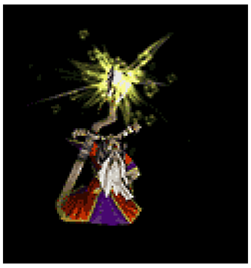
However, the authors bring nonetheless a novel approach to the design of games. Currently, in order to understand a game system and tune it, heavy play testing is the preferred method. This requires the designers to be assisted by numerous play testers and also requires good knowledge of the game system and of games in general in order to point out where the weak points are. New, more formal methods, such as that proposed in this article, are needed by the game industry for a more *scientific* approach. As we have seen, based on the nature of games, dynamic methods such as simulation environments should be preferred.

I would like to mention here that more recent and potentially more useful tools for game design have been created, such as the machinations framework, a dynamic simulation framework for building and analyzing gameplay: http://www.jorisdormans.nl/machinations/wiki/index.php?title=Main_Page

This is not to say that payoff matrices are useless in game design. In fact, they are often used by game designers in *balancing*, although without resorting to game theory. A better game example in this case would be that of a real-time strategy game, sporting numerous different units with many varied statistics. In such games, it is often the case that units are compared using matrices, comparing the combination of their values in order to balance their strengths. As an example, see the following tables which show the comparison of two Undead units in the game Warcraft III.

Level:	2
Cost:	120 2
Unit Type:	Normal
Attack Type:	Normal
Weapon Type:	Normal
Armor Type:	Heavy
Armor:	0 (6*)
Ground Attack:	13 avg (17.5 avg*)
Air Attack:	None
Cooldown:	1.30 (1.04*)
Hit Points:	340
Health Regeneration:	Blight
Mana:	None
Mana Regeneration:	N/A
Range:	Melee
Day Sight:	140

The Ghoul unit in the game Warcraft III



Level:	2
Cost:	145 20 2
Unit Type:	Normal
Attack Type:	Magic
Weapon Type:	Missile
Armor Type:	Unarmored
Armor:	0
Ground Attack:	8.5 avg
Air Attack:	8.5 avg
Cooldown:	1.8
Hit Points:	305 (385*)
Health Regeneration:	Blight
Mana:	200 (400*)
Mana Regeneration:	0.667 (1.167*)
Range:	60
Day Sight:	140

The Necromancer unit in the game Warcraft III

Balance matrices are also explained in detail in the books Rules of Play and The Art of Game Design.

As a last note, I would like to point out that the authors have chosen to address single player games, where the player struggles to win against the artificial intelligence of the program or against the carefully placed obstacles the game levels are littered with. It would be really interesting, and possibly even more useful, to address the topic of multiplayer games, i.e. games in which two or more players engage in competition or cooperation in order to win games.

Bound by game rules, players in a game can in fact be modeled by game theory actors. Players have their own strategies and desires, which can be taken into account. By considering all of this from a game design perspective, the game designer can make use of game theory concepts to improve the game experience.

DISCUSSION: GAME THEORY

Although from a game theory perspective the authors do not add nothing new, the application of its methods to a new field can still be regarded as novel. However, the authors just scratch the surface of what the field has to offer, focusing only on the game theory representations of games (and only on the matrix forms) and on simple strategies.

What other concepts of game theory could the authors have borrowed that would have been useful in such a discussion? I can make a few suggestions. It is clear that it was not in the minds of the authors to delve into the whole game theory field, but I feel that the article would have benefitted from a more complete analysis. We already said, however, that many assumptions of game theory are not fulfilled with video games, and as such many results cannot be used.

We mention here some additional concepts that pertain to game theory and explain where they can be useful, or why they cannot be used.

- *Strategies – pure, mixed*: this concept is just briefly mentioned in the article. There is however a similar concept in game design already, useful in the creation of game A.I., although game theory's formal approach could be useful too.
- *Extensive form, normal form, multi-agent form*: these forms are not explored in the article, but a valid point is made: video games, being inherently dynamic, are hard to represent with trees due to the huge space of possibility.
- *Imperfect information*: this is briefly mentioned in the article, but the concept is not explored further. Imperfect information, especially the fact that a player would not be able to determine where in the space of possibility he is after an action, would be detrimental to the game as the player must always know the results of his actions in order to achieve meaningful play (see Rules of Play).
- *Incomplete information:* this concept, instead, is useful to the game designer as the player can be initially given uncertain payoffs, which have to be discovered throughout the game, increasing the appealing of exploring the space of possibility of the game.
- *Non-equilibrium solutions*: like for strategies, the analysis of solution concepts could be useful for the creation of game A.I.
- *Domination*, in particular, is mentioned in the article as the player will take note of all the opportunities for domination. Dominant strategies are already present in many academic discourses on game design. They are known to be detrimental to a pleasurable experience, as they will be experienced as shortcuts by the player, which will lower the amount of choice at his disposal.

- *Equilibrium concepts:* in a single player versus game system situation, we have seen that an equilibrium would be detrimental to the fun of the gameplay. Concepts such as Nash equilibrium cannot be applied, since the game system does not act in order to maximize his payoff.

Note that many of the concepts could be useful for the creation of a game A.I. An article focusing on this fact could thus be quite interesting.

One last useful concept that we can borrow from game theory is *mechanism design*. It is already mentioned in the abstract of the article that the game designer *"is the creator of the universe of the game, he can choose the rules, the payoff matrices and the laws of the video game universe"*, it is therefore natural to move from the simple theories of matrix games to mechanism design, which is more akin to game design. In practice, mechanism design refers to the routing of the behaviors of the actors during a game.

The game designer can be seen as the *social planner* of the mechanism, while the players are the *actors*. Since players are bound by the rules of the game, the game designer is able to decide on the *social function,* that is the function that ties the types of the actors to the outcome of their choices, which could be seen as the path of play of the player, then create a mechanism to implement the chosen path of play. The game designer is also facilitated by the fact that the problem *of information elicitation* can be overcome by crafting the rules of the game carefully.

The application of mechanism design may bring benefits to different aspects of game design: from the creation of equilibriums in the gameplay for a fairer game, to the hindrance of cheating and unsportsmanlike behaviors. It would especially be useful in multiplayer games.

As a side note, many massively multiplayer online videogames (MMO) present some kind of player-controlled auction house. Mechanism design surely can be used (and probably already is) in this situation as well, in a more classic situation.

MY CONCLUSION

What we gather from the discussion of this article is that game theory and game design are very different fields, with different purposes, methods and results.

The methods used in the article have revealed to be useful, but limited, for game design, restricting their usefulness to the local analysis of a subsystem of a game. As a modeling tool, payoff matrices may be thus used to compare different game mechanics and the strategies that may be adopted to use them. Of course, special care must be taken since, as we have seen, the dynamics of the game have a huge impact on the gameplay and many variables intervene to shape the game situation, resulting in the need for more dynamic and complex analysis methods than payoff matrices.

Further research could be done by considering game theory in different aspects of the development of games, such as the design of multiplayer interactions and of game A.I.

The article is not exceptionally written, but nonetheless is an interesting read and since it is so hard to find research on the application of game theory in the field of game design, this article is an useful introduction to a further debate on the matter.