GameEvolver: A tool to potentially automatically improve board games

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Abstract

Board games as an entertainment tool have been enjoyed by humans for thousands of years, recently, with the development of computer science and artificial intelligence (Ai), computers are capable of outracing human players in certain board games. Their power in computing and memorizing even makes the professional Go player Ke Jie [19], who used to match with AlphaGo, state that it becomes boring and frustrating to play against Ai, it feels like they are just better in everything in Go games. I wondered, board games are supposed to bring joy and fun to the players, now Ai is breaking the balance of the game by utilizing their superpower of calculating during some board game. Making the optimal decision is important in both playing and designing board games, if computers are able to defeat human players by choosing the optimal solution, are they also capable of making optimal design decisions and ultimately generating or evolving a human-enjoyable board game? we will explore the possibility of automatically generating a board game, by building a random board game generation algorithm, The GameEvolver. The resulted game of GameEvolver will be tested with human players to investigate whether they enjoy it.

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Chapter 1. Introduction

Games have been a part of human entertainment since ancient times, while many can be remembered and reproduced, others were lost during the development of humanity. Although we cannot reproduce the procedure of our ancestors inventing those games, we can imagine the development of the games must take a lot of effort. Nowadays, computers are an indispensable tool in doing an enormous number of calculations during game development, but the detailed designs of the games are still controlled by humans. Since the invention of the first Artificial intelligence (AI), computers have proven the capability of making “optimal” decisions, while the game design is also heavily decision-making based, naturally, this leads the question whether AI can support or ultimately take over the game development process and free the human designers? This thought leads to my research question:

RQ: “is it possible for computers to improve or evolve board games and ultimately generate a human enjoyable board game to support game development?”

The aim of the research is to test whether an algorithm is capable of improving existing board games. The reason we focus on board game is that modern video games are too complex in the sense that the development of those games might take years of hard-working and contains various design elements (art, music, social impact etc.), whereas board games can be relatively easily reproduced and tested. People can play classic board games such as tic-tac-toe only with pen and paper, and they can easily tweak the rule of tic-tac-toe and turn it into a brand-new game. The clear mathematical game model and game interface of most board games make them easier to be studied by AI, thus making them more realistic for my project.

To answer the research question, an algorithm (GameEvolver) needs to be developed that is capable of tweaking the design of a certain game or generating a completely new game based on some criteria. The criteria should consist of the elements that make some games more popular than others, or the “human-enjoyable elements”. Then, with the outputted game from the GameEvolver, a playtest will be held to test whether human players can enjoy the game generated by computers. In order to develop the GameEvolver, a crucial step is to find out: what are the elements that are considered human-enjoyable in games. This leads to my Sub research question:

Sub RQ: “Are there common measurable elements in popular games that make players enjoy them? If yes, what are them?”

In the next chapter, the information extracted from different studies will be discussed together with the reflection on them regarding my GP. The “human enjoyable elements” will be concluded at the end of the chapter 2.

Chapter 2. Literature Review

Before we consider the human-enjoyable elements in games, since one of the main goals of game is to create an experience for the audience [13], it is wise to first categorize games based on the experience it creates. Games can be roughly categorized into two types, single-player games and multiplayer games, where the former is more self-challenging and the latter requires more team work or competition between players. These two types of games cover most of the board games, puzzles or modern video games, and the two of them creates different impact on player experience. As stated in chapter 27 of the book [7] by Joseph and Knuttila: *"This perceived split (of single-player and multiplayer games) manifests in a variety of historical and contextual forms: it emerges from the single-player games of the frenetic, quarter-driven arcades against the social play style dominant in early generations of home consoles;"*, the reason Jaseph and Knuttila split the games into two categories is that they are designed to serve different audiences, family console players and single players. But from the perspective of a game developer, what is the crucial element that separate the two types of games? In the research "Learning in Single-Versus Multiplayer Games: The More the Merrier?" Casper and Geertje [9] give an answer to the question, they have also divided the games into groups. From their perspective, the border between single and multi-player is blurry. A single-player game can certainly become a "multiplayer" game, because, for example, one of the player's friends decide to give the new game a try. So instead, they found the main difference between the multi and single-player games in the sense of game development, which is the player interaction within the game world. Often in single-player games, only one player interacts with the game world, while in multiplayer games, multiple players are interacting with the game world either at the same time or take turns. Furthermore, they found 2 major differences between single and multi-player games, labeled as "data versus process intensity" and "formal versus social rules". The former can be interpreted as the internal game mechanism and the latter refers to the rules of the game itself together with "Social rules" outside the game. The "Social rules" was concluded by the author as: *"Unwritten configurations that emerge during the game and socially-oriented goals that are prewritten by the designers"*. The two literatures support my previous conclusion that we should treat single and multiplayer games differently regarding the player experience they creates.

The next question is what are the corresponding human enjoyable elements in different type of games? The research of Jing Shi, et al. [3] interviewed 16 players that are self-identified as gamers. The findings revealed that gamers think video games are meaningful and purposeful activities. Interviewees claimed that they found friendship during gaming, games also offered them a moment of relaxation during life. Interviewees also stated that when they are playing games, they will be satisfied by achieving in-game goals or completing challenges. This inspired me that the games can be enjoyed in different ways, gamers can enjoy both the internal fun of the game

and the satisfaction brings by social interaction with other players. The conclusion of Vorderer, et al. [4] also states that, in general, there are two elements that are hypothesized to influence human enjoyment during gaming: the competitiveness of a computer game and the individual life satisfaction. If we take the conclusion from Voderer [4] and compare it to the finding of Casper and Geertje [9], we can see that social elements might be more determinative on players experience in multiplayer games, while in single player games, rules and game mechanism can be more crucial to the player enjoyment.

All these pieces of literature point to a conclusion: there are mainly 2 types of elements effecting the enjoyment of the game, the players' individual situation and the game mechanism. Alternatively, players' interest can be mainly driven by 2 types of elements, social elements and Game mechanism. In the flowing section, I will discuss both of these elements.

2.1 Social Elements (Multiplayer):

The social aspect of player enjoyable elements can be interconnected to lots of other research field, such as psychology, social science and economy. Since my graduation project is largely related to Artificial intelligence and computer science, and the social aspect of the human-enjoyable elements are hard to measure with the current technology, the outcome of social elements study will benefit the playtests at the end of the research as a reference to create a proper survey.

A lager number of the literatures is in the field of social science and psychology. As Mia, et al. [8] referred, the playful social behaviors during gaming are *"both enabled and mediated by factors such as the game's design, the gaming technology, pre-existing social relationships, and the superlusory goals of the session"*, game mechanism is only a part of the reason that players enjoyed a certain game, players' individual social situation also can have a big impact on the gaming experience. Although the social situation is not strictly relevant to my project, it can give me some insight later when it comes to the playtesting phase of the project. During the test, a survey on player's enjoyment is required for further statistical analysis. The questions on the survey are also essential when considering the data quality. To design a suitable and reliable survey, information on social and game mechanism aspect are equally important. In this section I will talk about the findings regarding the social aspect of human enjoyable elements, the game mechanism aspect will be discussed in the next section.

A quick way to investigate survey questions is through checklists. Mary and Helen [10] introduced a method called "the Value in Play approach" which is a supportive approach to let game designers investigate the human theme in games. In the method, they concluded a checklist of elements that creates value or experience during gaming, consists of 14 elements (Figure 1). These

elements presented as an extension on the existing game design theories and approaches, aiming for supporting the current design philosophies. To benefit our project, I will only consider some of the elements that are related to board games specifically. For example, justice, diversity, equality and potentially cooperation. These can be considered when designing the survey.

Diversity	Security/Safety
Justice	Creativity and Expression
Inclusion	Cooperation
Equality	Sharing
Privacy	Trust
Gender Equity	Authorship
Diversity	Liberty

Figure 1. Checklist of “Value in Play” (V.A.P) [10]

Apart from the checklist, a good in-game social interactions design can also lead to player enjoyment. For example, chatting system in MOBA (multiplayer-online-battle-arena) games or in-game market and trading system in MMO-RPG (massively multiplayer online role-playing game) games, these can be related to field of communication, economy and more. These designs often exist with the support of modern technology, board games do not rely on these kinds of social interaction, so for the purpose of my project, I will not get in deeper for that.

2.2 Game mechanism (Single-player):

In chapter 12 of the book “The art of game design”, Jesse Schell[11] concluded 7 game mechanism elements:

Space, Time, Objects, Actions, Rules, Skill and Chance

According to Schell, these elements can be commonly found in any game or puzzle. With the previous knowledge from the book, we found several pieces of literature that provide insight on game mechanism and its relationship with human enjoyments.

2.2.1 Flow theory in Game industry

To interpret and understand users’ experience on Hypermedia Computer-Mediated Environments (game is a type of HCME), Hoffman and Novak [5] used a model called the “Flow model” in their research. The “Flow Model” from Hoffman and Novak is an extended version of the original Flow Model

proposed by Csikszentmihalyi [17]. As Hoffman and Novak [5] presented, after many years of evolving, the “Flow model” contains 3 elements that were considered elements of enjoyment: “challenge”, “positive effect” and “exploratory behavior”. Moreover, Xiaowen and Fan [6] also referred the conclusion of Hoffman and Novak [5]. Based on their research, Xiaowen and Fan concluded that: nowadays there are eight elements that are widely considered to have an impact on human gaming enjoyment based on the evolution of Flow theory, Concentration, challenge, skill, control, clear goal, feedback, immersion and social interaction.[6] These are the factors widely considered as the human-enjoyable elements.

When comparing the gamic “Flow Model” to Schell’s 7 game mechanism elements [13], we can see that the elements in “Flow model” are the results of the combinations of game mechanism. For example: A clear goal is related to game mechanisms like Space and Objects, Challenge can be interpreted as the effect of Rules, Skill and Chances together. Schell [11] also points out in chapter 5 of the book that games are mainly consist of 4 elements, Mechanism, Technology, Story and Aesthetics. The “Flow model” can be interpreted as a layer made of Technology, Story and Aesthetics, laying on top of Mechanism. This layer is making the transition between Human input and computer output, which is the human-game interaction. The consistency of Schell’s Game elements and Flow theory convinced me that 8 elements of Flow theory can be a good support for my GP’s playtest survey design.

Although Flow theory is largely used during the design phase of the game, it is challenging to evaluate a Game based on the Flow theory. Chung-Hsiang, et al. [14] have proved the possibility of using Flow Model as a tool to investigate games regarding human enjoyment and engagement. In their project, they designed a game for education purpose and used The Flow Theory to evaluate and test the game. As they referenced in the article [14], there is a design pattern (Figure 3) regarding the game Flow theory consists of twentyish questions that can be statistically tested. Another literature by Loïc [15] which compared various previous methods of player-enjoyment measurements also suggest developing specific questionnaires (based on flow theory) to measure the human enjoyment in a game rather than to use the classical mathematical tools. In conclusion, in order to test whether the outcome of the algorithm is valid and useful in game design process, we need to perform a survey with human participants and measure their enjoyment.

2.2.2 Evolutionary game design & measurable metrics

The internal game mechanisms which control the game quality is another crucial criterion for human enjoyment. When we purely consider the game itself without any human factors, most games can be considered as a series of decisions that needs to be chosen by the player(s), just as Yixing [16] defined games in his research: *"A game is a decision process under competition where opponent players or opponent groups of players compete for the maximum gain or toward a success state in the same environment according to the same predetermined rules and constraints of the game."* In this statement we can see that the highlighted elements of a game are Decision, competition, opponent, success(goal) and rules. Later Yixing [16] also introduced a mathematical model to describe general abstract games. In the model, 4 tuples are considered measurable and valid to describe certain game: number of Players, number of Decisions, number of matches and Scores. By counting and comparing the 4 tuples, Yixing [16] presents a way to describe and interpret abstract games using mathematical model. The aim of this model is to describe and predict player behavior in an abstract game. This is one of the measurement methods we can consider when building the GameEvolver. The limit of this model is that it does not necessarily tell whether the game is enjoyable to not, but it gives an evaluation on the validity of the game. Meaning that, to make GameEvolver capable of recognizing whether the game can be enjoyed by human, we need a more detailed measurement method for human enjoyment elements.

In the previous literatures [14][15], Flow theory has been discussed and proven as a tool to statistically measure the human enjoyment. However, algorithms nowadays are not capable to examine or measure the human emotion. For example, it would require a lot of sensors to measure whether a player is immersed in a game, and would be out of the scope of this research. To find a way towards measurable metrics that can be studied by computers, Brown and Marie [2] stated that instead of trying to measure the elements in Flow theory, we can look at the elements that build up the quality of the game. A good quality game will naturally trigger the interest of players. Brown and Maire [2] concluded the critical elements of a good quality game into four key elements: Completion, Duration, Drama, and Uncertainty. According to Brown and Maire in [2], there are in total 57 aesthetical elements taken into account, and these 57 elements can be categorized into 3 sub-groups: intrinsic criteria: based on the rules and game mechanisms, viability criteria: based on the game outcomes (e.g. the probability of a draw game), and quality criteria: based on the trends in the game (e.g. the dramatic level of the game). All these 57elements support their research on human enjoyment and ultimately leads to computer program that can automatically generate random games. The four elements

from Brown and Maire are also inter-connected to the Schell's game mechanism elements [11], meaning that these can be the common measurable elements that can alter the player's enjoyment level. Now we have discovered the measurable metrics of human enjoyable elements, are there any applications of the elements?

Fortunately, Brown and Marie have also provided a possible application for the Four metrics they found. They ultimately came up with an AI concept, the "Evolutionary Game Design" theory [2], aiming at automatically generate new games based on existing games. To test the concept of "Evolutionary Game Design", Brown and Marie, et al. [2] built a program called the Ludii system which can randomly generate new board games based on existing board games, using the 4 elements as criteria. The step-to-step procedure of the theory is shown below.

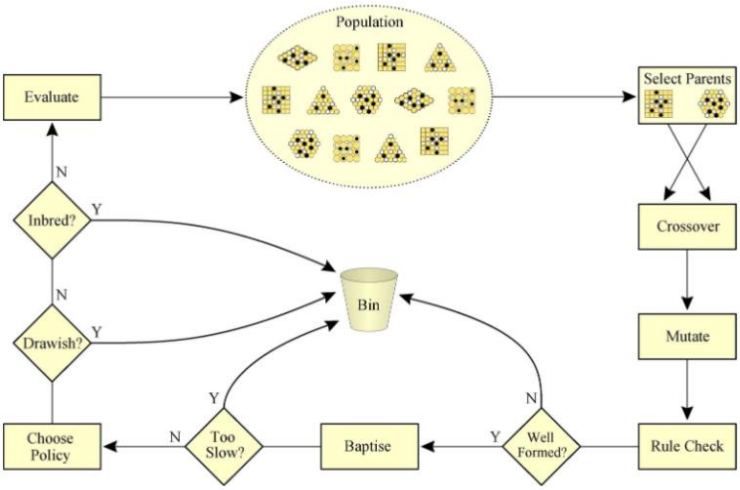


Figure 2. evolutionary game design process [2]

We can clearly see that the whole process is a cycle. The algorithm can run hours up to days and finally ends up with game(s) that are considerably (by AI) better than the parent games. For more details of the system, please visit the website of Ludii system [1] and "Evolutionary Game Design" [2]. This detailed and thorough AI concept together with the abstract game mathematical model will be a great support to the GameEvolver. A preliminary concept of the GameEvolver have already been drawn as the methodology of my GP based on these concepts.

2.3 Discussion

From the knowledge gained during studying previous works, we can conclude that there are mainly two categories of elements that are considered enjoyable by humans in a game, social elements and game mechanisms. Since the main

challenge of my GP is to develop the AI algorithm (GameEvolver), the elements of game mechanism will be more important than social elements, findings on social elements will contribute more in the playtesting phase.

The research from X. Fang and F. Zhao [6] presents a list of elements that have an impact on the human enjoyment of games. The list was a mixture of social elements and game mechanisms, and some of them are hard to measure in numerical methods. This means that a computer will not be able to process the information with these criteria. However, we can use it as a checklist for the testing of the algorithm. We can run a survey based on this list to investigate whether an actual human likes the games generated by a computer. The survey can also take into account the 14 elements (Figure 1) from Mary, et al. 10] and the GameFlow Design pattern (Figure 3) from Chung-Hsiang, et al [14]. These findings can help us evaluate human and social factors during the playtest.

From the research of Browne, et al. [2], we discovered the method to arithmetically measure human enjoyment during gaming. This is a great finding that is able to support the construction of the GameEvolver. With the methods Browne, et al. provide, computers will attempt to predict whether a game can be enjoyed by humans. The evolutionary game design artificial intelligent theory explained by Brown and Marie [2] will be one of the foundations for my graduation project, together with the abstract game mathematical model design by Yixing, et al. [16]. The two previous studies combined provides an insight to look at board games in a mathematically measurable aspect, thus allowed me to code it in computers. They are both great findings that can support my GP. Lastly, the lists discussed above can be found in Appendix 1

2.4 Conclusion

Throughout the literature review, we found lots of similar human-enjoyable elements. Studies reveal that they are interconnected in many ways. By comparing the criteria from different researchers, we conducted 3 lists of elements that can lead to human enjoyments. List A will be used in the designing phase in the Graduation project, where B and C will contribute to the testing criteria in the Playtesting phase. Some elements in List B and C are considerably not relevant to board games. During the design phase of the survey, the elements will be reviewed and evaluate based on whether there is existing valid statistical test method for it. The Elements that can be tested and measured using a survey will be optimal for the Playtest.

Chapter 3. Methodology

The methodology for my graduation project mainly focused on the algorithm and the Playtests. Before we go into the detailed design choices of the algorithm, it is important to first introduce the Ludii system [1]. In the literature review, we have discussed the Ludii system [1], it is a Java program that functions as a board game launcher allowing users to play various board games with Ai or other online users. The Ludii system stores all the different games in the .lud files (Figure 3), written in a language called Ludii language [1]. The .lud files work the same as a .txt file that can be processed by a lot of modern programming languages. The system is also capable of estimating human gaming enjoyment in a certain dimension by running simulations with specific Ai agents. For example, estimate the duration of a certain game, the win rate in each step for each player, the complexity of the decisions etc. This provides a platform to automatically "playtest" the game with simple board game Ai.

```
(game "Connect6"
    (players 2)
    (equipment
        {
        (board (square 19) use:Vertex)
        (piece "Marker" Each)
        }
    )
    (rules

        phases:{
        (phase "Opening"
            (play (move Add (to (sites Empty))))
            (nextPhase "Playing")
        )
        (phase "Playing"
            (play
                (move
                    Add
                    (to (sites Empty))
                    (then
                        (if
                            (is Even (count Moves))
                            (moveAgain)
                        )
                    )
                )
            )
            (nextPhase "Playing")
        )
        }

        (end (if (is Line 6 All) (result Mover Win)))
    )
)

//-------------------------------------------------------------------------
```

Figure 3. Ludeme description of Connect6.Lud [1]

The function of automatically simulating playtests is extremely handy for game designers. During the game design process, designers are constantly playtesting the prototypes at any stage of the design, these playtests often take lots of time and effort to conduct. Although the Ludii system can only estimate the behavior of human players, it is the only possibility we found to run the playtest automatically, making it the best candidate to support the GameEvolver. Once the algorithm has successfully generated a game, proper statistical tests need to be conducted on the result to evaluate the difference between the altered game and the original game. This chapter will be divided into 2 sections, algorithm theory, and statistical tests.

3.1 Ludii system and Evolutionary game design:

In the article "Evolutionary Game design" [2], Browne, et al. conduct research on their approach of auto-generation of board games. The model in Figure 2 shows the decision-making process of the evolutionary game design. It is clear that evolutionary game design takes loops when generating games. Inside each loop, numbers of pairs of games will be selected from a population of games as the parent games. By mutating the rules and game mechanisms of the parent

games, new games can be randomly generated. The evaluation function of the Ludii system [1] can specify whether any of these new games are executable, it can also provide estimated playtest data (e.g., estimated duration, depth of the decision tree and etc.) of the games for the program to determine the “quality” [2] of the games. Then at the end of each loop, games that are executable and considered “high quality” will be injected back to the population to start the next loop.

The design of GameEvolver is inspired by the evolutionary game design, instead of taking parents from a large population, one game will be selected as the original game, this will be the base game that gets evolved by the algorithm. To improve the game, other games that are considered “enjoyable” will be selected to create a dictionary of rules, then the original game will randomly mutate with the rules in the dictionary and create new games. By mutation, the GameEvolver will randomly assign or replace the parts of the original Ludeme description with the corresponding descriptions of other games from the dictionary of rules. These newly generated games will be pass back to the Ludii system to evaluate the validity and analyze the enjoyment using the four elements [2] we discussed in literature review. The game that is considered top 1 playable and enjoyable according to Ludii evaluation will be pass back to the GameEvolver to replace the original game. Until here, the GameEvolver has finished one iteration, and it will start another one right after, with the original game being the game generated in the previous iteration. After many loops, the game generated from the last iteration will be the output game, or the altered game. With the original game and altered game, a playtest needs to be run to test the difference in human enjoyment. The concept of GameEvolver is presented in Figure 4.

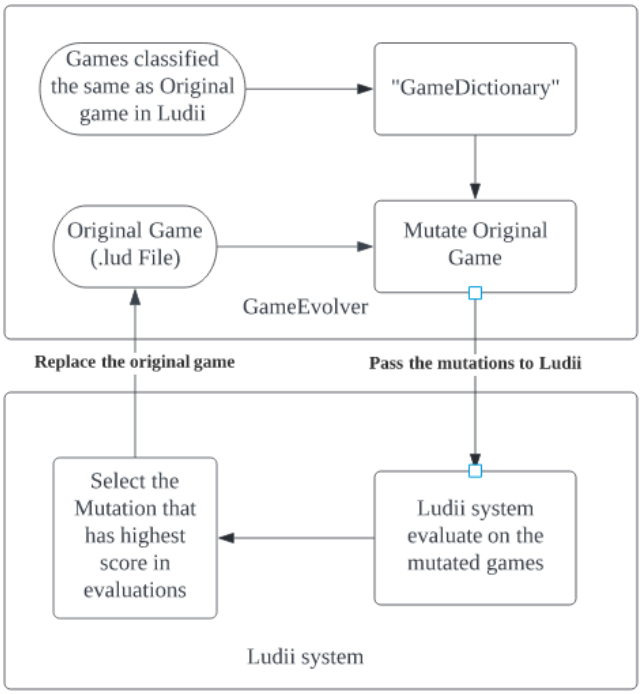


Figure 4. Structure of the GameEvolver

3.2 Playtesting and statistic:

With the playtest criteria we obtained from previous works [12], a between-group test with randomly sampled university students can be held, one group will be asked to play the original game, and the others will be asked to play the game generated by the algorithm based on the original game. After playing the game, the participants will be asked to fill up a survey. The question on the first section of the survey were phrased based on the 8 playtest criteria, and they will be close-ended questions with scaling from 1 to 5. In the second section, some open-ended question regarding specific aspect of the games will be asked to allow the players to elaborate their choices. The detailed design choices of the survey are discussed in chapter 5.

Chapter 4. Ideation

As discussed in chapter 3, there are mainly 2 things we need to prepare for the GameEvolver: the original game and the game dictionary. Where the game dictionary works the same as the “population” in “Evolutionary game design” theory (Figure 2). Besides that, a proper way to connect GameEvolver and Ludii system is needed to complete the iteration. The design choses will be presented in the following sections:

4.1 Original Game:

Following the method described in the previous section, a Python program has been made. The program is capable of extracting data from an existing game (.lud files) and creates a database of the rule sets and game equipment (board, pieces, and etc.). The original game we discussed in the methodology was chosen to be the “Connect 6” game. The original game should fulfill 3 requirements: Not famous, easy-to-follow rules and clear board design. The game needs to be not famous because a famous game can influence the result of the playtest regarding study effects. Participants might have heard or played the original game before if we select a famous game. The rules need to be easy-to-followed since that way players can focus on the experience not memorizing the rules. In the meantime, the clear design of the board also makes it easier to mutate the game. The Connect 6 matches with these requirements and makes it suitable to be the original game. The interface of the game is shown below, the rules provided by the Ludii system [1] is as follows:

“Played on a Go-like board (6x6 or larger, but a 19x19 go board is ideal) with two colors of stones (usually white and black). Black goes first by placing one stone. Play continues with each player playing two stones per turn. The first player to make a line of six in a row wins.” [1]

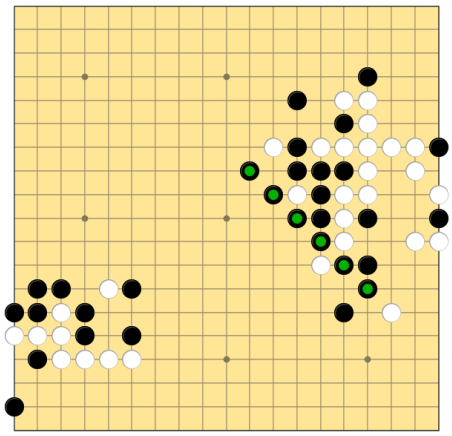


Figure 5. A winning position for Black in the game of Connect 6 from Ludii system [1]

4.2 Game dictionary(population):

In order to mutate the original game, some other games need to be considered to produce a dictionary of rules and game equipment. Then with this dictionary, the Python program can randomly append or replace the rules and equipment to create different mutations (.lud files) of the original game. The amount and quality of the games that builds the dictionary is very important. They decide the quality of the rules sets where the original game can pick from. The games need to be similar to the original game (Connect 6) in the sense of board design, that gives the program more chance to create an executable mutation. To illustrate, imagine adding a card game rule to Go, there is a higher chance that the game mechanism does not match with the rules. Fortunately, Ludii system [1] has a very specific classification for different type of games, where Connect 6 belongs to the category “board – space - line” in Ludii [1], other games like Go, Connect4 are well known and popular in this category to support the construction of the Game dictionary.

How many games do we need to create this dictionary? From our tests on the validity of the mutations, 20 to 40 games will often result in 2-3 playable mutations. The total playable games that are categorized as “board – space – line” in Ludii system [1] is around 120 games with different complexity in terms of board design, to control the quality of the game, we have run the analysis on all the games regarding the time length [2] and decision complexity [2] to roughly rank all the games, then we picked the 60 games that lays in the middle of the rank to be the parent games of the dictionary. The list of the games selected is presented in the Appendix 2. A larger number of games for the dictionary can increase the possibility of generating valid games, but this approach can be argued as biased since these games are still selected by human.

Another approach is to randomly select 40 games from all the games that are categorized as “board-space-line” games in each iteration. This approach reduced the bias in selecting the games but increases the probability of failing in generating new games. Since it is randomly selecting the games in each loop, more iterations might increase the possibility of success.

In the end, we decided to merge the 2 approaches, 60 games will be selected and the GameEvolver will randomly select 20 out of the 60 games to conduct the game dictionary. This gives us the control of the quality of the game dictionary or the population, while also ensuring a higher degree of randomness in the mutation.

4.3 GameEvolver to Ludii

Once the mutations have been created, they will be passed to the Ludii system [1]. The system will try to execute the .lud file to check the validity of the mutation. The ones that are not executable will be deleted; the rest will be scored by the Ludii analysis system. After scoring, the game-score pair will be passed back to the Python program, the top 1 scored game will replacing the original game and the program will start the mutation again. In this way, we ensure that the population remains of sufficiently high quality with respect to the metrics of interest. For the purpose of this project, we used Ludii system version 1.3.2.

Chapter 5. Realization

5.1 prototype:

The Python program is consisting of 4 classes and can be found on the following GitHub link: https://github.com/YilunChen12/GP_algorithm

5.1.1 Ludii_Accessor:

This is the main class that calls the function in other classes, it defines the path to the original game, games for dictionary and the place to store the output.

5.1.2 Ludii_reader:

This class reads the ludi file and extracts useful data from it. Data being: definition of the game, game type, game equipment, game rules and players. An example can be found in Figure 3 The function read_lud returns a dictionary of game mechanisms (from the Ludii files) of all 40 games passed in as the “games for dictionary”

5.1.3 randomizer:

This class randomly mutates the original game by appending or replacing the rules and equipment of the game, using the game dictionary created by Ludii_reader. Then it writes them into .lud files for the Ludii system to evaluate.

5.1.4 Receiver:

This class receives the information from the Ludii system and replace the original game with the top scored game passed in by Ludii. If there is no game executable, run the randomizer again and save the new games as Ludii files.

5.2 The connection with Ludii system:

Unfortunately, due to the lack of function from the Ludii side, it is not possible to run the evaluation automatically. The command line function of the Ludii system only allows users to evaluate preloaded board games that are built-in to the system, there is no way to call a newly generated game from the command line or the shell script, other than re-building the entire Ludii system program after each iteration. This is beyond the intended scope of this research, so instead, we tested 5 generations of games manually and the final result will be shown in Chapter 6.

5.3 Survey design:

To test the enjoyment level of players in games, selected literature [6, 10, 14, 15] suggests using the Game Flow theory as the criteria. Since we are considering board games, some aspects of the Flow theory do not apply, e.g., Immersion and Social interaction. During the Survey design, aspects of Flow theory that are considered not applicable for board games will be withdrawn.

Sweetser and Wyeth [18] have conducted a survey based on the Flow theory to find out whether the Flow theory criteria is able to distinguish the popularity difference between “World of Warcraft 3” (WoW 3) and “Lords of EverQuest” (LoE). The result turns out to be positive, meaning that the flow theory can help to identify the player's preference for different games. The survey investigated 2 games with the same number of questions and by comparing the average scores regarding each Flow theory criteria, Sweetser and Wyeth [18] confirmed that WoW 3 is considered more enjoyable than LoE. The same approach can be applied to the altered game generated by GameEvolver. Albeit we have entirely different types of games, some (close-ended) questions have been re-constructed to match the board game theme. The survey can be found in Appendix 3, by applying statistical tests to the scores, we can give the conclusion on which game is considered more enjoyable.

Apart from the closed questions, there will be some open questions asked at the end of the survey for detailed explanations on 3 specific aspects of Flow theory, competitive level, the skill required, and a clear goal. Additionally, a ranking of the 8 elements of Flow theory will be asked to weigh the scores obtained in the previous section. The survey can be found in Appendix 2 The test will result in a table shown below:

Different games → human-enjoyable ↓ elements	Original Game	Altered Game
Concentration	Score from the survey result	…
Challenge	…	…
Skill	…	
Control		
Clear Goal		
Feedback		
Immersion		
Social interaction		

Table 1. expected answer form of the survey

5.4 Playtest:

The Playtest will focus on human players' reflections on Connect 6 and the altered game, using the survey in appendix 2. The participants of the playtests will be randomly recruited through online platforms such as Discord, consisting of university students People who signed in on the online form will receive an information sheet describing the goal and method of the research, together with an informed consent form attached in Appendix 4.

Chapter 6. Result

6.1 Resulted game: The “YavaCon”

The GameEvolver successfully generated a game after 5 iterations, it is a combination of the original game and the game “Yavalath”. The detailed iteration process can be found in Appendix 4. The interface and Ludeme description generated are shown below:

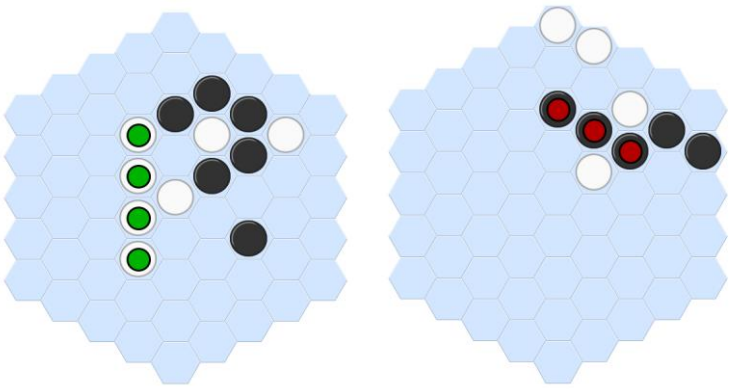


Figure 6. Winning condition (left) and losing condition (right) of the altered game [1]

```
(game "Connect6"
    (players 2)
    (equipment {
        (board (rotate 90 (hex 5)))
        (piece "Marker" Each)
        }
    )
    (rules
        <Version:playRules>
        phases:{
        (phase "Opening"
            (play (move Add (to (sites Empty))))
            (nextPhase "Playing")
        )
        (phase "Playing"
            (play
                (move
                    Add
                    (to (sites Empty))
                    (then
                        (if
                            (is Even (count Moves))
                            (moveAgain)
                        )
                    )
                )
            )
            (nextPhase "Playing")
        )
        }

        (end {
            (if (is Line 4) (result Mover Win))
            (if (is Line 3) (result Mover Loss))
        })
    )
)
```

Figure 7. Ludeme description of the altered game [1]

The rule is the combination of “Connect6” and “Yavalath”, where at the beginning player 1 who goes first can place one piece at any position on the board, then player 2 who goes next can decide whether he or she wants to place one or two pieces. If player 2 chooses to place 2 pieces, player 1 can also place 2 pieces in

the next round, the same goes with 1 piece. If one player controlled a line of 3, he or she loses the game; If one player controlled a line of 4, he or she wins the game. The game also supports multi-players by adjusting the size of the board, which is one of the characteristics of Yavalath. Figure 8 shows a completed YavaCon Game for 3 people, where Black is first to complete, White wins the second, and Red losses.

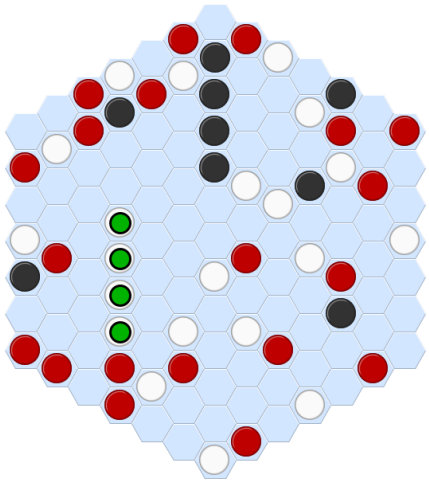


Figure 8. Multi-player (3 players) version of the Altered game

It is shown in Figure 8 that the number of decisions, estimated game time, and estimated rounds of the altered game has significantly decreased. Meaning that it is considered less time-consuming, less skilled and memorization required, making the Altered game theoretically “easier” than the original Connect 6. Notice that these data are collected from the trials run by Ludii-AI [1] which is a basic Ai that is able to play all kinds of different board games at a relatively low competitive level, the result of the AI trials can be significantly different with more advanced and specific AI.

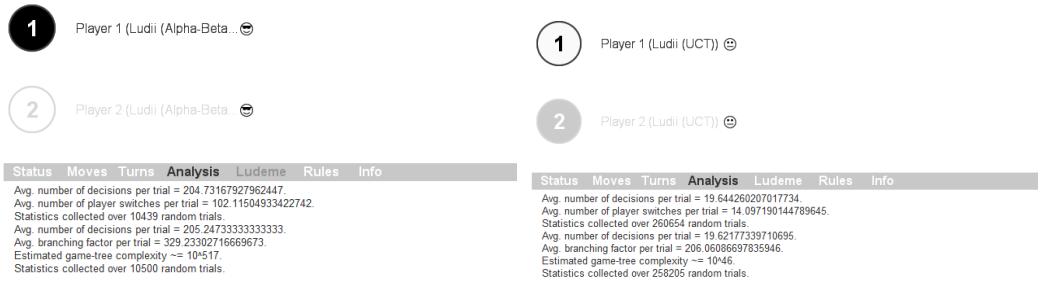


Figure 9. Ludii evaluation on Game Length and Tree Complexity of Connect 6 (left) and Altered game (right)

6.1.1 Board design

Because the board design has been changed from square-board into hex-board, the valid position for play has been shrunk from 361 to 61, causing a decrease in the number of decisions. In the meantime, the hex board only allows players to form a “Line” in 3 directions, whereas on the square board players can form a “Line” in 4 directions.

The shrink of board size is possibly one of the reasons that the number of decisions went down, the smaller size of the board means fewer valid positions to play with. To illustrate the importance of board size, imagine playing different games with different sizes of board: Tic-tac-toe can be enjoyed by kids because they were trying to find out the “optimal way” to play the game, once they know the strategy, the game gets boring; Connect 4 introduced a bigger board and novel way to place pieces, making it more interesting and skill required; Lastly the Go game, with its clear rules and big board, it becomes one of the most famous and skillful board games. However, Go might be successful in creating competitive matchups, Connect 4 and Tic-tac-toe are more widely known and enjoyed by casual players. In our case, Connect 6 is (theoretically) more time-consuming and requires more decision-making skills compare to the altered game. The complexity of rules can be an advantage or drawback, the playtest result can help to interpret the effect of board size.

6.1.2 Rule design

The rule of the altered game is a mutation of Yavalath and Connect 6. The altered game takes the player's movement from Connect 6 and ending condition from the Yavalath. There is always a problem in board games that the player who goes first will have some kind of advantage against the other players. In the same example, tic-tac-toe, the player goes first and never loses the game if the player plays optimally; in Connect 4, the player who takes the middle column has a higher chance to win. In the YavaCon, player 1(who goes first) will always have one more piece on the board than the other players, but the second player can choose to limit the number of playable pieces (1 or 2), giving the players a sense of balance that player 1’s movement can be limited by player 2. This rule is originally coming from Connect 6 Of course, there is still a “go first advantage” in the altered game, but a player who goes second can decide whether he wants to back up the defense by blocking with 2 pieces, being aggressive by taking two places on the other side of the board or play slow with one piece to probe the opponent and wait for the right moment. Where in connect 6, the player can only play 2 pieces per turn with a constant leading of 1 piece from player 1.

For some reason, when running the game with two AI players in Ludii [1], the AI players will always choose to play 1 piece instead of 2. There might be some issues for Ludii AI [1] to study the syntax of the newly generated game or there

can be some strategies-related problem that prevents the Ai players to place two pieces. We will discuss this in the following chapter.

In general, the altered game is considered to consume fewer turns and less decision-making required, but the board is constantly changing due to the ability to change the number of playable pieces. The time consumption of the Altered game is also considered less due to fewer turns required.

Chapter 7. Playtest Result & Evaluation

7.1 YavaCon vs Connect 6：

After visiting 20 participants and asking them to play both the original game and the altered game, we investigated their preferences for the two games.

The survey was structured based on the 8 elements of Game Flow theory [12]. Since we were testing board games, immersion and social interaction do not apply to the game type, so in the end, there are in total 6 sections in the survey and each of them contains 2 questions. The surveys with answers can be found in the following google Excel file:
https://docs.google.com/spreadsheets/d/1uXk_AxIK-CXZAb8QIXK9Zjo5363DD4ISdWidalJcg9o/edit?usp=sharing
Some interesting findings for each tested element will be shown below.

7.1.1 Concentration:

From the answer to the first question (appendix 3), we can see that a higher percentage of participants are more interested in the YavaCon when they first saw the new game without knowing the rules. However, they found out that Connect 6 is requiring them to remember more information throughout the game, thus causing them to be more concentrated during the game.

Original survey question: *"Dose the game "Connect 6" ("YavaCon") grabs your attention without knowing the detail rules?*

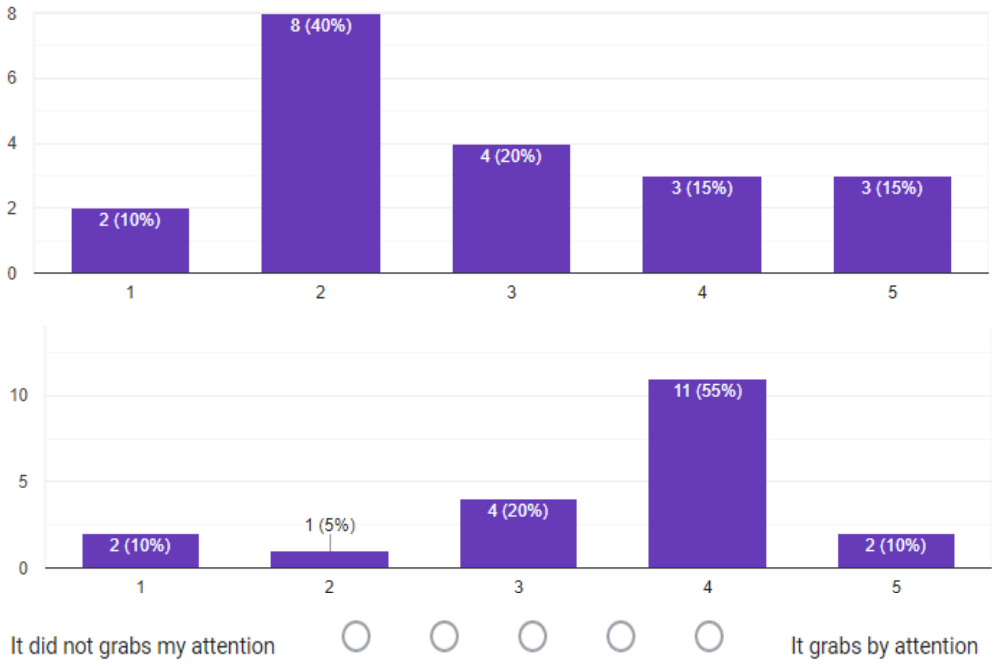


Figure 10. participants reflections on the attractive level of Connect 6 (up) and YavaCon (Down)

7.1.2 Challenge:

It is very obvious that the difficulty of the Connect 6 is higher than YavaCon, the result also matches with the evaluation from the Ludii system that Connect 6 has a higher score in terms of decision tree complexity and estimated turn numbers. Moreover, the result shows that the increment of the difficulty of the Connect 6 is considered larger than YavaCon. It is also shown in the open questions that the majority of the participants prefer to Connect 6 regarding the challenge level.

Original survey question: *"What do you think about the difficulty of "Connect 6" ("YavaCon")?"*

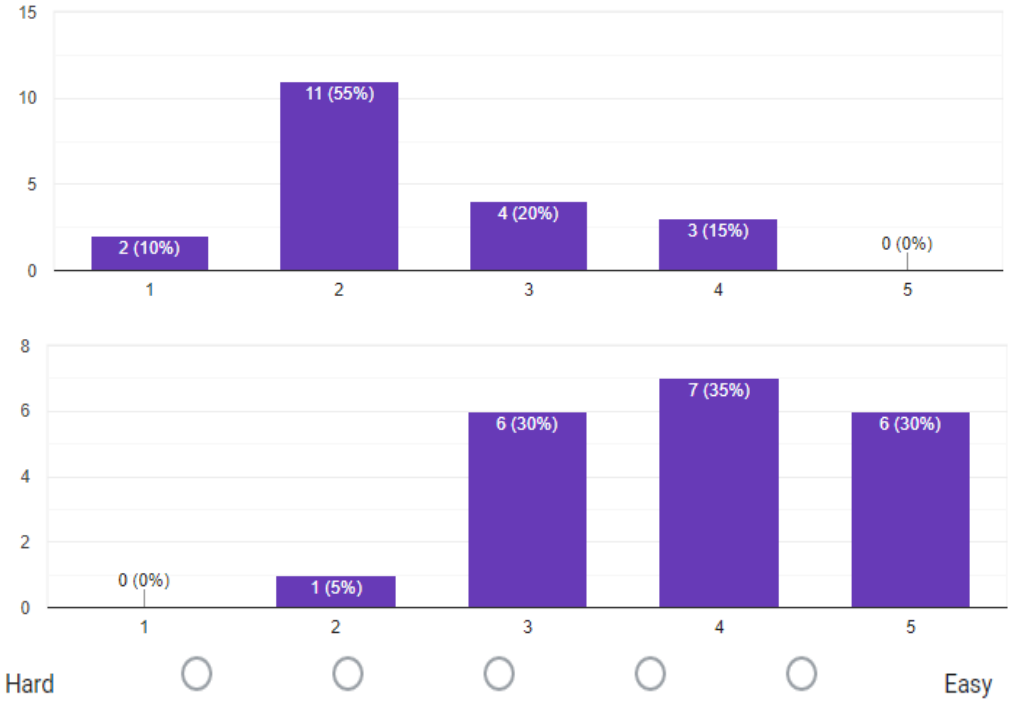


Figure 11. Participants reflections on the challenge level of Connect 6 (up) and YavaCon (Down)

7.1.3 Player Skill:

Similarly, the player level required for the game Connect 6 is also considered higher than YavaCon, this is partly the result of the "dominated strategy" which will be talked about in the later sections. Only players who did not aware of the dominant strategy gives a positive rating on the player skill of YavaCon.

Original survey question:
"Do you feel the increasement or decreasement regarding gaming strategy required when playing "Connect 6" ("YavaCon")?"

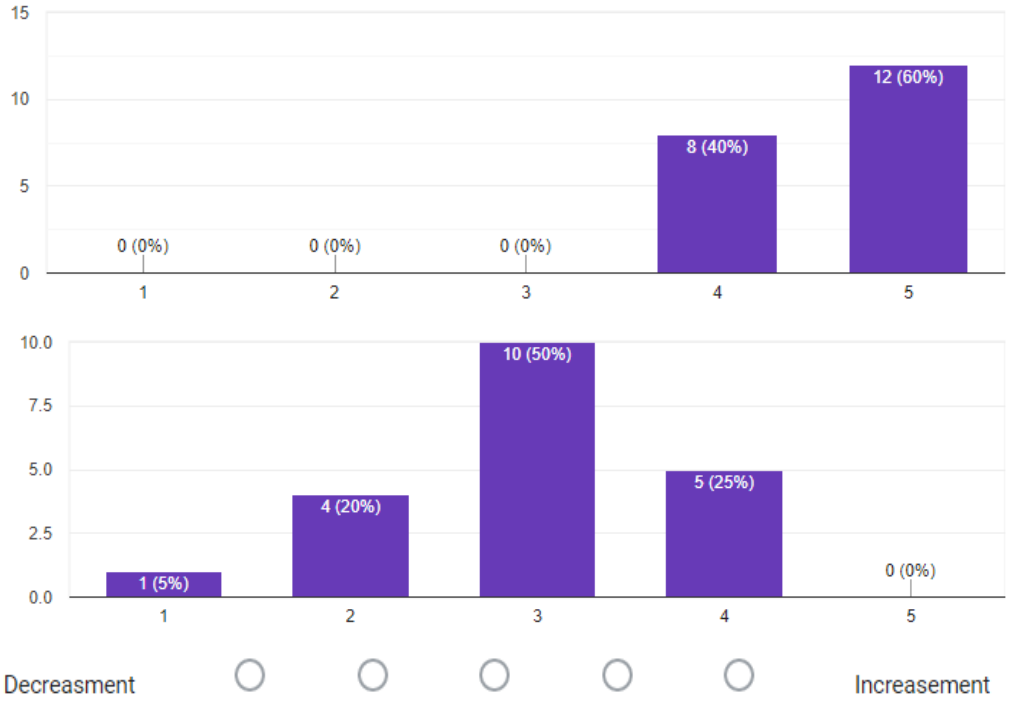


Figure 12. Participants reflections on changing of skill required throughout Connect 6 (up) and YavaCon (Down)

The result of the open questions is showing that the majority of the participants are more enjoying connect 6 than YavaCon (over 60 percent). On the last question, “Which game do you prefer, connect 6 or YavaCon?”, over 70 percent of the players have reflected that they are more interested in Connect 6 compare to Yavacon, most of the players who don’t enjoy YavaCon stated that the strategy required for YavaCon is less interesting than Connect 6. Some participants brought out that there are dominant strategy in YavaCon, where if a player forms a rhombus on the board, he or she can win the game next turn and the opponent cannot alter the situation. The example is shown below:

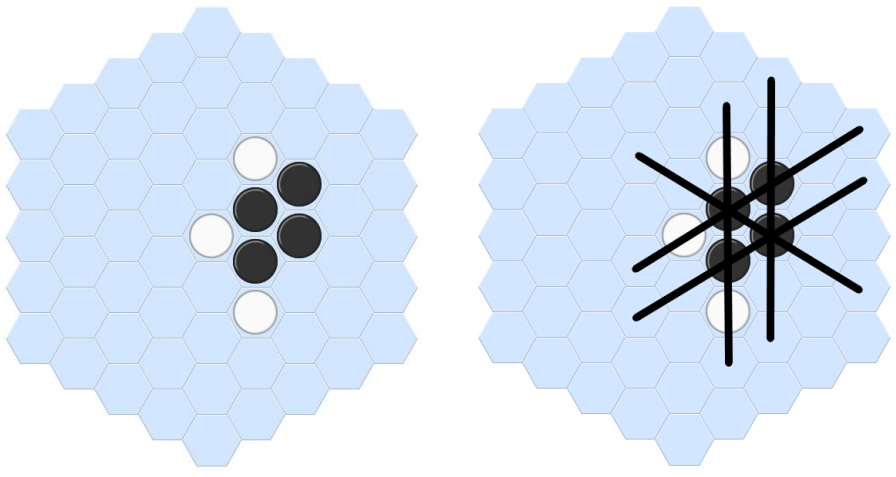


Figure 13. The possble movements for black player in turn 3 of YavaCon

This is the third turn of the game where the second player (black) has a rhombus shape on the board. Under this shape (figure 13 left) no matter which way the white player blocks, there will always be two directions (figure 13 right) left for the black piece to form a line of 4. This dominated strategy only exists with the rule “The one connects 4 in a line wins”, when we change the rule to the rule of “Gomuku”, which is “The one connects 5 in a line wins”, the game became more robust and playful.

Apparently, the Ludii basic Ai did not find this dominant strategy during the evaluation, instead, the Ai players are always only placing one piece per turn. To find out what cause this behavior, I broke down the decisions made by Ai using a built-in function of the Ludii system and compared the Ludeme description of the altered game, original game, and Yavalath. Finally, we spotted a possible reason: The syntax of the altered game and the other two were structured differently, caused by the random mutation of the GameEvolver. This difference in structure makes “Placing 2 per turn” an optional move (Figure 13) in YavaCon instead of mandatory in Connect 6. But because of this different structure of YavaCon, players are allowed to place one piece per turn as well, by selecting the left-right piece. If the player wants to place 2 pieces, he or she needs to select the left piece than the right piece. It seems that the Ai has an error of placing two pieces.

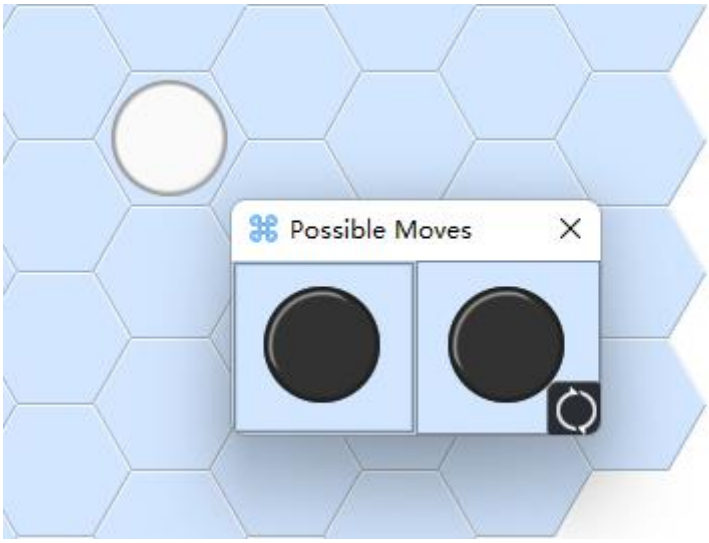


Figure 14. Option of placing one or two pieces displayed in Ludii system

In conclusion, the GameEvolver has generated a playable game after 5 iterations, but there are obvious bugs in the rules that ultimately lead to the dominant strategy. This dominated strategy is the key component that affected the enjoyment level of YavaCon. In the end, the result shows that more than half (13 out of 20) of the participants prefer to play connect 6 rather than YavaCon.

Chapter 8. Discussion & Conclusions

Throughout the research, we have discovered the enjoyment elements of flow theory [12] and the automatic board game generator and evaluator of the Ludii system [1]. With the support of the Ludii system and Evolutionary Game design, the GameEvolver was designed. The GameEvolver takes the idea of “Evolutionary Game design” and successfully applied it to a smaller scale, by generating a playable board game based on the existing board game in 5 iterations. Although the resulted game, YavaCon was considered less enjoyable by the majority of the players, some participants found the rule and the board more novel than the original “Connect Games”. The survey question of the attractive level also proves that participants are more willing to try out YavaCon instead of Connect 6 if they did not know the rules. However, when the participants, later on, found out that there is a dominant strategy in the YavaCon, the game become boring to them. It turns out that players are more enjoying the Connect 6 game.

After the experiments have been done, the YavaCon has been proven to be “not enjoyable”, partly due to the dominant strategy. To get rid of this, I have tried to change the rule of “Connect 4 wins” to “Connect 5 wins” and the game seems to be more balanced based on the result of the Ludii Evaluation system. The result of the playtest on the YavaCon 35 also proves that, although the sample size of the second playtests is smaller than the first one, we can see that the average turn number of the altered game has significantly increased, and this is done only by changing one number of the Ludeme description of YavaCon.

In a conclusion, the GameEvolver failed to generate an enjoyable board game within 5 iterations, but the resulting game is playable and attractive. Despite that it has dominated strategy, the novelty of the rule and the possibility of creating mutations automatically is more important for board game designers.

Since the GameEvolver was not able to run fully automatically yet (the bridge between Python and Java is out of the scope of the Graduation project), we are not able to take more iterations. With more generations of mutation, it is more possible to generate a game that has a higher score during evaluations. In other words, more iterations mean a higher chance of generating human enjoyable games, 5 iterations are too few. I believe that with an AI that is more developed in evaluating the Flow theory factors and with a more efficient way of connecting the two programs, GameEvolver will have a higher chance of generating human enjoyable board games.

8.1 Limitations:

The fact that my Graduation project is focusing on board games limits the broadness of my literature review findings, further studies can be done on the field of Player-game interaction, and different design elements between single-

player and multi-player games. Studies on multiplayer games required knowledge of psychology and communication science, but if there is a model that can mathematically describe human feeling during games, I can imagine the possibility of building an artificial intelligence program that can give useful suggestions in social perspective during game design processes.

The Ludii system [1] is constantly updating until the time I finished this report, The version we referred to in this report is Ludii 1.3.2. There are several new games added to the system on the newest updates, and the Ludeme project group seems to be also updating the Ludeme language syntax as well. Due to the updates, several decoding problems occurred. To keep the consistency of the program, we decided to run with only version 1.3.2

8.2 Recommendations:

For future research on automatic board game generation, I would recommend working on a systematic measuring model certain for game flow elements, such as difficulty, then implementing this model during the mutation evaluation and selection phase of the board game generator. To build this model, we need to discover the mathematical relationship between the flow theory elements and the measured data of the Ai playtests. I can imagine the massive number of experiments required to build the model, but the model can potentially increase our understanding of the relationship between game mechanics and Ai playtest results, thus increasing the efficiency and validity of the result of random board game generators.

Acknowledgement

The author would like to thank M. Gerhold and F. Ahmed. (University of Twente, Enschede, The Netherland) for useful guidance throughout the project, C. Browne, et al (Maastricht University, Maastricht, The Netherland) for developing and maintaining the Ludii system [1], the project would not be possible without the support of Ludii system, and lastly thank you for reading the thesis.

Appendix 1. Lists extracted from literature

A. List of elements that can be evaluate using Ludii (Evolutionary Game Design [2]):
   1. Completion
      - Games should produce more victories than draws.
   2. Duration
      - Games should neither be too short nor too long.
   3. Drama
      - Players should have at least a hope of recovering from bad positions if they are to maintain a vested interest in a game.
   4. Uncertainty
      - The outcome of each game should remain as uncertain for as long as possible if all players are to maintain a vested interest in it.

B. List of elements that can be checked by the survey (Game Flow Theory [12] & “Flow theory” [6]):
   1. Concentration
      - player doesn’t have to concentrate on what he’s doing to achieve an action. This is the state for the player is the merging of action and awareness.
   2. Challenge
      - The challenge of the activity is neither too easy or too difficult.
   3. Skill
      - The challenge is constantly adapted to the player’s skill.
   4. Control
      - The player feels that he can successfully beat the challenge. The objective for him seems reachable.
   5. Clear goal:
      - The players have clear goals and know what to achieves. There’s is no question about it and this element is important to be clear for the entire player progression through the game.
   6. Feedback
      - The player is guided by the feedback of the game and know what and how much to succeed.
   7. Immersion
      - The player is loss of consciousness and time during the game.
   8. Social interaction
      - Player should feel positive in the social perspective.

C. Checklist of “Value of Play” by Helen and Mary [10]
   1. Diversity

2. Justice
3. Inclusion
4. Equality
5. Privacy
6. Gender Equity
7. Security.safty
8. Creativity and expression
9. Cooperation
10. Sharing
11. Trust
12. Afuthorship
13. Liberty

Item	Question
C1	Game graphics attract my attention and enhance my willingness to play.
C2	I can generally stay focused on the game.
C3	This game is not too difficult for me.
C4	I respond intuitively during the course of the game.
C5	I think the degree of difficulty of the game is appropriate.
C6	As my skills develop, the game will become increasingly difficult to challenge me.
C7	I think this game is challenging.
C8	The "practice mode" helps me understand the game.
C9	I have a feeling of deep involvement in the game.
C10	I gradually mastered the ability to attain new levels.
C11	The interface is easy to use.
C12	I have no difficulty managing the process of the game (e.g., select, start, stop game).
C13	I can control complex movements of the virtual spinning top, such as moving forward, and coordinating collisions.
C14	I feel that I am in complete control during the game.
C15	The overall objective of the game is clear.
C16	I am fully aware of the sequence of the game.
C17	After playing this virtual game, I would love to use a real spinning top.
C18	I received sufficient visual feedback throughout the game (e.g., when the spinning top struck something).
C19	My actions were met with immediate reactions in the game.
C20	I am able to immediately comprehend the situations I encounter.
C21	I can earn rewards through my successes in the game.
C22	While playing, I am unaware of what is going on around me.
C23	While playing, time seems to pass quickly.
C24	While playing, I feel emotionally invested in the game.
C25	The game tips prompt me to accept further challenges.
C26	Competition among players makes me more committed to continue the game.
C27	Competition among players makes me want to beat the other players.
C28	I would enjoy discussing this game with other players.

Figure 15. GameFlow design pattern [14]

Appendix 2. Selected Games for evaluation

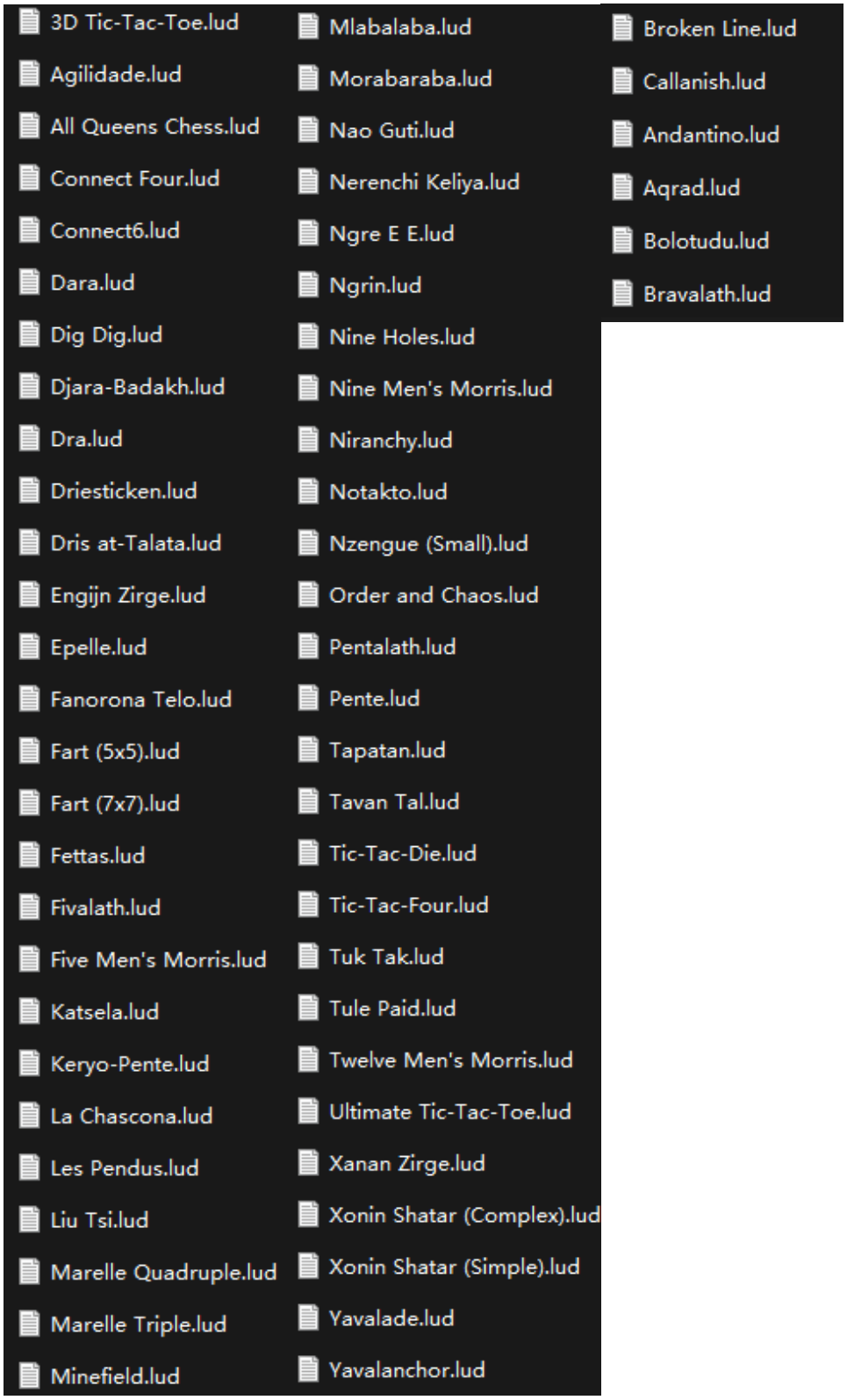


Figure 16. Evaluated Games

Appendix 3. Survey design

Section 1. Flow Theory Questions:

Elements	Criteria	Score
Concentration	1. Dose the game grabs your attention without knowing the detail rules? 2. How much effort did you put to remember the useful information in game?	1. Scale from “Not interesting at all” (1) to “Immediately interested me” (5) 2. Scale from Very easy (1) to Very hard (5).
Challenge	1. What do you think about the difficulty of the game? 2. Do you feel the increasement or decreasement of the challenges throughout the gameplay?	1. Scale from “Very easy” (1) to “Very difficult” (5). 2. Choose one from “Increasement” or “Decreasement”, then scale from: “Very low ~” (1) to “Very high ~” (5)
Player Skills	1. Can you play the game without knowing the rules? 2. Do you feel the increasement or decreasement regarding gaming strategy during playing? Scale from Very less to Very much.	1. Yes or no question 2. Choose one from “Increasement” or “Decreasement”, then scale from: “Very low ~” (1) to “Very high ~” (5)
Control	1. Can you successfully control your characters, units or pieces during game? 2. Dose the game world (board) shows your result of control (moves) in a clear way?	1. scale from “Failed to control” (1) or “Fully controlled” (5) 2. scale from “I didn’t notice any difference before and after the move” (1) to “I can clearly see the difference before and after the move” (5)
Clear Goal	1. is the goal of the game presented clearly? 2. Is the intermediate goal of the game presented clearly?	1. Scale from “Not clear” (1) to “Very Clear” (5) 2. Scale from “Not clear” (1) to “Very Clear” (5)

Feedbacks	1. Do you notice any feedback regarding your control (move) on the progress towards goal(s)? 2. Do you notice your score or status in the game?	1. Scale from “There are no feedbacks” (1) to “The feedbacks are very clear” (5) 2. Yes or no question
Social Interaction	1. How do you feel about the competition or cooperation level in the game? 2. Are there any interactions between the you and other players?	1. Scale from: Very Low level (1) to very high level (5) 2. Scale from: “No interaction” (1) to “Lots of interaction” (5)

Table 2. survey closed questions

Section 2. Open questions:

1. What is your ranking for the factors of human enjoyments (The 8 Flow theory elements)? Elaborate why.

2. What do you think about the COMPETETIVE level between the two games? Which one is higher? Which one you prefer?

3. What do you think about the SKILL level required by the games? Is one requiring more thinking and memorizing than the other? Which one you prefer?

4. Which game provides clearer GOALS? Connect 6 or the altered game?

5. Which one do you prefer? The original “Connect 6” or the alternative “Connect 6 + Yavalath”? Elaborate your reason.

Appendix 4. Informed consent form & information sheet

Informed Consent Form:

The goal of the study is to investigate human enjoyment when playing board games. The board games can be played on a computer-based platform called the Ludii system. Each participant will be asked to play 2 board games against other participants. After finishing the games, the participants will be asked to fill out a survey to reflect on the games. The whole experiment will take approximately 30 – 40 mins, where participants have 20 – 30 mins playing games and the 10 mins left are for the survey. The survey will be anonymous, participants will not be asked to fill in their name but age and gender will be needed.

Please read the information sheet before proceed to the next section.

Please tick the appropriate boxes below:

		Yes	No
1.	I have read and understood the study information sheet, or it has been read to me. I have been able to ask questions about the study and my questions have been answered to my satisfaction.	☐	☐
2.	I consent voluntarily to be a participant in this study and understand that I can refuse to answer questions and I can withdraw from the study at any time, without having to give a reason.	☐	☐
3.	understand that the information I provide shall be used to determine the effectiveness of the visualization as well as for the improvement of the prototype.	☐	☐

Signature:

_____	_____
Participants signature	Consent Date

More detailed information please contact: y.chen-11@student.utwente.nl

Project Supervisor: Marcus Gerhold, m.gerhold@utwente.nl

Contact Information for Questions about Your Rights as a Research Participant
If you have questions about your rights as a research participant, or wish to obtain information, ask questions, or discuss any concerns about this study with someone other than the researcher(s), please contact the Secretary of the Ethics Committee Information & Computer Science: ethicscommittee-CIS@utwente.nl

Figure 17. Inform Consent Form

GameEvolver: Information sheet

Context:

Since ancient time human starts to design and enjoy board games, Go, Tic-Tac-Toe or connect 4. In the 21 centuries, computers have become the main platform people design and play games, with the evolution of artificial intelligence, computers are capable of complete some of the board games, proven their power to make "optimal choices". Designing a board game is also largely related to decision making, the faster a designer finds the "optimal choices" for the game, the more time he saves. Is computer capable to automatically improve an existing game and makes it more human-enjoyable? To find out this question, we made a program called the "GameEvolver" to automatically evolve games based on the Ludi system (a board game luancher). The GameEvolver takes an existing board game, "Connect 6", as the original input game, and by mutating with "Yavalath", an altered game has been generated. The aim of this research is to test human player's enjoy level on the original game "Connect 6" and the altered game "Connect 6 + Yavalath"

Procedure:

Participants: participants must age 18+, informed consent form needs to be signed before the experiment.

A pair of participants will be needed to conduct the experiment. The experiment consists of 3 parts. In the first 10 mins, players can play against the Ludi build-in AI to practice the games. After both players finished practicing, they will have 20 mins to match against each other on both the original game and altered game. after the match, both players will spend 15 mins to fill out the survey.

All the games will be running on the Ludi platform shown below:

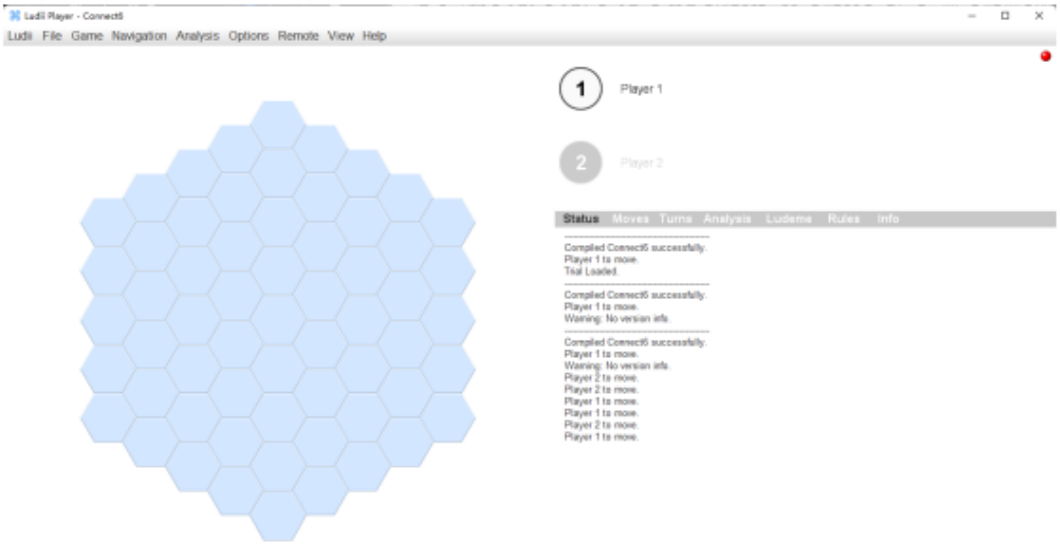
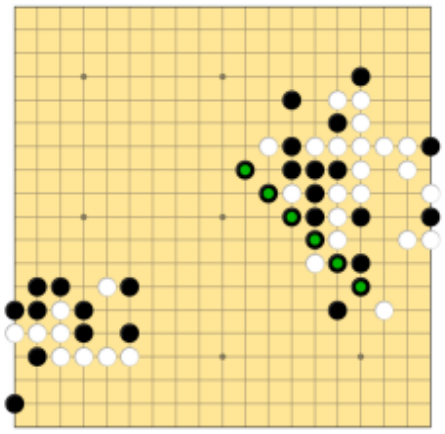


Figure 18. Information sheet page 1

Game rules:

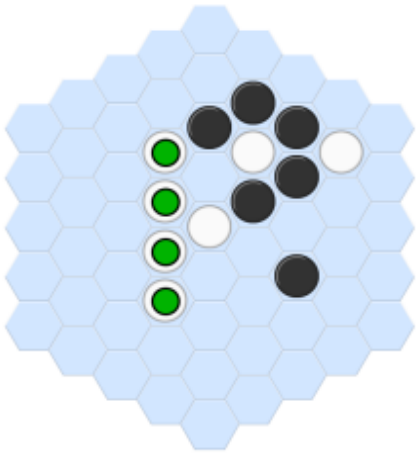
Connect 6 (original game):

Played on a Go-like board (6x6 or larger, but a 19x19 go board is ideal) with two colors of stones (usually white and black). Black goes first by placing one stone. Play continues with each player playing two stones per turn. The first player to make a line of six in a row wins.



Yavalath + Connect 6 (altered game):

Played on a hex-5 board (hex-5 for 2 players, hex 7 for 3 players) with two colors of stones. Black goes first by placing a stone. White continues by choosing to place 1 OR 2 stones. Black player can only place the same number of stones as the white player. If one connects a line of 3, he losses; if one connects a line of four, he wins.



Data obtained:

We will collect data on the number of turns of each match, the time consumed and questions regarding players enjoyment in each game. All data will be stored anonymously.

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If you have questions about your rights as a research participant, or wish to obtain information, ask questions, or discuss any concerns about this study with someone other than the researcher(s), please contact the Secretary of the Ethics Committee Information & Computer Science: ethicscommittee-CIS@utwente.nl

Figure 19. Information sheet page 2

References

[1] Ludii.games. 2022. Ludii Portal. [online] Available: https://ludii.games/index.php

[2] Browne C, Maire F. Evolutionary game design. IEEE Transactions on Computational Intelligence and AI in Games. 2010 Feb 2;2(1):1-6. Available: https://link-springer-com.ezproxy2.utwente.nl/book/10.1007/978-1-4471-2179-4

[3] Shi J, Renwick R, Turner NE, Kirsh B. Understanding the lives of problem gamers: The meaning, purpose, and influences of video gaming. Computers in Human Behavior. 2019 Aug 1;97:291-303.Available: https://www.sciencedirect.com/science/article/pii/S0747563219301153.

[4] Vorderer P, Klimmt C, Ritterfeld U. Enjoyment: At the heart of media entertainment. Communication theory. 2004 Nov 1;14(4):388-408. Available: https://www.academia.edu/18926596/Enjoyment_At_the_Heart_of_Media_Entertainment

[5] Hoffman DL, Novak TP. Marketing in hypermedia computer-mediated environments: Conceptual foundations. Journal of marketing. 1996 Jul;60(3):50-68. Available: https://journals.sagepub.com/doi/abs/10.1177/002224299606000304

[6] Fang X, Zhao F. Personality and enjoyment of computer game play. Computers in Industry. 2010 May 1;61(4):342-9. Available: https://www.sciencedirect.com/science/article/abs/pii/S0166361509002139.

[7] JOSEPH D, KNUTTILA L. “single-player/multiplayer” chapter 27 of the “Routledge companion to video game studies”. Available: https://www.taylorfrancis.com/chapters/edit/10.4324/9780203114261-37/single-player-multiplayer-daniel-joseph-lee-knuttila

[8] Consalvo M, Begy J, Browne P, Ganzon S, Scully-Blaker R, Waldie R. Finding sociality in single player games: A case study of tandem play amongst friends and couples. InProceedings of the 51st Hawaii international conference on system sciences 2018 Jan 3. Available: https://scholarspace.manoa.hawaii.edu/handle/10125/50125

[9] Harteveld C, Bekebrede G. Learning in single-versus multiplayer games: The more the merrier?. Simulation & Gaming. 2011 Feb;42(1):43-63. Available: https://journals-sagepub-com.ezproxy2.utwente.nl/doi/10.1177/1046878110378706

[10] Flanagan M, Nissenbaum H. A game design methodology to incorporate social activist themes. InProceedings of the SIGCHI conference on Human factors in computing systems 2007 Apr 29 (pp. 181-190). Available: https://dl.acm.org/doi/abs/10.1145/1240624.1240654

[11] Schell J. Tenth Anniversary: The Art of Game Design: A Book of Lenses. AK Peters/CRC Press; 2019 Jul 31. Chapter 5. Available: https://www.schellgames.com/art-of-game-design/

[12] THE FLOW THEORY APPLIED TO GAME DESIGN, website, Available: https://thinkgamedesign.com/flow-theory-game-design/

[13] Schell J. Tenth Anniversary: The Art of Game Design: A Book of Lenses. AK Peters/CRC Press; 2019 Jul 31. Chapter 14. Available: https://www.schellgames.com/art-of-game-design/

[14] Wang CH, Wu KC, Tsau SY. Flow learning experience: Applying marketing theory to serious game design. Journal of Educational Computing Research. 2019 Apr;57(2):417-47. Available: https://journals.sagepub.com/doi/abs/10.1177/0735633117752454

[15] Caroux L, Isbister K, Le Bigot L, Vibert N. Player–video game interaction: A systematic review of current concepts. Computers in Human Behavior. 2015 Jul 1;48:366-81. Available: https://www.sciencedirect.com/science/article/abs/pii/S0747563215000941

[16] Wang Y. Mathematical models and properties of games. InFourth IEEE Conference on Cognitive Informatics, 2005.(ICCI 2005). 2005 Aug 8 (pp. 294-300). IEEE. Available: https://ieeexplore.ieee.org/abstract/document/1532644

[17] Nakamura J, Csikszentmihalyi M. Flow theory and research. Handbook of positive psychology. 2009 Apr 21;195:206. Available: https://books.google.nl/books?hl=en&lr=&id=6IyqCNBD6oIC&oi=fnd&pg=PA195&dq=flow+theory&ots=INH5SEZbwy&sig=7X0dQ9nfIC1eD0RcV37nimXTY7Q&redir_esc=y#v=onepage&q=flow%20theory&f=false

[18] Sweetser P., Wyeth P. , GameFlow: A Model for Evaluating Player Enjoyment in Games. 2005 July. Available at: https://dl.acm.org/doi/abs/10.1145/1077246.1077253

[19] CGTN America, “GO champ Ke Jie talks about his match with Google's AI”. 2017 May 29. Online, Available at: https://www.youtube.com/watch?v=UHU8lCctC-Q