Greedy Aplication to Determine the Best Move in Trading Card Game Hearthstone Suitable to Particular Playstyle

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***Abstract*—Games have been the entertainment source of many people from old days. Nowadays games have grown into so many genres, introducing newer and fresher mechanics. These mechanics are one of the main reasons people choose a certain game. Be the person only wants to play calmly for fun or play with full tension for challenge. The terms casual and hardcore gamers are used to differentiate the two. Indeed the difference is not only just in what condition and for what target they play the game. Furthermore we can differentiate the two by (but not only) their obsession in winning and usage of strategy. Hardcore gamers are often obsessed in how they can win the game with the best strategy possible while the counterpart do not really frown upon their winning yet strategy. This paper will be using well-defined algorithm as a strategy for the games.**

***Keywords*—TCG, Card, Move, Greedy.**

I. INTRODUCTION

For a long time, games have been the most important entertainment source for people. Nowadays, games are not a rare occurrence anymore, with the existence of smartphone everyone can play games in their hand. Games has a large variety and flexibility, hence people have come to always find what they need. But as the first sentence suggests, people nowadays are not the only case.

Ancient people have been recorded several times to be having a certain activity involving a lot of people (or alone) resembling the same activity of our playing games. Obviously, the medium used was not like any that we use today. Ground was smartphone's substitute, rocks and other tools were its complement.

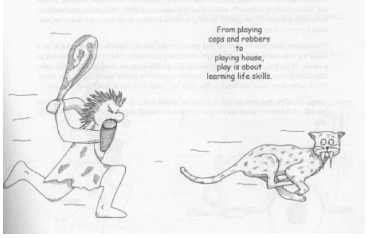

Image 1.1 Ancient People Playing
(Source: A Theory of Fun for Game Design, Raph Koster[1])

Interaction, in which the activity of playing games mainly lies, is what differentiates game from other entertainment source. The modern entertainment of movies, books, etc offer little to no interaction involving the audience (there are interactive movies indeed yet the amount). This results in the difference of feeling the audience can get from the source. Games offer several ways of completion which can lead to several different experience while others only offer single completion route, resulting in little replay value.

As time goes, games have also evolved from traditional (like "Dampu Bulan" or "Gobak Sodor") to digital games (as we know now). This evolution opens a larger board of possibility for game developers to further enhance games' replay value and mechanics. Traditional games fall to the disadvantage of limited rules and tracking possible, hence they tend to be simple and straight-forward. But as time grows, people become bored nonetheless.

Digital games, with its powerful tool called "programming", offer the ability to track many more things at once and implement a whole lot of rules for the game. This in a way complicated the game as well richen the game. The genre *Trading Card Game* is one that benefits the most from the evolution.

Trading Card Game or abbreviated **TCG** (sometimes called **CCG**) is a game played using specially designed sets of playing card. This genre of game typically implements different rules and cards as well as mechanics in its every game. The main similiarity of these games are how players have to collect cards, each with unique characteristics, and assemble a set of cards (generally called deck) to beat their opponent. This freedom opens up players' creativity in making his own deck and devising a strategy to conquer his opponent. With so many rules and things needed to be tracked, TCG is firmly supported by the existence of digital games.

One of TCG example is Hearthstone, a game developed and published by Blizzard Entertainment. The game was released in 2014 with its setting build upon the existing lore of the Warcraft series by the same company. Hearthstone is a turn-based game between two opponents, each using a constructed deck of 30 cards along with a selected hero with unique power. The game revolves around the use of mana crystal to summon minions are

use abilities.

Image 1.2 Hearthstone by Blizzard Entertainment (Source : https://esportsnesia.com/game/hearthstone/apa-itu-hearthstone/ accessed on May 1st 2020 3:00 PM)

In Hearthstone, the players have 10 classes with each unique hero and power to choose in every play. Every class has its own card available and hence *playstyle*. The main goal of every player is to construct decks which favors his playstyle and devising strategies to eliminate his opponent. With a lot of options to choose, players are given much freedom in how they strategize and execute their plan.

In devising strategies, there are (but not only) 2 factors, player's personality and the deck itself. Every deck favors a certain type of play while the player's personality affects how the deck will play out. In this paper, we will discuss substituting player's personality with the Greedy algorithm strategy in order to utilize the best of his deck (without much concern of it) and how it affects the game.

II. Basic Theories

A. Greedy Algorithm

Greedy algorithm is one of many basic and widely used algorithm strategy. The fundamental of this algorithm is, as its name suggests, *greed*. It has the principle "Take what you can get now!" which is realized in every step of its solution.

The algorithm will *greedily* choose the most minimum or maximum way in each step. This decision guarantees that in each step, the most optimal solution(locally) is determined. In every step, there will be chosen a solution candidate, best for the particular step. It will then be tested for the feasibility in contributing to the solution. If the candidate is deemed feasible, it will be inserted as a part of the global solution. The selection is based on the mindset that choosing the best solution will guarantee the optimum local solution and in turn *hopefully* guarantee the optimum global solution.

The phrase *hopefully* is used since an optimum local solution does not always bring us to the optimum global solution (in some cases). But in general cases and also a suitable heuristic, greedy can be guaranteed to give global optimum solution. Due to its simple manner, Greedy Algorithm is so widely used in optimization problems(problem concerning the need of maximum or minimum of a certain value).

In general, to define a greedy algorithm, 5 elements can be defined beforehand.

1. Candidate Set
   In every step of greedy algorithm, there will be a a lot of possible options to choose. One or none of which will be the local optimum solution. These options for the algorithm to choose are called Candidates Set. It comprises of all the different possible choice of local solution which can be chosen and be evaluated furthermore by the other functions. One example would be the candidates set of the knapsack problem will consist of all items in consideration.
2. Selection Function
   Selection function defines how, from the candidate set, will the local optimum solution be selected. It evaluates each candidate and if it fulfills the function requirement, it will be chosen for further evaluation. This function is arguably the core part of the algorithm. It is where the programmer define what is really needed to solve the problem. If the programmer is concerned for a maximum solution, what is considered the maximum, which value is taken as consideration, and many more.
   Another example is taken from the knapsack problem. Let every item has their own profit and weight known, the selection can be defined as 1) item with maximum profit, 2) item with minimum weight, 3) item with the most profit-to-weight rate, and many more. These wide possibilities is where the programmer is tested to determine the most suitable function for the problem because different selection function can lead to different solution hence its status as global optimum.
3. Feasibility Function
   Feasibility function is yet another function defined to aid the selection function in determining the local optimum solution. The function is, as it name suggests, used to determine whether the candidate chosen from the selection function as a result is feasible in contributing to the global optimum. "Can it be considered a part of solution?", is another way of saying it.
   An example of feasibility function from the knapsack problem is determining of the chosen candidate's weight does not exceed the maximum weight for the bag. If the candidate is deemed not feasible, the step will then be restarted without the candidate, selecting another candidate.
4. Objective Function
   Objective function is connected to the problem itself. It determines what kind of solution the problem actually want to be given. In the case of knapsack problem, it is to find the maximum profit.
5. Solution Set
   Solution set is the global solution given as result of inserting local optimum solution one by one after each iteration. When the algorithm is signaled to stop, the set will then be given as the solution, hoping to give the optimum global solution.

So how does greedy actually compare to other algorithms? Greedy helps defining strategy in a simple way of thinking, only focusing on the maximum or minimum *for* every step. This way greedy helps the programmer to be more focused and not be distracted by the cases too far away. It generally yields better performance than brute force yet it usually takes just little more

effort in devising.

B. Hearthstone

Hearthstone is a Trading-Card Game or sometimes called Collectible-Card Game developed and published by Blizzard Entertainment. It has the main settings of its predecessor game, Warcraft, and gives us the feeling of being in a tavern in every aspect of the game.

It is known as one of the biggest games made in Unity Engine, sometimes even deemed qualified for a *AAA game* (an informal classification of game, equivalent to the term *blockbuster* in film industry). The reason is Hearthstone spends a really great deal of effort in its development. The quality of its assets, the little details scattered in the game and even the updates makes the game really high-rated.

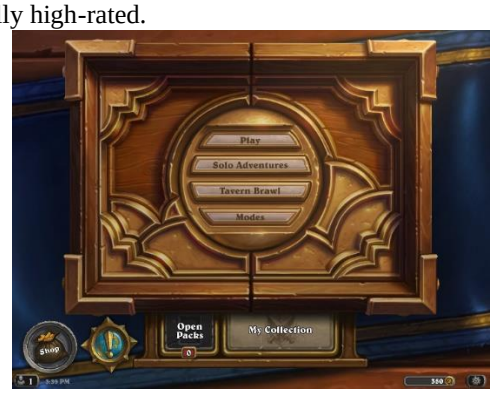

Image 2.1.1 Hearthstone Lobby in PC
(Source : Screenshot taken from the game)

The game revolves around the mechanic of battling with cards or sometimes called *dueling*. Players will be left on the search for cards and be assigned the task to make the best deck possible in order to beat their opponents. The mechanics can be explained in some part.

1. Classes
   Class is the primary determinant of the player's powers and abilities (sometimes called hero). It also plays the strongest role in deck selection and construction. In every play, players can choose from 10 available classes with their respective deck. Classes also determine "player ability" which is unique to each class and supports the class playstyle.

Image 2.2.1.1 A class and its ability
(Source : https://hearthstone.gamepedia.com/Classes#Death_Knight accessed on May 1st 11:20 PM)

   Image above is one of the 10 classes called *Paladin* with his ability *Reinforce*. The class is known with its fast and aggressive playstyle. It is well-accepted as the the *aggro* hero in game.
2. Cards
   Cards are the main tool for battle. It is used to move the game and as the players' weapon to beat the enemy. Every card in the game falls to one category of class (one of 10 Classes or All Classes), which is why choosing a class plays the biggest role in the deck-making. The reason is because the class you choose will determine what kind of cards you can play and for further reason that each cards have their own characteristics with unique playstyle when combined with other cards.
   Cards themselves have 3 big categories: *Minions*, *Spells*, and *Weapons*. Each has their own subcategories with their own unique characteristic which will not be of concern to us now. In order to use a card, players have to prepare a certain amount of mana crystal in the game.

Image 2.3.1.2 A Minion card with effect
(Source : https://hearthstone.gamepedia.com/Classes#Death_Knight accessed on May 1st 11:21 PM)

3. Decks
   Deck is, by simple means, an organized collection of cards with the primary identification of its class. A playing-deck in Hearthstone consists of 30 cards combined from the deck's class and neutral class (All Classes cards). With the right combination of cards, a certain playstyle can arise and be used by the player.

Image 2.4.1.3 Paladin Deck and Its Available Cards
(Source : Screenshot taken from the game)

4. Play
   Card Play is the main mechanics of the game where players' skill in constructing their deck and utilizing it will be tested. Hearthstone card battle is a turn-based where players alternate between respective turns to take actions. The battle starts with each player having 30 health and 0 *mana crystal*, the main currency for using a card, increasing by one and reset to full at the beginning of his turn.
   In each turn, player can choose which card(s) to play in order to defeat the enemy. The choice can vary between minions, spells, and weapons. Players have to carefully analyze the board condition as well as his opponent moves in making his choices.
   Minions can be used as the main rotor of the play. They can engage in battles with other minions or inflict direct damage to the enemy's hero. When a player has successfully depleted his enemy's damage to 0 (or lower) the player is deemed the winner.

Image 2.5.1.4 A Late-Game State of a Card Play (Source : Screenshot taken from the game)

In conclusion, the main flow of card play is:
1. Players each initiated with 30 health, 0 mana crystal and 3 cards (2 extra cards if even turn).
2. At the beginning of turn, player draws a card, add 1 crystal mana to his maximum capacity (capped at 10) and reset it to full.
3. In the main part of the turn, player can take actions with his cards to defeat the opponent.
4. When *End Turn* is signaled by the player, the turn alternates.

III. Determining Moves

A. Defining Playstyle

In the following sections, we will try to determine the best action to take each turn in Hearthstone card play with the Greedy Algorithm. To determine how we define the selection function, we first need to define how a chosen playstyle affects the algorithm. There will be 2 playstyle in consideration for this paper.

1. Aggressive
   Aggressive or more widely called *aggro* is a playstyle revolved around speed and momentum. Aggressive playstyle (in TCG) is often associated in how fast the player can summon his minions and finish the enemy. Sometimes with weak yet many weak monsters, the goal is to distribute constant damage to your opponent before they have the necessary cards to wipe the entire board and turn the game around.
2. Control
   Control is the counterpart of Aggressive, which focuses on how long can you last on the game. When playing Control, player needs to be smart and patient as he has to always keep the board in check, eliminating potential threat while setting stage for his table-turning card. Control is often associated in how it breaks the opponent's combo and securing the board for the player's strongest cards. It demands more thought to be use optimally and hence a risky playstyle.

For both of the playstyle, will be determined the selection function deemed the best for each. The followings are the function.

1. Aggressive
   Selection function for Aggressive Playstyle will revolve around how to outpower and/or outnumber the opponent. This can be achieved by the following consideration.
   - Mana Crystals has to be used for maximum output in every turn by summoning when possible.
   - Card with the most attack power will be prioritized.
   - If there are Mana Crystals left and no summon possible, weapons with most attack power would be prioritized.
   - If there are Mana Crystals left, no summon possible, and no weapons, spell will be prioritized in this order: Damage Spell, Attack Buff Spell.
   - Other cards will be ignored.
   - Attacks will be directed toward the enemy's hero when possible.
2. Control
   Selection function for Control Playstyle will revolve around how to hold the opponents attack and summon the strongest monster in the deck. This can be achieved by the following consideration.
   - Mana Crystals has to be used for minimum output in every turn by only summoning when needed. When enemy has a minion on their side, then it is deemed needed.
   - Card with the most health will be prioritized.
   - If there are Mana Crystals left and no summon possible, spells would be prioritized in the following order: Damage Spell, Card Draw Spell.
   - Other cards will be ignored.
   - Attacks will be directed toward the enemy's minions and only to enemy's hero when there are no enemy minions.

B. Generalizing Cards

After defining the playstyles we want to test, it's time to construct the decks used. But before that, we will generalize the cards to some extent in order to simplify how we choose the cards. Here are the assumption or consideration made for the cards.

1. Minions cards will only be considered by their attack power and health. Any effect attached to a card would be

ignored be it profitable for the playstyle or not.

2. Skill cards will be categorized into the following.
   - Damage Spell: Spell that inflicts damage be it to player or hero.
   - Attack Buff Spell: Spell that increases minion(s) or hero's attack power.
   - Card Draw Spell: Spell that invokes draw for player.

C. Player and Enemy

The test will be executed on practice modes to an NPC(non-playable-character) of the class Rogue which specializes in direct damage. We will use the basic deck of Paladin class, of which has the reputation of being an aggressive deck.

D. Determining Actions

The test is executed right on the game and recorded in a video. For complete play, please follow this video link https://youtu.be/6kUWwsnErrc.

1. Aggressive Playstyle

Image 3.4.1.1 Aggressive Starting Hand (Source : Screenshot taken from game)

In the beginning of the game, we were assigned the even turn, giving us an extra card and extra-mana card. At first, we only had 1 mana and had 3 available cards to choose(from left):
1. Minion with 1 Attack/ 2 Health
2. Minion with 1 Attack/ 1 Health
3. Extra Mana Card

As with the selection function, we immediately choose **1. Minion with 1 Attack/ 2 Health** and summoned it.

At the second iteration, we concluded that we could only use the **Extra Mana Card**, which again used immediately, gaining us one extra mana crystal. This then enables us to summon the **3. Minion with 1 Attack/ 1 Health** for 1 mana. Giving us at total 2 minions at the end of the turn.

Image 3.4.1.2 Summon results for 1st turn (Source : Screenshot taken from game)

As we see too, we could use one of our minions to attack the enemy. Therefore we attacked the enemy and resulting in 1 damage inflicted to enemy's hero. Here are the board just before we ended our turn.

Image 3.4.1.3 Board Condition before Ending 1st turn (Source : Screenshot taken from game)

This pattern then continued for another 7 turns (8 turns in total) and resulted in a **Win**.

Image 3.4.1.4 Board Condition just before winning the game (Source : Screenshot taken from game)

2. Control Playstyle

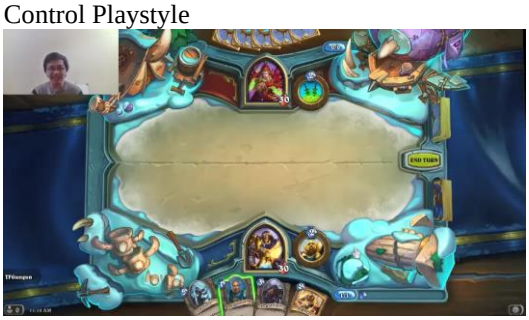

Image 3.4.2.1 Control Starting Hand (Source : Screenshot taken from game)

In the beginning of the game, we were assigned the odd turn. At first, we only had 1 mana and had 1 available cards to choose(from left):
1. Minion with 1 Attack/ 2 Health

But after analyzing the board condition, it wasn't deemed necessary for us to summon a minion. Therefore we don't do anything and ended the turn.

Image 3.4.2.2 Board Condition on 2nd Turn (Source : Screenshot taken from game)

At the 2nd turn, the condition changed. The enemy had summoned a minion and hence we deemed necessary to summon a minion. After examining our hand, we had 3 available moves to take (from left):

1. Minion with 1 Attack/ 2 Health
2. Attack Spell
3. Minion with 1 Attack/ 1 Health

As we are aiming for the minion with most **health** possible, it was decided to summon **1. Minion with 1 Attack/ 2 Health**. The next iteration gives no move to be taken anymore and results in the following board condition.

Image 3.4.2.3 Board Condition before Ending 2nd Turn (Source : Screenshot taken from game)

This pattern then continued for another 7 turns(9 turns in total) and resulted in a **Lose**.

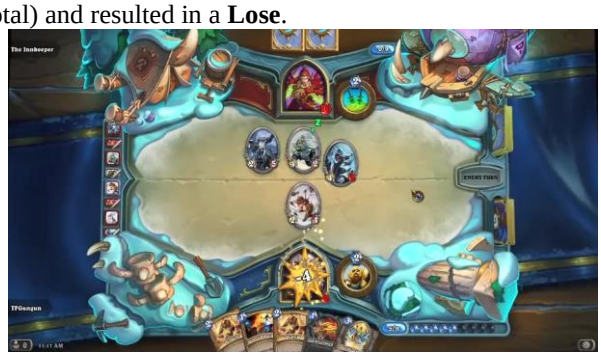

Image 3.4.2.4 Board Condition just before losing the game (Source : Screenshot taken from game)

IV. Conclusion

Greedy as one of the most widely-used algorithm proved to be useful in not only programming but also in devising a strategy in games. It can indeed be affected with many factors such as player's deck, luck, and the defined playstyle itself. But the fact that different playstyle produces different function and therefore result, implies that greedy is indeed a powerful tool if used with caution.

The result can of course be more convincing if we do a lot more test. Nonetheless this versality allows greedy to be modified and applied in so many things we can imagine. This paper is one proof of it, that with even simple effort we can use greedy to be a champion (exaggerated). With confidence I can say that the application is still wide, with sky is the limit and imagination is our wings.

Video Link at Youtube

https://youtu.be/6kUWwsnErrc

Acknowledgment

In this section I would like to express my gratitude to Ms. Masayu Leila Khodra, our Algorithm Strategy lecturer. No other than her imaginative way of teaching and passion to explore induces my creativity to start this paper. I would also like to express my gratitude to my friends for supporting my paper. And lastly, I would like to express my apologies for any mistakes I did in this paper. I highly hope this paper can be publicly read and induce more of people's creativity, in order to make more useful applications of discrete mathematics.

References

[1] Koster. Raph, A Theory of Fun for Game Design : Paraglyph Press, Inc United States of America, 2005.

Pernyataan

Dengan ini saya menyatakan bahwa makalah yang saya tulis ini adalah tulisan saya sendiri, bukan saduran, atau terjemahan dari makalah orang lain, dan bukan plagiasi.

Bandung, 2 Mei 2020

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