Greedy Algorithm Application in Forty-One Card Game

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***Abstract*—One of the card games that is popular among people nowadays is Forty-One. This game has become famous because it can be played together with friends using playing cards called Remi in a simple but competitive way. Players must take a card from the deck or from pile of cards discarded by the previous player, then discard one unwanted card. This is repeated until there is one player who gets 41 points, or in another case, someone ends game by closing their cards. The goal of this game is to get the most points when the game ends with a maximum of 41 points. One of the promising solutions to win this game can be produced by implementing the renowned Greedy Algorithm. This paper is written to present the application of Greedy Algorithm in the mentioned card game.**

Keywords—greedy; forty-one; card game; algorithm

I. INTRODUCTION

In today's digital era, games that involve direct interaction without a screen are very rarely played. Most of the times, when a group of friends meet, they will play games on their cellphones, either alone or with each other. However, that doesn't mean that live games are no longer interesting. There are many kinds of games without using technology that are still fun to play and can be played together when gathered. These games will certainly create stronger bonding and a sense of togetherness between the players because they interact directly without using any media or modern technology.

Fig. 1. Game Cards, also known as 'Remi' Playing Cards (Source: https://www.jakartanotebook.com/blog/sejarah-panjang-kartu-remi-yang-mendunia/)

One game that has passed the test of time and is still often played is game cards. Game cards or better known as remi playing cards are a collection of hand-sized cards used for card games. These cards are often also used for other things, such as magic, encryption, board games, and making houses of cards. The word 'remi' itself is actually the name of a card game, but most people now call this game cards as 'remi' which can be played in various types of games. Various games using playing cards that are popular in the world today are 'Poker', 'Canasta', 'Blackjack', 'Casino', 'Solitaire', 'Bridge', which can be played with different numbers of players.

Card games have existed since the 14th century in Europe as proven by concrete historical evidence. However, Europe may not have invented this type of game. Some researchers argue that card games first emerged from the east, especially from Egypt, China, India or Persia, which were then brought to Europe. This opinion is based on several games that may be related to card games, such as dice games or mahjong games. Unfortunately, this opinion cannot be proven and is difficult to prove because paper is very fragile and it is very likely that the card evidence, if there is any, has been destroyed.

The concrete evidence that exists regarding card games today is card games in Europe. In a manuscript made in 1377, it was written that there was a game that used cards. In the 1400s there were also frequent references to card games with dice games as examples of games that were prohibited by religion. At that time, the symbols used were different from the symbols now, the symbols were glasses, coins, swords and sticks/clubs. This symbol is still used today, especially in Italy and Spain and is called Latin suits. This symbol then underwent another change in the hands of Germany as a country that innovated in terms of making cards, their method of making cards made it easier for people to produce cards on a large scale. In France, the symbol has undergone another change, this time with the same image as is commonly used today. Apart from that, there is also the addition of red and black color separation.

More respect for the Ace of Spades or Ace with spade symbols began with the British decision to use the Ace as proof of tax exemption. Initially, the Ace could only be produced by the government itself to avoid tax evasion, but gradually the decision was changed, and each factory was allowed to produce its own Ace of Spades. The United States also took part, initially the United States depended on England for its card stock,

coupled with the former preference of Americans for British products. In the United States, the card arrangement was changed with the addition of two Joker cards, one each red and black. The United States also later became one of the main producers of playing cards.

Card games continue to develop until now it can be said that the whole world has tried playing at least one variant of the game. Many card games are now official sports and are played at prestigious events. In fact, the prizes can reach hundreds of millions or more. In Indonesia itself, there are also many variations of games that use playing cards. Such as the game 'Forty-One' or *'41 (re: Empat Satu)', 'Truf', 'Capsa', 'Cangkulan', 'Tepuk Nyamuk'*, and many more. These games usually have slightly different rules between regions, making it all more interesting by learning new perspectives that exist in each region. Playing card games are still one of the main choices when gathering with friends, especially for generations who were not very exposed to smartphones in their childhood. These playing cards are considered to have practical and flexible properties because by carrying just one deck of cards, a person can play various types of games together with his friends.

Fig. 2. Playing cards form 41 points in the Forty-One card game (Source: https://www.kompasiana.com/yudil/551b67eca33311b023b65e6b/tips-mengingat-urutan-kartu-remi-yang-dikocok)

The Forty-One card game itself is not clearly known where it originates from. In several sources it is said that this game was played in Lebanon, Syria, and surrounding areas under other names and with the same game target, namely making the number of cards in the hand total 41. However, the game procedure is different from what the author usually uses. In one source, the Philippine version of this game is also seen which is more similar to the one the author usually plays, but there are still slight differences. It can be concluded that the Forty-One games that are usually played in Indonesia today are most likely the same as games abroad after going through several adjustments which later became the current standard.

II. THEORY AND METHOD

A. *Forty-One Card Game*

The Forty-One is a card game that uses a set of playing cards containing 52 cards without the joker card. Usually, this game is played by four or more people. But, in this paper we will only evaluate the game which played only by four players. In this game, players must collect four cards with the highest value. As the name of the game suggests, 41 is the maximum score in this game. In the rules of the Forty-One playing card game, each card has different points. If a player collects four cards, whether they win or not is determined by the score of each card obtained. The following table calculates the points for each card.

TABLE I. POINTS ON EACH TYPE OF CARD

Card	Point
As/Ace	11
2	2
3	3
4	4
5	5
6	6
7	7
8	8
9	9
10	10
Jack	10
Queen	10
King	10

However, players must not collect cards carelessly, because to get a good score, players must take cards of the same suit and color. If there is a card of a different suit among the four cards they have, then the number will be reduced by the number of points from the card. different. The beginning of the game is almost the same as playing hoe, someone shuffles the cards then distributes four cards to each player, then keeps the remaining card stock in the middle. The first player will start taking cards from the card stock and take turns clockwise. Players may discard their cards if there are any that do not match or are not of the same suit, but they are not allowed to pick up cards that have been discarded. The game ends when either player gets a perfect score, player covers their cards, or the stock of cards runs out. A perfect score is four cards of the same suit with a value of 41 and will be the clear winning case of the game.

In detail, the procedure for the Forty-One card game is as follows:

1. Each player will get 4 cards to start the game.
2. The player who has the first turn will take a card from the pile of cards.
3. After taking a card, the player will discard one of his cards.
4. The next player will have two options to choose from, namely taking the card that was just discarded by the previous player or taking a card from the pile of cards.

5. After the player makes a choice and takes a card, the player will discard one of his cards.
6. Procedures number 4 and 5 will be repeated continuously until one of the players closes the cards and ends the game or the pile of cards runs out.
7. After the game ends, each player will calculate the total points they have and compare them with the results of other players.

Something to remember is that players can cover their cards and end the game after their turn is over regardless of the number of rounds. This can be a special strategy that can be done when you feel that the cards you have in your hands are better than others or the cards you have just cannot be any better.

B. Greedy Algorithm by Definition

Greedy is one of the popular methods in optimization of problem-solving and it is closely tied to optimization problems. Moreover, optimization problems consist of two elements: maximization and minimization. Greedy focuses on what is happening at the moment without considering what will happen in the future. Therefore, its idea is to choose the best solution that is available at that time (local optimum solution) and through this local optimum solution it is expected to find the global optimum solution. However, the global optimum solution is not always guaranteed to find the best solution available and that is one of the main disadvantages of using Greedy compared to the traditional approach such as: Brute Force Algorithm and Exhaustive Search. In order to prove that the algorithm based on the concept of Greedy, we will need to prove it through a complex mathematical equation.

Using Brute Force algorithm or Exhaustive Search is much more accurate in terms of finding the optimum solution. However, the process is much less efficient compared to Greedy, as it will have to check each one of the possible solutions and will be time-consuming and inefficient for the memory storage if we are working with a large set of data. Brute Force algorithm and Exhaustive Search work preferably with a small set of data, otherwise we can use other alternative algorithms such as greedy.

The Greedy algorithm itself runs step by step, and at each step it will choose the most optimal choice at that time in the hope that it will produce optimal results. Greedy is widely used because the steps are easy to understand and easy to use. Greedy's efficiency analysis is also easier compared to other algorithms, such as Divide and Conquer. The Greedy algorithm is usually used for optimization problems because there are many problems that if explored in detail will take a lot of time. Therefore, the Greedy algorithm is used in the hope of getting as close an approximation as possible to the optimal solution.

C. Elements of Greedy Algorithm

There are six elements which are crucial in our process of finding the right solution through Greedy such as the following:

1. Candidate set: the set of elements that will be selected then included on the solutions.
2. Solution function: to make sure whether a solution is reached or not reached yet.
3. Objective function: to determine whether to maximize or minimize the solution.
4. Solution set: the set of elements that will be chosen as a solution.
5. Feasibility function: to determine whether the element can be included as a solution based on the initial condition.
6. Selection function: to filter the elements from candidate set and to choose the best candidate that will be included in the optimum solution.

It is required to fulfill all the elements above. The general scheme of the Greedy algorithm is as follows.

```
function greedy(input C: himpunan_kandidat)→
himpunan_kandidat
Deklarasi
    x : kandidat
    S : himpunan_kandidat
Algoritma:
S ← {} { inisialisasi S dengan kosong }
while (not SOLUSI(S)) and (C ≠ {} ) do
        x ← SELEKSI(C) { pilih sebuah kandidat dari C }
        C ← C - {x} { elemen himpunan kandidat berkurang 1 }
    if LAYAK(S ∪ {x}) then
    S ← S ∪{x}
    endif
endwhile
{ SOLUSI(S) or C = {} }
if SOLUSI(S) then
    return S
else
    write('tidak ada solusi')
endif
```

Fig. 3. The general scheme of the Greedy Algorithm (Source: https://informatika.stei.itb.ac.id/~rinaldi.munir/Stmik/2020-2021/Algoritma-Greedy-(2021)-Bag1.pdf)

D. Case Example of Using Greedy Algorithm

One of the optimization problems that can be solved using this algorithm is the integer knapsack problem. Given a knapsack with capacity M. There are n objects, each object has a weight wi and a gain pi. The objective of this problem is how to select the objects to be inserted into the knapsack so that the total profit obtained is maximized.

There are several heuristic greedy strategies that can be used to select objects to be inserted into the knapsack. The greedy strategy carried out can be divided into 3 objectives, namely greedy by profit, greedy by weight, and greedy by density.

1. Greedy by Profit
    i. At each step, select the object that has the greatest advantage.

ii. Trying to maximize profits by selecting the most profitable objects first.

2. Greedy by weight
   i. At each step, choose the object that has the lightest weight.
   ii. Trying to maximize profits by fitting as many objects as possible into the knapsack.
3. Greedy by density
   i. At each step, select the object that has the largest density (pi/wi).
   ii. Try to maximize profit by selecting the object that has the greatest profit per unit weight.

The following is an example of an integer knapsack problem with the number n = 4,

w1 = 6; p1 = 12;

w2 = 5; p2 = 15;

w3 = 10; p3 = 50;

w4 = 5; p4 = 10;

with knapsack capacity K = 16, then if written in the table, it is as follows:

TABLE II. GREEDY ALGORITHM IN INTEGER KNAPSACK PROBLEM

Properties				Greedy by			Optimum Solution
i	wi	pi	pi/wi	Profit	Weight	Density	
1	6	12	2	0	1	0	0
2	5	15	3	1	1	1	1
3	10	50	5	1	0	1	1
4	5	10	2	0	1	0	0
Weight Total				15	16	15	15
Profit Total				65	37	65	65

The optimal solution to this problem will provide a total profit of 65. Greedy by profit and density can achieve the optimal solution but greedy by weight cannot. In conclusion, greedy algorithms do not always provide optimal solutions.

III. PROBLEM ANALYSIS

The goal of the Forty-One game is to get more points than your opponent, either by getting a set of 41 or by closing your cards early so that your opponent cannot add to their points. The second strategy can be used when the value of the cards in hand can no longer increase because better cards have been discarded or when you believe your opponent has not finished preparing cards that have the same symbol.

Another challenge in the Forty-One card game is choosing a symbol which will then be used as a reference during the game. The challenge here is a little easier because it only allows 4 people in the game, as stated before in the section 2, the theory and method. You can determine the symbol by looking at the cards you have, whether there are cards with large values that can be a starting point for getting points. If you already have the Ace of a symbol then it is likely that it is better to look for that symbol, likewise if you have got one of the cards with a value of 10. If you already have two of the two cards, the chances are greater because you already control two of the six cards needed to win.

A. Greedy Elements Mapping

The initial step that needs to be taken to apply the Greedy algorithm is to map each algorithm element according to the game element. Greedy algorithm elements that will be used:

1. Candidate set: the set of cards in hand and the option to take cards from the deck or discard pile.
2. Solution set: the set of cards after drawing from one of the decks and after discarding one of the cards.
3. Solution function: function that determines whether the cards in your hand have exceeded your opponent's points or not.
4. Selection function: function that determines from which pile a card will be taken and determine what cards will be discarded after taking it.
5. Feasibility function: function that checks whether the card deck is empty or not, whether the card has been discarded, and whether the move violates any of the rules.
6. Objective function: the function of making the cards in your hand have the greatest possible chance of winning.

The element mapping above is based on the idea that the cards in hand do not have to total 41 to win the game so the objective function is not to maximize the number of cards. Apart from that, the selection function itself is a function that will be explored and changed more to find a strategy that is suitable for this game.

B. Solution Function Exploration

The solution function can also be changed to fit the results you want to obtain. The temporary solution function is a function to determine whether the number of points you have exceeds your opponent or not. This solution function means that it will estimate whether the cards in hand are better than the cards in the opponent's hand, if so then the player will close his cards and end the match. With this, players don't need to focus on the value 41 to win. If converted into a function to determine whether the number of points is worth 41 or not, the cards in hand will be considered a solution if and only if the total of the cards is worth 41.

C. Objective Function Exploration

The objective function can also be explored as needed. For example, if a player is in a situation with great risk and it would be fatal if they lost, the objective function can be modified into

a function to minimize the chance of losing. If the situation supports pursuing victory and there is no big risk in losing, then a better objective function is the function of maximizing the chances of winning.

D. Selection Function Exploration

This selection function plays a big role in determining whether the algorithm created will produce an optimal solution or not. For game Forty-One, there are several selection functions that can be used, each has its own strengths and weaknesses. Possible functions are as follows.

1. Greedy by Total Points

   Game Forty-One is won based on the largest total points therefore it makes sense to create a greedy strategy based on the total points. This strategy will calculate which symbols have the largest total points and will select those symbols to prioritize. Cards with different symbols and the highest value will be discarded so that the total value becomes greater. This strategy will take a card in the pile of cards discarded by another player if the card has the same symbol as the symbol determined by this strategy.

2. Greedy by Best Card

   To win the game Forty-One absolutely requires exactly 1 Ace and 3 of the cards with the number 10, Jack, Queen, or King. A card selection strategy can be made based on this information, where the weight of a card becomes greater if the card is one of the cards above. Cards with different symbols and the smallest value will be discarded, special cards with the largest symbols will not be discarded to open the option if you get another special card. Special cards with other symbols will only be discarded if 2 special cards with the same symbol are obtained, which means the chance of getting the number 41 is big enough to focus on just one symbol. Cards in other players' discard piles will be taken if they are special cards. Additionally, cards will be drawn from the drink card pile.

3. Greedy by Opponents' Discard

   In the Forty-One game there will be a struggle for a symbol which will determine whether the player can reach the value of 41 or not. Therefore, it is important to see what cards your opponents discard so you can choose which symbols you will not use. If one of the special card symbols has been discarded at least 2, this strategy will not choose that symbol as priority, unless the player has at least 2 special cards too.

4. Custom Greedy

   By combining selection functions, a more complete and broad strategy can be taken. This strategy will use the best card strategy first, if no special cards are found, the total points will be used temporarily. Apart from that, the opponent's discards will be used to determine whether the cards in hand still have a chance of reaching or approaching 41.

E. Selection Function Analysis

The selection functions that have been formulated will be analyzed and the best ones will be selected. From the analysis, there are two profiles that can be selected, namely when the player wants to play safe and just not be the least and when the player wants to play aggressively and become an absolute winner.

1. Greedy by Total Points

   This strategy will make it easier for players to avoid points becoming 0 or minus because they prioritize those with the largest total value. In this way, this strategy can be said to be 'low risk, low reward' because the chance of a final score of zero will be low but the chance of winning is also low.

2. Greedy by Best Card

   This strategy aims to obtain and control important cards so that you can win the match absolutely. This strategy is the opposite of the first strategy because this strategy is high risk high reward, the chance of getting a final score of 0 will be greater, but the chance of getting a high score is also greater.

3. Greedy by Opponents' Discard

   This strategy relies on the opponent to determine which cards will be prioritized, this can backfire, especially at the start of the game when the opponents may still not have made their choice. As a result, players become confused and cannot make the right decisions.

4. Custom Greedy

   With this strategy, the weaknesses and advantages of each of the strategies above can be minimized and maximized simultaneously.

F. Greedy Algorithm Application

After analyzing and considering which Greedy strategy is suitable to be implemented, an algorithm will be created according to the general scheme attached above. This algorithm is written so that the steps and considerations made at each step are clear. The Greedy algorithm elements that have been mapped above will be converted into pseudocode.

```
function greedy(C: candidate_set) -> solution_set
{ Return the solution of Forty-One card game with Greedy
Algorithm }

Declaration
    X: candidate
    S: solution_set

Algorithm
S <- {}
tempS <- {} // temporary solution
while (not SOLUSI(S)) and (C != {}) do
    if bestCard(C) and opponentDiscard(C) then
         tempS <- SELEKSI(C)
    else if totalPoint(C) and opponentDiscard(C) then
         tempS <- SELEKSI2(C)
    if LAYAK(S union {x}) then
    endif
endwhile

if SOLUSI(S) then
```

```
    return S
else
    write('There is no solution.')
endif
```

G. *Bonus Feature: The Implementation of Integer Knapsack Problem in Forty-One Card Game*

In the integer knapsack problem, the knapsack has a limit on the maximum weight that can be carried by the bag. If it is an analogy to the problem of the Forty-One playing card game, it can be assumed that the maximum weight of the bag is the maximum number of cards that a player can have, namely four cards, so the player must discard a card after taking a card from the pile of cards, then the cards they have on their hands do not exceed the limit. Each card has the same weight, namely one.

The integer knapsack problem determines the objective of a greedy algorithm based on weight, profit, and density. Since each card has the same weight, greedy based on weight will have no effect (it cannot optimize the value of the card) so greedy based on weight is not used in this problem. For the problem of selecting cards to form a maximum value combination, two objectives are used, namely greedy based on points and greedy based on card type. This is also the background and the knowledge base to the strategy that has been applied and analyzed above, namely Greedy by Total Points, Greedy by Best Card, Greedy by Opponents' Discard, and finally the Custom Greedy.

IV. Conclusion

The Greedy algorithm has many applications in the real-world problems, one of which is determining the strategy for the Forty-One card game. The algorithm strategy implemented and written in this paper is still in the analysis and illustration stage and has not yet been practically tested. However, from the analysis itself we can obtain the advantages and disadvantages of each strategy created. Greedy algorithms are usually chosen because they prioritize speed and efficiency over accuracy, so they choose to use approximation. If the Forty-One card game has no time limit for each turn, it is better to use another algorithm that is more precise and has guaranteed accuracy. However, in the case of the Forty-One card game, we often compete with the finishing time of the opposing player and are limited by a certain time in each turn we take. Therefore, we need an algorithm that is not only precise and accurate, but also simple and efficient, where the Greedy algorithm could be the right option.

On the other hand, we must note that Greedy algorithm does give us disadvantages such as Greedy does not guarantee optimal results because this algorithm focuses on efficiency, while the results are not always guaranteed to be perfect. The global optimum produced by Greedy is not necessarily the optimum (best) solution, it could be a sub-optimum or pseudo-optimum solution since we know that Greedy does not operate comprehensively on all possible solutions. Apart from that, there are other strategies to support victory (for example: probabilities) which are not discussed in this paper and other factors that might hinder winning (for example: the cards obtained each round are random).

Video Link at Youtube

https://youtu.be/BQY1PtDNOeA

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In preparing this paper, the author is aware that there are still many shortcomings, such as a lot of simplification of cases, lack of detailed data, and less complexity in preparing requirements and methods so that the use of Greedy algorithm is less than optimal. The author apologizes if there are any errors, both in the way of writing and the content of the paper that the author wrote. Finally, the author hopes that this paper can be used as a reference and developed further so that it can be useful for more people.

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PERNYATAAN

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