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Golf: Strategies for Success

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Golf: Strategies for success
A Senior Thesis by: Lauren Dunaway
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I. Introduction

From the time I was 3 or 4 years old, I would frequently go to my Grandma Margie's house when my parents were working. My grandma loved playing card games, everything from Go Fish to War. I recall being fascinated with the ways that cards worked. Each game was so unique. Some games were strategy based whereas some were based on luck. In some games the goal was to get as many cards as possible and in some the goal was to not have any cards. Many afternoons spent playing cards with her led to my loving card games and discovering all types of games from the classic Hearts to Spoons. On Christmas break in 2019, my grandparents taught me a new card game, *Golf*. Named after the popular sport, *Golf*, too, has the goal of having the lowest score of the table in order to win. The simple mathematics, highly strategic thinking, and quickly-paced play hooked me from the beginning.

When considering games that I could study for their strategy and mathematics, *Golf* was among the first games to pop into my head. *Golf* is quick to learn and play, which made it ideal to research. It is also built heavily upon mathematics, making it a great subject. After playing just one game with my thesis in mind, I came up with several things I could study in the game. I knew the best way to do this would be by creating a program that could record games I would play. My computer science background proved handy in doing this. Using Java, I created a program that would allow me to play a real life opponent and record the moves of our game. I was then able to see different scenarios and work out how certain play tactics would alter my win results.

In the following pages, I will explain the rules of *Golf* for those that might be unfamiliar with the game. Proceeding that, I will lay out several options that one may be

presented with throughout a *Golf* game and I will go in depth about some of the outcomes of different decisions. With the discoveries made, I will explain some strategies that can be taken in a game of *Golf*, including moves that should always be made when the opportunity arises. Similarly, I will explain moves that should always be avoided when possible.

II. Terminology

To help aid in understanding of *Golf*, I have included a brief terminology section.

I have included what I mean when I use certain terms.

Face: The face name associated with the card (i.e. seven of spades has face seven, Queen of hearts has face Queen)

Value: The numerical value associated with the card (i.e. Queen of hearts has value ten)

Face-Up: Refers to a card's face being shown, available for players to see

Face-Down: Refers to a card's face being down on the play surface, so players can't see

III. The Rules of *Golf*

As is true with many card games, the rules of *Golf* depend heavily on whom you ask. There are several slightly different variations of the game. For the purposes of this study, I will be explaining and using the rules that I learned how to play with. I will also be focusing on two player games of *Golf* since that is what I programmed and it is the most basic level of play.

Golf uses a standard deck of fifty-two playing cards (Jokers are not used during play). Someone will assume the role of dealer for the first round and the job will alternate between players after each round. The first player will shuffle and deal 6 cards to each player, face down. The remaining cards are placed in a face down draw deck in the middle of the players, with the first card being turned face up next to the draw pile. Players then arrange their cards, face down, in a random order with 2 rows of 3 cards. Each player will choose two random cards to flip over, with their faces showing. Players do this one at a time, one card each time, in turn order.

Starting with the non-dealing player, each player takes turns doing any of the following choices :

- a. A player may turn over a face-down card in their set of 6.
- b. A player may draw a card from the center draw pile. They may either place that card face up on top of the discard pile OR they may replace that card with a card in their set. If they swap the card for a card that was face down, they have the new card face up.

- c. In a similar fashion to drawing from the draw pile, a player may also draw the top card off the discard pile. They may swap that card for one in their set of 6, as done with one off the draw pile.

When a player turns their last card face up so that all 6 are face up, the other player gets one last turn and the round is over. Each game consists of nine “holes” (rounds). Players will keep score after every round, and the player with the lowest total score at the end of the nine rounds wins. Scoring is the most complicated part of the game, and it goes as follows:

- i. Aces are each worth negative one point
- ii. Kings are each worth zero points
- iii. Jacks and Queens are each worth ten points
- iv. Numbered cards are worth face value (i.e. a two of hearts is worth two points)
- v. A pair of any equal cards in the same column is worth zero points (i.e. two Aces in one column is worth zero points, two seven's in one column are worth zero points) (This rule always overrides the stated value of the card in i-iv)

Players count their score using the following rules, record after each round, and tally up their total at the end of the game.

III. Programming my opponent

I knew that in order to study different game scenarios in *Golf*, I needed a way to play many games rather quickly while also recording the moves to study later. I did this using Java as I previously mentioned. Not only did programming *Golf* give me the game and play recordings that I needed, but it also strengthened my understanding of the game's rules. As a programmer, I need to make sure the computer knows what it needs to do to let players execute a game, which means I need to know very well what it needs to do. I have included the code for the *Golf* program in the appendix of this study, and I will briefly explain what I have done in the code.

The program I wrote runs a game of golf between two human players. I did this mainly to record games for later study. Because it is very simple, it does not handle incorrect input. Thus, it assumes the players make the correct input. I used two classes in my program. A class in object-oriented programming is a structure that creates objects. There is a Game class that handles the logic of the game such as turns and actions that players can make. There is a Hand class which contains the data for each player's hand. That is, it contains card faces and suits. It also includes functions that can be used on the hand such as revealing or replacing a card, and finding the score of the hand at the end. The Card class contains the information of a single card in the game. It also has a function match that will compare the rank with another Card. The Deck class builds a list of cards that would be in the 52 card deck and contains functions like shuffle and draw. These come together to create the entire program. In the appendix I have included some records from the program of particularly interesting games that I used as I studied certain moves. These records made it easy to see where certain moves were made and how it affected a player's final score. The program saved me a lot of time as I did not have to hand record games I played.

IV. Beginning a game

Directly after the cards are dealt, each player is presented with their first decision of the game. Each player starts the game with flipping over two cards of their choice in their selection of six. There are essentially two options when it comes to which ones to flip. A player may turn over two cards in the same column or they may turn over two cards in two different columns.

While both of these have their benefits, there is one that is substantially smarter than the other.

From my experience, players typically choose to flip over two cards in the same column in order to see if their faces will be the same, which would cancel them out making that column worth zero points. This sounds like a good idea, as if they do match, that player suddenly has a significant point advantage. However, there are only 4 of each type of card per deck. So, say a player turns over their first card, and it is a 7 of hearts. There are only three other face 7 cards in the game. With 51 unknown cards left, there is only a 5.88% chance ($3/51$) that the other card in the same column would be a 7. While these odds aren't awful, they certainly aren't great.

If a player instead decides to turn over two cards in two different columns, there is obviously no chance that they would zero out being in different columns. However, assuming the cards the player turns over are differently faced, this creates two cards that can be matched with. That is a 12% chance ($6/50$) of getting a matching card in the first move. 12% is clearly better than 5.88%, making the decision of turning over two cards in two different columns a clear winner.

There is a chance that one of these cards may be in your opponent's hand, face-down. The chances of this being true are quite low. Since each player is dealt 6 cards, the likelihood of all 12 of them being different is approximately 1.6%. Figuring this out requires finding each probability per 12 cards. In most cases, a player won't know if their opponent has a card of the

same face. The only event in which they would know would be after they have already flipped at least one card before play. However, since only 2 cards are flipped at the beginning, there is a 66.66% chance ($\frac{2}{3}$) that if their opponent does have a card of the same face as them, they won't flip it over until after gameplay begins. There is also the possibility that a player has more than one card of a particular rank in their own beginning set of 6. It is 93.16% likely that this will happen. If a player does happen to have more than one of a rank in their set, there is an 80% chance that the player won't turn it over until after gameplay begins (i.e, if a player has two Queens, if they turn one up as part of their two initial flips, there is an 80% chance they won't turn over the second Queen until gameplay begins).

Because the chances of knowing if a player's opponent has the face card that the player turns up is low, it's a safe bet to assume that they do not and to proceed as if the other 3 are in the deck, or at the very least will be traded in to the discard pile to draw from. Thus, it is best to start a game by flipping over two cards in two different columns to open up a player's chances of matching cards together to zero out on points for any given column.

V. Gameplay

Now that both player's two cards are flipped over, the game can begin. I will proceed assuming that the player began the game with the first two cards they flipped being in separate columns. There is the question of what to do with a first turn. The options are flipping over another one of a player's 6 cards, taking the card off the top of the discard pile, or taking a new card off the top. Right off the bat, it is clear that a player should only take a card off the discard pile if it would be greatly beneficial to them. These situations primarily include the card matching one of their face up cards or the card being a low face. There is also the chance that the card in the discard pile might match an opponent's face up card, in which case it could be beneficial to take it to stop an opponent from getting it. I'll touch more on that later.

For a player's first turn, unless the discard pile has a beneficial card, there are the two options of drawing a card or flipping a card over. Recall that there is currently a 12% chance of a player turning over a matching card from the draw pile. If the player turns over a third card in the last face down column, this now increases the player's chances of getting a matching card to 18.75% (9/48) on their next turn. This doesn't have any immediate payout; however the higher chance of success on the next turn makes this a viable option. The second option of drawing a card is a good choice as well. Assuming a player has 2 differently faced cards flipped in different columns, there are at least 4 cards a player would want from a draw (one of their card matches, Ace and King). They may also deem some low faced face cards worth a take as well. I usually take cards for their face only if they are two or three. So this is potentially up to 6 faces a player is looking for. At best, a player and their opponent would not have any of these 6 cards in their hand. That would be a 45% (18/40) chance of drawing a needed card successfully. At worst, all of the opponent's cards are ones the player would need and every face down card the player has

is one the player would need. This would result in a 20% (8/40) chance of success. However, if the first turn is spent turning over a third card in a different column, this gives a player another face card out of the deck that would be beneficial to them. If with 2 cards flipped, there are 6 or so cards, with three turned over, there are now at least potentially 7 cards. This is a 52.5% (21/40) chance of success at best and a 30% (12/40) chance at worst. These chances are increased fairly significantly for the next turn a player would have.

The only real downside to flipping a third card over for a player's first turn is the possibility that a player might miss out on a beneficial card that was on top of the draw pile. However, if an opponent does turn over a good card after a player spends a turn flipping a card, there would still be plenty of desirable cards left in the deck for the player to obtain. Then there is the very real possibility that the first cards on the draw pile are high faced cards. For this reason, I think players should flip over a card in their last fully face-down column before drawing cards to give them the best shot at obtaining desirable cards to them. Of course, there is always the possibility that the opponent has all the Aces in their set of 6. This is drastically unlikely (the exact chance being $16/6497400$). For this reason, I'm going with decisions that would work best in most games where a majority of the desirable cards are in the draw pile.

Now I want to get back to the discard pile. As I mentioned, there is always the third option of drawing from the top of the discard pile. This would be the other option on a first turn that should be considered over flipping a third card in specific circumstances. One of these circumstances would be if the card on the top was a low faced card (Ace, King, 2). Later on I will touch on which cards are low enough to be taken instead of being left; however Aces, Kings, and 2's are always great cards to pick up. Another situation in which a card should be taken off the discard pile is if it matches one of your face-up cards. There are only 3 possible matches to a

given card you have face up, so once you see one, immediately take it and replace it with the other card in that column. Finally, the other option is if the card on top matches an opponent's face-up card. This can be a challenging decision whether to stop an opponent from matching a column if they have a high card to match (say a Queen) and the player would have to take the Queen himself to stop them from taking it to zero out the column.

When I am deciding whether to take a high card that an opponent needs there are a couple situations in which I always know what to do. The first is when I have an equally high card that I can replace the drawn card with to stop my opponent from matching a column. For example, if the card drawn is a Queen (ten points), my opponent needs a Queen to match one of theirs, and I have a Jack (ten points). In that case, I will swap the Queen for the Jack. That way, I'm not gaining any points and my opponent does not lose any points. I would do the same if I had a 9 or an 8. In situations where an opponent needs a high card and I have a medium faced card (5 to 7), I look at other factors to determine whether to make the swap. For example, if it is near the beginning of the game and I still have time to get rid of high cards, I would likely take the high card to stop my opponent from taking it. However, if it is near the end of the game and the opponent seems to be in the lead, I might just let them take their match to have a better chance at a lower score myself.

Another situation where it is obvious what to do is when an opponent would give a player a good card in exchange for them receiving a matching set. For example, if the opponent has a column with two face up cards, one being a high faced card and one being a low faced card (say a Queen and an Ace). If the player were to draw a Queen, it would benefit both players if they forfeited the Queen they drew. Then, the opponent would take it, giving the player an Ace in return after swapping it for the new Queen. Then the player can take the Ace. Similarly, the

player could do the same move if in exchange they would get a card that gave them a matching column set. While this isn't the perfect solution since the opponent will benefit from it, it usually ends up being better than not taking the beneficial card for himself.

With this, every player has a straightforward guide on how to play their first turn. To have the best chance at getting matching sets, players should turn over a card in their third face down column. The only reason they should not do this is if there is a more beneficial card to take from the top of the discard pile. If this is true, the player should flip over that third card on the soonest turn that they can where there is not a beneficial card on the discard pile.

From this point on, *Golf* is essentially filled with drawing cards in turn order and deciding whether to keep them or to discard them or taking cards off the discard pile. Players do always have the option to flip over more cards in their 6 (say a player has three cards flipped over, they could turn over a fourth as a turn). After turning a card in each column, this could seem like a pointless turn to take since there are at least 3 cards in your set you could match with. However, sometimes not knowing what a card is and swapping it with a drawn card can result in an unfortunate mistake. For example, if the player has a column with a Queen of hearts and a face-down card and they draw a 2 of spades. They might decide to replace the face-down card with the 2 of spades. In most cases, this would be a good move. However, there is some chance that the card they replaced it with might have been a Queen. In the event that was true, instead of having 0 points they would have 12, turning a seemingly smart move into a poor choice.

It always hurts when a player makes a swap that seems good and ends up being more detrimental than helpful. However, the chances of doing this are rather slim. The actual chances of it happening at any given point in the game vary. Let's consider if it happened on the first turn of the game. If the player has a face up Queen and a different card face up and their opponent has

two face up cards that are not Queens, then there is a 6.25% ($3/48$) chance that the card in the same column that is face down is also a Queen. As I mentioned, this chance would change depending on how many Queens have shown up at a certain point in the game and how many cards are left. Despite this, the chance will never be very high. Because of this, I do not suggest flipping over a card for a turn after the initial 3 are flipped solely for the sake of not making a swapping mistake. Since the chances are so low, the player's turn would be better spent drawing a card.

However there is also the bonus of flipping over more than 3 cards which would create more cards to match to. If you turn over say 4 cards, one column now has 2 cards revealed, which means matching to either card would result in a column score of zero. Unless a player is ending the game, they could only ever have 2 columns completely revealed. This could prove beneficial if they had, say, a 7 of diamonds and a Jack of spades in one column. Since both of these are high cards, this could greatly increase your chance of getting the column to equal zero. At best, they would have a 12.76% ($6/47$) chance of doing so instead of a 6.25% chance from just having one in the column face up. I wouldn't go as far as to say they should immediately turn over all their cards except one. That said, if the discard pile isn't turning up anything they need and there isn't a quick need to get rid of points, a turn spent flipping over a fourth or fifth card is not a waste of a turn. At worst, they would increase your chances of matching a card in the column and maybe miss out on an Ace at the top of the draw pile. At best, they might turn over a match and no longer have to worry about that column.

Throughout describing the best moves to make during gameplay, there have been instances of when a card should be taken. That is, it is helpful to know when a card is low-faced enough to swap for one of a player's hand and when a card is high-faced enough that it should

just be discarded. An Ace or a King is an obvious card to take and similarly, Queens, Jacks, and tens are obvious cards to get rid of. However some cards, like fours, threes, and even twos cause questioning over whether they are worth swapping. These questions also arise when there is a ten on the top of the discard pile that an opponent needs to match to a ten they have. Is it worth taking it to stop an opponent when the only cards a player could consider swapping it for are low-faced? With all these questions, I have come up with a way to know in most scenarios if a certain face of a card is worth taking/leaving.

The best way to break this up is by looking at the different scenarios in which a player can take a card. The main way a player can do that is by drawing a card off the top of the draw deck. Obviously, a player should never consider taking a card that is higher than any card they currently have unless it would benefit their opponent. In that case, they may choose to take it to stop their opponent. Some cards, however, are difficult to know whether to take. For example, a 5 of any suit. Face 5 cards are not great cards to have, however they aren't very high. In many cases, it would work to take the 5 and swap it for a high faced card a player has face-up, such as a Queen. A 5 is clearly better than a Queen. The only way in which this would hurt a player would be if there were no more 5's to be drawn and there were more Queens. Then they would potentially be stopping themselves from drawing a Queen in the future to zero the column out. However, keeping track of cards still in the draw deck can be very difficult, and not very fun to do. Because the goal of the game is to have the lowest amount of points possible, I would say the best move is to always replace high cards with cards lower in face, especially as the end of the game is nearing. A player doesn't want to be caught holding on to a Queen to match it just to be stuck with it at the end of the game.

A player could draw a face 7 card and the highest card they might have face up is an 8. This begs the question if a one point difference will really matter, especially with such high cards. However, unless the player knows there are more eights in the deck than sevens, they might as well use their turn to go down a point in score. Thus, a good rule of thumb is to always trade a drawn card from the deck for a face up card that is higher in face.

This then leads to questioning when to swap a drawn card for a face down card. Swapping a 6 for a face-up Queen is an easy positive choice. However, when a mid-faced card is drawn, it is hard to know if a player should swap it for a face down card they have. Again, it is impossible to know in every single situation the exact probabilities of switching their card for a face down and swapping it for a higher face, making it a good move. Because the location of a given card being in a certain location (opponent's set, the discard pile, or the draw pile), there is never an exact probability to know. However, we can consider what cards are in a 52 card deck to begin. We know we have the following, in order from lowest face to highest (with the last three being equal in face):

Ace King Two Three Four Five Six Seven Eight Nine Ten Jack Queen

We can see that face six cards are in the middle of the faces. So, with a perfect full set of 52 cards, there is a 46.15% chance ($24/52$) that a card will be lower than six, a 7.69% chance ($4/52$) that it will be higher than six, and a 46.15% chance ($24/52$) that it will be six. Even though these percentages are assuming a full deck, we can use these ranges to produce a moderately safe move when deciding to swap for a face down card. If the player draws a face six card, the chance that the face down card they will swap it for is lower than six can never be more than 46.15% ($24/52$). Similarly, if they draw a face three card, the highest possibility that the card they will swap it for will be lower than three is 23.07%, making this a decent move in most circumstances.

Based on this, when a card is drawn from the top of the draw pile, if there is a higher face up card they can swap it for (that isn't in a column with a matching card, of course), the player should take that move. If not, a player should likely avoid swapping out anything drawn that is higher than a seven for a face down card, and assess the likely risk for a face six or less. These rules can generally go for the card on top of the discard pile as well. Obviously a King, Ace, or even two would be a card to instantly take off the discard pile. However, a face four, five, or six may not immediately seem like a good move. However, if the game is nearing its end, a face four or five, and sometimes even six, might likely be lower than the face down card the player would swap it with. As I mentioned, there is no perfect answer to every situation, but based on a perfect full deck, we can assess the risk to some extent to determine which cards are worth taking.

The final important piece to playing a game of *Golf* is the end of the game. This happens when all of a player's cards are face-up. Once this is true, the opponent can take one last turn. Any cards of theirs after the last turn would stay in place and be turned face-up. Either player is capable of ending the game. More often than not, the player who ends the game is also the player who wins since they ended because they figured they had a low enough point amount. There are times that it is obvious that a player should end the game. For example, if they had a column with two Queens, a column with an Ace and a King, and a column with a five and a face-down card. If they draw another five, they would clearly replace the final face-down card with the five, giving them a score of negative one. However, many times it is challenging to know when to end the game. A challenging time could be if a player and their opponent each have one card left to turn over and the opponent's points total to five and the player's total to 4. The game is so close that if the player chooses to take a three and they end up getting a King, it will give the opponent a win. After many games like this, I have gotten a good idea of when a game should be ended.

As with any move in *Golf*, there are some times where it is obvious that a player should end the game. For example, if a player has 2 columns that equate to no points and they have a King in their last column and they turn over an Ace. They should replace their last card with this Ace, to end the game with a score of negative one. Any move to end the game that will give a player less than zero points is likely always a good move, unless the opponent happens to have less. In that event, the opponent is likely unbeatable anyways.

Over the *Golf* games I have observed and played, there are two common scenarios in which it can be difficult to know when to end the game. The first is when a player has significantly more cards turned over than their opponent, yet they might not be very low-faced cards. For example, say these were the two hands in the game, where * is a face down card.

Player:	Opponent:
4H 5S 3D	10C 7H QH
KS 2D *	* * *

In this event, if the player were to draw a low faced card, say an Ace of diamonds, this might not initially seem like a great move to end the game since they would end with a score of 13 and 13 is a high score for *Golf*. However, the opponent in this case has 3 high faced cards and 3 unknowns. The opponent at this point could only win if the game ended if they matched at least 2 of their columns. The best chance they have of this would be at the very beginning of the game, and even then that chance is only 0.47% likely. So, while the player wouldn't end with a great score, they would most likely score significantly higher than their opponent if they chose to end the game. I would always recommend doing this if a situation like this arises, since the only qualification to win is to have the least amount of points.

The other common situation that arises is when each player has one card left that is face-down and they both have the same scores, or are only a point off from each other. At this point, it is a battle for who happens to draw the best card first. It can be tempting in a situation like this to take a face three card, but that might not always be a good move and can lead quickly to a loss. Let's look at another example. Say the two hands were:

Player:	Opponent:
QH AD KD	JS AS AC
QS KH *	JD AH *

In this event, the players both have a current score of negative one. This is a case where whoever happens to draw the best card first wins. However, if a player draws a face two card, it could be challenging to know if they should use that as their last card. There is a chance that the opponent could then draw a King, giving them the win. However, in this particular case, keeping a two would likely be a good bet. Every Ace is in play and two Kings are. That leaves only two cards less than two, both of which are Kings. Now these cards could be deep in the draw or discard pile, or they could be one of the face-down cards. Assuming the last King is not the opponent's face down card, the best chance the player has of the opponent getting it would be a 5.26% chance. That is assuming the discard pile is empty and they are both in the full draw pile. In the event one of the Kings have been discarded in gameplay, that brings the percent lower, and if they have both been discarded, that brings it down to 0%. For each card in the discard pile that is not a King, the chances of the opponent drawing a King would increase slightly. That means the player has a 7.89% chance of having a tie with the opponent (if the opponent also draws a two) , or a 86.84% chance of winning with a two at best. In this exact case, a three wouldn't be a bad card to take either. There would be only a 13.15% chance that the opponent would end up with

something less than that. Each case varies based on what cards are spoken for and what the exact scores are currently, but the best bet in these situations is to take an Ace, King, two, or maybe a three the moment the player gets one and hope their opponent doesn't draw one first. Because *Golf* is a game of both strategy and luck, it's impossible to guarantee a win depending on the card taken, but taking these low cards gives the player a good chance.

VI. Conclusion

Golf is a card game made up of strategic moves and lucky draws. Despite the randomness of card draws, based on some simple probabilities, players have a guided set of smart moves that will help in their goal of winning. These suggestions won't always result in a win due to the random cards; however they will lead to a win in many cases. Players should always choose to turn over two cards in two different columns at the beginning of the game. For their first turn, players should turn over a card in the third column to give themselves the highest possible chance at drawing a match to one of those cards. From then on, players should focus on drawing cards and swapping out lower faced cards for higher ones currently in their hand. Players should also keep an eye out for card matches they might draw. If a player knows their opponent's hand, they will be able to prevent them from taking needed cards which might also give the player a better chance at winning. When the end of the game is near, the player who decides to end the game will likely win. Because of this, players should keep an eye out for a good time to end and make that final move whenever they will likely pull out ahead, whether that is with very few points or a higher (but less than their opponent) amount of points. Following these suggestions, a player will greatly increase their chance of winning any given round and game of *Golf*.

Appendix A

Java code for *Golf*

Main.java

```
import java.io.BufferedWriter;
import java.io.FileWriter;
import java.io.IOException;

public class Main {

    public static void main(String[] args) throws IOException {
        BufferedWriter writer = new BufferedWriter(new FileWriter("log.txt",true));
        writer.append("##### NEW GAME #####\n");
        Game game = new Game(writer);
        game.start();
        writer.close();
    }
}
```

Game.java

```
import java.io.BufferedWriter;
import java.io.IOException;
import java.util.ArrayList;
import java.util.Scanner;

public class Game {
    Deck drawPile;
    Deck discardPile;
    Hand p1;
    Hand p2;
    Scanner input;
    BufferedWriter writer;
    Game(BufferedWriter writer){
        this.writer = writer;
        drawPile = new Deck();
        discardPile = new Deck(new ArrayList<>());
        p1 = new Hand();
        p2 = new Hand();
        input = new Scanner(System.in);
    }

    public void start() throws IOException {
        System.out.println("Welcome to the game of Golf");
        System.out.println("To pick your card use the following guide:");
        this.printGuide();
        System.out.println("Dealing Cards");
        drawPile.shuffle();
        for (int i = 0; i < 6; i++) {
            p1.replace(i, drawPile.draw());
            p2.replace(i, drawPile.draw());
        }
    }
}
```



```

discardPile.place(drawPile.draw());

for(int i = 0; i < 2; i++){
    choseCardToFlip("Player 1",p1);
    choseCardToFlip("Player 2",p2);
}
boolean gameOver = false;
Hand[] hands = {p1,p2};
int t = 0;
Hand lastPlayer = null;
while(!gameOver){
    this.turn("Player " + (t+1), hands[t]);
    gameOver = hands[t].finished();
    lastPlayer = hands[t];
    t = (t+1)%hands.length;
}

System.out.println("LAST TURN!");

for (int i = 0; i < hands.length; i++) {
    if(hands[i] != lastPlayer){
        this.turn("Player " + (i+1), hands[i]);
    }
}
p1.reveal();
p2.reveal();
System.out.println(p1);
System.out.println("Player 1 Score: " + p1.score());
System.out.println();
System.out.println(p2);
System.out.println("Player 2 Score: " + p2.score());
log(p1.toString());
log("Player 1 Score: " + p1.score() + "\n");
log(p2.toString());
log("Player 2 Score: " + p2.score() + "\n");
}

private void debugPiles(){
    System.out.println("Draw: " + drawPile);
    System.out.println("Discard: " + discardPile);
}

private boolean turn(String player, Hand hand) throws IOException {
    boolean result = false;
    System.out.println();
    System.out.println(player + " Turn");
    System.out.println("Current Hand:");
    System.out.println(hand);
    System.out.println("[1] Draw a card from draw pile");
    System.out.println("[2] Take top card from discard pile " + "(" + discardPile.top().toString() + ")");
    log("Top card on discard: " + discardPile.top().toString() + "\n");
}

```

```

System.out.println("[3] Flip a card");
System.out.print(player+" >");
switch(input.nextInt()){
    case 1:
        Card drawn = drawPile.draw();
        System.out.println("Drew " + drawn.toString());
        log(player + " drew " + drawn + "\n");
        System.out.println("[1] Replace with card in Hand");
        System.out.println("[2] Discard");
        switch (input.nextInt()){
            case 1:
                discardPile.place(replaceCardInHand(player,hand,drawn));
                break;
            case 2:
                log(drawn + " discarded\n");
                discardPile.place(drawn);
                break;
        }
        System.out.println("new hand:\n"+hand);
        break;
    case 2:
        Card discard = discardPile.draw();
        log(player + " took " + discard + " from discard pile\n");
        discardPile.place(replaceCardInHand(player, hand, discard));
        System.out.println("new hand:\n"+hand);
        break;
    case 3:
        choseCardToFlip(player, hand);
        result = true;
        break;
    default:
        break;
}
log(player + " new hand:\n");
log(hand.toString() + "\n");
return result;
}

private void log(String str) throws IOException {
    this.writer.append(str);
}

private Card replaceCardInHand(String player, Hand hand, Card card) throws IOException {
    System.out.println(player + " choose a card to replace");
    System.out.print(player + " >");
    int chosen = input.nextInt();
    log(player + " replaced card " + chosen + " with " + card + "\n");
    return hand.replace(chosen,card,true);
}

private void choseCardToFlip(String player, Hand hand) throws IOException {

```

```

System.out.println(player + " choose a card to flip");
System.out.print(player + " >");
int chosen = input.nextInt();
boolean flipped = hand.flip(chosen);
while(!flipped){
    System.out.println("Choose a different card to flip");
    chosen = input.nextInt();
    flipped = hand.flip(chosen);
}
log(player + " flipped " + chosen + "\n");
log(hand + "\n");

System.out.println(player + " Hand:");
System.out.println(hand);
}

private void printGuide(){
    System.out.println("0,1,2");
    System.out.println("3,4,5");
}
}

```

Card.java

```

public class Card {
    private String suit;
    private String value;
    private int points;
    Card(int points, String value, String suit){
        this.suit = suit;
        this.value = value;
        this.points = points;
    }

    public boolean match(Card other){
        return this.value.equals(other.getValue());
    }

    public String getValue() {
        return value;
    }

    public int getPoints() {
        return points;
    }

    @Override
    public String toString() {
        return this.value + this.suit;
    }
}

```

Deck.java

```
import java.util.ArrayList;
import java.util.Collections;
import java.util.List;

public class Deck {
    final String[] values = {"A","2","3","4","5","6","7","8","9","T","J","Q","K"};
    final int[] points = {-1,2,3,4,5,6,7,8,9,10,10,10,0};
    final String[] suits = {"C","H","D","S"};
    private List<Card> cards;
    Deck(){
        cards = new ArrayList<>();
        for (String suit: suits) {
            for (int i = 0; i < values.length; i++) {
                Card c = new Card(points[i],values[i],suit);
                cards.add(c);
            }
        }
    }

    Deck(List<Card> cards){
        this.cards = cards;
    }

    public void shuffle(){
        int swaps = (int)(Math.random() * 200 + 500);
        for (int i = 0; i < swaps; i++) {
            int a = (int)(Math.random()*cards.size());
            int b = (int)(Math.random()*cards.size());
            Collections.swap(cards,a,b);
        }
    }

    public Card draw(){
        if(cards.size()==0){
            return null;
        }else{
            return cards.remove(cards.size()-1);
        }
    }

    public void place(Card card){
        cards.add(card);
    }

    public Card top(){
        return cards.get(cards.size()-1);
    }
}
```

```

public int size(){
    return cards.size();
}

@Override
public String toString() {
    StringBuilder result = new StringBuilder();
    result.append('{');
    for (int i = 0; i < cards.size(); i++) {
        result.append(cards.get(i).toString());
        if(i!=cards.size()-1) {
            result.append(',');
        }
    }
    result.append('}');
    return result.toString();
}
}

```

Hand.java

```

public class Hand {
    private Card[] cards;
    private boolean[] flipped;
    private int nFlipped;
    Hand(){
        cards = new Card[6];
        flipped = new boolean[6];
        nFlipped = 0;
    }

    public boolean flip(int index){
        boolean result = false;
        if((index >= 0 && index < 6) && flipped[index]==false){
            flipped[index] = true;
            result = true;
            nFlipped += 1;
        }
        return result;
    }

    public boolean finished(){
        return nFlipped == 6;
    }

    public int score(){
        int result = 0;
        for(int i = 0; i < 3; i++){
            if(!cards[i].match(cards[i+3])){
                result += cards[i].getPoints() + cards[i+3].getPoints();
            }
        }
    }
}

```

```

    }
    return result;
}

public Card replace(int index, Card card){
    return this.replace(index, card, false);
}

public Card replace(int index, Card card, boolean flip){
    Card result;
    if(index < 0 || index > 5){
        System.out.println("out of bounds");
        result = null;
    }else{
        result = cards[index];
        cards[index] = card;
        boolean prev = flipped[index];
        flipped[index] = flip;
        if(!prev && flip){
            nFlipped += 1;
        }
    }
    return result;
}

public void reveal(){
    for (int i = 0; i < flipped.length; i++) {
        flipped[i] = true;
    }
}

@Override
public String toString() {
    StringBuilder result = new StringBuilder();
    for (int i = 0; i < cards.length; i++) {
        if(flipped[i]){
            result.append(cards[i].toString());
        }else{
            result.append("--");
        }
        if(i == 2){
            result.append("\n");
        }else if(i != cards.length-1) {
            result.append(",");
        }
    }
    return result.toString() + "\n";
}
}

```

Appendix B

Example games recorded with program

Player 1 flipped 0

KD,--,--

--,--,--

Player 2 flipped 0

6C,--,--

--,--,--

Player 1 flipped 1

KD,3S,--

--,--,--

Player 2 flipped 3

6C,--,--

7D,--,--

Top card on discard: 2D

Player 1 took 2D from discard pile

Player 1 replaced card 2 with 2D

Player 1 new hand:

KD,3S,2D

--,--,--

Top card on discard: 4C

Player 2 flipped 1

6C,AD,--

7D,--,--

Player 2 new hand:

6C,AD,--

7D,--,--

Top card on discard: 4C

Player 1 drew 6D

6D discarded

Player 1 new hand:

KD,3S,2D

--,--,--

Top card on discard: 6D

Player 2 took 6D from discard pile
Player 2 replaced card 3 with 6D
Player 2 new hand:
6C,AD,--
6D,--,--

Top card on discard: 7D
Player 1 drew 6S
6S discarded
Player 1 new hand:
KD,3S,2D
--,--,--

Top card on discard: 6S
Player 2 drew 5S
5S discarded
Player 2 new hand:
6C,AD,--
6D,--,--

Top card on discard: 5S
Player 1 flipped 3
KD,3S,2D
8D,--,--

Player 1 new hand:
KD,3S,2D
8D,--,--

Top card on discard: 5S
Player 2 drew QD
QD discarded
Player 2 new hand:
6C,AD,--
6D,--,--

Top card on discard: QD
Player 1 drew JC
JC discarded
Player 1 new hand:

KD,3S,2D
8D,--,--

Top card on discard: JC
Player 2 drew 9H
9H discarded
Player 2 new hand:
6C,AD,--
6D,--,--

Top card on discard: 9H
Player 1 drew AC
Player 1 replaced card 3 with AC
Player 1 new hand:
KD,3S,2D
AC,--,--

Top card on discard: 8D
Player 2 drew 8H
8H discarded
Player 2 new hand:
6C,AD,--
6D,--,--

Top card on discard: 8H
Player 1 flipped 4
KD,3S,2D
AC,JH,--

Player 1 new hand:
KD,3S,2D
AC,JH,--

Top card on discard: 8H
Player 2 flipped 2
6C,AD,8S
6D,--,--

Player 2 new hand:
6C,AD,8S

6D,--,--

Top card on discard: 8H
Player 1 drew KC
Player 1 replaced card 4 with KC
Player 1 new hand:
KD,3S,2D
AC,KC,--

Top card on discard: JH
Player 2 drew 7S
Player 2 replaced card 2 with 7S
Player 2 new hand:
6C,AD,7S
6D,--,--

Top card on discard: 8S
Player 1 drew TD
TD discarded
Player 1 new hand:
KD,3S,2D
AC,KC,--

Top card on discard: TD
Player 2 drew 2C
Player 2 replaced card 2 with 2C
Player 2 new hand:
6C,AD,2C
6D,--,--

Top card on discard: 7S
Player 1 drew AS
Player 1 replaced card 1 with AS
Player 1 new hand:
KD,AS,2D
AC,KC,--

Top card on discard: 3S
Player 2 took 3S from discard pile
Player 2 replaced card 4 with 3S

Player 2 new hand:

6C,AD,2C

6D,3S,--

Top card on discard: 4H

Player 1 drew KH

Player 1 replaced card 5 with KH

Player 1 new hand:

KD,AS,2D

AC,KC,KH

Top card on discard: TS

Player 2 drew 7C

7C discarded

Player 2 new hand:

6C,AD,2C

6D,3S,--

KD,AS,2D

AC,KC,KH

Player 1 Score: 0

6C,AD,2C

6D,3S,4S

Player 2 Score: 8

NEW GAME

Player 1 flipped 0

QD,--,--

--,--,--

Player 2 flipped 0

TC,--,--

--,--,--

Player 1 flipped 2

QD,--,KD

--,--,--

Player 2 flipped 4

TC,--,--
--,JS,--

Top card on discard: 7H
Player 1 drew 8C
Player 1 replaced card 0 with 8C
Player 1 new hand:
8C,--,KD
--,--,--

Top card on discard: QD
Player 2 drew 8D
Player 2 replaced card 4 with 8D
Player 2 new hand:
TC,--,--
--,8D,--

Top card on discard: JS
Player 1 drew 7C
7C discarded
Player 1 new hand:
8C,--,KD
--,--,--

Top card on discard: 7C
Player 2 flipped 2
TC,--,KH
--,8D,--

Player 2 new hand:
TC,--,KH
--,8D,--

Top card on discard: 7C
Player 1 flipped 1
8C,9H,KD
--,--,--

Player 1 new hand:
8C,9H,KD

--,--,--

Top card on discard: 7C

Player 2 drew 5S

Player 2 replaced card 4 with 5S

Player 2 new hand:

TC,--,KH

--,5S,--

Top card on discard: 8D

Player 1 took 8D from discard pile

Player 1 replaced card 3 with 8D

Player 1 new hand:

8C,9H,KD

8D,--,--

Top card on discard: AC

Player 2 took AC from discard pile

Player 2 replaced card 5 with AC

Player 2 new hand:

TC,--,KH

--,5S,AC

Top card on discard: 4S

Player 1 took 4S from discard pile

Player 1 replaced card 1 with 4S

Player 1 new hand:

8C,4S,KD

8D,--,--

Top card on discard: 9H

Player 2 drew 9D

9D discarded

Player 2 new hand:

TC,--,KH

--,5S,AC

Top card on discard: 9D

Player 1 drew 7S

7S discarded

Player 1 new hand:

8C,4S,KD

8D,--,--

Top card on discard: 7S

Player 2 drew 3H

Player 2 replaced card 0 with 3H

Player 2 new hand:

3H,--,KH

--,5S,AC

Top card on discard: TC

Player 1 flipped 5

8C,4S,KD

8D,--,6D

Player 1 new hand:

8C,4S,KD

8D,--,6D

Top card on discard: TC

Player 2 drew 4D

Player 2 replaced card 4 with 4D

Player 2 new hand:

3H,--,KH

--,4D,AC

Top card on discard: 5S

Player 1 drew 2S

Player 1 replaced card 5 with 2S

Player 1 new hand:

8C,4S,KD

8D,--,2S

Top card on discard: 6D

Player 2 drew KC

Player 2 replaced card 3 with KC

Player 2 new hand:

3H,--,KH

KC,4D,AC

Top card on discard: 9C

Player 1 drew 2H

Player 1 replaced card 2 with 2H

Player 1 new hand:

8C,4S,2H

8D,--,2S

Top card on discard: KD

Player 2 took KD from discard pile

Player 2 replaced card 0 with KD

Player 2 new hand:

KD,--,KH

KC,4D,AC

Top card on discard: 3H

Player 1 drew KS

Player 1 replaced card 4 with KS

Player 1 new hand:

8C,4S,2H

8D,KS,2S

Top card on discard: AD

Player 2 took AD from discard pile

Player 2 replaced card 1 with AD

Player 2 new hand:

KD,AD,KH

KC,4D,AC

8C,4S,2H

8D,KS,2S

Player 1 Score: 4

KD,AD,KH

KC,4D,AC

Player 2 Score: 2

