BlackJack DealerBot

An interactive ROS enabled Bot which assists in playing BlackJack and cheats in a believable way

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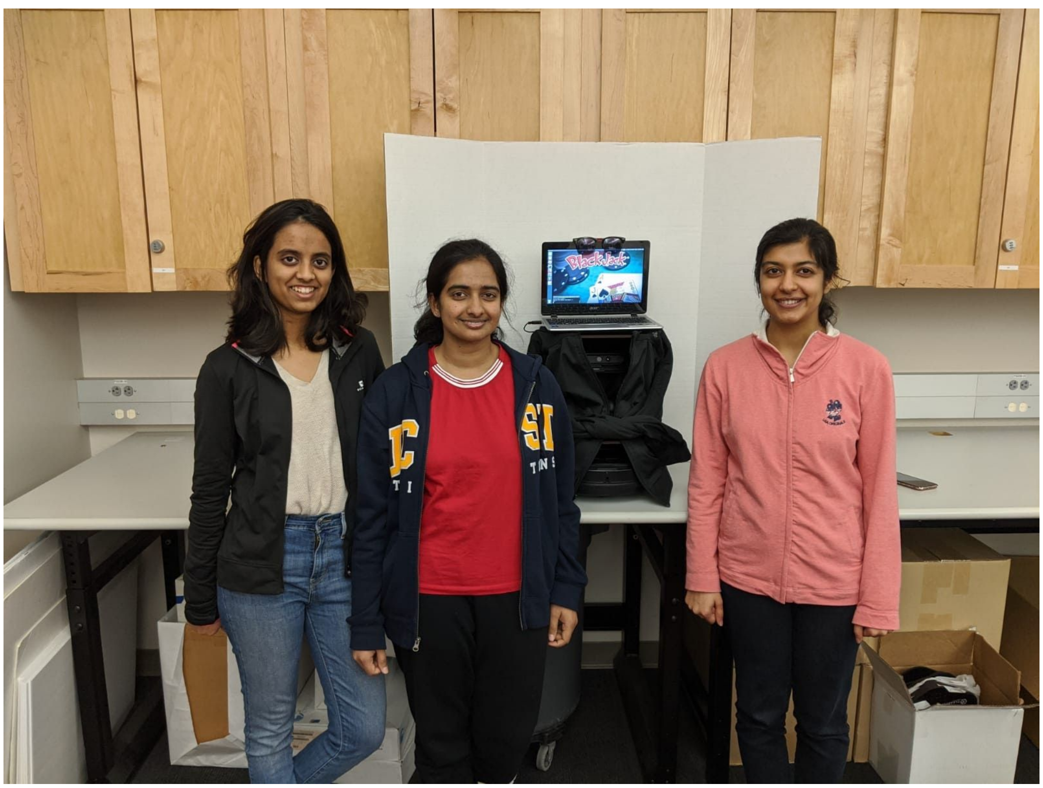
1- Jessica, Lead: Expressivity (Section 3.1.2), Comp Exam: Command Recognition [Section (3.1.3)]



Team Picture: From Left → Sai Jadhav, Sneha Kondur, DealerBot, Jessica

1. Executive Summary

The high cost of personnel and facilities has put a squeeze on the low end of live blackjack in recent years. Casinos simply cannot afford to pay dealers to cater to players who want to wager minimums of $1, $2 or $3 a hand. But there is still plenty of demand among beginners for inexpensive ways to play BlackJack. Hence there is a need for developing low-cost alternatives to live dealers while ensuring that the players receive the qualities of a human-dealer interaction. This project aims to mimic the human-dealer interaction methods and develop a robot which is capable of replacing the dealer. Much of the emphasis is on exploring the expectations and trust, the players have on the robot while they interact with it.

Section 2 gives a brief introduction to the aims and goals of this study. It describes in detail the major research questions of this study, which seek to explore two major ideas. The first being how effectively a robot can perform the task of an entertainer and facilitator in a card game. And the second exploring how humans trust (or don't) the robot that is dealing to them, in a situation where they cannot see all cards upfront, and if told that the robot has been deceiving them, how they respond.

Section 3 provides a detailed description of the technical approach used to accomplish our aims and goals. A high level diagram/graphic of the project components and an overall control architecture of how the robot senses, detects and aligns itself to the players is given. Further a Stimulus-response diagram for representing the robot-human behaviour is provided.

Section 4 showcases the quantitative and qualitative results and findings from the responses of the participants. A brief analysis is made on the ability of humans to understand the robot's speech, accuracy of the robot in understanding human speech, the level of trust participants had on the robot, finding trends in the participants response when they get to know that the robot has cheated and the entertaining capability of the robot.

Section 5 gives a brief discussion of the results and future research possibilities. The robot was found to be quite entertaining by the participants of the study, however, contrary to our team's expectations, most participants decided that they would not prefer to keep playing with the robot, once they found it was cheating. They did however, trust the robot to keep an accurate score, which was in accordance with our hypothesis. Future work for further study on the hypothesis by comparing trust upon a human dealer and a robot dealer is proposed.

2. Introduction

The project aims at implementing a robot that can facilitate a self-sufficient, autonomous blackjack dealer for a multi-player game, where it provides the players with virtual cards and can interact with them via speech. The robot is programmed to occasionally cheat in order to increase its chances of winning. The perceptions of humans on the robot's trustworthiness would be studied by analysing their reactions to the cheating robot. The participants would also be asked to rate the overall functioning and expressivity of the DealerBot.

There are numerous studies performed to understand the characteristics of a human robot interaction and the effects on a player's mind state, if the robot cheats while playing the game. Short et. al. [1] examines the relationship between the levels of social engagement and attributions of mental state while the players interact with a cheating robot in the game Rock-Paper-Scissors. The robot either plays fairly, or cheats in one of two ways. In the "verbal cheat" condition, the robot announces the wrong outcome on several rounds which it loses, declaring itself the winner. In the "action cheat" condition, the robot changes its gesture after seeing its opponent's play. It is found that the participants display a greater level of social engagement and make greater attributions of mental state when playing against the robot in the conditions in which it cheats.

Our project mainly aims at testing whether a robot could service as an interactive dealer, and keep people engaged while playing a fun card game that people usually associate with casinos. Primarily a task entrusted to a human requires physical handling of cards and a certain level of human-human interaction. In order to make a robot capable of performing this task, it is programmed to display cards using its own screen rather than having the robot to handle physical cards. The display was made interactive using multiple graphics and sound effects.

One of the interesting and curious research questions was to find out if people are aware of what cards the robot shows them and try to keep a tally of their scores themselves, or if they trust that the robot displays all scores correctly and without bias. We were further interested in understanding whether people inherently trust a robot to play fairly - that is, if they believe it can't cheat because it has been programmed that way - without realising that it could have been programmed to cheat.

To sum up, the major questions we wanted to answer were two fold:

- Could a robot be expressive enough to engage and retain the attention of humans in a recreational activity such as a card game?
- Would the humans playing with the robot inherently trust it to play fairly, and if they found that it cheated, would they be discouraged from playing further?

3. Methodology

3.1 Technical approach

The project has the backbone of the underlying blackjack game that starts once the number of players has been specified. The cards are selected randomly from a deck that is maintained and kept for the entirety of one complete run of the game. Each time a new card is given to a player, the display screen that shows all the open cards and the current scores of the players is displayed. Also, during each player's turn, sound commands and voice recognition is used to ask the player its next move, get the next move from the player, and play the game accordingly. Between any two players' turns the robot moves to find the next player so it can begin its turn. And finally it orients to the middle of the group to display and announce the results.

Once the initial cards have been dealt, for each player's turn, the robot follows the following steps. It moves to find the next player until it detects a human at close range using point clouds, if the game specifies that a player should be found and their turn should begin, then the robot stops in front of that player and starts their turn. Within that turn, until either the player's score is 21 or above or the player responds with a "stand" or "stay" command, the robot tells that player their score and asks them for their next response. Then it takes in the response from the voice recognition, and after each response, updates the scores and checks the conditions again to check whether the current turn continues. Once the turn ends, it moves to find the next player and repeats for each player.

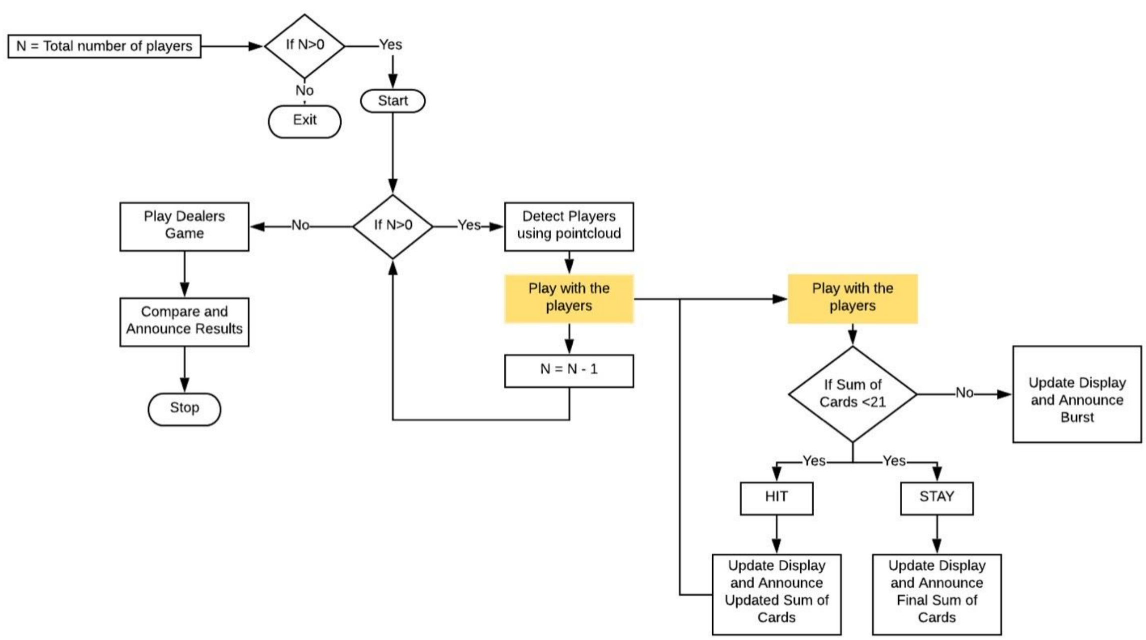


Figure 1. High Level overview

After each player is done playing, the robot turns towards the middle of the group using the information about the number of players, and conducts the dealer's turn. At the end of the play, each player's score is compared to the dealer's and the results are calculated. Then, the robot displays all the final scores and announces the results, ending the game.

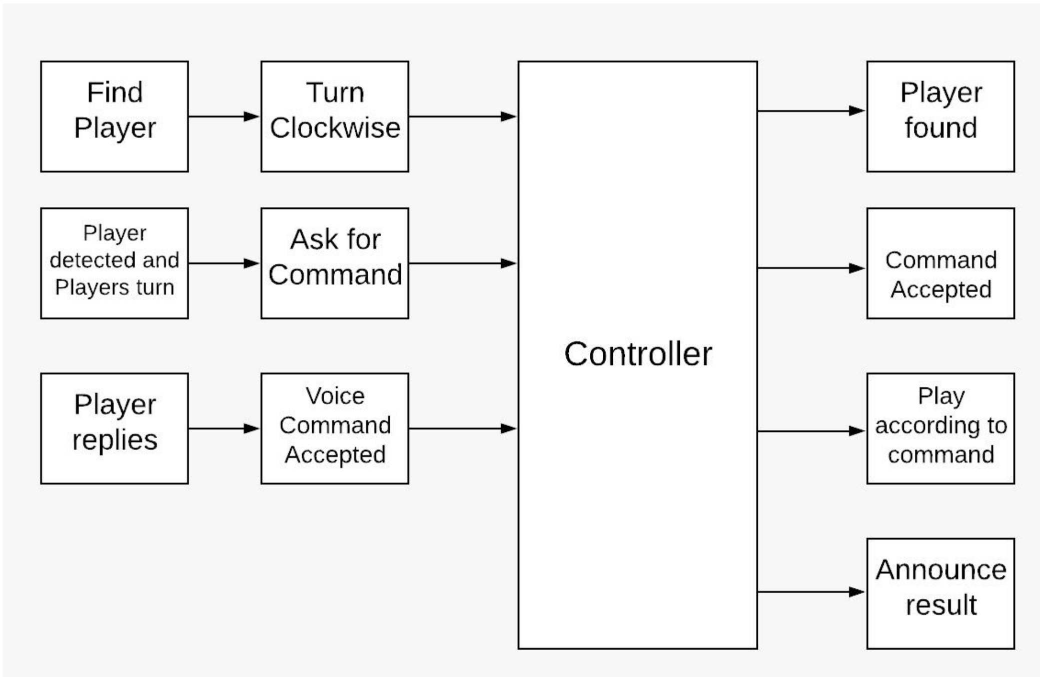


Figure 2. Control stimulus diagram

Each technical section has been described below:

3.1.1 Blackjack game algorithm (Lead: Sai Jadhav)

The blackjack game is played between the dealer and one or more players. The dealer deals two cards each to every player. the dealer is also dealt two cards, normally one up (exposed) and one down (hidden). The dealer then draws cards from a randomly shuffled deck until the player tells him to stop. Once all the players have completed their hands, it is the dealer's turn to draw cards for himself. In the end, each player compares his score with the dealer. The winner between a player and the dealer is the one who has a score less than 22 and nearest to 21. If at any point the score crosses 21, the player/dealer busts.

The following are the important steps in the game:

- Hit: Draw a card randomly from the deck and remove it from the deck. Add the card to the players deck of cards.
- Stay: Stop drawing cards for that player.
- Burst: If the score >21, the player or dealer loses automatically.

The rules or basics of the game are as follows:

- All cards from 2 to 10 have their own respective values.
- High cards ie K, Q, and J have a face value of 10.
- Ace or A has a face value of 1.
- The dealer is forced to hit until he reaches a least of 17. After that he can choose to hit or stay.

Card	A	2	3	4	5	6	7	8	9	10	K	Q	J
Value	1	2	3	4	5	6	7	8	9	10	10	10	10

There are 3 main phases to the game:

Start:

- The dealer randomly deals 2 cards to each player. All the players cards are put face up
- Then the dealer deals two cards to himself, out of which one is hidden and one is revealed.

Middle:

- The player decides to hit or stay.
- If the score crosses 21 the player busts.
- After each player has played, the dealer reveals his hidden card and then decides to hit or stay according to his score or till he busts.

End:

- If the player exceeds a sum of 21 ("busts"); the player loses, even if the dealer also exceeds 21.
- If the dealer exceeds 21 ("busts") and the player does not; the player wins.
- If the player attains a final sum higher than the dealer and does not bust; the player wins.
- If both dealer and player receive a blackjack or any other hands with the same sum, no one wins.

Algorithm:

We will maintain a global deck of cards. The drawing of cards will be done from this deck.

Deck = {A, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, J, Q, K} *4

function Hit (player):

```
        card = randomly choose card from Deck
        remove card from deck
        player.score += value[card]

Start:

        For p in players:
                Hit(p)
                Hit(p)
        For dealer:
                Hit(dealer)
                Hit(dealer)

        For p in players
                If p.score<21:
                        Hit or Stay?
                Else:
                        The player has BUST
        For the dealer:
                While dealer.score<17:
                        Hit
                While dealer.score<21:
                        Hit or Stay?
                        If dealer.score>21:
                                The dealer has BUST
        If dealer has BUST:
                For p in players:
                        If p.score<=21:
                                Player WIN
                        Else:
                                Player LOSE
        Else:
                For p in players:
                        If p.score < dealer.score:
                                Player LOSE
                        Else if p.score > dealer.score:
                                Player WIN
                        Else:
                                TIE
End.
```

Cheating:

The Dealerbot is not an ordinary robot. It is a smart robot which cheats to win! After the dealer crosses the score of 17 and has a choice of hit or stay, the robot tactically chooses cards from the deck such that it will get a score greater than the other players but still less than 22.

```
function Cheat():
m = max(valid players scores)
for cards in Deck:
        if dealer.score + value[card] >= m and dealer.score + value[card] < 22:
                dealer.score += value[card]
                break
```

The dealer can still BUST or not find a card which will fetch a score greater than the top player. So the cheating appears very discrete and is not easily caught.

3.1.2 Expressivity: Sound play & effects and aligning to players (Lead: Jessica)

Sound play: We used the sound_play library for all the sound produced by the robot. This included asking a player to “hit” or “stay”, announcing the scores for the players and the various sound effects like drum roll and applause at the appropriate stages to increase the engagement with players.

Aligning to players: For this task we used two major packages: Point Cloud Library to detect the players and geometry_msgs to issue command velocity messages to the turtlebot. We created a subscriber to subscribe to the topic “camera/depth/points” and a publisher to publish cmd_vel messages to the topic “cmd_vel_mux/input/teleop”.

Since the DealerBot is basically a desktop robot and would only turn to align to each player during their turn, we only used angular motion in this project. The robot would be aligned to the middle of the group of players at the start of the game, while it distributes the initial cards, and then would conduct each player’s turn from left to right. At the end, it would again align to the middle of the group to conduct the dealer’s play and finally announce the results.

Since the subscriber to the ‘points’ topic would continuously get input, we tied it with the game using condition variables that would toggle between whether a player was detected, and whether it was a certain player’s turn or not (Figure 4). Only when the ongoing game expects there to be a turn going on and a player is detected by the camera, does the turtlebot stop turning to align with the player.

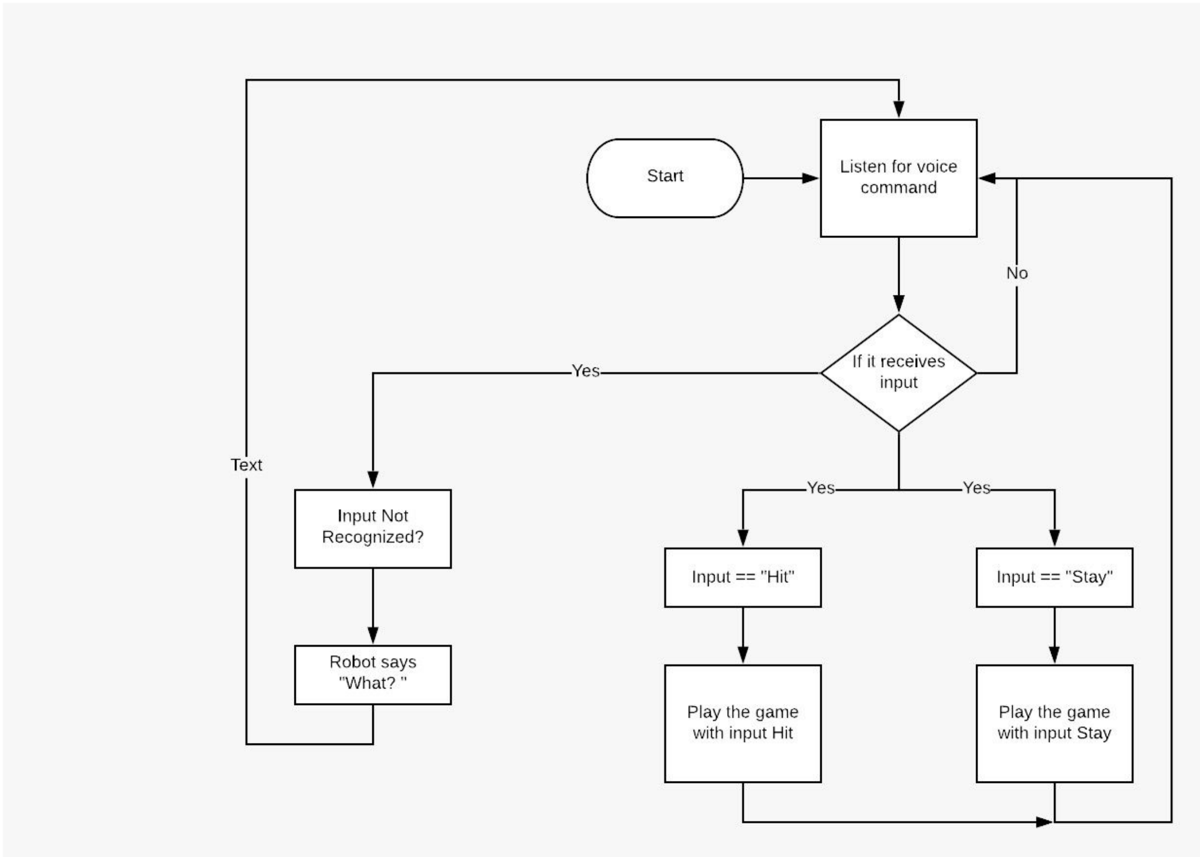


Figure 3. Controller diagram for voice command recognition

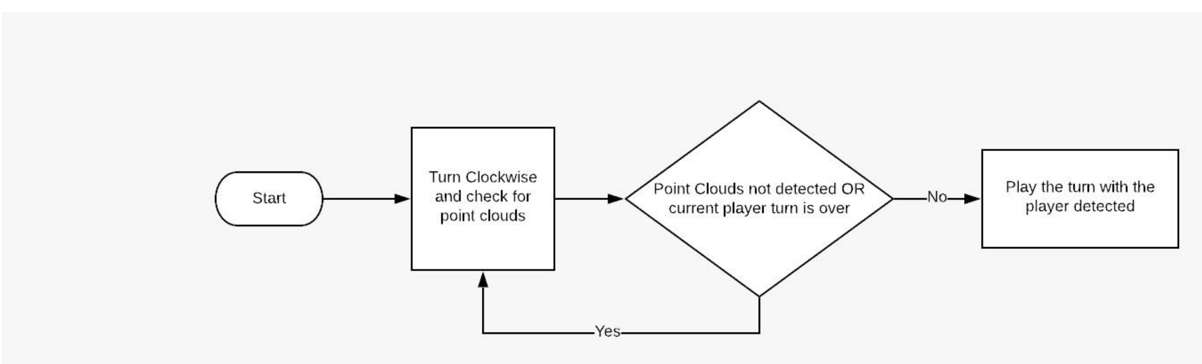


Figure 4. Controller diagram for player detection and alignment

3.1.3 Command recognition (Lead: Jessica, Comp Exam)

Instead of asking the players to type in their choice of command (hit or stay) at each stage during their turn, we used voice recognition to ease the play and usage of the DealerBot.

For voice recognition, we used the 'pocketsphinx' library and created our own dictionary of words that a player could use while playing: "Hit" to continue playing and "stay" or "stand" to stop at the current score.We used this package with our own dictionary of words, we created a separate launch file that took as input our customized corpus of words, and used it in parallel with our primary game, so that the voice commands could be published to the topic "recognizer/output" continuously. To use the voice commands with the game we created a subscriber to the topic. In the callback function for this subscriber, we specified what action to take for each of the commands given by the player.

To ensure that the robot would only take those actions for a player when a turn is going on, and to avoid any extraneous voice commands being recognized by the robot, we used condition variables such that the callback function would only take the appropriate action ("hit" or "stay") during the player's turn, once the robot finished asking for the input from the player (Figure 3).

3.1.4 Visual Display of the Scoreboard (Lead: Sneha Kondur)

A dealer's task in a Blackjack game requires physical handling of cards and a certain level of human-human interaction. In order to make a robot capable of performing the same task, it is programmed to display cards using its own screen rather than having the robot to handle physical cards. The display was developed using a tkinter module which is a standard Python interface to create Graphical user interfaces.

The display GUI must contain the list of cards present with the players and the dealer, just like how the blackjack table displays all cards. Further, if the sum of cards present with each player and the dealer are displayed, it would be more convenient and avoid the extra hassle of calculating every time. This also provides a chance for understanding if the players blindly believe the sum displayed or they recalculate it and check to validate the displayed scores. With these points in mind, the layout and design of the score board was designed.

Initially, the dealer opens only one card and keeps the second card closed until the dealers plays its turn as shown in figure 5.

Fig 5: Display board until the Dealers turn hides the dealers second card.

It's only after all the players have played the game, that the dealer plays its turn. While it plays its turn, it reveals the second card and updates the scoreboard appropriately as shown in figure 6.

Fig 6: Dealer reveals the hidden card and updates its score on the scoreboard..

To bring this functionality and provide a constant update system for the scores, we have used the publisher-subscriber functionality in ROS. The values of the global variables which contain the cards of players and dealer are published on a ros topic "Chatter". The display function subscribes to the same ros topic and updates the scoreboard. Further various widgets in tkinter such as labels, frames etc were explored to design the display. The multi-player game requires the dashboard to be adaptive to the number of players. In order to make the placement of the cards and score in the space available in a full screen mode without the use of scroll option needed an adaptive algorithm to calculate the positions and sizes of the labels required for display.

3.2 Human-centric work

The main objective of the project was to create a Dealerbot which can function in a manner similar to a human dealer and might be better. Other than the basic goal that the players should have fun while playing this game, there were a few other research questions which we hoped to answer in this project. The whole project is based on effective communication between the robot and the player. It is very important for the robot to be able to convey what it is doing and how the game is proceeding through speech. The basic research questions we had were based on effective communication between the player and the robot. How easy or difficult is it to speak to the robot and understand what the robot is saying to you? We wanted to experiment with the different aspects that can control the effectiveness of this exchange of dialogue between the robot and the player. Those aspects involved the diverse ways in which each person was talking, the sensors with which the robot is capturing data and other environmental factors which we cannot control.

Another important aspect of our human focused study was to see how humans react to a robot who cheats. What effect does that attribute bring about on the way humans perceive the robot? This is a very vast topic of research and has a lot of scope for the point of view of human studies. We studied how trusting people are of a robot dealer using two aspects: whether they actively kept a tally of scores instead of relying on what the robot displayed, and how they responded after learning how the robot had been cheating.

3.2.1 Methodology

A. Overview

The participants were brought in, and explained the basic rules of Blackjack and how it is played. Then they were asked to play with the DealerBot in groups of 1, 2 or 3, making sure that each participant got to play the game and interact with the robot multiple times. Also, we made sure that each player witnessed at least once the different win-lose scenarios, to get a full range of the robot's expressivity in different cases.

Once a participant had successfully played multiple games without any help from anyone other than the robot, they were asked to fill out the first 7 questions of our questionnaire. Once they filled those out, they were informed that the robot had been cheating during the dealer's play, and then they were asked to fill out the 8th question as well. This process was followed for each participant.

The questionnaire:

1. How entertaining was the experience of playing with the robot?
   1 Not at all 2 3 4 5 Very entertaining

2. How accurately did the robot detect your position?
   1 Not at all   2   3   4   5 Very accurately

3. How was the clarity of the robot's speech?
   1 Not at all   2   3   4   5 Very clear

4. How well does the robot listen and interpret your words?
   1 Not at all   2   3   4   5 Very well

5. Were you as a player keeping a track of your cards sum?
   Yes   No

6. Did you trust the robot completely on the scores displayed?
   Yes   No

7. Did you think the robot(Dealer) played the game in a fair way?
   Yes   No

8. Given the new information provided by the organizers, would you like to play again?
   Yes   No

B. Participants

The participants were all between 20-30 years of age and roughly equally distributed between male and female. We made sure to explain the rules of Blackjack equally to all of them so that there would be no bias when checking if they realised if the dealer was cheating or not.

C. Protocol

- Make sure the robot is charged and all the sensors are working fine. This is to make sure that the participants can participate in the study without any sensor failures and other glitches. Hence testing the robot once before the study is always a good practice.
- Bring participants in the room. Explain the overview of the study and walk them through the experiment. This involves explaining the game blackjack to all the participants so that there is uniformity between all participants.
- Form groups or ask each participant to play individually.
- Conduct the experiment. Start playing the game. Other than how the game is played, the players won't have any other information about how the robot is playing or what to expect.
- As soon as the game is finished, give the feedback sheet to the participants and ask for their reviews. The players won't still be told that the robot was cheating. Only when the

players reach the last questions (which talks about cheating) will the players be told that the robot was winning because it was cheating. The players can then answer the last question. Take the form back from the participants.
- Thank the participants for their time.
- Charge the robot in the meantime. This is to ensure that the study is not halted because of low battery.

D. Measures

Understanding Robot speech: In an usual case, the robot can see what the dealer is doing and so the player is well aware about the status of the game. But in our case, since everything is proceeding in a virtual manner, it is hard to know what the state is at any given moment. So the dealer bot should voice out the actions it is doing and keep all the players in the loop. An effective speech is characterized by the following qualities:

- Clarity
- Correct pauses
- Proper annotations
- Audible

Accuracy of the robot in interpreting your speech: Since conversations are two way, in addition to speaking, the robot should also be able to interpret the speech of the participant correctly. The participants will be asked rate the robot's capability to understand speech based on:

- How convenient was it to speak with the robot?
- How efficiently does the robot interpret your speech?
- How frequently do you need to repeat what you said?

There are a lot of factors which are involved here. The quality of the microphone is the biggest one. Other than that, the accent of the person, the pitch, clarity, ambient noise etc. It is very difficult to manage all these things and hence we wouldn't be expecting good results in this section.

Entertainment through funny sounds and displays: The main goal of this game is for the participants to have fun. To make the experience more entertaining, we have included funny sounds like clapping to congratulate the winner and a sad sound to console the loser. Here we are trying to test the overall experience of the players in terms of entertainment. Because at the end of the day, according to our hypothesis, the player will come back if he feels the robot/game was fun.

To engage the players, we have made an interesting display. The display shows the image of a black jack game and is supposed to attract people to want to come and play; as opposed to a black screen/terminal. We are also displaying the scores of each player and updating it timely to keep the player engrossed in the game. All these factors will be tested for entertainment after the person plays the game.

Trusting the robot: There is a certain level of trust that we are expecting from each player. We are asking them to trust that the robot knows how to play and be fair. The robot is the dealer and is responsible for the major part of the game like drawing cards, adding scores etc. We wanted to see how far the player trusts the robot in carrying out these actions effectively. This was testing through the following questions?

- Does the player maintain its own score and tally that with what the robot is telling? Or does he/she blindly follow the robot?
- Does the player think the robot is playing in a fair manner (since it's a virtual game which can be looked at as a black box and we don't know what is happening internally in this black box)?

Cheating: This is the most interesting part of our project. Making a robot play a game is common. But giving the robot the tools to cheat and try to achieve its goal which is winning, is an interesting concept to experiment. Cheating gives the robot an intelligence factor, and might make it seem more worthy as a player to the humans. We hypothesize that the cheating will give the robot an edge which will make the game more interesting to play.

- Do the participants perceive the cheating behavior dealerbot as an intelligent move and attribute more mental state to the dealerbot in this condition?

We had kept the cheating quality of the robot a secret and only after playing the game a couple of times, the participants were asked this question: "Did you notice anything unusual about the dealerbot's behavior?" After being aware that the robot was cheating, we wanted to see whether the participants would be interested to play with a cheating robot.

- Does the cheating attribute of the robot make the game more challenging or do the players feel offended and not want to play anymore?

3.2 Robot-centric work

Human detection: The robot needs to understand the placement of humans in front of it. Using this information, the robot will be able to correctly orient itself with respect to the player. Correct orientation is important for the player to understand that the actions of the robot are directed towards him/her. This was tested by placing the players at different angles from the robot and taking feedback from the players. The robot's movement was tested for a dynamic number of players ranging from 1 to 4, by placing each player wherever he wanted.

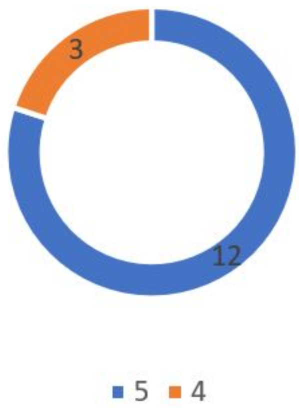
Game play: The robot should be able to perform the role of the dealer perfectly by understanding and playing the game like a dealer would. We will test the robot by playing a variety of different games leading to different situations in the game. Based on the scores, the robot should also be able to cheat effectively and win. 3 games were played in each group and the scores were tested using human supervision.

Speech understanding and human interaction: The robot will ask each player if he wants to hit or not. The player can give responses like "hit me", "out" or "don't hit me". The robot should correctly understand whether it should give a new card or not. The whole game is dependent on this. This was tested by saying sentences which had the required words in them in different environments like the lab, chez bob room, common hanging area.

4. Results

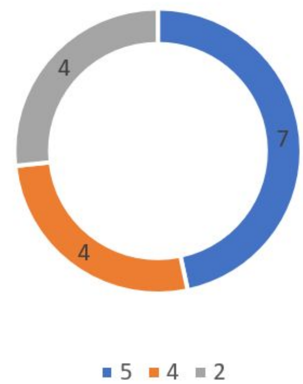
We asked a total of 15 participants to play blackjack with our dealerbot. The protocol mentioned in the previous section was followed. After playing multiple games with the robot, the participants were asked to fill a questionnaire having multiple questions. The participants were still not told that the robot was cheating. After answering the questions, the participants were informed about the robot's cheating nature. They were then asked questions about the cheating attribute of the robot. Following were the results we obtained:

Understanding Robot speech:



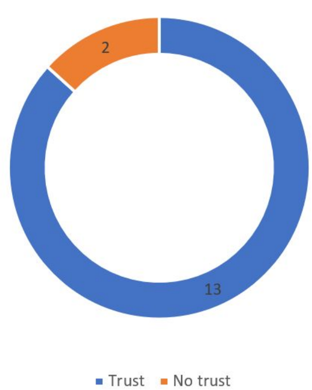
12 out of 15 partipants gave a score of 5 for the robot's speech.

Accuracy of the robot in understanding human speech:



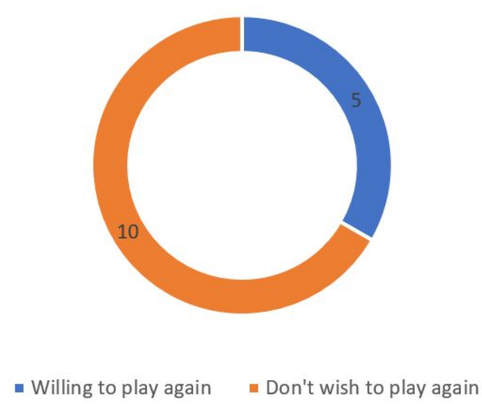
Because of noisy surroundings and poor quality microphone, the results of the robot trying to understand human speech were not that great. Only 7 participants gave a high score of 5 while 4 participants gave a score of 4 and the rest gave a score of 2.

Trusting the robot:



86% of the participants trusted the robot blindly and had no suspicions of it cheating. 13 out of 15 participants did not keep a tally of their score and were dependent on the robot to tell them their score.

Cheating:



As opposed to our hypothesis, 66.66% of the participants did not wish to play with the robot once the found out that the robot was cheating. The other 33.33% found the robot more interesting and wanted to play more.

Entertainment:

All the participants were very content and happy after playing the game. All of the players gave a score of 5 and seemed to have a lot of fun.

Challenges:

The biggest challenge was the communication between the robot and the player. Some aspects in this resulted in success while some in failure. The challenge of removing external noise from human speech was not overcome which resulted in unsatisfactory results. They are mentioned in the success and failure section. To maintain uniformity, all players were explained the game beforehand. The robot initially was detecting random points in space, and was stopping because it thought that it was a player. To overcome this challenge, the robot was designed to detect players only within a certain range of itself.

Successes:

The project was a success overall. The things which worked fantastically were understanding what the robot was saying, the entertaining display and sounds and cheating the players. The point cloud detection system was used to detect the presence of a hum in front of the robot. The system worked beautifully and the robot was able to stop exactly facing the current player. The players were satisfied with the alignment and there was no confusion between the players as to who the robot was speaking to.

Failures:

The biggest failure of the project was interpreting human speech. The robots dictionary was limited to the words which were useful in the game like hit, stay etc. But the quality of the microphone was not great. Also because of ambient noise, the robot was picking up words even when the player hadn't said anything. This sometimes left the participants confused and frustrated.

5. Discussion and Future Work

Before conducting the study our team hypothesized that the humans would not inherently suspect the robot, perhaps because humans generally tend to trust the written word - and since the code behind the game is unchanging during the play. And it is evident from the results that hardly any of the participants thought to suspect the robot of even not keeping their scores correctly, let alone suspect it of actually cheating in card play! Most participants didn't think to keep track of their scores during their turn, even though that is generally something people do intuitively while playing such games.

So this part our study actually met our expectations and ran in accordance with our hypothesis - that people would inherently trust the robot as the dealer and not suspect foul play. While our robot's cheating was quite subtle and not as obvious as in the case of [1] it is possible to interpret that the results obtained were because of this subtlety. However there are still two factors that support our hypothesis: 1. That each participant played multiple games and also saw and heard how often the others lost to the dealer - even after seeing the dealer win by cheating for multiple games, they did not think the robot could be cheating, and 2. Just the fact that participants did not even try to ensure the scores announced and displayed by the robot, matched the actual scores shows that they did not suspect any cheating at all.

One of the results that was unexpected however, was how a majority of the participants reported that they would not want to play with the robot again after finding out that it was programmed to cheat, despite the high ratings they gave it for being entertaining! This did not align with our expectations, which were that people would still be willing to play against the cheating robot if they found it entertaining enough. This could perhaps be indicative of human psychology, and how people do not like to lose!

The participants rated robot's expressivity in terms of speech and aligning to the players as high, overall. Even though the robot's voice was monotonous and lacked intonation, it seemed to serve the purpose well enough for the task at hand. However, the command recognition aspect of the robot's interaction got pretty low ratings, primarily because the microphone often picked up on random noise from the environment and interpreted it as one or the other command, often before the participant had a chance to decide!

Future work in this project could look into comparing subtle signs of cheating to more obvious ones and try to find a level of how obviously a robot needs to be cheating for people to realise. Another comparison study between a human dealer that cheats in a similar way as the DealerBot could help analyse if cheating in card games is difficult to detect regardless of whether the dealer is a robot or not. These could help refine the hypothesis presented in this study and provide appropriate support/contradiction needed to study it carefully.

References

[1] Short, Elaine & Hart, Justin & Vu, Michelle & Scassellati, Brian. (2010). No fair!! An interaction with a cheating robot. 5th ACM/IEEE International Conference on Human-Robot Interaction, HRI 2010. 219-226. 10.1145/1734454.1734546.