ECE 445 SP23
Project Proposal
Autonomous Card Dealer

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1. Introduction

a. Problem

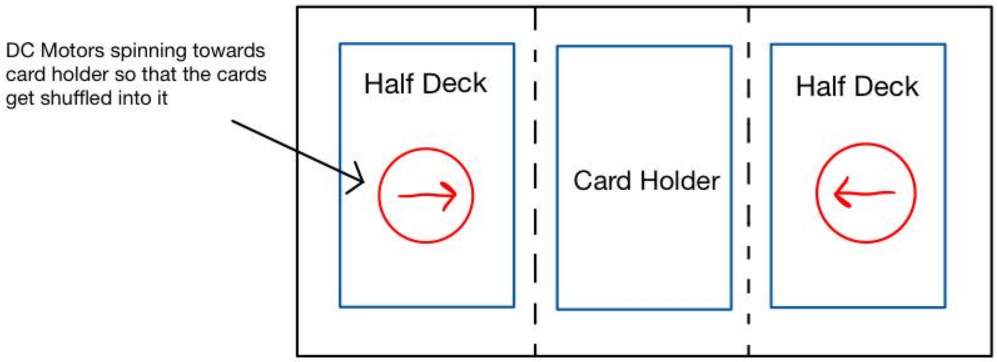
We all love card games, whether we are just playing casually with our friends or going to the casino. To name a few: Poker, Literature, Blackjack, Kings Corner, etc. Our goal is to create a fair card shuffling and distribution system in which the gameplay is smooth, effortless and eliminates the possibility of cheating. To add complexity, our group plans on implementing programmable game modes including and/or not limited to the ones named above. In these cases, we plan on programming the bot to deal cards to the players and set up the card game playing field.

b. Solution

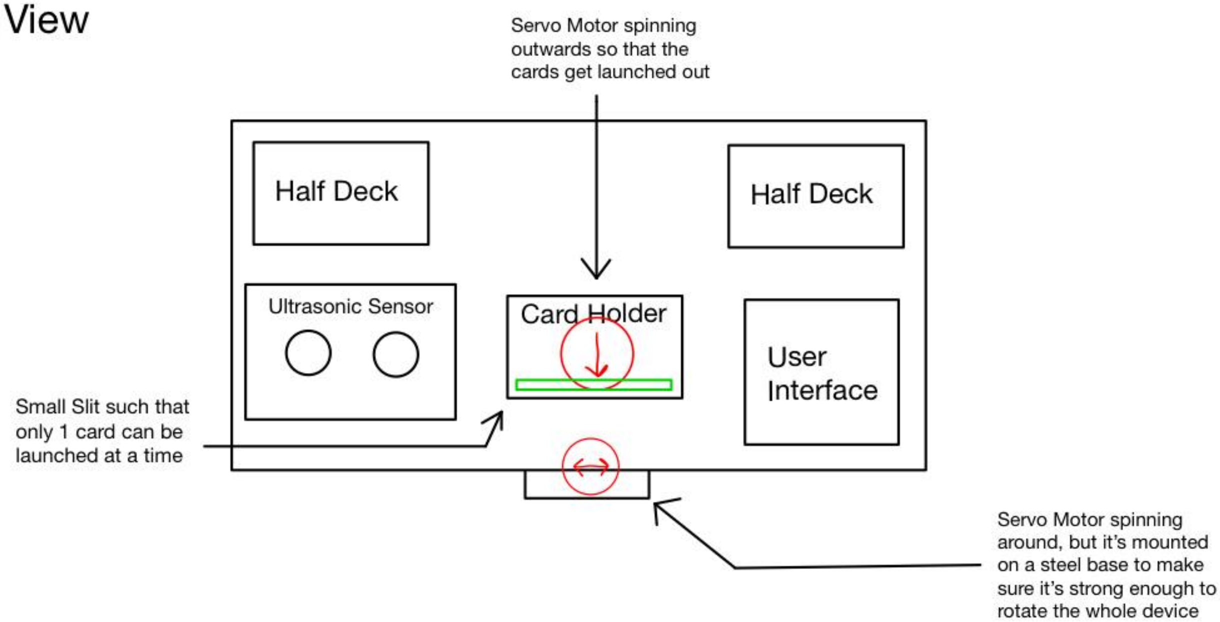
At a high level, we want to make the card game playing process more effortless and fair by replacing the dealer with a device. There are a few different subsystems of this project including the card shuffler, card dealer/distributor, and the user interface. The card shuffler allows the games to be more fair because it gets rid of human error that is often present with shuffling. The card distributor would basically replace the dealer by being able to rotate and shoot out cards to certain locations on the board. The user interface for this would be some kind of buttons that allows the user to control turning the device on and off, the number of players, the game mode, and starting/pausing the game, etc. This will solve the problems of current human dealers by making the whole process a lot more fair.

c. Visual Aid

Top View



Front View



d. High-level requirements list

a. Shuffle a set of cards evenly

i. Given any two sub-decks, the shuffling system shall perform one riffle shuffle. The result of the riffle shuffle shall be a deck of cards that are aligned and ready to be distributed. No card left behind.

ii. One test that our group plans to perform and test the riffle shuffle mechanism involves two sub-decks. i.e. *13 in-ascending-order cards Spades suited and 13 in-ascending-order cards Hearts suited*. The test will be noted as a **SUCCESS** if the result of the shuffling mechanism is shuffled any order of *As-Ah-2s-2h-3s-3h-4s-4h-5s-5h-6s-6h-7s-7h -8s-8h-9s-9h-Ts-Th-Js-J-Qs-Qh-Ks-Kh*. The test will be noted as a **FAILURE** if the resulting deck does not include all of the cards (some cards were left behind). We will analyze the effective-ness of the mechanism by comparing the order of the sub-decks before and the resulting pile of cards after the card shuffle is done.

b. Distribute the cards to the players and Set up playing field

i. Given an aligned and ready to be distributed deck of cards, the distribution system shall perform a dealing mechanism. The dealing mechanism shall pick up the cards one at a time and deal the card towards its intended trajectory. This 'dealing' action is performed until the deck has been depleted.

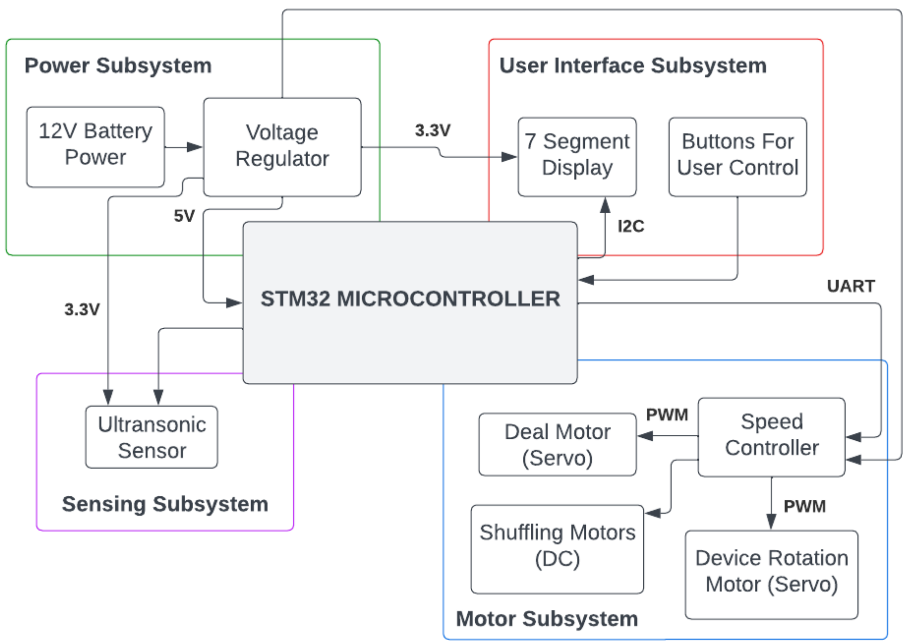
ii. The first test that our group plans to perform in order to test the card distribution system involves one deck of unshuffled cards and preset modes. i.e. number of players = 2, and game mode = evenly distributed amongst all players. The test will be noted as a **SUCCESS** if the number of cards dealt to each player is the same (26 each). The test will be noted as a **FAILURE** if not all cards are dealt OR if the number of cards dealt to each player is **NOT** the same. The distribution system shall rotate to a preset 'next' angular position, stop rotating, and deal a card. The system shall continue to perform this act for all preset 'next' angular positions (0,90,180,270) until the deck is depleted. Our group plans on generating more tests that involve various number of players (4,8) which are restricted by the game mode. Overall, this system can be tested visually by checking that the cards that are on the board have been distributed correctly and in the right order.

c. A functioning user interface with a display and buttons for parameter adjustment

i. Our goal is to abstract the device to work on multiple game modes and various numbers of players. The user interface shall involve 4 buttons. On/Off, Start/Pause, toggle number of players, and toggle game mode. It will also have a 7-segment display that shows the user the current setting for number of players, and game mode (numbered). This high level requirement is software heavy, given that the various game modes restrict the number of players. This, in turn, will impact how the deck is dealt. The test will be noted as a **SUCCESS** if the device deals the correct piles of cards to the correct number of players for a given game mode and num_players. The test will be noted as a **FAILURE** if the dealing sequence fails to match the request of the user. Test each of the buttons to make sure they are performing as expected and updating the displayed game settings correctly.

2. Design

a. Block Diagram



b. Subsystem Overview

Note: For the subsystems described below, we will be using an STM32F4 to interface between all of them in our device.

Power Subsystem:

The function of this system is to power all of the other subsystems in our device. It will be powered by a 12V battery and have 5V and 3.3V voltage regulators in order to make sure the microcontroller, servo motors, range finder, and 7-segment display are powered sufficiently.

User Interface Subsystem:

The function of this subsystem is to allow the user to be able to have control over our device. The user will be able to select the number of players and the game mode, and either shuffle or deal the cards through clicking buttons. The current game mode and number of players will be shown on the 7-segment display. The buttons will indicate what values to change or begin displaying on the 7-segment display which will receive instructions from the microcontroller through I2C.

Sensing Subsystem:

The purpose of this subsystem is to correctly identify how far away each player is from the device in order to ensure that the cards are dealt close to the players on the table. This will be done by collecting readings from an ultrasonic sensor such that when a sound wave hits a player, the device knows roughly where to deal the card. This information will then be used to adjust the speed of the servo motor in charge of launching the cards detailed further below to ensure it lands closer to the player on the table.

Motor Subsystem:

The purpose of this subsystem is to control the motors for the various functions that we need to perform. There will be 4 DC motors (12V) that will run with a constant speed to handle the shuffling mechanism, 1 servo motor (5V) that will be used to distribute the cards by launching them out of our device, and 1 servo motor (5V) to rotate the device the correct amount when dealing to each player (using PID control and an encoder). This subsystem will contain a PWM speed controller that communicates to the microcontroller through UART to power the servo motors accordingly.

c. Subsystem Requirements

Power Subsystem:

- Must be battery powered and rechargeable
- Must provide a stable 12 ± 0.1V and support up to 2A of current drawn.
- Must contain 5V and 3.3V regulators (possibly 6V) to provide overcurrent/voltage, undervoltage, and short-circuit protection

User Interface Subsystem:

- 7-Segment Display must be able to indicate number of players and game mode (by number)
- 7-Segment Display will communicate with microcontroller through I2C
- 7-Segment Display operation voltage must be 5V
- Must have buttons to change current game mode and number of players
- Must have buttons to initiate shuffle or deal process

Sensing Subsystem:

- Ultrasonic sensor must be mounted on device such that the waves hit the people and bounce back
- Ultrasonic sensor must get accurate readings so that the device will know when to start/stop dealing cards
- We want to make sure that the ultrasonic sensor can get readings from at least 2 meters
- We want the measure angle for this sensor to be around 10-15 degrees wide which is typical for inexpensive ultrasonic sensors
- The operating voltage must be 5V

Motor Subsystem:

- Dealing and rotation servo motors must have an operating voltage of 4.8-6.0V
- Rotation servo motor must have enough torque (>60 oz-in) to rotate the device,
- Rotation servo must be able to have at least 180 degrees of freedom
- Dealing servo motor needs at least 55.54 oz-in of torque in order to successfully launch a typical bicycle card (weighs roughly 100-150g)
- Shuffling DC motors must have an operating voltage of 12V
- Shuffling DC motor again must be able to output at least 40 oz-in of torque in order to shuffle the cards

d. Tolerance Analysis

Identify an aspect of your design that poses a risk to successful completion of the project. Demonstrate the feasibility of this component through mathematical analysis or simulation.

The most difficult part of this project will be distributing the cards in such a way that they go the right distance and angle to the player without the cards being flipped or revealed. Error in this distribution of the cards can occur for various reasons including false measurements from the ultrasonic sensor, friction from the device platform, air resistance while the cards are traveling, the dealing motor not having enough torque/power to distribute the cards a long distance, and the slit not being the correct length to which it will only allow 1 card to go through it. Now to show the feasibility of all of the potential problems we might have:

Risks:

1. False measurements from the ultrasonic sensor
   - In order to combat this problem, we plan to mount the ultrasonic sensor in a straightforward direction so that every player can be detected by the sensor.
   - We also will do heavy testing to make sure that our ultrasonic sensor is outputting valid results by testing repeatedly with objects to determine their distance.
   - We will also do a simulation from objects of various lengths away to determine the maximum distance that our ultrasonic sensor is able to deal with accurately.
2. Friction from the device platform
   - In order to maintain the integrity of the card deck that is being used, the motors used to traject one card at a time shall be tuned to ensure that the friction between the cards and the device are not harmful to any given card in the deck.
3. Air resistance while cards are traveling through the air
   - To address this, we will simulate launches at various predicted distances using the following equation: $d = v_0\sqrt{\frac{2h}{g}}$ where v_0 is the initial velocity, h is initial height of the card, and g is the force of gravity. Since v_0 is dependent on the torque of the motor, we will use the following equation to calculate $v_0 = \frac{2\tau r}{m(R)}$: where τ is the applied torque, r is the radius of the wheel, m is the weight of the playing card, and R is the radial distance between the center of the wheel and the point of launch for the card (r+h, where h is the thickness of a playing card, typically 0.17-0.24mm). When launching at the various

predicted distances, we will measure the error and account for it in future launches through developing a lookup table with offsets for different distance ranges.

4. The dealing motor not having enough torque/power to distribute the cards a long distance
   - We will initially test our servo motor to see if it provides enough torque to push the card and a certain specified distance. However, if that does not work as planned, we have a backup plan in mind, in which we will have the servo motor simply push a card one at a time through the slit to another small platform with a DC motor powered through a PWM pin on our microcontroller that launches the card immediately.
5. The slit not being the correct length to which it will only allow a single card through
   - The dimensions of a card are 64 mm by 89 mm by 0.17 mm to 0.24 mm thick. Using this knowledge, we know that the actual slit has to be wider than the 64 mm measurement, but it doesn't matter a whole lot what the width of the slit is because as long as it's over ~67 mm the card will fit through it. As for the height, this is the more important measurement, we want to make sure only a single card can go through at a time. Since we know that the size of a card can be anywhere from 0.17 mm to 0.24 mm thick, we need the height of the slit to be approximately 0.27 mm, this will give enough room for the card to squeeze through. At the same time, we would need a minimum of 0.34 mm to fit two cards through, so 0.27 mm is a good height to choose.

3. Ethics and Safety

In terms of the ethics of this project, we mainly chose to follow the IEEE Code of Ethics [1]. The main purpose of this project is to prevent cheating and make card games more fair by eliminating the role of a dealer. It makes the game fair by allowing the machine to take care of anything outside of actually playing the game.

1. *IEEE Code of Ethics:* To uphold the highest standards of integrity, responsible behavior, and ethical conduct in professional activities.
   a. To ensure the health, safety, and welfare of anyone who may use the card dealer we are developing, we will make sure to thoroughly test each of our components for proper functionality.

   b. As our project is quite mechanical, we will also frequently meet the Machine Shop Technicians to make sure none of the mechanical components or our design can prove hazardous to a user, or if any uncertainties surface during the development of our project.
   c. Our team will also meet with expertise (Teaching Assistants, Professors, etc.) and accept any constructive criticisms of our project.
2. *IEEE Code of Ethics:* To treat all persons fairly and with respect, to not engage in harassment or discrimination, and to avoid injuring others.
   a. To ensure proper teamwork etiquette, our team shall practice frequent and efficient communication via the following method: Discord servers with TA (Nikhil Arora) and text message group chats. Documentation and designs related to the project SHALL be shared virtually on a Google Drive to ensure ease of use and accessibility and physically on lab notebooks. This allows our team to keep track of the whereabouts of the project and have a running log of the progress the team has made.
3. *IEEE Code of Ethics:* To strive to ensure this code is upheld by colleagues and co-workers.
   a. To ensure this code is upheld by colleagues and co-workers, our group has decided to schedule a weekly meeting to discuss any violations of the code of ethics that may surface throughout the semester. If any matters are brought up, we will discuss them with our TA and/or the professor.

In regards to the safety and regulations in this project:

1. For each of the motors used to rotate the base, shuffle the deck, and traject a given card, the housing for the cards and wire harness SHALL be protected from the following events: (1) wire twists and entanglements (2) cards 'accidentally' falling in between 2 moving parts. Given that the project is mechanical movement heavy, it is important to consider (1) ease of use (2) limiting system failure due to moving and rotating parts (3) noninvasive to any given card deck that is to be operated on. The system shall have a kill switch (ON-OFF) button to ensure that all power is cut when prompted.
2. When launching the cards in the players' directions, it is important to send a 'safe' amount of power that ensures no-injury to the player. Too little power, and the dealer system will be useless. Too much power, and the dealer system may cause injury to the users. The direction and speed of the card trajectory SHOULD be consistent and predictable in order to minimize the chances of injury to the user(s).

3. Given that the device holds electronic components, it is important to ensure that the enclosures and housings can keep the electronic hardware safe. At the minimum, our device's electronic housings will protect the electronics from liquid spillage and wire entanglement.
4. Since ultrasonic sensors produce such high frequency signals, having too much exposure to these noises can damage your hearing. We shall set a limit on the use of the ultrasonic sensor by only turning it on when the device is in "DEALER MODE ONE"

4. References

[1] "IEEE Code of Ethics." *IEEE*, June 2020, https://www.ieee.org/about/corporate/governance/p7-8.html