TruShuffle

Amirali Eghbal — aeghbal@sfu.ca
Daniel Istifanus — distifan@sfu.ca
James Lin — jhlin@sfu.ca
Kiel Henkelman — khenkelm@sfu.ca

July 13, 2023

Dr. Micheal Hegedus
Simon Fraser University
Burnaby Campus
Applied Science Building, 9872

Dear Dr. Hegedus,

I am writing to submit the Design Specifications for the ongoing Combined Shuffler and Dealer project, TruShuffle, as per your request. Enclosed is a comprehensive document outlining the project's design specifications, selected parts and components and assembly methods for the development of TruShuffle, an innovative card shuffler and dealer.

This document will outline the physical parts, design specifications and required parts, as well as some simple electronics setups and software design. Overall this document, although not final, should give a good overview of how we will create this product.

On behalf of the team, we would like to thank you in advance for your review of our project and document as well as the continued advising in the process of bringing the TruShuffle into reality.

Please let the team know of any questions or concerns that you have about this document or the project overall, and we will respond to the best of our abilities. We look forward to your continued support of TruShuffle and will continue working hard to make it a reality.

Yours Sincerely,

Chief Financial Officer
James Lin

Design Specifications

TruShuffle Combined Shuffler and Dealer

Course: ENSC 405W

Company Number: 11
Date: July 13, 2023

Project Authors:

Amirali Eghbal (COO)
Daniel Istifanus (CCO)
James Lin (CFO)
Kiel Henkelman (CEO)

0 Abstract

This document presents the design specifications for TruShuffle, an innovative card shuffler and dealer. TruShuffle aims to introduce pioneering techniques that facilitate more efficient shuffling, dealing and sorting processes.

This includes a detailed look at the mechanical systems and how they will be implemented, along with alternative options if current designs run into roadblocks. There will also be a general overview of the electronics being used to control the TruShuffle system.

The successful outcome of this project holds the potential to revolutionize card gaming by eliminating the prevalent issues of inadequate shuffling and dealing mechanisms, consequently safeguarding cards from damage.

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4 Glossary

Table 1: Glossary

Term	**Definition**
UI	User Interface
Deal	Proffering a player or players a card or cards
Dealer	Person (or mechanism) that deals
Cut	Separating a deck into two or more separate decks
Hand	The cards a player is holding
PCB	Printed Circuit Board
Sleeved	Card placed in a protective holder (usually clear plastic)
Riffle Shuffle	A technique of shuffling cards where the deck is separated into two halves which are interleaved together

Overhand Shuffle	A technique of shuffling cards where one or several cards are stripped from the top of the deck into the non-dominant hand repeatedly
Deck	A complete collection of cards used for a particular game
Servo motor	A small motor that operates with PWM signal
Stepper motor	A small motor that has discrete positions to rest in, usually 200
PWM	Pulse-width modulation

5 Version History

This document is unversioned as it was created in a continuous process using Google Docs in advance of the deadline. The first and final version was created between July 12 and July 13, 2023.

6 Approvals

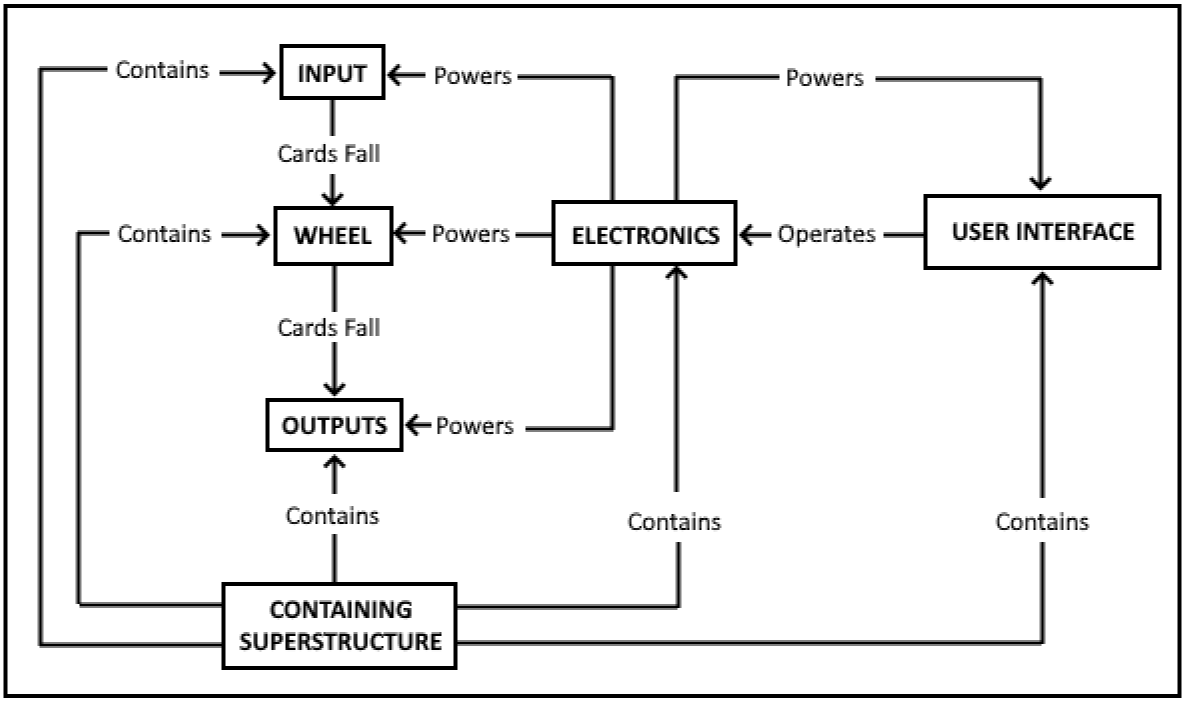
This document has been reviewed and approved by the TruShuffle Company and provides the initial design specifications for the TruShuffle device currently in development.

7 Introduction

Playing cards are widely used in games due to their ability to introduce randomness and diversity. The standard 52-card deck has remained popular throughout history for its affordability and versatility. Shuffling and dealing cards are crucial steps in various games, and proficiency in these skills is important. However, shuffling can slow down gameplay and be challenging for some. Overhand shuffling lacks randomness and can be exploited for cheating[1]. Mechanical shufflers exist but have drawbacks such as card damage, jamming, and high cost[2]. We aim to design a robust mechanical shuffler to ensure randomness, prevent cheating, reduce card damage, and enhance gameplay speed.

To accomplish this, TruShuffle is a system which will take input of a deck of cards, drop them into a wheel of cards, and selectively drop them into various outputs, depending on the mode selected. This could be for sorting or shuffling, and will be able to handle various cards, not just playing cards, as well as sleeved cards and decks of varying sizes. Below is a block diagram of the entire system.

Figure 1: Introductory Flow Chart



8 Background

Playing cards are rectangular paper rectangles coated in plastic, providing resistance to damage while being susceptible to wear over time. Standard decks are widely accessible and affordable, but specialized decks tailored for specific games, such as Magic: The Gathering, can carry a hefty price tag, averaging around $250 CAD for competitive decks. In some cases, cards may be protected with sleeves, adding an extra layer of safeguarding but complicating the shuffling process.

Shuffling is the act of randomizing the arrangement of playing cards. Various shuffling techniques exist, including the Riffle Shuffle, Overhand Shuffle, Casino Wash, and mechanical card shuffling machines. Each method differs in complexity and effectiveness, requiring a specific number of repetitions to achieve a desired level of randomness. For instance, a Riffle Shuffle typically necessitates seven shuffles to be considered truly random[3], while an Overhand Shuffle would require a staggering 10,000 shuffles to reach the same level of randomness[4].

Automatic shufflers and dealers are available, catering to different needs and price points. Consumer-grade automatic shufflers typically focus on performing the Riffle Shuffle, but their aggressive rubbing and squeezing motion can potentially damage cards, making them unsuitable for higher-quality or more expensive decks[5][6]. In contrast, casino-grade shufflers effectively shuffle cards while preserving their integrity, but they come at a significant cost, with even the simplest models priced in the thousands of dollars range[7][8]. Although casino shufflers are more efficient, they are relatively slow and can handle multiple decks simultaneously.

Automatic dealers, designed to eliminate the need for human intervention during card distribution, can be found in the market. These dealers typically range in price from $100 to $200 or more. They feature rotating mechanisms positioned in the center of a table, allowing cards to be dealt to players positioned around the table[2].

However, it is worth noting that no existing shuffler solution effectively preserves the quality of cards, and true random shuffling is primarily achieved through expensive casino-grade machines.

9 Design

The *TruShuffle* device will be composed of several components and subcomponents:

- Input
  - Containing Body
  - Platform
  - Continuous-Rotation Servo Motor
  - Gearing
  - Sensor
- Wheel
  - Slots
  - Swings
  - Stepper Motor
  - Structure
- Containing Superstructure
- Outputs
  - Chute
  - Pickup Location
  - Non-Continuous Servo “Swing Motor”
- User Interface
- Electronics
  - 5V Power Supply
  - 24V Power Supply
  - Arduino Uno
  - Input Servo Motors
  - Output Servo Motors
  - Input Sensor
  - Stepper Motor
  - User Interface Buttons

These components and subcomponents are all described in detail in following sections. An overview of the ways the components interact with each other can be seen in Figure 1 in the Introduction part of this document.

9.1 Input Component Design

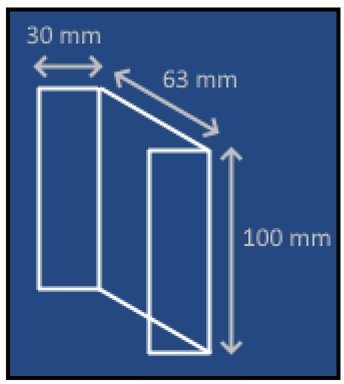
The project requires an input for the deck of cards. This section describes the design and nature of this input component.

In the chosen design, the input is not only the location where the user drops the cards, it also serves a dual-purpose as a *card separator*. A critical part of this project has been the need to separate the individual cards out from the deck of cards without bending or applying damaging pressure to the cards.

While the following diagrams will show the pieces as vertical for simplicity's sake, in reality the *entire* Input Component will be tilted at an angle of approximately 5 degrees backwards.

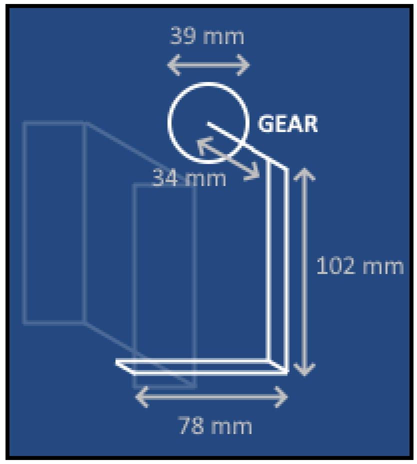
The following diagram shows the containing body, made out of an opaque material. TruShuffle intends to use ABS plastic. This is where the deck of card sits, leaning backwards 5 degrees so it does not fall forwards and out of it. The reason for the chosen dimensions is so that it can "snugly" carry a deck of cards without much room for the cards to tilt.

Figure 2: Input Containing Body



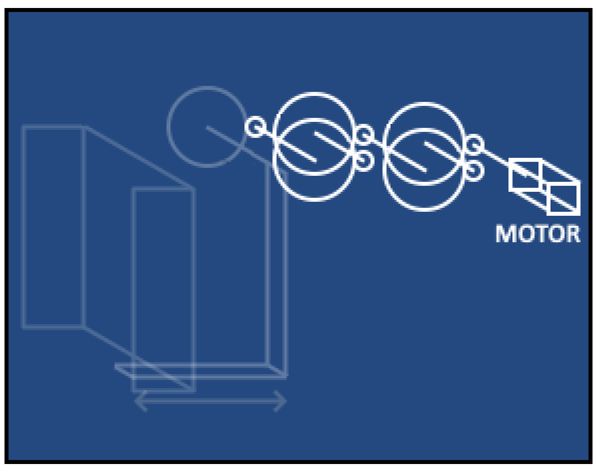
This next diagram shows the design of the platform, which is a small object that prevents the cards from falling down into slots in the wheel, except when appropriate. The principle is that the platform can be moved slowly, releasing the cards one-by-one so that they fall into the next part of the device as individual cards. The gear can rotate this platform in and out of place with extremely slow speeds, with extremely high torque and rigidity. This component will be made out of ABS plastic or otherwise 3D printed. The dimensions were chosen such that when it is rotated to be parallel with the containing body, it will not be preventing any cards from falling down.

Figure 3: Input Platform



For the input component, we will use a continuous-rotation servo motor [9] to power the movement of the platform. The rotational movement of this motor will be transferred through a gearing setup of five pairs of two approximately 39 mm to 7 mm diameter gears. The distance between the gears is arbitrary as long as the gears do not incorrectly lock with each other and is as such unmarked on the diagram. For the Engineering Prototype, this component has been constructed through ABS plastic via *LEGO*. For the production version, alternatives such as stainless steel gearing setups will be considered.

Figure 4: Input Gearing



Directly beneath all of this, a single ultrasonic sensor [11] will be used to determine if and when cards drop from the input. The reason for this subcomponent is that cards will not always fall in a regular, evenly-spaced manner, so management of this fact so that cards properly fall into the wheel below is necessary.

This novel type of input is justified over alternatives because, as long as the gears are protected, there are no conceivable moving parts to damage the cards, and there are no pinch points, as long as the wheel rotates away from the input rather than towards it, which is intended.
TruShuffle is actively considering the degree to which the Input will “hover” above the wheel while the wheel rotates below. Due to the anticipation that small changes will need to be made while iterating

through the test plan, the entire superstructure has not been modeled yet, but it will include a slope just beneath the input so that the cards always fall precisely into an appropriate slot.

These design choices for the input particularly ensure compliance with the following requirements:

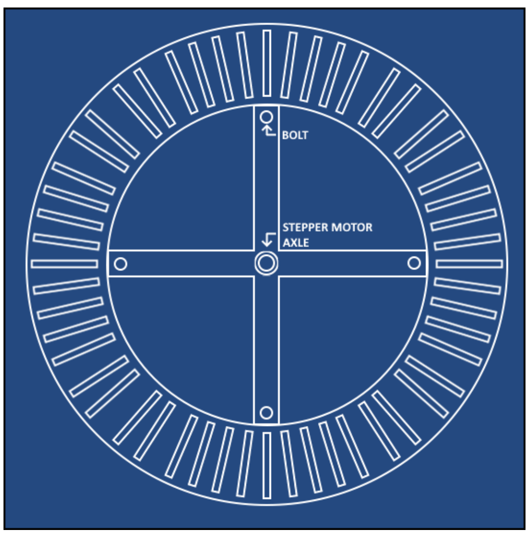
Table 2: Input Requirements

ID	Description
2.2	Be able to handle up to 52 cards
3.1	Have an input in which a user can place a deck of cards
5.1	Exact virtually no wear or damage on cards

9.2 Wheel Component Design

For the wheel component, a soft constraint exists that it cannot be wider than approximately 500 mm, as that is the maximum width that the CNC machine available to us can tolerate. [12] This is a challenging constraint but one that will be manageable, even while sorting 52 cards. The name "wheel" may be a bit of a misnomer, as the structure itself will be composed of not one but two wheels, bolted together and moving as one for stability, structure, and lightness. The following diagram is a top-down view of the overall appearance of one of the two wheels, 500 mm wide. Both wheels are extremely similar in appearance.

Figure 5: Plate Diagram

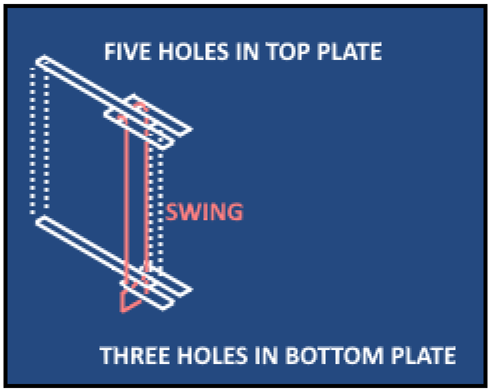


The wheel will be composed of four subcomponents, the "slots", the "swings", the "stepper motor", and the "structure". The above figure shows the approximate structure, with the slots running around the outside, and the axle of the stepper motor in the centre. The apparent "irregularity" of the spacing of the slots is due to the fact that the stepper motor we intend to use has 200 steps, a number that is not evenly divisible by 52.

The two aluminum plates will be nearly identical in appearance, except that the slots will be slightly different in each. The two plates will be bolted together such as they hover 86 mm apart, which is the height of a playing card. The slots of the top plate and bottom plate will be connected together with walls of cut plastic, which is slippery and cheap, creating a single containing unit for every single slot.

Neglected in figure 5 for simplicity's sake, but shown in figures 6 and 7, every single one of the 52 slots will be accompanied by some additional holes to allow for the existence of a small 3D-printed "swing", which will sit freely to interact with each slot. A diagram elaborating on this concept is as follows:

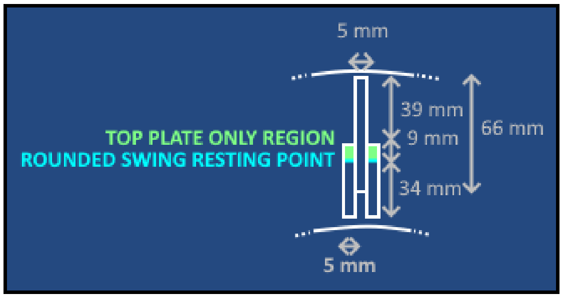
Figure 6: Slot Design



In the diagram, dotted lines show the connecting structure between the two holes in which a single card sits. The card is held in place by the "swing", which can be moved out of the way by any one of the outputs's non-continuous servo motors, allowing the card to drop down into the output.

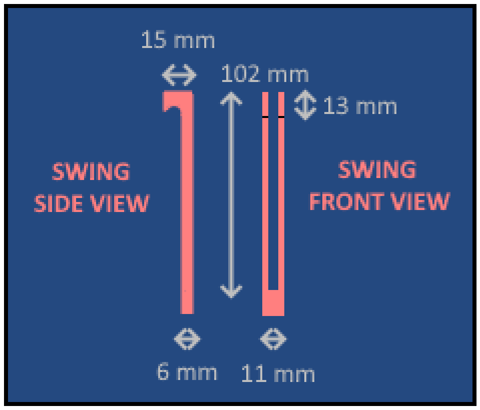
Given the 500 mm diameter of the wheel, we have approximately 19 mm to work with for every slot at its narrowest point. A more detailed diagram of the holes in the two plates is as follows:

Figure 7: Holes in Plates



The holes in both plates are the same, except that the top plate also has a hole in the green and cyan shaded region, with the cyan line indicating a rounded resting point for the swing. A diagram showing a side view and front view of an individual swing element is as follows:

Figure 8: Swing Diagram



The wheel will be turned on a central axle by a stepper motor powerful enough to be used for this purpose. As such, the wheel will be composed mostly of air, plastic, and aluminum, so that it will be light enough to be turned by an appropriate electric stepper motor. The central axle will be a screw carefully attached to the stepper motor.

This novel "wheel" design for the shuffler is justified over alternatives on several bases. The group has also considered a linear design for the "separating slots" for the cards, but it was decided that such a design would be slower. The group also considered the possibility of having the "wheel" not move at all, instead having the inputs and outputs move above and underneath, but the relative complexity of this option, and considerations of speed and pinch points, led us to settle on this wheel option.

These design choices for the wheel particularly ensure compliance with the following requirements:

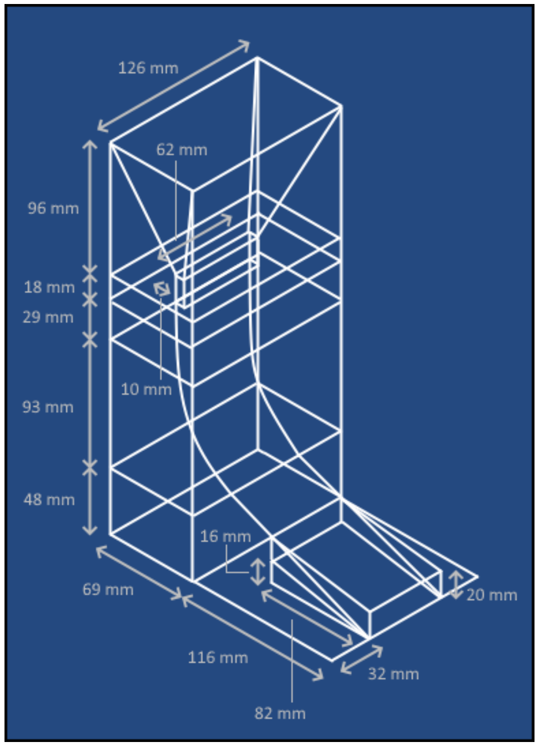
Table 3: Wheel Requirements

ID	Description
2.2	Be able to handle up to 52 cards
2.4	Shuffle with true randomness at least 99% of the time
5.1	Exact virtually no wear or damage on cards
5.2	Complete any shuffling or dealing operation in less than two minutes

9.3 Output Component Design

The outputs of the design are essentially troughs, which capture the cards, reorient them, and stack them neatly through the use of gravity. The following figure shows the design that has been prototyped that facilitates this:

Figure 9: Output Diagram



The cards drop into the top from the wheel, then drop down into the holding location (the "pick up location") at the bottom, from which the user can grab their newly shuffled deck of cards.
The output will be constructed out of a material that is smooth and easy to work with: wood. If the result is not sufficiently smooth, TruShuffle may choose to use plastic lining to allow the cards to fall easier, if sanding the wood is not enough.

The other subcomponent of the output is the need for a "push rod" that can manipulate the swings in the wheel above. For this purpose, we will use a non continuous servo [9] motor with 180 degrees of movement, mounted with a small rod to extend reach. This device will be able to rotate into the swings, allowing cards to drop down.

This design was justified on the basis that we needed to be able to "capture" and reorient the cards properly, without pinch points, and an gravity-based output of this sort was the most natural way of accomplishing it, allowing us to keep the "visible trust" that we are looking for in this project. We further justified the design when we found that it worked properly in practice, after we constructed it.

These design choices for the outputs particularly ensure compliance with the following requirements:

Table 4: Output Requirements

ID	Description
3.2	Have an output that can return cards after an appropriate function has been applied to them (Dealing)
3.3	Return Cut cards to multiple parties synchronously
5.1	Exact virtually no wear or damage on cards

9.4 User Interface Component Design

The User Interface will be composed of a number of electronically operated buttons, which control various features of the device.

For the Engineering Prototype, we intend to implement a minimum number of buttons to allow the project to accomplish all mandatory features. This means one button for each of:

- Turning the Device on and off
- Running the Device
- Switching the Device between “shuffling” and “non-shuffling” modes
- Switching the Device to “deal to one” mode
- Switching the Device to “deal to two” mode
- Switching the Device to “deal to three” mode
- Switching the Device to “deal to four” mode

All of the buttons will be connected to the electrical parts of the device. We currently intend to purchase buttons that have the capability to light up depending on the current state of the device. Button presses will have to be “debounced” at the software level.

The User Interface component will be placed in an accessible location in the containing superstructure, such that users will be able to easily operate it.

We justify the use of buttons for this component as they are simple, culturally widely accepted as an input method, and affordable for the company’s budgetary constraints. An alternative option, a touch screen, was considered, but a touch screen would require a more complex interaction with the Arduino.

These design choices for the user interface particularly ensure compliance with the following requirements:

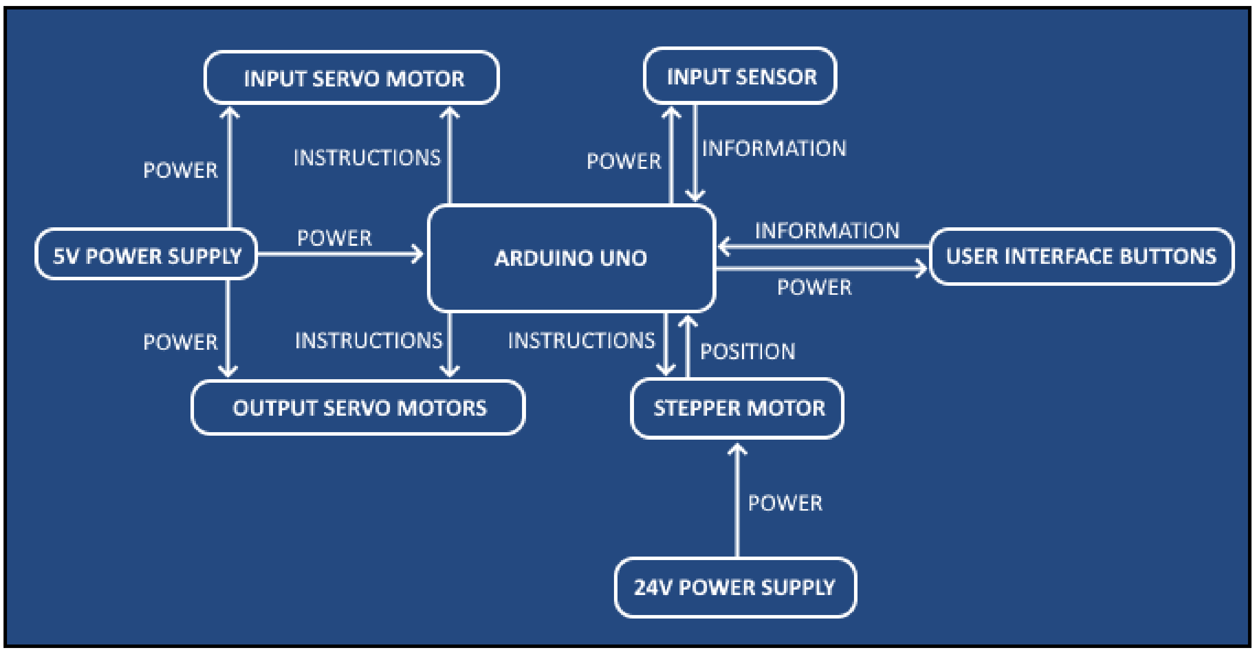
Table 5: User Interface Requirements

ID	Description
4.3	Have an option to Cut into up to four decks of equal size
4.4	Have an option to Shuffle without Cutting
4.8	Have an option to Cut without Shuffling
7.5 Sustainability	Be able to be shut down without unplugging

9.5 Electronics Component Design

The electronic components of the project are fairly complex as there are several subcomponents that each need to be powered and controlled. A system overview is as follows:

Figure 10: Electronics Connections Diagram



The central processing for the device will be an Arduino Uno [10]. The Arduino can be programmed to manage all of the motors, sensors, and buttons required for this project. A 5-volt power supply [9] will power the Servo Motors and Arduino, while a 24-volt power supply will be required to move the large central Stepper Motor.

Careful consideration is being given to how the motors will interact with the software, and TruShuffle intends to leave sufficient time to manage bugs. As individual components are added to the project and Arduino, each will be checked to ensure that they function properly. The exact software and algorithms to be used in the project will be written in the final week of July and the first week of August, but with a limited number of inputs, the project has a limited number of states to program for. Once the completion of the engineering prototype has been passed, a state diagram of a more complex program may be provided on request as more features are added.

All electrical components will be shielded from the user, and constructed following appropriate electrical safety standards as laid out in the appendix of the requirements document so that the device does not constitute a fire hazard.

Justifications for individual components of the electrical system are laid out when describing the individual components throughout section 9 of this document.

These design choices for the electronics particularly ensure compliance with the following requirements:

Table 6: Electronics Requirements

ID	Description
7.2 Safety	Have any electrical components shielded from the user
7.3 Safety	Not constitute an electrical fire hazard
7.3 Sustainability	Be able to draw from a wall outlet as a power source

9.6 Containing Superstructure Component Design

All subcomponents will ultimately be connected together by a “containing superstructure”. This segment of the design is currently difficult to ascertain definitively because, as of July 13, 2023, the TruShuffle team is actively awaiting certain details of the CNC machine that will be used. For the containing superstructure, the exact dimensions of every other part of the device will have to be known to a high degree of accuracy, and so this is unambiguously the last part of the design to be created.

The ultimate design of the containing superstructure for the Engineering Prototype will be mostly left until the week of July 17 to July 23, at which point we will have enough information to definitively model the entire project and everything in it. What we do know at this point is that it will most likely be composed of some material that will be light and easy to work with, such as wood, rather than metal or plastic, such that it can be constructed in a way that is relatively flexible for active development.

The ultimate design of the containing superstructure for the production version of the device will include barriers so that the wheel cannot be easily interacted with by the user, and appropriate regions of transparency and opacity so that the use of the device is fair during gameplay and visible so that the device is visibly trustworthy.

What TruShuffle is certain of is that:

- The input will be hoisted above the wheel with a very small distance between the two
- The wheel will be hoisted above the outputs with a very small distance between the two

- All components except that those that need to move will be as securely connected to each other as possible.

We justify the need for a containing superstructure on the necessity for the project to be sturdy and internally well-connected.

These design choices for the superstructure particularly ensure compliance with the following requirements:

Table 7: Containing Superstructure Requirements

ID	Description
1.1	Be light enough to be carried by the vast majority of people
1.2	Be sturdy enough to be transported gently by hand without breaking
1.3	Be able to suffer minor to moderate knocks without breaking

10 Conclusion

The design of the TruShuffle device is intended to meet all of the “Proof-of-concept” requirements as laid out in the previously created requirements document. The overall final design remains uncertain, as the included test plan will need to be followed so that we can iterate on current design ideas if they do not function as anticipated. The current phase of the project as of July 13, 2023 is “realization”, as enough progress has been made on the design to actively put the prototype together. We anticipate that TruShuffle will be able to properly shuffle and deal as planned in the requirements document.

Pertinent feedback given in regards to the requirements document has been applied to this document. Figures are now centered and a larger number of figures has been provided.

In the construction of the device, TruShuffle is making use of CNC machining, 3D printing, and manual creation of metal and plastic parts. As the creation of a prototype is a hands-on process of converting imagined design to reality, it is likely that the need to make small or moderate changes to the design will occur over time. TruShuffle believes that the risk of the need for large-scale changes has been minimized by actively prototyping throughout the semester.

A selection of alternative designs have been compiled in Appendix A. The test plan for the project has been thoroughly considered in the requirements document, the user interface & appearance design appendix, and appendix B of this document.

The development of the project proceeds on-schedule such that TruShuffle will be able to demonstrate the fundamental capabilities of the device on August 8, 2023.

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Appendix A – Design Alternatives

Some design alternatives are being considered, in case certain components do not function as expected. While none of them are entirely laid out, they are listed here alongside what failure might necessitate them.

- Input
    - If the input overall does not work as intended due to cards sticking together, cards falling prematurely, an electrostatic effect holding cards in place, or the unexpected need for unrealistically low tolerances for error, we are considering the use of a roller, such as those in printers, to facilitate the movement of cards from the input to the wheel. The design for the input is completely novel, so TruShuffle does not have perfect confidence in its design, but we hope that we will not have to resort to alternative plans as using rollers would have a negative effect on the "visible trustworthiness" of the project.
    - If the ultrasonic sensor does not work as intended, TruShuffle might be inclined to return it and use a motion sensor or cuttable laser, which could both serve the same purpose.
    - If the gearing system proves too unreliable or error-prone, we may attempt to find an existing servo motor that already has extremely high torque.
- Wheel
    - TruShuffle is currently actively soliciting advice from an expert third party on the use of a CNC machine. Depending on the limitations and abilities of a CNC machine, the design of the wheel may have to be subtly modified in certain ways.
    - If the stepper motor we are using does not work properly due to unexpected difficulties, the use of a servo motor, instead, may be preferred. In this case, additional sensors would have to be added to the project in order to manage the servo motor.
    - If the slots on the edge of the wheel prove unwieldy, unusable, or too large for whatever reason owing to the geometry and limitations of the CNC machine, TruShuffle is considering the use of 3D printing to make the slot design more "solid".

Appendix B – Test Plan

Test: Movability/ stability

Testing procedure:

- tester picks up the device without cards
- tester moves the device to a new location and place on a surface
- Tester uses device as normal and ensures all functionality

Expected outcome:

- Device completely functional after moved without any intervention after move
- Device able to not be affected by minor bumps and forces

Test: Ease of use and User Interface

Testing procedure:

- Tester able to fully operate device without assistance with a short guide
- User interface is easily understanded by tester

Expected outcome:

- Device used successfully by tester easily

Test: Shuffling ability

Testing procedure:

- Tester able to shuffle a deck of cards according to settings
- Tester uses device and is unable to see internal workings of device
- Tester Verifies the cards are properly shuffled at the end

Expected outcome:

- Device used successfully by tester easily and without revealing card order
- Device achieves a “random” shuffle as described earlier and by reference [1]

Test: Card Handling

Testing procedure:

- Tester uses various card types, sizes , and with and without sleeves and the cards maintain their shape and form with no damage
- Tester can uses varying deck sizes up to 52 cards

Expected outcome:

- Device is able to accept many card varieties and types without inflicting damage
- Device is able to handle all deck sizes up to 52 cards

Test: Card Safety

Testing procedure:

- Tester can halt the card machine at any time during the shuffling process
- Tester removes cards from the machine manually

Expected outcome:

- Device is accessible to remove cards if required
- Device is able to halt the process of shuffling at any time with user input

Test: Card Safety 2

Testing procedure:

- Tester forces a “stuck card” in input and verifies that device stops
- Tester gets a card stuck in wheel area and verifies that device stops
- Tester gets a card stuck in output shaft and verifies that the device stops

Expected outcome:

- Device is able to halt the process of shuffling at any time with user input
- Device self halts if an error occurs