Beer Pong Mat Project Proposal

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ECE 445 Senior Design Document

Spring 2023

03/02/2023

Team 20

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What is the problem we are trying to solve?

You would be hard pressed to find a college student or graduate in the United States who has never played a game of beer pong. This game, in which players take turns attempting to throw a ping pong ball into cups of beer across a table, has evolved over the years from a simple drinking game to a ubiquitous American pastime. People of all ages play this game – with or without alcohol – at parties, tailgates, and even on their iPhones, where users can use the GamePigeon app to challenge their friends to a virtual game of pong over text. Professional tournaments are even held for the game, with the largest such tournament, the World Series of Beer Pong (WSOBP), regularly having over a thousand participants.

Given that it is commonly played in an informal setting, beer pong, similar to games of wiffle ball or pickup basketball, is often the source of heated arguments amongst participants. Throughout an average game, cups may be shifted, spilled, or tilted in ways that give one team an unfair advantage over the other, and with no impartial official to make final decisions on what to do in these situations, players are often left feeling slighted. In addition, especially after many games are played in a row, it can be easy to lose track of the score, how many games each team has won, and whose turn it is. For such a prevalent game to have so much unnecessary unpredictability is unacceptable, and our goal is to ensure that future beer pongers can compete on an even playing field, so that every game is fair and every victory is that much sweeter.

What is our solution?

To address these problems, we propose the construction of a mat that will indicate where to place each cup and whether each cup has the correct amount of liquid. In addition, our design will indicate to players the current score and how many games each team has won. This mat is intended to be placed upon a 72” x 30” folding table, the typical surface used for a game of beer pong. In addition, this mat is intended to be portable, so that users can bring it wherever they feel a game of pong must be played.

The mat will feature indentations that show the user where to place the cups, with each indentation being surrounded by an LED ring that lights different colors to indicate whether the correct amount of liquid is in each cup. Force sensors inside the indentations and under the cups will be used to sense whether each cup has the correct amount of liquid. A mini LCD screen on each side of the mat will display to both teams the score of the current game and number of wins of each team. Two push buttons will allow the user to start and reset the game.

Think of our solution as being to beer pong what a robot plate umpire is to baseball. By regulating the game through the use of technology, we eliminate the possibility of human error and ensure a fair game for all players. Figures 1, 2, and 3 are visual aids demonstrating the layout of our design and how we intend it to be used.

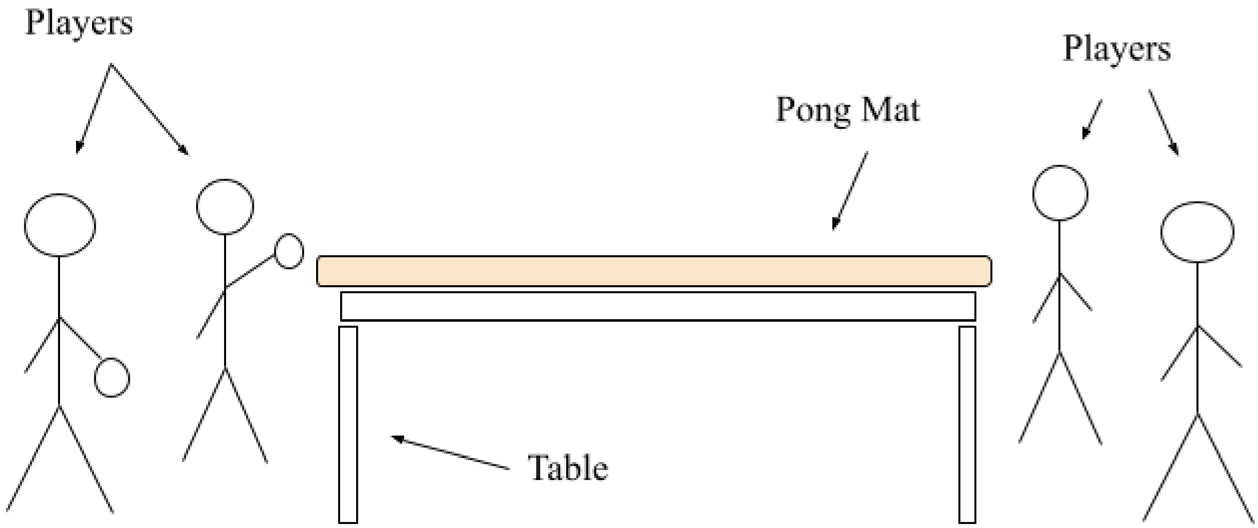

Figure 1

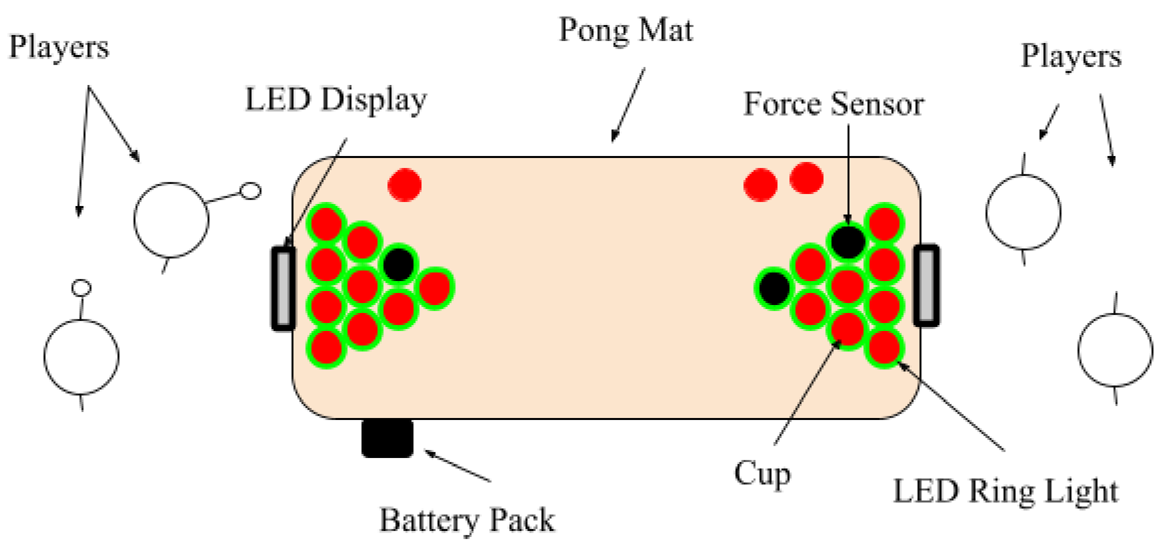

Figure 2

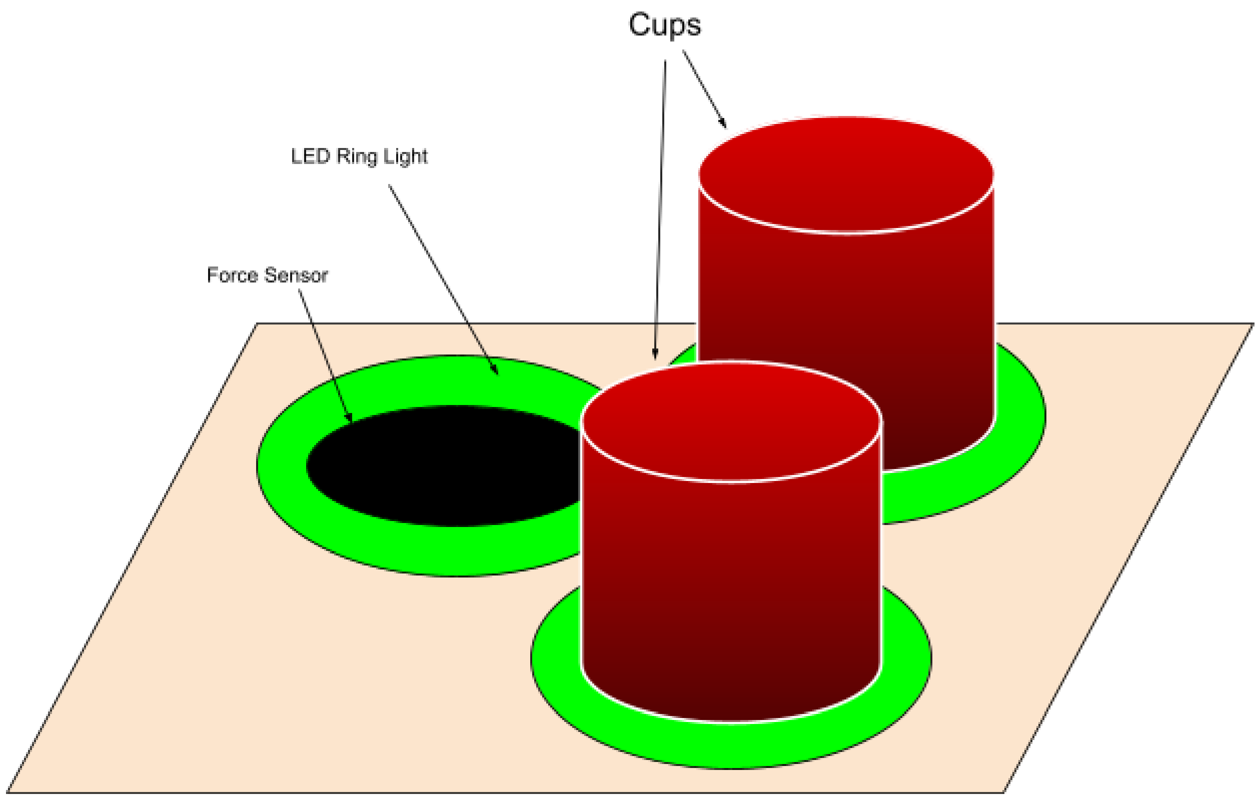

Figure 3

Figure 1 is a side profile of our pong mat, and shows four players engaging in a game of beer pong and using our mat. Figure 2 gives a bird's eye view of the mat, and shows the general layout of the mat, including the location of the twenty cups, LEDs, and force sensors, as well as the scorekeeping displays and the power subsystem. The cups off to the side of the table are those that have already been hit by the opposing team. In Figure 3 we see a close up side view of the cup sensors. Each cup sensor subsystem consists of an indentation in the mat that indicates where the cup is to be placed, a force sensor to detect if the correct amount of liquid is in each cup, a ring light to indicate whether a cup has the correct amount of liquid, and the cup itself. Each subsystem will also send data to the display screens through the microcontroller for scorekeeping purposes.

High Level Requirements

The three main characteristics we feel our design must exhibit in order to successfully solve the problems stated are as follows:

> **Portable**: One of the most appealing aspects of beer pong is its ability to be played wherever there are cups and balls. Our design should be portable enough to follow even the most adventurous ponger to wherever his or her chosen playing location may be. Portability is a hard characteristic to define in exact terms, but for our design to successfully solve the stated problems it should at the least be in some way reducible in

size from its laid out, playable form, whether through folding, rolling, or some other method.

Accurate: There's no point in using a mat to determine proper placement and volume if said mat can't do so accurately. Our design must incorporate tight tolerances to ensure the proper placement and filling of cups, or else it will merely reinforce the problem that it is supposed to solve. Traditionally, each cup should be about ⅓ full of beer. Our design dimensions assume the user is playing with traditional 16 fl. oz. Solo Cups, which weigh approximately 12 grams when empty. Taking the average density of beer to be 1.050 g/cm^3 [1], this means that each cup, when filled, should weigh approximately 178 grams (12 grams + (1.050 g/cm^3 x 29.5735 cm^3 / fl. oz. x 16 fl. oz. x ⅓)). While each cup should contain roughly the same amount of beer, users will not want to waste time trying to pour exactly the right amount of beer into each cup; therefore, our design will accept a range of weights, "approving" cups between ¼ full and ½ full, which leads to an acceptable weight range of 137 g to 250 g. The force sensors used, then, must be able to handle weights across this range, and should be able to sense differences in weight down to the gram to ensure accurate measurement of cups.

Intuitive: Players need to focus on perfecting their shot or defending against bounces, not figuring out how to operate the mat. Our user interface needs to be extremely simple in order to improve the game of beer pong and not serve as an anchor on the boat of fun. Like portability, intuitiveness is not a quality to which exact quantitative constraints can be given, so our main goal is to minimize the number of buttons on the user interface as well as the number of button presses needed to begin a game , so that anyone can learn to use the mat in a matter of minutes.

Block Diagram

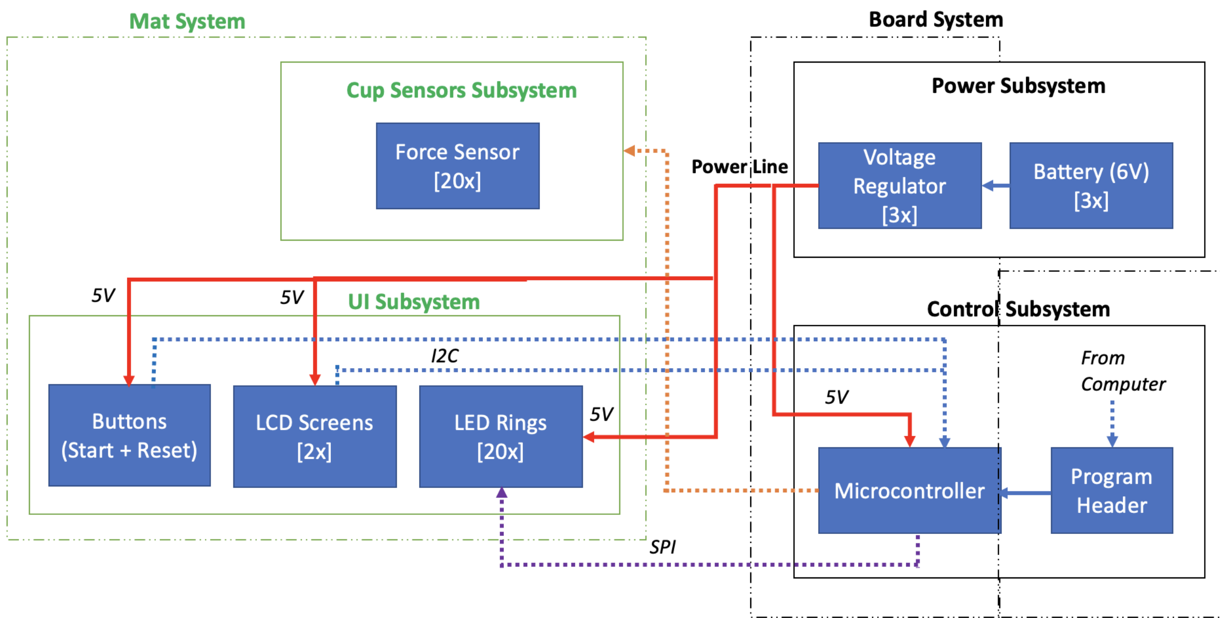

Figure 4

Subsystem Overview

A block diagram of our design is shown above in figure 4. Our overall system is made up of four subsystems: Power, Control, UI (User Interface), and Cup Sensors. The power and control subsystems will be a part of our PCB, while the UI and cup sensor subsystems will be located on the board.

- The power subsystem consists of a 5V battery that supplies DC power to each subsystem, as well as a voltage regulator.
- The control subsystem consists mainly of our microcontroller chip. This subsystem is the brain of our design, and is in charge of reading the force sensors to ensure cups are properly filled, turning the LEDs on/off and changing their color, using input from the buttons to begin and reset games, and updating the LCD display.
- The overall cup sensor subsystem consists of twenty cup sensors, ten on each side of the table. Each individual cup sensor consists of a force sensitive resistor used to determine the weight of the cup.
- The UI subsystem consists of the two LCD displays, one on each side of the table, which display the score of the current game as well as the overall win count to each user, and the two buttons that are used by the user to start the game and restart the game. The twenty LED rings surrounding each cup, used to indicate to the user whether a cup is at the proper weight, are also a part of the UI subsystem.

Each cup sensor consists of one force sensitive resistor (FSR). The FSRs are used as weight sensors to determine whether a cup is filled with the proper amount of liquid. This is done using a voltage divider circuit. Each FSR will have one pin tied to ground and the other tied to a resistor of constant resistance that is connected on the other side to the positive power supply. The voltage in between the FSR and fixed resistor will be connected to an analog read pin on the microcontroller. When a cup is placed on the FSR, its resistance will go down, thus increasing the voltage drop across it, decreasing the voltage drop across the fixed resistor, and changing the voltage read by the microcontroller. It is in this way that the microcontroller will be able to know when the weight of the cup changes, and through careful tuning, we can determine a voltage range that corresponds to the acceptable weight range of the cup. The force sensitive resistors are passive components,and therefore do not require a dedicated connection to the power subsystem.

The UI subsystem consists of the LED rings, the LCD displays, and the buttons. The LED rings, unlike the force sensors, are active components, and each one must be connected directly to the power subsystem. In addition to these two connections, each LED will also be connected to a digital output pin on the microcontroller that can feed it serial data and tell it when to turn on/off and what color to turn to (the rings we will be using use RGB LEDs and as such will be able to shine multiple colors). Each LED ring has an onboard microcontroller through which our control unit can turn the LEDs on/off and change their color. A program written to the microcontroller will effectively read the weight of each force sensor through the use of the aforementioned voltage divider circuits and, using this information, tell the LED what to do. When a cup is within the acceptable weight range, the corresponding LED ring will shine green; otherwise, it will shine red.

The LCD screens are also active components and require connection to the power subsystem. They will also be connected to the control system via digital output pins on the microcontroller, which will communicate with the two displays via the I2C protocol. As each screen will display the same information, they may be wired to the same pins on the microcontroller to reduce the number of pins needed on the MCU. Each screen will display the score of the current game as well as the overall win count of each team, with this data being stored by the microcontroller before being sent to the displays via the data lines described above. The two buttons will function respectively as Start and Reset buttons, with the user pressing the Start button to begin a game if one is not currently being played and the Reset button to restart a game.

The control subsystem consists of the microcontroller as well as a programming header chip that allows us to connect to the microcontroller chip from a computer in order to program it. The microcontroller is powered by the power subsystem. It receives input from the force sensors and buttons and outputs data to the LED rings as well as the LCD displays, as described in the previous paragraphs. The entire control subsystem will live on the PCB.

The power subsystem, as one could probably deduce by the name, is in charge of powering the entire system. It consists of 6V batteries connected to voltage regulators that are located on the PCB. 6V batteries were chosen rather than 5V batteries because the voltage supplied by a battery decreases as it ages, and because our power supply cannot drop below 5V due to the power requirements of the LCD displays, microcontroller, and LEDs, we chose to use a 6V battery and step down the voltage to ensure our batteries are usable with our system for a longer period of time. The voltage regulators on the PCB will serve to both step down the voltage from 6V to 5V and to maintain a fixed 5V output voltage that connects to and powers the displays, LEDs, and MCU.

Subsystem Requirements

- **Power**
  - Power supply must be able to output a constant 5V DC voltage and supply power to the microcontroller, LEDs, and LCD screens simultaneously.
  - Batteries must have enough energy to power the mat for at least six hours. Assuming a current draw of 1.44 A for each LED ring, this means that the batteries used to power the system should have at least 864 kWh of energy (1.44 A x 5V x 20 LED rings x 6 hours).
- **Control**
  - The selected microcontroller must have an ADC with at least 20 channels, so that it can simultaneously read voltages from the 20 voltage divider circuits corresponding to the 20 force sensors.
  - The selected microcontroller must have an additional 22 digital output pins, one for each LED ring and 2 for the LCD screens (as the screens will be the same model and display the same thing, they can share the 2 pins needed for communicating via the I2C protocol.
  - The selected microcontroller must have at least 2 digital input pins in order to read input from the buttons.
  - The selected microcontroller must be reasonably easy to solder; this means it must both be large enough and come in a package well-suited for hand soldering, such as a DIP package.
- **UI**
  - The LCD screens must be readable to a user standing at least 2 feet away.
  - The LED rings must be RGB so that they are able to shine different colors.
  - Each LED ring must have an inner diameter of at least 62 mm so as to allow a Solo Cup to be placed inside of it.
  - The LCD screens must be compact so as to not interfere in any way with gameplay.
- **Cup Sensors**
  - The force sensors must be able to successfully detect whether a cup is in the range of 137 to 250 g.
  - The force sensors must be flat so as to allow a cup to be stable when placed atop them.
  - The resistance of the fixed resistor in the voltage divider circuits used to sense weight changes on the sensors should be selected so as to maximize the range of voltages used to represent the weight on the sensor (see Tolerance Analysis).

Tolerance Analysis

An aspect of our design that could prevent the successful completion of our project are the force sensors. Our design incorporates force sensitive resistors as a way to measure the amount of liquid in each cup, and while FSRs are effective, cheap, and simple, they are not nearly as precise or accurate as a typical load cell. This is acceptable for our purposes, as we only need the force sensitive resistor to confirm whether the cup is within a wide weight range (137 g to 250 g, as stated earlier) rather than give precise readings on the weight of the cup. However, we still would prefer our force sensors to be as accurate as possible, and in order to do so, we must carefully select the resistance of the fixed resistor in the voltage divider circuit to maximize the precision of the voltage reading sent to the microcontroller. In order to do so, we want to have the widest possible voltage range representing the range of forces on the FSR (5V in our case, as the DC bias across the divider circuit will be provided by our power supply). Typically, an FSR will have infinite or very high resistance (> 10 MΩ) when experiencing no force and a resistance of down to 20Ω when experiencing maximum force. If the fixed resistor in the voltage is, say, 20Ω, then the voltage read by the microcontroller when the FSR experiences no force will be 0V while the voltage read by the microcontroller when the FSR experiences maximum force will be 2.5V. This can be understood by using the previous facts given about an FSR's resistance and referring to Figure 5, which shows a diagram of a typical voltage divider circuit. When the FSR experiences no force, it has such a high resistance that practically the entire voltage drop will be across it and practically none will be across the fixed resistor, meaning that Vout, which will be read by the microcontroller, will be 0V. When the FSR experiences maximum force, it has a resistance of about 20Ω, and if the fixed resistor is chosen to be 20Ω, then the voltage read by the microcontroller will be 2.5V, as there will be a 2.5V drop across each resistor ([20Ω / [20Ω + 20Ω]] x 5V). Clearly, then, 20Ω is not an acceptable value for the fixed resistor, as this gives a voltage range of 0V to 2.5V, which is only half of the range we have available. If we instead gave the fixed resistor a value of 10kΩ, then the voltage read by the microcontroller when no force is experienced by the FSR would be 0V, for the same reason as above; however, the voltage read by the microcontroller when the FSR experiences maximum force would be 4.99V ([20Ω / [20Ω + 10kΩ]] x 5V). This gives us a voltage range of 0V to 4.99V, which is clearly superior to the range given by the 20Ω resistor, and sufficiently wide for our purposes.

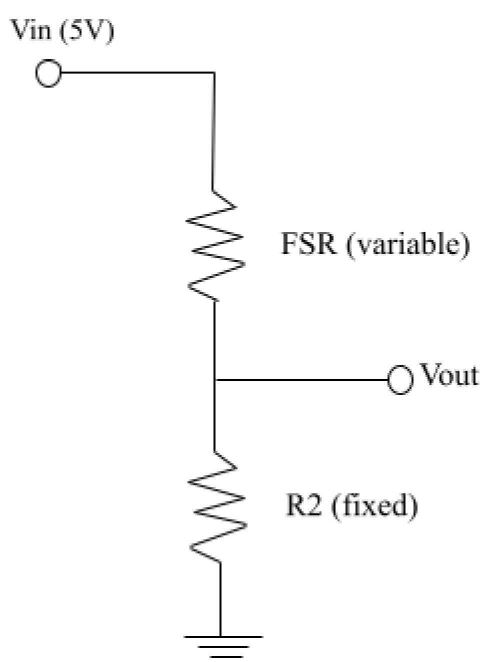

Figure 5

Ethical Concerns

Our team does not foresee any ethical issues arising during the development of our project, seeing as all necessary testing can be done in a safe and harmless manner. The main ethical concern we have is the fact that our project, being an accessory for a game commonly played with alcohol, may encourage unhealthy and unsafe drinking habits. This would be in direct contradiction to our duty as engineers to ensure the good health and safety of the users of our project, as per the IEEE Code of Ethics section I.1 [2] and the ACM Code Of Ethics section 1.2 [3]. However, considering the widespread popularity of the game of beer pong, we do not believe that our project will be introducing anyone to this game and perhaps by extension binge drinking. Theoretically, if our product was mass produced, we would include with it a disclaimer stating that the creators do not encourage binge drinking, as well as a warning detailing the harmful effects of binge drinking and the dangers of alcohol poisoning. We do not want to encourage unhealthy drinking habits of any sort – rather, we hope with this project to help streamline an already immensely popular game that can be played in a safe and controlled manner.

In addition, we as a team will need to work to ensure that our project is completed in an ethical manner with regards to plagiarism in compliance with section I.5 of the IEEE Code of Ethics [2]. Given that this project will likely involve a significant amount of research, our team will have to take care to ensure credit is given where it is due and that all sources used are included in our reports and properly cited.

Safety Concerns

We have no concerns regarding mechanical or lab safety. The one safety concern that we will need to address is the fact that beer pong is a game played with liquids, and that cups full of liquid will by design be in close proximity to our project and therefore to electrical components. Due to the low voltage requirements of this project, this does not pose any extreme danger, but it will need to be addressed in order to prevent the destruction of our product and/or minor injuries to the user. This issue can easily be remedied through the use of protective encasing for sensitive electronics. The force sensors will be covered with a thin waterproof material that keeps water out while also not interfering with the force readings of the sensor. The LED ring lights will also need to be covered in a manner that protects them from water while not interfering with their ability to be seen. The main microcontroller and power units encasings do not have special requirements apart from being waterproof, as the user will not actively interact with these units.

References

[1] Manning, Martin, P. "Understanding Specific Gravity and Extract. Brewing Techniques." *Brewers Market Guide*. September 1993.

[2] “IEEE Code of Ethics,” *IEEE*. [Online]. Available: https://www.ieee.org/about/corporate/governance/p7-8.html. [Accessed: 17-Feb-2023].

[3] “ACM Code of Ethics and Professional Conduct” *Code of Ethics*. [Online]. Available: https://www.acm.org/about-acm/acm-code-of-ethics-and-professional-conduct. [Accessed: 17-Feb-2023].