<u>Team House Rules</u>

High Level Design Document

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1. Introduction

Our team will build an automated beverage pong table in order to improve multiple aspects of this popular party game. For example, we can better manage the position of the cups on the table through the use of an internal computer which can respond to the specific situations in the game in real time. In this way, the game rules of the traditional beverage pong game will be better enforced and the possibility of spills is reduced when cup movement is necessary. A streamlined version of this game will help to maximize enjoyment for all parties.

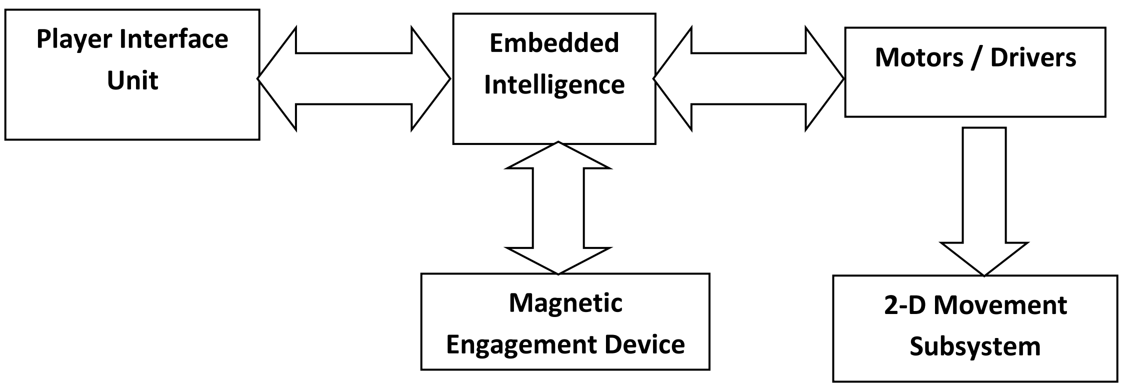
2. Overarching Problem / Design Objective

The major issue that we wish to address with this new product is the lack of standardization within the game of beverage pong. The setup and game play can vary significantly in each different game; for instance, the placement of the cups is left to the players, who often arrange them in an unorganized manner. Additionally, the rearrangement of cups during a re-rack is often sloppy and creates the possibility of spilling during the act of moving the cups. Our system will also provide the players the opportunity to record overall statistics for individual players.

In order to provide a solution for the problems listed above, we will use a variety of technologies and embedded intelligence to build an automated beverage pong table. Our automated beverage pong table will consist of a two-axis system underneath each side of the table that will control the movement of cups on the table. The two-axis system will dictate the placement of a magnet below the table; this magnet will interact with special magnetized coasters on which each of the cups sit to move the cups when movement is necessary. In addition, our automated beverage pong table will contain a user-interface to a processor, which will control the position of the cups and record desired statistics, such as the percent accuracy of each shooter and the number or used re-racks for each team. The implementation of such a system will not only help to standardize the game for experienced players, it will also help to guide new users on the aspects of proper game play.

3. Block Diagram and System Descriptions

Our automated beverage pong table is an elaborate system that consists of five major subsystems. The correct functionality of each of these subsystems is essential to the overall system. The following block diagram provides a visualization of the separate subsystems involved in the automated beverage pong table and the interaction of each block with the others.



Subsystem 1: Player Interface Unit

The user will first interact with this subsystem when attempting to start a game. This subsystem will consist almost exclusively of software. We will implement this interface through either a small, but sufficient, computer processor or an external touch screen device. Regardless of the hardware used to provide the interface, our program will offer the user a number of buttons in order to begin game play and interact with the program throughout the game. The display will contain a diagram of the field of play, the number of unused re-racks for each team, and the percent accuracy of each player on the table. The users will have the ability to click the desired cup when a cup is made and prompt the system to then move that cup over to the side of the table and out of the field of play. Therefore, this event must prompt some interface between this subsystem and the embedded intelligence block.

Subsystem 2: Embedded Intelligence

The automated beverage pong table will implement a microcontroller as the embedded intelligence. The microcontroller will receive commands from the user interface subsystem and relate those commands into mechanical actions for the magnetic latching and motors/drivers subsystems. In addition, the microcontroller will need to understand when the mechanical actions have completed so that it notifies the players that game play can resume and updates the user interface when the game situation changes.

Subsystem 3: Motors/Drivers

This subsystem will control the mechanical movements of the motors and drivers that dictate the placement of the magnet below the table. It will receive its input signal from the microcontroller and then output the necessary signals to insure proper speed and direction of the motors. This movement of the motors will result in the precise placement of the magnetic latching device. It must also be able to relay its on/off status to the microcontroller.

Subsystem 4: Magnetic Engagement Device

This subsystem will receive its input commands from the microcontroller, which will tell it whether to latch. For instance, if a cup needs to be moved outside of the field of play, the magnet controller will wait until the motors have correctly placed the magnet at its proper position and then activate the latching power of the magnet. It must also be able to detach its magnetism and relay its magnetized/demagnetized status to the microcontroller.

Subsystem 5: 2-D Movement Subsystem

This subsystem simply consists of the mechanical pieces necessary to insure that the magnetic latching device settles at its intended location. It consists of no intelligent parts; the motors/drivers subsystem controls the actions of this subsystem. The exact mechanical pieces included in the X-Y axis will be described later in this document.

4. Requirements Definition and Design Decisions

4.1 Overall System

Our automated beverage pong table will be powered through an electrical cord that plugs directly into the wall. In an engineering sense, this is most feasible because it provides us with a constant source of power that is more than sufficient. In addition, reliability of the power supply will not pose an issue because we are drawing from a powerful and consistent source. Furthermore, the lifetime of the table will not need to be considered because the power source is constant. Aesthetically, the power cord will not look out of place or prove to be a limitation because the size of the table is so large and the game is intended to be played inside, where power outlets are provided.

Our interface will consist of one of two possibilities, either a computer program or wireless touch screen device. In the case that we utilize a computer as our user interface, it will be directly wired to the necessary components within the table through either USB or serial connections. Therefore, wireless capability will not be an issue. However, if we opt to utilize the wireless touch screen interface, some defined wireless range will become necessary. In this case, only two wireless devices are involved (one controller for each end of the table). The necessary range of the controllers is relatively small because the players should be standing next to the table at all times. A suitable wireless range for these touch screen devices is 10 feet. Given that the wireless signal receiver is located in the middle of the table, this gives the users a six foot range outside each end of the table in which to use the controllers.

The system will be very simple to install. In order to begin game play, the user will only need to plug the table into the wall. In the case that a computer serves as the interface for our system, the user will also need to start the computer and open the program that is constructed for the table. In the case that wireless touch screen devices are used as the interfaces, the devices will simply need to be turned on using some prescribed button.

4.2 Subsystem Requirements Breakdown

4.2.1 – Player Interface Unit

4.2.1.1 – Overall Subsystem Objective

The main objective of this unit is to be the primary center of interaction with the beverage pong players. This unit will be used both to display current game information as well as accept user inputs and react accordingly.

4.2.1.2 – Subsystem Requirements

This subsystem:

- Shall have a display to present game information to users in an attractive manner
- Shall have the ability to run game management software created by the group
    - This software:
        - Shall be able to keep track of current cups in play and their positions
        - Shall be able to accept user inputs with regards to cups made and send movement commands accordingly
        - Shall be able to present re-rack options from the user, accept a choice, and send commands appropriately
- Shall have the ability to accept user inputs

4.2.1.3 – Possible Implementation Solutions

Here are some possible implementations scenarios for various aspects of this subsystem design:

- The display system could consist of one of the following two units
    - A dedicated external laptop that will run the game management software
        - Inputs will be given using a mouse
        - Commands will be sent using RS232 over a USB port modeled as a Virtual COM Port (VCP)
    - A dedicated touch screen mounted in the playfield with on-board memory able to run our game-management software
        - Inputs will be given by tactile motion
        - Command distribution will be governed by the on-board characteristics of the touch screen

4.2.1.4 – Major Subsystem Design Decisions

One main design decision that we are facing is whether to use a dedicated laptop or a touch screen unit to implement this system. A laptop/netbook will enable rapid software development using familiar languages such as C++ or Microsoft .NET. This will also enable easy interfacing due to the ready availability of VCP components/drivers.

However, using a mouse would be somewhat clunky and difficult to use under the influence of certain beverages. The benefits of using a touch screen are obvious, eliminating the bulkiness of mouse use. The drawbacks of this implementation are cost and limitations of available hardware.

4.2.2– Embedded Intelligence

4.2.2.1 – Overall Subsystem Objective

The main objective of this unit is to be an intermediary between the primary interface unit and the motors/controllers. This unit's responsibility is to perform some low-level data processing that will enable a beneficial division of software labor between different subsystems of the table.

4.2.2.2 – Subsystem Requirements

This subsystem:

- Shall be able to accept encoded commands from the player interface unit.
- Shall be able to parse inputs and send appropriate movement commands to the motor and magnetic latching controllers.
- Shall be able to perform its necessary functions without reference to the current game situation/layout (should be a blind operator).

4.2.2.3 – Possible Implementation Solutions

Our primary implementation idea thus far is to have two parallel Arduino development boards

4.2.2.4 – Major Subsystem Design Decisions

One of the major problems with regards to cup movement was the fact that due to the relative cup positions in various setups, straight horizontal or vertical movement may not be possible without knocking over other cups. This eliminates the possibility of our system moving cups by moving the necessary amount in the x-direction and then moving the necessary amount in the y-direction. Thus, simultaneous motor movement must occur. To do this we need a way of synchronizing motor commands to allow simultaneous movement. This problem will be the primary driver for our design decisions with regards to this subsystem moving forward.

4.2.3 – Motors and Drivers

4.2.3.1 – Overall Subsystem Objective

The overall objective of this system is to power the movement of the X and Y mechanism. The system can move the carriage to any position within the 40x24 inch playing field. Additionally, the control should be able to move the carriage in any possible direction to trace out any and all shapes and curves.

4.2.3.2 – Subsystem Requirements

The subsystem:

- Shall be able to power the carriage at least 3 feet per second.
- Shall control each axis independently and simultaneously.
- Shall be able to precisely place the carriage within 5 mm of target location.
- Shall operate quietly below an acceptable noise level.
- Shall not allow carriage to exit the 40"x24" play field.

4.2.3.3 – Possible Implementation Solutions

Here are some possible implementation scenarios for various aspects of this subsystem design:

- Stepper motor and stepper motor control boards-one mounted on the base plate driving y-axis motion by a chain coupled to the x-axis cross beam.
- DC-motors with shaft encoders could be used if the stepper motors cannot provide sufficient speed to fulfill the speed requirement.

4.2.4 – Magnetic Engagement Device

4.2.4.1 – Overall Subsystem Objective

The overall objective of this system is to engage the cups through the plexi-glass playing surface. This system includes both the magnetic engagement device and the magnetic coasters. The system needs to be able to maintain engagement with the cups throughout the movement routine.

4.2.4.2 – Subsystem Requirements

The subsystem:

- Shall engage and disengage the coasters at any position within the grid. This is going to require the device be wired to the control system.
- Shall precisely engage only one cup and maintain engagement throughout the cup movement routine.
- Shall have enough force to drag the coaster against friction forces.
- Shall have coasters which maintain their placement on the table once positioned.
- Shall fit comfortably on the carriage from the mechanical subsystem.
- Shall be less than 3"x3" and weigh under 0.5 kg to sit on the carriage.

4.2.4.3 – Possible Implementation Solutions

Here are some possible implementations scenarios for various aspects of this subsystem design:

- Solenoid electromagnet which can be switched on or off at will.
- We could use a permanent magnet and vary the position to change between engaged or disengaged states.
- The Permanent magnet could be raised to engage the coasters or rotated so the field lines up. Either way this solution requires additional mechanical components that could be difficult to implement.
- The coasters can be hewn from plastic and fitted with some magnetic material. They could have metal plates in them or small magnets in them.

4.2.4.4 – Major Subsystem Design Decisions

The major design decisions in this case revolve around the type of engagement deice in use as well as the type of coasters being used. The magnets in the coasters will cost more but may provide better engagement. These magnets also may allow for a small amount of position maintenance. The table could use a metal table top so the coasters will stay put unless forcibly moved. The metal coasters are cheaper and provide a larger engagement area. The device will likely be a solenoid because of its ease of use and compact size. If costs are too high we will be forced to switch to permanent magnet system which will require more mechanical parts which would be more difficult. Also, because there is no way to turn off a permanent magnet we need to consider residual effects of the magnet when not engaged. Also we must consider the transient effects as the permanent magnet moves into position.

4.2.5 – 2-Dimensional Movement Subsystem

4.2.5.1 – Overall Subsystem Objective

The overall objective of this subsystem is to enable movement of a loaded carriage device in the 2-dimensional X-Y plane. This subsystem will enable the removal and replacement of cups to and from the active beverage pong playfield.

4.2.5.2 – Subsystem Requirements

This subsystem:

- Shall reside 1 foot below the main playfield on a separate table surface and be adequately supported.
- Shall allow 40 inches of movement in the x-direction and 24 inches of movement in the y-direction.
- Shall contain a cart mechanism that can carry a load with dimensions up to 3 inches by 3 inches and weight up to 0.5 kg.
- Shall be able to interface with a driver/control subsystem to control movement.
- Shall be able to move a fully loaded cart 3 feet per second.
- Shall allow the implementation of a cable to the cart for electronic control purposes without interfering with the movement process

4.2.5.3 – Possible Implementation Solutions

Here are some possible implementations scenarios for various aspects of this subsystem design:

- The y-axis movement system may be implemented using two parallel 24 inch center-mounted drawer slides that will allow the full range of necessary motion in this direction.
    - These slides can enable the full load and speed requirements stated above.
    - This is a low cost option that can be purchased for a total of around 10-15 dollars.
- The x-axis movement may be implemented using a 40 inch by 4 inch beam spanning the y-axis slides.
    - The beam will support the loaded cart that will be able to move the full 40 inches.
- Underneath the span there will be an L bracket clamped to a cable that will be used for propulsion
- The cart will be a hobby railroad flatbed car mounted on railroad track on the span beam

4.2.5.4 – Major Subsystem Design Decisions

We have several major design decisions that need to be addressed. The first is the propulsion system for the y-axis. We have several options in mind. The first is the proposed railroad cart with the motor mounted on it that has a protruding gear. This gear will be pressing onto a long span of tank tread material and will propel itself up and down the span. The other option is having the motor/lead screw combo providing motion.

4.3 Scalability / Future Adaptation Possibilities

Although we believe we have designed a very unique and enjoyable product, there are a few upgrades and modifications that could be made. This small section will detail certain enhancements that may be made in the future and the features that they will require.

One addition that would increase the user experience on the automated beverage pong table would be to add a beverage dispenser during the game initialization. This would require a beverage storage container or reservoir, the hardware to dispense liquid from the reservoir into the cups, a flow meter to determine how much is dispensed into the cups, and extension of the intelligence to move the cups from this location to the field of play. It must be noted that adding this feature would mean increasing physical space available for a reservoir as well as adding an initialization sequence to the intelligence across multiple subsystems.

Another addition would be a “reach” sensor to notify players when a shooter reaches too far across the table when performing a shot. This would require a sensor that would notify players if the reach plane is broken, thus causing a foul. This sensor would need to then communicate with the user interface to display the Foul message and react appropriately, whether that means missing a turn or allowing the player to re-shoot. Adding this feature would require some additional hardware as well as some new algorithms in the software.

Cellular and web initialization could be used to initialize the game with the reception of a text message or Internet connection notification. Alternately, there could be a web server that accepts http game initializations. This would require the user interface to be able to communication wirelessly, which would require additional hardware to receive these signals.

It must be realized that all of these upgrades, although not included in the initial design, are entirely feasible and would add a few very enjoyable aspects to the beverage pong unit.

5. Remaining Questions

- Will the magnetic coaster be able to overcome friction with the table to move smoothly and efficiently?
- Will we be able to design magnetic coasters that attach well through the table to the magnet below the table?
- Will we have the resources to build automate both sides of the table, or will our budget limitations force us to restrict our construction to only one end of the table?
- Will an electromagnet or a permanent magnet attached to an actuator be used to drag the cups from beneath the table?

6. Initial Cost Breakdown

Below is a table of initial estimates of costs for major subsystem components that would be needed in order to complete one half of the game table. These figures are subject to change and are in no way binding throughout the course of the project.

Component	Subsystem	Cost Estimate	Functionality
PC/Netbook	Player Interface Unit	$0 - (Team provided)	Primary player interaction device
USB A to B Cable x2	Player Interface Unit	$10	Subsystem connection
Arduinos x2	Embedded Intelligence	$50	Motor command decoder
4 Wire DC Stepper Motor x2	Motors/Drivers	$30	Primary motion device
Stepper Motor Controller x2	Motors/Drivers	$30	Stepper control
22" Drawer Slides x2	2-D Movement	$10	Y-axis motion
X-Axis Span Beam	2-D Movement	$10	X-axis platform
Coasters/Magnets	2-D Movement	$50	Cup movement
Custom X-Axis Cart	2-D Movement	$15	X-axis movement

This brings the initial project cost estimate to around $205. We believe that this is a somewhat liberal estimate, so caution should be taken when consulting these figures. However, these results do show that we have a lot of room to operate in terms of our financial situation.

7. Moving Forward/Conclusions

Our project clearly has a lot of unique complexities and design challenges. We believe, however, that we have devised a design approach that will give us the best chance at successfully meeting the requirements laid down within this document. We believe that a bottom up approach focused on designing, developing, and testing complete and functional subsystems before proceeding will enable us to ensure we are on the right track from the get-go. With this in mind, we believe that it is imperative that we start development with the 2-Dimensional Movement subsystem and complete it as soon as possible. Ensuring we have two degrees of freedom to work with at our leisure is the most important step on the path to success with this project. Also, we believe that we have laid out the requirements, design goals and objectives, and critical decisions in a manner adequate enough to begin development. Thus, we believe that we should proceed with subsystem construction as necessary.