# ECE 445 Proposal:
# BAGS: Bags Automated Game System

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## 1 Introduction

### 1.1 Background

Cornhole, or bags, is one of the most beloved sports in the Midwest. The game is played with two teams of two, 8 total bags, 4 for each team, with two angled, opposing boards spaces around 15 feet away from each other. Players take turns throwing bean bags at the opposing boards in an attempt to either land their bag on the board or into the hole cut out on the board. Each bag on the board awards that player's team with one point while making it into the hole is three points. The game ends when either team reaches 21 points.

### 1.2 Problem

Due to its fairly simplistic nature, cornhole is a staple at events such as barbeques, tailgates, and other outdoor get together. Some other staples at these type of events are adults drinking, energetic children, and engaging conversations. While these are great and part of what makes these events fun, they are distractions that can affect one's ability to keep track of the score. This can lead to heated arguments that are heightened due to alcohol consumption or take away the competitive edge as it can devolve into just throwing bags back and forth no clear objective.

### 1.3 Solution

To combat participants losing track of score, we will be removing the need for them to score the game entirely. This will be accomplished by creating a set of bags, a board, and an app that will automatically score the game for them.

The bags will contain RFID tags that communicate with receivers embedded into the board to recognize when a bag has landed on the board. This will work in conjunction with the force sensors to determine if the bag has stuck on the board. This change to the board-state will be sent to the micro-controller which will then interface with our app via Bluetooth to update the game score appropriately.

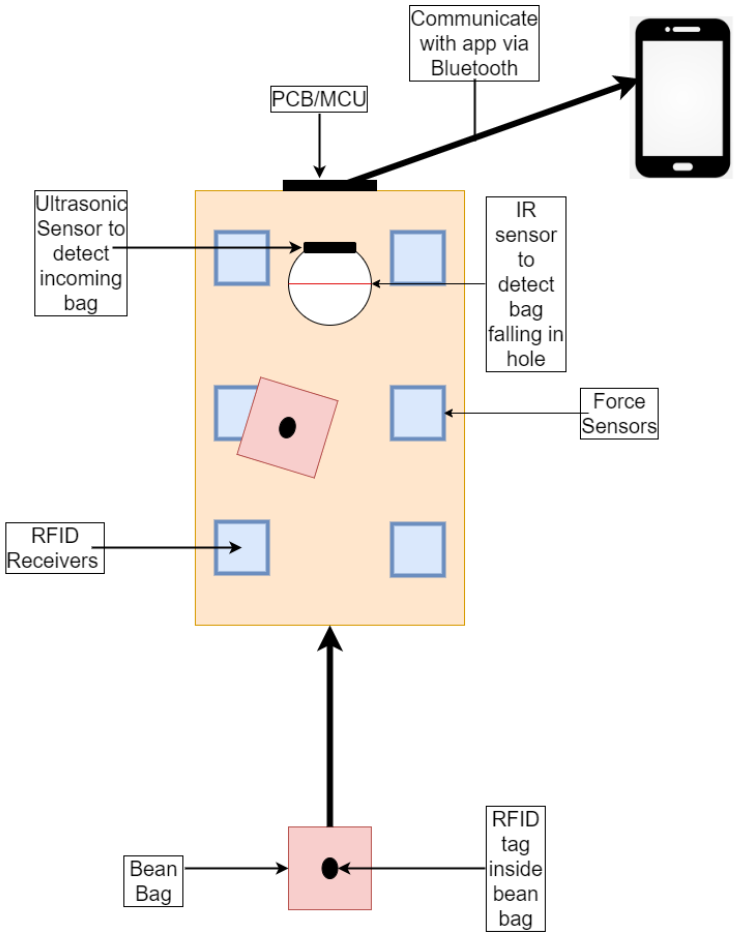
To detect a bag falling into the hole, we will be placing IR emitter and receiver in the hole, which when momentarily broken, will determine that a bag has completely fallen into the hole. As before, this will be sent to the micro-controller and interfaced with the app via Bluetooth.

An ultrasonic sensor will also be placed in the board the detect an incoming bag. This will be used to determine if a player has missed the board completely. If an incoming bag is detected by the sensor but there was no change in board-state, the throw is determined to be a complete miss. This will allow the app to alternate which team is throwing after each through with no issues.

**High Level Requirements**
To consider our project successful, we want to accomplish several objectives:

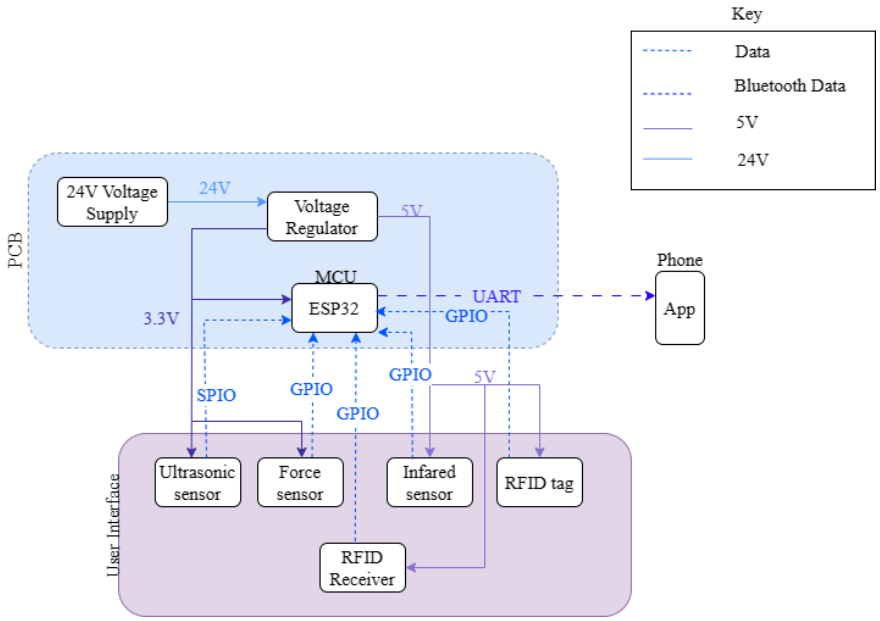
1. System must be able to accurately determine bags on the board and in the hole and deliver that information to the app
2. System must be able to determine misses and correct switch turns between teams
3. System must be able to communicate between app and cornhole board sensor array using Bluetooth

## 1.4 Visual Aid



# 2 Design

## 2.1 Block Diagram




## 2.2 Subsystems

### 2.2.1 Power Subsystem

The intended goal of the power subsystem is to provide adequate power for all other components of the design, primarily the sensor array and control unit. This subsystem will consist of a 24 Volt replaceable battery that will be mounted underneath the physical cornhole board.

Battery

Our project will be using a 24 Volt replaceable battery to power the sensor array as well as the PCB and microcontroller. The PCB will be used as a voltage regulator for the rest of the subsystems.

#### Subsystem Requirements

- Supply sufficient 24 V power to all components in the various subsystems.

#### Verification

- The power supply will be powered on and the voltage across the power supply will be measured using a multimeter to verify it is correctly outputting 24 volts.

### 2.2.2 User Interface Subsystem

The user interface system is the aspect of the project that will allow users to actually play the game and interact with the system. It will consist of a typical cornhole board and one set of bags to allow players to throw the bags on the board and test the auto-scoring of the system. It will also consist of the various sensors, including: ultrasonic, force, infrared, and RFID. These will be the components determining bag placement on the board and in the hole and sending this information to be transferred into a score.

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Cornhole Board

Physical wooden board used to play cornhole game

- 2'x4' surface with the hole being 6" in diameter, 6" away from the back of the board.
- Inclined at an angle of 10°

**Requirements:**

- Embedded electronics must have minimal effect on physical game play in comparison to a standard board

**Verification:**

- Bags must be able to slide on board unimpeded by the sensors
- RFID tags in bags must not add a noticeable amount of weight

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Ultrasonic Sensor

Located at the back of the board to sense when a bag is incoming. It will send a signal to the microcontroller, which will then use the signal to compare with the result of the toss. If an incoming bag is detected and there is not change in score, the throw will be considered a miss.

**Requirements:**

- Must be able to detect that a bag is incoming within a reasonable area
- Must be able to communicate with MCU through the PCB
- Must be positioned on the board such that it does not interfere with incoming bags
- Must not recognize players as bags

**Verification:**

- Must be able to sense if a bag within 2 feet of the board is heading in the direction of the board
- Players standing next to the board must not be detected as an incoming bag
- Bags sliding up past the hole should not stay on the board due to running into the ultrasonic sensor

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Force Sensors

Force sensing resistors will be spread out across the surface of the board in an array layout. These will be used in conjunction with the ultrasonic sensor to determine whether a tossed bag has either landed on or missed the board completely. In addition, they will be able to determine the amount of force a bag has imparted on impact.

**Requirements:**

- Must be sensitive enough to sense the impact of a bag,
- Must be able to determine the impact of the bags, as well as stationary bags on the cornhole board in order to ensure that the throw was not a miss
- Must be able to determine impact of bags on board and communicate that information to MCU

**Verification:**

- Impact of a bag provides a change in resistance significant enough such that it can be used by the MCU to determine that a bag has hit the board

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IR Emitter and Sensor

A pair of IR emitter and sensor will be placed inside of the hole to determine when a bag has fallen into the hole, which requires different score than simply landing a bag on the surface of the board. When the connection between the two are momentarily broken and restore, it will determine that a bag has fallen in.

**Requirements:**

- Must be able to detect that a bag has fallen in the hole
- Must be able to distinguish between a bag hanging over the hole and a bag that has completely fallen into the hole

- Must send a signal to the MCU that a bag has completely fallen into the hole

**Verification:**

- All bags going through the hole break the connection between emitter and receiver
- Connection not reestablished after three seconds is determined to be a bag hanging over the edge and points are not rewarded
- MCU must be able to use signal sent by the IR receiver to award the appropriate team three points

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RFID Receiver

A simultaneous RFID receiver will be mounted to the back of the board and will serve as points that will detect bags making contact and sticking onto the board.

**Requirements:**

- Must be able to communicate with RFID tags through board and bags material.
- Must be able to determine location of RFID tags.

**Verification:**

- To ensure that the internal antenna of the RFID reader is strong enough to receive the signal of the bags, the reader will be mounted under the board and the tags will be placed on top of the boards. The RFID reader outputs will be gathered to ensure that the antenna is receiving the signal of the tags through the material of the board.

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RFID Tags

RFID tags communicate with the RFID receivers when in close contact with each other. This serves to register that a bag has landed on the board. When a bag is registered, data is sent to the MCU which then sends data to the app via Bluetooth to tell it that the score has changed.

**Requirements:**

- Must not drastically the weight and feel of the cornhole bags
- Must be able to communicate with RFID receiver through the material of the bag

**Verification:**

- To ensure that the RFID tags will be read through the material of the cornhole board, the tags will be tested by mounting the reader underneath the board and layering the tags on top of the board to ensure the signal of the tags is received by the RFID reader.

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User Interface Subsystem Requirements

- Sensors accurately determine board impact and can communicate that information to app
- Sensors accurately determine board impact and can communicate that information to app
- Sensors can determine which bags are on the board and/or within the hole

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### 2.2.3 App Subsystem

The visual scoring component of this project will comprise of a mobile app which will be used to display the current score and game statistics of the game. The app will receive information from the control system and correctly compute the round score from those sensor outputs. The app will created using Android Studio to work on an Android phone and will communicate with the cornhole board control system using Bluetooth.

**App Subsystem Requirements:**

- To display the game score, an app will created that will provide an updated scoring and game statistics to users.
- Game statistics include percent of bags landing on the board and a player ranking to see who has scored the most points.
- App is able to provide correct game statistics to users, including game score and percent of bags landing on the board.
- App is able to receive information from MCU using Bluetooth.

**Verification:**

- To test the Bluetooth connection between the app and rest of the system, a test bag will be thrown at the board to see if the app correctly recognizes that a bag has hit the board and can display that information.
- Another round of test bags will be laid on the board to see if the app can correctly calculate and display score in a timely manner.

### 2.2.4 Control Subsystem

The control subsystem for this project will consist of an ESP32 microcontroller and PCB that will be used as a voltage regulator as well as a way to interface with the different sensors on the board. This project consists of several different sensor types and the control subsystem will be responsible for differentiating between each sensor and its respective outputs.

PCB

- Holds the microcontroller and provides power to the MCU

Microcontroller

- Utilizing an ESP32 microcontroller due to its Bluetooth capability

**Control Subsystem Requirements**

- Function as a voltage regulator to deliver power from the power subsystem to the sensors.
- Interface with the different sensors contained within the user interface subsystem.
- Correctly deliver outputs to the app subsystem.

**Verification**

- To verify the control system of this project, the PCB and microcontroller will be connected to the 24 V power supply and the voltage and current through the PCB will be measured to ensure the PCB is functioning properly as a voltage regulator.
- To verify the microcontroller, the otuputs received by the ESP32 will be recorded to ensure it is properly receiving signals from the user interface subsystem.

## 2.3 Tolerances

The focal point of the entire cornhole board system is the sensor array on the board used to determine where the bags are thrown. The primary set of sensors consist of an RFID receiver located on the board and that will interface with RFID tags in the bags to determine when the bags are located on the board. However, this leaves room for error, whether it be the bags moving or receiver inaccuracy. To ensure further accuracy, additional force sensors will be placed throughout the board to determine the location of impacts of the bags. The end goal is to ensure that each hit is accurate and has been through a series of checkpoints using various sensors that prove the bag is on the board.

For the RFID reader, we plan on using the M6E Nano, SparkFun Simultaneous RFID Reader, which will read up to 150 tags per second, much higher than the amount of tags we will be using in our system. With the onboard antenna, the bags will be able to be read up to 1 to 2 feet away. This range should be more than enough to read bags on the board while the reader is mounted underneath the board. However, to further decrease the likelihood of bags on the board not being measured by the RFID reader, we will using laundry RFID tags sewn into the bags as well as conductive thread sewn through that will ensure the tags make contact with the board and are therefore received by the M6E Nano internal antenna. By sewing the tags into the bags themselves, we also decrease the possibility of the tags being damaged or moved around by being continuously thrown.

The other potential issue is determining misses during the game. We want to be able to determine misses that were thrown within 2 feet of the board. By forcing a series of checks before determining a hit, we will also be able to determine when the bag hasn't hit the board.

# 3 Ethics and Safety

For a successful senior design project, it is imperative that safety and ethics policies are followed throughout the entire process.

For a successful project, any potential safety concerns with the project must be addressed (IEEE Code of Ethics I.1) [1]. Because our project is an auto-scoring cornhole game, there are not many immediate safety risks to users. However, there is the potential of electrical shock or fire due to faulty wiring or degradation of the board in inclement weather. This can be remedied by ensuring the wiring in our design is done with proper wires and that the board is built with weather-withstanding materials to protect the electronics. Although there is always going to be some risk, every care will be taken to minimize the little risk our project poses.

Ethical concerns must also be addressed to ensure that our senior design project is compliant with IEEE standards. Due to the nature of our project, the main ethical concern would most likely be plagiarism. In this project, designers will be researching several different components and methods and looking at other products in the automated game industry, such as auto-scoring dart boards. It is vital to make every effort to ensure each source is correctly cited and referenced in the senior design process.

# 4 Citations and References

[1] "IEEE code of Ethics," IEEE. [Online]. Available: https://www.ieee.org/about/corporate/governance/p7-8.html. [Accessed: 12-Sep2022].