Portable Sport Boundary Sensors

ECE 445 - Spring 2017

Project Proposal

Neil Bhide
Modhura Kar
Andreya Dart

February 8, 2017

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1 Introduction

1.1 Statement of Purpose

Imagine yourself playing tennis and the game is starting to get very close. You're getting paranoid that your opponent is starting to call a few of your shots incorrectly which causes tensions in the match that affect your gameplay. Our goal is to create a sensor system that would sense whether a shot is out or in and beep to inform the players.

Ideally, this sensor system will be small so it won't present hazardous to players. The sensors used will be similar to a garage door sensor and reflector system. The sensor will detect balls that land close to the line and determine if any part of the ball has touched the line or not. The sensor system will be easy to install, portable, able to withstand wind, and waterproof. The current plan is to have the sensors be battery-powered but if we have additional time we will try to make them solar powered. The sensors will be able to work on various courts making it usable for any sports court. This project will benefit recreational and competitive sports as it will remove the tensions that line calls provide during games as well as allow the players to pay more attention to the game itself instead of lines.

1.2 Objectives

1.2.1 Goals & Benefits

- ➔ Eliminates the distraction of watching if a ball is in or out
- ➔ Cheaper than using advanced camera technology

1.2.2 Functions & Features

- ➔ Rechargeable battery
- ➔ Small, compact and lightweight
- ➔ Sound will alert users if ball is in or out
- ➔ LED lights will notify user of battery charge

2 Design

2.1 Block Diagram

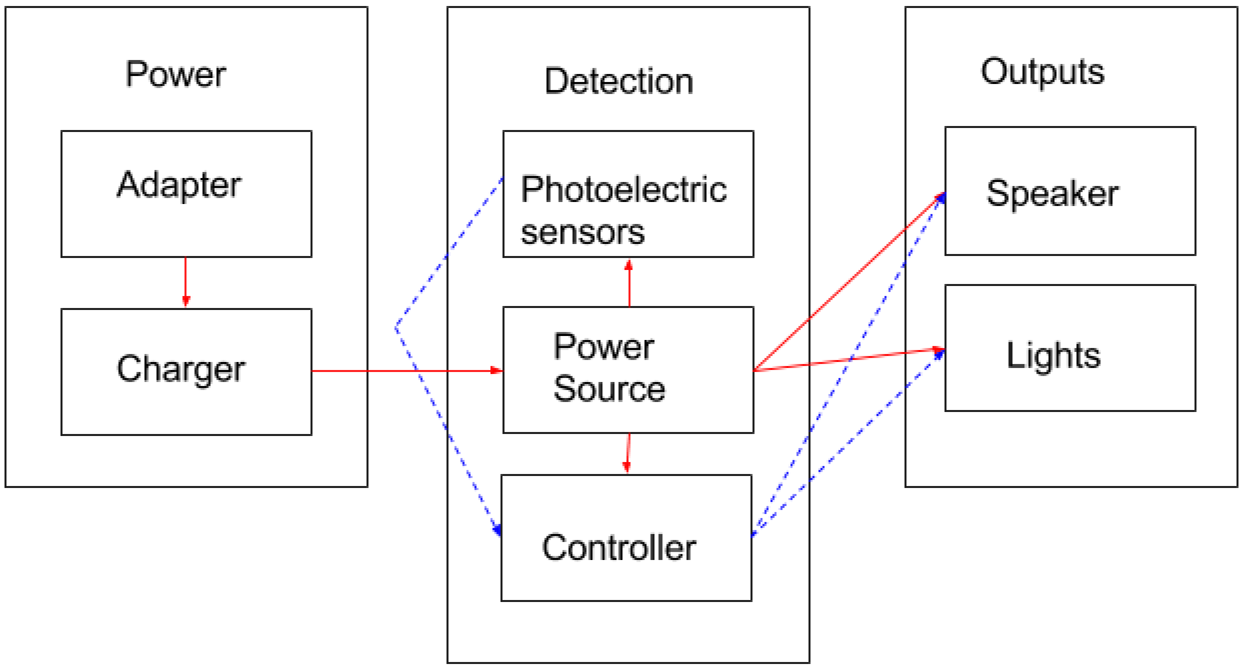

Figure 1. Top-Level System Block Diagram.
(The red lines represent power and the blue dotted lines represent controller signals)

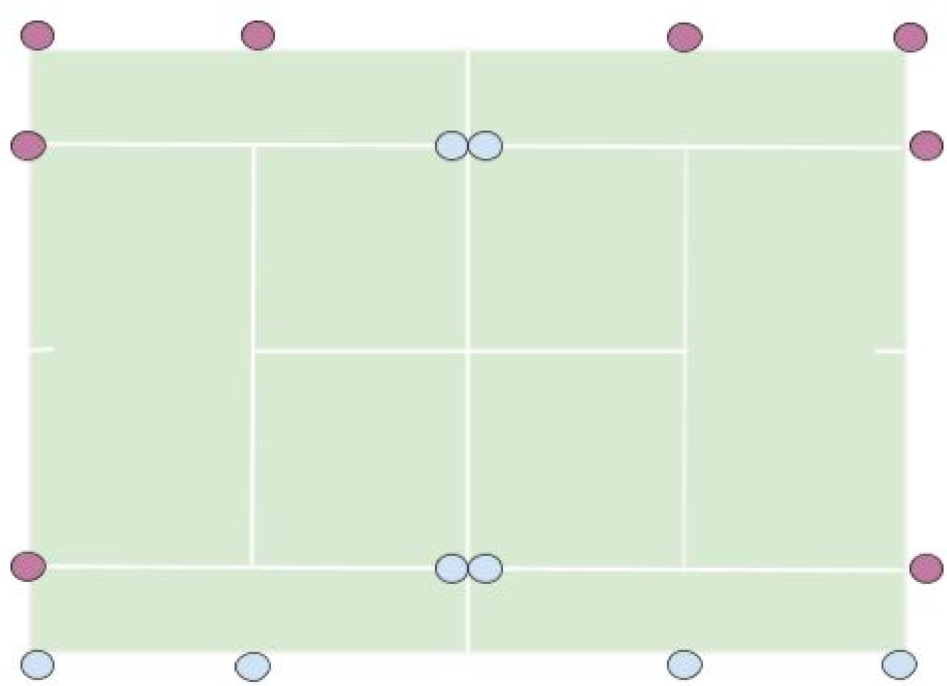

Figure 2. Tennis court diagram with sensor placements
(Blue ovals are emitter/receivers, purple ovals are reflectors)

2.2 Block Descriptions

The high block diagram in figure 1 corresponds to each single pair of sensors. There will be one power module for all sensors but each sensor will have an individual detection and output modules. Figure 2 is a diagram of a tennis court with sensor placements.

There are other possible solutions to checking if a ball has hit the line or not. One is using a high definition camera similar to systems used in professional sporting events. Another solution is computer vision where using a computer program to acquire, process, and analyze digital images of the ball hitting the line. While the two mentioned alternative solutions will be probably be more accurate, they are very expensive. Our project goal as mentioned in section 1, is to create a cheap system that can be used for recreational games.

For the sensors, the retroreflective arrangement was chosen over the trough-beam arrangement because it is less expensive while only slightly less accurate. We decided against the diffuse arrangement as well since it is significantly less accurate and takes a long time to install. The sensor we will be using is a photo eye EMX NIR Reflective Photo-beam with Reflector. It has a range of 0.3-30 ft and is easier to install. It has an LED on top that will light up when it is properly aligned and unobstructed. The gray wire at the output will switch from low to high when an obstruction is detected. The signal from the switch will get passed to the controller.

2.2.1 Power System

Power: This module will supply up to 4.5 to 5.5 V of voltage and at most 28 mA of current to the sensors, LED lights, and speakers without interruption.
Charger/Adapter: This component will charge the sensor system when the batteries have been drained. The range of values are between 0 and 12 V therefore it is an analog system. The charger and adapter will take 120 volts from a standard wall outlet and be able to charge the battery of the sensors. This charger and adapter will be a completely separate from the rest of the system.

2.2.2 Detection System

Detection: This module will be the brains of our project. It will receive analog inputs from the sensors and then decide whether the ball is in or out and notify the user with outputting noise.
Controller: This component will act as the middleman between the sensors and output module. Whenever the beam is broken, the ball is out and an analog signal from the sensor will be sent to the controller which will respond by using the speakers to “beep” allowing players to know the ball was out. Likewise, if the beam isn’t broken, then no signal will be sent to the controller, and no “beep” will be heard. The voltage range for the microcontroller is 4.5 to 5.5 V.The input will be when the output of the sensor and the output of our controller is a digital signal that goes to the speakers. The signal will be high when a ball has been detected and low when nothing has been detected.
Senors: This component is made up of photoelectric sensors set up in a retroreflective arrangement. A retroreflective arrangement is when the transmitter and receiver are in the same spot, while the reflector is opposite to them. A beam of light is sent from the transmitter to the reflector which is reflected back to the receiver. An object is detected when the beam is broken,

such as a ball hitting outside the line. Figure 3 is a diagram that shows how the sensors work with a reflector. The sensor has a pre built micro controller that outputs high when the beam is broken (an object has been detected/intercepted the receiver beam). This output becomes the input for the controller discussed above.

Power Source: This component is the battery that will be used to power the rest of the system. The battery is charged using an external power source. The battery is used to power the LEDs, speakers, microcontroller and photoelectric sensors. The battery is rechargeable and will have a minimum battery life of 8 hours.

2.2.3 Output

Outputs: This module will be what the users see when using the sensor system. It is made up of two components.

Speaker: This component will be how our system communicates with users. When the ball is out, the speakers will beep notifying the users that the ball is out. The speakers are driven with a analog signal.

Lights: This component will notify the user when the sensors need to be charged. Likewise, it will notify the user when the sensors are fully charged. More on this in Table 1. The turn on voltage for the LEDs are in the range 1.8 V to 3.3 V.

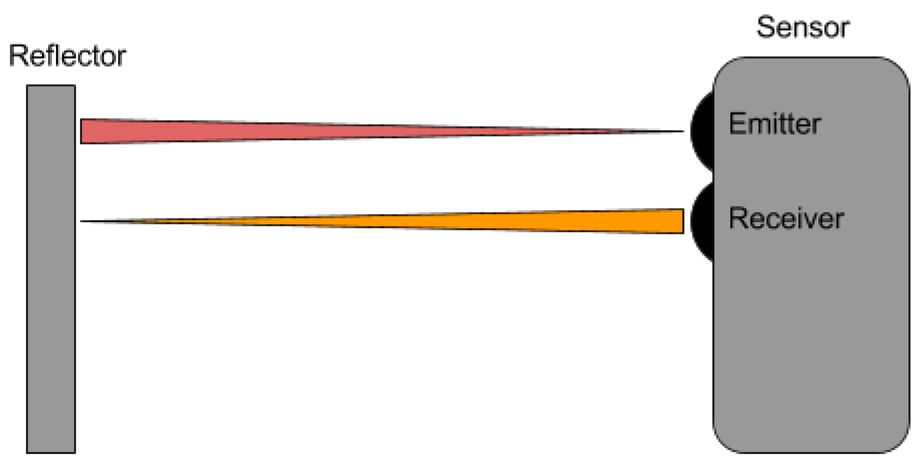

Figure 3. Photoeye sensor with reflector diagram

3 Requirements and Verification

This product is for recreational tennis use so the sensors may beep if there foot is there. This is not an issue because if the sensor beeps when there is a foot then the person is close enough to determine if the ball is in or out. Some design techniques to combat this is to have an infrared sensor that detects temperature and when the photoelectric sensor detects something, and the infrared sensor doesn't the system beeps. Another solution is to have the sensor stop beeping after 2 seconds. If anything is there longer than 2 seconds, chances are it is a foot or another item is present and the system can stop beeping. The first design solution is expensive and not necessary, however the second design solution could be something that can be implemented.

Table 1. Requirements and verification table

Requirements	Verification
Detection Must be able to detect 90% shots that are within 1 inch of the line. 1 inch is an appropriate amount because anything more will be able to be seen by at least one the players	1. Hit 1000 balls near the line: (20% lobs, 20% forehands, 20% backhands, 20% serves, 20% volleys) & (50% wilson balls, 50% penn balls). We are using two different types of balls and 5 different types of shots to account for different ball sizes and speeds. 2. The first test case is to launch 1000 balls that are out and see if 90% of those balls are in fact out. The way to do this is to take pictures of the ball as it hit to make sure it is in or out and then determine if the sensor correctly detected it. 3. The second test case is to launch 1000 balls that are on the line or within one inch of the line (in) and see if 90% of those balls alert the sensors.
Output Module The speaker must be played at 80 dB +/- 3 dB when balls are out.	1. Use a decibel meter to determine the sound output of the speakers in the following trials for each speaker. a. From the baseline, net, righ alley, left alley, and from the back of the court on either side of the net
Output Module Control panel light must be green (560 nm) for 50-100% battery (5 V - 2.5 V), yellow (570 nm) for 25-50% (2.5 V - 1.25 V), and red (635 nm) for 0-25% (1.25 V - 0V).	1. Use a multimeter to measure the amount of voltage left in the battery and see if the color matches the amount left. 2. Repeat 2-3 times to determine if it is accurate 3. We can generate the voltage battery curve
Power Module The charger/adapter must be able to work with a 120 V standard outlet. At the USB cord, we will have 5V +/- 0.5 V and upto 1A.	1. Test to see if the battery is charging on a standard US Port 2. Measure the current and voltage of the battery to determine if the power rating is in check.
Power Module The sensors must be able to detect if a ball is in or out for a minimum of 8 hours. Being able to detect is making a noise if the ball is within one inch outside of the line	1. Use the sensors for 8 hours total (2 hour; 4 times a week for 1 week) 2. Repeat 2 times
Power Module The battery must be able to perform fully for at least 500 cycles.	1. Connect multimeter to the battery while its discharging and plot the voltage produced by the battery over time. 2. After battery is fully discharged, recharge and repeat 50 times. 3. Check for any charge variation between the 50 trials to determine battery life.

4 Tolerance Analysis

The most critical component of circuit is the detection block because without the detection block, the product would be completely useless and wouldn't be able to alert the user if the ball is in or out. The detection block is vulnerable to not only electrical issues, but mechanical and practical issues. Mechanical issues include the sensor getting hit, losing calibration, and wind knocking the sensors over. These incidents would cause it to be a non-functioning product. Some practical issues include the sensors detecting leaves and debris on the court or a person's foot while playing. This would cause the output noise to go off, which shouldn't be an issue because this sensor system is for recreational purposes. An electrical issue is the sensor unabling to charge which would deem the product to be useless. Our battery will draw 240W of power, 24 Volts, and up to 10 A of current to power the LEDs, speakers, microcontroller, and photoelectric sensors. Using 3 standard LEDs will draw 60mA, the microcontroller will draw 3.6mA when on and 1mA when it is not being used, 28mA for the sensors, and .5A for the speakers. The current output is sufficient for all the components we want to have run.

An appropriate threshold for us is 3.5 because the sensor system will be used for recreation sports. Table 2 is a risk analysis table that we created to compare situations that would cause our sensor system to lose functionality.

Table 2. Risk analysis table

Situation	Scale 1-10	Probability	Score
The sensor gets hit and loses calibration	8	.20	1.6
Sensor is unable to charge	8	.1	.8
The wind knocks the sensor over	7	.3	2.1
Sensor detects leaves/debris on the court	5	.5	2.5
Sensor detects a person's feet while playing	6	.65	3.9

Looking at the table above, the most critical component is if the sensor detects a player's foot while playing. To meet reliability goals, the sensors need to have a period of > 1 ms. To test this, we will measure how long the sensors take to calibrate after sensing an object. By doing this, we will be able to figure out how long after sensing an object, the sensors will sense another object. The probability that the sensors gets hit is about 20% because players tend to hit closer to the lines, and from casual recreation play, about 20% of the shots are close to the line. Factors like wind, leaves, and a person's feet are 30, 50, and 65% respectively. This is because plays like to play close to the baseline especially for service and rallies. The wind and leaves are approximated from personal experience while playing.

5 Cost and Schedule

5.1 Cost Analysis

This project will require a big workload, as none of us have experience working with this type of sensors. We will have to perform a lot of tests beforehand to fully understand how certain parts work by themselves and in relation to other parts.

5.1.1 Parts:

Table 3. Parts cost

Part Name and Quantity	Unit Cost	Total Cost
8 EMX NIR Reflective Photobeams with Reflectors (includes LED's)	$80	$640
2PCS Round Micro Speaker Diameter 28mm 8Ohm 8R 2W	$3	$3
24V 240W 10A switching power supply 7PIN adjustable voltage	$37	$37
1 ACUS-12V - AC 90-240V input power adapter	$9	$9
1 Tripp Lite UR022-006-SLIM 6FT USB 2.0 High Speed Super Slim Cable Reversible A to B M/M 6Ft	$6	$6
8 Dynamic Receivers SD153BH	$0.01	$0.08
1 Pololu USB AVR Programmer	$19.95	$19.95
8 ATMEGA8 Microcontroller	$2.24	$17.92

5.1.2 Labor:

Table 4. Labor costs

Name	Hours Invested	Hourly Rate	Total Cost
Neil Bhide	360	$27.50	$9,900.00
Andreya Dart	360	$27.50	$9,900.00
Modhura Kar	360	$27.50	$9,900.00
Total	1080	$82.50	$29,700.00

5.1.3 Total:

Table 5. Total costs

Scenario	Labor	Parts	Total
Paid Engineering	$19,800.00	$732.95	$20,532.95
Volunteer Engineering	$0.00	$732.95	$732.95

5.2 Schedule

Table 6. 10-week schedule

Week	Task	Responsibility
1	Determine circuit design & parameters	Neil
	Design circuits	Modhura & Andreya
	Investigate ball/leg detection	Andreya
2	Code microcontroller	Neil & Andreya
	Order parts	Modhura
3	Test parts	Neil & Andreya
	Design power connections	Modhura & Andreya
4	Program microcontroller	Neil & Andreya
	Build power system	Modhura
5	Implement microcontroller with sensors	Neil & Modhura
	Design PCB	Andreya
6	Debug microcontroller system & write on report	Neil
	Debug power system and write on report	Modhura & Andreya
7	Test PCB and work on report	All
8	Test charging capabilities	Neil & Modhura
	Test PCB with power system and sensors	Andreya

9	Test PCB with sensors and prepare for presentation	All
10	Field testing and prepare for presentation	All