Embedded Systems Design II Final Project **Dr. Semeraro**
Tennis Ball Tracker

1. Introduction

This is the final project for Embedded Systems Design II which is the culmination of the curriculum capstone experience for the Computer Engineering Technology program. This project consists of two phases:

Preliminary Design Review (PDR)
Critical Design Review (CDR)

Due to the complex nature of the challenges, you will self-organize into groups that consist of between four and six individuals. You are encouraged to divide up the work between team members; however, you are expected to understand and be able to explain, in detail, all aspects of the project. A list of likely tasks /roles are listed below – you must decide the project organization and roles; this is just a possible list. It is recommended that at least two team members work on each item to mitigate the risk of a single-point failure, bringing down the entire project for everyone in the group. You are also strongly encouraged to maintain up-to-date status of all items so that nothing gets lost and ends up not getting done.

- System Architecture
- Firmware
- Software
- GUI
- Algorithm Development
- System integration
- System and Subsystem Testing
- Program Management (cost and schedule)
- Risk Assessment and Mitigation
- Documentation

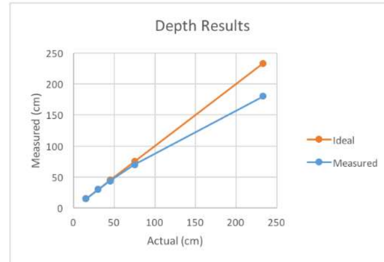
The information needed for the project will be covered during the course, but it won't be organized by tasks / roles; it will be available to you, but you need to take the initiative by asking questions and deciding what needs to be done and who needs to do it.

2. Project Description

Since 2003, Hawk-Eye has been used to make calls for the United States Tennis Association [USTA]. Recently it has been determined that under windy conditions the calls are not very accurate. This is because the wind slightly shifts the cameras resulting in increased error. The USTA has decided to fund the development of a new FPGA-based tennis ball tracker that can guarantee accurate results every time. The USTA has agreed to fund several companies up through a preliminary design review [PDR], and critical design review [CDR], and then will ultimately select a single company to design their system. The USTA expects to see detailed technical and financial analysis as well as a summary of potential risks pertaining to cost, schedule, and technology. They have also requested that each company put together a fully working demo that makes use of a virtual camera and 3D world. The selected company will be one that demonstrates the best overall design and that comes in at the most attractive price point. In short, each company must develop a tennis ball tracker system that accurately determines ball position within 3D space.

3. System Accuracy Analysis Based on Ball Position [static camera] [15 pts]

The customer needs to know how accurate your system is at finding the exact location of the tennis ball. Develop a technique to generate accuracy plots for your system. Note that your system accuracy might change over X,Y,Z positions. Refer to the paper located here for some ideas about how to determine accuracy.
Paper link

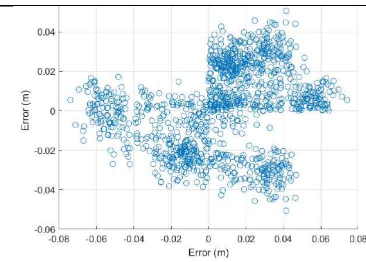


Grading Rubric

Description	Points
Accuracy Technique	6
Total Accuracy	6
GUI Appearance\Functionality	3

4. System Accuracy Analysis Based on Camera Position [static ball] [15 pts]

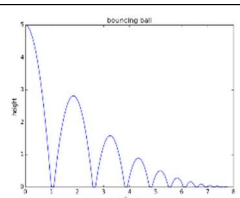
The customer needs to know how accurate your system is at finding the exact location of a tennis ball when the camera is shifting. Develop a technique to generate accuracy plots for your system as your camera moves around. The customer is interested in knowing the maximum error that can be expected on a windy day



Grading Rubric

Description	Points
Accuracy Technique	6
Total Accuracy	6
GUI Appearance\Functionality	3

5. Coefficient of Restitution [10 pts]



Surface	Characteristics	Best for
Clay	• Slow • High bounce	• Baseline players • drop shots
Grass	• Fast • Low bounce	• Serve and volley • Big servers
Hard (concrete, macadam)	• Medium speed • Highest bounce	• Baseline players • Longer rallies

$$\text{Coefficient of restitution } (e) = \frac{|\text{Relative velocity after collision}|}{|\text{Relative velocity before collision}|}$$

There has been some controversy over the past couple years about the advantages of various types of tennis courts. The USTA would like you to determine the coefficient of restitution for your court, which effectively determines how bouncy it is.

Grading Rubric

Description	Points

Algorithm Development	4
Accuracy	4
GUI Appearance\Functionality	2

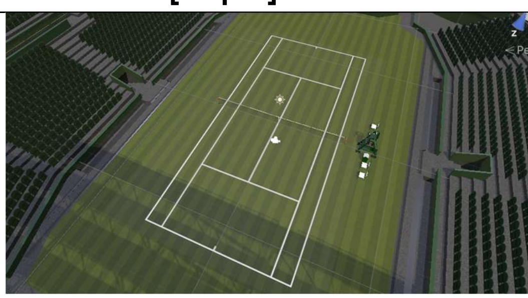
6. LED Visualizations [10 pts]

To create a better experience for fans the USTA is thinking about adding large LED structures to many of the tennis stadiums. When a ball is in bounds, they want a green LED to stay on constantly and when the ball is out of bounds, they want a red LED to blink at a rate of 10 Hz with a 50% duty cycle.

Grading Rubric

Description	Points
Blink on Bounce	4
Flash on Out	4
GUI Appearance\Functionality	2

7. Tennis Tracker [45 pts]



You will be given a Blender tennis court, and you will be allowed to place 2 cameras anywhere around the court. You can use the Mathworks to Blender link to move the Blender camera and/or ball via a MatLab interface. An image of the Blender tennis court is shown to the left. Feel free to use any custom camera resolution, focal length, etc. The only constraint is that the parameters that you use must exist in the real world.

Track Serve

You will be given a function that receives the time and generates the X,Y,Z of the tennis ball. You will be required to determine if 5 serves are in or out.

Track Volley

You will be given a function that receives the time and generates the X,Y,Z of the tennis ball. You will be required to determine if 5 volleys are in or out.

Instant Replay

You are to demonstrate a way to show an instant replay of a shot.

Grading Rubric

Description	Points
GUI Appearance\Functionality	10
Track Serve	15
Track Volley	15
Instant Replay	10

8. Grading

The final project grade will be determined based upon the below chart

	Points
System Accuracy Analysis based on Ball Motion	15
System Accuracy Analysis based on Camera Motion	15
Coefficient of Restitution	10
LED Visualization	10
Tennis Tracker	40
Professionalism, Documentation, Presentation, and Promotional Videos	10
Total	100

9. Tips

- Frontload your work on this project. Plan to finish at least 1 week ahead of time.

- See me to go over your design before you go too far down the wrong path

- Use version control

- Meet at least weekly to keep all group members honest

- Clearly assign roles to all group members and set concrete delivery dates

10. Key Dates

PDR	During lab times **30-March-26 through 3-April-26** ▪ **Monday March 30th, 10am-11:50am** ▪ **Wednesday April 1st, 10am-11:50am** ▪ **Wednesday April 1st, 12:00pm-1:50pm**
CDR	During Final Exam times the week of **29-Apr-26 to 6-May-26** ▪ **Wednesday April 29th, 8:00am-10:30am** ▪ **Thursday April 30th, 8:00am-10:30am (the scheduled final exam time for this course)** ▪ **Friday May 1st, 8:00am-10:30am**