BallBot

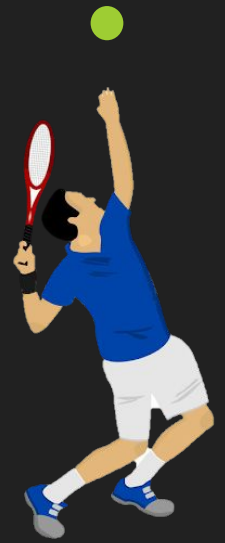
Team B3 - **Rashmi Anil**, Ishaan Gupta, Ryan Stentz

Introduction and Motivation

- In tennis equipment market, there exist very few advanced electronic devices assisting in the feeding and picking of tennis balls
- Tennis players often spend more time picking up balls after a serving practice session than hitting them
- Current approach - Ball Hopper
  - Can hold 70-80 balls
  - Heavy and Cumbersome
  - Takes away from practice time
  - Players are already exhausted after practice

Use Case and Project Scope

- Robot that autonomously detects and collects tennis balls after serving practice
  - There will be many balls on the court clustered together
  - Detects lime green tennis balls
    - 20 - 30 ball capacity
  - Outdoor courts in daylight
- ECE Areas:
  - Software
  - Signals
  - Hardware



High-level User Requirements

- Make tennis practice more efficient and less painful
- Quickly autonomously collect 20-30 balls
  - Average case: 6 balls / minute
- Has a battery life of at least 30 minutes
  - Average person practices their serve for a maximum of 30 minutes
- Weighs less than 20 pounds - i.e easy for the tennis player to carry onto and off of the courts

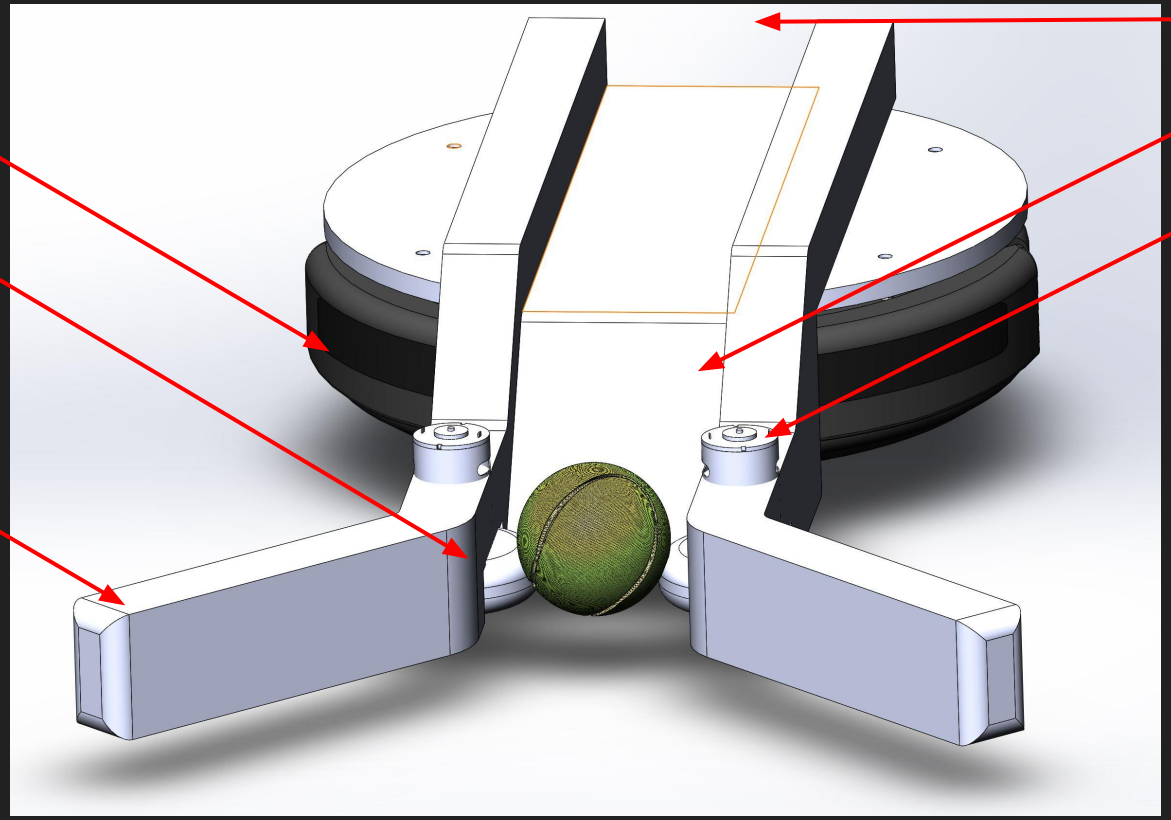
Technical Requirements

- Software:
  - Can process video frames from camera at at least 10 fps.
  - Have a 0% false positive rate for detecting a ball so that the robot does not start moving towards a nonexistent ball.
  - Have a less-than 5% false negative rate for detecting a ball so that it is rare that there is a ball that the robot does not go after.
  - Robot is completely autonomous
- Hardware:
  - Can propel tennis balls at a speed of 2.2 m/s
  - Can capture tennis balls within 1 foot from the center of the robot
  - Can hold on to tennis balls while turning

Key Technical Challenges

- Being able to detect tennis balls in varying outdoor lighting
  - Use OpenCV to develop algorithm to track balls
    - Thresholding range of possible colors and filtering out noise
- Picking up the balls from the ground and storing it.
  - Design a front with long side arms to gather balls
  - Have 2 spinning wheels that launch tennis balls from ground into onboard basket
- Building a Robot capable of pulling 30 tennis balls in addition to its own weight
  - Use iRobot Create 2 which is capable of towing 9kg
    - Trade off: Modifying the iRobot externally and programming it will be its own challenge

Solution Approach – Mechanical



Solution Approach – Hardware

- **Robotics**
  - iRobot Base
  - 2 motors to launch tennis ball (RS555)
    - L298N motor driver
  - Intel RealSense Depth Camera D435i
- **Power**
  - Buck Converter
  - 12V Lipo Battery
    - Battery to power Jetson Nano and Motors
- **Computer**
  - Nvidia Jetson Nano

Solution Approach - Software

- Locate balls using computer vision
  - OpenCV (python)
- Use color thresholding to detect tennis balls
  - Use HSV color space
  - Check range of colors near that of a tennis ball since balls have distinct color
  - Filter out noise using erode and dilate functions in OpenCV
  - Find minimum enclosing circle around regions of tennis ball color to locate tennis balls
- Track tennis balls across frames
  - Keep track of previous location of closest tennis ball
- Determine best path for the robot to reach the ball
- Control iRobot based on best path

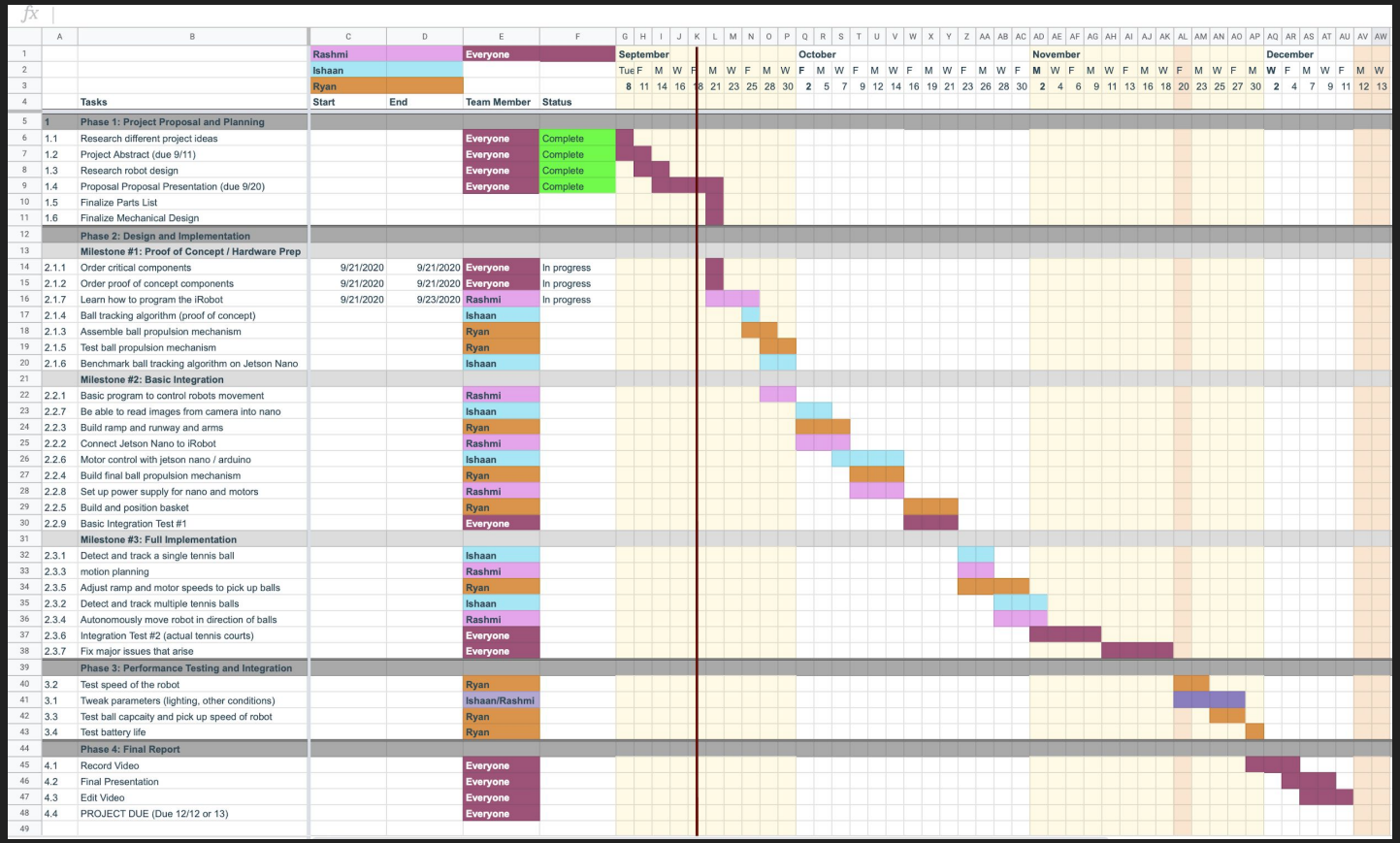
Metrics, Testing & Verification

Requirements	Testing	Metrics
Quickly and autonomously collect tennis balls	Time robot picking up 30 balls	Picks up 20-30 ball at an average of 6 balls per minute
Battery lasts a serving session	Run robot until battery dies	Battery lasts at least 30 minutes.
Lightweight and portable	Weigh robot on scale	Weighs less than 20 pounds
Fast image processing	Run ball tracking algorithm on Jetson Nano	Tracking algorithm runs at > 10 frames per second
Robot does not move towards non existent balls	Drive robot around empty tennis court and check output	0% false positive rate in tennis ball detection
Rarely misses existing ball	Place multiple balls in robot FOV and check output	Less than 5% false negative rate for tennis ball detection
Can pick up tennis balls into basket	Run robot picking up 30 balls	Balls get launched by wheels at 2.2 meters/second and land in basket

Tasks and Division of Labor

01	Ishaan Gupta	• Motor control with jetson nano / arduino • Ball detection • Benchmark ball tracking algorithm on Jetson Nano
02	Rashmi Anil	• Learn to program the iRobot create 2 • Integrate jetson nano and iRobot create • Set up the power supply for the robot • Using the outputs from the sensors, control the robot
03	Ryan Stentz	• Build ramp and runway and arms • Build ball propulsion mechanism • Build and position basket • Final testing (post Thanksgiving)

Schedule / Gantt Chart



		Tasks	Start	End	Team Member	Status
		Rashmi			Everyone	
		Ishaan				
		Ryan				
1		**Phase 1: Project Proposal and Planning**				
2	1.1	Research different project ideas			Everyone	Complete
3	1.2	Project Abstract (due 9/11)			Everyone	Complete
4	1.3	Research robot design			Everyone	Complete
5	1.4	Proposal Proposal Presentation (due 9/20)			Everyone	Complete
6	1.5	Finalize Parts List				
7	1.6	Finalize Mechanical Design				
8		**Phase 2: Design and Implementation**				
9		**Milestone #1: Proof of Concept / Hardware Prep**				
10	2.1.1	Order critical components	9/21/2020	9/21/2020	Everyone	In progress
11	2.1.2	Order proof of concept components	9/21/2020	9/21/2020	Everyone	In progress
12	2.1.7	Learn how to program the iRobot	9/21/2020	9/23/2020	Rashmi	In progress
13	2.1.4	Ball tracking algorithm (proof of concept)			Ishaan	
14	2.1.3	Assemble ball propulsion mechanism			Ryan	
15	2.1.5	Test ball propulsion mechanism			Ryan	
16	2.1.6	Benchmark ball tracking algorithm on Jetson Nano			Ishaan	
17		**Milestone #2: Basic Integration**				
18	2.2.1	Basic program to control robots movement			Rashmi	
19	2.2.7	Be able to read images from camera into nano			Ishaan	
20	2.2.3	Build ramp and runway and arms			Ryan	
21	2.2.2	Connect Jetson Nano to iRobot			Rashmi	
22	2.2.6	Motor control with jetson nano / arduino			Ishaan	
23	2.2.4	Build final ball propulsion mechanism			Ryan	
24	2.2.8	Set up power supply for nano and motors			Rashmi	
25	2.2.5	Build and position basket			Ryan	
26	2.2.9	Basic Integration Test #1			Everyone	
27		**Milestone #3: Full Implementation**				
28	2.3.1	Detect and track a single tennis ball			Ishaan	
29	2.3.3	motion planning			Rashmi	
30	2.3.5	Adjust ramp and motor speeds to pick up balls			Ryan	
31	2.3.2	Detect and track multiple tennis balls			Ishaan	
32	2.3.4	Autonomously move robot in direction of balls			Rashmi	
33	2.3.6	Integration Test #2 (actual tennis courts)			Everyone	
34	2.3.7	Fix major issues that arise			Everyone	
35		**Phase 3: Performance Testing and Integration**				
36	3.2	Test speed of the robot			Ryan	
37	3.1	Tweak parameters (lighting, other conditions)			Ishaan/Rashmi	
38	3.3	Test ball capcaity and pick up speed of robot			Ryan	
39	3.4	Test battery life			Ryan	
40		**Phase 4: Final Report**				
41	4.1	Record Video			Everyone	
42	4.2	Final Presentation			Everyone	
43	4.3	Edit Video			Everyone	
44	4.4	PROJECT DUE (Due 12/12 or 13)			Everyone	