BallBot - Design Review

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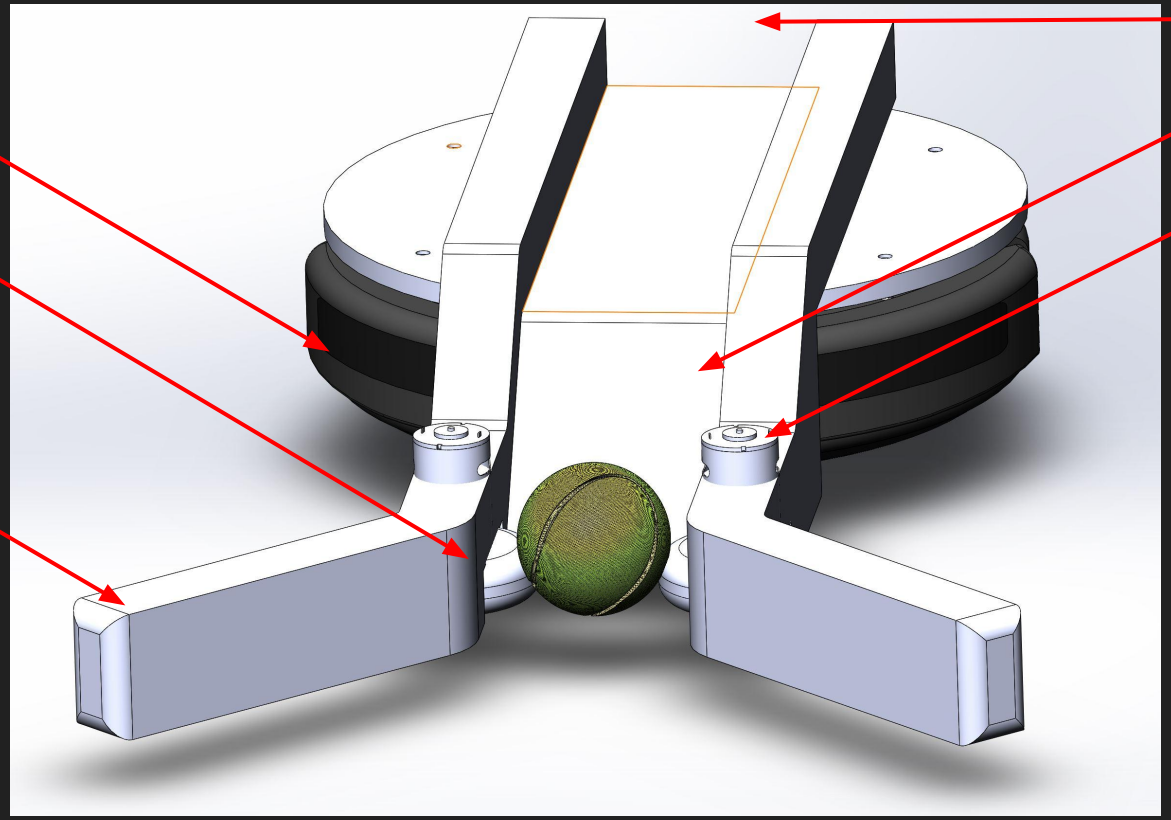
Application Area

- 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

Solution Approach

- Ballbot - 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
  - Hard surface courts

Solution Approach – Mechanical



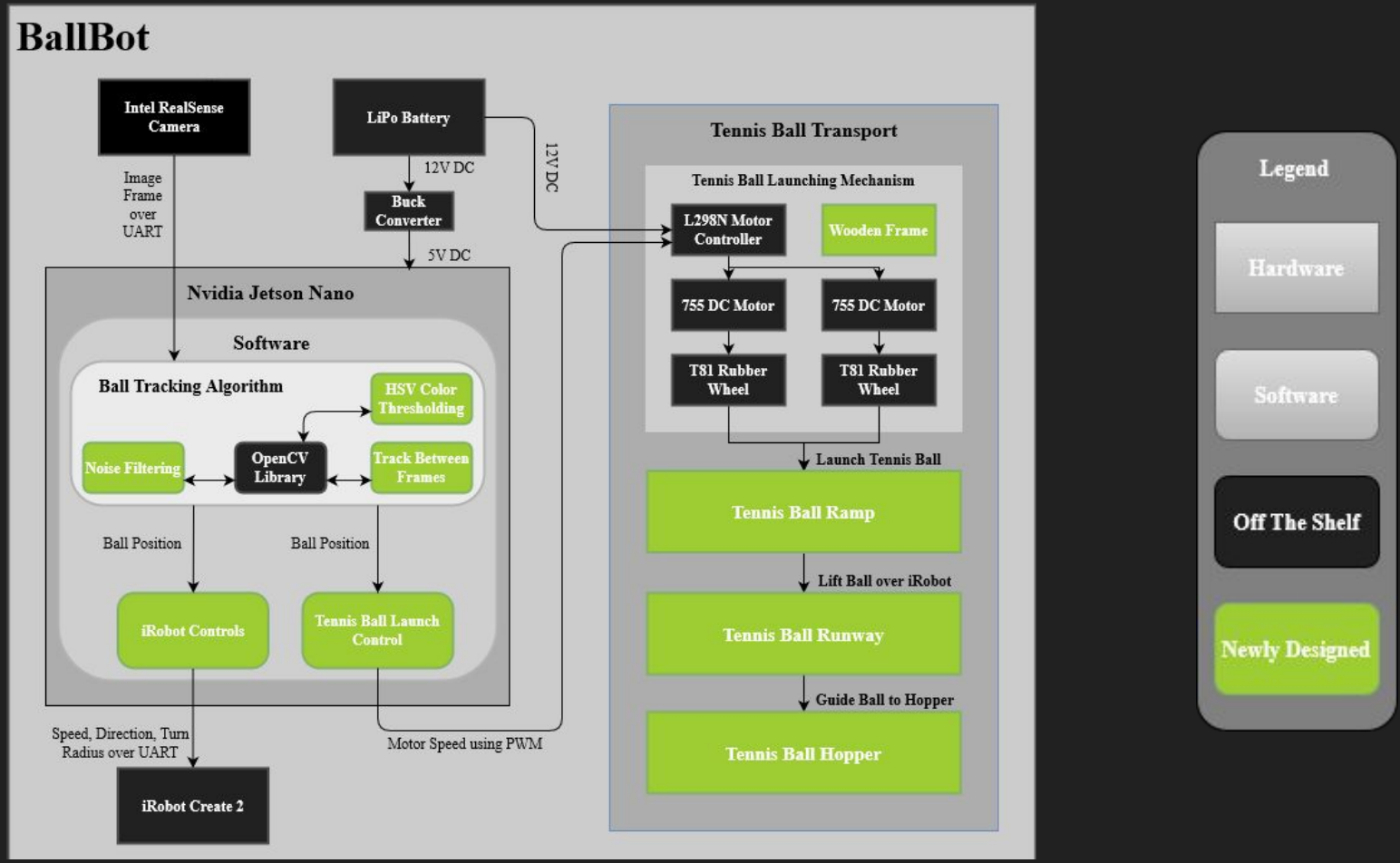
Solution Approach – Hardware

- **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
- 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
  - Program via opcodes

System Specification



Implementation Plan

- Ball Tracking
  - Bought Intel RealSense Camera and Nvidia Jetson Nano
  - Downloaded OpenCV
  - Designing/Implementing own noise filtering, color thresholding, and tracking algorithms using OpenCV to interface with image frame.
  - Developing software to use ball location from ball tracking algorithm to send commands to iRobot and control the ball collection motor speeds
- Robot Assembly
  - Bought wood, acrylic, motors, wheels, iRobot, and Jetson Nano
  - Modeled robot design in CAD
  - Designing/Prototyping custom mechanical components including ball launcher and ball ramp

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 often move towards non existent balls	Drive robot around empty tennis court and check output	Less than 5% 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

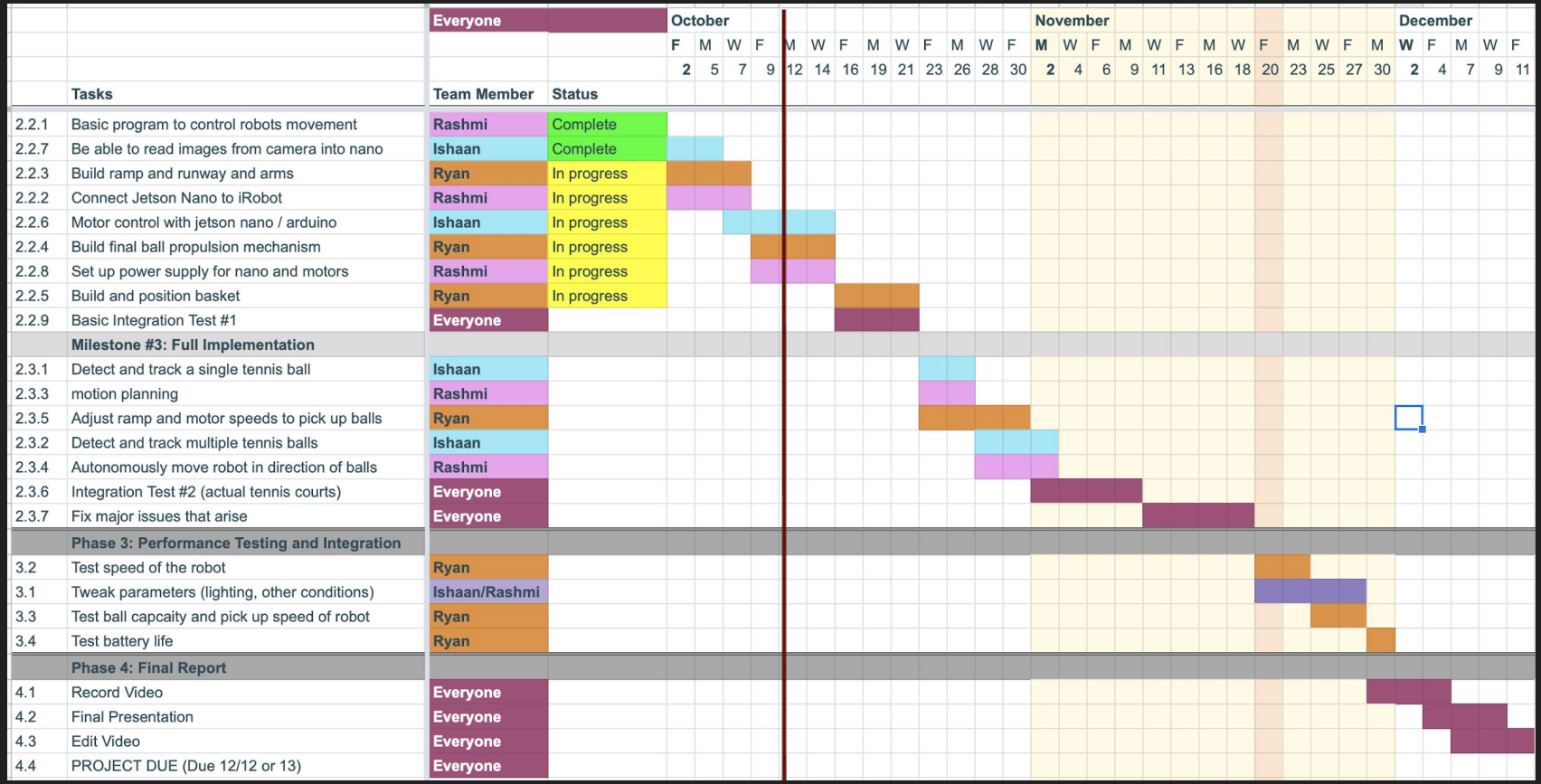
Risk Factors/Unknowns

- **Risk:** battery may have insufficient capacity to allow robot to run for 30 minutes
  - **Mitigation:** buy a second battery and wire the two in parallel
- **Risk:** lighting varies from day to day depending on weather and can cause significant effects on CV algorithm performance
  - **Mitigation:** Have auto calibration to adjust color threshold values each time robot is run.
- **Risk:** Ballbot doesn't move fast enough to collect at least 6 balls/minute.
  - **Mitigation:** Implement a planning algorithm using depth information from the RealSense camera to make Ballbot more efficient

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	Team Member	Status
2.2.1	Basic program to control robots movement	Rashmi	Complete
2.2.7	Be able to read images from camera into nano	Ishaan	Complete
2.2.3	Build ramp and runway and arms	Ryan	In progress
2.2.2	Connect Jetson Nano to iRobot	Rashmi	In progress
2.2.6	Motor control with jetson nano / arduino	Ishaan	In progress
2.2.4	Build final ball propulsion mechanism	Ryan	In progress
2.2.8	Set up power supply for nano and motors	Rashmi	In progress
2.2.5	Build and position basket	Ryan	In progress
2.2.9	Basic Integration Test #1	Everyone	
	Milestone #3: Full Implementation		
2.3.1	Detect and track a single tennis ball	Ishaan	
2.3.3	motion planning	Rashmi	
2.3.5	Adjust ramp and motor speeds to pick up balls	Ryan	
2.3.2	Detect and track multiple tennis balls	Ishaan	
2.3.4	Autonomously move robot in direction of balls	Rashmi	
2.3.6	Integration Test #2 (actual tennis courts)	Everyone	
2.3.7	Fix major issues that arise	Everyone	
	Phase 3: Performance Testing and Integration		
3.2	Test speed of the robot	Ryan	
3.1	Tweak parameters (lighting, other conditions)	Ishaan/Rashmi	
3.3	Test ball capcaity and pick up speed of robot	Ryan	
3.4	Test battery life	Ryan	
	Phase 4: Final Report		
4.1	Record Video	Everyone	
4.2	Final Presentation	Everyone	
4.3	Edit Video	Everyone	
4.4	PROJECT DUE (Due 12/12 or 13)	Everyone	