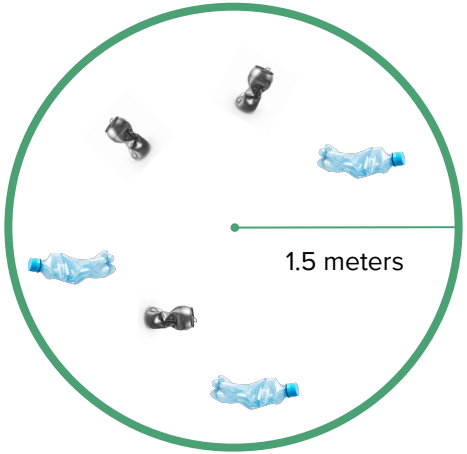
Use Case/Application

- RecycleBot will autonomously:
  - Detect, pick up and store littered bottles
  - **Avoid** potential non-bottle obstacles
- Key Task: locate and pick up **3 water bottles** within a 1.5 meter radius of the robot
- Changes:
  - Decided to pivot to standard size empty bottles at different orientations and crush levels

Photo credits: tinyurl.com/4438ebdd

Quantitative Use-Case Requirements

- Algorithm correctly identifies the following with less than 10% false positive rate:
  - 90% water bottles
  - 80% obstacles
- Robot avoids obstacles with 80% success
- Picks up and stores detected bottles with 70% success
- Takes less than 1.25 minutes to pick up 3 items distributed
  within a 1.5 meter radius with no obstacles

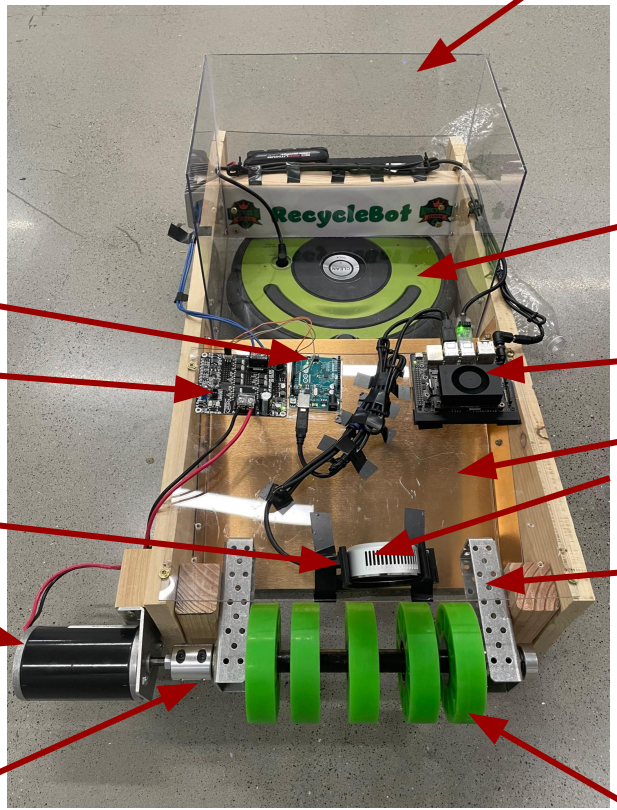


tinyurl.com/4a25ju2y, tinyurl.com/4uhytvna

Solution Approach

- **iRobot Augmentation**
  - Intake mechanism + storage structure
- **Object Detection - ML model**
  - Pre-labeled bottle dataset to train model; identifies bottle in field of vision
- **Navigation - LiDAR and iRobot control**
  - LiDAR measures distance between robot and detected bottle
  - Object tracking determines when object is centered
  - iRobot Open Interface for actuator command
- **Obstacle Avoidance - LiDAR and multi-object tracking**
  - Track all objects when moving forward
  - Turn to avoid when tracked obstacle is closer than target

Complete Solution



Lexan Backboard

iRobot

Arduino Uno

Cytron Motor Driver

Nvidia Jetson Xavier

Ramp

3D Printed Camera Stand

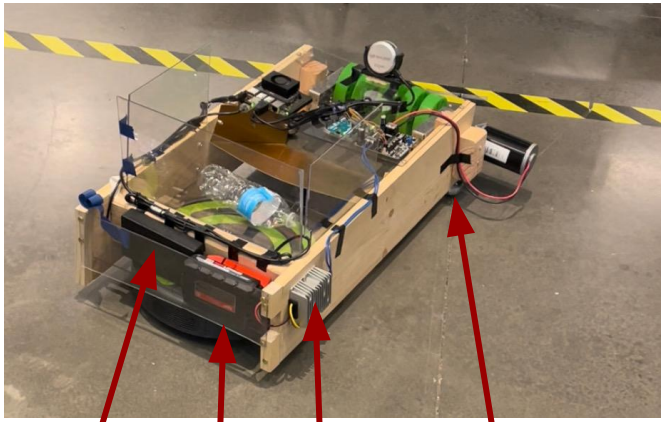
Intel Realsense

Intake Mounts

Cim Motor

Intake Shaft and Shaft Couplers

Compliant Wheels



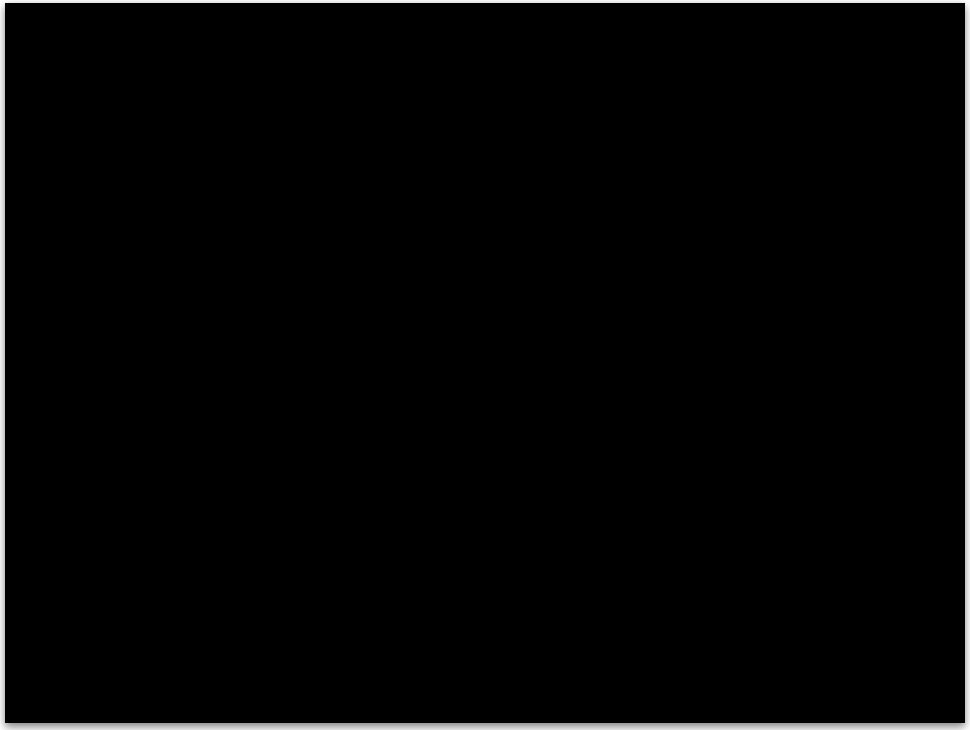
Jetson 12V Battery

Drill Battery 18V to 12V Step Down

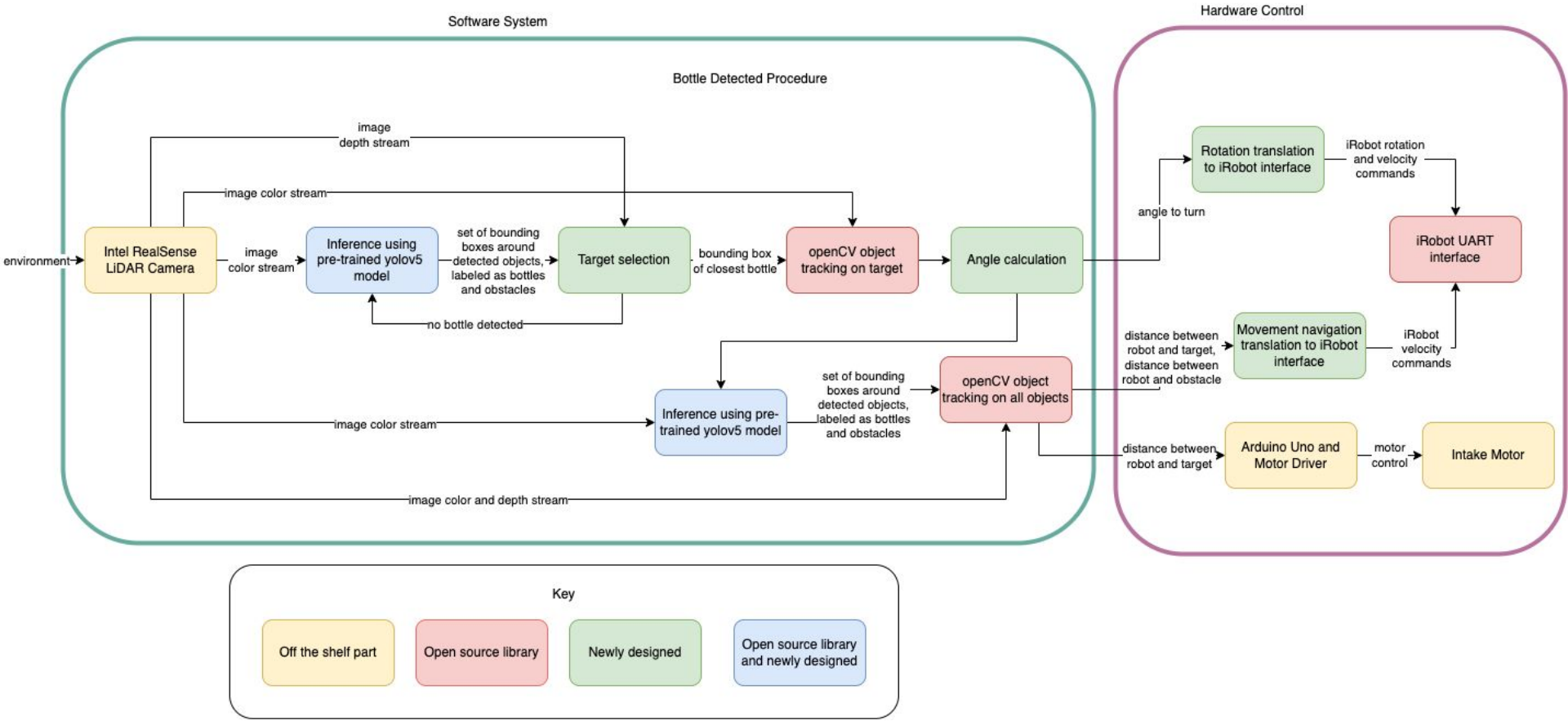
Milwaukee 18V Drill Battery

Caster Wheels

Complete Solution



System Specification - Block Diagram



Test, Verification and Validation

- Environment- Techspark
  - Objects randomly placed within a 1.5m radius
  - Objects at least .45m apart from each other
  - Concrete background
  - Fixed lighting
- Test cases
  - 3 bottles
  - 3 bottles + 3 obstacles
- For each test case, we will compare the average of 10 runs (1 run = completion of one 1.5m radius) with our metrics

Testing Specifications and Performance

Testing	Metric Goals	Current Robot Performance (out of 10 trials)
3 bottles	- 90% detection accuracy - 70% pickup success - < 1.25 min (when 100% detection) - < 10% false positive rate	- 83% detection accuracy - 66% pickup success - 1.95 min average (when 100% detection) - 0% false positives
3 bottles + 3 obstacles	- 90% bottle detection accuracy - 80% obstacle detection accuracy - 80% obstacle avoidance success - 70% pickup success	- To be tested ...

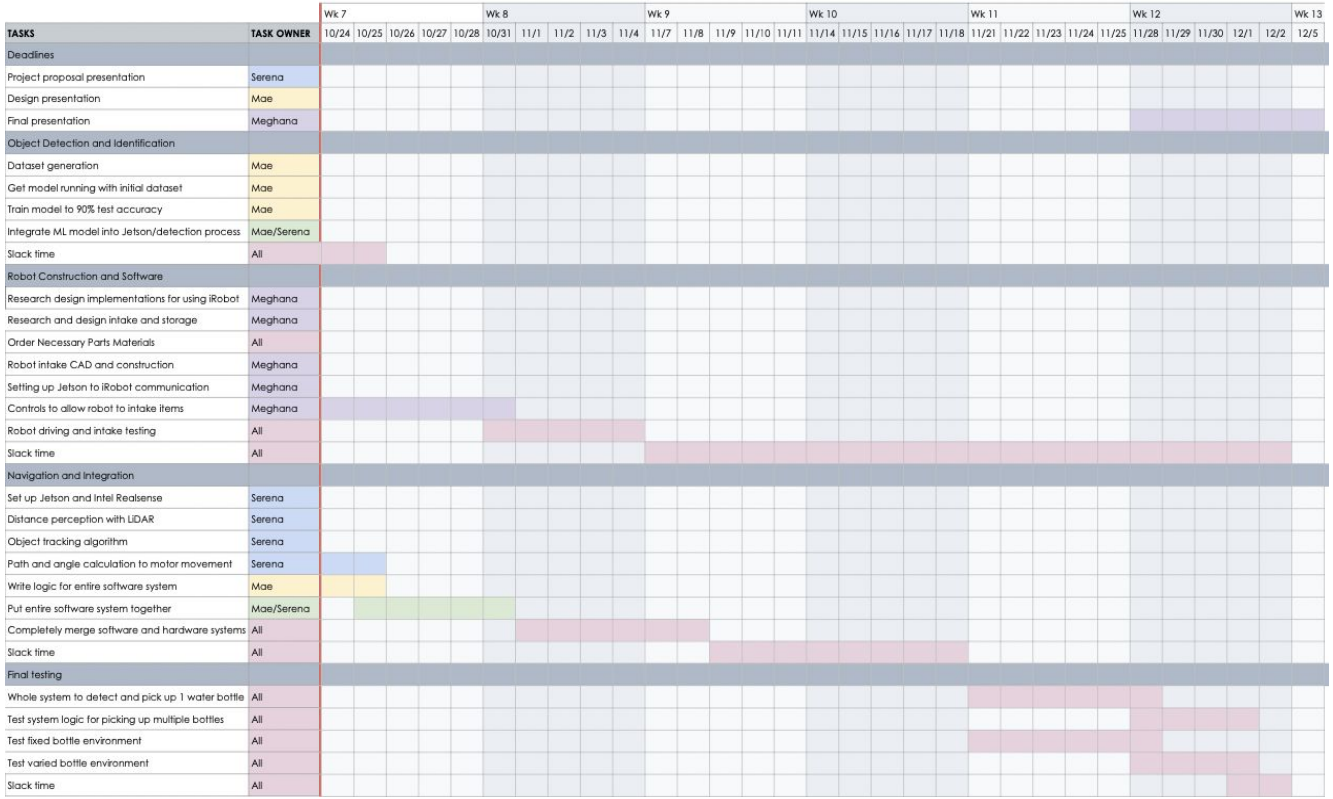
Robot/Hardware Design Trade-offs

Requirement	Our Solution
Motor to power intake: Needed to have enough RPM to go up ramp into storage	**CIM Motor:** 12V DC Motor with Free Speed of 5310 RPM and 2.7 AMPs
Battery to power motor: Needed to be 12V and provide enough current for the motor to draw	**18V Milwaukee Drill Battery 3 AMPs with 18V to 12V Step Down Converter**
Motor driver: Needed to be able to handle large amounts of current	**Cytron Motor Driver:** 30 Amps 5V-30V DC Motor Driver, PWM and DIR pins
Microcontroller to control motor driver: Needed to be compatible with motor driver	**Arduino Uno:** Compatible with Cytron motor driver and Cytron motor driver Arduino library
Robot Movement and Weight Control: Needed to be able to move smoothly with iRobot Controls	**Caster Wheels, Placement of Components:** Added Batteries to back of robot

Software Design Trade-offs

Requirement	Our Solution
Obstacle avoidance: Needed to avoid picking up non-bottle objects	**Second inference stage** to see if obstacles appear after rotation Trade-off between time and accuracy
Thorough target search: Rotating 6 times wasn't thorough enough to search the 1.5 meter radius	**More comprehensive search rotation and quantity** to turn 8 times and rotate 45 degrees each Trade-off between time and accuracy

Project Management



		Wk 7					Wk 8					Wk 9					Wk 10					Wk 11					Wk 12					Wk 13
TASKS	TASK OWNER	10/24	10/25	10/26	10/27	10/28	10/31	11/1	11/2	11/3	11/4	11/7	11/8	11/9	11/10	11/11	11/14	11/15	11/16	11/17	11/18	11/21	11/22	11/23	11/24	11/25	11/28	11/29	11/30	12/1	12/2	12/5
Deadlines																																
Project proposal presentation	Serena																															
Design presentation	Mae																															
Final presentation	Meghana																															
Object Detection and Identification																																
Dataset generation	Mae																															
Get model running with initial dataset	Mae																															
Train model to 90% test accuracy	Mae																															
Integrate ML model into Jetson/detection process	Mae/Serena																															
Slack time	All																															
Robot Construction and Software																																
Research design implementations for using iRobot	Meghana																															
Research and design intake and storage	Meghana																															
Order Necessary Parts Materials	All																															
Robot intake CAD and construction	Meghana																															
Setting up Jetson to iRobot communication	Meghana																															
Controls to allow robot to intake items	Meghana																															
Robot driving and intake testing	All																															
Slack time	All																															
Navigation and Integration																																
Set up Jetson and Intel Realsense	Serena																															
Distance perception with LiDAR	Serena																															
Object tracking algorithm	Serena																															
Path and angle calculation to motor movement	Serena																															
Write logic for entire software system	Mae																															
Put entire software system together	Mae/Serena																															
Completely merge software and hardware systems	All																															
Slack time	All																															
Final testing																																
Whole system to detect and pick up 1 water bottle	All																															
Test system logic for picking up multiple bottles	All																															
Test fixed bottle environment	All																															
Test varied bottle environment	All																															
Slack time	All																															

TODO:

- Mae
  - Implement ideas to make pipeline faster
- Meghana
  - Testing
- Serena
  - Write interrupt logic
  - Small changes to improve accuracy

Conclusion

- Key challenges
  - Testing Metrics
    - Speed and Accuracy
  - Weight and Movement of Robot
    - Added caster wheels
    - Placement of components
    - Drift right due to heavy motor
- Lesson learned
  - Design and Integration of components
  - Don’t underestimate setup time