Mechanical Engineering
Carnegie Mellon University

Golf Ball Collecting & Cleaning (C&C) Robot

Senior Capstone Design Project
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Problem Description:

Currently, driving ranges spend anywhere from $9-19k and 3-4 hrs to collect and clean up to 50,000 golf balls each day. Automating this process can reduce time, labor, and cost.

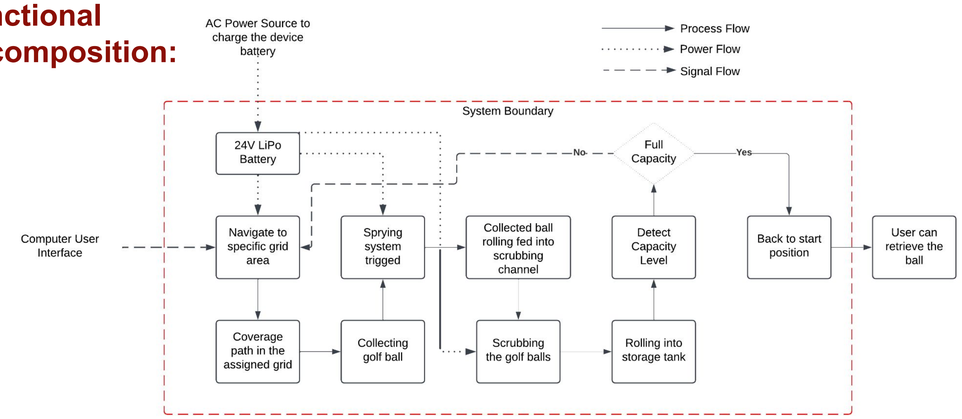
Customer Needs and Specs:

Customer needs were identified through phone interviews with driving range managers, employees, and avid golfers.

Key Needs
Low maintenance: *optimized power supply, minimal replacements needed, easy to operate, low cost*
Effective collection: *reliable collection, minimizes previous labor*
Effective cleaning: *reliable cleaning, minimizes previous labor*
Enhances range: *dynamically interacts with golfers & environment*
Durable: *withstands various weather & terrain conditions*

Key Specifications	Target Value:
High picking accuracy	85%
High cleanliness rate	85%
High ball storage	200 balls
Fast travel speed	3.5 mph
High positioning accuracy	1.5 m
Large coverage area	10,000 m^2
Low cost	$1,000

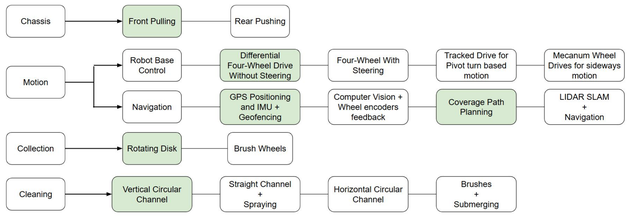
Functional Decomposition:

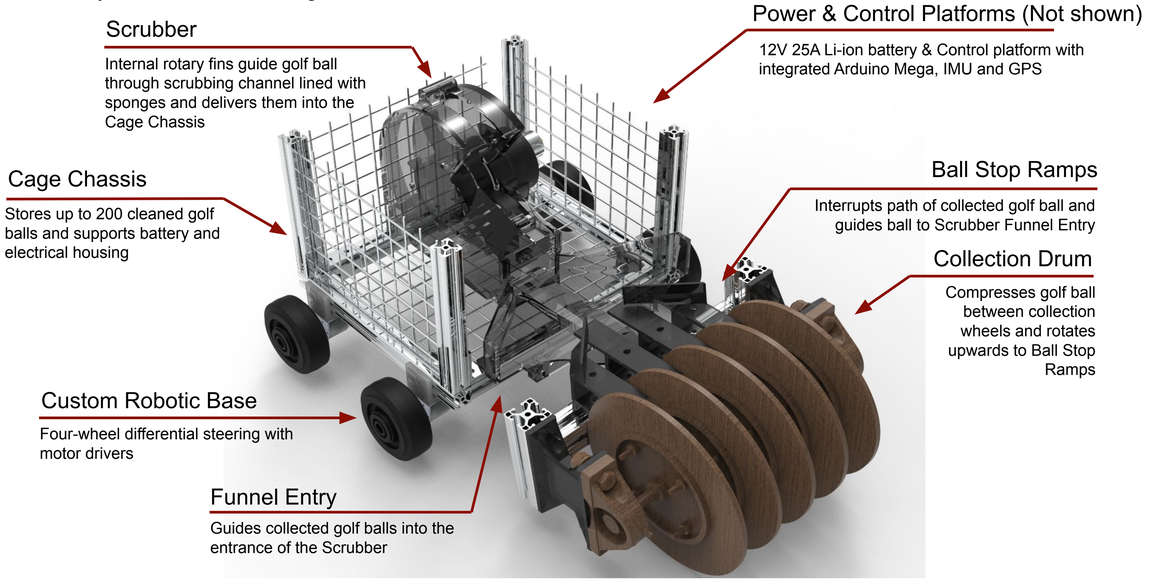


Concept Generation and Selection:

Four main function subsystems:
Robot Base Collecting Cleaning Navigation

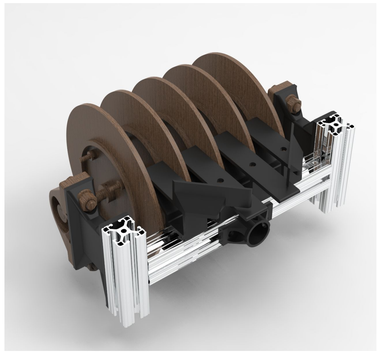
- Current industry solutions were researched to inform design developments
- Designs were filtered through function performance rating
- Final designs were carried into iterative prototyping
- Subsystems were then integrated and tuned





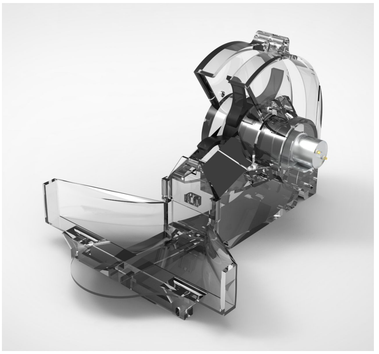
Final System Model

Concept Description:



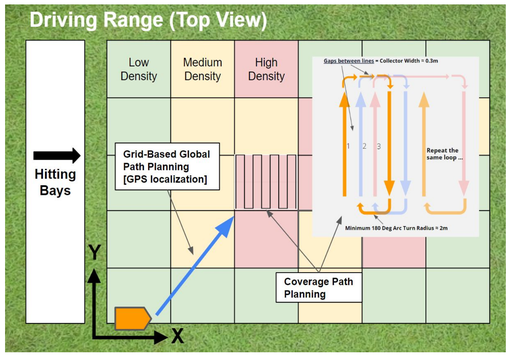
Collecting

- Rolls on top of golf balls on the ground
- Applies sufficient pressure to compress the ball between tracks of silicone sealant on collection wheels
- Rotates and carries golf ball around the circumference of the wheel
- Ball stopper ramps forces the golf balls out of compression between wheels with and sends balls down a funneled ramp to the cleaning subsystem



Cleaning

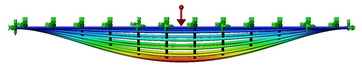
- Guides balls into the scrubbing channel via ramp entrance
- Prevents jams utilizing a passive gate that allows only one ball at a time
- Motor with fins propels balls and lifts them to the top exit and into the storage basket
- Ensures equal distribution of golf balls on either side of the scrubber using angled details on the fins



Navigation

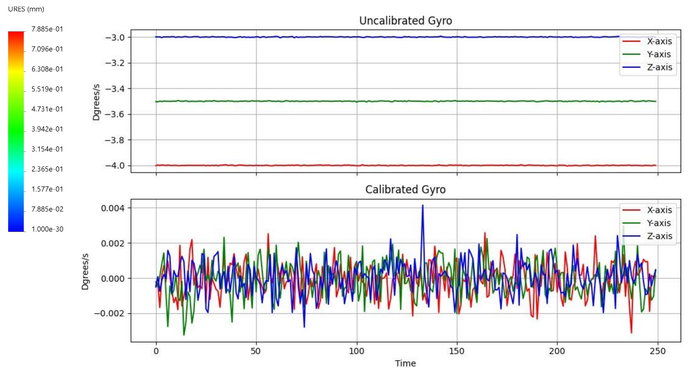
- Geo-fences and divides the golf range into equal shaped grid blocks
- Sends C&C robot to user selected, high-density grid blocks
- Employs Hybrid A* for navigation and spiral lawnmower pattern coverage of the selected grids using GPS navigation.

Analysis:



Case frame and net maximum loading FEA:

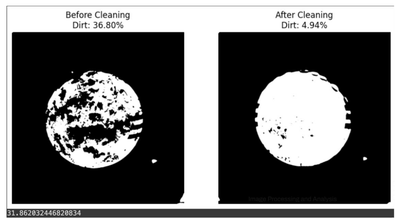
- Target max capacity : 9.81kg (200 balls)
- Max displacement: 0.28”
  - Clearance from ground: 2.75”
- Max Stress: 9.645 x10^7 N/m^2
  - Yield Strength: 2.039x10^8 N/m^2



MPU6050 gyroscope performance before and after applying a Digital Motion Processing (DMP) filter:

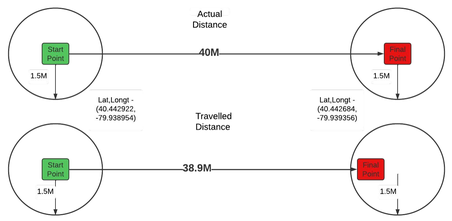
- Uncalibrated data exhibits significant offsets in roll, pitch, and yaw
- Post-calibration, the offsets are eliminated, resulting in accurate and stable measurements

Testing:



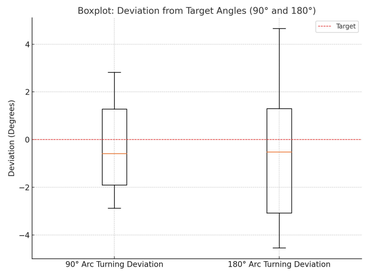
Computer Vision Cleaning Evaluation

- 90.87% of dirt removed from golf ball surfaces
- Amount of residual dirt consistently low across various conditions



GPS Accuracy Testing

- GPS Neo M9N demonstrated 1.5-meter precision, recorded an average distance of 38.9 meters over 20 trials
- Closely aligns with the actual 40 meters (confirming reliable accuracy)



Base Steering Accuracy Test

- Use of IMU feedback allows steering accuracy within 3 degrees recorded over 20 trials
- Enables more accurate spiral coverage paths

Conclusions:

- Our prototype successfully collects and cleans golf balls while autonomously navigating, providing an alternative solution that is cost-effective and scalable.
- Further product enhancement would include refinement of motor control to cover rougher terrain, waterproofing of components, and larger storage space.