

Onboard Vision System for Swarm Robotics

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Objective

- Incorporate a vision system on a swarm robotic system
- Compare and evaluate different camera methods
 - 360° camera system vs Servo motor camera
- Identify objects obtained from LIDAR reading
 - Robot vs Obstacle
- Obtain formation control

Background - Swarm System

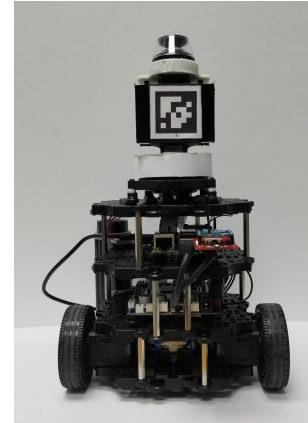
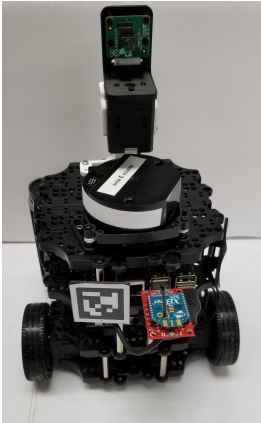
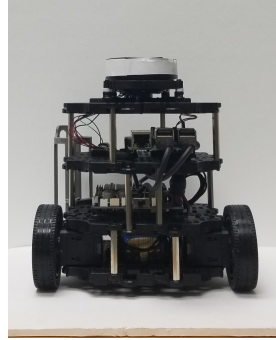
- Centralized vs Decentralized system
- System that can be supervised on an abstract level
- Robust system
- Maintaining connected formations
- Robots can facilitate mapping and localization
- Path planning and obstacle avoidance

LIDAR Sensor

- Sends Ping when unknown object is detected
 - New object enters system
 - Blobs merge then separate
 - Manual reset from user
- Outputs:
 - x, y, z position of object, object number, theta, identification
- Identification:
 - 0-7: Apriltag ID
 - 99: Unknown
 - 999: Confirmed obstacle



TurtleBot3



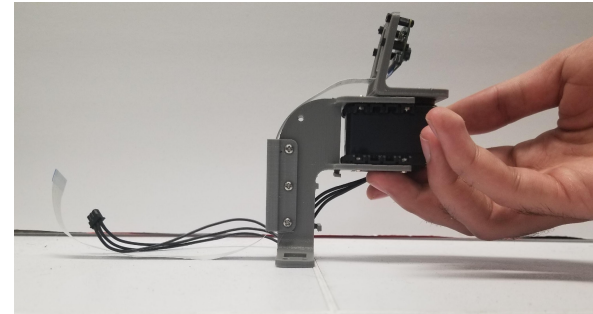
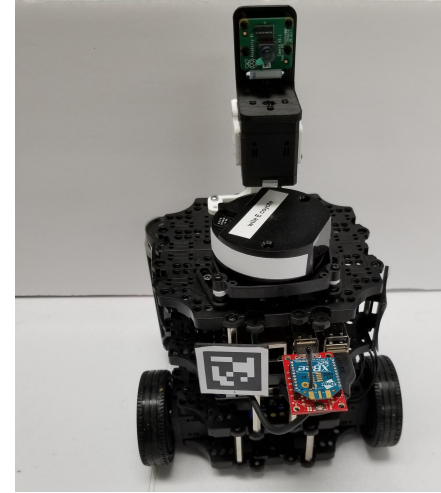
Servo Motor Camera System

Pros:

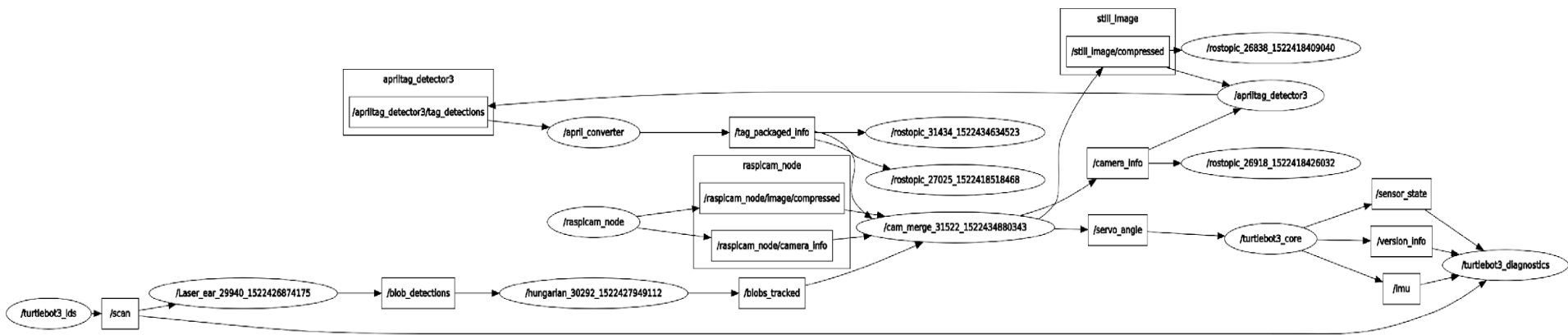
- High Resolution
- Large Detection Range
 - ~2 meters

Cons:

- Wire can snap
- Wait time
- Extra moving part
- Not ideal for busy environment



RQT Graph of Servo Motor System



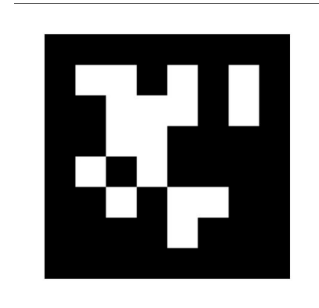
Servo Calibration

- Add motor identification
- Enable torque of motor
- Set max velocity
- Set RPM of motor
- Enable position control
- Set Baud rate

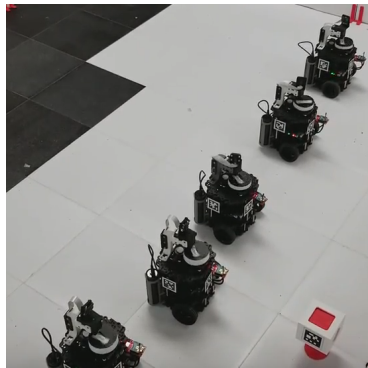


Apriltag Detection

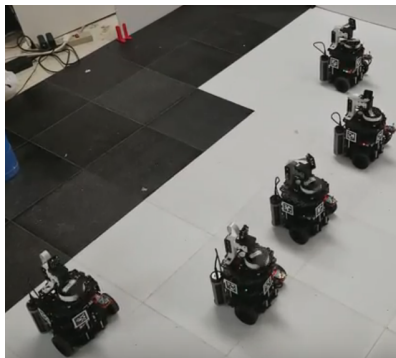
- From Ping, servo moves to the angles of unknown objects
- After 2-3 seconds camera determines whether robot (detects tag) or obstacle (does not detect tag)
- Tags relay x, y, z position of robot and the tag ID
- The data obtained is then cross checked with the LIDAR data
 - Needed to constrain the camera range



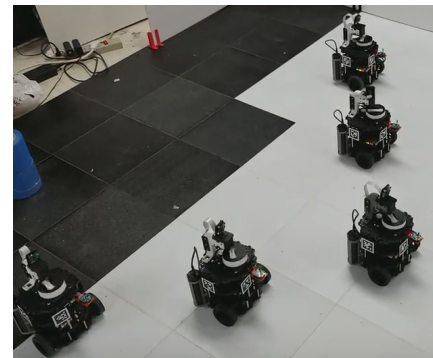
Formation Control



Formation 1



Formation 2



Formation 3

- Linear formation control
- Graph theory
 - Rooted out branching
- Camera and LIDAR cooperation
- Abstract human interaction

Servo Motor System Formation Video



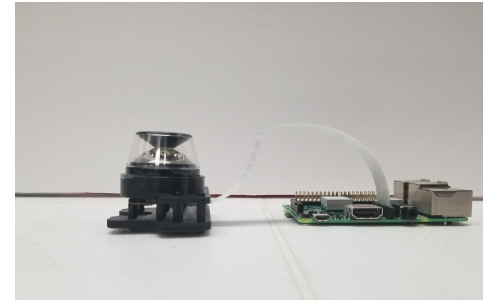
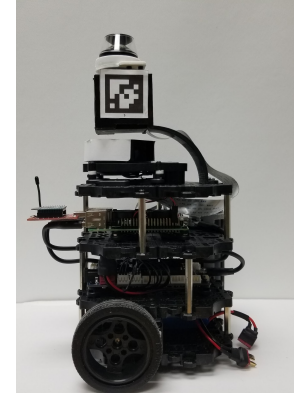
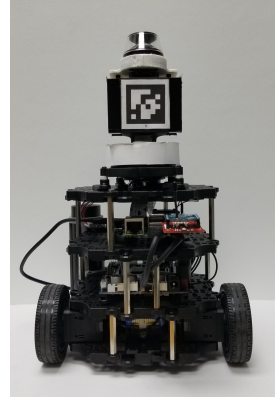
360° Camera System

Pros:

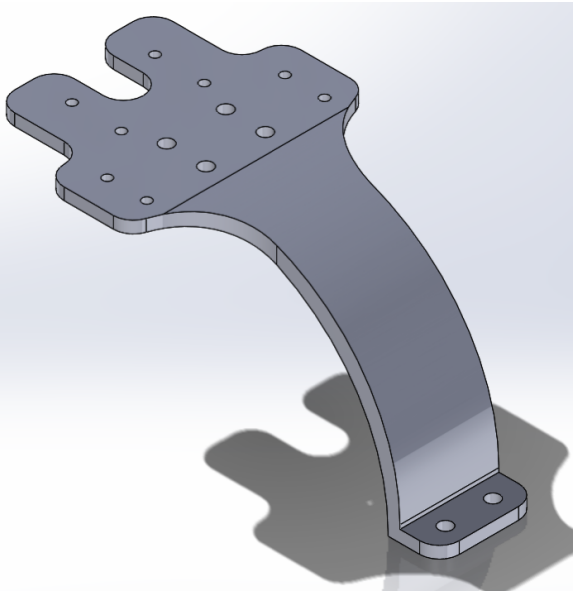
- Ideal for crowded areas
- Wire is steady
- No extra moving parts

Cons:

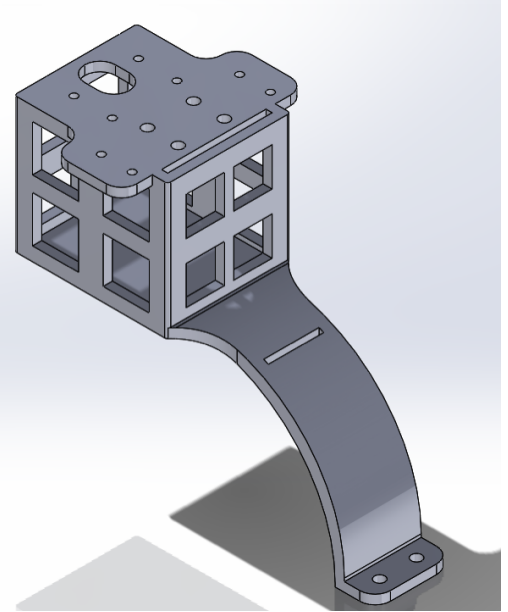
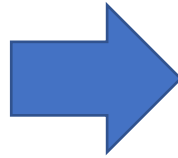
- Range
 - ~0.24 - ~0.3 meters
- Poor Resolution



Hardware Design



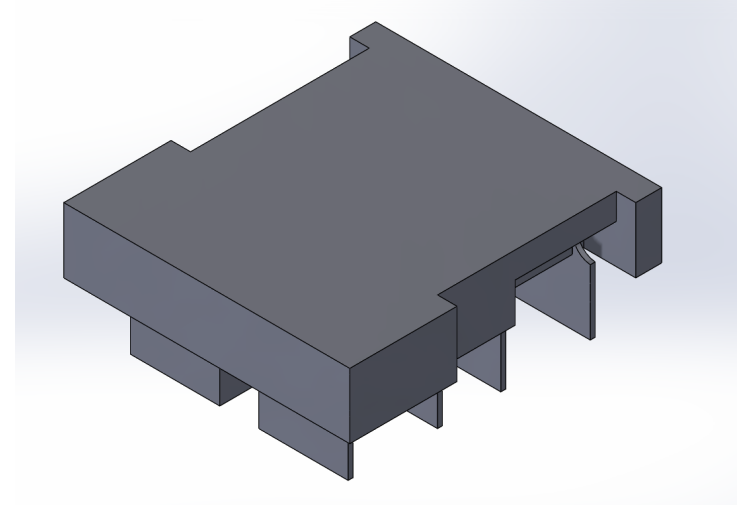
First Design



Second Design

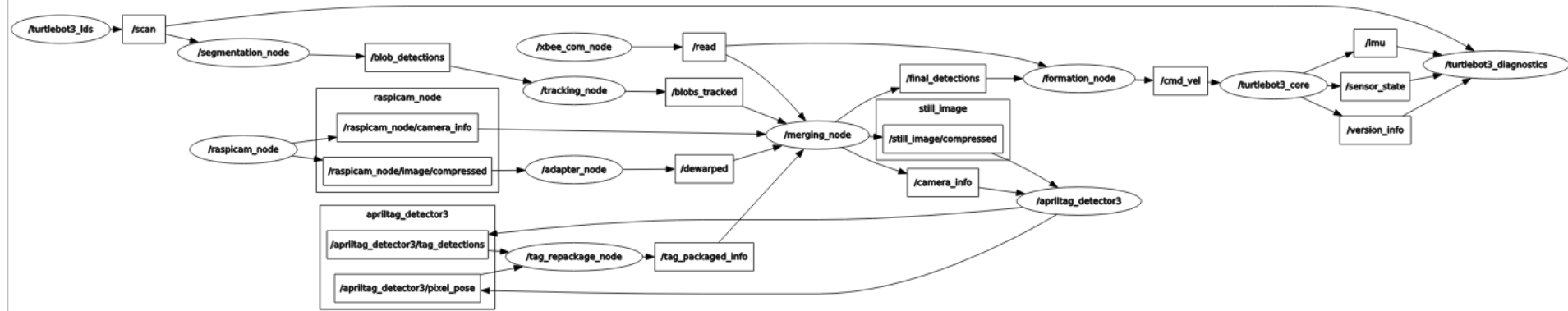
Hardware Design

- Designed to fix issues with second design
- Designed to be robust
- Black background helped with AprilTag detection

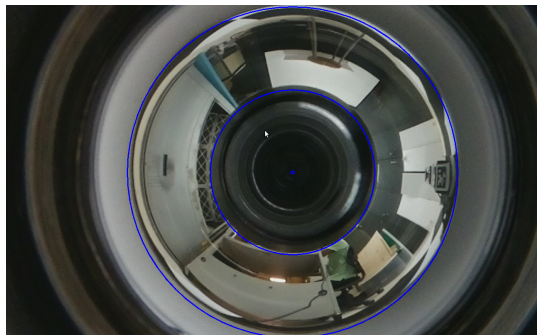


AprilTag holder

RQT Graph of 360° Camera System



Dewarping



- Remapping of pixels
- AprilTags can be detected
- Allows for easy angle calculation



Thresholding

- Threshold limit = 80
- Range increases to
 - ~0.3 meters

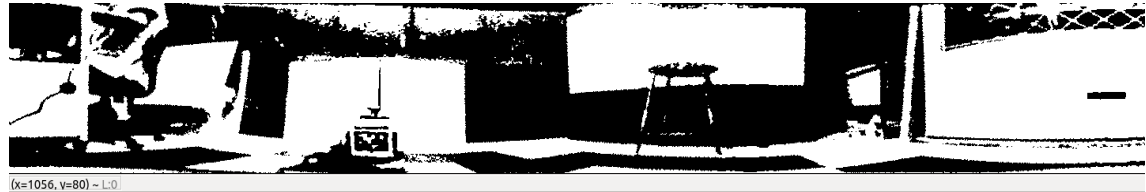
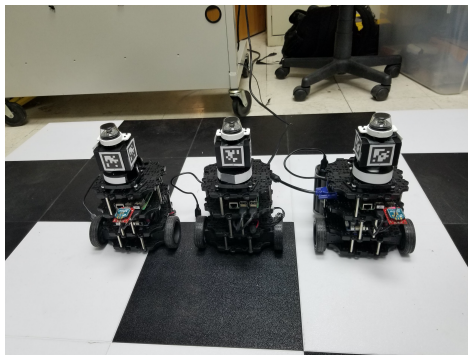


Image Transformations

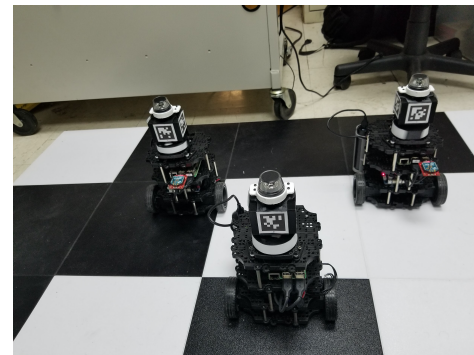


Formation Control

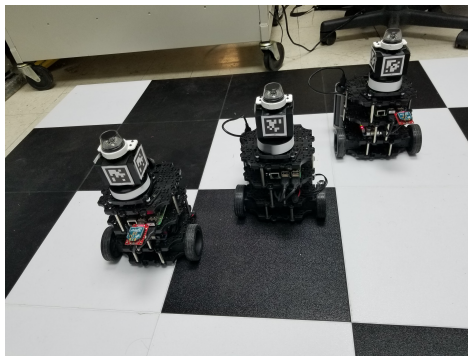
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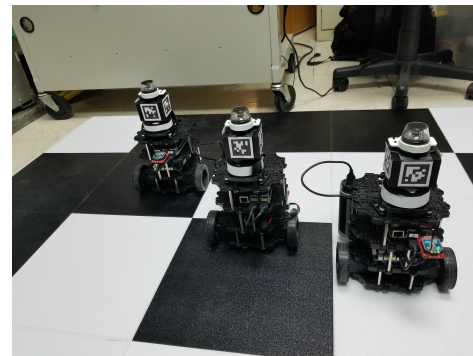
Formation 1



Formation 2

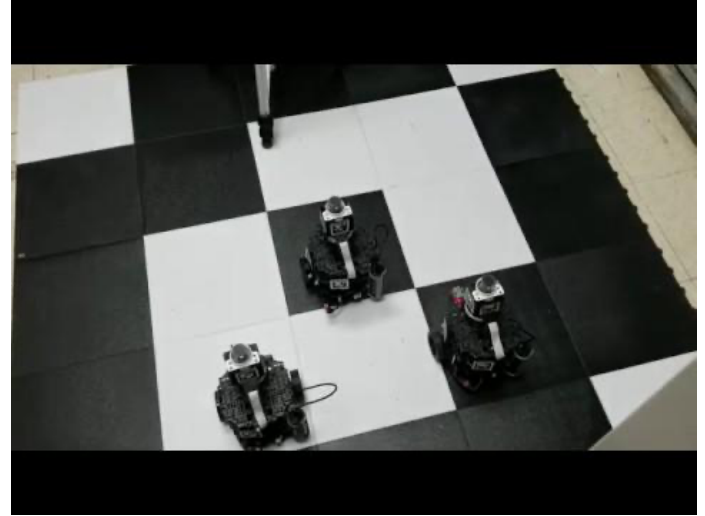
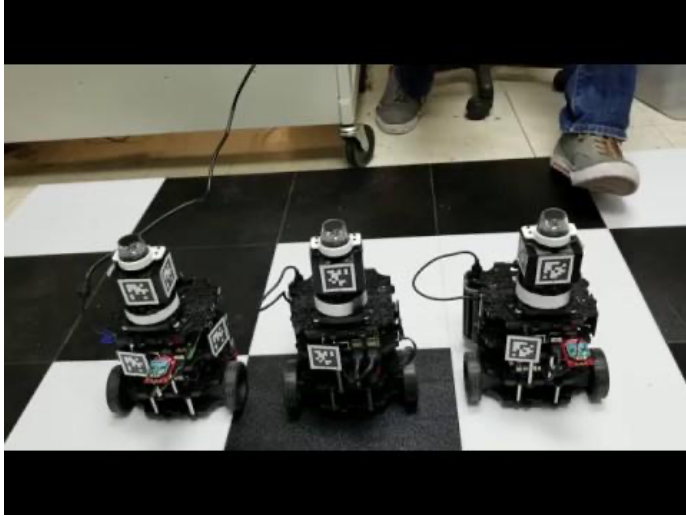


Formation 3



Formation 4

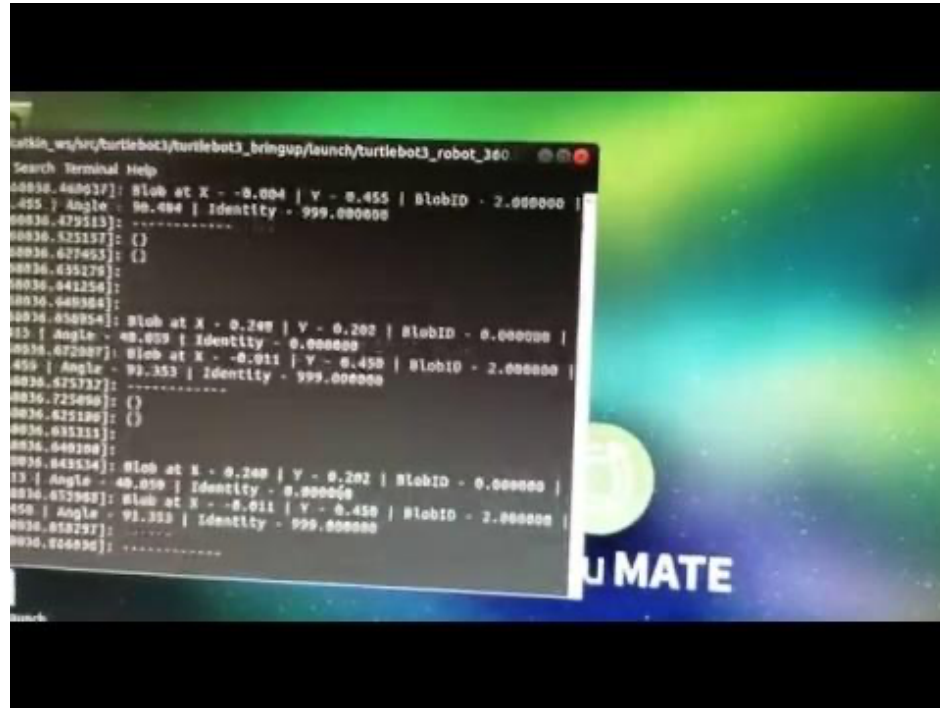
Formation Control Video



Apriltag detection

- Focus on pixel location in remapped image
 - Complex to use x, y, z coordinates system
- From pixel location, the angle of the identified object can be determined
- Obtains information for each tag detected

Detection Video



Future Work

- Implement better thresholding algorithms to the vision system
- Reduce the latency issue shown in both swarms
- Reduce the blind spot of both swarm systems

Conclusion

- Both swarm systems achieved linear formation
- 360° camera system worked better in a crowded environment
- 360° camera system range is drastically lower than the servo motor camera system
- Both systems were able to interact with humans through a user interface