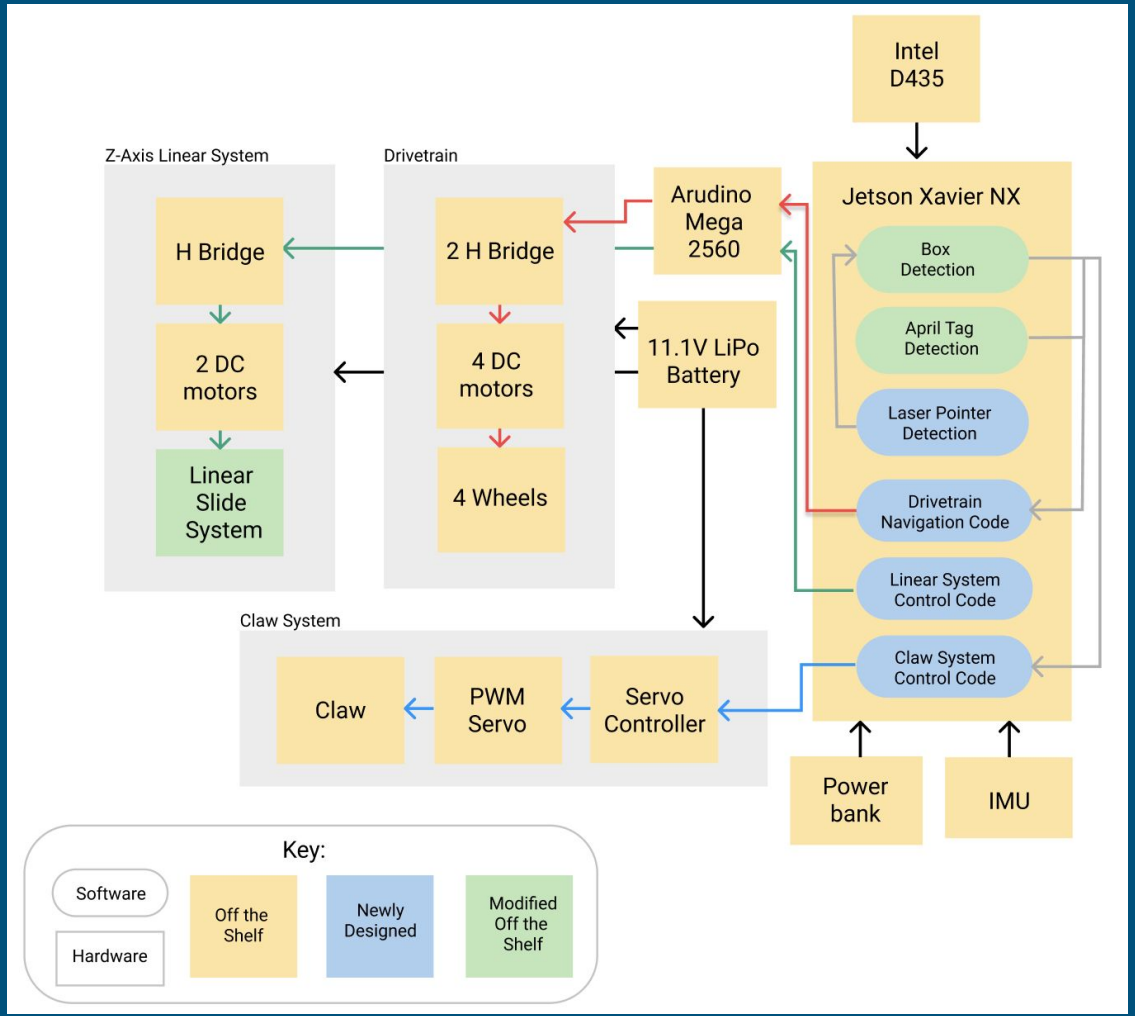
Application Area

- Robot that retrieves items off a shelf
  - User points at desired item with a laser pointer
  - Robot navigates to shelf and grabs item
  - Robot puts item in user's basket
- Requirements:
  - Navigation: 98.5% accuracy
  - Speed: 0.5m/s
  - Laser Detection: 99% accuracy
  - Grabbing Item: 99.5% accuracy

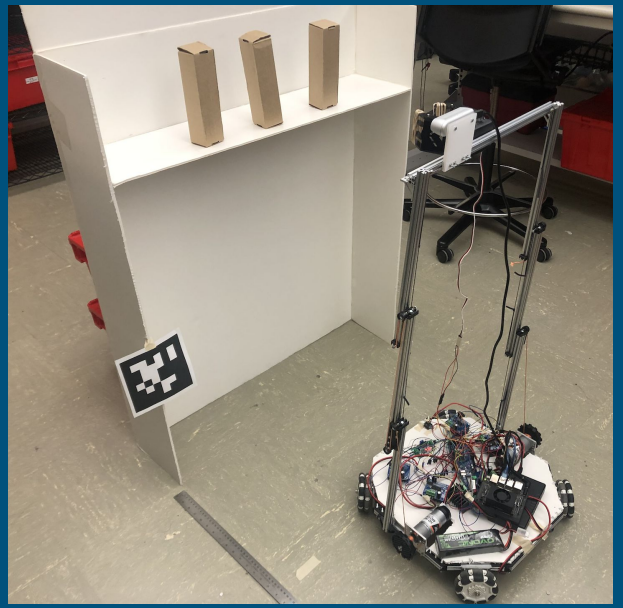

Intel D435
Jetson Xavier NX
Box Detection
April Tag Detection
Laser Pointer Detection
Drivetrain Navigation Code
Linear System Control Code
Claw System Control Code
Arudino Mega 2560
11.1V LiPo Battery
Z-Axis Linear System
H Bridge
2 DC motors
Linear Slide System
Drivetrain
2 H Bridge
4 DC motors
4 Wheels
Claw System
Claw
PWM Servo
Servo Controller
Power bank
IMU
Key:
Software
Hardware
Off the Shelf
Newly Designed
Modified Off the Shelf

Changes from Design Review

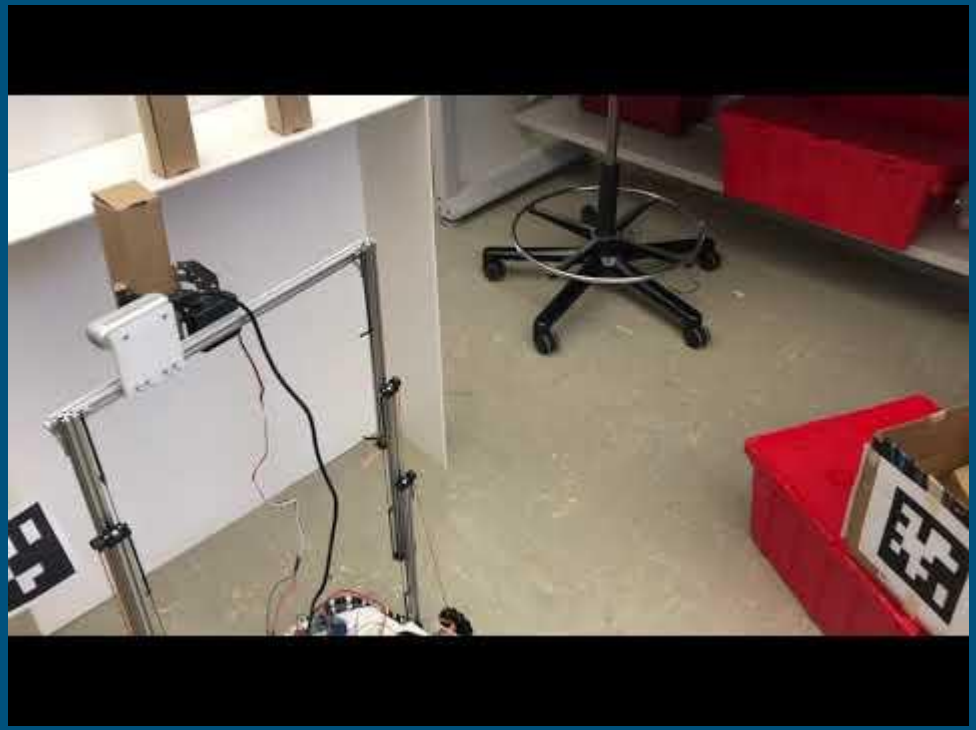
- Arduino Mega
  - Replaced 2 Arduino Unos
  - More pins
  - Eliminate communication issues
- IMU
  - More accurate angle measurements
  - Used to be parallel to the shelf
- Power bank
  - Powers the Xavier

Complete Solution

- Robot rotates 360 degrees in search of April Tag on user's basket
- Navigates to about one foot in front of basket
- Rotates 360 degrees to find April Tag on shelf
- Navigates to about 40 cm in front of shelf
- Raises linear slide and searches for laser pointer
- Navigates to center of detected object
- Grabs objects
- Lowers slides
- Navigates to basket and delivers object



Complete Solution (4x speed)



Testing, Validation, Metrics

- Navigation Test:
  - Robot starts anywhere
  - Travels to basket/shelf using April Tag
  - Stops 6 inches in front of tag
  - Rotate to be parallel to the tag
- Laser Detection Test:
  - Point laser on any object on the shelf
  - The object is correctly identified
  - No object identified if no laser
- Grab Test:
  - Object that the laser points to is successfully grabbed by the robot’s claw
  - No object selected if no laser

Results

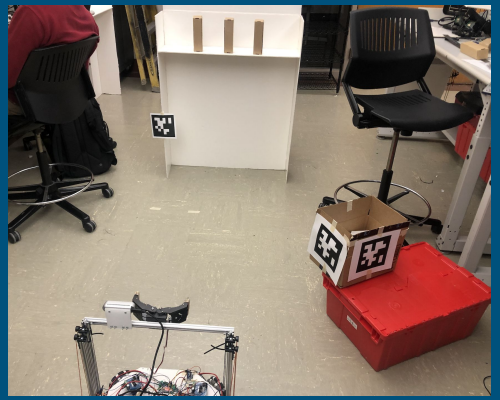
Test	Requirement	Method	Result
Navigation to shelf	98.5% accuracy	Initialize in random positions, record success to shelf	18/20
Navigation to basket	98.5% accuracy	Initialize basket, record success to basket	16/20
Laser Detection	99% accuracy	Displace robot from shelf, record success in navigating to correct item	• 33cm: 4/5 • 35cm: 4/5 • 38cm: 4/5 • 41cm: 5/5
Grabbing Item	99.5% accuracy	Record success rate to grab correct item	17/20

Results cont.

Spec.	Requirement	Method	Result
Speed	.5 m/s	Distance/time for robot to drive straight	0.33 m/s
Grabbing latency	3 seconds	Time to navigate up to + grab detected item	8.5 seconds
Laser Point latency	1 second	Latency of detecting laser point item	0.561 seconds
Item dimensions	3 inch width, 1 lbs	Measured dimensions of shelved items	2 inch width, 1 lbs
Distance between items	2 inches	Measured between items	4 inches

Overall Process Performance

- Latency: 2.5 min
- Our team is still tuning the integration of the subcomponents for the overall process
- After 20 trials, we had almost all close successes but tended to have at least one slight inaccuracy render the trial unsuccessful

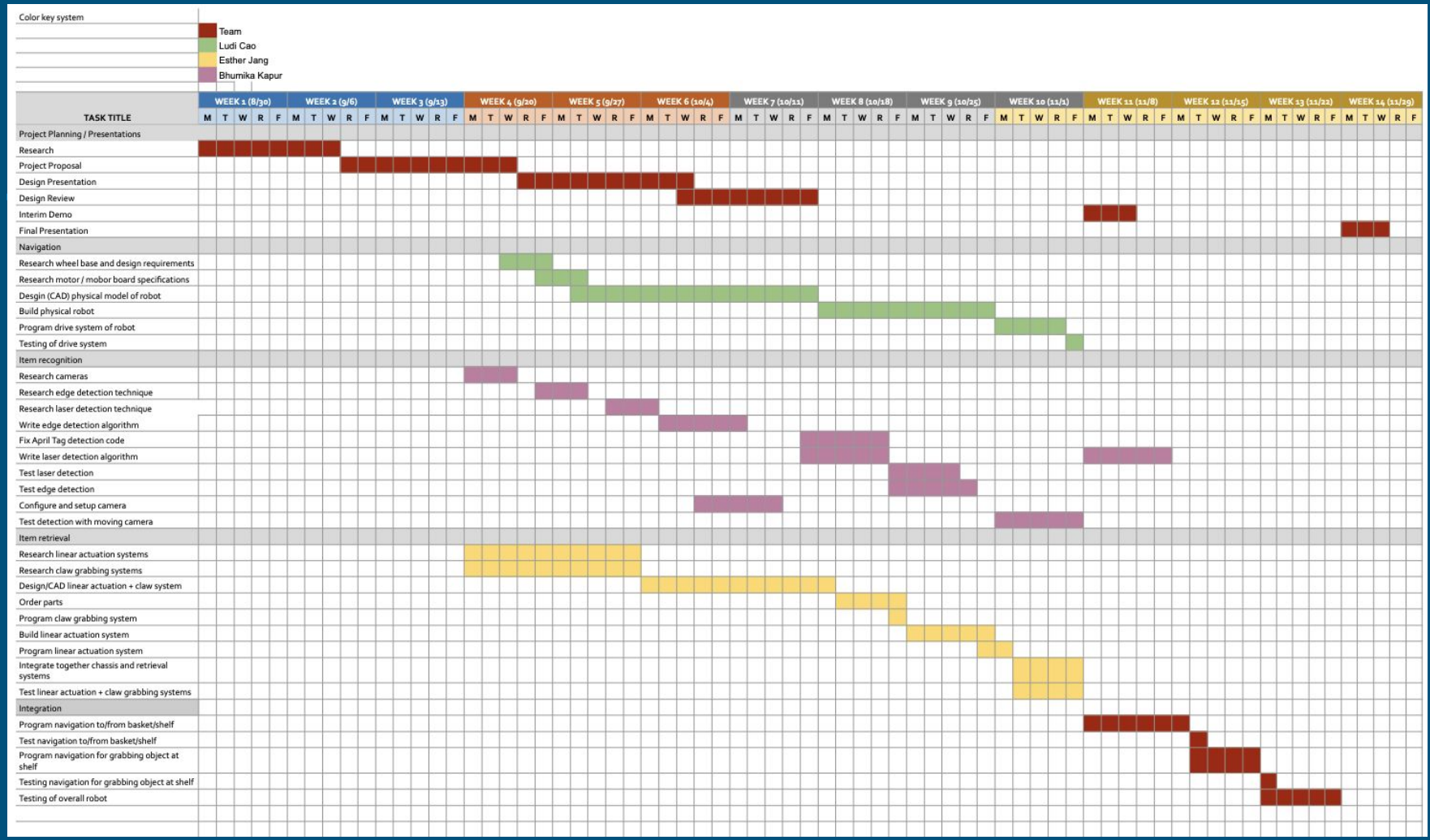


Trade-Offs

- Device Communication
  - Average time for message to be read by Arduino from Xavier: 2 seconds
  - Pro: delegate PWM control to a better suited device
- Wheels
  - 90 vs 60 mm
  - High speed vs lower torque
- Motors
  - Planetary vs Spur gear
  - 20:1 vs 40:1
  - Differences in rpm vs torque

Trade-Offs cont.

- Battery
  - NiMH vs LiPo
  - 12V, 1.25A, 2000mA h vs 11.1V, 1.35A, 5000mA h
- End Effector
  - Usage of a vacuum suction
  - Claw A vs Claw B
    - 43 vs 100 mm link radius
    - .349 Nm vs .419 Nm servo torque
- Camera
  - Intel Realsense vs Arducam & depth sensor
  - 75 vs 85 degree FOV


Color key system
Team
Ludi Cao
Esther Jang
Bhumika Kapur
TASK TITLE
WEEK 1 (8/30)
WEEK 2 (9/6)
WEEK 3 (9/13)
WEEK 4 (9/20)
WEEK 5 (9/27)
WEEK 6 (10/4)
WEEK 7 (10/11)
WEEK 8 (10/18)
WEEK 9 (10/25)
WEEK 10 (11/1)
WEEK 11 (11/8)
WEEK 12 (11/15)
WEEK 13 (11/22)
WEEK 14 (11/29)
M T W R F
Project Planning / Presentations
Research
Project Proposal
Design Presentation
Design Review
Interim Demo
Final Presentation
Navigation
Research wheel base and design requirements
Research motor / mobor board specifications
Desgin (CAD) physical model of robot
Build physical robot
Program drive system of robot
Testing of drive system
Item recognition
Research cameras
Research edge detection technique
Research laser detection technique
Write edge detection algorithm
Fix April Tag detection code
Write laser detection algorithm
Test laser detection
Test edge detection
Configure and setup camera
Test detection with moving camera
Item retrieval
Research linear actuation systems
Research claw grabbing systems
Design/CAD linear actuation + claw system
Order parts
Program claw grabbing system
Build linear actuation system
Program linear actuation system
Integrate together chassis and retrieval systems
Test linear actuation + claw grabbing systems
Integration
Program navigation to/from basket/shelf
Test navigation to/from basket/shelf
Program navigation for grabbing object at shelf
Testing navigation for grabbing object at shelf
Testing of overall robot