PARROT

Parallel **A**synchronous **R**obots,
Robustly **O**rganizing **T**rucks

Final Presentation

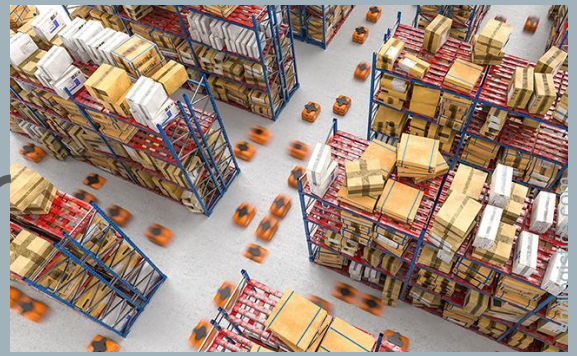
Omkar Savkur · Prithu Pareek · Saral Tayal

Use Case & Requirements

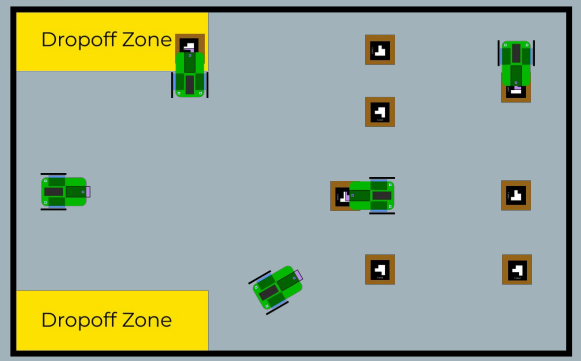
#1 Pick-Up and Drop-Off Pallets

#2 Efficiently Scale to Multiple Robots

#3 Long Runtime and Low Latency

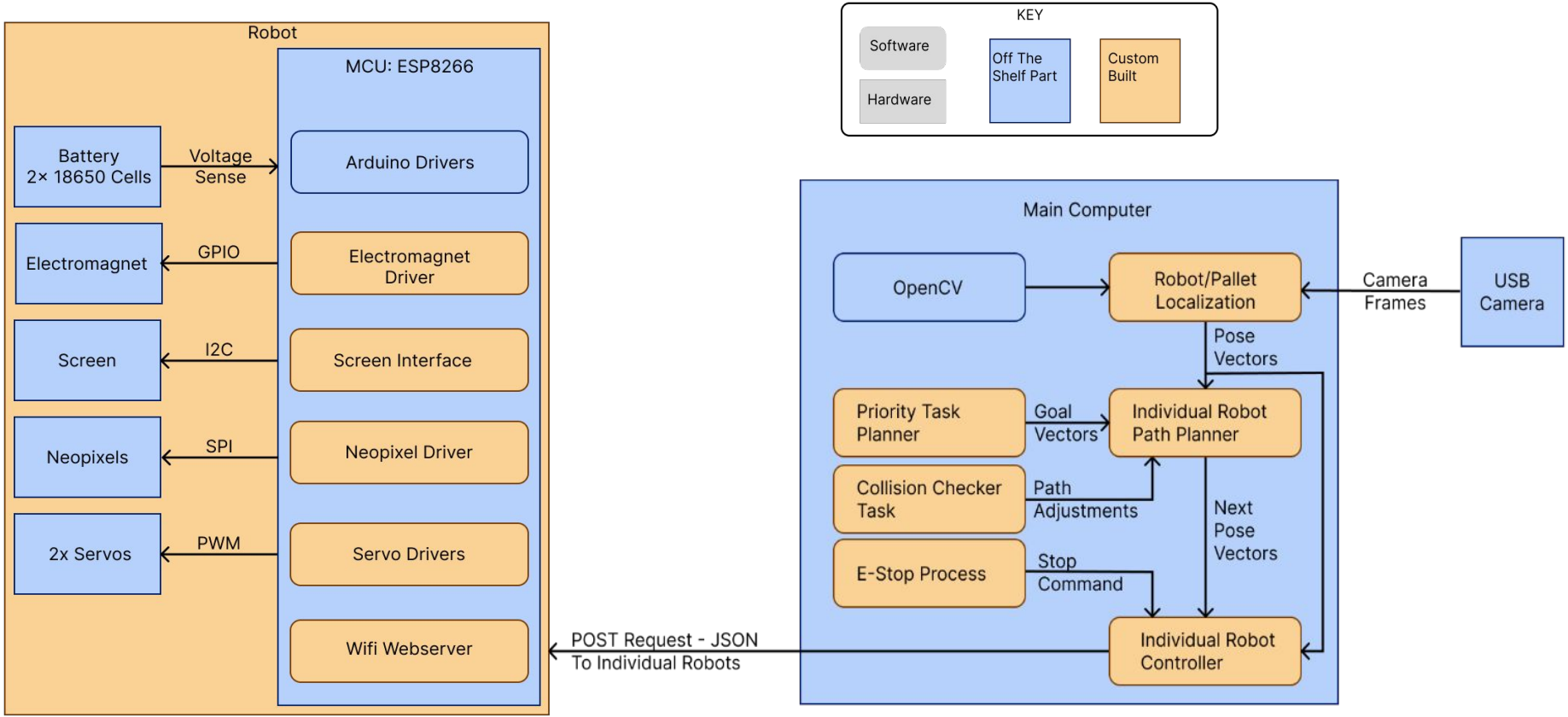


Real-World Warehouse Robotics

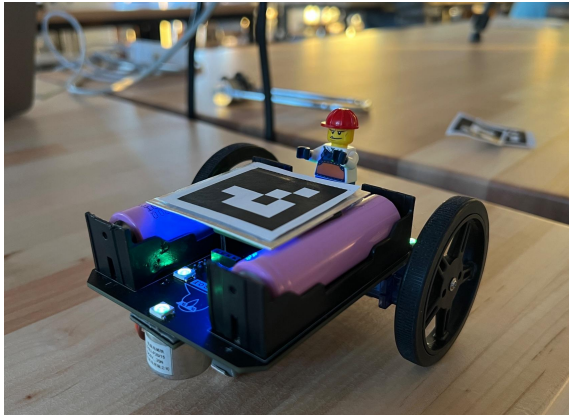


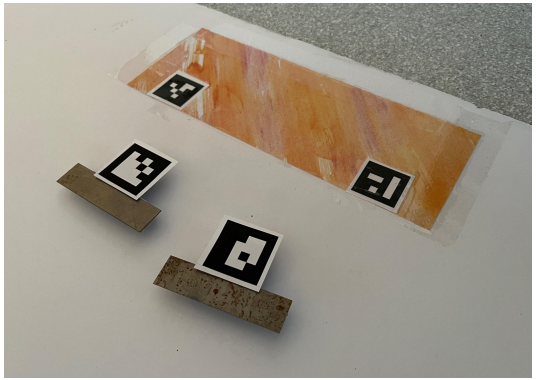
Our Sandbox

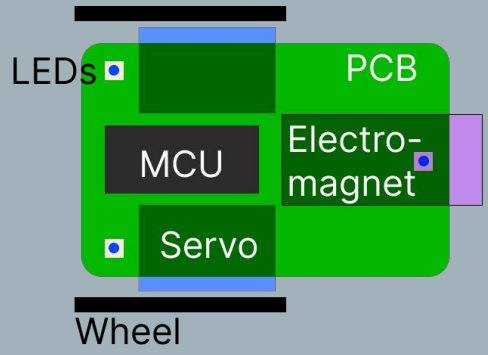
Solution Approach

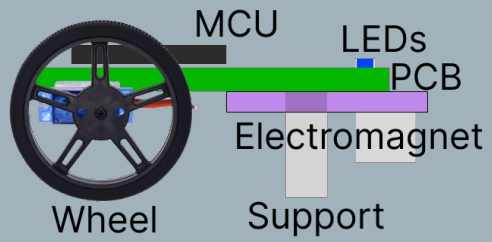


Our System

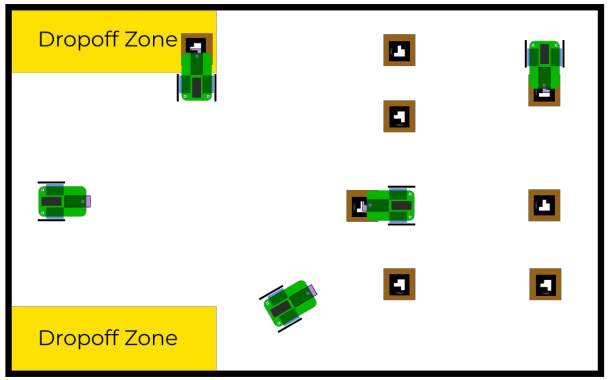


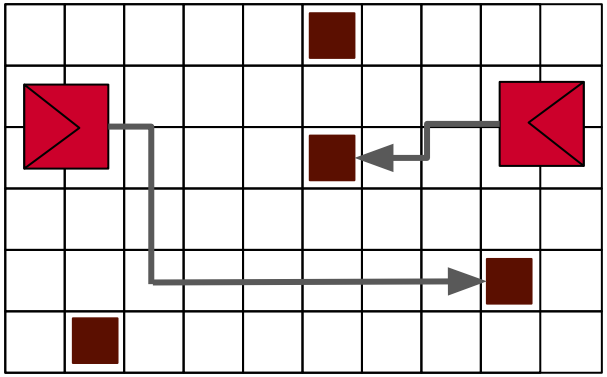


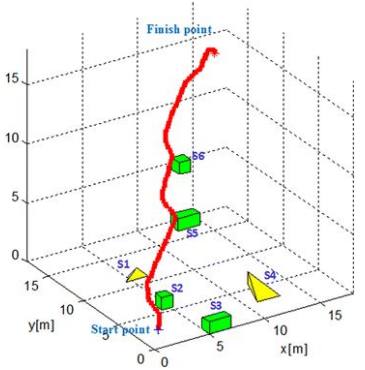

LEDs
PCB
MCU
Electro-
magnet
Servo
Wheel


MCU
LEDs
PCB
Electromagnet
Wheel
Support

Motion & Task Planning







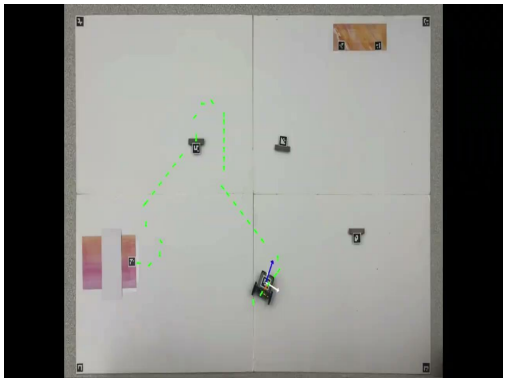
https://link.springer.com/article/10.1007/s40815-017-0403-1

Our Sandbox

Planner Abstraction

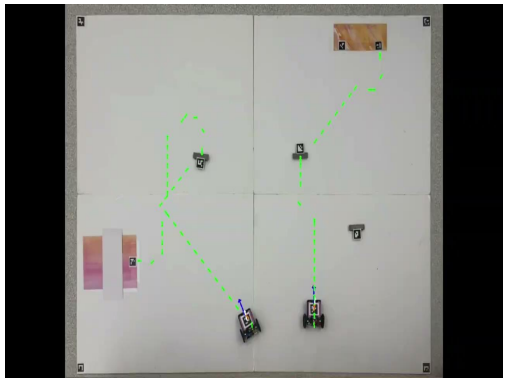
- State Space → {x, y, theta, velocity, **time**}
- Set of motion primitives/lattice graph representation
- Robots **assigned priority** based on task and **plan around others**

Demo Video!



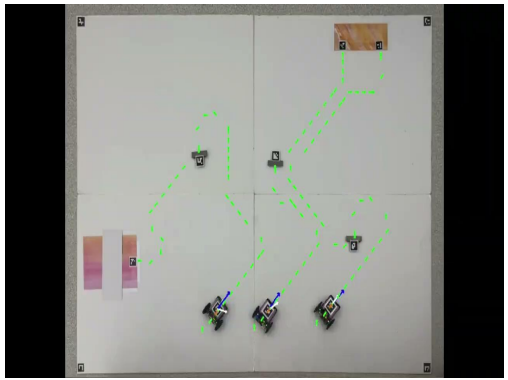
1 Robot

Time: 9 mins



2 Robots

Time: 5 mins 20 secs



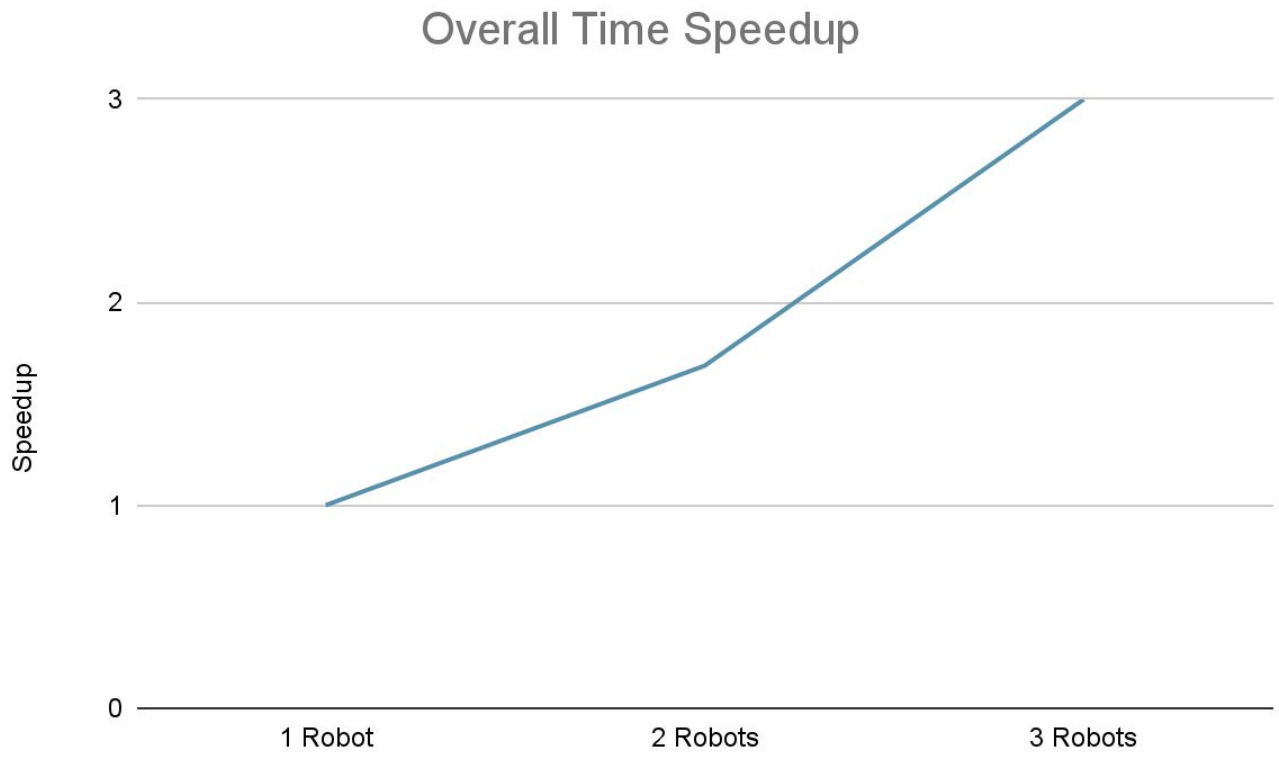
3 Robots

Time: 3 mins

Testing & Verification

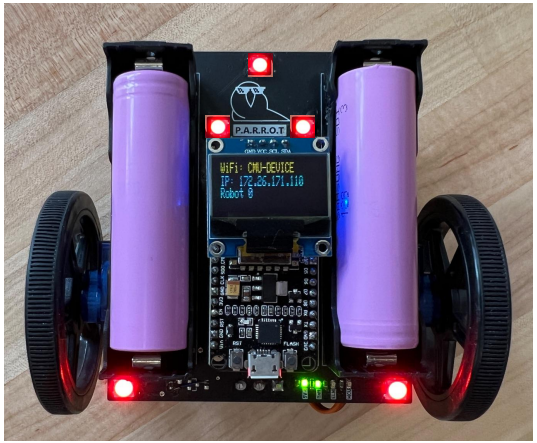
Metrics	Tests	Results
Localization accuracy of 1mm	Test Localization accuracy of robot, pallet, and goals on 10 grid spots	***Pass!*** Accuracy = 0.8mm
Planner / Controller accuracy of 5mm	Test Motion accuracy against 10 start-goal pairs	***Pass!*** Path Following accuracy- 2.3mm
Sense-Plan-Act loop time under 300ms	Run system and measure frame rate for at least 10 minutes	***Pass!*** We achieved a loop time of 30ms
Pallet Pick-Up/Drop-Off Reliability (100%)	Run system 50 times against a robot-pallet-goal tuple and measure pickup reliability	***Fail!*** We achieved a 90% pick-up rate and 84% drop-off rate
Scalability Testing; 2x faster at 3 robots	Test task speedup against multiple robots on 3 layouts	***Pass!*** Our system gave us a ... speedup at 3 robots
Battery runtime > 6 hours	Keep an internal track of robot runtime in EEPROM and pull data when the robot dies.	***Fail!*** Our robots only lasted ~1.5 hours

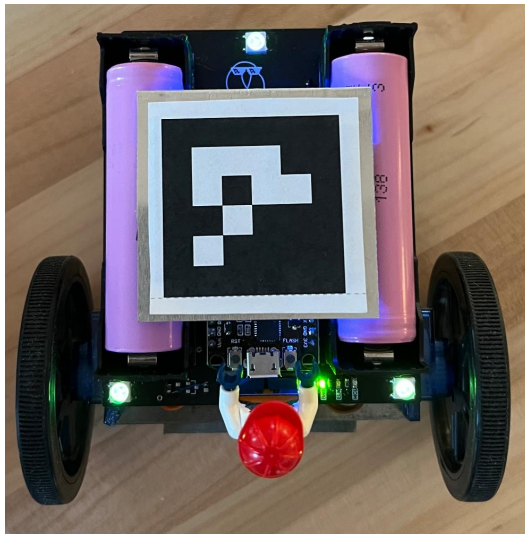
Parallelization



Trade-offs

- Neopixels vs. Fiducials for accuracy
- PID vs. Pure Pursuit Controller
- Mechanized pallet pickup vs electromagnets
- Single vs. multiple cameras
- Single sensor vs. Sensor fusion
  - Single vs. multiple cameras
  - Encoders + IMU + CV localization
- Robot weight balance vs robot size
- Planner optimality vs. usability
  - Pre vs dynamic planning

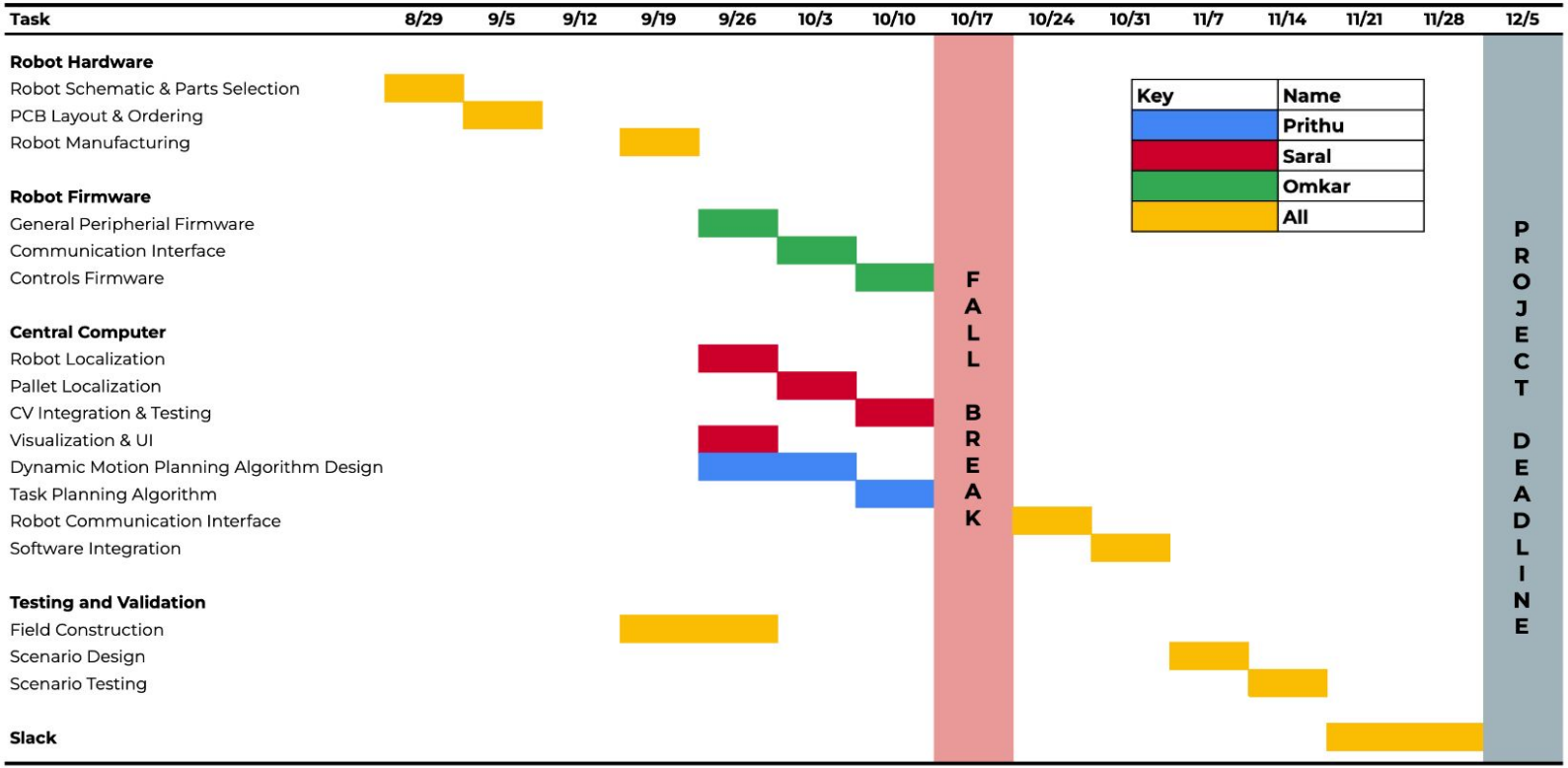




System performance metrics

Robot speed	2 cm/s, 0.38 knots, mach 5.8 (e-5)
Sense-plan Act loop	~65 ms (15fps)
Controller Interpolator	Cubic hermite spline interpolation
Path Planner time	<10 seconds
Robot Mass	456 grams 0.07 stones
Camera system	Webcam/Iphone overhead angle <30 degrees off-axis
Field Size	2x3 meters

Gantt Chart


Task
8/29
9/5
9/12
9/19
9/26
10/3
10/10
10/17
10/24
10/31
11/7
11/14
11/21
11/28
12/5
Robot Hardware
Robot Schematic & Parts Selection
PCB Layout & Ordering
Robot Manufacturing
Robot Firmware
General Peripherial Firmware
Communication Interface
Controls Firmware
Central Computer
Robot Localization
Pallet Localization
CV Integration & Testing
Visualization & UI
Dynamic Motion Planning Algorithm Design
Task Planning Algorithm
Robot Communication Interface
Software Integration
Testing and Validation
Field Construction
Scenario Design
Scenario Testing
Slack
FALL BREAK
PROJECT DEADLINE
Key
Name
Prithu
Saral
Omkar
All

Conclusions

- Robots are **hard**
    - Really hard
        - Really really hard.
- Warehouse packing problems are NP-Hard, impossible to do perfectly
- Hardware integration is **tricky**. Always over-allocate time
- We are **proud of our progress** over the last 13 weeks