Grid-Based Navigation System for Robots (GNUS)

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What is the problem?

1

Companies such as Amazon, Alibaba and Walmart are experiencing challenges in meeting the demands of an active consumer base

2

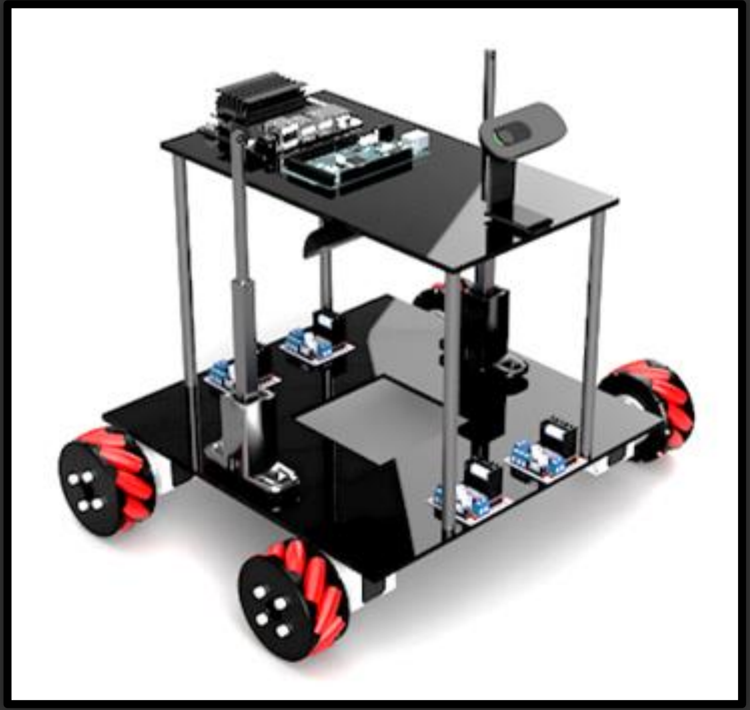
Traditional warehousing and logistics methods are not scalable or practical in today's environment

3

With large-scale delivery and fulfillment, handling returns can be quite challenging

Where does GNUS fit in?

- Develop a semi-autonomous system of robots capable of self-localizing and navigating accurately in an indoor environment using Aruco markers
- Combines fields of
  - Electrical engineering – robotics, circuit design, power management
  - Mechatronics - programming microcontroller, utilizing feedback sensors, precise motor-control, actuation and 3D printing
  - Computer science – artificial intelligences, data processing, image processing, spatial awareness, machine and computer vision
- Two teams
  - Hardware – Muhammad and Joseph
  - Software – Janaki and Aziz



Motivation

- Reliable and efficient alternative to manual object transportation
- Benefits
  - Employee safety
  - Operational efficiency
  - Overall costs
- Applications
  - Logistics operations and warehouse environments
  - Self service shop restocking
- All areas of warehousing operations including:
  - Storage
  - Truck loading
  - Worker assistance
  - Return management

[1]

Competitors

- **Amazon's Kiva Systems**
  - Use QR codes to track location
  - Manage inventories in warehouses
  - Pick up, organize, deliver products
- **Knapp's Open Shuttles**
  - Laser navigation
  - Transportation in warehouses

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Project Objectives

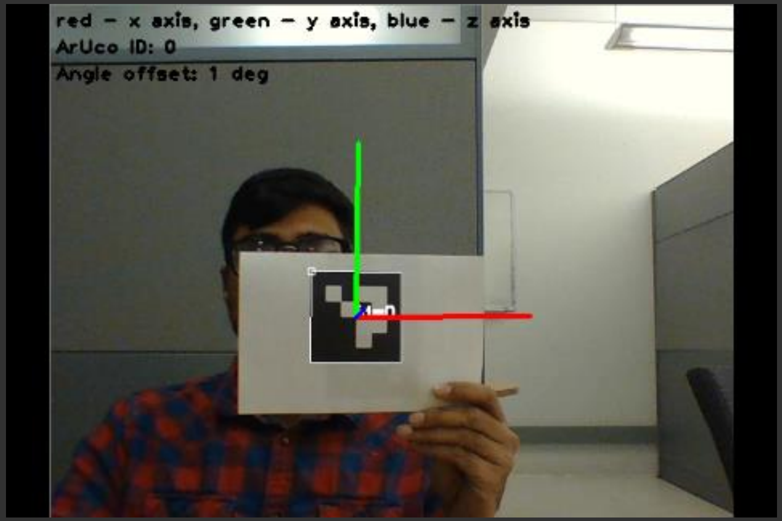
Mission planning	Receive info on payload pickup and dropoff destinations
Environment analysis	Interpret accurately the environment using vision equipment and sensors
Self-localization	Determine position relative to the master grid
Artificial intelligence	Determine best path to accomplish the given task based on previous tasks
Motion Control	Perform required motor movements in order to reach destination
Payload displacement	Displace payload by positioning directly under the payload and lifting or lowering based on destination type

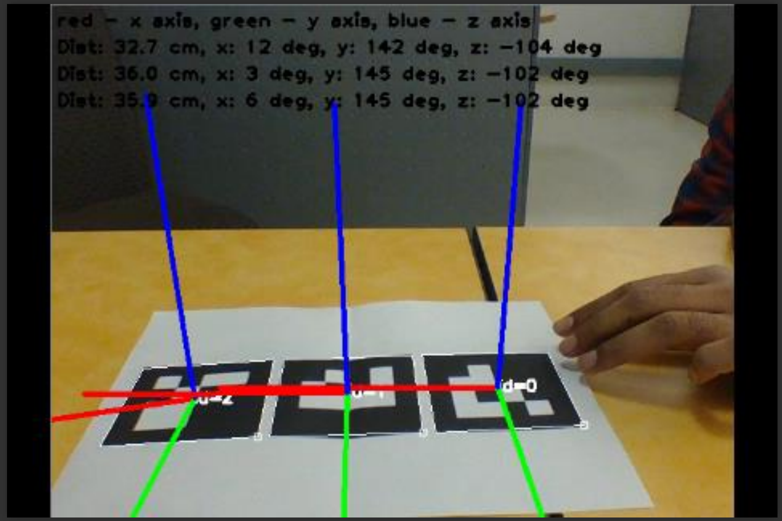
Requirement Specs

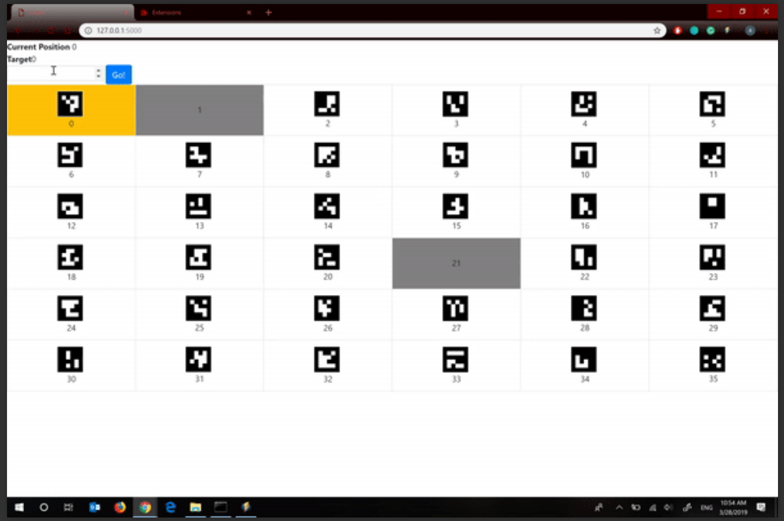
1. An independent robot system capable of moving specific objects to their desired locations with a high degree of accuracy
2. Discrete navigation to limit the bandwidths for data processing.
3. Robust, yet scalable, to accommodate for specific user needs.
4. Reliable, high quality parts deigned to operate in a variety of environments.

Modelling and Simulation Prototype

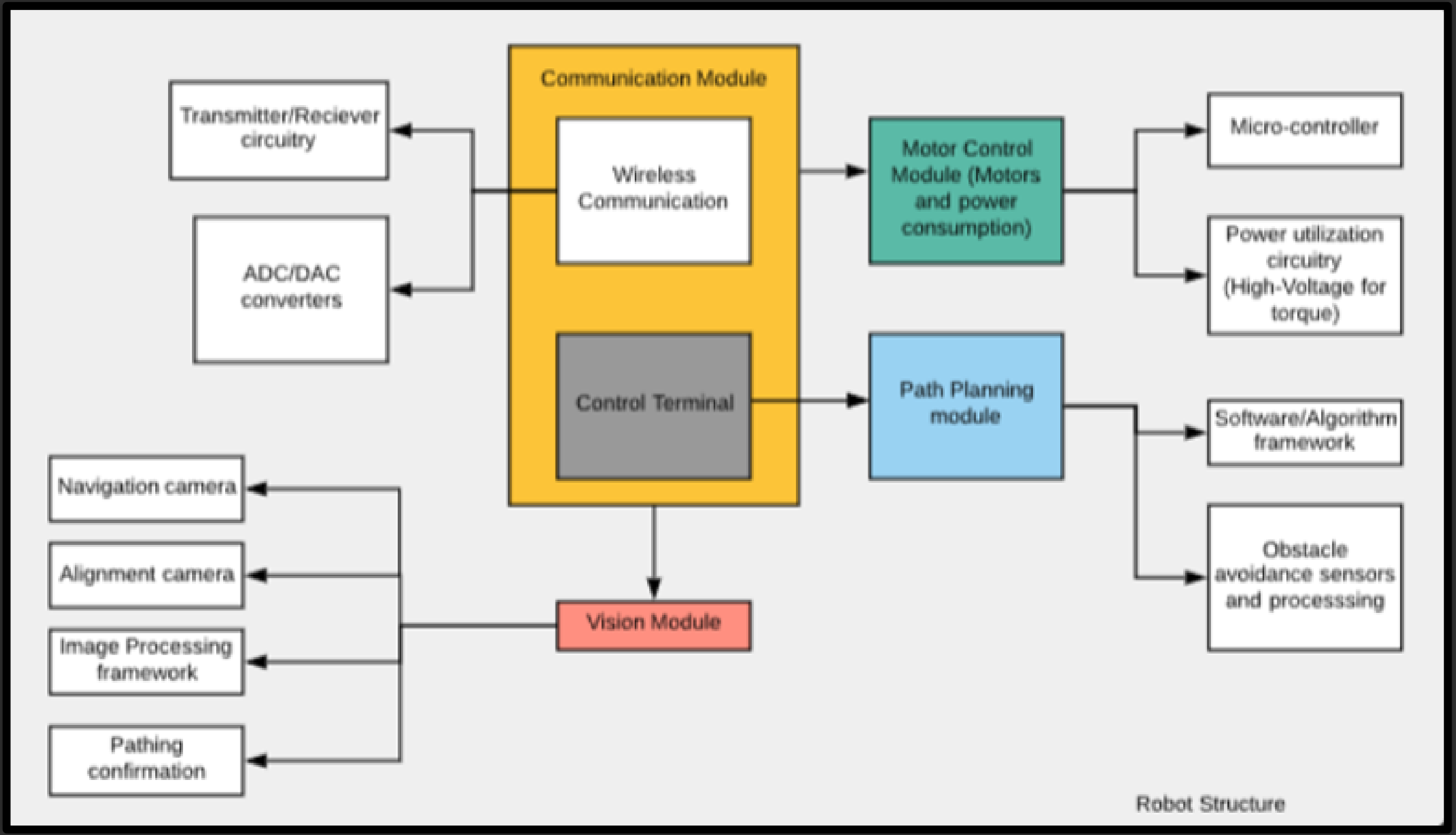
- Preliminary image processing for camera + Path planning algorithm
- Create robot
- Integrate software with microcontroller







System Block Diagram



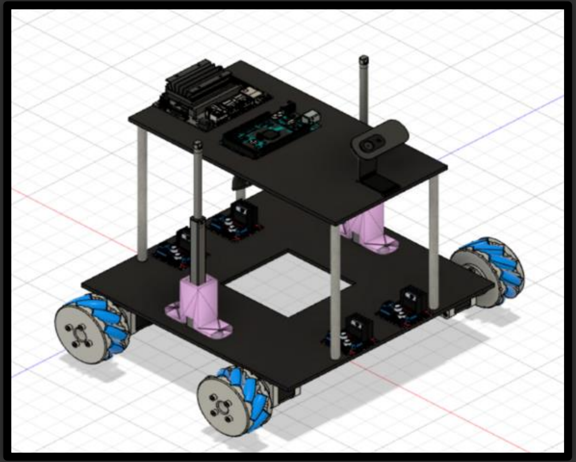
Prototype Assumptions

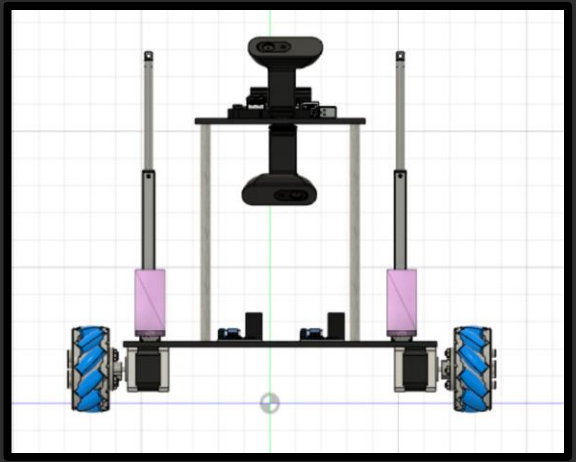
- Operate using a simple discrete grid system where all markers will be located at the center of the tile
- ArUco markers on the grid must be sized accordingly to allow a certain white space margin around the marker to ensure successful detection and identification by the vision module. The markers must be legible and detectable by the vision systems (ie. free of dirt, dust, damage and peelage).
- The payload assigned for pickup and dropoff during the robot's mission will be located on the 4x4 grid created for the demonstration of the prototype.
- Payload shall not exceed 5 kilograms and will be positioned on a pallet with surface area greater than or equivalent to the dimension of the base
- Operate in an environment where wireless signals will not be subject to attenuation

Prototype Description

General Specifications

- Robot Unit
  - Microcontroller based motion control
  - Onboard processing (image processing and path planning)
  - Stepper motors attached to custom 3D printed Mecanum wheels
  - Custom laser cut Acrylic base with thickness ¼ inch





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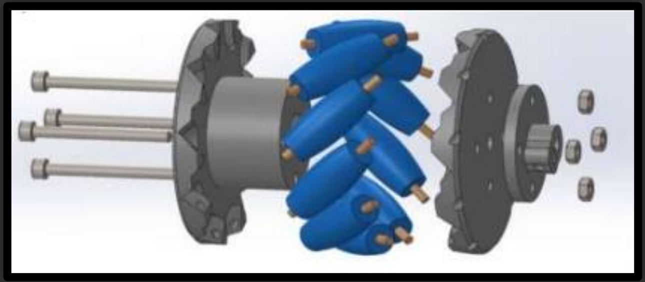
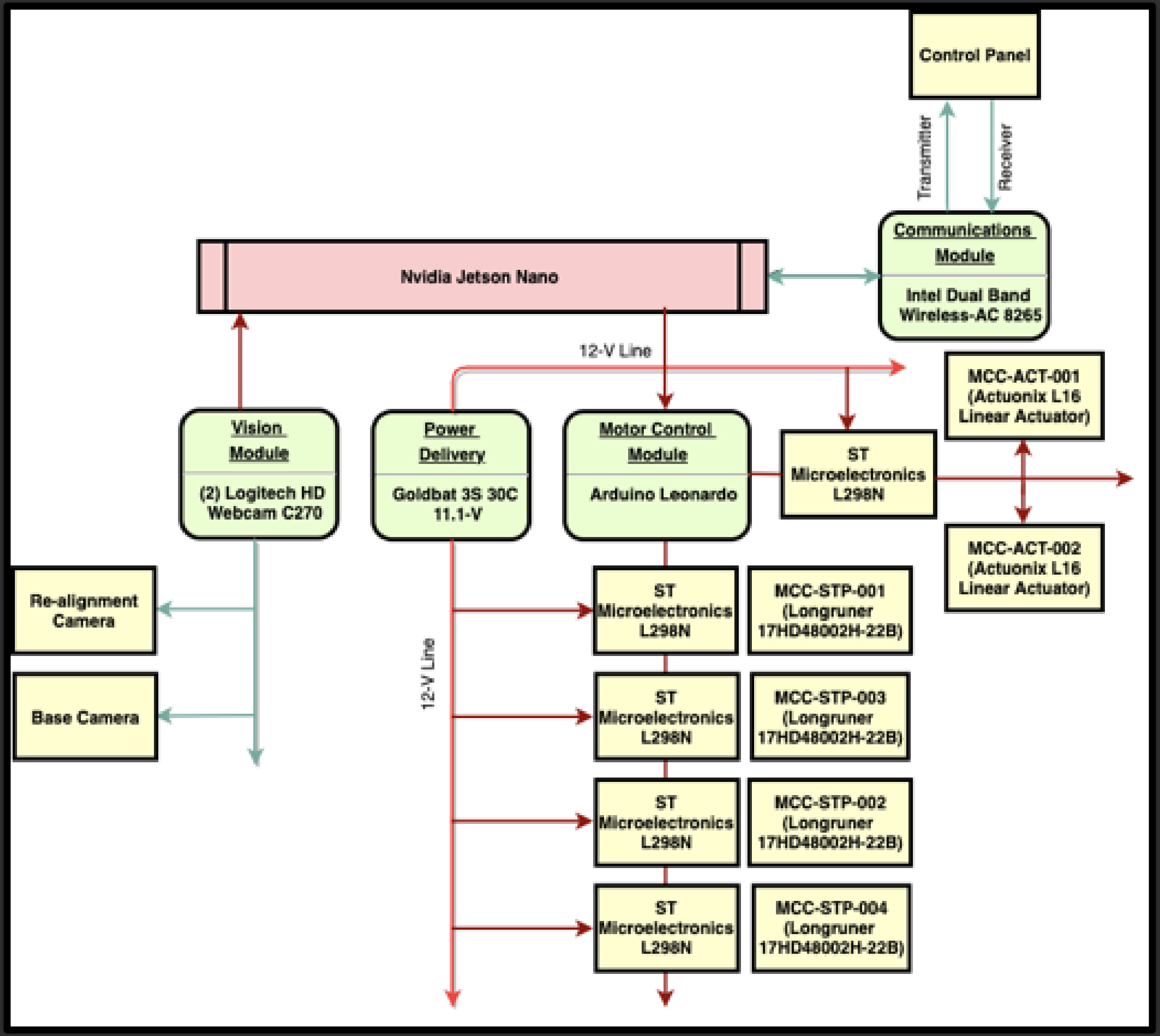


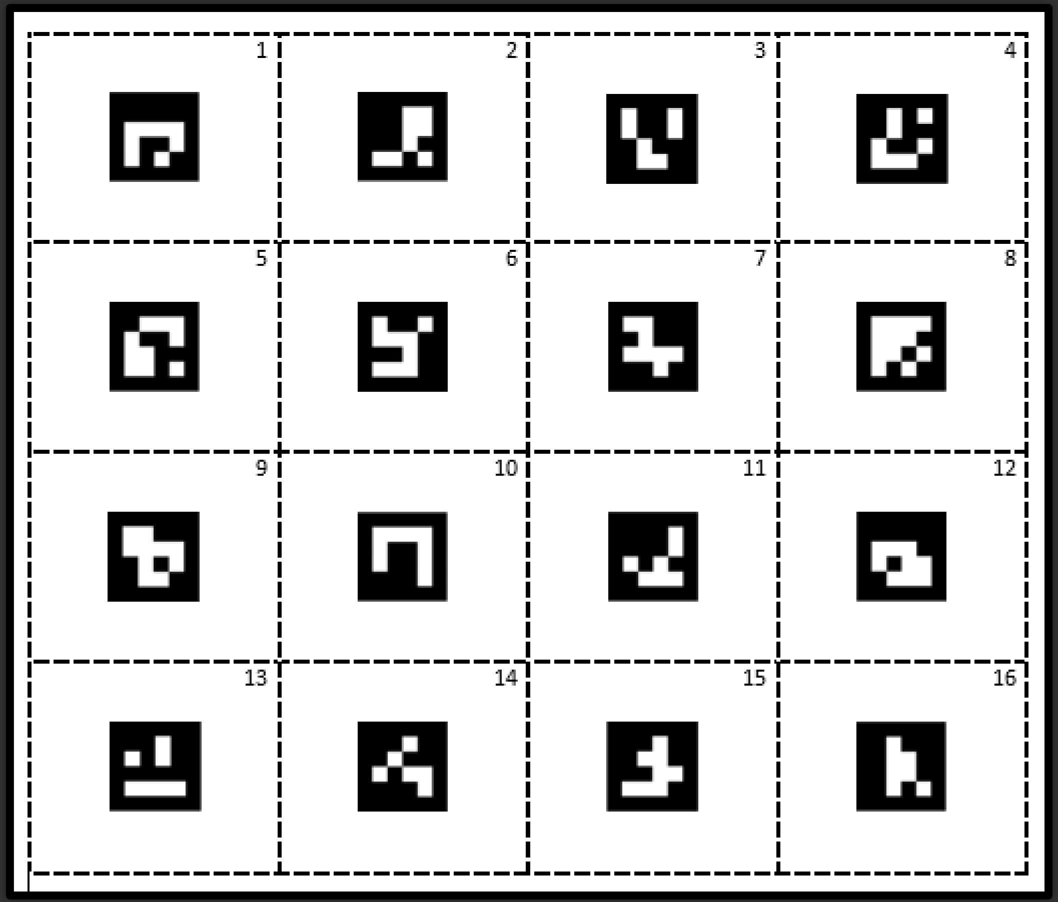
Prototype Block Diagram



Prototype Description

General Specifications

- Pallet and Payload
  - Pallet base dimensions: 12cm by 12cm
  - Payload = box weighting up to 10kg with varying dimensions
- Grid System and Layout
  - 4x4 grid with markers 1 to 16
  - 6cm by 6cm markers at the centre of each block on grid
  - Grid squares: 12cm by 12cm



Prototype System Specs

Detailed Specifications

- Processors
    - NVIDIA Jetson Nano
        - NVIDIA Maxwell GPU architecture
        - 128 NVIDIA CUDA cores
        - Quad-core ARM Cortex A57 CPU MPCore processor
        - 4 GB Memory, 16 GB Storage
    - Arduino Due
        - Atmel SAM3X8E ARM Cortex-M3 CPU
        - 32-bit ARM core microcontroller processor
        - data transfer rates up to 480 Mbits/sec
- Sensors
    - Logitech C270 HD Webcam
        - 720p quality
        - 30 frames per second

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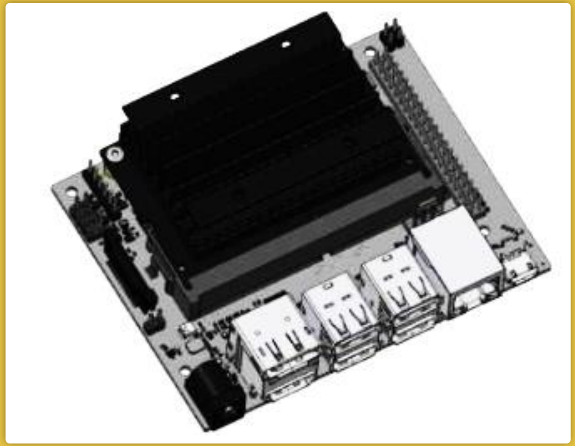

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Prototype System Specs

Detailed Specifications

- Motors
  - Nema-17 Stepper motors (17HD48002H-22B)
  - L16 Linear actuators
- Power Consumption
  - Custom power electronics PCB design
  - Nvidia Jetson Nano: 10 watts
  - Arduino Leonardo: Powered through USB port @ 500 mA and 5V (5V*500mA = 2.5W)
  - DRV8825 Motor Drivers: 12.3 watts
  - L16 Linear actuators: 3.2 A @ 12 V DC = 38.4 Watts

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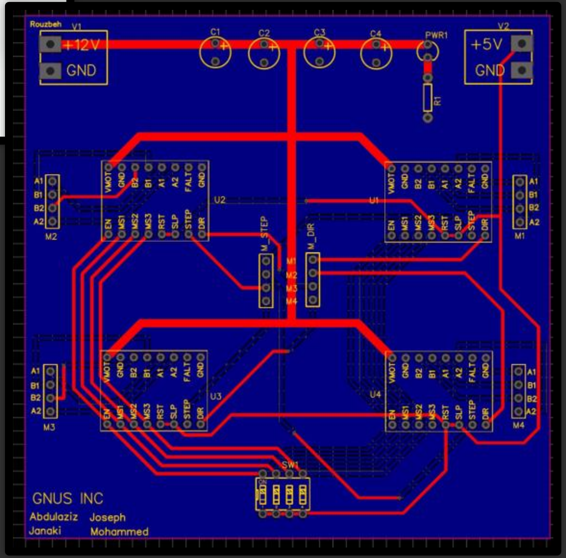
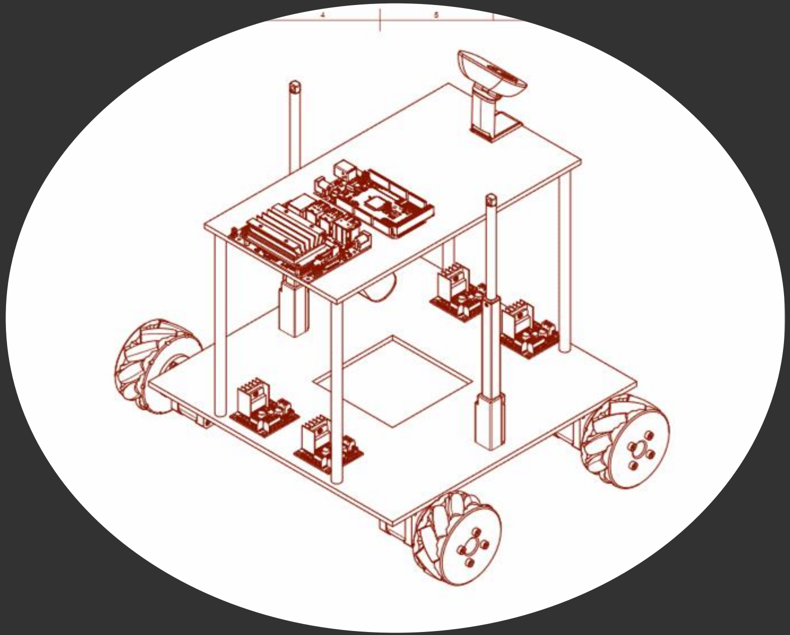


Prototype vs. Product

- Simplifications
  - Improved Power Management System
  - Wiring – use PCB for cleaner circuit design
  - Central Processor that is Wi-Fi enabled
  - Integrated motion control using Jetson Nano as microcontroller
  - Dust-proof and weather-proof casing
  - Increase load and lift capacity

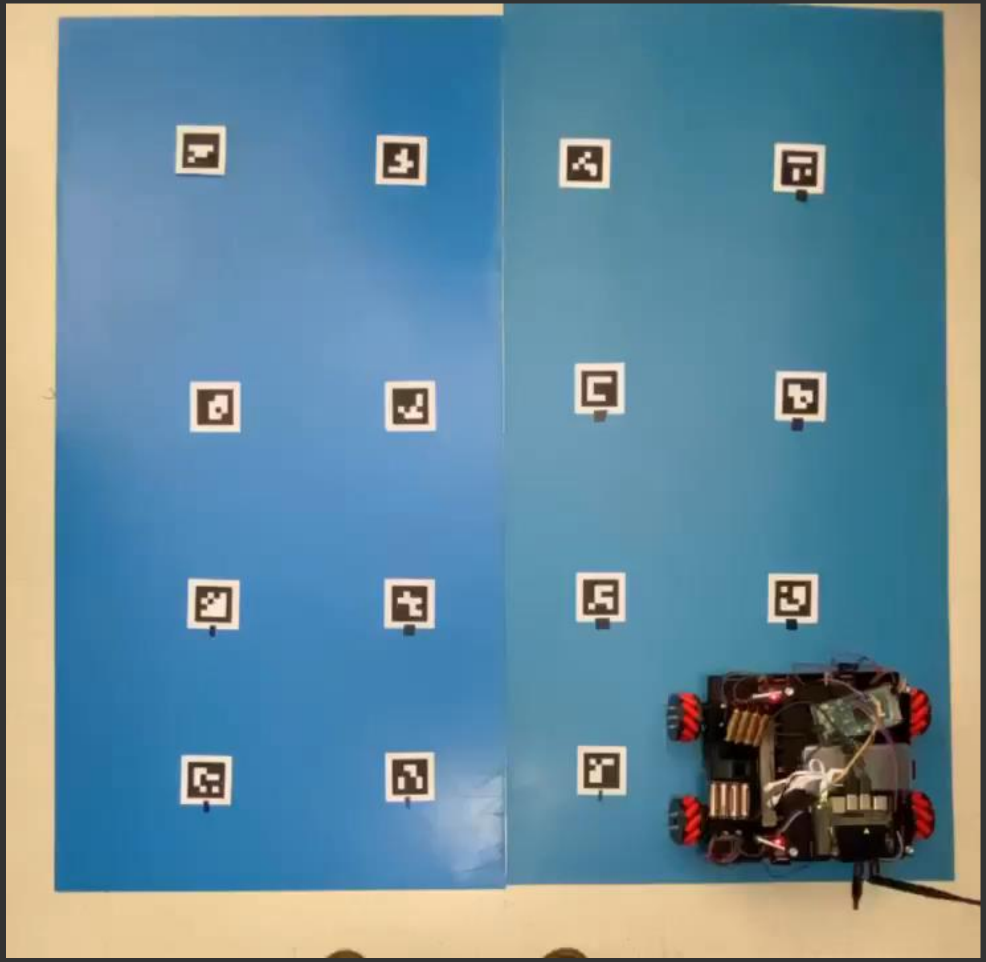


Test Cases for Prototype

- Set 1: Test whether prototype is operational (e.g. wireless communication is established between robot and control panel)
- Set 2: Test path planning module (ie. Given valid ids and most efficient path computed)
- Set 3, 4, 5: Test camera and image processing framework (base camera, hunting camera detection and identification)
- Set 6,7,8: Test physical motor movements of robot (stepper motors and actuators)
- Set 9: Ensure robot can notify operator that mission is completed successfully

Video of Working Prototype

Video plays in PowerPoint



Thank you.

References

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