AUTONOMOUS HOSPITAL TRANSPORTER

- A Patient Transporter is a minimum-wage job with country-wide staffing shortages whose job it is to shuttle patients to and from medical facilities.
  - For example: Patients are waiting for hours after being discharged to get back to the lobby due to lack of transport.
  - COVID has exacerbated these problems.
- Goal - Create an autonomous wheelchair that can transport patients throughout the hospital.
- Requirements
  - Navigate to a specified location inside the hospital safely without human intervention
  - Move in a smooth and predictable path at average human walking speed
  - No sensors or equipment in front of the patient (must be above, below, or behind)
  - Continuous operation for >2 hours per charge (see slide 5 for justification)
- SWaP-C
  - Size: Keep nominal dimensions of typical wheelchair
  - Weight: Is not a problem provided CG remains low enough to avoid tipping
  - Power: Discussed in next slide, must be rechargeable
  - Cost: Less than annual minimum wage income ($15,000)

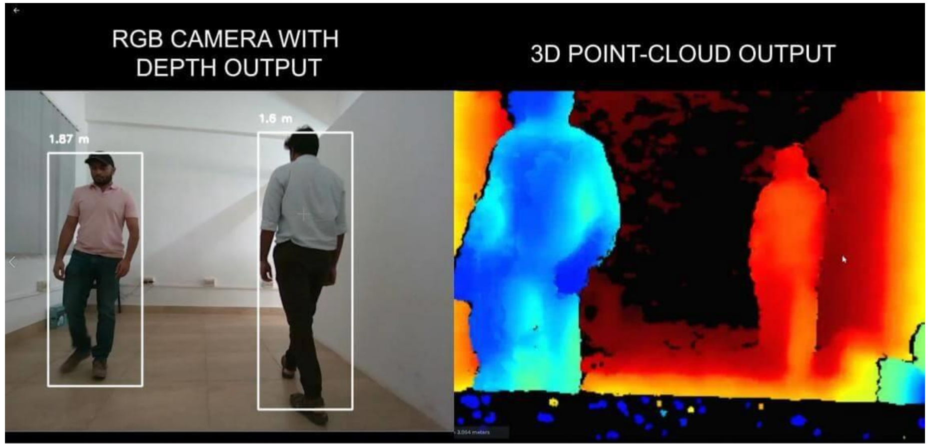
POWER


- Drive Motors: Total 144W
  - Two PCS-250 24VDC 160RPM Motor w/spur gearbox and optical encoder (current draw <=3A) - Specs
  - Meets Requirements:
    - Differential Drive
    - Maximum weight = 1500N
    - Nominal speed = 1.5 m/s (walking speed)
    - Accelerate from rest to nominal speed in < 2s

- Propulsion Battery: Two 12V, 35Ah Lead-Acid in series = 420Wh
  - 420Wh/114W = 2.92 hours of continuous operation
- Sensing and Computing: Total 15.75W
  - Jetson Xavier NX with Wi-Fi Module – 10W - Specs
  - Intel Realsense RGBD Camera – 3.5W - Specs
  - RPLIDAR A2 – 2.25W - Specs
- Electronics Battery: One 11.1V, 5.1Ah LiPo = 56.61Wh
  - 56.61/15.75 = 3.60 hours of continuous operation
  - 5V DC-DC step down converter for RPLIDAR
  - 3.3V DC-DC step down converter for Realsense
  - Xavier NX accepts 9-20V

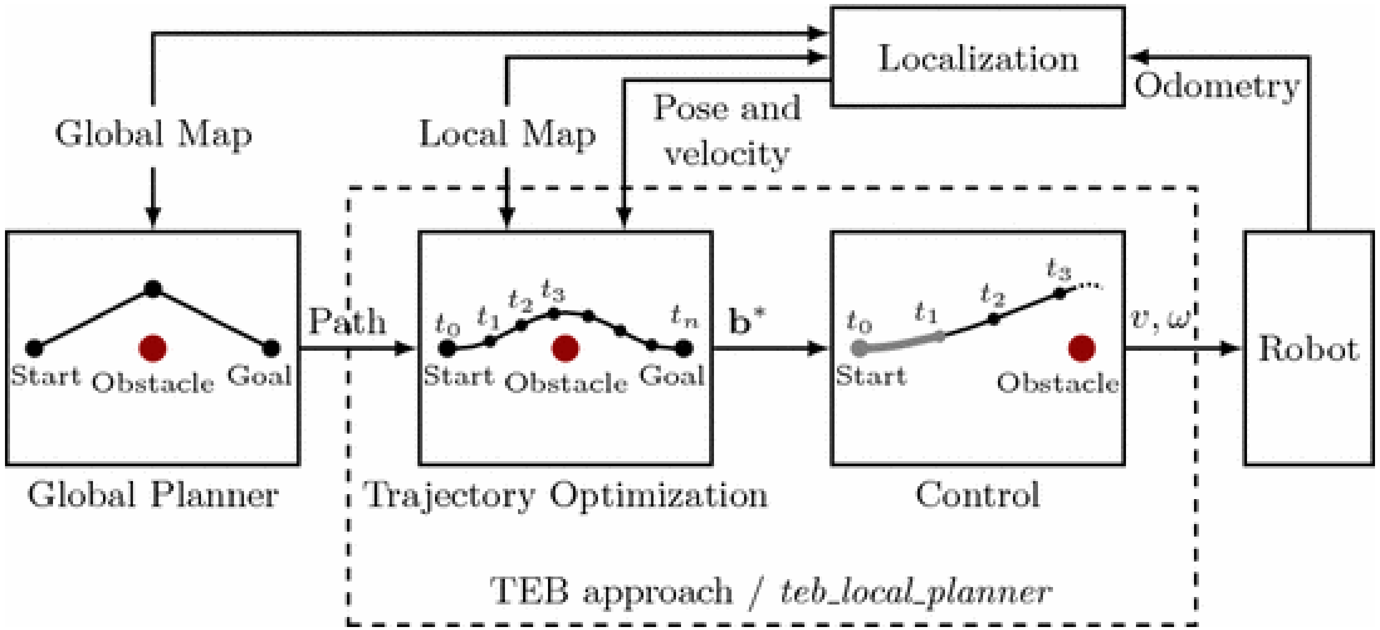
SENSING AND COMPUTING

- Odometry will be performed primarily using Lidar and wheel encoders at 10Hz.
  - RPLIDAR A2 laser scanner
    - 12-m range, 360°
  - Optical Wheel Encoders on drive wheels
- Depth camera used for redundancy and additional dynamic object (human) detection and prediction
  - Intel Realsense with Integrated IMU – 90Hz
- Jetson Xavier NX with Wi-Fi Module
  - Capable of running ROS Noetic in Ubuntu 20.04
  - Processes wheel encoder, laser scanner, and RGB-D camera data and computes desired torques to apply to drive wheels
  - Future Considerations – Built-In GPU capable of implementing deep learning algorithms for detection and prediction of human movement from RGB-D camera

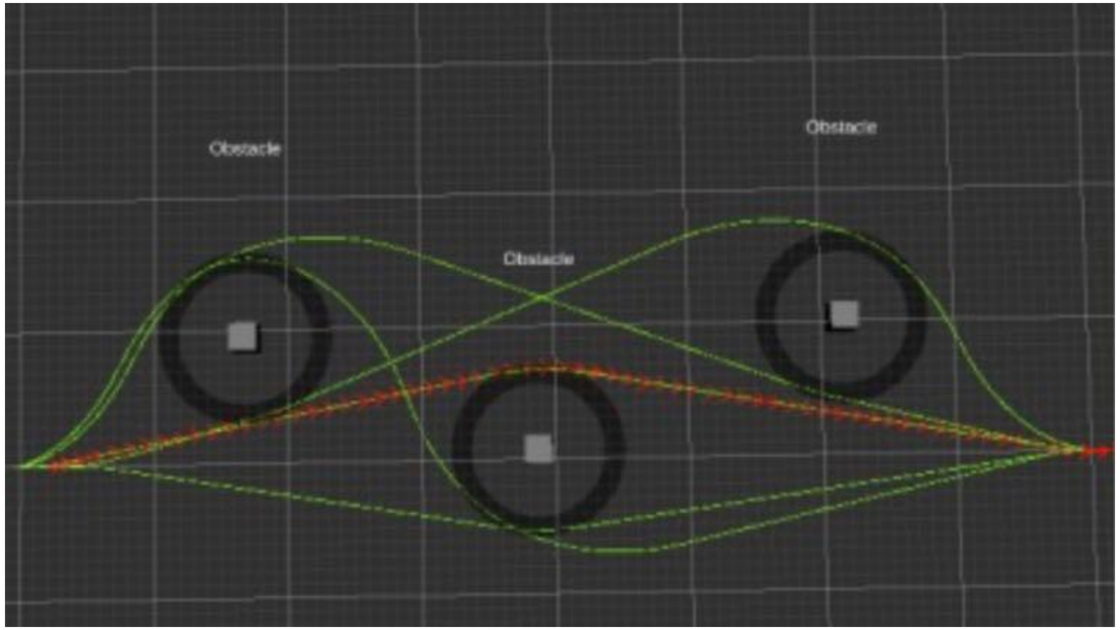


NAVIGATION

- Mapping – Pre-Built
  - The first step is to use the specified sensors to create a mm-level-precision 2D map of the hospital environment
  - Allows for cm-level real-time localization during path-planning.



- Path Planning - Timed Elastic Band
  - Online – immediate response to changes in a dynamic environment
  - plugin for ROS navigation package – *teb_local_planner*
  - time-optimal objective – take the fastest route
  - separation from static and moving obstacles – avoid people
  - implement kinodynamic constraints – minimize jostling of patient



Rösmann C., Hoffmann F., Bertram T. (2017) Online Trajectory Planning in ROS Under Kinodynamic Constraints with Timed-Elastic-Bands. In: Koubaa A. (eds) Robot Operating System (ROS). Studies in Computational Intelligence, vol 707. Springer, Cham. https://doi.org/10.1007/978-3-319-54927-9_7

ADDITIONAL SYSTEM DESIGN AND CONSIDERATION

- Several units will be deployed in each hospital, depending on needs.
- A minimum of 2-hr continuous operating time was chosen based on the knowledge that each trip would be 5-10 minutes. Idling times between shuttles can be used for charging at one of a few hubs spaced throughout the hospital.
- A request will be sent to the hospital-wide internal system requesting a transport via Wi-Fi, which will be received and processed. The nearest unoccupied transport will be dispatched to the desired location and notify the sender upon arrival.
- Most hospitals have an elevator specifically for patients that can be ordered in advance. This system can be used over Wi-Fi by the transport to navigate between floors, as needed.
- Each transport is periodically transmitting its location over Wi-Fi for monitoring and error reporting.
- Prevent patients from sliding off or getting out – Belt – access to emergency stop
- The existing transport staffing will still be necessary for cases requiring patient monitoring or emergency response as well as helping patients into and out of the autonomous transports.
- Hardware costs = ~$5,000/unit
  - Sensors = $800
  - Motors = $675
  - Computer = $350
  - Batteries = $250
  - Structure, chair, wheels, accessories =~ $3000