Meal Delivery AMR

- Use Case
    - In retirement communities, elderly individuals are able to get meals delivered to a table outside of their apartment door on days of their choosing
    - **Goal:** Automate this process!
- High-Level Solution Description
    - An autonomous mobile vehicle that is able to localize and navigate through the hallways of an apartment building, detect surrounding objects, identify individual apartments, and place certain meals on a surface outside of those apartments
- Key Features
    - Localization LiDAR: maintain a steady pose during navigation
    - Safety LiDARs: create a safety field around the vehicle
    - April tag detection: ensure correct meal is dropped off in correct location
    - Hydraulic arm: place meal on surface
    - Remote communication
        - Ability to call and use an elevator
        - Send a delivery confirmation to the receiver and management
- Target Environment: Retirement Communities
    - Easy to navigate hallways
    - Slow moving environment
    - Large need for extra assistance

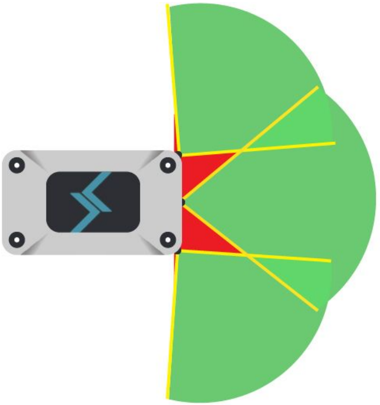

Figure 1: Meal Delivery AMR Field of View

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Power

- Power Estimations
  - Drive motor .... 220 W (HP: 0.35)
  - Steering encoder .... 0.5 W
  - Safety LiDAR (2) .... 4 W = 8 W
  - Localization LiDAR .... 10 W
  - Camera .... 2 W
  - IMU .... 0.8 W
  - Screen .... 15 W
  - Computer .... 10 W
  - Food rotation motor .... 70 W (0.1 HP)
  - Food door motor .... 35 W (0.05 HP)
  - Food delivery arm motor .... 40 W (0.08 HP)
  - **Total Wattage.......... 412 W**
- Weight
  - **Assumptions:** Size: ~ 24" x 30" x 36"; holds 50 meals; including component casings, add ons
  - **Total weight:** ~120 lbs.; Required HP to move 120 lbs = ~0.25 HP → ~185 W of power (added buffer power)
- Battery
  - **Requirements:** Expected to last max 6 hours (2 shifts), ability to be charged in between shifts
  - Battery capacity to run 412 W for 6 hrs = ~ 250 Ah @ 85% efficiency = **~ 315 Ah** battery capacity required

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Navigation

- Overview
  - Use SLAM to create a 2D map of static features of each floor of the facility
  - Match live LiDAR data to the map to identify a global position
  - Use a system of safety LiDARs to create safety fields surrounding the vehicle, detect nearby obstacles, and control velocity depending on the location of those obstacles
- Process
  - SLAM map creation
    1. Record LiDAR and odometry data for each floor
    2. Process each dataset to create a map of each floor
  - LiDAR data matching
    1. Align the map with a 2D global coordinate system
    2. Match live LiDAR and odometry data to the floor map; calculate vehicle position relative to the global coordinate system to obtain and hold an accurate position estimation during navigation
  - Safety system
    1. Steering and motor encoder used to control the velocity of the vehicle depending on the vicinity of obstacles
    2. Warning and stop zones created based on vehicle velocity and orientation trajectory
       1. Vehicle will slow down if an object is in the warning zone, and stop if an object is present in the stop zone
- Navigation Advantages in Retirement Home Hallways
  - **Easy to map and localize:** Map will consistent of all static objects and straight, smooth features
  - **Easy to navigate:** Floors are very flat, predictable, and free of clutter
  - **No presence of fast dynamic obstacles:** safety system can be simple yet very effective due to the simplicity of the surrounding environment

Figure 2: Example Floor Map Using SLAM

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Sensing

- Sensor System Components
  - Localization LiDAR
    - Location: High up on vehicle, in a location where it can detect max of 360° range possible
    - Purpose: **Feature matching and position estimation**. Matches live LiDAR and odometry data to pre-existing map to estimate and hold a relative position in its virtual world

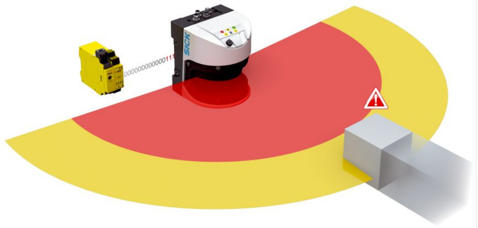

Figure 3: Example Sensor Safety Zones

  - Safety LiDARs
    - Locations: Front bottom left and right of vehicle (~2 in. level off the floor)
    - Purpose: **Obstacle avoidance and safety zone creation**. Create warning and stop zones based on vehicle velocity and orientation (via an IMU device)
      - Vehicle will slow down or stop if an obstacle is present in the respective zone (*Figure 3*)
      - Only two forward facing 2D sensors required due to low velocities, one directional movement, and simplicity of environment
  - Camera
    - Location: Right side of vehicle, level with the location of April tags (~33 in. off the floor)
    - Purpose: **April tag detection**. Provides a high level of accuracy in determining the final position and orientation of the table in which to drop the food
      - Provides confirmation that the vehicle is delivering the correct meal to the correct apartment
  - IMU
    - Purpose: **Orientation calculation**.

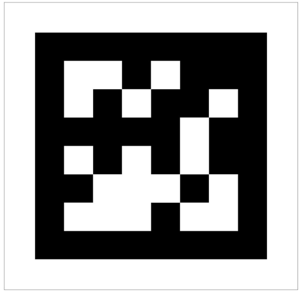

Figure 4: April Tag

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Computing, Use Cases, and Technology

- Computing and Communication Platform
  - **ROS:** Constantly publishing live LiDAR data to the system, including the steering encoder and motor controller for real time reactions
  - **Database:** Navigation missions to be queued before the vehicle is sent out. Mission status' update on external server as they are completed and communication is sent to apartment (ring, phone call, etc.) and apartment management to track status
- Alternative Use Cases
  - Can be used to deliver...
    - Medicine
    - Laundry
    - Packages/Mail
  - In environments such as...
    - Apartment buildings
    - Hospitals
    - Office buildings
- Similar Technology
  - **Badger Technologies:** Marty
    - Scans shelves at grocery stores and reports missing inventory, price discrepancies, and more *(Figure 5)*
  - **Amazon Robotics:** Bert and Ernie
    - Used to deliver stacks of inventory around Amazon warehouses *(Figure 6)*
- Extra note: This is a real use case! I visited my Grandfather in North Carolina over spring break and based this solution off of the community he lives in. This type of technology could be extremely effective where he lives.

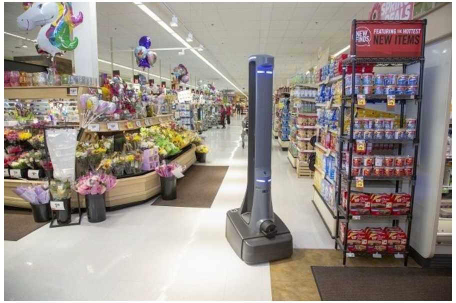

Figure 5: Badger Technologies - Marty

Figure 6: Amazon Robotics - Ernie

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