Food Basket Delivery with the Stretch

Final Presentation

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Outline

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Robot-Assisted Meal Delivery

Problem we want to solve

Frail senior citizens, patients with physical disabilities have trouble performing Activities of Daily Living (ADLs), including fetching food for themselves

Proposal

Use Hello Robot's Stretch RE2 for **automated meal preparation and delivery** to patients in **hospitals and nursing homes**

Motivation

1.4M+ Individuals live in 15K nursing homes in the US

94%

94% of nursing homes, 81% of assisted living communities cite shortage of staff as a barrier to timely delivery of essentials

Staff engage in manual tasks including delivering

- EVS, Dietary, Pharmacy, Lab, Linen items
- 4,547 meals delivered (= 61 miles) per week in a facility in Pittsburgh

Value to the Population

Staff in hospitals & assisted living facilities

- Reduced repetitive workload for nursing staff
- Ability to focus on critical care

Patients

- Timely delivery of meals and other essentials

Frail Senior Citizens

- Personal robot butler at homes to transport items
- Networking with IoT devices at homes

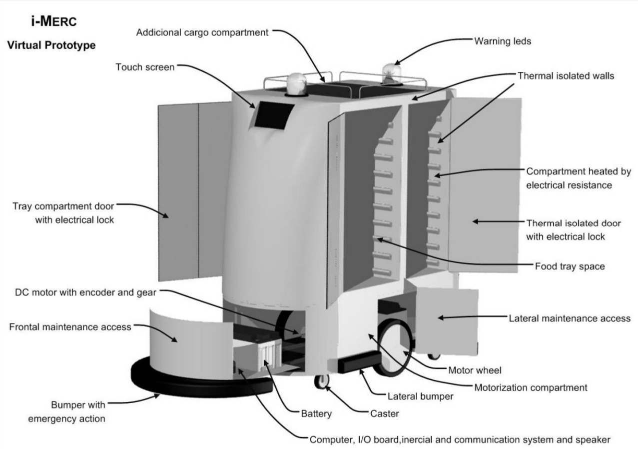
Literature Review

Service Robots in the Healthcare Sector (2021)

- **Sterilization**: sterilising surfaces and objects
- **Cleaning**: disinfecting high contact points (doors, handrails)
- **COVID-19 Testing**: monitoring social distance adherence, mask compliance, signs of fever & testing
- **Logistics**: delivery of meals, medications, supplies, lab results
- **Social Care**: provide social interaction, promote physical activity
- **Telehealth**: monitoring vital measurements, patient monitoring

Literature Review

I-Merc: A mobile robot to deliver meals inside health services (2006)



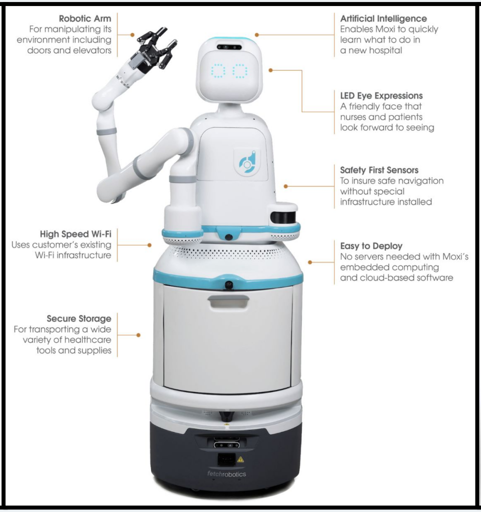
- 10 food trays
- Heating compartment to maintain 60ºC temperature
- Prototype for a Master's thesis
- Not productionized due to bulky mobility

Literature Review

Existing Industry Solutions

Aethon TUG
(used in UPMC!)

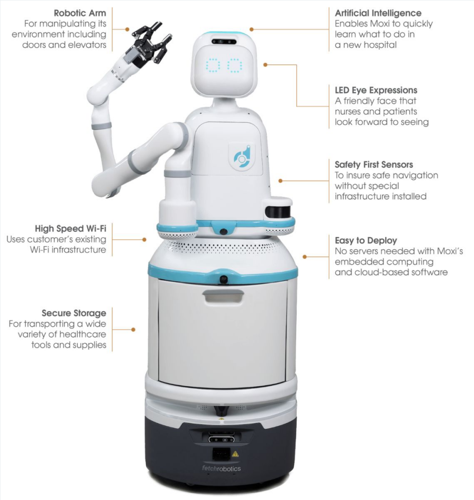
Usage	Medication, Laundry delivery
Size (W x L x H)	22.4 x 33.8 x 47.7
Max Payload	1000 lb
End Effector	NA
Price	$105,000
Voice interface	Speaker only


Robotic Arm
For manipulating its environment including doors and elevators
Artificial Intelligence
Enables Moxi to quickly learn what to do in a new hospital
LED Eye Expressions
A friendly face that nurses and patients look forward to seeing
Safety First Sensors
To insure safe navigation without special infrastructure installed
High Speed Wi-Fi
Uses customer's existing Wi-Fi infrastructure
Easy to Deploy
No servers needed with Moxi's embedded computing and cloud-based software
Secure Storage
For transporting a wide variety of healthcare tools and supplies


relay

Literature Review

Existing Industry Solutions



Moxi

Usage	Social intelligence, mobile manipulation
Size (W x L x H)	Full spec sheet unavailable
Max Payload	Full spec sheet unavailable
End Effector	Yes
Price	RaaS monthly subscription
Voice interface	Speaker only

Literature Review

Existing Industry Solutions

Relay Robotics

Usage	Safe, dynamic navigation
Size (W x L x H)	20 x 20 x 36
Max Payload	10 lb
End Effector	NA
Price	$2,000 per month (2017)
Voice interface	Speaker only

Literature Review

Existing Industry Solutions

Stretch RE2

Usage	Safe navigation, pick & place, flexible arm, voice control
Size (W x L x H)	14.0 x 13.1 x 55.5
Max Payload	~10 lb estimate
End Effector	Yes
Price	$19,500
Voice interface	Mic & Speaker

Challenges

Meal Preparation

- Object Detection
- Grasping objects
- Placing objects in a basket
- Picking up the basket

Delivery

- **Navigation to the patient**
- **Holding the basket stable**
- **Safe placement near patient**
- Obstacle avoidance

Interaction with Stakeholders

Carol

Nurse at UPMC

- Cluttered hallways require **sleeker bots**
- Voice control interface would be great
- Different patients have different needs for meals
- Aethon TUG used for laundry and medication delivery
    - Manual restart is inconvenient
    - Robot itself is small but linen carts are large (difficulty in navigation)

Shared mid-term demo video for feedback

Interaction with Stakeholders

Dr. William Mills

BrightSpring Health Services

- Confirmed usefulness of a sleek mobile robot
- Feeding capability might be required for some patients
- Voice control interface would be helpful
- Adapting to changes in patient position

Shared mid-term demo video for feedback

Next Steps from Midterm

Navigation

- Detection-based navigation
- Obstacle avoidance

Manipulation

- Detection-based grasping
- Automating pick and place interactions

User interface

- Allow voice interactions

Next Steps from Midterm

Navigation

- **Detection-based navigation**
- Obstacle avoidance

Manipulation

- **Detection-based grasping**
- Automating **pick** and place interactions

User interface

- Allow voice interactions

Previous Assumptions

- Basket has a handle on the top to facilitate grabbing
- The room is mapped out in advance
- The coordinates of the basket and patient bed are known

Updated Assumptions

- Coordinates of the patient bed are known
- **Exact coordinates of the basket are unknown!**
- **An Aruco tag is attached to the basket**

Task Decomposition

Delivery to the Patient

- Navigate to basket **based on tag detection**
- Pick up the basket
- Navigate from point A to point B **based on coordinates**
- Place the basket at point B

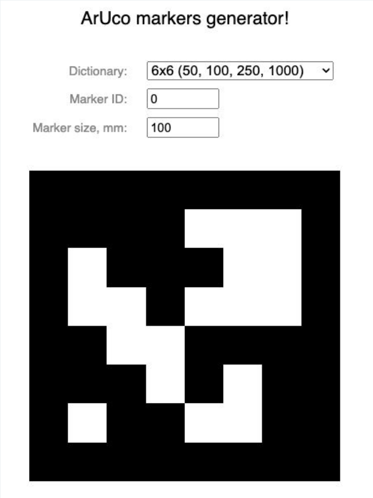
Implementation : Navigation

- ROS navigation stack
- Uses LiDAR sensor to map the space
- Capturing 2D pose estimates in RViz
- ROS Topic messaging to send point navigation, and joint trajectory goals

Map of AI Makerspace

Our code is available at: https://github.com/prasoonvarshney/stretch-robot

Implementation: Aruco Navigation



- More robust and easier to incorporate than object detection-based systems
- Yolo-V3 could not detect current basket

Implementation: Required Services

`aruco_navigation.launch`

1. Basic ROS navigation stack
2. Lidar sensor
3. RealSense 435i (low resolution)
4. Mapping stack (loads previously mapped Tepper room)
5. Localization (amcl_diff)

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Implementation: Aruco Navigation

Detecting the basket and navigating to a rough location

- If the basket is in current viewpoint …
  - Base link: `tf_listener.lookupTransform(‘map’, ‘base_link’)`
  - Basket: `tf_listener.lookupTransform(‘map’, ‘basket’)`

- If the basket is <u>not</u> visible … repeat till max tries
  - Look around (rotate camera in 45 degree increments)
  - Navigate to rough location (map-based navigation)

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Implementation: Aruco Navigation

After detecting the basket

- `angle_z       = euler_angles_from_quaternion(tag_quaternion)[2]`
- `tag_normal    = angle_z + 3* pi/2`
- `goal_angle_z = tag_normal - pi/2`

- `goal_x        = tag_x + r*cos(tag_normal) - d*cos(goal_angle_z)`
- `goal_y        = tag_y + r*sin(tag_normal) - d*sin(goal_angle_z)`
- `goal_z        = 0.0`
- `goal_quat     = quaternion_from_euler(0.0, 0.0, goal_angle_z)`

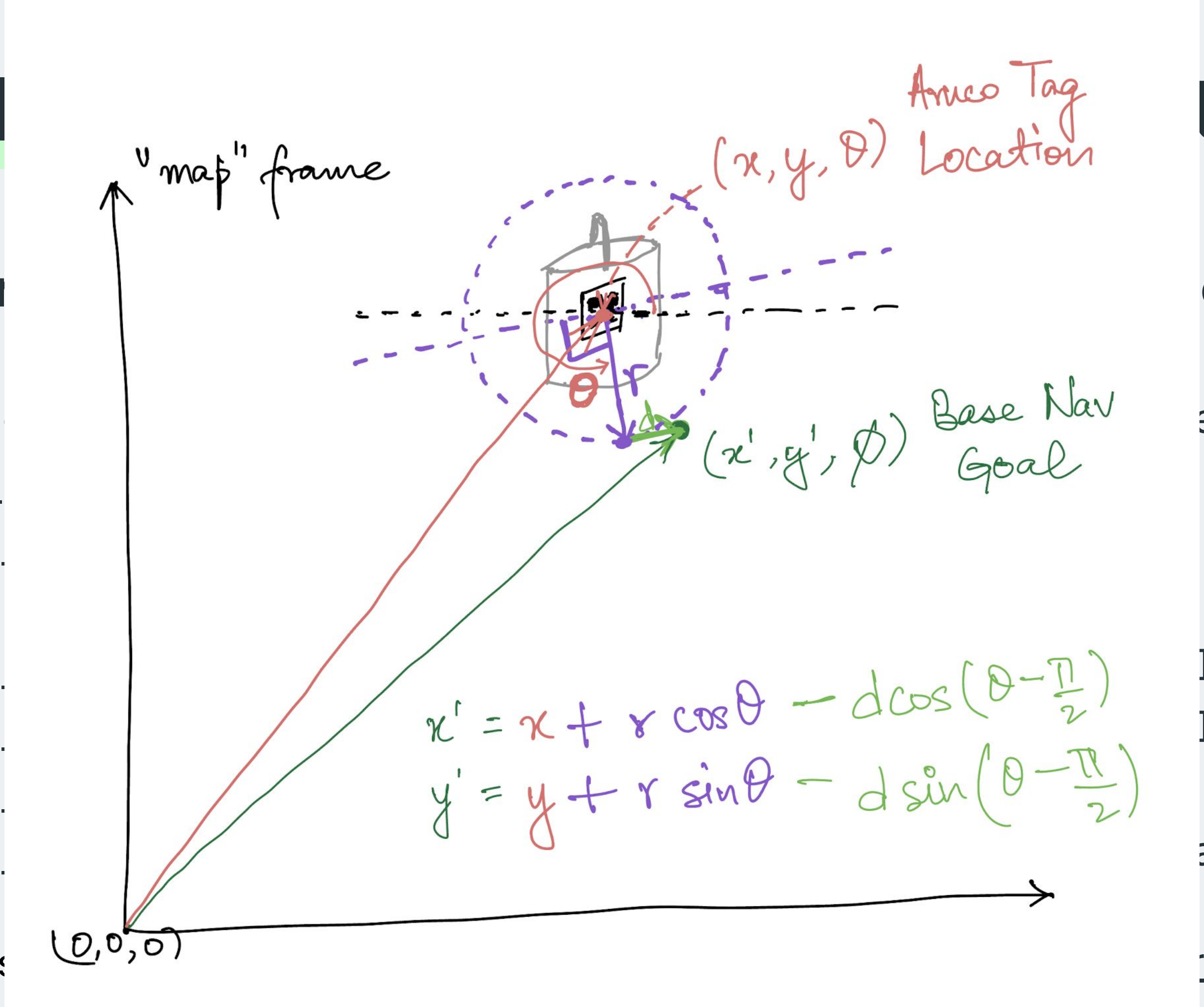
Our code is available at: https://github.com/prasoonvarshney/stretch-robot

Impl… tion

Detecti… cation

- angl… ernion)[2]
- tag_
- goal_

- goal_ … l_angle_z)
- goal_ … l_angle_z)
- goal_
- goal_ … angle_z)



Our code is … robot

Implementation: Navigation

Sending coordinate goals

- Coarse navigation to kitchen area
- Fine-grained navigation to detected basket
- Navigation to patient bed (hardcoded coordinates)
- Coming back to original location (coordinates saved dynamically at mission start)

Our code is available at: https://github.com/prasoonvarshney/stretch-robot

Implementation: Manipulation

Compute and send goals for

- `joint_lift`
  - From basket's z coordinate (adaptive)
  - Fixed couch height
- `joint_wrist_pitch`
- `wrist_extension`
- `gripper_aperture`

Our code is available at: https://github.com/prasoonvarshney/stretch-robot

Evaluation : (1) Success Rate

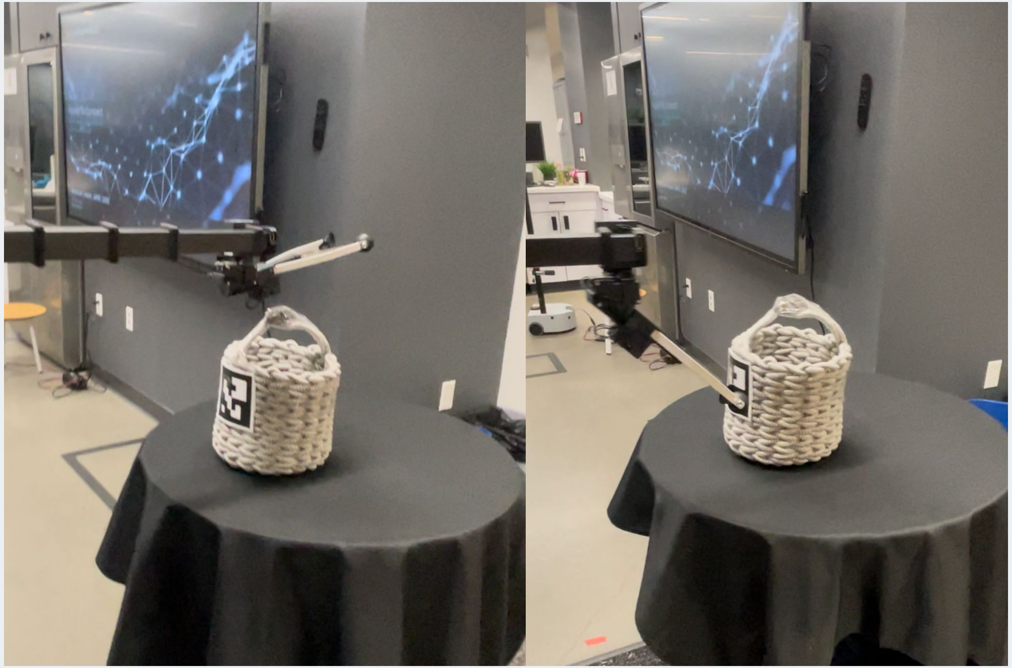
- Number of Trials: **8**
- End-to-end Basket Delivery Success Rate: 62.5%

Step	Success Rate (%)
Found Basket	100
Nav to Basket	87.5
Pick up Basket	87.5
Nav to Couch	75
Place Basket	**62.5**
Nav back to home	37.5

Note that the success of sequential steps is dependent on the previous step

Failure cases

Arm stretched too far in / Off by a few degrees to the right



Evaluation : (2) Duration

- Number of Trials: **8**

Step	Duration (sec)
Nav to Basket	20.99
Pick up Basket	44.02
Nav to Couch	51.71
Place Basket	35.11
Nav back to home	53.32
Total	**205.15**

Evaluation : (3) Navigation Errors

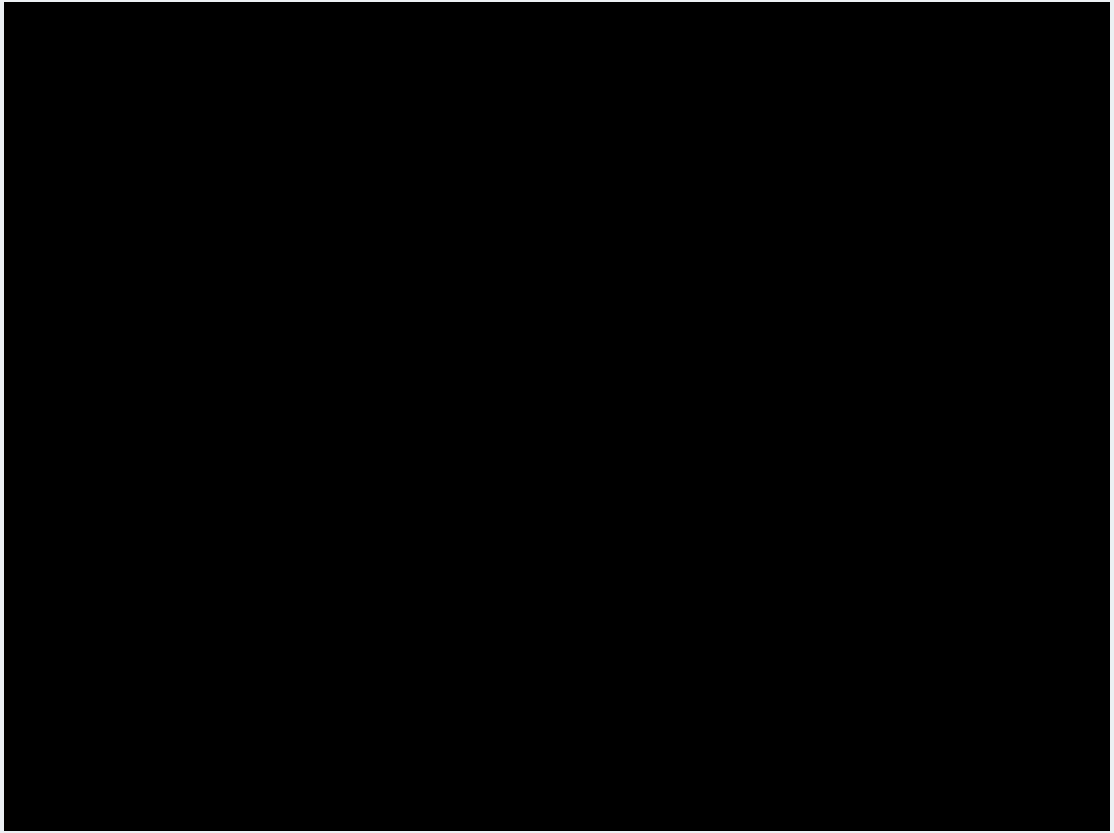
- Number of Trials: **8**
- Errors are computed between the computed navigation goal coordinates, vs robot coordinates after succeeding

Step	Translation Error (m)	Orientation Error (deg)
Nav to Basket	0.07 (std=0.01)	3.5 (std=1.01)
Nav to Couch	0.06 (std=0.02)	1.62 (std=1.34)

6-7 cms on average, due to errors in initial pose estimation of the starting location

Higher for navigation to basket due to errors in Aruco surface normal detection

Demo Video



Next Steps

Navigation

- Obstacle avoidance

Manipulation

- Automating place interactions
- Targeted delivery through face detection & pose estimation
- Assistance with meal preparation

User interface

- Allow voice interactions