Robotic Activity Support (RAS)

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Introduction

- **The Problem:** Fifty percent of adults age 85+ require assistance with activities of daily living (ADLs) [1] and for those with MCI and/or AD, memory issues necessitate a robotic aid with an elder adult-friendly user interface to offer assistance automatically for ADLs, and function as more than a companion.
- **The Goal:** Design and build a robot, that in conjunction with our Smart Home sensor network, has activity learning capabilities and an elder-friendly user interface to serve as a cognitive aid for ADLs that will allow elder adults in cognitive decline to age in place.

Robot Design

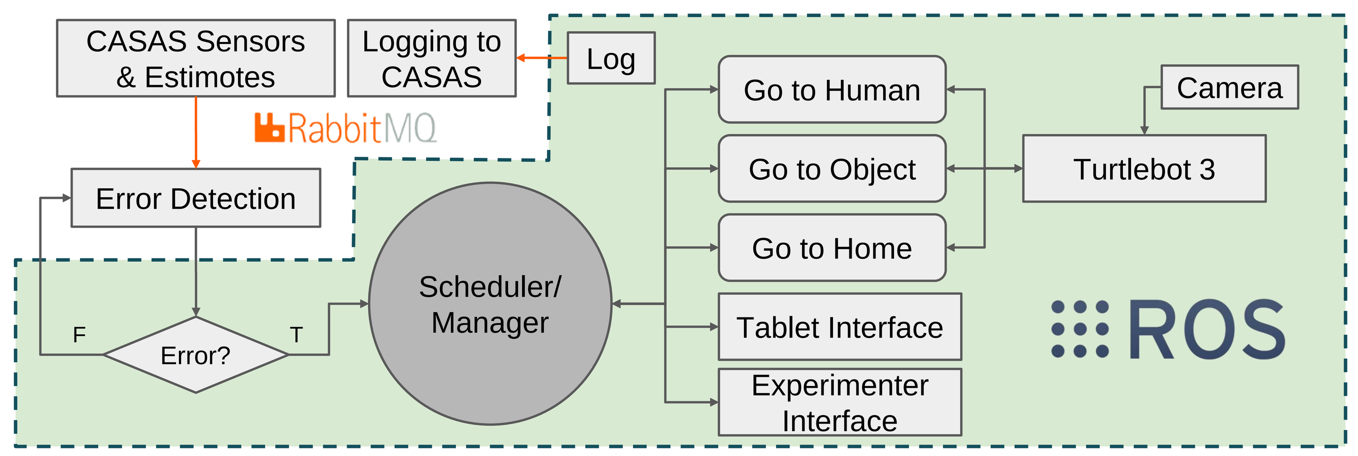

Figure 1. Robot components connections

<u>Requirements</u>

- Interface for prompting resident whether assistance is needed (see Figure 4)
- Visually recognize human and objects, keeping track of last-seen locations
- Navigate to human and object locations in the house

<u>Components</u>

- Hardware: Turtlebot 3 (see Figure 2)
- Software: ROS nodes for each component (see Figure 1)
- Components connected by manager node

<u>Navigation</u>

- Cartographer with 2D LiDAR for SLAM (see Figure 5)
- Dijkstra's for fast interpolated navigation
- Linearization of paths for complex environments

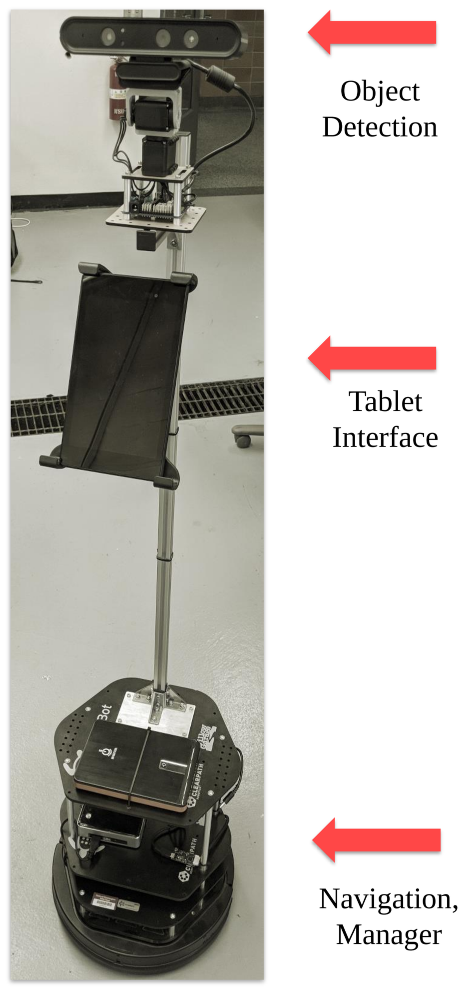

Figure 2. Robot hardware

<u>Object Detection</u>

- Training CNN
  - Create image dataset of objects of interest
  - Label each object in image and draw a bounding box
  - Train an object detection convolutional neural network (CNN)
  - Export the network and run live on the robot
- Dataset for training & evaluation
  - 20k of the 64k human images from Microsoft COCO dataset
  - 2.5k images of smart-home specific objects
  - Split into 80% training and 20% testing sets (see Figure 6 for test results)
- Running CNN on robot
  - Capture RGB and depth images on the robot camera
  - Run the RGB image through the CNN to predict bounding boxes (see Figure 7)
  - Using point cloud from the depth image, find the 3D center of each bounding box
  - Transform 3D point from the camera reference frame to the map reference frame
  - Update the last-seen location of each object in the database
  - Only SSD networks run on robot due to memory constraints. Framerate achieved: ~10 fps.

Methods and Procedure

<u>Participants</u>

- Three undergraduate Washington State University students, comfortable with using technology and do so on a daily basis (2 F, 1 M, age: *M* = 20 years)

<u>Methods and Procedures</u>

- Participants completed three scenarios representative of ADLs (once without error, three times with different errors of omission) and accepted help from the robot in one of three ways, then fixed their error and finished the task:
  - **Tasks:** (1) Preparing to Walk the Dog, (2) Taking Medication with Food and Water, & (3) Watering the Plants.
  - **Prompts:** (1) Lead to task-relevant object, (2) Show a video of how to complete the missed step, or (3) Show a video of how to complete the entire task sequence. See Figure 3.

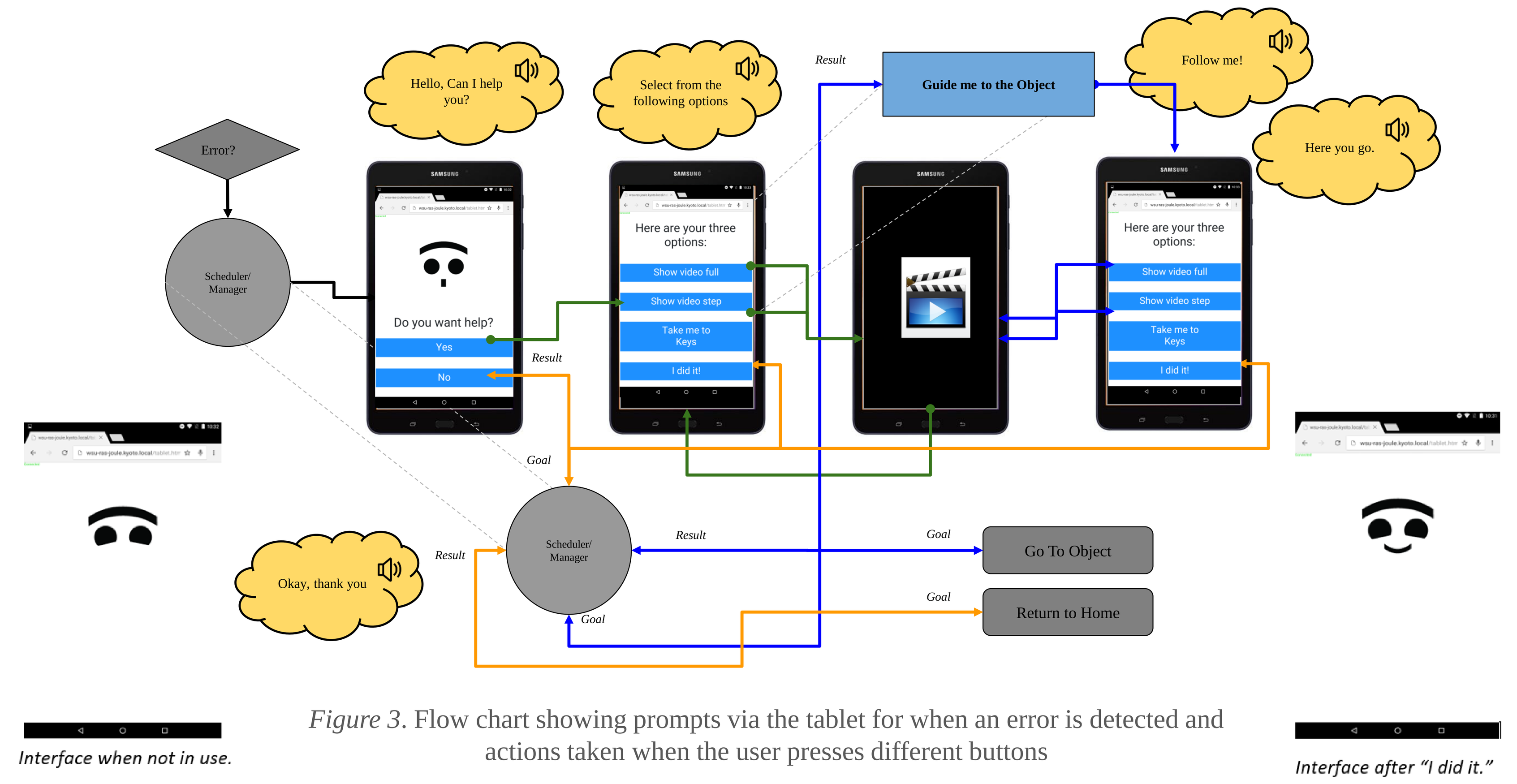

Figure 3. Flow chart showing prompts via the tablet for when an error is detected and actions taken when the user presses different buttons

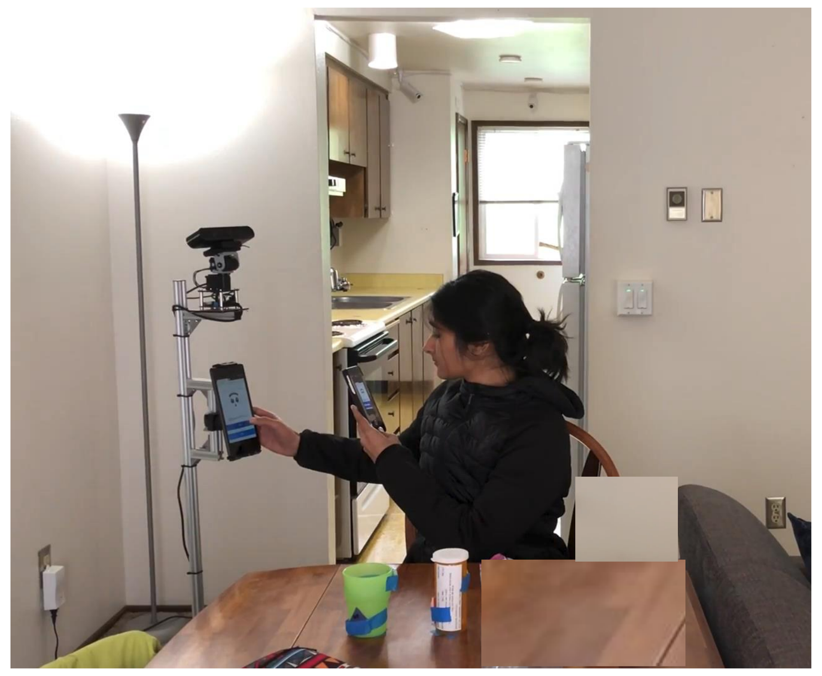

Figure 4. Human-robot interaction after a mistake was made during the take medication task.

Figure 5. Cartographer map of the smart apartment, green dots show current lidar scan, the green rectangle represents the robot footprint

Precision by Class	Faster R-CNN	R-FCN	SSD Inception	SSD MobileNet
Food	0.96	0.97	0.94	0.90
Glass	1.00	1.00	1.00	1.00
Keys	0.90	1.00	1.00	1.00
Pill Bottle	0.96	0.97	0.87	0.89
Plant	0.99	0.96	0.99	0.97
Umbrella	0.98	1.00	0.96	0.97
Water Can	1.00	1.00	1.00	1.00
Human	0.47	0.46	0.43	0.34

Figure 6. Smoothed average precision @ 0.5 IoU on testing set of all the classes for each of the 4 TensorFlow-trained object detection networks

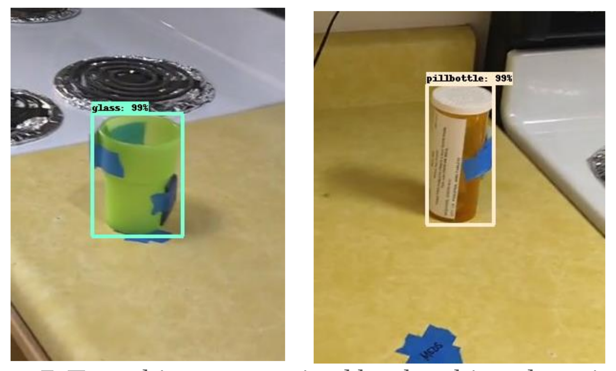

Figure 7. Two objects recognized by the object detection and the predicted bounding boxes from the CNN, showing the Estimotes mounted on the sides of each object

Conclusions and Future Work

<u>Participant Feedback (Qualitative)</u>

Regarding Prompts…	SHOW OBJECT	NEXT STEP VIDEO	ENTIRE TASK VIDEO
BEST LIKED	X	XX	
MOST HELPFUL	XX	X	
LEAST EFFECTIVE		X	XX

Prompt Preference Feedback Survey

Regarding Interface…	STRONGLY DISAGREE			NEUTRAL			STRONGLY AGREE
LIKED USING IT					XX		X
THE ROBOT LOOKS FRIENDLY				X		X	X

Post-study System Usability Questionnaire

Regarding Movement…	STRONGLY DISAGREE		NEUTRAL		STRONGLY AGREE
WOULD SUCCESSFULLY GET MY ATTENTION		X		XX	
WOULD STARTLE ME		XX	X		

Robot Design (Movement) Feedback Survey

Regarding System…	0 = UNRELIABLE								9 = RELIABLE
SYSTEM RELIABILITY					X	XX			

Questionnaire for User Interface Satisfaction (QUIS)

Regarding System…	STRONGLY DISAGREE						STRONGLY AGREE
SYSTEM IS ACCURATE						XXX	

Subjective Assessment of Speech System Interfaces (SASSI)

Regarding Feasibility…	NO	MAYBE	YES
COMFORTABLE HAVING THIS ASSIST RELATIVE WITH ADLs		X *Depends on task/ how they're taught to use it	XX *CNA-approved
ASPECTS THAT MADE YOU UNEASY	XX		X *Not very friendly looking/looks elementary

Robot Design (Appearance and Comfort) Feedback Survey

<u>Robot Performance</u>

Successes:

- Robot intervened when an error (incorrect sequence of events) occurred
- Tablet responded when buttons were touched
- Played appropriate videos and spoke correct dialogue
- Moved according to driver's guidance

Failures:

- Estimote sensitivity lapsed in communication between CASAS network – delays in intervention initiation (lasting as long as 66 s)
- Tablet buttons lacked sensitivity – required multiple taps
- Robot intervened at incorrect times – when an error was not made (fixed with update)
- Robot approached too close for participant comfort at times (fixed with driver adjustment)
- Time lost in battery replacement and/or system reboot

<u>Future Work</u>

- Make robot fully autonomous
  - Attempted for Iteration 1 testing
- Hardware adjustments
  - Larger batteries, move computer to not trigger IR motion sensors
  - Increase stability
  - Robotic arm to facilitate pointing (toward objects or locations)
- Improve estimote sensitivity to address consequent delays in robot intervention
- Test with individuals with mild cognitive impairment (MCI)/AD

Acknowledgments

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References

[1] The Alzheimer's Association (2018). 2018 Alzheimer's Disease facts and figures. Retrieved from https://www.alz.org/facts/.