Robotic Activity Support (RAS)

A Cognitive Assistant for the Smart Home

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Introduction

The Problem:
- 50% of adults age 85+ require assistance with activities of daily living (ADLs)
- Cognitive impairment necessitates a robotic aid to offer automated assistance for completing ADLs with an elder-friendly user interface

The Goal:
- Design and build a robot to serve as a cognitive aid for ADLs
- Coordinate with our smart home for activity learning and step-by-step tracking

RAS (Robotic Activity Support)

Robot:
- Hardware: Turtlebot 3 (see Fig. 1)
  - 360° LiDAR, Astra RGBD camera on 4' mast
- Software: (see Fig. 2)
  - ROS Components connected by manager node
  - RabbitMQ to communicate with CASAS smart home

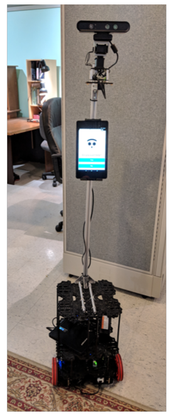


Fig. 1. RAS hardware.

Navigation:
- Cartographer for SLAM
- Dijkstra's for fast interpolated navigation
- Linearization of paths for complex environments

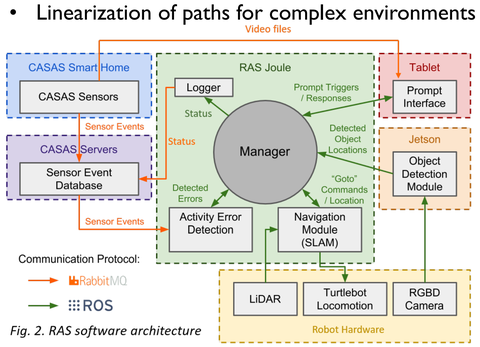


Fig. 2. RAS software architecture

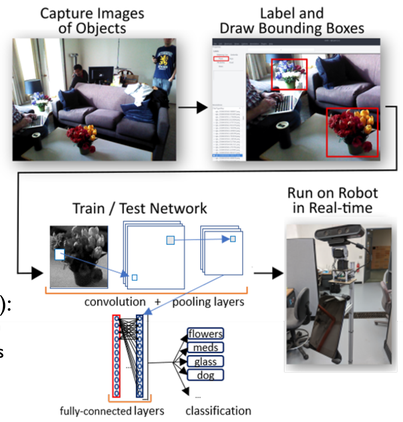


Fig. 3. RAS object detection.

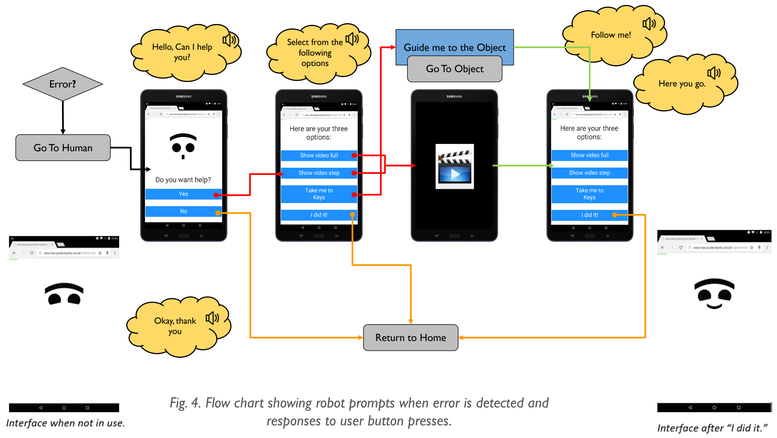
Object Detection (see Fig. 3)**:**
- Convolutional Neural Network (CNN):
  - 20k human images from Microsoft COCO
  - 2.5k images of smart home-specific objects
  - Recognize 9 objects (precision=0.99)
  - Recognize humans (precision=0.46)

Error Detection:
- Track activity steps using activity recognition
- Use smart home sensors (see Fig.5 and Fig. 6) to detect errors of *omission*

Robot Activity Assistance: On-campus Testbed

Participants:
- 54 participants (27 younger adults, 27 older adults)

Procedures:
- Participants complete three representative ADL scenarios, interacting with robot prompts:
  - **Tasks:** (1) Prepare to walk the dog, (2) Take medication with food and water, (3) Water plants
  - **Error Conditions:** Complete once without error, three times with different omission errors
  - **Prompts:** Robot navigates to participant and prompts upon error detection (see Figure 4)
  - **Participant Response:** Accept help with one of three options: (1) Lead to task-relevant object, (2) Show video of how to complete missing step, (3) Show video of how to complete entire task
  - **Finish:** Participant fixed their error and completed the rest of the task



Interface when not in use. *Fig. 4. Flow chart showing robot prompts when error is detected and responses to user button presses.* *Interface after "I did it."*

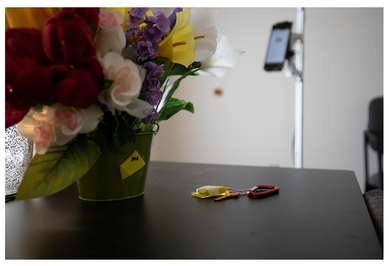


Fig. 5. Estimote sensors are attached to objects such as house keys and a flower pot.

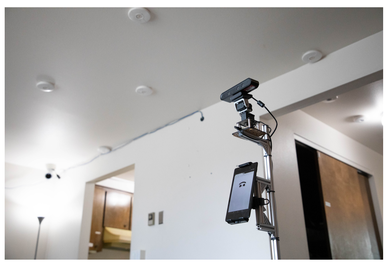


Fig. 6. Passive infrared motion sensors are installed on ceilings of the smart homes.

Error type	Total
FP	0.008
FN	0.005
Object detection	0.000
Human detection	0.088
Navigation	0.054
Interface	0.021
System	0.029
Experimenter assistance	0.455

Fig. 7. RAS error rates for activity error detection, human/object detection, navigation, interface, and overall system, along with amount of needed experimenter assistance of any type. Activity errors were detected with sensitivity=0.955 and specificity=0.992.

PSSUQ	Younger adults (n=27)	Older adults (n=17)
Overall	4.55 (1.95)	4.38 (1.92)
System usefulness	4.37 (1.89)	4.22 (2.07)
Interface quality	4.83 (1.94)	5.06 (1.70)
Information quality	4.66 (2.23)	5.50 (1.72)

*Fig. 8. Participant feedback scores (average and standard deviation) on the usability of RAS for activity support using the Post-Study System Usability Questionnaire (PSSUQ). PSSUQ uses Likert ratings, where 1=strongly agree and 7=strongly disagree. (**Lower** number=stronger agreement.)*

Robot Activity Assistance: In-home

Participants:
- RAS provided support for 3-4 days in two smart homes
- One home housed younger adult
- Second home housed older adult couple

Procedures:
- Participants performed specific routine activities of their choice at least 2 times/day
- Injected one omission error for each activity 1 time / day
- Robot intervened when error was detected (see Fig. 10 and Fig. 11)

Question / Scale	Home 1	Home 2
Ease of completing activity	6.83	4.38
Mistake caught in time to fix	4.00	6.00
Robot offers enough support for day-to-day activities	6.13	4.67
Satisfied with robot and its help	5.58	3.50
I was able to complete the activities using RAS	6.00	7.00
I felt comfortable using this system	6.00	7.00

*Fig. 9. Survey responses for in-home study. Feedback uses scale 1 (extremely dissatisfied) – 7 (extremely satisfied). (**Higher** number=more satisfied.)*

Fig. 10. The tablet offers four responses: "Show full video", "show video of skipped step", "take me to needed object", and "I did it!"

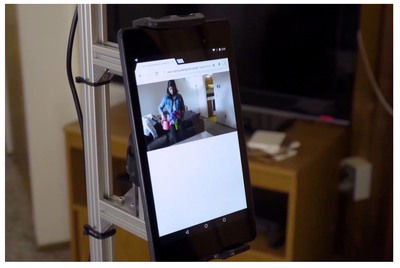


Fig. 11. If a video is requested, then it is played on the tablet. If the object is needed, RAS guides the person to the object.

Successes:
- Robot intervened when errors occurred
- Overall participant impressions favorable
- Next-step video found to be helpful

Challenges:
- Human detection accuracy low (false positives)
- Delayed network communication and slow robot movement (assistance may be too late)
- Sensor firings (misfired sensors lead to missed errors)

Future Work

- Improve object detection (track humans with smart home sensors and update object locations when moved)
- Improve error detection:
  - Quicker detection speed
  - Detect more activity types and multiple simultaneous errors
- Evaluate system in real-world scenarios
  - Test in users' homes for multiple days with non-scripted activities
- Develop self-docking system to allow long-term usage