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

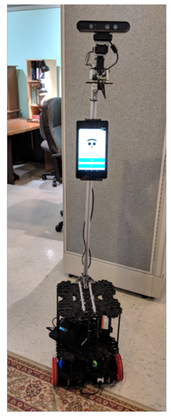


Fig. 1. RAS hardware.

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

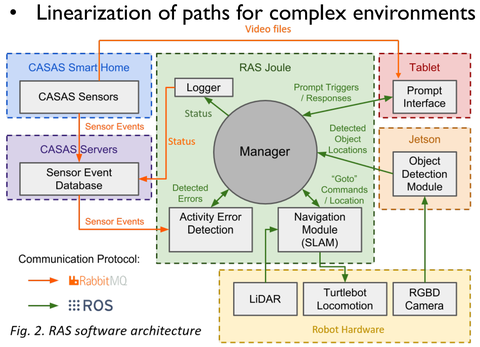


Fig. 2. RAS software architecture

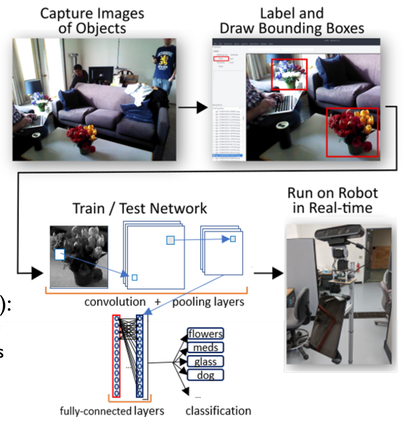


Fig. 3. RAS object detection.

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)

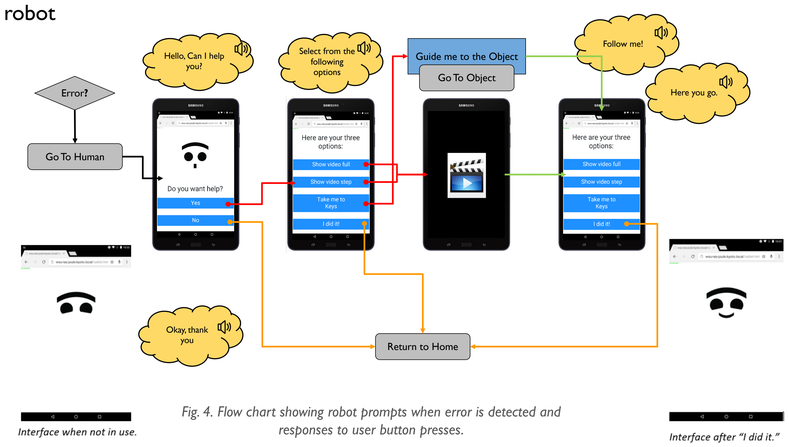
Error Detection:
- Track activity steps using activity recognition
- Use smart home sensors (see Fig. 5 and Fig. 6) to detect errors of *omission*

Robot Activity Assistance: On-campus Testbed

Objective:
- Evaluate opinions of younger and older adults regarding design and performance of RAS

Participants:
- 52 participants; 26 younger adults (ages 18-29), 26 older adults (ages 52-87)

Procedures:
- Participants complete three representative ADL scenarios with the RAS system: (1) Prepare to walk the dog, (2) Take medication with food and water, (3) Water plants
- Participants made task errors to cue the robot to offer help in one of three modalities: (1) guide to object (2) video of forgotten step, and (3) video of full task
- Participants then completed questionnaires to report opinions of and satisfaction with the robot



Interface when not in use. *Interface after "I did it."*

Fig. 4. Flow chart showing robot prompts when error is detected and responses to user button presses.

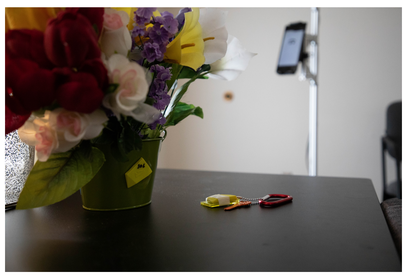


Fig. 5. Estimote sensors are attached to objects such as house keys and a flowerpot.

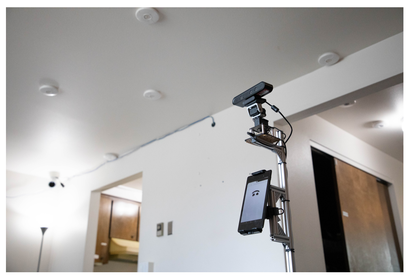


Fig. 6. Passive infrared motion sensors are installed on ceilings of the smart homes.

SASSI	Younger adults (n=24)	Older adults (n=26)
System Response Accuracy	4.93 (1.24)	4.23 (0/25)
Likeability	5.45 (1.29)	5.16 (0.24)
Cognitive Demand	5.72 (0.85)	5.23 (0.18)
Annoyance	4.19 (1.18)	4.12 (0.16)
Habitability	4.95 (1.03)	4.97 (0.16)
Speed	3.19 (1.77)	3.02 (0.24)

Fig. 7. Participant feedback scores (average and standard deviation) on the usability of RAS for activity support using the Subjective Assessment of Speech System Interface subscale scores uses Likert ratings, where 1=strongly disagree and 7=strongly agree.

Results:
- There were minimal differences in younger and older adults' perceptions of RAS system (Fig. 7)
- Both groups rated full video of task prompt as least effective, helpful and liked
- Participants recommended robotic system's accuracy, movement speed, alerting system and system flexibility be improved
- Younger adults (M = 3.59) overestimated how much older adults (M = 2.59) would like the robot, $t(47) = -3.26$, $p = .002$, on 1-5 scale

Conclusion:
- This underscores importance of testing technology with target population

Raghunath, N. et al. (2020). A Robotic Assistive Support (RAS) system for persons with memory impairment: comparing older and younger adults' perceptions of the system. *Gerontechnology, 19(3),* 1-11.

Robot Activity Assistance: In-home

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

Procedures:
- Participants performed activities of their choice
- Injected one omission error for each activity 1 time / day; survey data collected (Fig. 8)
- Robot intervened when error was detected (see Fig. 9 and Fig. 10)

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. 8. Survey responses for in-home study. Feedback uses scale 1 (extremely dissatisfied) – 7 (extremely satisfied).

Fig. 9. The tablet offers four responses: "Show full video", "show video of skipped step", "take me to needed object", and "I did it!"

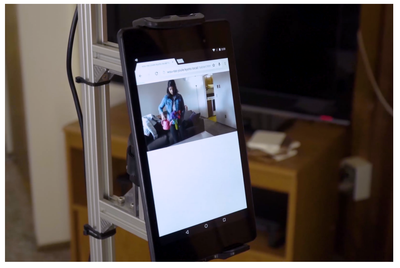


Fig. 10. If a video is requested, then it is played on the tablet. If the object is needed, RAS guides the person to the object.

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)

Pereyda, C. et al. (2020). Cyber-physical support of daily activities: A robot/smart home partnership. *ACM Transactions on Cyber-Physical Systems*, 4, No.21, 1-24.

Future Work

- Improve object detection (track humans in home and update object locations)
- 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