Performance Evaluation Methods for Assistive Mobile Manipulation and Human-Robot Interaction

Georgia Institute of Technology, Healthcare Robotics Laboratory
Tiffany L. Chen and Charles C. Kemp
http://healthcare-robotics.com

Introduction

There are an estimated 10.8 million Americans who need assistance with activities of daily living [1]. There is also a documented shortage of nurses [2]. These factors contribute to the potential benefit of mobile manipulators that provide assistance with activities of daily living as well as assistance with performing nursing tasks.

Evaluation of such robotic systems require metrics not only for the robustness of the technology itself, but also for the entire human-machine system, involving the target user. In this poster, we present several evaluation methods developed in the Healthcare Robotics Lab.

Guidelines for Evaluation

1. *Success*
   Clearly define what "success" and "failure" are.
2. *Real-world*
   Test with real-world objects and within conditions representative of real-world environments.
3. *Robustness*
   Test performance over repeated trials over varying conditions.
4. *Human-Robot Interaction*
   Test with end-users.

A Prioritized List of Objects

- Object type is an important factor when evaluating the performance of assistive robots that manipulate objects.
- We asked 25 patients with Amyotrophic lateral sclerosis (ALS) to rate a list of objects using a Likert scale according to importance for robotic retrieval
- We have used this prioritized list of 43 objects to assess the performance of mobile manipulators in several publications from this lab [3]

Fig. 1

RFID-Guided Robots

- System:
  - Videre Design mobile base, Katana arm, Festo vertical linear actuator
  - Methods that use two actuated far-field RFID antennas to detect and navigate to tagged objects
- Experimental setup (Fig. 2):
  - 37 objects on shelf, 36 locations in front of shelf
- Success:
  - Correctly read RFID of a tagged object, robot stopped <1m away from tagged object
- Evaluation:
  - Read an average of 23.75 tags per location, Approached object from 32/36 (88.9%) locations

Fig. 2

Fig. 3

Point and Click Interface

- System:
  - Off-the-shelf laser pointer, ear-mounted laser pointer (Fig. 5), and touch screen interface (Fig. 4)
- Success:
  - User selects object and robot drives over and picks it up
- Evaluation:
  - 8 ALS patients
  - 3 objects, 2 locations, 2x
  - 94.8% success (134 trials)
  - Selection was 69% faster with laser pointer interfaces
  - 5 preferred laser pointers, 3 preferred touch screen

Fig. 4

Fig. 5

Object Fetching and Delivery

- Experimental setup:
  - Robot delivered objects to the patient's hand (direct delivery, Fig. 6) and to a table (indirect delivery)
  - 3 objects, 3 starting positions, 3 times (134 trials)
- Success:
  - User grabbed the object from the robot or surface
  - User rested the object in his lap
- Evaluation:
  - 8 patients with ALS
  - 78% success, direct delivery
  - 97% success, indirect delivery
  - 4 preferred direct delivery, 4 preferred indirect delivery [5]

Fig. 6

Opening Doors and Drawers

Opening doors and drawers may enable a robot to move within a human environment or retrieve objects.

- System:
  - Segway RMP 50 omni-directional base, MEKA A1 compliant arms, Festo vertical linear actuator, ATIMini40 6-axisforce/torque sensors
  - User provides location and orientation of handle
  - Robot autonomously approaches and opens doors and drawers
- Success:
  - Doors opened >60 degrees (Fig. 7)
  - Drawers opened >30cm (Fig. 8)
- Evaluation:
  - 7 doors, 3 drawers, 4 starting positions (40 trials)
  - 26/28 (92.3%) success for door opening
  - 11/12 (91.7%) success for drawer opening [6]

Fig. 7

Fig. 8

Leading a Robot by the Hand

- System:
  - *Direct Physical Interface* (DPI): move the robot's base by grabbing the robot's arms (Fig. 9)
  - *Gamepad Interface*: move the robot's base using a gamepad controller (Fig. 10)
- Experimental setup:
  - Obstacle course to simulate hospital hall (Fig. 9)
  - Simulated patient room with bed (Fig. 10)
- Success:
  - Complete obstacle course; position hands over bed
- Evaluation:
  - 18 nurses from metro Atlanta
  - 2 interfaces, 2 tasks, 2 directions (144 trials)
  - DPI significantly outperformed gamepad according to NASA TLX (workload), time to complete task, and number of collisions
  - 88.3% preferred DPI, 16.7% preferred gamepad [7]

Fig. 9

Fig. 10

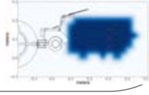
Robustly grabbing objects from the floor

- System:
  - iRobot create, end effector with a compliant finger, thin plane of metal resembling a dustpan (Fig. 11)
  - Robot drives up to the object and slides the plane of metal underneath, compliant finger sweeps the object onto the plane, lifts object from the floor
- Success:
  - Object is grasped in end effector and lifted up
- Evaluation:
  - 4 floor types, 34 objects, 5 poses (680 trials) with 94.71% success rate
  - Spatial variation: 2 objects tested on wooden floor at 3cm grid spacing (416 trials) (Figs. 12, 13) [8]

Fig. 11

Fig. 12 Small object

Fig. 13 Large object



Towards Robotic Bed Baths

- System:
  - MEKA A1 compliant arms, force/torque sensors
  - Operator selects area on person's limb for robot to clean
  - Robot rubs a wet bath mitt across the selected area to clean off debris on limb segment
- Success:
  - Remove debris from subject's limb segment
- Evaluation (Fig. 14):
  - 1 subject
  - Robot cleaned 4 segments of subject's limbs
  - Dirty pixels left in image after robot cleaned: 3.05% on upper arm, 0.0 % on forearm, 0.0% on thigh, and 2.08% on shank [8]

Fig. 14 Robot (a) wiping to left (b) to right (c) to left (d) completed

Discussion

The development of semi-autonomous robotic systems to assist people in human environments can benefit from rigorous testing in real-world scenarios. Using the guidelines for evaluation discussed in this collection of work may provide more structure when developing robots to interact with people within human environments.

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