Toward Physical Navigation Assistance with a Dynamically Stable Mobile Robot

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Funded by Google Faculty Research Award *

Motivation

- Elderly population in US alone will nearly double to 83.7 million between 2012 and 2050 [1]
- Impaired vision and mobility will affect quality of life
- Global shortage of health-care workers expected to rise from 7.2 million in 2013 to 12.9 million in 2035 [2]

Objective: Develop a robot that can guide and provide physical support in the navigation of a home or building

- Develop a state machine for learning locations and navigating to and from said locations
- Implement voice control of state machine to aid in gentle "forceful" interaction

Robot Platform Selection

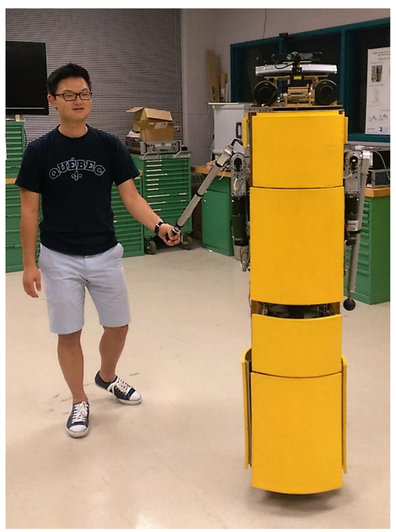
In 2004, Microdynamic Systems Laboratory invented a novel class of robots that can balance dynamically and move using a single ball at its base

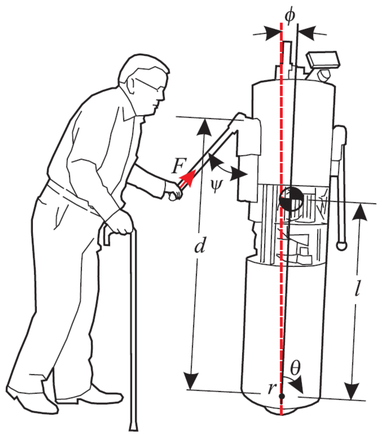
Dynamic stability provides the following benefits

- Slender form factor can navigate cluttered environments
- Weight and size can provide > 120 N of force [3]
- Eye level interaction
- Intrinsic compliance for gentle interaction (ballbot can be moved with 3 N of force from a single finger)

Onboard hardware for perception and interaction

- Asus Xtion 3D camera
- Acoustic Magic array microphone
- JBL stereo speakers
- Series-elastic arms
- Inverse mouse-ball driving mechanism





Left: Envisioned interaction between ballbot and human in navigation assistance task
Right: Schematic detailing how supportive forces are generated and applied in navigation assistance task

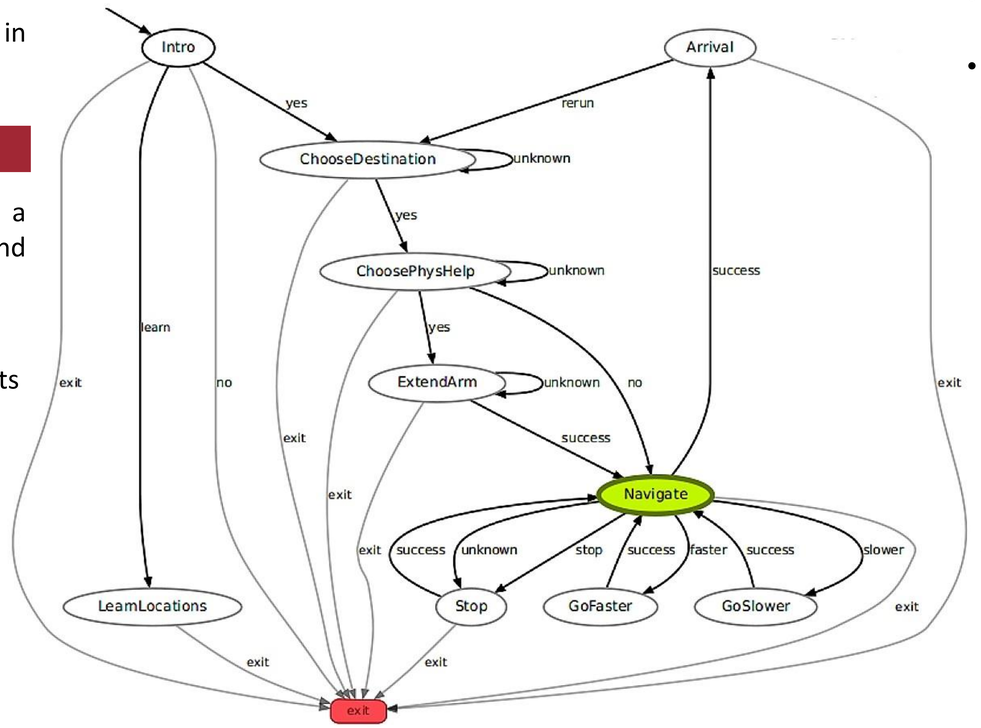
State Machine and Voice Control Implementation Details

Hierarchical state machine

- Platform: ROS SMACH, a library for task-level execution where all possible states and transitions are explicitly defined
  - Introspection into current state, variables, and overall state architecture via smach viewer package (see figure below)

Text to speech voice synthesis

- Platform: Cepstral
  - High quality, small memory footprint, low cost



Voice activity detection

- Platform: WebRTC
  - Uses a Gaussian Mixture Model that is typically more effective than simple energy-threshold detector in noisy environments
  - Filters blank audio clips from being processed for speech

Speech to text recognition

- Platform: Google Speech API
  - Powered by neural network models whose accuracy improves with usage
  - Robust to noise

Algorithm 1 General execution of state machine

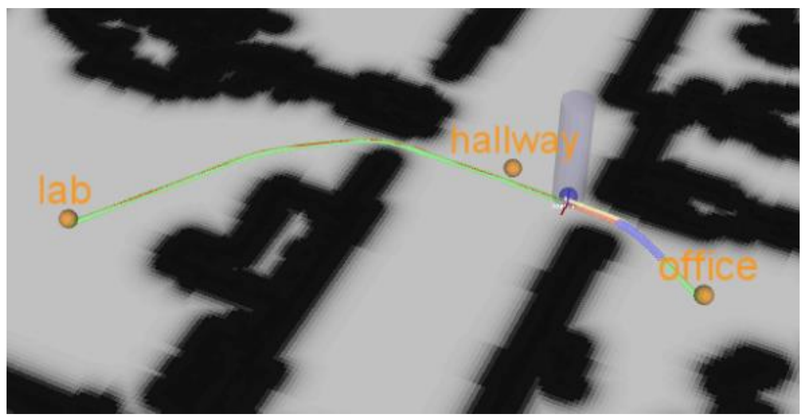
```
arrive at state X
verbalize state X's prompt using Cepstral

Thread 1:
execute state X's actions

Thread 2:
while speech is not detected by WebRTC do
    record audio until certain period of silence has passed
send audio clip to Google Speech
interpret recognized phrase with keyword matching
select corresponding transition out of state X
```

Left: State machine developed for navigation assistance task

Right: Algorithm for general execution of a state

Simulation Environment

Developed in ROS rviz to verify functionality of state machine, speech capabilities, and navigation in pre-mapped environment



Simulation environment for navigation assistance task in premapped environment of first floor of Smith Hall at CMU (orange markers: learned locations, blue cylinder: ballbot)

Future Work

Planned navigation assistance HRI studies [4]

- Study 1: With able-bodied people
  - IRB for this study has been approved
- Study 2: With people temporarily handicapped first by a leg splint with an optional cane, then by a blindfold
- Structure of studies
  - Subject voices desired location using limited lexicon and is led to said location (by hand if desired)
  - Ballbot can vary speed and stop upon request
  - Ballbot state variables, speech, and video will be recorded

References

[1] Ortman, Jennifer M., Victoria A. Velkoff, and Howard Hogan. *An Aging Nation: The Older Population in the United States*. Rep. N.p.: United States Census Bureau, 2014. Print.
[2] World Health Organization, and Global Health Workforce Alliance. *A Universal Truth: No Health Without a Workforce*. Rep. N.p.: n.p., 2013. Print. Third Global Forum on Human Resources for Health Report.
[3] Shomin, Michael, Jodi Forlizzi, and Ralph Hollis. "Sit-to-stand assistance with a balancing mobile robot." *2015 IEEE International Conference on Robotics and Automation (ICRA)*. IEEE, 2015.
[4] Hollis, Ralph. *Physical Navigation Assistance with a Dynamically Stable Mobile Robot*