SmartWheeler: A robotic wheelchair test-bed for investigating new models of human-robot interaction

McGill University SmartWheeler team

Jeremy Cooperstock, Joelle Pineau, Doina Precup, **Amin Atrash**, Robin Jaulmes, Robert Kaplow, Nan Lin, Chris Prahacs, Julien Villemure, Hiba Yamani

http://www.cs.mcgill.ca/~smartwheeler

IROS 2007

October 29, 2007

Outline

- Project Motivation
- Hardware
- Current Research

Project Motivation

- Long-term aim: To reduce physical and cognitive workload to operate wheelchair for individuals with mobility impairments.
- Technical aim: To serve as a test-bed for novel AI methods and robotics research
  - Robust control of intelligent wheelchair
  - Design of interface between user and wheelchair

Project collaborators

- Universities
  - McGill University, Univ. de Montréal
  - Contribution: technical development, system integration, prototype validation.
- Rehabilitation centers
  - Contribution: problem definition, interaction with target population, collaboration for validation.
- Industry partners
  - Wheelchair and robotic manufacturers
  - Contribution: hardware platform, funding.

Target Population

- People suffering from mobility impairments
  - Spinal cord injuries
  - Multiple sclerosis
- Choose population based on abilities, not pathologies
  - Why? Convenient to assess with well-established metrics.
  - E.g. Wheelchair users who exhibit steering and maneuvering difficulty on a standardized test.

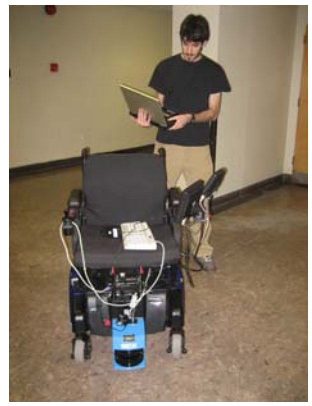
October 29, 2007 IROS 2007 McGill

Robot Platform

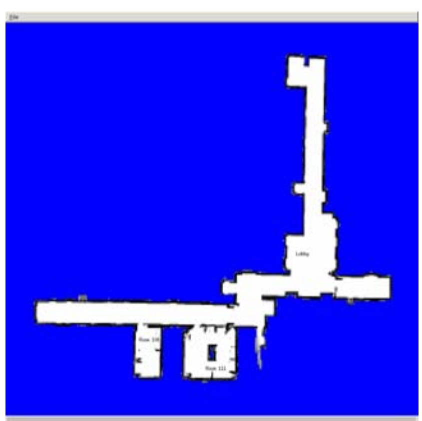
- Sunrise Quickie Freestyle electric wheelchair
- Navigation
  - Front and rear SICK laser range-finders
  - Wheel encoders for odometry
- Interface
  - Touch-sensitive graphical display
  - Voice interface
  - Joystick
- Onboard computer (linux, wireless interface)
- CARMEN robot navigation toolkit

October 29, 2007 IROS 2007 McGill

Robot Platform



Mapping



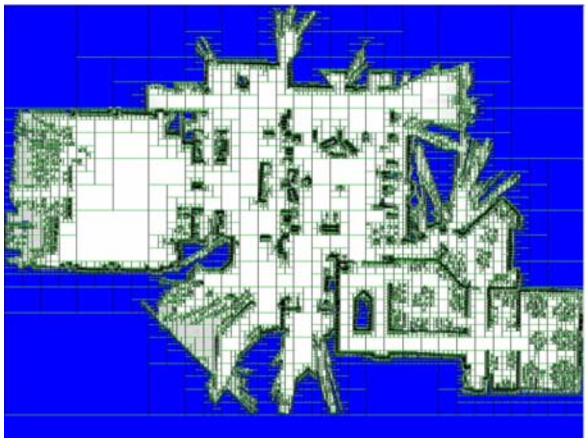
Ongoing research projects

1. Adaptive planning in large-scale environments
2. Learning and control under model uncertainty
3. Large-scale dialogue management
4. High-level goal specification

Adaptive Planning in Large Scale Environments

- Technical challenge:
  - Robust localization and path planning can be done using POMDPs.
  - Regular discretization of maps yields very large POMDPs.
- Insight:
  - Combine POMDPs with variable cell decomposition (Quadtree) for efficient map representation.
  - Estimate model parameters using sampled traces.
  - Compute optimal path using POMDP methods.
  - During execution, maintain probability distribution over location.

Adaptive Planning in Large Scale Environments



- Get 400-fold reduction in computation (compared to full resolution)
- Trade-off computation vs performance by selecting desired resolution near obstacles.
- Currently able to solve larger problems.

Learning and control under model uncertainty

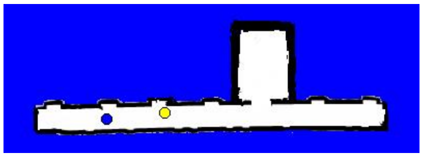
- Technical challenge:
  - Want to learn POMDP parameters during execution
- Insight:
  - Take a Bayesian approach.
  - Specify prior over model parameters.
  - Update distribution over model parameters using data traces.

Learning and control under model uncertainty

- MEDUSA algorithm
  - Maintain set of POMDPs sampled from Dirichlet distribution
  - Use models for decision making
  - Periodically request state information from “oracle”
  - Update Dirichlet hyper-parameters
  - Resample new POMDP

Learning and control under model uncertainty

- Successfully run on several POMDPs, including robot tag problem.



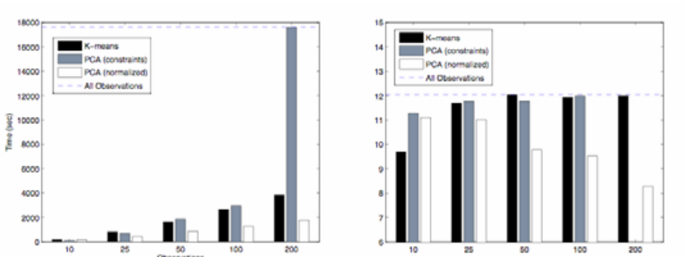
- Use heuristics or forward search to determine when to query “oracle”
- State oracle vs. policy oracle
- Capture user’s behavior through reward

Large-scale Dialogue Management

- Technical challenge:
  - Would like to model dialogue as POMDP to get robust dialogue system.
  - Dialogue yields large observation space.
- Insight:
  - Apply data summarization techniques (K-means, constrained PCA) to reduce observation matrix

Large-scale Dialogue Management

- Results:
  - Significant reduction in observation space (and therefore planning time).
  - Little or no impact on performance quality.

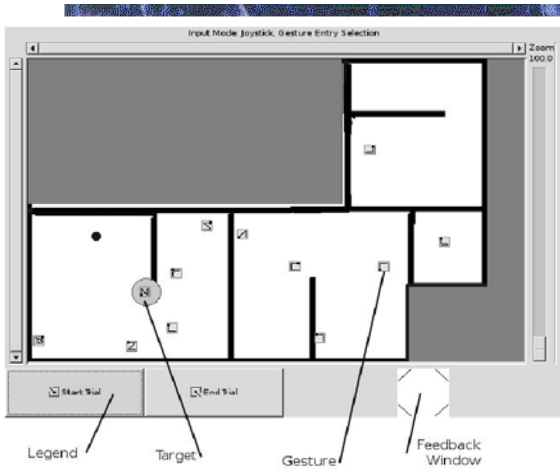


  - Extendable to general POMDP case.

High-level Goal Specification

- Technical challenge:
  - Target audience may lack fine motor control.
  - Need to develop input method to specify high-level navigation goal.
- Method:
  - Examine three candidate input methods
    - Direct map selection
    - Menu selection
    - EdgeWrite Gesture entry
  - Measure error rate and input time

High-level Goal Specification



- Results with control population:
  - Menu selection is fastest.
  - EdgeWrite is slowest.
- Experiments currently being planned for target population
  - Different results expected.

Ongoing Work

- Integration of navigation and communication capabilities
- Integrate large-scale dialogue commands with low-level navigation
- Translate free speech into core observations
- Train POMDP-based dialogue management system
- Integrate into framework for shared control (robot and user)

Standardizing the evaluation Process

- Development of wheelchair “obstacle course”
  - Standardized method for testing users’ capabilities with wheelchair
- Exists for manual wheelchairs
  - Curbs, wheelies, reaching objects, gravel, etc…
  - http://www.wheelchairskillsprogram.ca
- Design for electric wheelchairs
  - How well can an autonomous wheelchair perform?

Metrics

- Task Metrics
  - Record error rate, time to task completion
- Psycho-metrics
  - Use existing tools for measuring fatigue, attention, and workload

Acknowledgements

- Natural Sciences and Engineering Research Council (NSERC)
- Fonds Québécois de la Recherche sur la Nature et les Technologies (FQRT)
- Canada Foundation for Innovation
- Sunrise Medical Canada, Inc.