HERB: a Home Exploring Robotic Butler

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Motivation

"Our goal is to create a robotics system that can perform routine tasks within the home [...] quickly enough that the person who requested them is not frustrated."

- As population ages, demand for assistive agents grows
- Existing solutions (monkey helper, roomba, ...) are limited due to their non-antropomorphism.
- Recent advances in robotic research have made the prospect of a humanoid helper robot more likely than ever
- HERB is an attempt to tie it all together.

Assumptions and Goals

- HERB has to perform the following tasks:
  - Open and close fridge, door and cabinets
  - Grab and manipulate objects from cluttered space
  - Navigate around the room

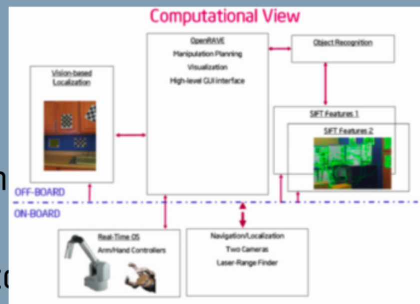
⇨ All of them have to be done quickly. For example, the entire decision making pipeline for object manipulation has to take less than 1 s by requirement.

- Several Asumptions are made:
  - The map of the kitchen is known
  - Computing powered is considered unlimited
  - Minimal to no human input is available

System Architecture: Hardware

- Segway base for navigation
- WAM arm: 4 DOF anthropomorphic arm with proprioception
- Barrett Hand: 3 fingers, 4 DOF hand
- SICK Laser Measurement Sensor: used for SLAM when navigating the space.
- Pointgray cameras for vision based localization and object recognition
- Logitech webcam for ellipse finding.
- 6 multi core computers, most of them offboard for computation

System Architecture: Software



- ROS for the communication management
- openCV checkboard detect
- SIFT feature detection for object recognition
- openRAVE ties it all together and plans the motion

Perception: Overview

- Several Cameras and a laser rangefinders are used to perceive the world
- The perception is broken down in three parts:
  - Segway Localization: uses the laser rangefinder and camera to estimate 2-d pose
  - Mapping of environment and large objects
  - Object recognition: uses SIFT, GATMO and Ellipse Finding to identify and estimate the pose of objects.

Localization

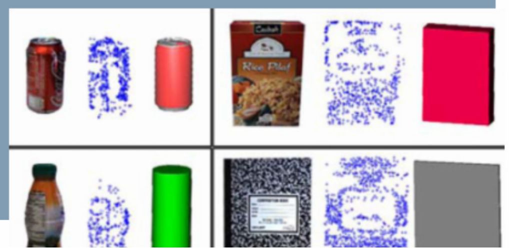
- The localization relies on a hardcoded model of the kitchen and a map generated by the LMS.
- Checkerboards are added to landmarks to make them more easily recognizable. 20+ checkerboards were necessary
- Monte Carlo localization is used for coarse localization during navigation
- Checkboards are used for finer control (~5mm error)

Mapping

- Although all the fixed landmarks are known, mapping is necessary because some obstacles are moving.
- A list of all known objects is kept. They are identified according to a hierarchy:
  - "persons" are objects that actively move. They are tracked with a Kalman filter
  - "chairs" are objects that seldom move. They are assumed to be static unless they are not found by the sensor, in which case the robot attempts to find the new location of the object.
- The algorithm used is called GATMO.

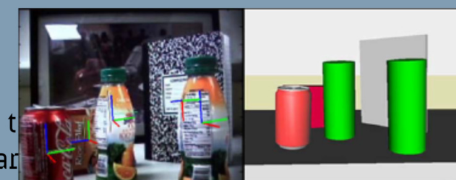
Object Recognition - 1

- Object Recognition relies on both the dragonfly camera with the SIFT algorithm and the webcam with ellipse finding
- For each object, a 3D model is built using local descriptors from several images



Object Recognition - 2

- When an "object clutter" is considered, the following steps are taken:
    - Features are clustered using a Mean Shift algorithm
    - Estimate the pose of each cluster
    - Merge all instances of each cluster whose estimated pose is similar
- Ellipse finder necessary to find t
  to make many assumptions regar

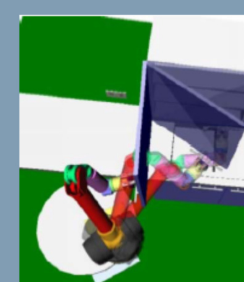


Planning: Overview

- The robot runs several planners to execute the different required tasks.
- The planners take as inputs the description of a robot and parts of the environment it should not collide with. They also take kinematics of the environments such as the presents of constraints (hinges, ...)
- No models of dynamics or friction are used.
- Kinematic uncertainty is addresed by jittering the plan and ensuring it is still kinematically feasible

Door Opening

- Opening doors is a greatly constrained action, which reduces the free configuration space greatly.
- HERB uses caging grasps. This means that the end effector does not have to be always rigidly attached to the handle, rather, it just needs to "cage" it.
- A set of all configurations of the arm and hand is computed offline to speed calculations
- Randomized A* is used to plan the actual path



Object Manipulation - 1

- Object manipulation refers to several tasks ranging from picking up a cup of coffee to put it in the sink to grabing an can from the counter among others and disposing of it.
- Main challenge is to exploit the wide range of possible poses while maintaining speed and efficiency.
- To handle loose task specification, the concept of workspace goal regions is introduced. WGRs are 6 dimensional poses. Multiple WGRs can be defined for a task.

Object Manipulation - 2

- The goal is not the only constraints: many objects cannot be moved arbitrarily
- A set of constraints is therefore added to the planning algorithm.
- A BiDirectional RRT is used to rapidly find the path that best reached the desired goal within the constraints

HERB in Action

Experiments and Results

- Many experiments were run both on independent modules and complete tasks.
- Checkerboard localization was found to be more precise but less "natural" than AMCL.
- Object pose estimation was precise within 0.67 cm and 3.81 deg
- The grapsing success rate was 91%
- The system ran on average at 4 fps for grasping
- Door and cabinet opening was much more challenging
- The Segway planner required a large goal zone, which sometimes led to further error in grasping
- Overall, the robot performed as expected, and managed to sustain day long demonstrations with little errors.

Lessons Learned

- Robots are not yet as useful as helper monkeys
- Most error could be traced to one of three things:
  - Inaccuracy in joints (~0.5 deg)
  - Localization errors
  - Segway positionning innacuracy
- One of the greatest challenge that remains unsolved, according to the authors, is recovery from unexpected collisions
- Ultimately, the authors hope that the robot will be able to maps the kitchen environment without relying on models.