A New Mobile Manipulation Platform for Automatic Coffee Retrieval

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Task

Deliver coffee
- Locate cup
- Obtain cup
- Fill with coffee using coffee machine
- Bring cup back to delivery area

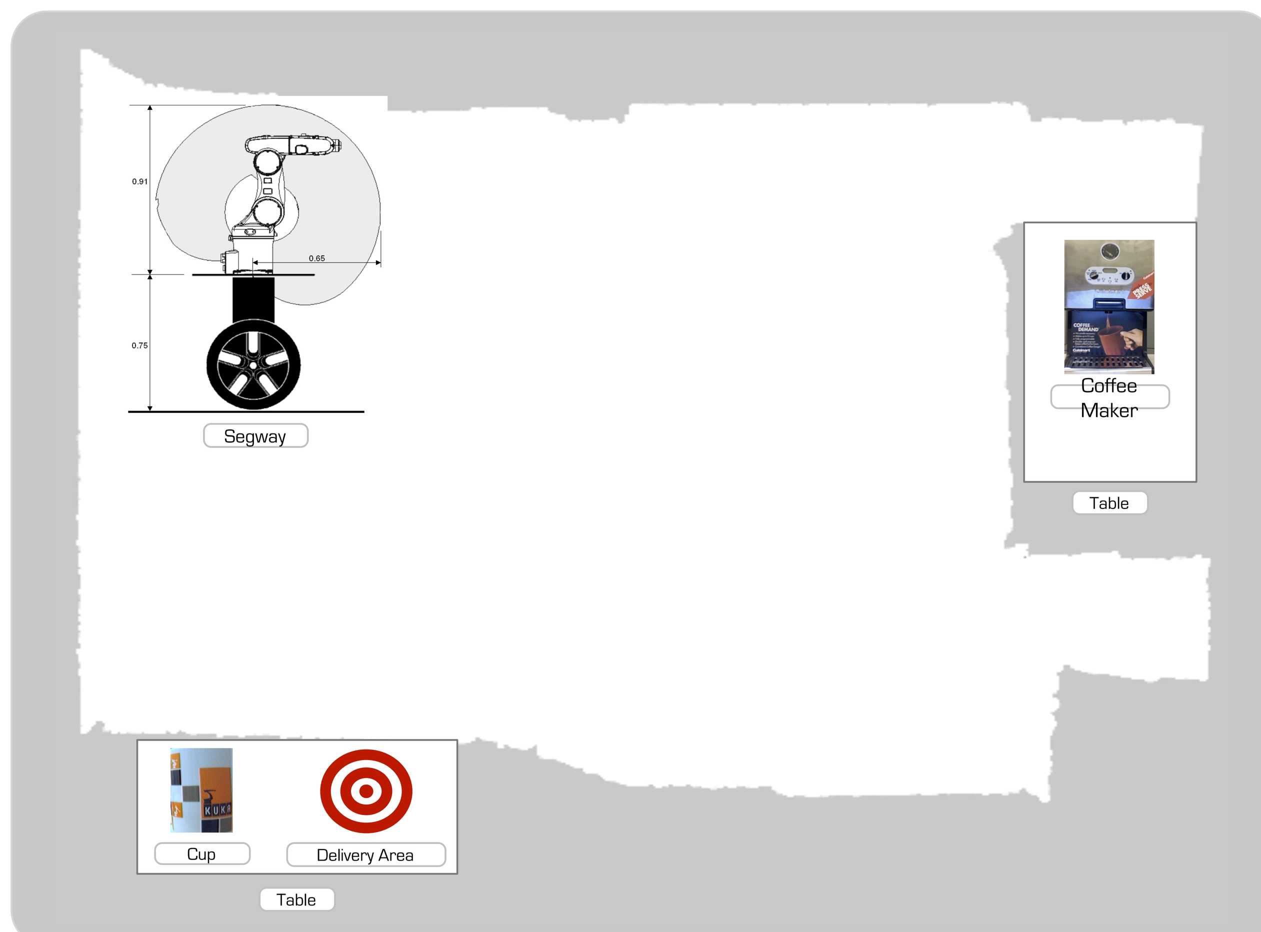
Assumptions

Map of environment

Approximate location & appearance model of cup and coffee maker

Setup

Segway RMP with KUKA KR5-Sixx Mounted



Map Made with SLAM

Results

* To reliably estimate pose, multiple estimates of the object of interest are necessary.

* For perceptual purposes, using a model that can account for variations caused by three dimensional movement was important to obtain an accurate pose estimate.

* Whole body manipulation was necessary for this task; incorporating both the Segway pose and KUKA arm configuration was essential.

* Specular reflections are problematic for many vision systems, so care must be taken to minimize their effects on templates and feature models.

* Students who used Microsoft Robotics Studio found that it's interprocess communication system helped speed development of this complex system.

Acknowledgements

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References

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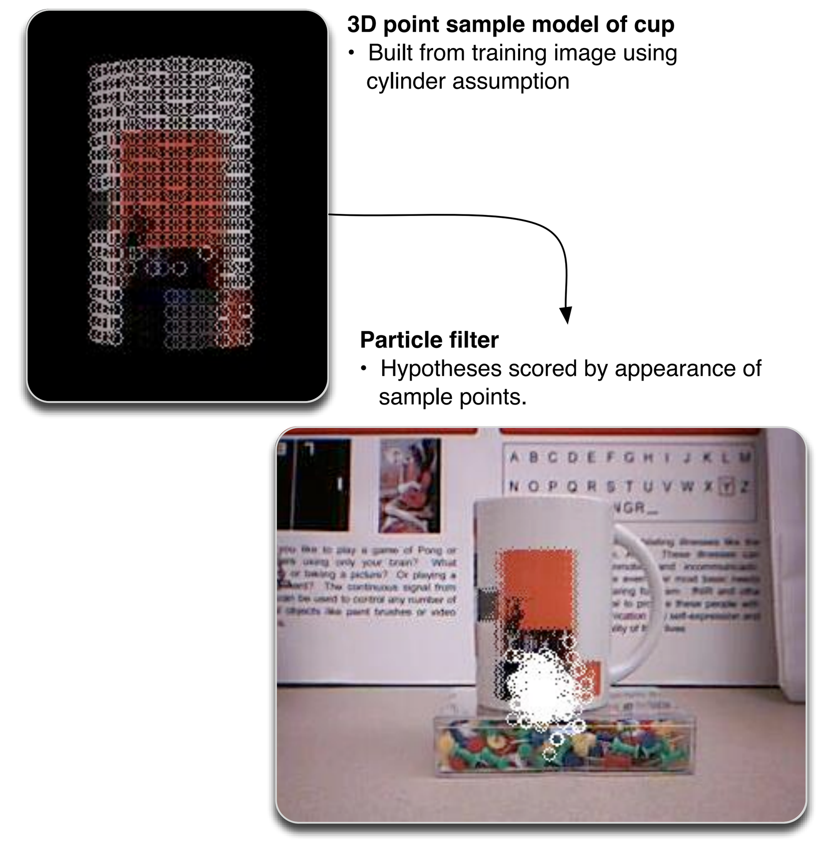
Team 1



System Integration
* Player/Stage
* C++ and Java, TCP/IP IPC

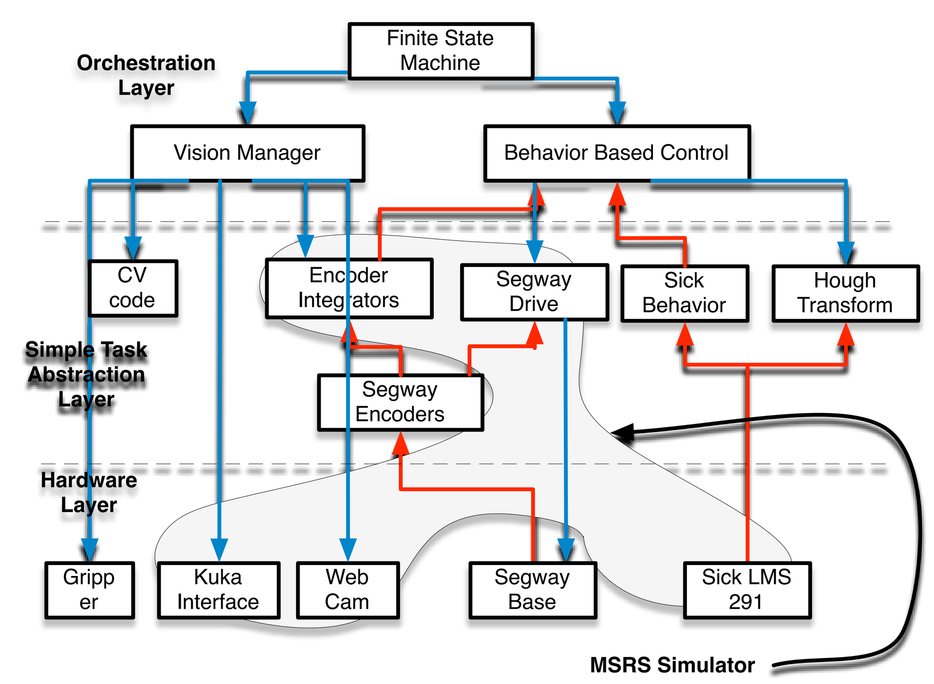
Vision
* Particle filter estimates 6-DOF pose by projecting a 3D model into the image
* Prior on object orientation included
* Motion model accounts for camera movements

Grasp Robustness
* Closed-loop control of end-effector position by moving the platform - corrects for changing tilt
* Closed-loop visual servoing
* Servo to a pre-chosen target position relative to the object, continues servoing until system is stable

Advantages
* 6-DOF pose estimation allowed end effector "points" to be set by measuring real distances
* Cascaded closed-loop controls resulted in very robust manipulation

Disadvantages
* Platform corrected for tilt to hold position instead of moving towards object, which resulted in large tilts when the object position was significantly different from what was expected. This made grasping difficult in this situation.

Team 2



System Architecture

System Integration
* Microsoft Robotics Studio
* Computer Vision code ported from Linux to unmanaged .NET, then wrapped to integrate with managed Robotic Studio services.

Perception
* Image segmentation using superpixels combined with edges.
* A representative combination of color blobs are used to locate object.
* Homography calculated using the corners and physical dimensions of the object

Error Prevention/Recovery
* Segway base is moved parallel to table to reduce lateral arm motion
* Multiple pose estimations of the object are made to continually refine grasp.

Advantages
* Nice distributed service architecture through MSRS.
* Robust grasping once target was found.

Failure Modes
* Coffee maker recognition not completed.
* Slow and flakey CV in windows environment.

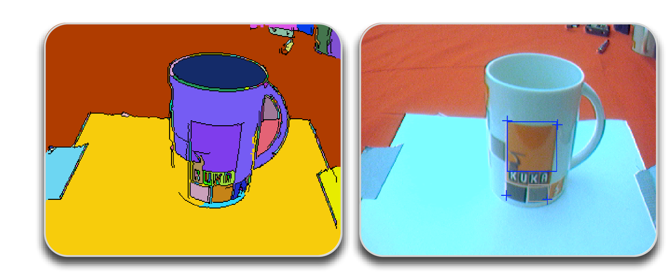
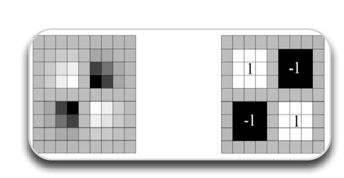


Image Segmentation and Homography Estimation

Team 3



SURF Features

Detected Features & Estimated Homography for Pose Estimation

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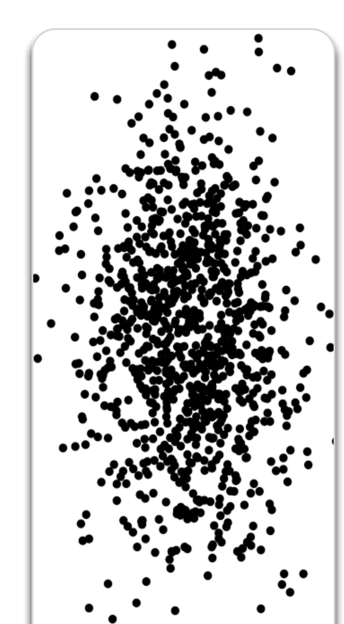

Particle Filter in Robot Centric Coordinates

System Integration
* Player/Stage
* OCAML/C++ processes over TCP/IP

Perception
* Homography calculated using SURF features, estimates tracked with particle filter in egocentric coordinates

Error Prevention/Recovery
* Waited for particle filter convergence before before attempting to grasp
* If cup is still detected after grasp attempt, robot retries the entire process

Advantages
* Easy to acquire object models as homography estimation is not significantly distracted by specular features.
* Able to detect & recover from grasp failures

Failure Modes
* Susceptible to low contrast images.
* Segway motion was not modeled when performing manipulation tasks, which introduced uncertainty