

# A New Mobile Manipulation Platform for Automatic Coffee Retrieval

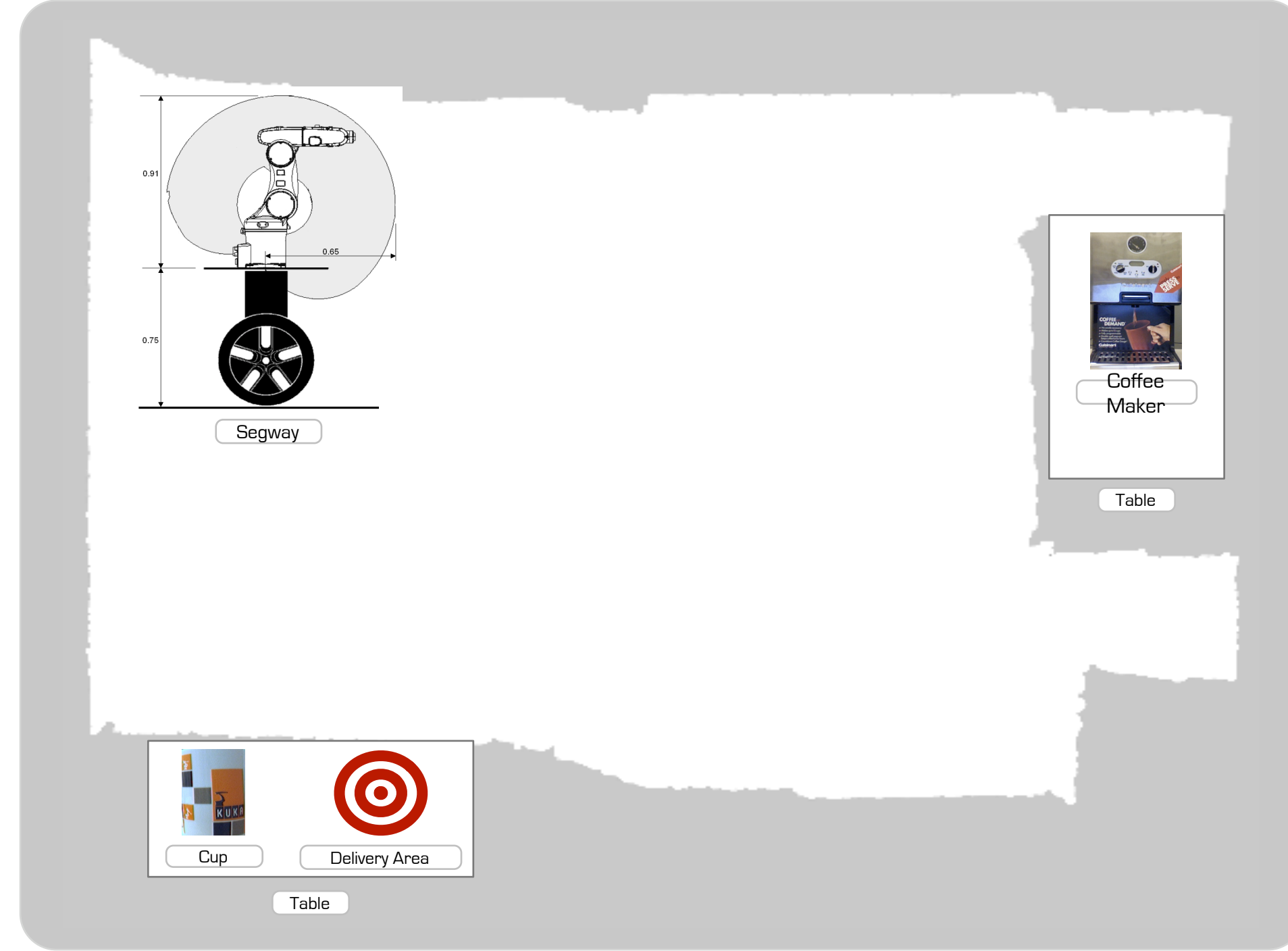
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- Task** Deliver coffee
- Locate cup
  - Obtain cup
  - Fill with coffee using coffee machine
  - Bring cup back to delivery area

## Setup



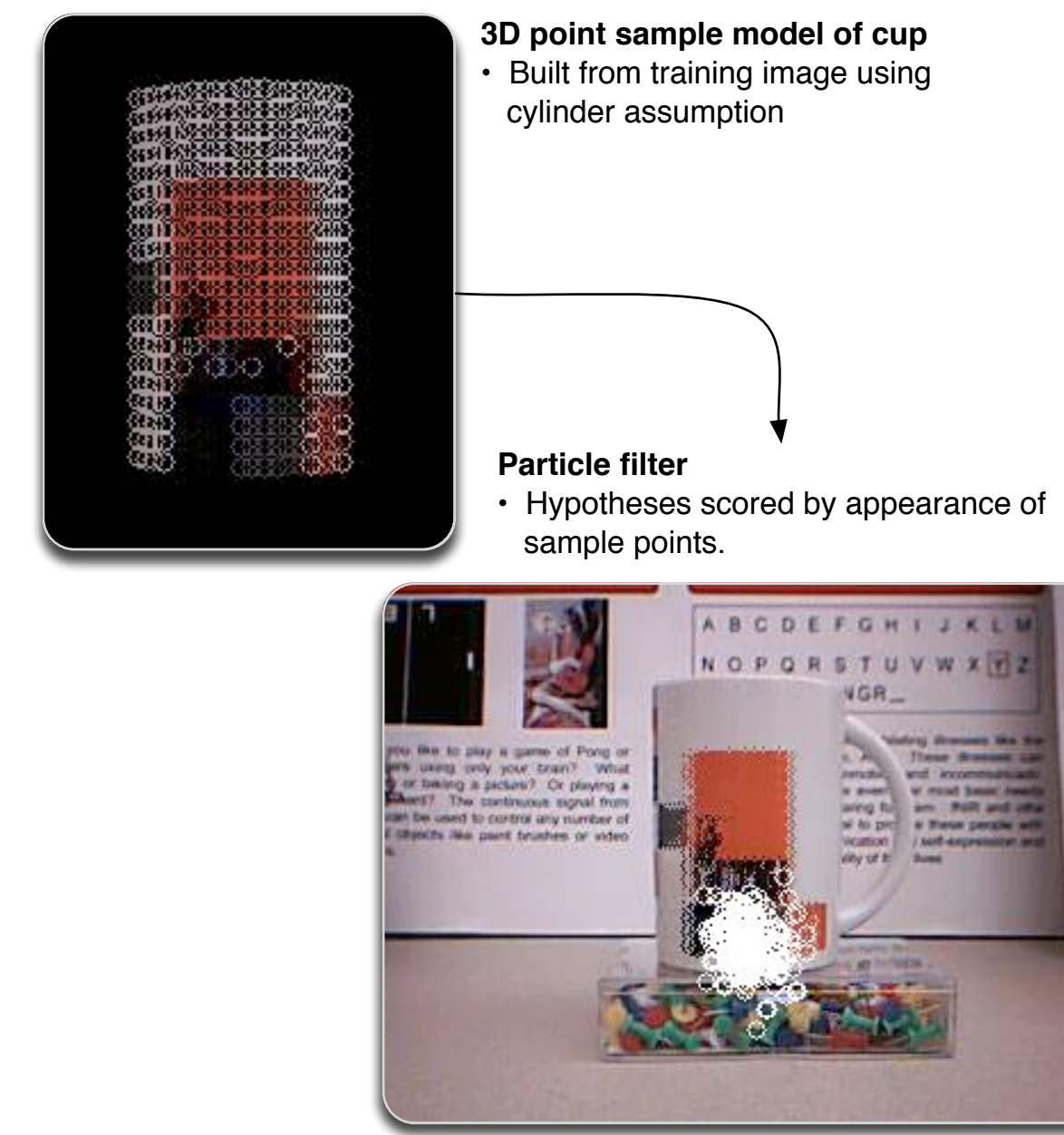
Segway RMP with KUKA KR5-Sixx Mounted



Map Made with SLAM

- Assumptions**
- Map of environment
  - Approximate location & appearance model of cup and coffee maker

## Team 1



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

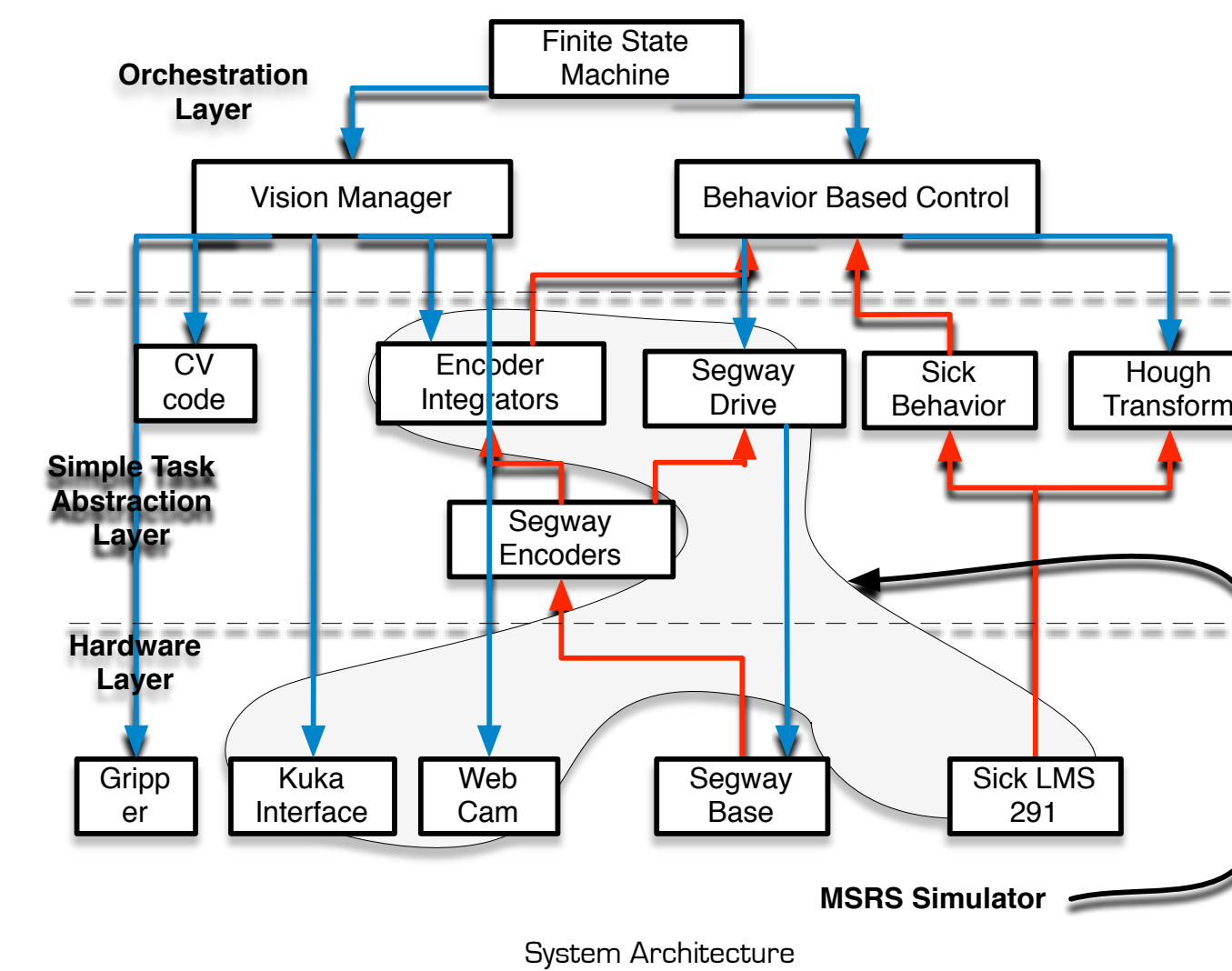
- Vision**
- \* Particle filter estimates 6-DOF pose by projecting a 3D model into the image
  - \* Prior on object orientation included
  - \* Motion model accounts for camera movements

- 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 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.

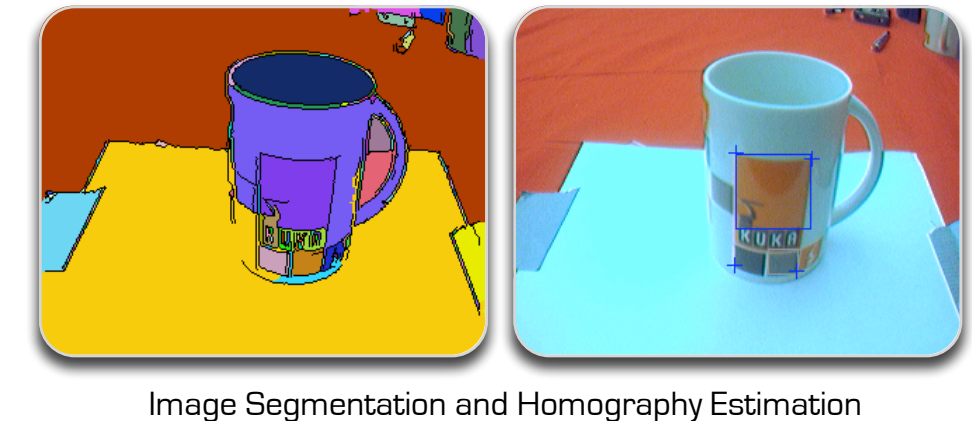


Image Segmentation and Homography Estimation

## 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.

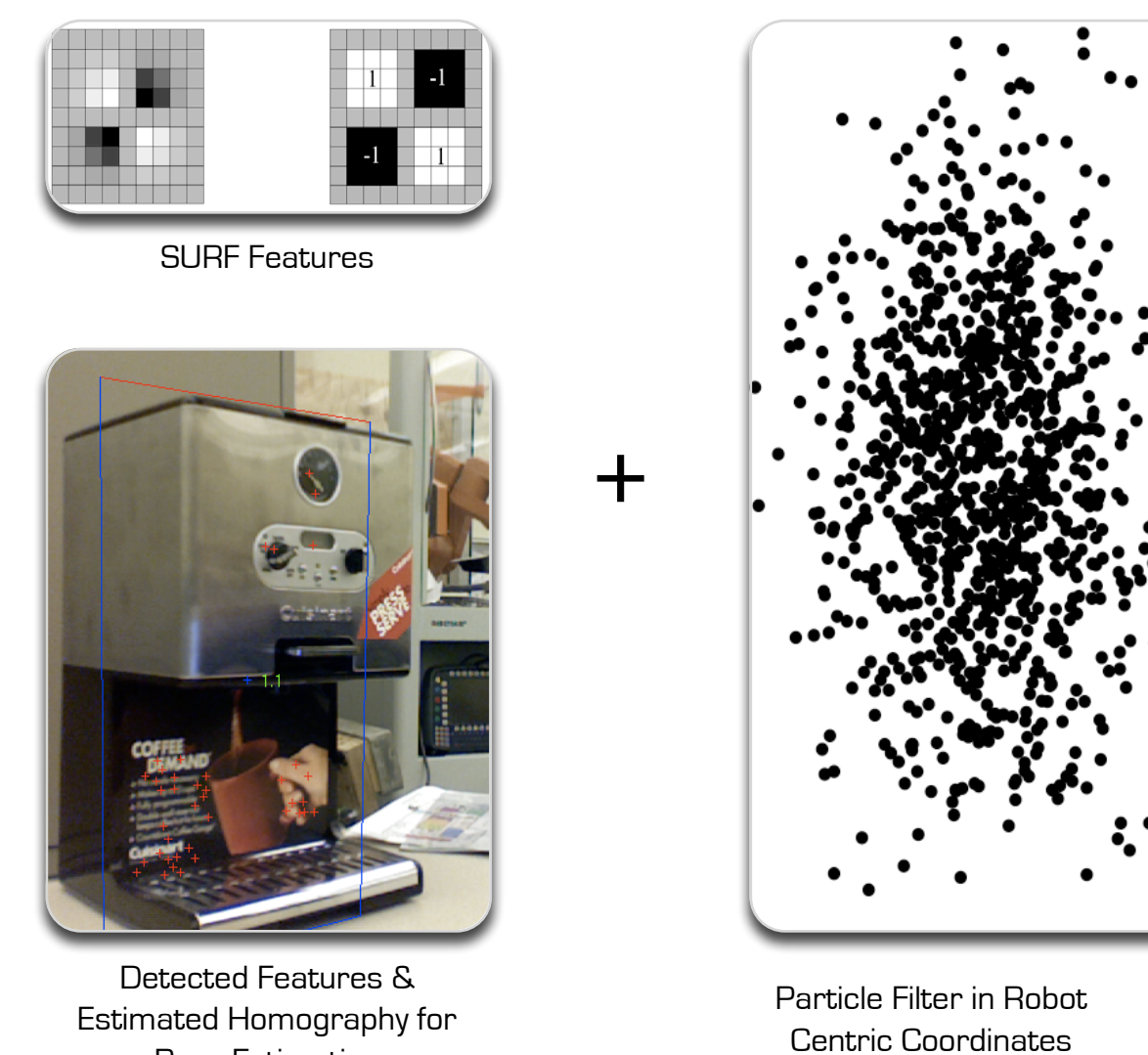
## Acknowledgements

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## References

- [1] Microsoft, Corp.: Microsoft robotics studio. <http://msdn.microsoft.com/robotics/> (2006)
- [2] Richter, J.: Concurrent affairs: Concurrency and coordination runtime. MSDN Magazine (10) (2006)
- [3] Nielsen, H., Chrysanthopoulos, G.: Decentralized software services protocol - dsp. Technical report, Microsoft Corporation (2006)
- [4] Herbert Bay, Tinne Tuytelaars, and Luc J. Van Gool. Surf: Speeded up robust features. In Ales Leonardis, Horst Bischof, and Axel Pinz, editors, ECCV (1), volume 3951 of Lecture Notes in Computer Science, pages 404–417. Springer, 2006.
- [5] Brian Gerkey et al. The Player Robot Device Interface, 2006. Online document from <http://playerstage.sourceforge.net/doc/Player-2.0.0/player/>.

## Team 3



- 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 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