The b-it-bots RoboCup@Work Team

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Team

The b-it-bots RoboCup@Work team at Bonn-Rhein-Sieg University of Applied Sciences was established in the beginning of 2012. Participation in various international competitions has resulted in several podium positions such as

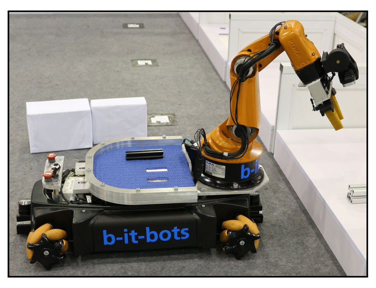
- **1st place:** RoCKIn '15 Control Benchmark, Lisbon, Portugal
- **3rd place:** RoboCup '15, Hefei, China
- **2nd place:** RoboCup GermanOpen '15, Magdeburg, Germany
- **1st place:** RoCKIn '14 Object Perception Benchmark, Toulouse, France
- **2nd place:** RoboCup World Championship '14, João Pessoa, Brazil

Our main research interests include *mobile manipulation* in industrial settings, *omni-directional navigation* in unconstrained environments, *environment modeling* and *robot perception* in general.

Robot Platform

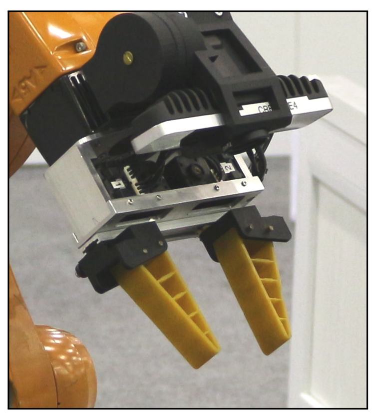
The KUKA youBot is the applied robot platform of our team. The default configuration is equipped with

- *omni-directional base*,
- *a 5-DoF manipulator* and
- *a two finger gripper.*



Several support and extend the perception capabilities, like scene segmentation, object recognition and SLAM:

- *Hokuyo URG-04LX laser range finders*
- *Intel RealSense F200 close-range RGB-D camera*



A new custom designed gripper has been integrated to enhance the opening range up to 6.5 cm and enable grasping a wider range of objects.

Navigation

Localization and mapping is performed using the ROS navigation stack *move_base* with the following configuration:

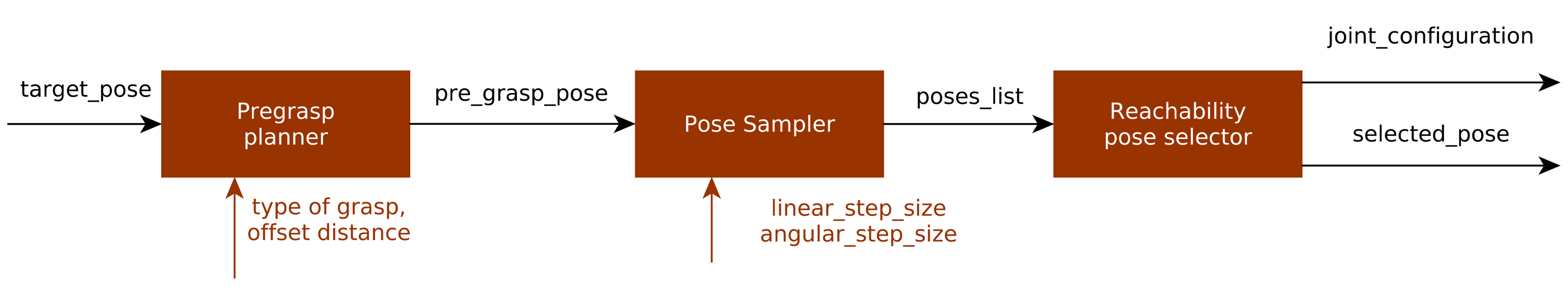
- **Local planner:** Dynamic-Window-Approach
- **Global planner:** Modified version which calculates an orientation for each pose of the global path. The path itself is partitioned into three segments (start, middle, end). To avoid unnecessary rotations while leaving a start or approaching the goal pose, the robot utilizes its full omni-directional maneuverability. In between it moves in differential way.
- **Recovery behaviors:** ForceFieldRecovery and ClearCostmapRecovery
- **Maximum velocities:** 1.0 m/s (linear) and 1.5 rad/s (angular)

Future development focuses on a modified local planner, which incorporates the orientations of the global plan to produce a much smoother and more efficient motion.

Object Manipulation

Once the pose of an object is being determined, several manipulation components are deployed to perform the actual grasp:

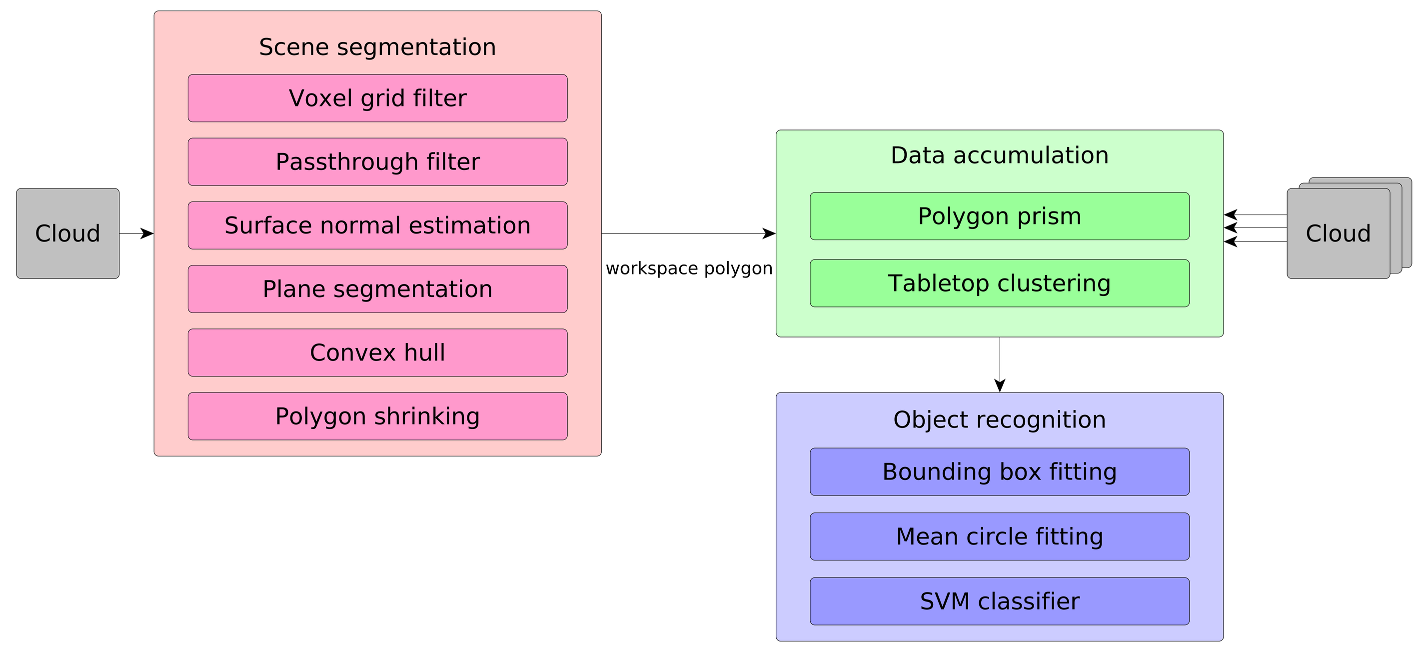
1. **Pre-grasp planner:** computes a pre-grasp configuration based on the desired type of grasp, a distance offset and constraints imposed by the robot's manipulator.
2. **Pose sampler:** a set of poses is sampled uniformly around the pre-grasp pose.
3. **Inverse kinematics solver:** to find one reachable pose out of the sampled pose set.
4. **MoveIt! Interpolation planner:** to generate and execute a trajectory between the current and target joint configuration.
5. **Cartesian controller:** to execute a linear motion for the final grasp.
6. **Grasp verification:** by evaluating the torque and position information of the Dynamixel gripper motors.



The rationale using a pre-grasp configuration is to move the end effector close to the target object instead of directly onto the object. This ensures that the end effector will not collide with the surface the object is located on.

Object Perception

For perception-related tasks, both intensity and depth images of a RGB-D camera are being processed. For the object recognition, a three-stage pipeline has been devised:



The classification of object candidates is being performed using **Support Vector Machines** (SVM) based on the following features:

- *minimal fitted bounding box*
- *fitting error of mean circles*
- *radius of fitted mean circles*
- *color distribution*

In addition to the particular object name, the classifier outputs the probability of the classification for each object as well.

Task Planning

Instead of fixed and human designed finite-state machine, we deploy a task planner for scheduling different actions. The deployed **Mercury planner** allows to specify various cost information. For RoboCup@Work, e.g.

- *distances between locations*,
- *perception probabilities* and
- *grasp probabilities.*

As part of the planner integration, the existing FSMs have been refactored to very small and clear state machines covering only basic actions, such as

- `move-to{`*location_name*`}`,
- `perceive-objects{}`,
- `grasp-object{`*object_pose*`}` or
- `place-object{`*object_name*`}`.

By a utilizing a task planner instead of FSMs, the maintenance has become more efficient, since only small state machines need to be modified or tested.

Related Publications

[1] Nico Hochgeschwender, Sven Schneider, Holger Voos, and Gerhard K. Kraetzschmar. Declarative specification of robot perception architectures. In *Proceedings of the 2014 International Conference on Simulation, Modeling, and Programming for Autonomous Robots (SIMPAR)*, Bergamo, Italy, 2014.

[2] Gerhard K. Kraetzschmar, Nico Hochgeschwender, Walter Nowak, Frederik Hegger, Sven Schneider, Rhama Dwiputra, Jakob Berghofer, and Rainer Bischoff. RoboCup@Work: Competing for the Factory of the Future. In *Proceedings of the 18th RoboCup International Symposium*, Joao Pessoa, Brazil, 2014.

[3] Sven Schneider, Frederik Hegger, Nico Hochgeschwender, Rhama Dwiputra, Alexander Moriarty, Jakob Berghofer, and Gerhard Kraetzschmar. Design and development of a benchmarking testbed for the factory of the future. In *Proceedings of the 20th IEEE International Conference on Emerging Technologies and Factory Automation (ETFA): Special Session on Mobile Robotics in the Factory of the Future*, Luxembourg, 2015.

[4] Sven Schneider, Nico Hochgeschwender, and Gerhard K. Kraetzschmar. Declarative Specification of Task-based Grasping with Constraint Validation. In *Proceedings of the IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)*, Chicago, Illinois, USA, 2014.

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