RUR53: an Unmanned Ground Vehicle for Navigation, Recognition and Manipulation

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DIPARTIMENTO DI INGEGNERIA DELL'INFORMAZIONE

DESERT LION

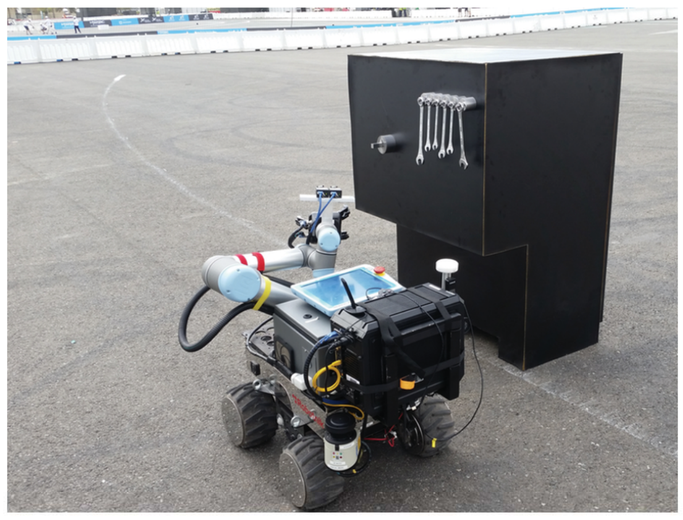
RUR53 is the unmanned mobile manipulator robot developed by the Desert Lion team of the University of Padova (Italy), for the Challenge 2 of the first Mohamed Bin Zayed International Robotics Challenge (Abu Dhabi, March 2017).
MBZIRC fostering research in advanced robotics applications like operations in disaster scenarios, oil and gas maintenance, manufacturing, construction, and housework.
The Desert Lion team rank third in the Gran Challenge in collaboration with the Czech Technical University in Prague, Czech Republic, the University of Pennsylvania, USA, and the University of Lincoln, UK.

Objectives

Developing an UGV robot able to:
- navigate inside an outdoor arena;
- locate and reach a panel;
- recognize and manipulate a wrench;
- use this wrench to physically operate a valve stem on the panel itself.

This applications require a combination of sensorized robots and advanced artificial intelligence techniques able to fulfill object perception, motion planning, grasping, and manipulation task.

Approach



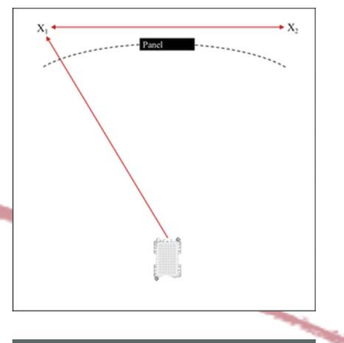
RUR53 is able to perform these tasks both autonomously and in teleoperation mode.

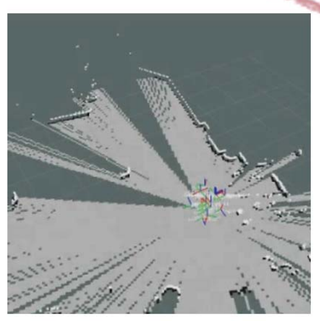
The adopted hardware and software architectures key aspects:
- modularity
- generality
- ability of exploiting sensor feedback

System Architecture

Navigation and Docking

The arena in which the robot has to find the panel is well defined but the panel could be located along a curve in the farthest side of the arena and it is not excluded the presence of obstacles to be avoided.
We adopted a semi-autonomous approach for the exploration of the arena: the robot visit a set of manually pre-defined way-points which are periodically visited until the panel is found.
Navigation is implemented exploiting the ROS Navigation Stack and with the laser scan in order to prevent any collision.
While the exploration task is running another task is in charge of finding the panel. In order to locate the panel in the scan, we take advantage of the fact that we know its size.



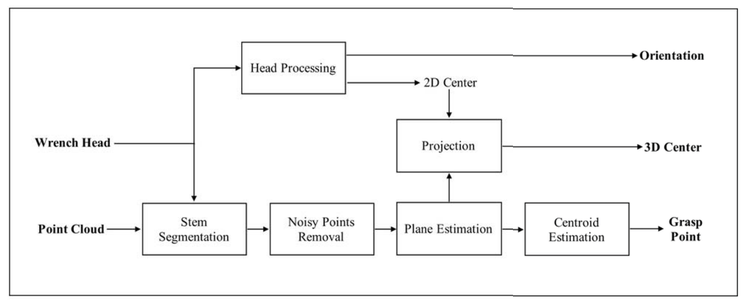


Manipulation

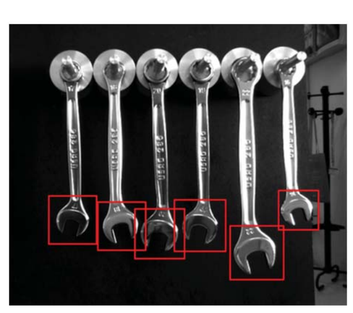
The manipulation routines are in charge of picking up the right wrench and operating the valve.
The wrench grasping routine align the end-effector to the grasp point (fingers opened), it approaches the wrench, closes the fingers, and comes back to its initial pose. The robot inserts the wrench on the valve by aligning the reference systems of valve and wrench grip center and a 360° rotation trajectory is imprinted. This trajectory is computed by sampling a set of way-points on a radius *r* around the valve.

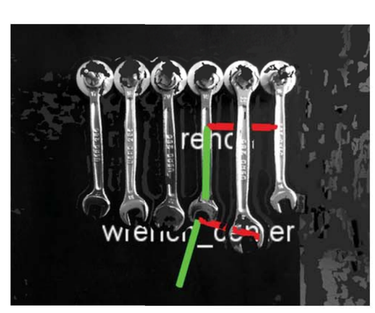
Perception

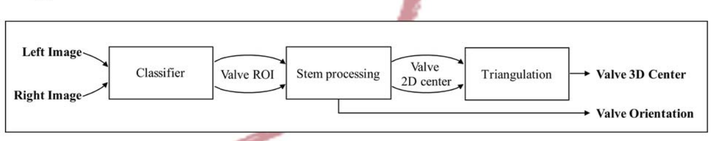
Wrenches and valve are recognized by an object detector and an accurate pose estimator lets retrieve their poses for manipulation.

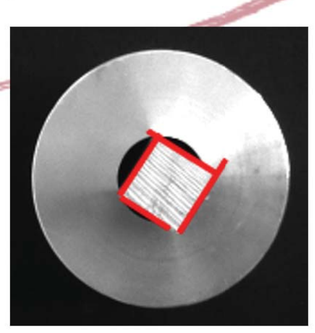


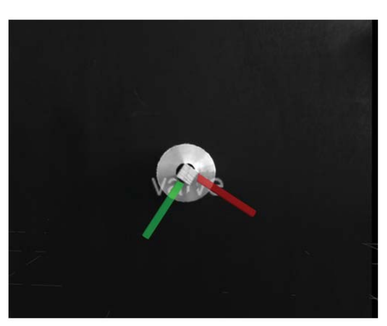
Wrench We developed an approach based on both 2D and 3D data where left and right camera images are used to reconstruct the point cloud by using the Semi-Global Block Matching (SGBM) algorithm.







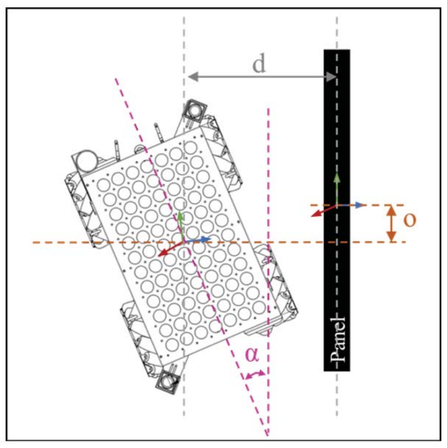




Valve The valve has a large metal surface and its stem generates many reflections that cause a noisy 3D reconstruction. For this reason, we decided to use the Triangulation algorithm on the interest points extracted from the stereo images.

Results

Docking Performance



	Desired Value	Average	Median	Max	Min
d (m)	0.80	0.78	0.78	0.81	0.77
o (m)	0.00	-0.15	-0.17	-0.08	-0.20
α (deg)	0.0	9.4	7.8	15.5	5.4

Docking performances. In detail, *d* is the distance (in meters) between the robot and the panel expressed along the z axis (blue line); *o* is the offset (in meters) separating the two reference systems along the x axis (green line); *α* is the docking angle: the angle between the robot and the panel (in degrees).

Wrench and Valve Manipulation Performance

Correct Recognition	Grasp	Loss
92%	86%	14%

Performances of the wrench detection and grasping routine on 50 reps.

Performances of the valve detection routine. Measures are in degrees.

α (deg)	Average	Median	Max	Min
0	0.21	0.01	0.73	0.0
15	16.51	16.39	17.53	15.96
30	30.79	30.65	33.69	29.20
45	45.24	45.00	46.01	45.00

	Average	Median	Max	Min	Std. Dev
Wrench Detection (s)	3.338	3.305	3.770	3.266	0.106
Valve Detection (s)	0.059	0.059	0.071	0.052	0.005

Execution times of wrenches and valve detection algorithms. Measures are in seconds.