Combination of 2D and 3D vision systems into robotic cells for improved flexibility and performance

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The projects

THE ROBOSCAN PROJECT

- Integrates 3D vision into a single robot cell, for flexible bin-picking
- 2D vision is used to enhance the performance of the 3D component
The system needs to be calibrated in order to work properly. The robot and the vision system need to share the same coordinate reference.

The system uses both 2D/3D algorithms and methods for the estimation of the position and orientation of the objects placed inside the working area.

When the system has collected all the useful information about the scene, the robot can start grasping the objects.
The Roboscan System needs three different calibrations to work properly. In fact, the grasping operations performed by the robot, and also the detection of the positions of the objects, require the definition of specific reference systems, expressed in real world coordinates.

- Robot calibration
- 2D calibration
- 3D calibration

For this application all the calibrations must share the same reference system!
✓ **Robot calibration**
   It defines a new workspace for the robot, and it is obtained using a calibration master placed inside a pre-defined working area.

✓ **2D calibration**
   The Camera is considered as stand-alone and is moved in a place that permits to acquire the whole working area; then a common 2D calibration algorithm is applied, using the calibration master in the same position that has been used during the robot calibration.
The 3D calibration is performed using a pinhole model, applied to the optical head composed by the laser and the camera. The calibration master is in the same position that has been used for the 2D calibration.

The optical head is moved along the vertical direction by the robot, in order to acquire the scene at different z-quotes.

The final result is a set of parameters that characterize the camera and the laser slit in an absolute way.
The System Calibration (3)

Example of the 3D acquisition of an object after the calibration of the optical head.
Example of 2D acquisition of the scene: objects are detected using pattern-matching and their XY positions and boundary limits are collected.
The working area is acquired by the optical head, in order to get also the z information from the scene.
Each object is segmented from the whole 3D cloud, thanks to the boundary information collected during the 2D analysis.

Calculation of the best fitting surface for each object.

Calculation of the possible robot pose (gripper position and orientation) for a correct grasping operation.

One pose file for each object!
3D Object Description (2)

The performances have been tested comparing the Euler angles (orientation estimation) found by the algorithm with the corresponding angles calculated by Polyworks on the same 3D cloud.

Example of comparison using 9 objects that are differently oriented in the space.

<table>
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<th>Measured a (°)</th>
<th>Polyworks a (°)</th>
<th>Measured b (°)</th>
<th>Polyworks b (°)</th>
<th>Measured g (°)</th>
<th>Polyworks g (°)</th>
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</table>

- **a** mean absolute residual = 0.302°
- **b** mean absolute residual = 0.175°
- **g** mean absolute residual = 0.380°
The robots grasps iteratively all the objects that have nearly the same z-quote. Then, if objects are not finished, another 2D/3D analysis is performed.
Conclusions

✓ The Roboscan system offers a quite robust way to handle bin-picking applications.

✓ The flexibility of the developed vision procedures permits to adapt the application to a number of cases, also with different objects.

✓ In order to further test the robustness and flexibility of the system, it is necessary to use more suitable end-effectors, because we can not pick all the objects by using the gripper we have now.