DOI 10.5162/SMSI2025/C4.3

Optimized Grasp Planning for Bin-Picking Robots with 2D and 3D Sensor Data

Roman Haas[1], *Nikolai Hangst*[1] *and Thomas M. Wendt*[1]
[1]Offenburg University of Applied Sciences, Work-Life Robotics Institute, 77652 Offenburg, Germany
roman.haas@hs-offenburg.de, nikolai.hangst@hs-offenburg.de, thomas.wendt@hs-offenburg.de

Abstract: Bin-picking systems face challenges in fully emptying containers due to collision risks in real-world scenarios. In this contribution, we present a grasp planning approach that combines 2D and 3D sensor data to ensure collision-free handling. The method is successfully tested on objects with eccentric centers of mass and is implemented directly on the robot's control unit, eliminating the need for separate computing hardware.

Keywords: robotics, bin-picking, grasp planning, sensor fusion, object detection

Introduction

Robotic bin-picking tasks are essential in industries such as manufacturing, warehousing, and logistics. Effective grasp planning remains challenging due to real-world complexities like eccentric centers of mass, the lack of collision checks with the bin, and the handling of tightly packed bins [1]. Existing methods often rely on point clouds, which are time-consuming to compute and fail to incorporate 2D information of the objects.

Related Works

Buchholz et al. [2] apply depth images and parallel projections of the gripper to evaluate various grasps from a given pose and defined degrees of freedom. Shi and Koonjul focus on automating the generation of grasps to reduce setup times in bin-picking systems [3]. Spenrath and Pott employ a heuristic tree search for grasp planning, leveraging a neural network-based approach that reduces computational time by 45 % [4]. Another approach involves the constrained placement of unknown objects, but faces problems with low accuracy and the lack of consideration for the center of mass [5].

Developed Method

The proposed grasp planning system combines 2D and 3D sensor data to localize objects within a bin. While 3D data is crucial for accurately determining object position and orientation, 2D data enhances object detection in tightly packed bins. Placement requirements of the objects can be met, as the surface texture provides feedback on the center of mass and object features that are not detected in the point cloud. Specially designed grippers reduce collision probability, but do not eliminate the need for grasp planning. Fig. 1 shows the bin-picking robot along with the coordinate systems involved.

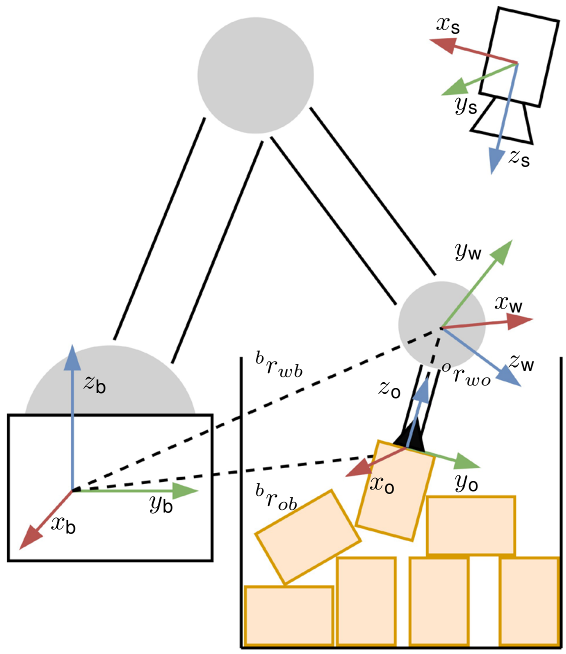

Fig. 1: Robot bin-picking with the required coordinate systems for the proposed grasp planning.

The method incorporates coordinate systems for the robot base, wrist center, sensor and object. This grasp planning approach relies on the position of the wrist center in base frame coordinates $^b r_{wb}$ (see Eq. 1).

$$^b r_{wb} = {}^b r_{ob} + {}^{bo}T \, {}^o r_{wo} \tag{1}$$

The sensor, in combination with image processing, determines the position of the object in the sensor's coordinate system. With a valid hand-eye calibration, the object's position is then transformed to the robot base frame $^b r_{ob}$.

DOI 10.5162/SMSI2025/C4.3

A three-dimensional space within the bin, where ${}^b r_{wb}$ is allowed during grasping, is defined by P as specified in eq. (2). In this context, all coordinates (x, y, z) refer to the base frame.

$$P = \left\{ (x, y, z) \in \mathbb{R}^3 \;\middle|\; \begin{array}{c} x_{\min} \leq x \leq x_{\max}, \\ y_{\min} \leq y \leq y_{\max}, \\ z_{\min} \leq z \leq z_{\max} \end{array} \right\} \quad (2)$$

The system is designed to be implemented on a robot controller with simple commands, without the need for additional computing power.

Experiments

We conducted experiments to test the grasp planning system, utilizing a *Yaskawa GP50* robot equipped with a vacuum gripper (see Fig. 2). For object detection, a *Roboception rcvisard 160 m-6* stereo sensor generates a 3D point cloud that includes 2D textures of the objects. The tests involved objects, which are characterized by eccentric centers of mass. For each object, multiple grasp options were defined, from which the system selected and executed a collision-free grasp with the developed method.

Fig. 2: Experimental setup of the robot performing a grasp in a bin with multiple objects with uneven center-of-mass

Results and Discussion

The experiments demonstrated that the proposed method successfully identifies collision-free grasps. The integration of 2D sensor data enhanced object detection in tightly packed bins, improving system reliability. The approach enabled the handling of objects with uneven centers of mass and features that 3D data alone cannot capture. Identifying the center of mass is critical for vacuum grippers, while small object features are essential for proper positioning, particularly when specific orientations are required. The current system does not account for potential collisions with other objects in the bin or along the robot's path to the object.

Conclusion and Outlook

The developed grasp planning system combines multimodal sensor data to increase object detection. By implementing coordinate transformations and predefined grasp points, the system calculates collision free grasping points. By considering the 2D textures of the objects, information about their center of mass can be inferred. The system operates efficiently without the need for additional computing hardware, reducing both complexity and cost.

Future work could focus on evaluating the robot's full path to the grasping point and incorporating self-learning capabilities for model-independent tasks. Key improvements could include integrating parameters such as weight, center of mass, and surface conditions to further enhance grasp reliability.

Tools

This paper benefited from OpenAI's ChatGPT, which was applied to improve grammar and sentence clarity.

References

[1] M. Schwarz *et al.*, "Fast Object Learning and Dual-arm Coordination for Cluttered Stowing, Picking, and Packing," in *2018 IEEE International Conference on Robotics and Automation (ICRA)*, May 2018, pp. 3347–3354.

[2] D. Buchholz, M. Futterlieb, S. Winkelbach, and F. M. Wahl, "Efficient bin-picking and grasp planning based on depth data," in *2013 IEEE International Conference on Robotics and Automation*, May 2013, pp. 3245–3250.

[3] J. Shi and G. S. Koonjul, "Real-Time Grasping Planning for Robotic Bin-Picking and Kitting Applications," *IEEE Transactions on Automation Science and Engineering*, vol. 14, no. 2, pp. 809–819, Apr. 2017.

[4] F. Spenrath and A. Pott, "Using neural networks for heuristic grasp planning in random bin picking," in *2018 IEEE 14th International Conference on Automation Science and Engineering (CASE)*, Aug. 2018, pp. 258–263.

[5] C. Mitash, R. Shome, B. Wen, A. Boularias, and K. Bekris, "Task-Driven Perception and Manipulation for Constrained Placement of Unknown Objects," *IEEE Robotics and Automation Letters*, vol. 5, no. 4, pp. 5605–5612, Oct. 2020.