Towards a modular bin-picking framework for handling object pose uncertainties

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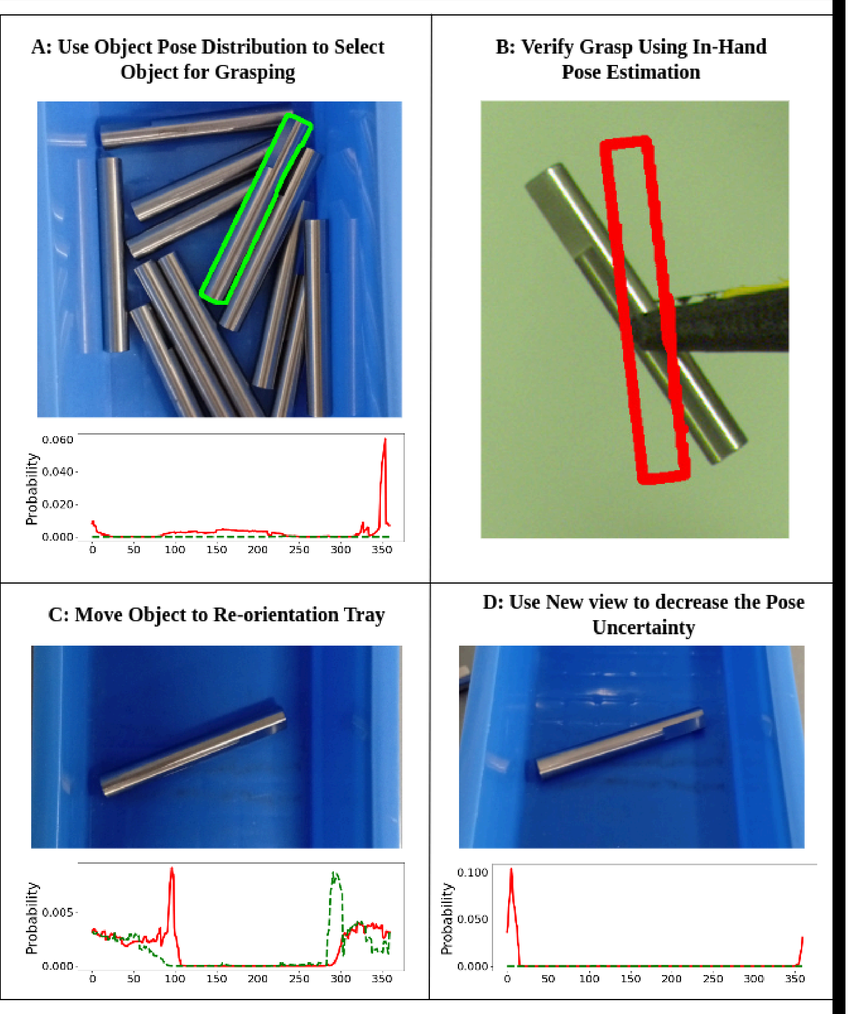
Motivation

- Reliable bin-picking is challenged by:
  - Uncertain object pose estimation
  - Grasp execution errors
- Existing approaches address these issues individually, limiting robustness
- We present a unified modular system for:
  - Pose uncertainty handling
  - Grasp error compensation
- Represents object pose as a distribution
  - Handles ambiguous observations where a single pose is insufficient
- Grasp Error Compensation
  - Independent modules for mitigating execution errors
  - Improve grasp robustness
- Components can be:
  - Combined for optimal performance
  - Used individually depending on system constraints

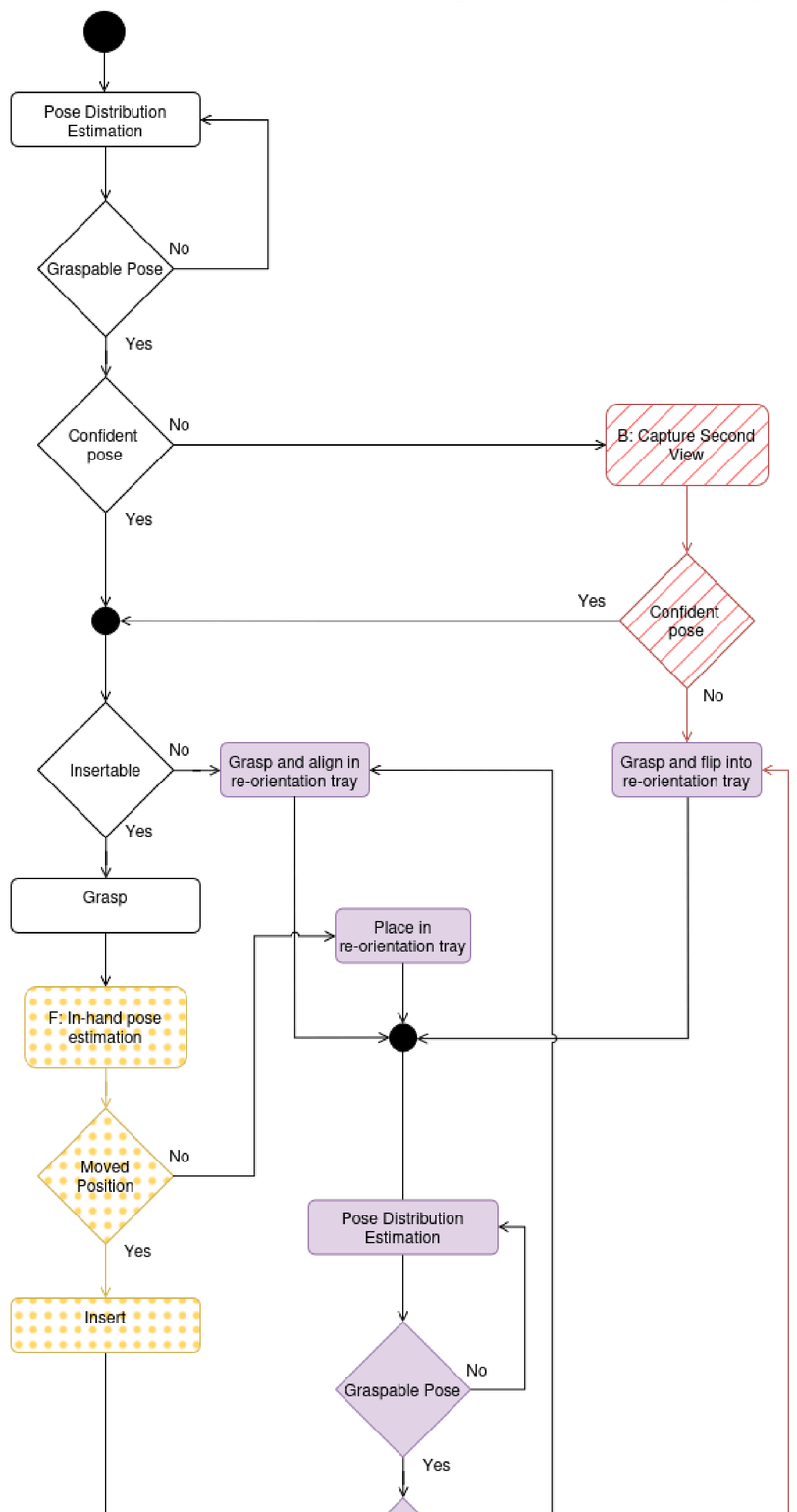


Example of the framework when inserting an object.
A: First, an object with a pose distribution under the cutoff value is selected for grasping. (The red and green lines indicate the probability of revolution for the two reflections. The correct orientation is the red line at 0 degrees rotation).
B: The grasped object is moved in front of the in-hand camera to verify the grasp, and the expected pose (red outline) does not match the grasp pose.
C: As a result, the object is moved to the re-orientation tray, and a new object pose distribution is computed.
D: As the uncertainty is too high, a second view is obtained, and the uncertainty is re-estimated. As the new uncertainty is low and the object is in the re-orientation tray, it is inserted.

The created framework

Modules:

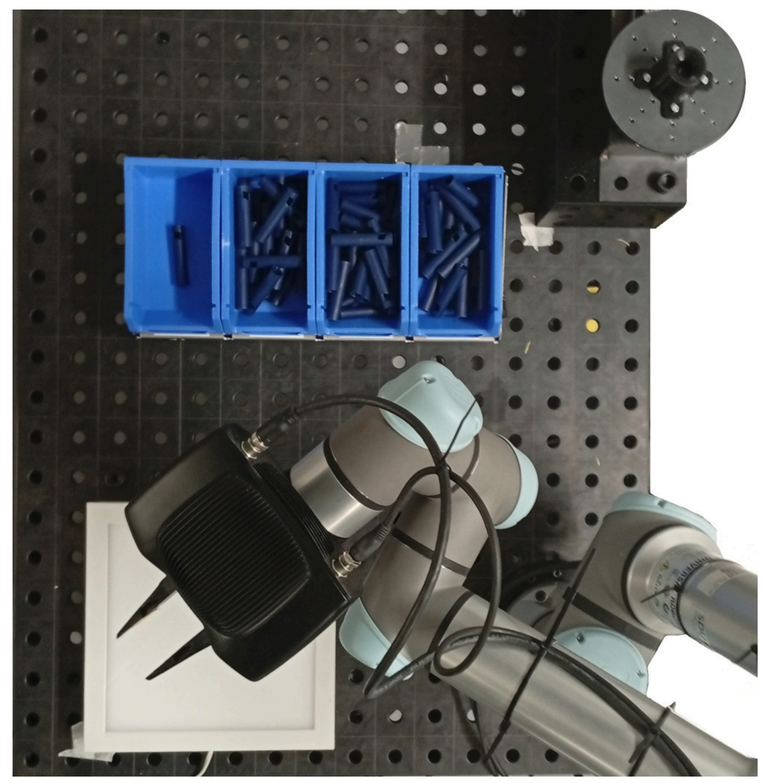
- White: Use object pose distribution to avoid erroneous pose estimation (Original Method [1])
- Red: Use a second view to compute new pose distribution and combine decrease uncertainty and obtain more successful pose estimations
- Purple: To avoid erroneous grasps, move object to re-orientation tray [2]
- Yellow: Or use in-hand pose estimation [3]



Experiments

- Evaluated on real robotics setup with an insertion task
- The new system had zero failures
- By using the additional modules an improved efficiency was obtained

Strategy	Success	Grasps
Original (O)	89	2.5
O + In-hand Pose (IHP)	100	2.8
O + Reorientation Tray (RT)	100	2.25
O + RT + New View (NV)	100	2.05
O + RT + NV + IHP	100	1.91



Conclusion

- First framework to jointly address:
  - Object pose uncertainty
  - Grasping uncertainty
- Demonstrates benefits of:
  - Probabilistic pose estimation
  - Modular error-aware design

Limitations & Future Work

- Current implementation limited to SO(2)
  - Future extension to SE(3)
- Open for integration of additional modules

References:

[1] Hagelskjær, F., Arapis, D., Madsen, S., & Iversen, T. M. (2025). Object Pose Distribution Estimation for Determining Revolution and Reflection Uncertainty in Point Clouds. arXiv preprint arXiv:2512.07211.

[2] H. Cao, J. Zhou, J. Huang, Y. Li, N. C. Meng, R. Cao, Q. Dou, and Y. Liu, "Two-stage grasping: A new bin picking framework for small objects," arXiv preprint arXiv:2303.02604, 2023.

[3] Hagelskjær, Frederik, and Dirk Kraft. "In-hand pose estimation and pin inspection for insertion of through-hole components." 2022 IEEE 18th International Conference on Automation Science and Engineering (CASE). IEEE, 2022.

For more information on the project, scan the QR Code or go to posehistogram.github.io

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