



3D Virtual Activation Volume for Automated Grasping in Teleoperated Robotic Manipulation

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Problem

Depth estimation during teleoperation makes grasping slow and error-prone, increasing the operator's mental load and fatigue

Key Idea: 3D Virtual Activation Volume (VaV)

An adaptive 3D VaV, centered on the object, acts as a dynamic constraint: when the end-effector enters the sphere, automatic grasp assistance is activated along the depth axis, maintaining lateral/vertical freedom (see Fig. 1). Selected radius (r): 150 mm

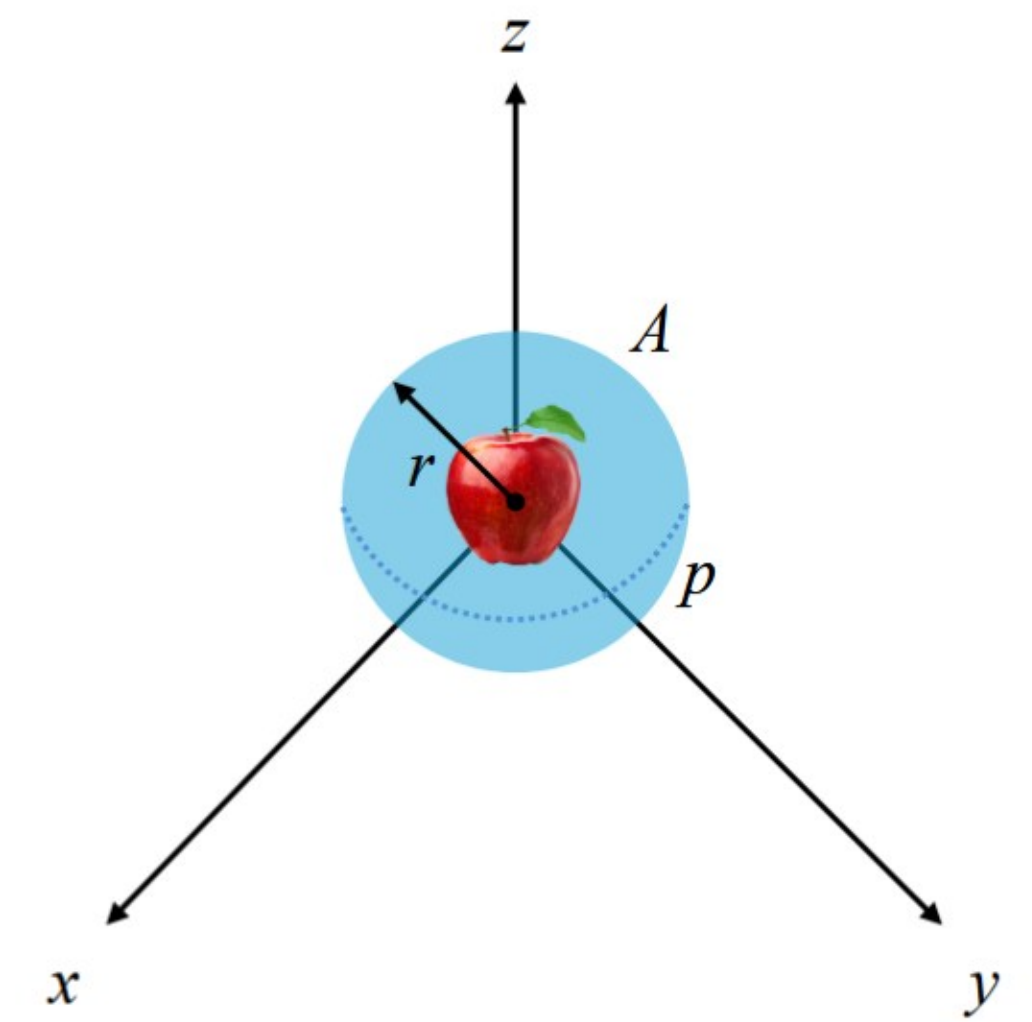


Fig. 1

Experimental Setup

UR5 teleoperation + modified CORA hand, Leap Motion for hand tracking, Intel RealSense D455 for segmentation/affordance (MobileNetV3 + segmentation head) and bounding box (YOLO11x). Cartesian velocity control; Simulink 100 Hz. Object: 70 mm × 250 mm bottle at the center of the bench (see Fig. 2)

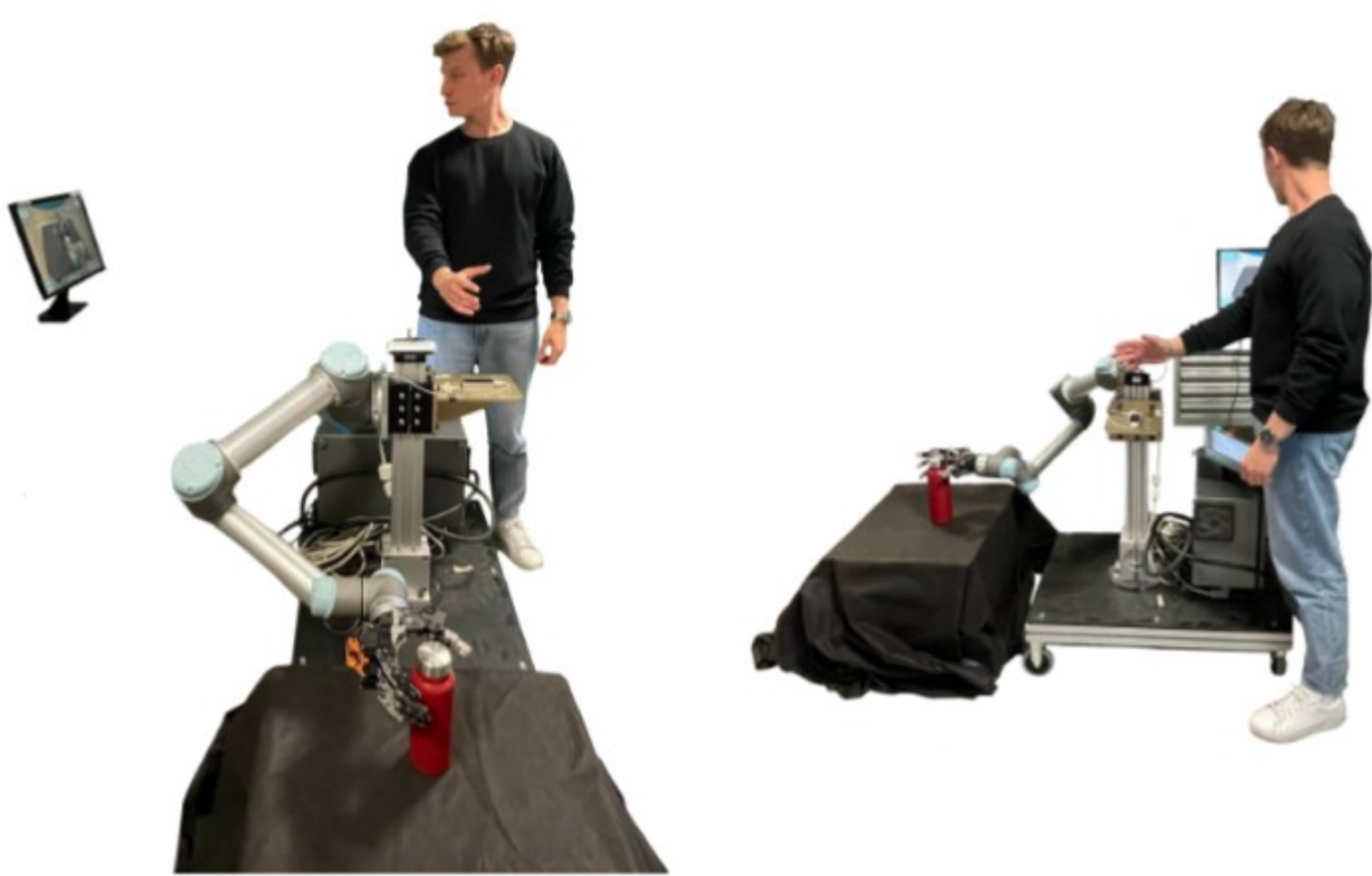


Fig. 2

Protocol

30 pick-and-places with/without VaV

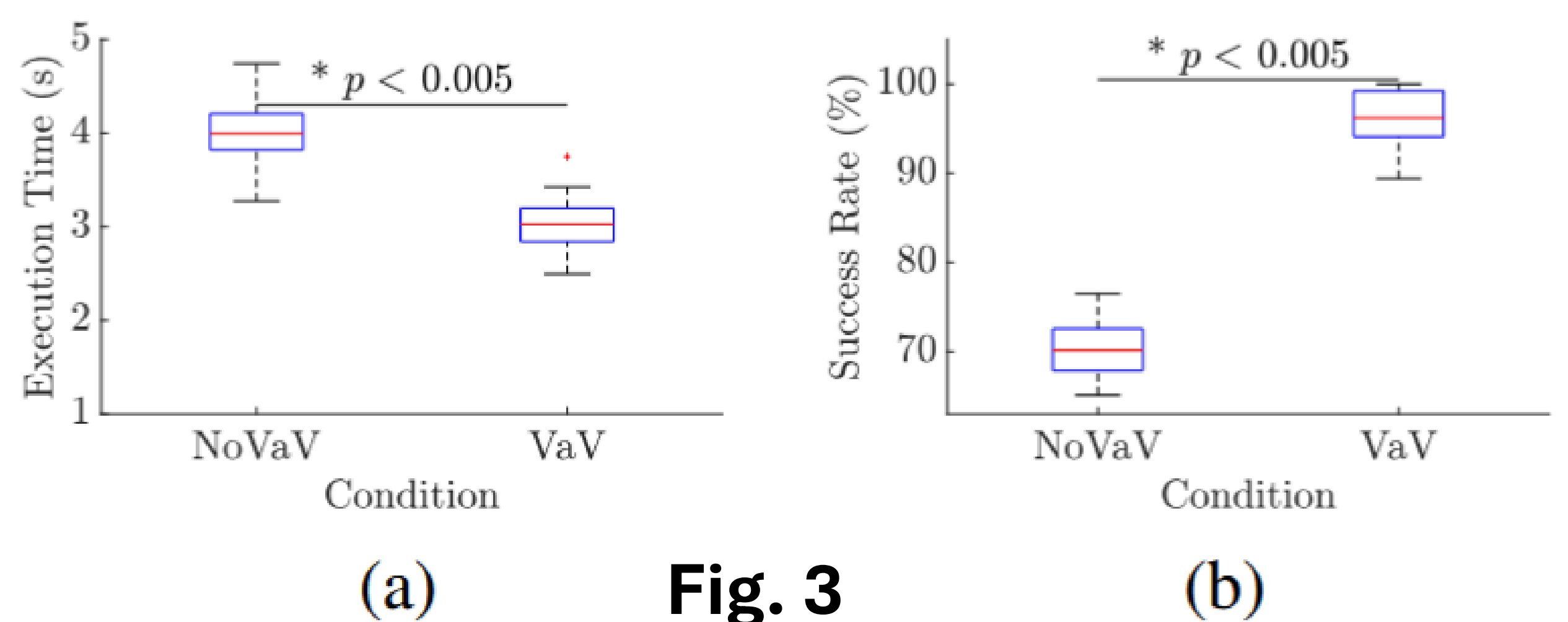
Metrics: execution time (movement initiation → object release) and success rate (stable grasp and lift ≥ 50 mm), with Paired t-test ($p < 0.005$)

Key Findings

Time: 3.97 s (NoVaV) and 3.01 s (VaV) (-24%)

Success: 70.3% (NoVaV) and 96.7% (VaV)

Result: faster and more reliable grasp, with less cognitive load (see Fig. 3)



Contributions

1. Introduced a simple-to-implement 3D volumetric constraint that activates only when needed
2. Evaluation with dual metrics (time and accuracy), often treated separately in the literature

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