CZECH INSTITUTE OF INFORMATICS ROBOTICS AND CYBERNETICS CTU IN PRAGUE

COMENIUS UNIVERSITY BRATISLAVA

TU Delft

Imitrob: Imitation Learning Dataset for Training and Evaluating 6D Object Pose Estimators

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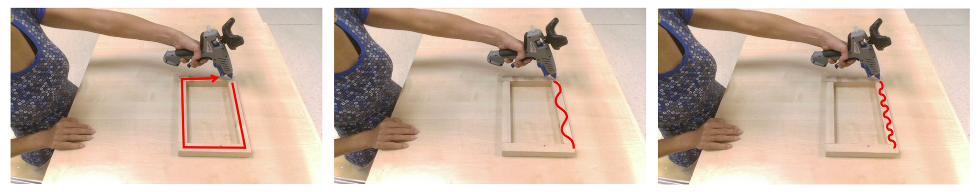
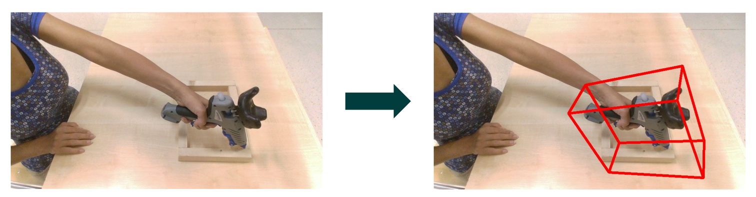
Motivation

TOOL MANIPULATION TASKS



EXAMPLES OF DIFFERENT TASKS WITH ONE TOOL

6D OBJECT POSE ESTIMATION



INPUT IMAGE — 6D OBJECT POSE

Imitation learning in industrial applications

- Robot learns how to perform a task from demonstrations
- Requires 6D pose (position & orientation) of the tool

Challenges for 6D object pose estimation

- Manipulation and occlusion of the tool by the hand
- Lack of benchmarking datasets

Contributions

New 6D object pose benchmarking dataset

- Evaluation of a given 6D object pose estimation method
  - Suitability for imitation learning of a given robotic task
  - Generalization capabilities w.r.t. various setups

Methodology and software for dataset extension

- Acquisition of data for new tools and manipulation tasks
- No need for manual annotation or 3D model of the tool

Dataset and code

- imitrob.ciirc.cvut.cz/imitrobdataset

AGIMUS INNOVATIVE ROBOTICS FOR AGILE PRODUCTION

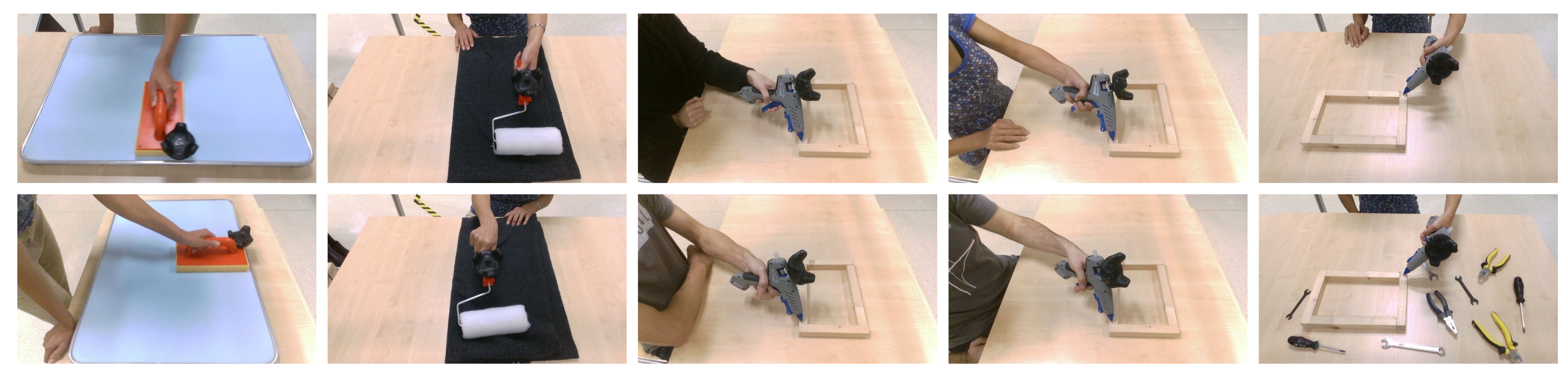
2023 IROS OCTOBER 1 - 5, 2023 IEEE/RSJ International Conference on Intelligent Robots and Systems

Imitrob dataset

TOOLS

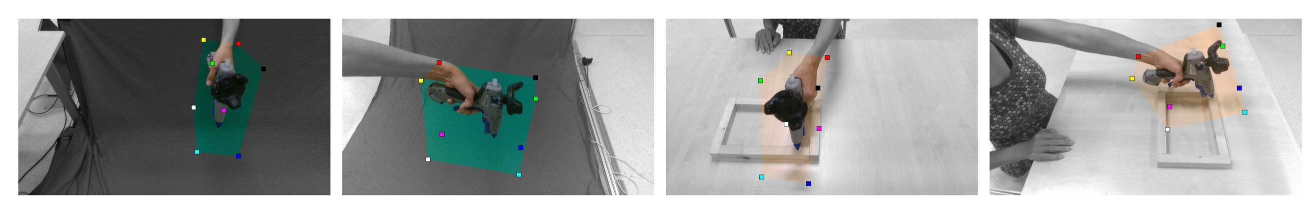
GLUE GUN — GROUT FLOAT — ROLLER — GLUE GUN 2 — GLUE GUN 3 — GLUE GUN 4 — HEAT GUN — POWER DRILL — SOLDERING IRON

SETUP VARIABILITY



FRONT / SIDE **CAMERA** — LEFT / RIGHT **HAND** — FOUR **DEMONSTRATORS** — WITHOUT / WITH **CLUTTER**

GROUND TRUTH 6D POSE



TRAINING SET — TEST SET

Test dataset

- 208 videos of 12 manipulation tasks with 9 tools
- Industrial use-cases in manufacturing-like environment
- 2 cameras, left/right hand, 4 demonstrators, (no) clutter

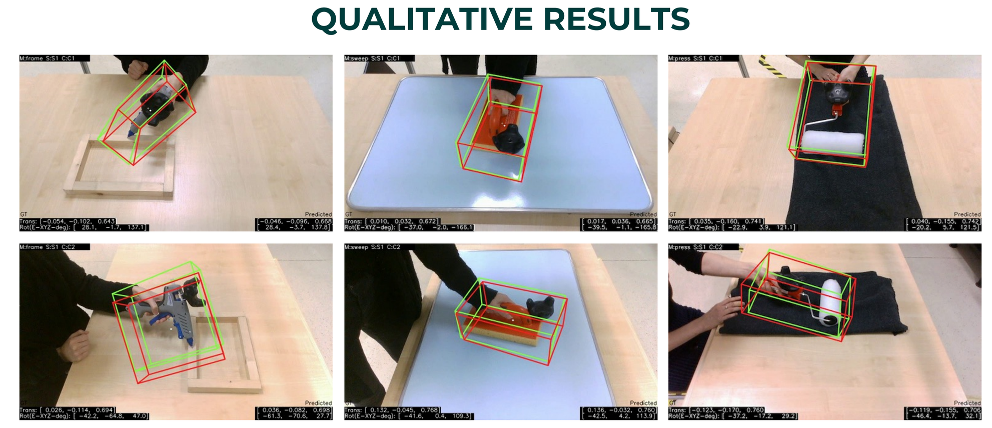
Training dataset

- 144 videos of random manipulation with 9 tools
- 2 cameras, left/right hand, 4 demonstrators

Ground truth 6D object pose

- Measured by HTC Vive tracker attached to the tool

QUALITATIVE RESULTS



PREDICTED 6D POSE (DOPE method)
GROUND TRUTH (HTC Vive)

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Experimental results

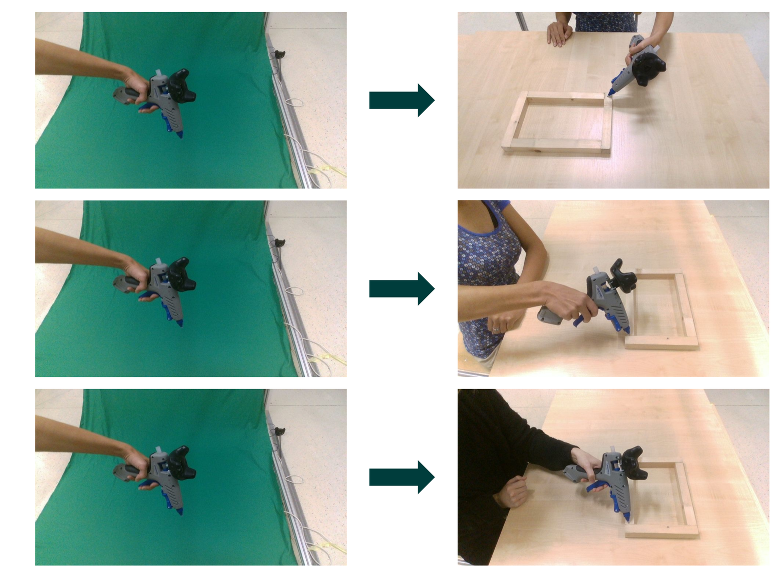
Tool	glue gun	grout float	roller	glue gun 2	glue gun 3	glue gun 4	heat gun	power drill	soldering iron	average
ADD_{5cm}	60.4	78.6	50.5	9.0	4.7	23.4	13.2	59.8	12.8	**34.7%**
E_{rot}	7.3	4.1	8.7	38.5	40.3	20.9	14.3	8.0	35.6	**19.8°**
E_{tra}	4.0	2.5	3.7	9.9	10.2	8.4	7.0	3.8	9.0	**6.5 cm**

GENERALIZATION EXPERIMENTS

DIFFERENT **CAMERA VIEWPOINT**

OPPOSITE **HAND**

DIFFERENT **DEMONSTRATOR**



TRAINING SET — TEST SET

Experiments

- Evaluation for each task and tool
- Generalization between training and test data setups

Evaluation metrics

- ADD (average bounding box distance) 5 cm pass rate [%]
- Rotation [deg] and translation [cm] errors

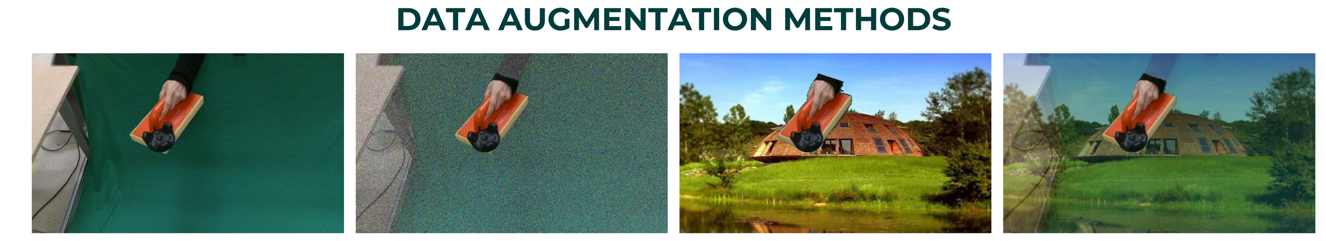
Example usage

- 6D object pose estimation method DOPE [1]
- Depth channel or 3D object model not required

Data augmentation

- Blending of original background with random images (first application in 6D object pose estimation domain)

DATA AUGMENTATION METHODS



NoAug (no augmentation) — **BgNoise** — **BgRandom / BgAlternate** — **BgBlend** (best results)

	NoAug	BgNoise	BgRandom	BgAlternate	BgBlend
ADD_{5cm}	29.2%	29.6%	45.6%	56.5%	**60.1%**
improvement	—	1.0×	1.6×	1.9×	**2.1×**

[1] Tremblay et al, Deep object pose estimation for semantic robotic grasping of household objects, CoRL 2018.