From Screws to Tools: Detection, Classification, and Tool Suggestion for Robotic Disassembly

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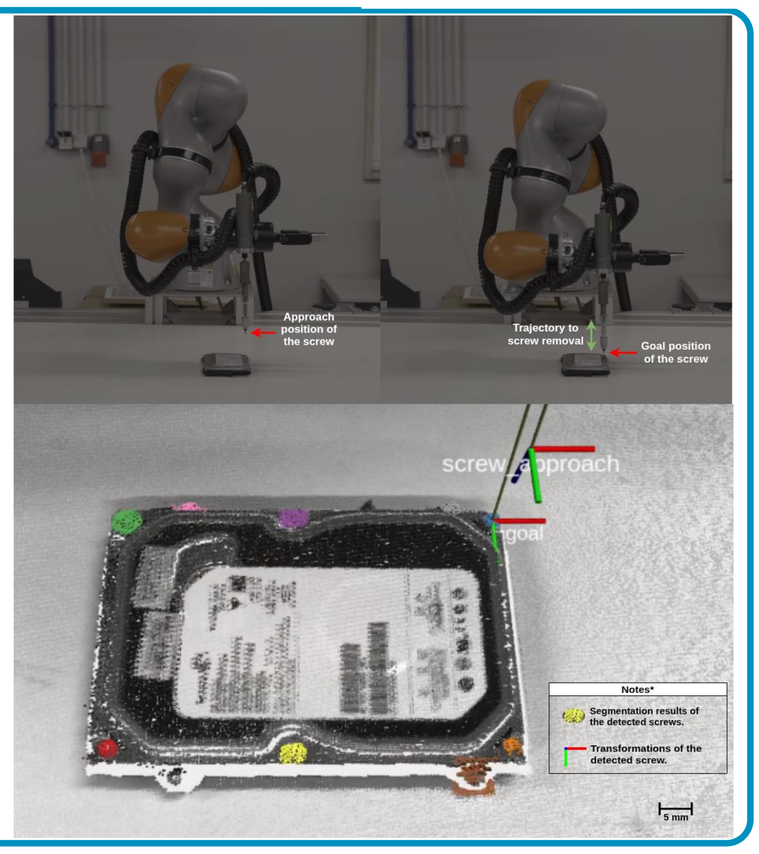
Abstract

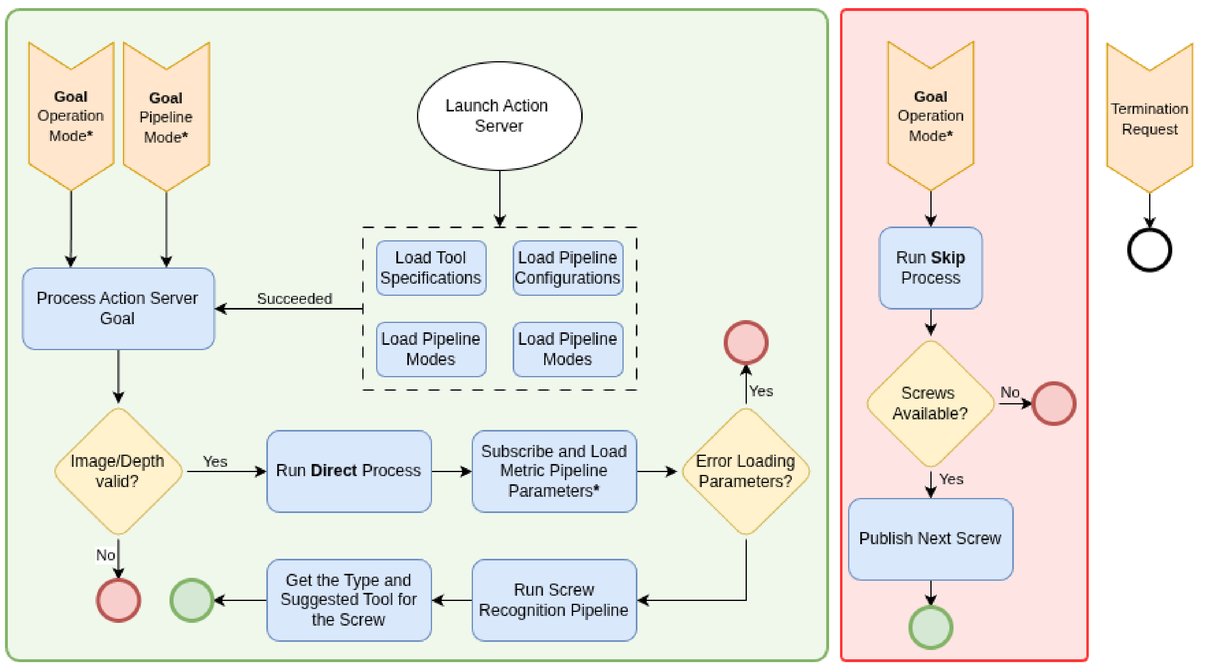
Automated disassembly is paving its way into a more sustainable and efficient e-waste disassembly. This paper presents a robotic disassembly skill for screw detection, classification, and tool recommendation, implemented as a modular ROS action server. The system integrates YOLOv11-based detection, contour matching, and RGB-D dimensional estimation to identify screw types and sizes, and **suggests appropriate tools** according to **ISO standards**. The framework supports direct recognition, enabling flexible integration into robotic pipelines. Experimental validation on a hard disk drive demonstrated a **detection recall of 94.7%**, accurate classification across multiple screw geometries, and consistent tool recommendations. The results confirm the system's capability to automate screw handling tasks with high reliability, supporting its deployment in robotic disassembly operations.



Contributions

- A system for screw disassembly, capable of detecting and classifying at least **10 types of fasteners**, including Screws (Philips, Torx, Security Torx, Slotted, Square, Hex, Pozi), Nuts, Bolts, and Washers. It also suggests the **best tool for unscrewing** each fastener and **returns a disassembly sequence**.
- A modular and flexible pipeline that allows **quick parameter reconfiguration**. This enables the system to retrieve only the necessary information, classification, sizes, or suggested tools, depending on the application needs.

System Architecture



- **Modular Pipeline**: The system's architecture is built around a modular ROS action server. It uses a YAML-based heuristic pipeline, allowing flexible configuration for different tasks, such as screw detection, classification, size estimation, and tool suggestion. The workflow has two main modes: Direct Process (full task flow, in green) and Skip Process (for iterating through screws, in red).
- **Classification & Tool Recommendation**: The system can classify at least 10 fastener types recommends tools based on the type and size of the screw. The size estimation is done via 3D point cloud data, using a RANSAC algorithm to fit circles to the screw's cross-sectional points.

Models Performance and Main Insights

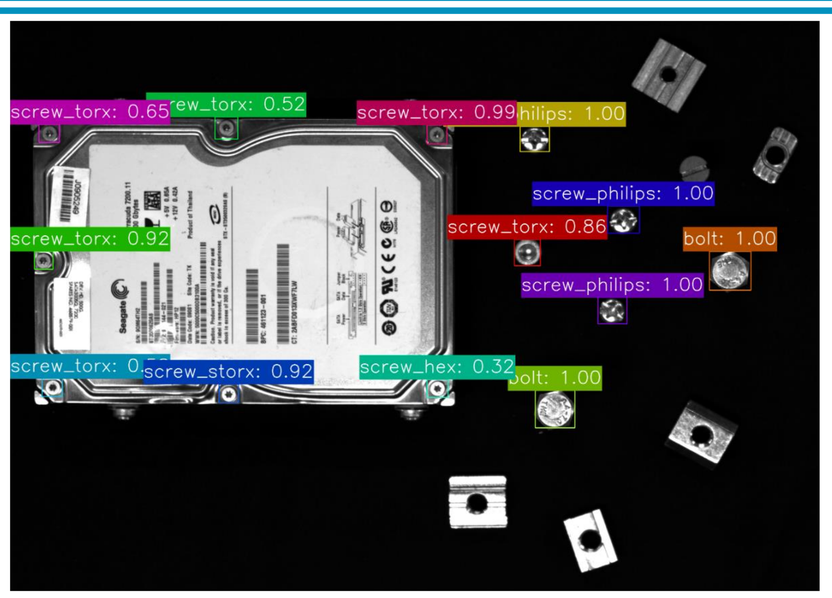
Training: Trained on a dataset of 20,000 images, achieving high recall (94.7%) with few false positives.

2D and 3D Localization: Combines RGB images and depth data for accurate 3D localization of screws.

Classification Performance: Varies by screw type, with high recall for Philips but lower precision due to resemblance with other types.

ISO Standards: Recommends tools based on screw type and size, matching ISO specifications.

Disassembly Sequence: Retrieves a sequence optimized both in distance and screw type.



Class	AUC	Precision	Recall	F1-score
Bolt	0.91	0.96	0.51	0.67
Nut_hex	0.96	0.92	0.54	0.68
Screw_hex	0.97	0.84	0.86	0.85
Screw_philips	0.95	0.39	0.94	0.55
Screw_pozi	0.91	0.92	0.49	0.64
Screw_slotted	0.93	0.66	0.73	0.69
Screw_square	0.95	0.93	0.74	0.83
Screw_storx	0.96	0.95	0.72	0.82
Screw_torx	0.85	0.40	0.69	0.51
Washer	0.96	0.74	0.39	0.51
mean	0.93	0.77	0.66	0.67

iBot4CRMs

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