JARVIS

ADVANCED PERCEPTION SYSTEMS: UTILISING MULTI-SENSORY SYSTEMS FOR ENHANCED SAFETY AND EFFICIENCY IN ROBOTIC

Funded by the European Union

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MULTI-SENSORY PERCEPTION IN JARVIS

IIn the EU-funded JARVIS project, several companies—including KUKA, TECNALIA, LMS, COLLINS, and CEA—are collaborating to develop a multi-sensory perception (MSP) module. This module combines artificial intelligence and classical machine vision techniques to transform raw sensor data into actionable insights for automation tasks across sectors such as automotive, aeronautics, nuclear, and offshore industries.
A key function of the MSP module is to feed real-world data into digital twins, bridging the gap between simulation and reality. This supports more accurate and efficient task execution and enhances planning capabilities.

Another essential component of the module is the collection of semantic information from the environment. Understanding the context and meaning of sensor data significantly improves decision-making, task planning, and overall system efficiency. AI algorithms process real-time data from both task execution and human operators, enabling the system to adapt and optimise its performance based on live input
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PROCESS OVERVIEW: PERCEPTION AND MODELLING

The perception process involves several stages:

1. 3D Reconstruction & Environment Modelling
2. The first step is acquiring and modelling the environment through 3D reconstruction. This creates a volumetric model using voxels or meshes.
3. Object detection and pose estimation then transform this model into a geometric representation using CAD models and abstract shapes (e.g. boxes, spheres).
4. Once the robot and sensors are fully calibrated, real-world data can be aligned with digital twin models, enabling the detection of discrepancies and anomalies.

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SUB-MODULES AND KEY ACTIVITIES

1. Environment Acquisition, Modelling & 3D Reconstruction

This sub-module focuses on:

- Developing visual SLAM and segmentation methods
- Registering point clouds with robust techniques
- Implementing autonomous exploration using next-best-view and voxel-based strategies

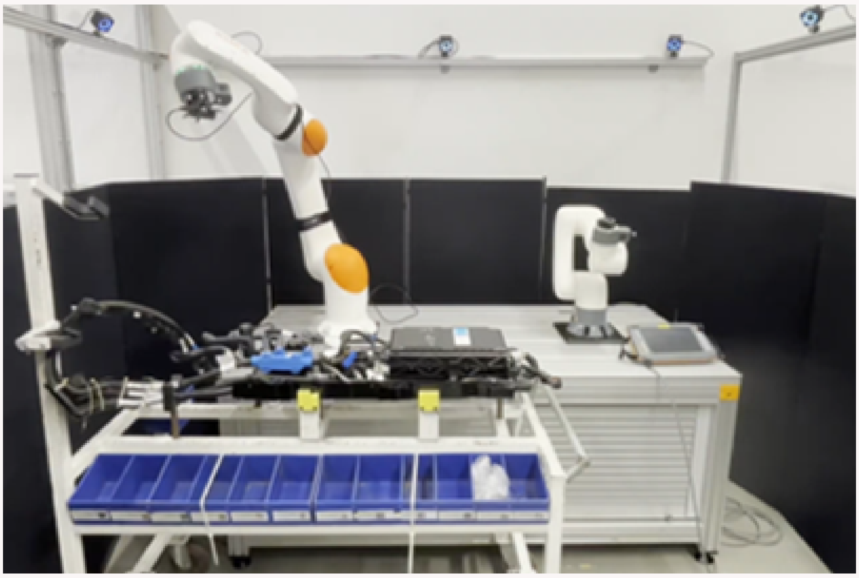

Figure 1: Setup for 3D reconstruction (robot, camera, TOFAS battery).

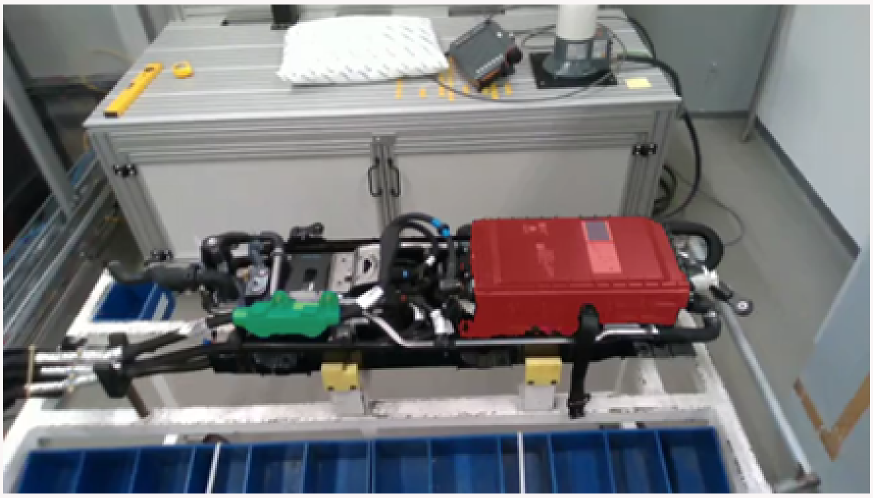

Figure 2: Segmentation (based on SAM2) of the battery during the reconstruction process

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Figure 3: Result of 3D reconstruction (based on ORB-SLAM3)

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2. Object Detection and Pose Estimation

Following environment modelling, this sub-module focuses on:

- Object detection for the TOFAS use case
- Screw tracking and 6D pose estimation
- Evaluation on the IMSOLD dataset containing industrial-relevant objects

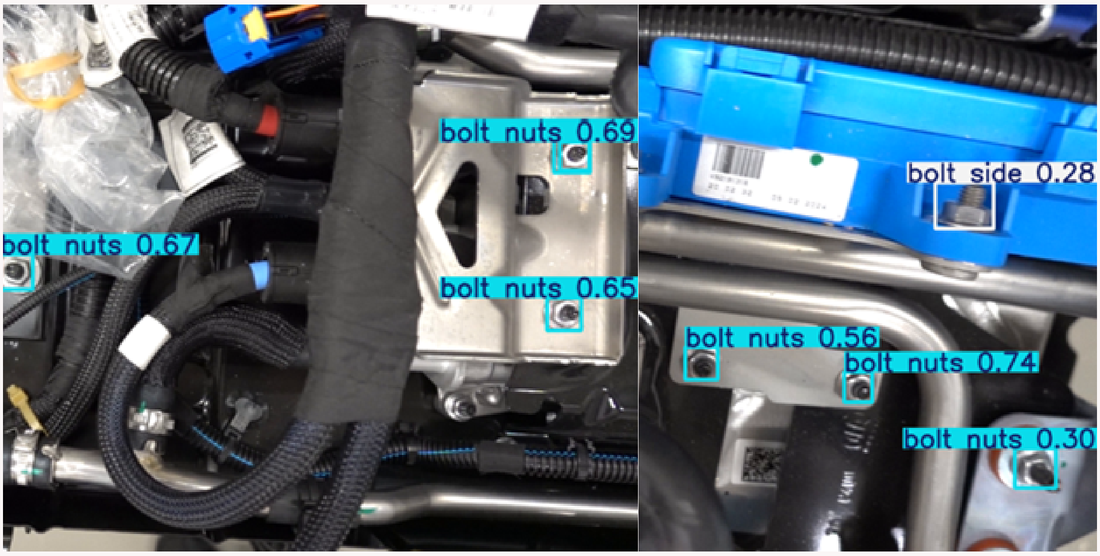

Figure 4: Object detection (screws) using Yolo

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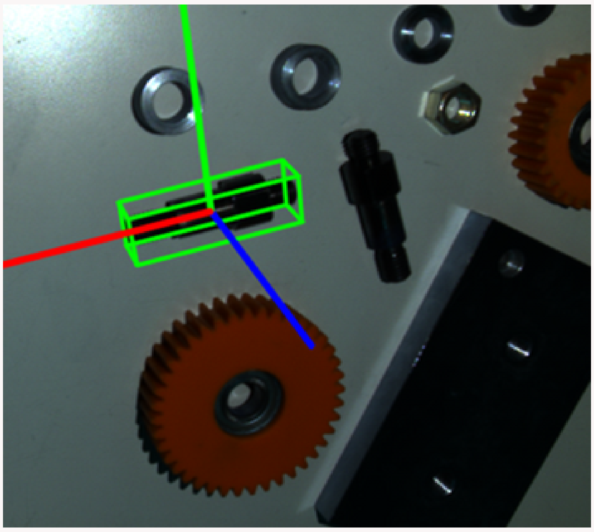

Figure 5: Object pose estimation on IMSOLD database using FoundationPose

3. Automated Calibration

This sub-module supports both intrinsic and extrinsic calibration for various cameras (ASUS Xtion, Roboception, RealSense, Zed2) in both static and robot-guided settings.
Calibration is managed via an RViz2 plugin for robot handling.

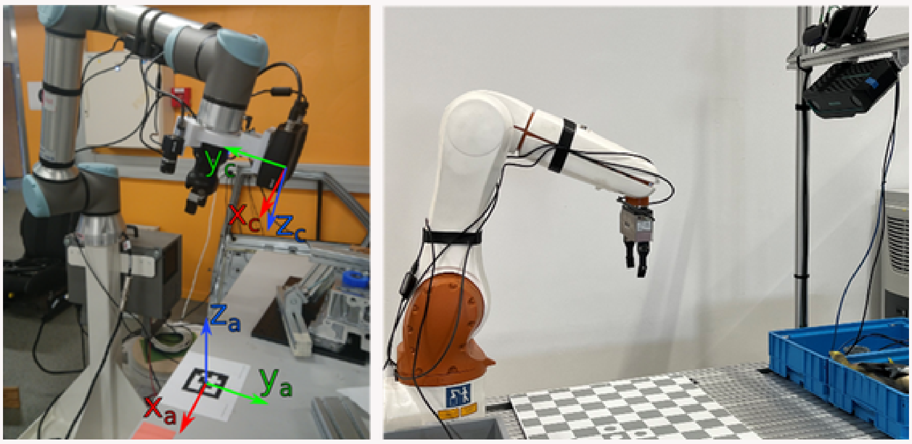

Figure 6: Calibration setup (UR and KUKA robots)

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4. Alignment with Digital Twin

This module ensures the alignment of CAD models with the real-world scene.
When models fit, they are overlaid onto the real scene; otherwise, tubes and planes are reconstructed for idealised alignment.
Goal:

- Facilitate teleoperation of robots in accurately modelled environments

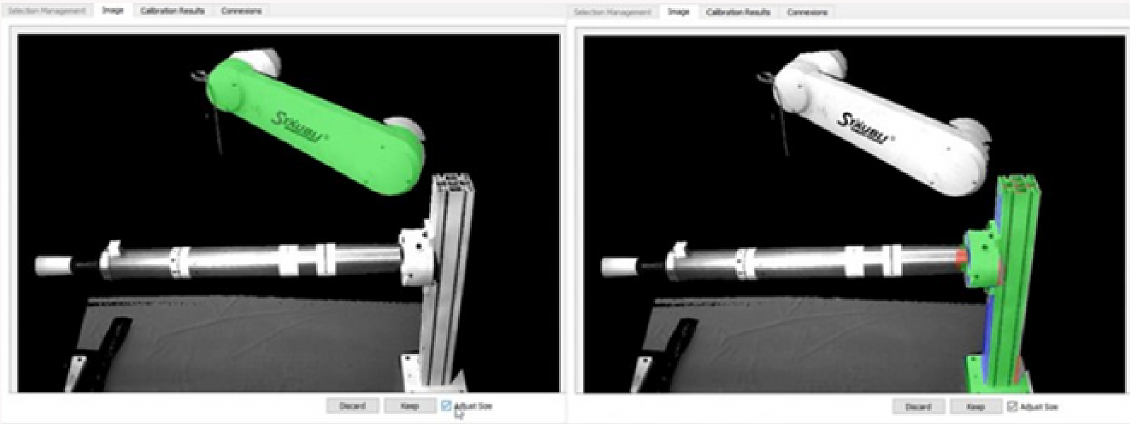

Figure 7: Alignment of the digital twin with the real scene data

5. ANOMALY DETECTION

Using RGB-D and force/torque data, this sub-module inspects tasks such as assembly and placement accuracy.
It identifies anomalies like faults or missing components, enhanced by generative AI and few-shot learning to reduce dependence on labelled data.

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Figure 8: Visual inspection of assembly task

SUMMARY: MULTI-SENSORY PERCEPTION SYSTEM

The MSP system—centred around vision-based sensors—enhances safety and operational efficiency by integrating data from multiple cameras using advanced machine vision algorithms.

By fusing inputs, robots gain a detailed environmental understanding, enabling more precise detection, navigation, and task execution.

Machine learning allows the system to:

- Adapt to dynamic environments
- Predict potential hazards
- Make real-time, data-informed decisions
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As a result, the MSP system provides a robust foundation for safer and more efficient automation across a range of industrial applications.

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