



Combined AI and Data solutions for AUTOMATION

Challenge 4.3

Semi-automated EV battery disassembly for recycling: introducing digital work instructions

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Challenge and context

Complex assemblies, such as EV batteries and motors, across manufacturers and vehicle models vary significantly. E.g., virtually each battery type has its own type of cables, bus bars, battery modules, and different types of cells. This variability makes the automation of EV drivetrain components dismantling for recycling challenging. Additionally, current EV batteries subjected to recycling are mainly Li-ion based, posing a multitude of hazards for recycling processes. Automating each process for each battery type is time-consuming and costly, if at all possible. Given the end-of-life state of such assemblies, there is often little to no reliable information on their internal composition, condition, or hazards. Therefore, battery recycling companies are (sub)consciously building a mental, written, or digital catalog of product-specific datapoints, based on the operator's experience. Capturing both operator actions and hazardous components (whether mechanical, electrical, chemical, or thermal) and subsequently registering them uniformly for each product type/variant would allow, on one hand, a more efficient manual disassembly for recurring models by integrating digital work instructions, and on the other hand, the opportunity to, where possible, automate specific hazardous, unergonomic, or repetitive tasks.

Use case and expected solution

A consortium partner has a laboratory for EV motor and battery dismantling available, with an industrial robot at TRL 4, specifically focusing on developing flexible human-machine collaborative demanufacturing processes. This partner has several technology blocks at TRL 4, leveraging computer vision and AI technologies from other areas, enabling the development of dismantling operations for different products without requiring specific robot programming for each. Another partner has significant knowledge and experience regarding, specifically, battery-related hazards and the required safety precautions. A missing key element is an operator interface that enables structured recording of manual operations, hazards, and status feedback, based on which the system can later present product-specific work instructions to the operator. All relevant product and process data should be logged in the Digital Product Passport (DPP), which can then be utilized to base future robotic/manual work instructions on. The consortium partners will support the selected SME by providing the following contributions:

- A suitable lab environment for the final demonstration, including a workbench setup with product clamping, a top frame for a projector and cameras, tool mounting, and demo case study products, including a dummy EV battery assembly and EV motors.
- A draft DPP data structure. The partner will demonstrate the use of the registered data in the DPP by the robotic disassembly system.
- In-depth knowledge and guidance in battery-related safety hazards.

Specification for use case

The consortium partners will guide and mentor SMEs to develop the operator's interface for a robot cell for semi-automatic dismantling of various EV component types, extending to overall mechatronic system demanufacturing approaches. In this solution, a human operator manually records operations on newly encountered products, of which some will later be performed by industrial robots and some, which a robot cannot perform, will still be performed by the operator, although supported by digital work instructions.

Expected solution

- Detection and logging of manual operations and hazards
- Detect and evaluate the manually performed operations, using common/smart hand tools (e.g.,

screwdrivers, pliers, cutters) and hand tracking (e.g., component pickup and component drop off), also incorporating hazard logging.

- Storage of manual operations and product data in a Digital Product Passport (DPP)

All relevant parameters (such as fastener locations and types, and relevant hazards) should be saved in a standardized digital format so that they can later be used to perform human-robot cooperative disassembly tasks on the same model type. All disassembly operations should be registered in such a way that a reusable (chrono)logical disassembly sequence is compiled.

Digital work instruction visualization

Intuitively display digital work instructions by projecting them on the workbench (2m width and 1,2 m depth) and on the product itself to reduce mental overload and to align instructions directly with the product and setup. To allow for the projection of markers and instructions on the complex geometries of the case study products, 3D mapping and multi-angle projection are required.

Hazard warning and monitoring visualization

Clearly display relevant operator safety instructions during manual disassembly. For example, highlight electrical contacts of battery modules that may still hold a charge, sharp objects, unknown chemical substances, warm surfaces, and other potential hazards. Use clear and unambiguous pictograms to reduce language dependence and support a safer working environment. In addition, proposals that include complementary monitoring systems are encouraged. This may include the integration of thermal vision systems, not only to detect potential thermal runaway events and trigger both local (work cell) and plant-wide safety alarms, but also to support monitoring, testing, and validation activities during disassembly operations.

Key Performance Indicators

Key Performance Indicators (KPIs) should clearly demonstrate the relevance and impact of the proposed solution. They must address at least two of the following dimensions: resource optimisation, Green Deal objectives, and social impact. All KPIs must be SMART (Specific, Measurable, Achievable, Relevant and Time-bound), ensuring they remain quantifiable throughout the project.

Resource optimization

- Position accuracy of the recorded locations: The position accuracy of the recorded locations and operations should be at least $\pm 10\text{mm}$ and $\pm 10^\circ$.
- Reduction in teaching time for new product types: Increase the speed at which a new product type can be taught for robotic disassembly by a minimum of 50%, comparing manual data logging versus the implemented technologies.
- Reduction in time for supporting and intermediate actions: Achieve a minimal time reduction of 50% for supporting and intermediate disassembly actions, such as tool switching, picking and placing components in designated bins, cutting cables, or repositioning the product. These improvements should be measured separately from primary disassembly actions (e.g., unscrewing or prying), which are not expected to be significantly impacted by digital work instructions.
- Completeness of hazard logging and visualization: Log and clearly display all relevant hazard warnings on component/location level.

Green Deal impact

- Improved recovery of components and materials: Increase the share of disassembly steps for which components, fasteners, hazards, and removal sequences are correctly logged in the DPP, supporting more consistent separation and recovery of valuable or hazardous (battery) materials.
- Reduction in mixed or incorrectly handled fractions: Reduce the number of components or subassemblies sent to mixed, unknown, or manual rework streams due to missing product-specific disassembly information.
- Reduction in repeated teaching and rework effort for recurring product types: Reduce the need to repeatedly define disassembly instructions for the same product type by reusing previously recorded DPP data and digital work instructions.
- Improved safe separation of hazardous battery components: Increase the share of relevant

electrical, thermal, chemical, and mechanical hazards that are logged and visualised at component or location level before removal.

Social impact:

- Improvement of operator workload and usability: Demonstrate a measurable reduction in mental and physical workload associated with manual disassembly by implementing projected digital work instructions. This should be evaluated by comparing a limited guided approach (e.g. with printed paper instructions) with the proposed system, in a manner similar to [1], using a structured assessment method such as the NASA Task Load Index [2]. Evaluation should consider mental demand, physical demand, temporal demand, effort, frustration and perceived performance, while maintaining at least the same task success rate.

[1] W. Mahy, D. Gors, B. Van Doninck, H. Qin and J. R. Peeters, "Projection-Based Augmented Reality to Support Human Intervention in Robotic Disassembly: A Case Study for Bike Batteries," 2026.

[2] S. G. Hart and L. E. Staveland, "Development of NASA-TLX (Task Load Index): Results of empirical and theoretical research," 1988.