Pioneering Automated EV Battery Recycling: Leveraging Synthetic Data and Reinforcement Learning for Sustainable Disassembly

Swiss Battery Technology Center

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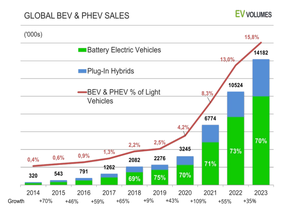
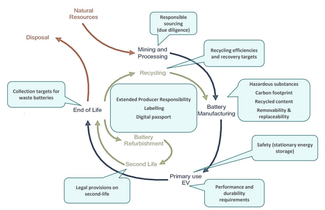
Motivation

Our goal is to enable automated battery disassembly to:

- Increase the recovery rate of valuable raw materials
- Reduce energy consumption in the recovery process
- Minimize risks such as short circuits and thermal runaway
- Contribute to a more sustainable **circular economy**



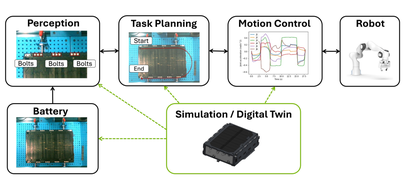


Challenges

- No available datasets including EV batteries
- Enormous variety of possible EV battery appearances
- Complex connectivity affecting detection performances
- EV batteries' end of life conditions are unpredictable
- Risks related to charged EV batteries handling

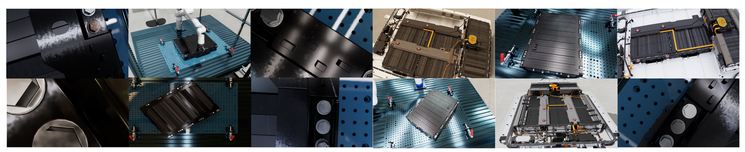
Contributions

- Developed the first synthetic dataset specifically for EV batteries
- Achieved 6D pose estimation of EV battery components
- Integrated real-time robot and vision systems using ROS2
- Trained reinforcement learning (RL) skills for robot-battery interaction in simulation



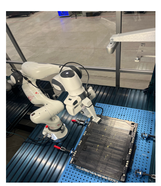
Synthetic data generation

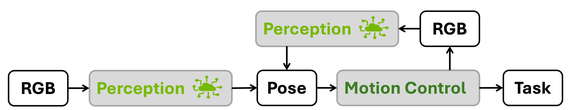
- Developed digital twins of batteries
- Modelled a realistic environment in Nvidia Omniverse [3]
- Generated synthetic data with Nvidia Omniverse [3]
- Trained detection models within the simulation environment



Setup & Pipeline

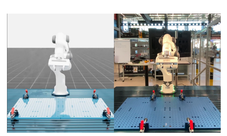
We present a modular pipeline for robotic interaction with EV batteries, utilizing a dual-camera setup. The first camera provides coarse estimations, while the second, mounted on the manipulator's end-effector, enables precise, real-time adjustments.





Sim-to-real for robotic skills

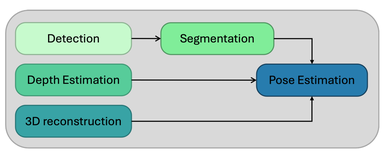
- Disassembly operations simulated using Isaac Lab/Sim [4]
- Robotic skills trained with RL (e.g., PPO)
- Applied domain randomization to facilitate sim-to-real transfer
- Successfully deployed trained skills to real robots via ROS2

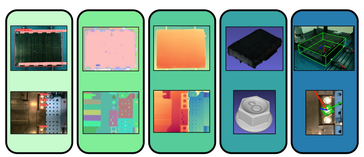


Perception

The perception blocks process RGB images to output the 6D pose of target objects. These blocks are modular and adaptable. Specifically, for 6D pose estimation of bolts, they consist of the following components:

- Detection model [7] trained on synthetic data
- Segmentation model [6]
- Depth estimation model [8]
- 3D data, either provided or generated by a 3D reconstruction model [10]





Results

Achieved successful sim-to-real knowledge transfer with:

- Detection precision and recall of battery parts exceeding 96%
- 3D position estimation of bolts with a precision of within 3mm
- Developed and applied learned policies for robot-battery interaction skills

References

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9) Wen, Bowen, et al. "Foundationpose: Unified 6d pose estimation and tracking of novel objects." *Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition*. 2024
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