

To Refurbish or not to Refurbish?

Towards an AI-based Evaluation System for Power Tool Batteries

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- **Research Interest:**
- Digitized Circular Economy
- Planning Systems for Automation Processes
- Digital Twin Design
- Cyber-Physical Systems
- Artificial Intelligence for Robotics

- **CV:**
- 2019: B.Sc. Energy and Raw Materials
- 2021: M.Sc. Petroleum Engineering
- 2021: Academic Researcher Center for Digital Technologies TU Clausthal & Ostfalia
- 2022: Academic Researcher Institute for Software and Systems Engineering



“The design of each element should be thought out in order to be easy to make and easy to repair.”

Leo Fender

Relevance of the Research

- Global resources are limited and therefore scarcity is increasing
- Repairing, Refurbishing and Remanufacturing (3Rs) of products can tackle those shortcomings
- Digitized Services can enable such operations on a broader scale
- Key elements are hereby a fast assessment of product conditions as well as an easy and clear structured repair process



Fig.1: Circular Economy loop



Scope of the Paper

- Two central subjects:
 - Systematic level of process conduction to enable refurbishing
 - Simultaneously acquisition of data on different levels to enable assessment support through artificial intelligence
 - Data set generation for image based assessment of power tool battery condition
- Contribution to the research question:
 - Conception of a system which is able to handle refurbishing operations while conducting data acquisition
 - Preliminary results drawn from the data acquisition





Problem Statement

- Discarding of products is easy nowadays
- 3R operations are hard to conduct because they are often time and resource consuming for the product user and challenging for the repairer because of a lack of information
- This leads to:
 - Increasing of waste due to discarded products
 - Resource and energy consuming processes for waste managing, recycling and manufacturing of new products
 - “Hoarding” of products out of convenience by end-users





Methodology and Key Features

- Systematic approach of the system was conducted with *Domain Story Telling* to:
 - Assess the necessities of the different stakeholders
 - Identify the potential data acquisition nodes
 - Clarify the responsibilities of the subsystems
- On the level of data acquisition, different approaches were used to:
 - Design the questionnaire sent to the End-User
 - Programming the automated image acquisition
 - Capturing the feedback of the operator

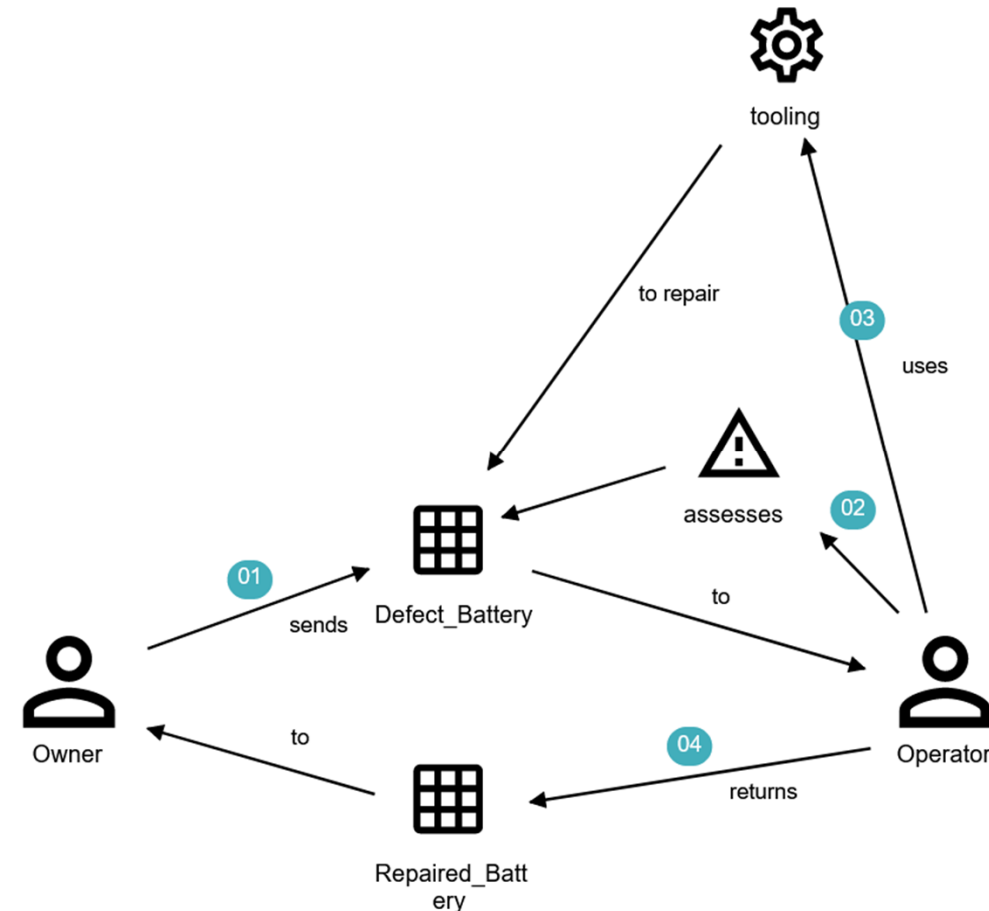


Fig.2: Domain Story of a typical repair conduction process (created with Egon.io)



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Systematic Design



- System consists of three main sections:

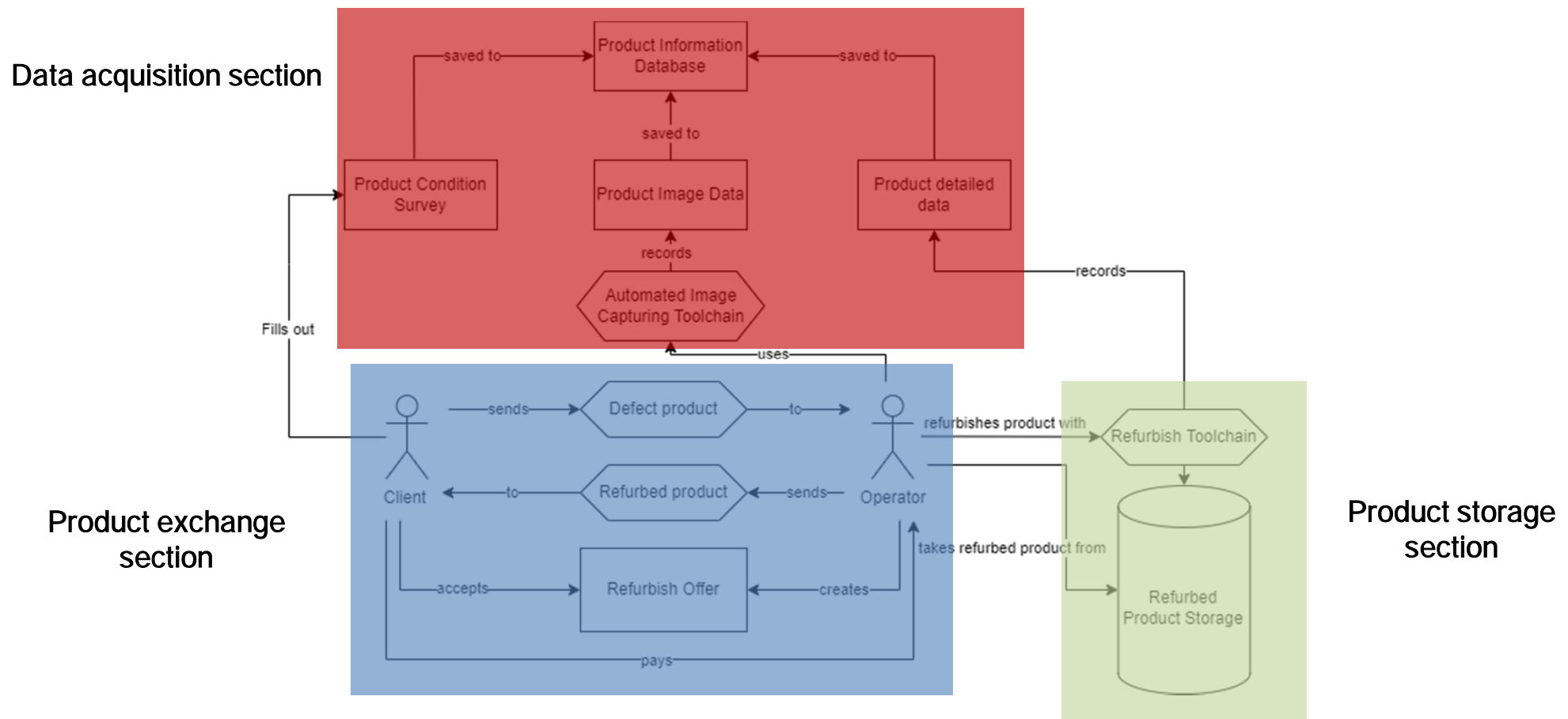


Fig.3: Overview of the subsystems of the Service Design



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Systematic Design

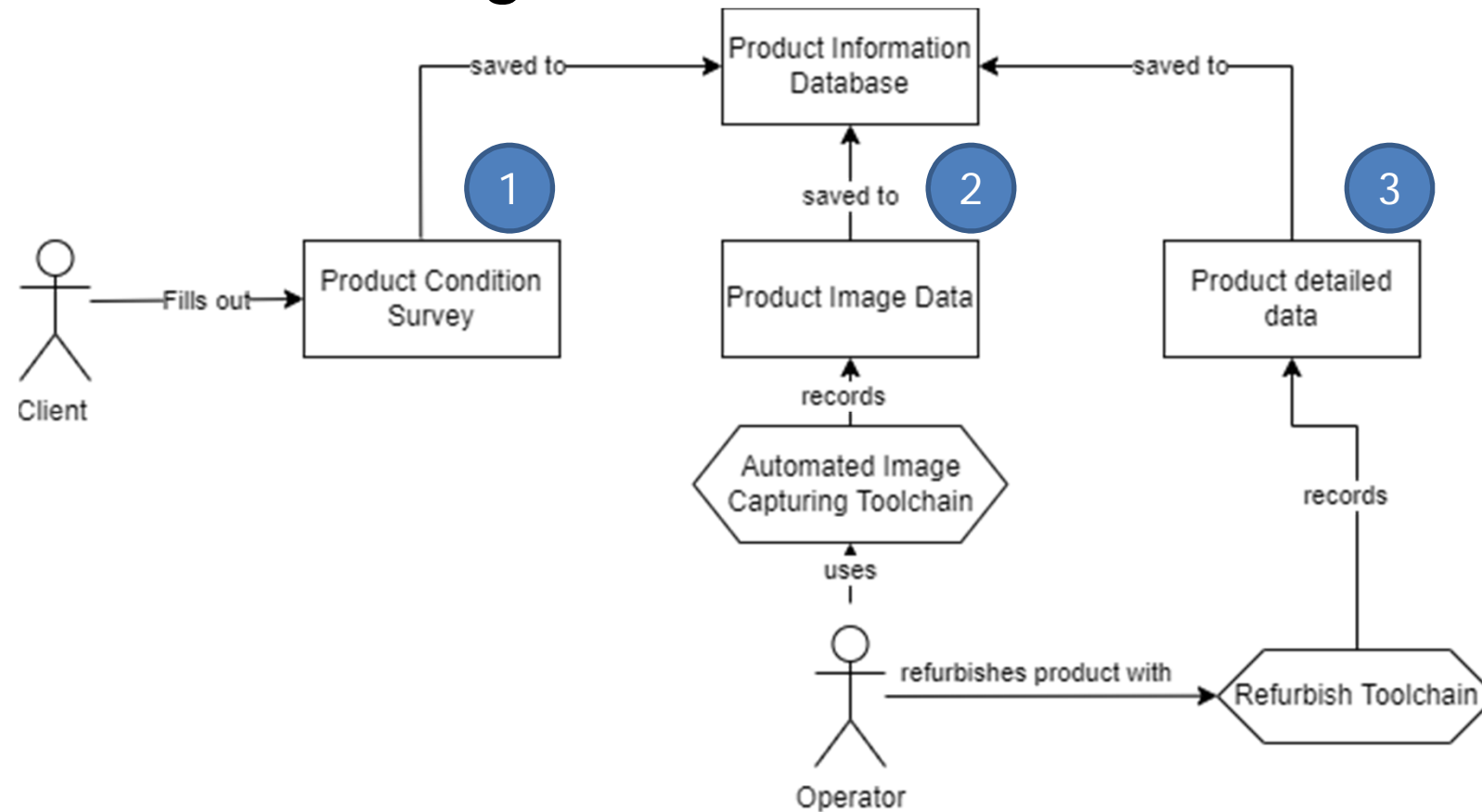


Fig.4: Data acquisition streams



1. Product Condition Survey

- Contains questions for a brief pre-assessment by the owner
- Contains questions assessing the:
 - Functionality of the battery
 - Usage of the battery (which product group)
 - Storage of the battery
 - Preferred business model (exchange and repair of the original battery, etc.)



2. Product Image Data

- Semi-automated System for Image data acquisition
- Total of 17 images were taken per battery:
 - Battery is recorded 4 times in topside position
 - Afterwards Robots turn battery
 - Battery is recorded from 4 sides in bottom side position
 - Label is recorded for additional data input
 - 2 different camera angles were used for the recording

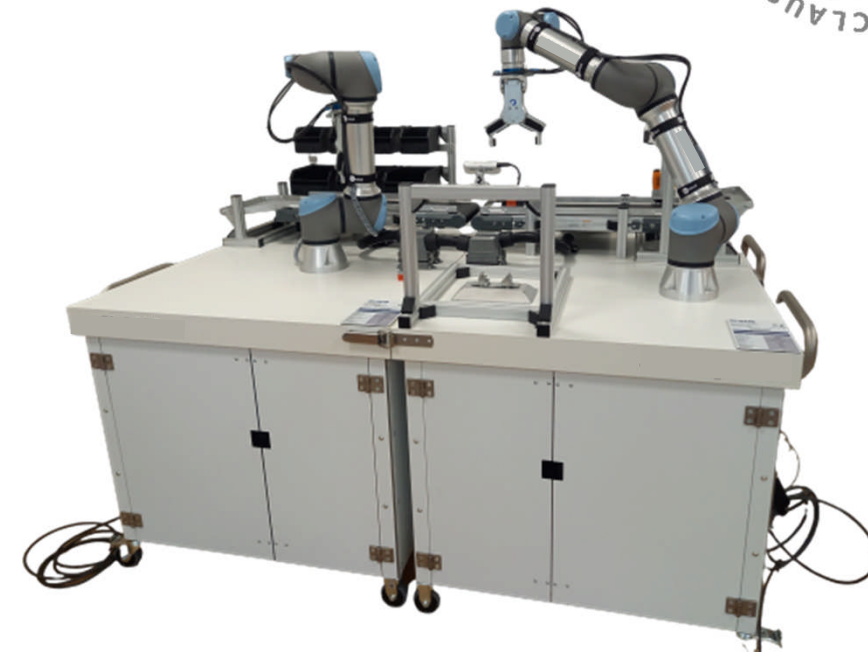


Fig.5: Automated Image Capturing Toolchain

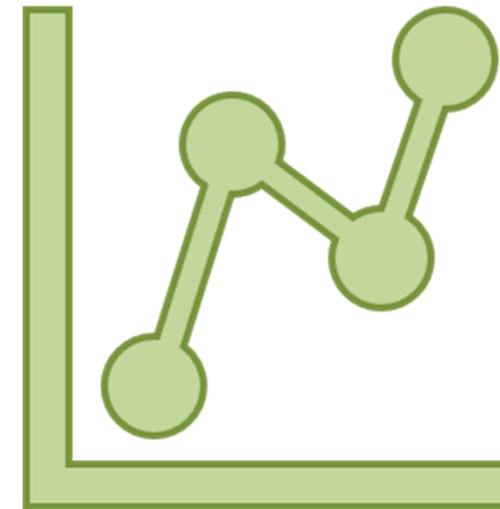


Fig.6: Recorded images of the power tool batteries



3. Product Detailed Data

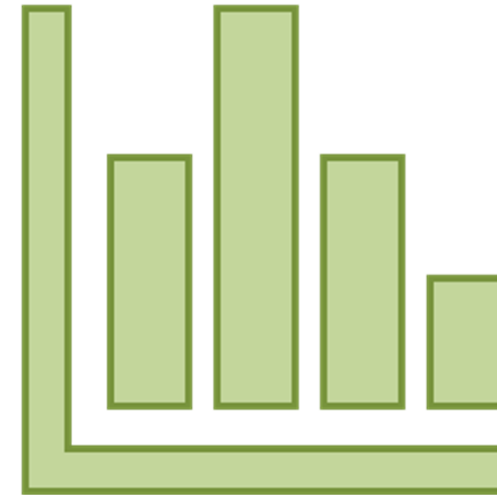
- Products are investigated in detail by the operator to assess condition
- The operator conducts the following measurement at a designed testing station:
 - Resistivity and electric current for each of the cells
 - Cell type
 - Manufacturing data
 - Resistivity and electric current for the battery in total
 - Remaining capacity of the battery
 - Cause of defect if determinable





Preliminary Results

- On a systematic level, we have found out that...
 - the concept proved applicable and Operators as well as End-Users already provided positive feedback
 - Automated image recording proved successful and applicable for data acquisition
- On a domain level, we have found out that...
 - So far evaluated battery packs feature mostly two types of error: deep discharging of the cells and degraded cells with low capacity
- However:
 - No evaluation of the economical impact of the system has been conducted on a system wide level
 - Data collection is still in progress
 - Applicability of the data for AI-training has still to be proved



Future Outlook

- Assessment of the product and its state is planned to be carried out by an AI
- Therefore, the model will be trained with the three different data inputs:
 - Questionnaire
 - Recorded images
 - Measurement data
- However:
 - Information selection process is still researched
 - Concept needs to be tested in different domains
 - Final evaluation will show the applicability of such semi-automated systems for 3R business models





Conclusion

- Designed system enhances 3R services by providing a suitable foundation for logistics and assessment
- Currently used data acquisition section will be decoupled once the artificial intelligence component is usable
- AI-based classification system will be linked to the system in order to further automatize the handling of products
- However:
 - Information selection process is still researched
 - Concept needs to be tested in different domains
 - Final evaluation will show the applicability in different domains!



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