TU Clausthal

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

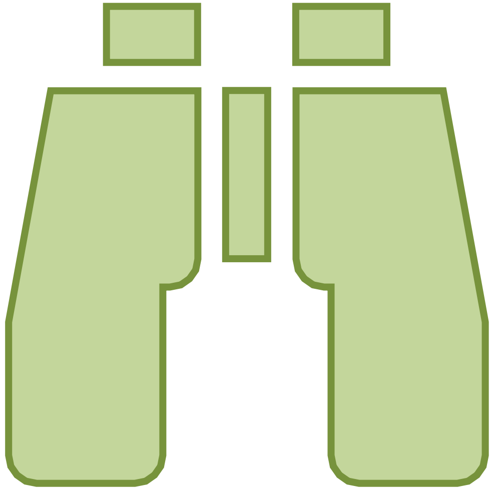
- Global resources are limited and therefore scarcity is increasing
- Repairing, Refurbishing and Remanufacturing (3Rs) of products can help tackle those shortcomings
- Digitized Services can enable such operations on a broader scale
- Key elements are hereby a fast assessment of product conditions as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

Fig.1: Circular Economy loop

https://www.digit-research.de/uns-kennenlernen/presse-und-news/downloads

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 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 from system conception and first incoming data



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

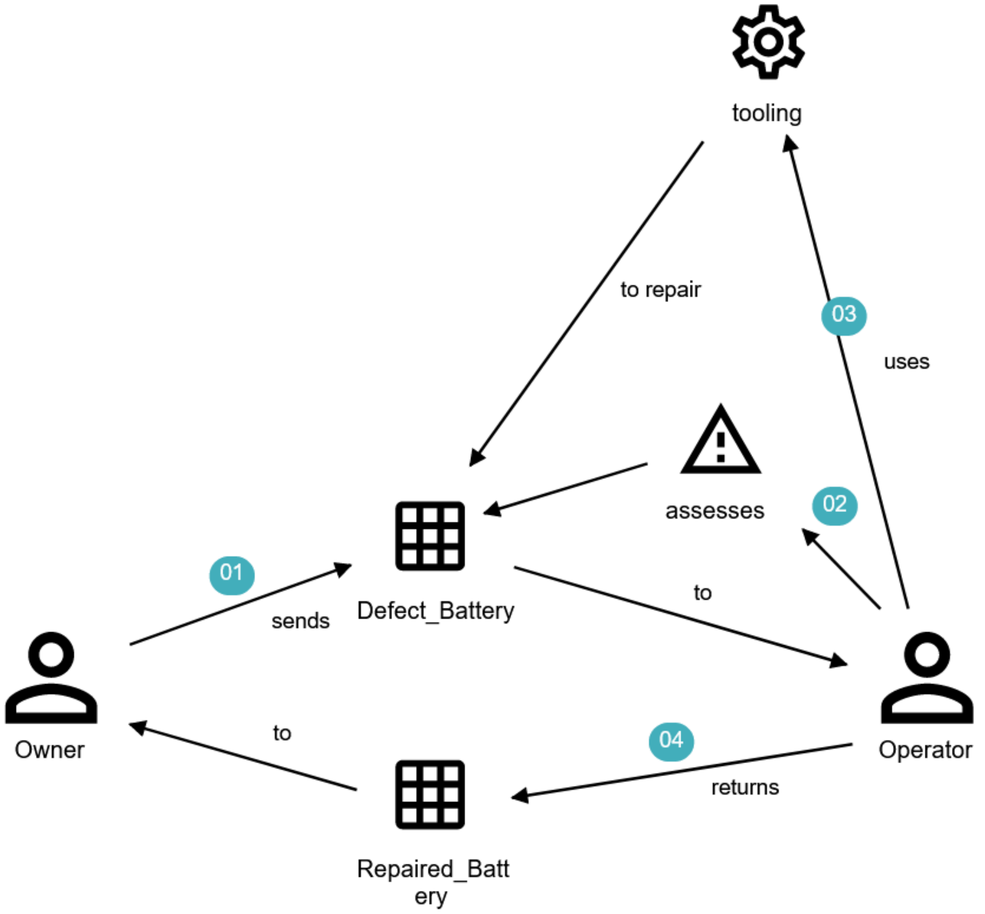


Fig.2: Domain Story of a typical repair conduction process (created with Egon.io)

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Systematic Design

- System consists of three main sections:

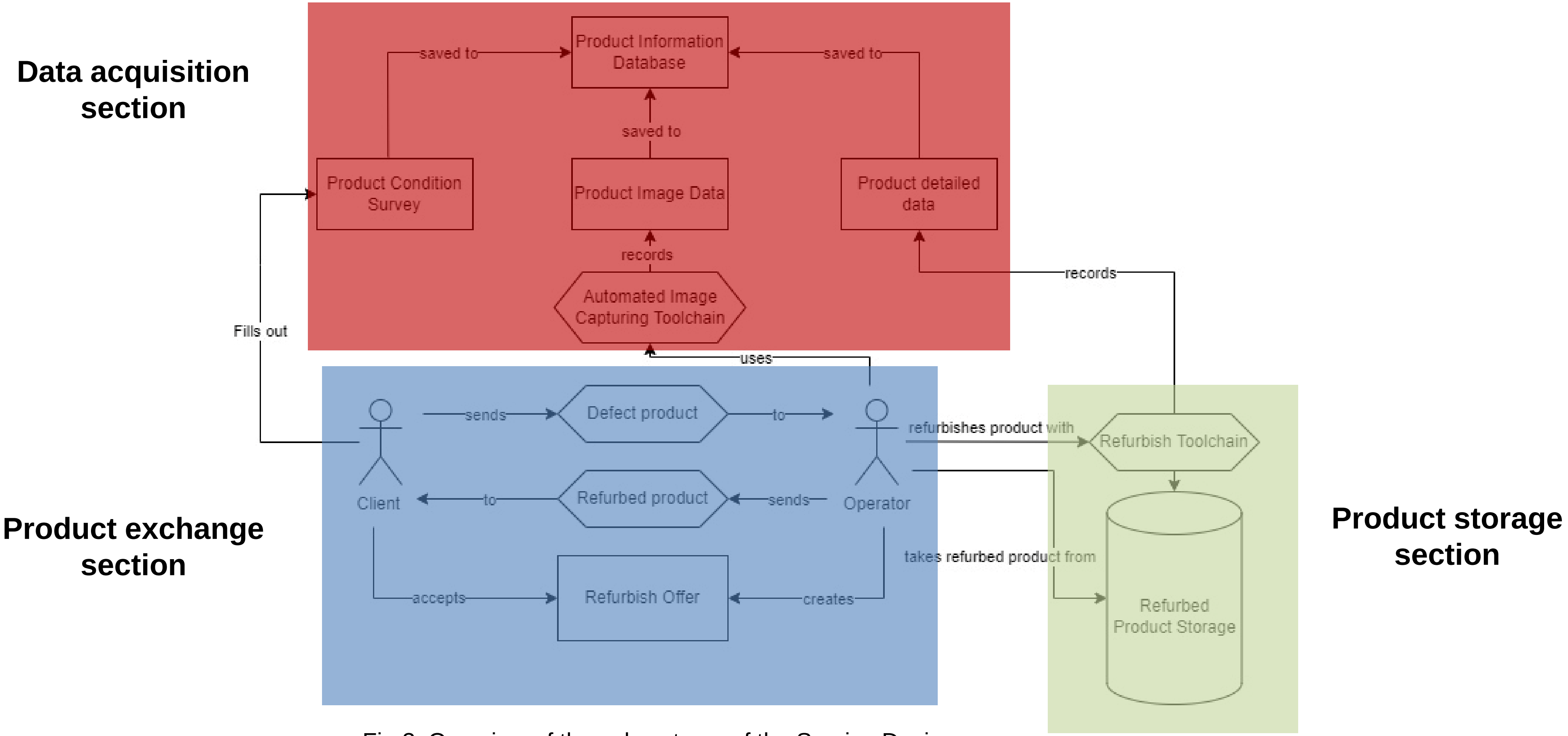


Fig.3: Overview of the subsystems of the Service Design

Systematic Design

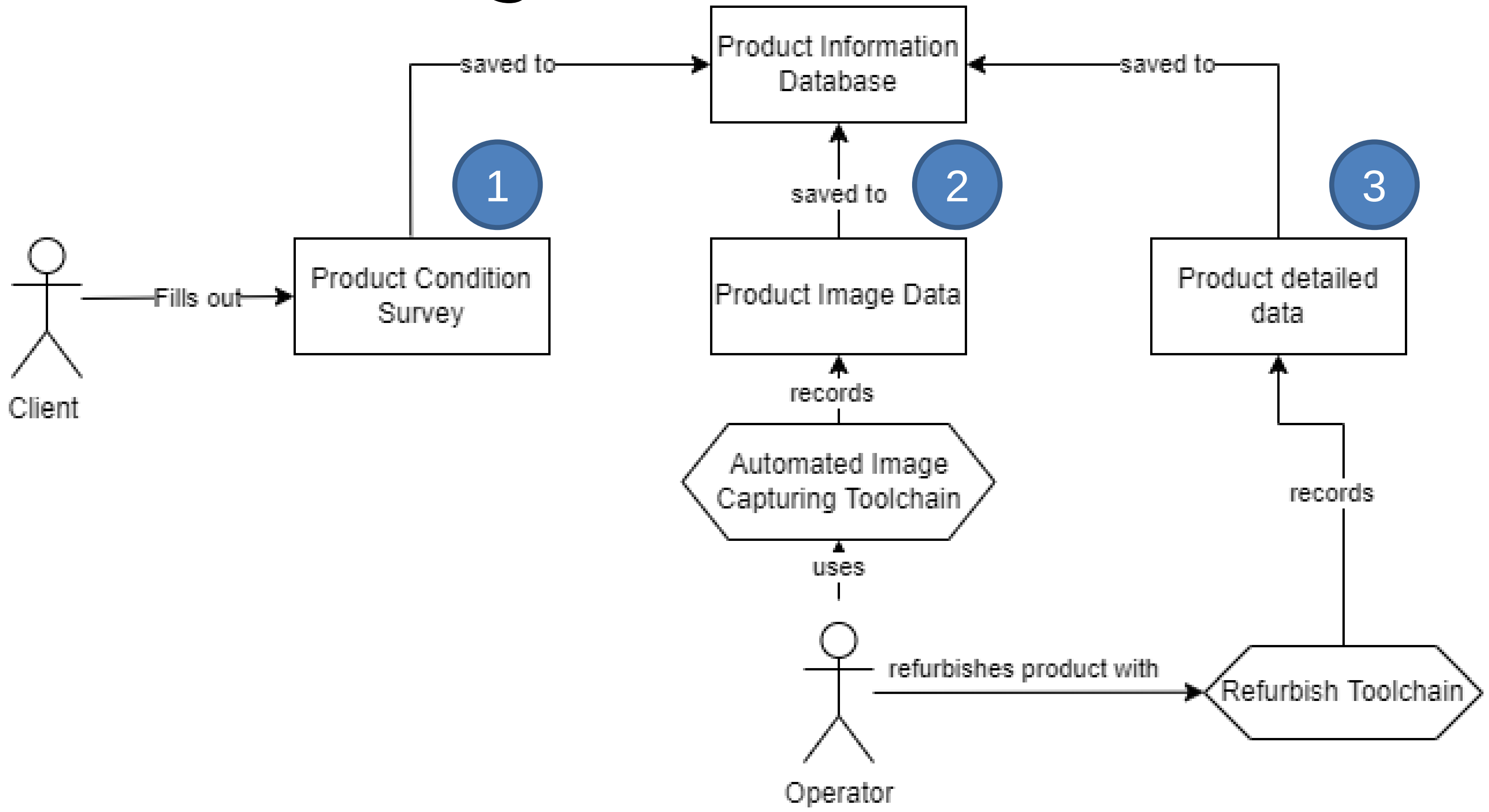


Fig.4: Data acquisition streams

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

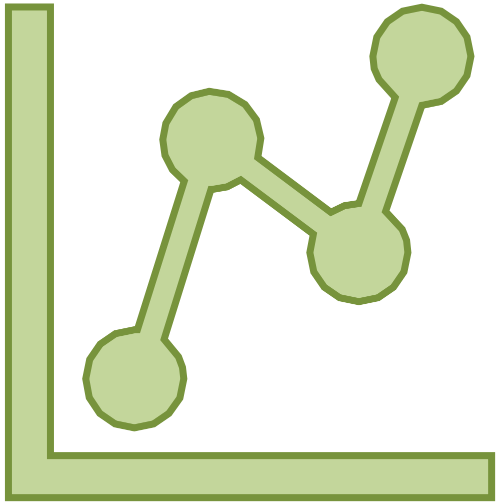
- Semi-automated System for Image data acquisition
- Total of 17 images were taken per battery:
  - Battery is recorded 4 times in topside position
  - Afterwards Robots turn battery
  - Battery is recorded from 4 sides in bottom side position
  - Label is recorded for additional data input
  - 2 different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

Future Outlook

- Assessment of the product and its state is planned to be carried out by an AI
- Selection of input data & parameters has to be carried out
- Therefore, three different data inputs can be used for AI training
  - Questionnaire
  - Recorded images
  - Measurement data
- Data has therefore need o be evaluated and pre-processed

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 is planned to 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 of the AI for this task

References

- [1] J. Grafstr¨om and S. Aasma, ”Breaking circular economy barriers, Journal of Cleaner Production”, vol. 292, 2021.
- [2] J. Kirchherr, L. Piscicelli, R. Bour, E. Kostense-Smit, J. Muller, A. Huibrechtse-Truijens, and M. Hekkert, ”Barriers to the Circular Economy: Evidence From the European Union (EU)”, Ecological Economics, vol. 150, p. 264-272, 2018.
- [3] C. Hagel¨uken, M. Schmidt, L. Schebek, and C. Liedtke, ”Opportunities and limits of recycling in the context of the circular economy: Framework conditions, requirements, and recommendations for action, position of the resource commison at the german environment agency (kru)”, June 2023.
- [4] G. D. A. Galv˜ao, J. de Nadae, D. H. Clemente, G. Chinen, and M. M. de Carvalho, ”Circular Economy: Overview of Barriers”, Procedia CIRP, vol. 73, p. 79-85, 2018.
- [5] M.Van Der Velden, E. Maitre-Ekern, and D. K. Wanja, The Role of Independent Repair in a Circular and Regenerative Economy. Circular Economy and Sustainability, pp.1-26, 2023.
- [6] S. Svensson-Hoglund, J. D. Russell, and J. L. Richter, ”A process approach to product repair from the perspective of the individual”, Circular Economy and Sustainability, 3(3), pp.1327-1359, 2023.
- [7] I. Güsser-Fachbach, G. Lechner, T. B. Ramos, M. Reimann, ”Repair service convenience in a circular economy: The perspective of customers and repair companies”, Journal of Cleaner Production, vol. 415, 2023.
- [8] M. D. Bovea, V. Ib´a˜nez-For´es, and V. P´erez-Belis, ”Repair vs. replacement: Selection of the best end-of-life scenario for small household electric and electronic equipment based on life cycle assessment”, Journal of environmental management, vol. 254, p.109679, 2020.
- [9] W. Steffen, K. Richardson, J. Rockstr¨om, S.E. Cornell, I. Fetzer, E. M. Bennett, R. Biggs, S. R. Carpenter, W. De Vries, C. A. De Wit, and C. Folke, ”Planetary boundaries: Guiding human development on a changing planet”, Science, 347(6223), p.1259855, 2015.
- [10] M. Sonego, M. E. S. Echeveste, H. G. and Debarba, ”Repair of electronic products: Consumer practices and institutional initiatives”, Sustainable Production and Consumption, 30, pp.556-565, 2022.
- [11] D. McLaren, J. Niskanen, J. and Anshelm, ”Reconfiguring repair: Contested politics and values of repair challenge instrumental discourses found in circular economies literature”, Resources, Conservation ‘I&’ Recycling: X, vol. 8, p.100046, 2020.
- [12] M. Young, ”The Technical Writer’s Handbook”, Mill Valley, CA: University Science, 1989.
- [13] M. Imaizumi, and K. Fukumizu, ”Advantage of Deep Neural Networks for Estimating Functions with Singularity on Hypersurfaces”, Journal of Machine Learning Research, vol. 23, p. 1–53, 2020.
- [14] E. H. Ahmed, and M. N. Moustafa, ”House price estimation from visual and textual features”, Computer Vision and Pattern Recognition, 2016.
- [15] S. Lathuili`ere, P. Mesejo, X. Alameda-Pineda, and R. Horaud, ”A Comprehensive Analysis of Deep Regression”, IEEE Transactions on Pattern Analysis and Machine Intelligence, vol. 42, issue 9, p. 2065–2081, 2018.
- [16] M. Tan, Q. v. and Le, ”EfficientNetV2: Smaller Models and Faster Training”, Proceedings of Machine Learning Research, vol. 139, p. 10096–10106, 2021.
- [17] X. Yu, Y. Xue, L. Zhang, L. Wang, T. Liu, and D. Zhu, ”NoisyNN: Exploring the Influence of Information Entropy Change in Learning Systems”, 2023.
- [18] K. Laitala, I. G. Klepp, V. Haugrønning, H. Throne-Holst, P. Strandbakken, ”Increasing repair of household appliances, mobile phones and clothing: Experiences from consumers and the repair industry”, Journal of Cleaner Production, vol. 282, 2021.

Thank you very much for your attention!