PhD Proposal : Design for Circularity (and 2nd Life of Components) and Artificial Intelligence

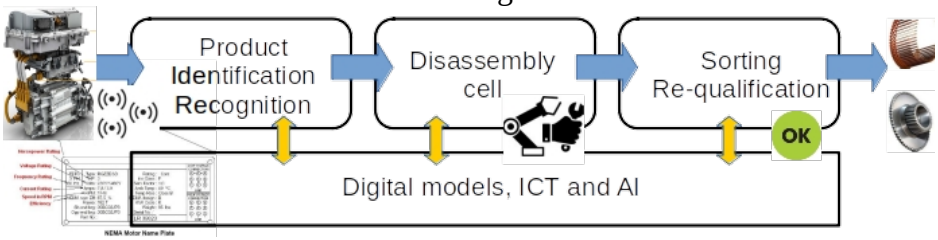
Arts et Metiers Bordeaux — I2M - Institute of Mechanical Engineering

Context of the project

This subject is part of a large project entitled SDC2 for Smart Disassembly Cell for Circularity.
Part of the work will be carried out on the Arts et Métiers campus in Bordeaux-Talence / I2M Institut de Mécanique et d'Ingénierie (project leader) in collaboration with other laboratories and structures in France.

The aim of this project is to develop methods, technologies and knowledge to provide solutions for the robotised disassembly of complex parts in order to recover functional (and therefore requalified) components or modules for 2nd life use in repair or as components in new products. Failing that, develop refined sorting technologies to move towards regeneration and recovery of high-value materials (recycling).

SDC2 at a glance



We therefore need to work with engineers, researchers and manufacturers on a process that:
a- identifies / characterises a product entering the process,
b- generates a range and disassembly operations (robotics / cobotics, automatic …),
c- monitors disassembly and (re)qualifies the recovered component,
d- assists in the decision to recover or not to recover on the basis of multiple indicators: market needs and criticality, residual performance, environmental and economic cost of operations, all fed into an AI to assist in the choice,
e- provides solutions for using 2nd life components in product design, aided by structured AI via design heuristics,
f- sends end-of-life information back to designers to facilitate and re-architect products for a circular economy designed from the outset.

PHD subject description

Working title: Ecodesign for circularity: development of a support environment for the integration of 2nd life components resulting from the disassembly of end-of-life products (based on expert knowledge and AI technologies).

To sum up, this research project aims to answer the question: How can we help find solutions for reusing components recovered from the disassembly of end-of-life products, other than in their initial context?

It is therefore important to formalise the business expertise of the designers and products involved (ontologies, heuristics, knowledge bases, etc.), and to develop or find AI approaches that help to navigate through the alternatives (identify them, evaluate them and help to propose the most relevant solutions) while integrating information on the criticality of materials and components (market view, material view, demand projection, etc.), as well as modelling the loss of performance of these components at the end of their first life and disassembly operations.

The scientific challenges are to use feedback to analyse products and contribute to rating processes (such as the demountability index proposed by the AGEC law, but also the future sustainability index planned for 2025) and to provide factual and quantified feedback to those who place products on the market. By translating the constraints and opportunities of disassembly/recycling solutions, as well as systematically analysing construction solutions, it is also possible to propose design orientations and strategies, product architectures and also to evaluate assembly solutions by developing methods for finding the best compromise between technical/economic/circularity performance. This work will help to enrich the material and product circularity indicators initiated by the E.McArthur Foundation. The I2M is taking advantage of its strong expertise in eco-design for end-of-life, built up through work with eco-organisations (Ecologic and Ecosystem) and their members (designers and recyclers). This subject is beginning to be addressed in the field of power converters in the Vivae ANR (bringing together academics and industry), with a PhD student starting in January 2022 on design methods in this sector, and with a post-doctoral student to be recruited in 2023 who will focus on the development of dedicated converter disassembly solutions.

In addition, it seems necessary to develop an environment to assist in the search for second-life components (from the designer's point of view) and to search for fields of application for second-life materials or components and to assist in the search for cases of application (from the recycler's point of view). An approach along the lines of Ashby's performance maps, applied to recycled materials on the one hand and components on the other, could be envisaged.
One of the aims of this work is to use AI technologies, data mining and learning to analyse a set of existing and known cases (multi-sectoral), and to classify the material/component associations and use cases into families of cases, looking in particular at the assembly or connection options. These approaches should be based on and inspired by the material performance indices and design choice aids developed by M. Ashby.

The first step will be to transpose the materials vision of Ashby's approach with a component/module vision and define the nature of the databases and indicators required.
In this way, a second life component or recycled material is analysed as a set of performances. It is therefore necessary, in the same way as for material data sheets, to propose structures for component performance data sheets by crossing multi-sectoral visions.
Finally, we will need to evaluate the various AI technologies, as well as knowledge formalisation technologies (in design, among other areas), to assess their suitability for use in the type of preliminary design assistance context. It seems necessary to combine guided learning approaches with ontology-based approaches for formalising knowledge.

The ultimate aim is to provide an environment to help choose usage domains and products. This is currently a key issue for the development of component and often material remanufacturing processes and solutions. This will make it possible to respond to the criticality of components and materials.

Design objectives and existing solutions must therefore be defined on the basis of functional definitions, enriched by the functions/solutions database, and processed using the AI solution. The method proposed by Prof. Ashby for the selection of materials based on material performance indicators will be extended and adapted to the search for component/module applications based on the performance characteristics of second-life components/products.
The various phases that should be carried out could be as follows:

- a formalism must be selected or defined for the functional representation and transform a design solution into knowledge for the AI (ontologies, heuristics, knowledge book, ..)
- a guide to help with the functional breakdown of the product to translate the overall design objectives and the specific local solutions (based on existing approaches such as Fast, SysML, SADT, etc.) to translate the design process,
- structure and populate a specific database linking the functionality and the solution, feeding design knowledge into the AI models
- propose an inference algorithm to ensure navigation and bijection between functional definitions and existing solutions, paving the way for automatic processing,
- propose automatic evaluation indices for proposed solutions to justify proposed choices.

This work will be applied to stimulate the circular economy with an assistant for a use case based on second life components (and their residual functionalities) or secondary primary materials (and their performances). This topic extends the work on design assistance, steering the way towards AI for end-of-life design.

Key words

- Circular economy, Urban mining, Critical components and materials, Recycling, Ecodesign
- Design method and approach, Artificial Intelligence, Knowledge-based digital engineering environment (ontologies, design heuristics, knowledge book), Decision Support,
- Second life components, Recovery of functional components, Qualification of residual functionality/performance,

Candidate profile

This subject is aimed at Engineering and/or Master2 level students who have either:

- a background in information sciences, applied mathematics, data management, and who want to experiment and develop in a context linked to the approaches, methods and engineering tools for the Circular Economy and Ecodesign,
- a culture of product design and choice of components/materials, and who want to discover, test, develop and apply AI methods structured on product and design knowledge, in an engineering context for the Circular Economy and Ecodesign.

This work will be carried out in collaboration with the University of Delft, Faculty of Industrial Design Engineering - Sustainability Design Research group (Pr.Ruud Balkenende and Dr Jelle Joustra and their team). One or more visits are envisaged.

Application

Please forward your application to the supervisors with :

- Curriculum Vitae
- a short message or covering letter on the proposed subject
- optional: one or more names of teachers to contact for recommendations.

If your application is accepted, it will be followed by a face-to-face or video interview.

Surpervisors

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