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Developing an Imaging Software for Automated Recycling Processes (Phase 1)

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Abstract. Several procedures have been proposed to overcome various challenges of product-content analysis after manufacturing and downstream automated recycling processes. These procedures have been restricted by factors such as the inability to determine exactly the physical state of the hidden parts of End-of-Life products. This inhibition among others has resulted into an explosion of solutions by researchers. This paper presents the initial investigations in the development of imaging software. The software supports a novel method of integrating scanned and digital imaging in material identification to overcome some of the existing shortcomings of automated recycling processes. The description of the software-algorithm structure and its centrality in post-manufacturing and automated recycling processes concludes this paper.

Introduction

Reuse and remanufacturing of End-of Life (EOL) manufactured products such as Waste Electrical Equipment (WEE) and Mechanical Waste Components (MEC) are a matter of current concern, driven by economic, ecologic, social and legislative factors [1]. Different methods are emanating from various researches in automation of recycling processes to support measures of monitoring and controlling major life-affecting areas as dictated by world ecological and environmental Standards. [2]

There are setbacks in designing robust automated systems due to arbitrary changes in the condition of recyclable/reusable products. These conditions may include: damage physically, rust, missing components and replaced components. Therefore, for effective detection and product sorting process, there is a need for a cost effective and suitable automated visual analysis. This can be accomplished by installing scanning and image processing technology that provides information about the state of the product as well as an account of the hidden parts (i.e. undetectable parts by naked eye or photography) it contains [3].

The approach considered in this paper focuses on integrating imaging techniques at the downstream of recycling procedures. The repertory software developed will be capable of performing product-content analysis, pre-sorting, pre-classification of products and generation of material content information to be communicated with disassembly sequence planning. Discussed in this paper is the present-state and future research on repertory software capable of storing and linking product content information from manufactures to demanufacturers. The features of the software and its integration into demanufacuturing processes have been fully discussed [3]. However its centrality in the complexity of remanufacturing considering a close-loop economy [1] is considered in this paper.

Review of Research on Software Application in Automated Recycling Processes

The two important aspects in EOL research [4] are recycling cost and environmental impact. These aspects form the basis for the development of any recycling strategy. The introduction of computer-aided methods at various stages and aspects of recycling is one of the means by which cost and environmental impact are reduced.

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Considering cost reduction, an approach [1] was presented for the design, evaluation and implementation of remanufacturing processes in a given facility. The approach was actualized in a developed graphical user interface (GUI) that assists the planner to visualize the developed remanufacturing process in the form of a network. Researchers [5] also focused on cost and time reduction by creating an object/component oriented requirements analysis method and software tool. The method enabled enterprises to analyse and design all critical aspects of their user interfaces for product/process design, manufacturing, demanufacturing, and other processes, including total quality control and even software engineering over the web and/or their company intranets. A Computer-aided recycling process planning (CARPP) model was also developed [4] for end-of-life electrical and electronic equipment. The system calculates and analyses the environmental impact and cost of the recycling processes. The CARPP starts by gathering the material breakdown of given product and passes this information to the recycling process planner module. It also identifies any hazardous material requiring selective treatment to assign feasible and appropriate recycling processes.

Relating to environmental impact, research on eco-sustainable energy and environmental strategies in design for recycling was performed [6] Software named "ENDLESS" was developed and used to address the design process towards more eco-compatible solutions. In particular, this tool supports the designer in the choice of the product with a higher recyclability potential from a set of different alternatives. A commercially available software system ProdTect [7] supports the development of ecologically sound products by providing information related to a product's treatment and recycling at an early product development stage [8]. ProdTect calculates technical, economic and ecological parameters. The resulting data, such as disassembly times and sequence, can then be utilised for the planning of the end-of-life processes for a product [9].

Most of the software applications discussed are for recycling process planning with few addressing EOL product-content analysis and sorting as discussed in this paper. The principle of computer vision-based sorting (similar to that presented in this paper) was applied not to EOL products but to Antlatic Salmon fillets according to their colours [10]. The images of fillets were captured using a digital camera of high resolution. Images of salmon fillets were then segmented in the regions of interest and analyzed.

The Imaging Software

Shown in Figure 1, is the overall structure of the imaging software. The MATLAB codes comprising the image processing module and the graphical user interface (GUI) tools were used in its development. The structure comprises algorithms for (i) updating the database base product attributes, (ii) searching the database for product information, (iiv) image sorting and classification analysis of EOL products. The structure and type of attributes contained in the software database are shown in Fig. 2. The scanned and digital image attributes are obtained using appropriate scanners and cameras respectively by the software operators. Shown in Fig. 3 is the interaction for updating the database with image attributes.

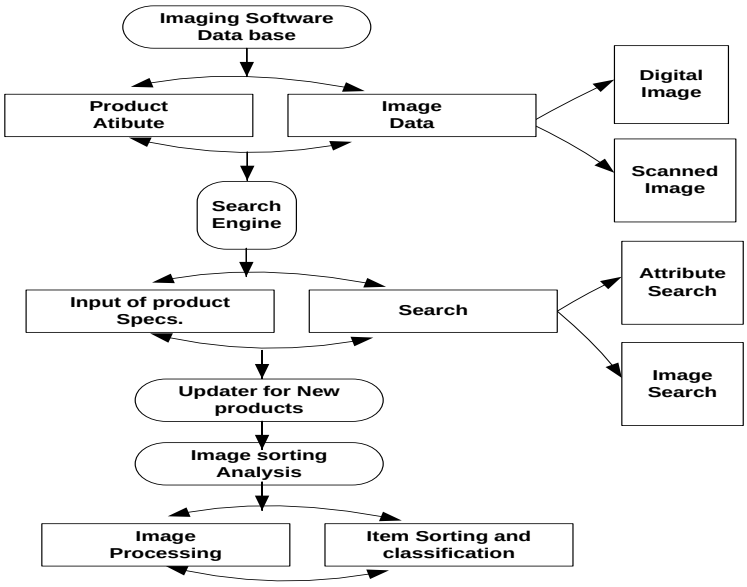

Figure 1: Overall Structure of Imaging Software

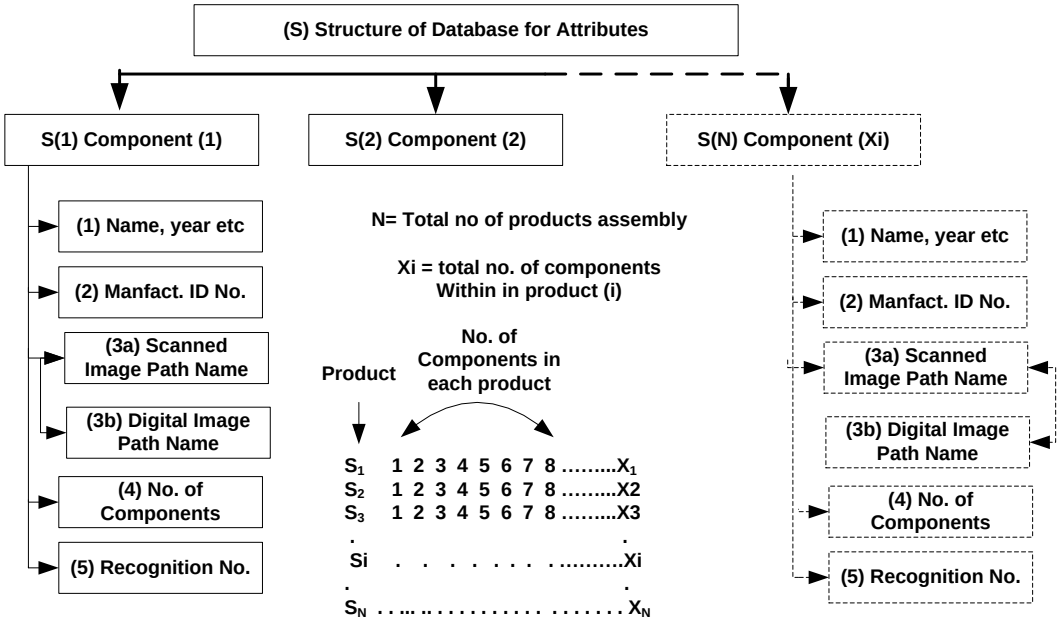

Figure 2: Structure of Software Database

The Centrality of the Imaging Software in Remanufacturing

Research [1] has also shown that fourteen actors involved in a closed-loop-economy and complex remanufacturing relationship. In relation to this work, the centrality of the developed software is explained by its incorporation in the remanufacturing complexity presented by earlier researchers [1] in Fig. 3. The original equipment manufacturer (OEM) supplies information such as product attributes, scanned and digital images to the imaging software. This information is later used for product-state monitoring by the distributors and retailers before selling. Herein products with factory faults are returned before getting to the users by the application of the imaging software. This aspect is different from earlier work [1]. At the collection and remanufacturing centers the Software is used in analyzing the hidden contents of the EOL products and electronic sorting is done based on the result of the content analysis. Based on the result of sorting, distribution of the EOL products to various actors is done. Users at the retailers' centers may also know the state of the product purchased using the imaging software.

At the initial stage of development (Figs. 4 and 5), the imaging software uses the concept of image subtraction [11] for product-content analysis. The dark image at the center in Fig. 5 shows that the product analysed at (EOL) has the same internal contents as at beginning of life (BOL). Future works entails the application of neural networks in image processing for the detection of (i) foreign objects (ii) shape defects (iii) absence or excess of products (iv) overly compacted products (iv) object position (v) missing items and item count (even if parts overlay).

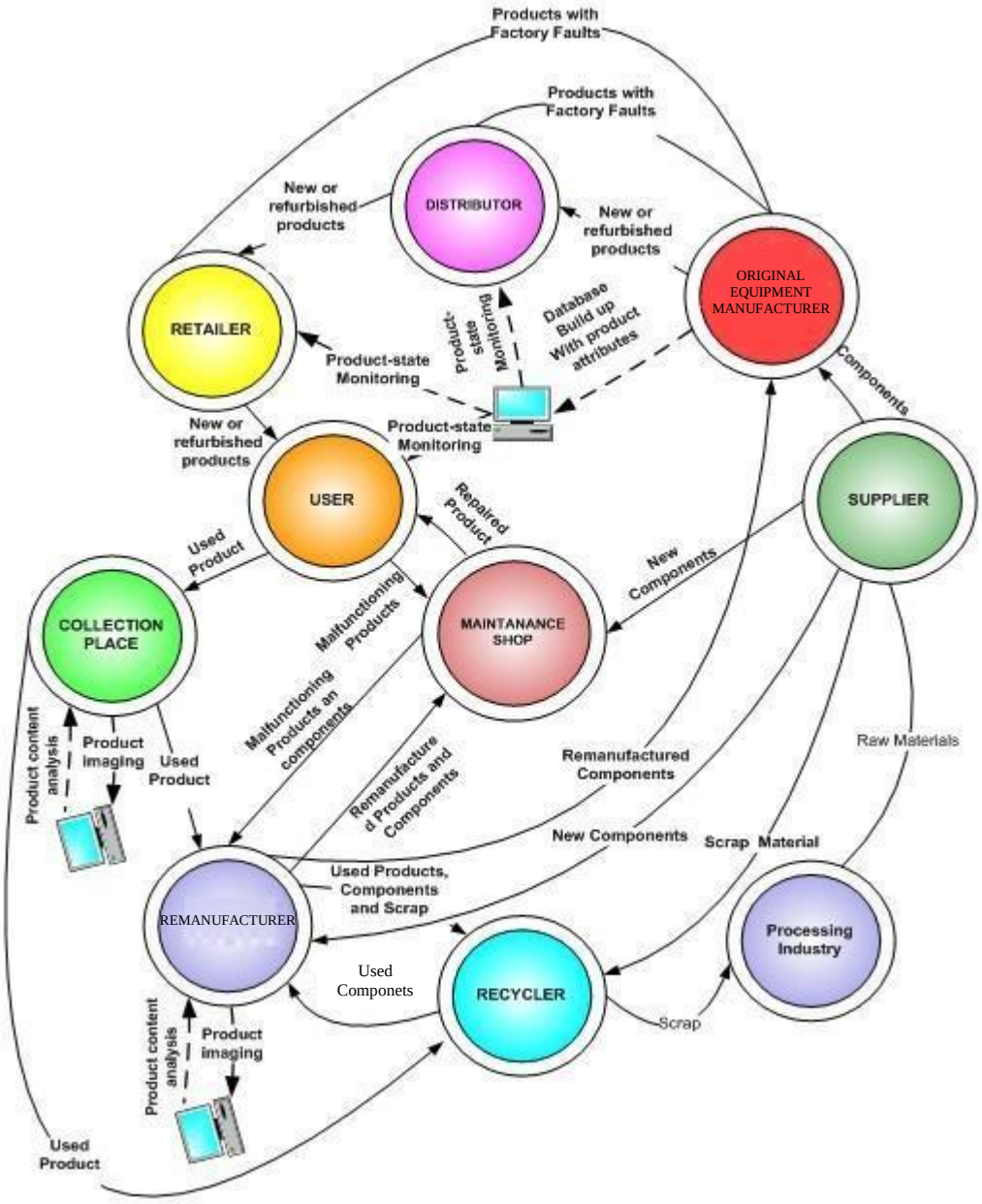

Figure 3: The Centrality of the Imaging Software in Remanufacturing.

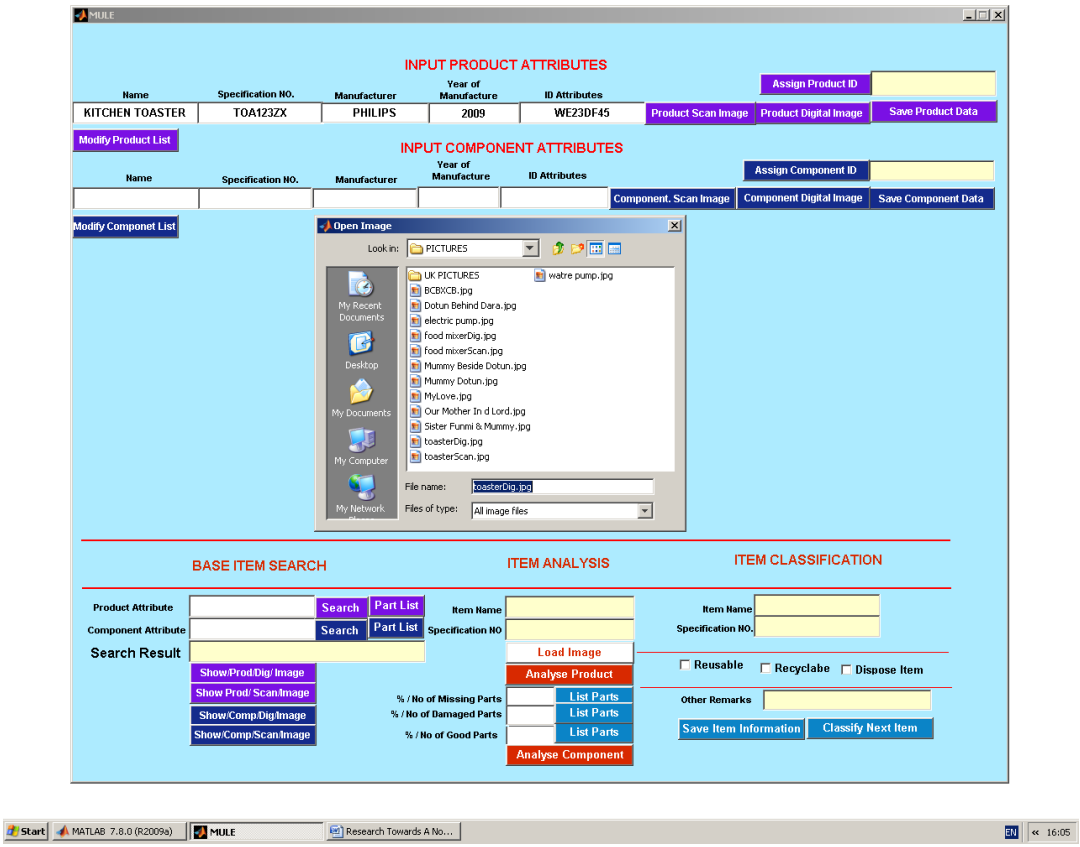

Figure 4: Updating of Software Database with Toaster Attributes

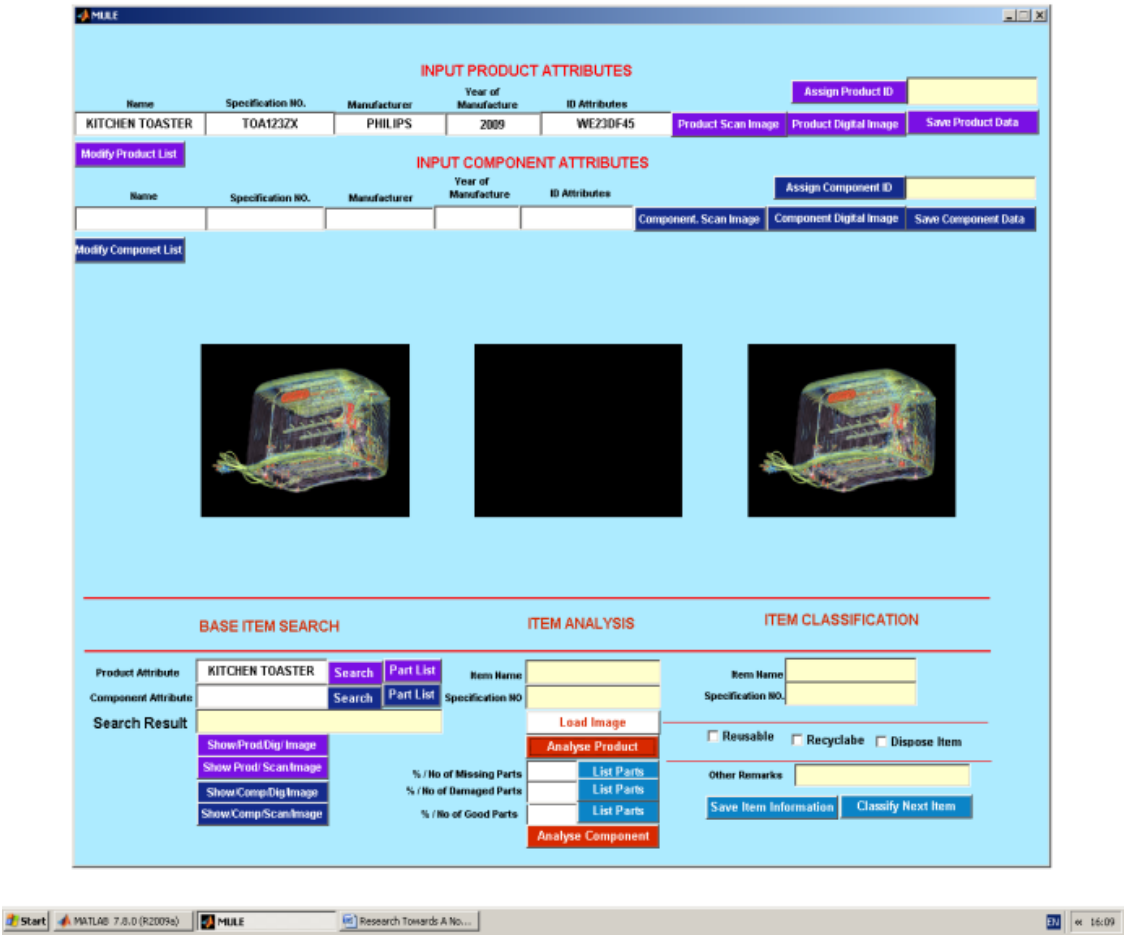

Figure 5: Content analysis of Kichen Toaster Using Software

Summary

The integration of image sorting software in the automation of component remanufacturing activities is an approach that supports the implementation of various researched methods and models. Researchers in the recent years have increasingly stressed the need for the integration of imaging and materials identification techniques in automation of industrial recycling processes. This work discussed some of the computer-aided remanufacturing processes and thereafter presented the centrality of the proposed software in remanufacturing activities. The proposed product scanning and content analysing software has four distinct models namely, the repertory database, search engine, product-attributes update and the image sorting and classification. The overall structure consisting of the four modules describes the functionalities of the software. An overall assessment of the effect of applying the developed technique in various aspects of recycling processes suggests an improvement to general process of automated industrial recycling.

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