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NONDESTRUCTIVE DISASSEMBLY PROCESS OF TECHNICAL DEVICE SUPPORTED WITH AUGMENTED REALITY AND RFID TECHNOLOGY

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Abstract: This paper presents nondestructive disassembly process of technical device supported with augmented reality system and RFID technology. During the last few decades, the rapid development of automobiles, electric and electronic equipment, resulted in creation of billions tons of waste. For instance, "around 3 billion tons of waste are generated in the EU each year - over 6 tones for every European citizen. The new recycling/reuse concept uses the nondestructive disassembly process of technical device supported with augmented reality and RFID technology. System includes marking the products with components of interest by using a RFID tag. The products can be marked with a RFID tag that will contain the ID of the product design in the centralized database. The recycling/reuse facilities use this ID to download data relevant for nondestructive disassembly of the product and obtaining the components of interest. The system is modular and extensible in terms of the services and re-manufacture offered. The overall system has a forum that is helpful in communication between recycling/reuse facilities and product designers. Augmented reality system offers video presentation when possible to visualize the disassembly process. The database contains valuable data for the product regarding the materials and component of interest used for each of the components in the product. Main objective of this paper is developing of a new recycling/reuse concept by using the nondestructive disassembly process supported with augmented reality and RFID technology.
Keywords: disassembly, reuse, augmented reality, RFID

INTRODUCTION

Waste created by obsolete equipment and other machine assemblies and white goods becomes actual problem in the modern society. This problem is interesting for investigation for a lot of institutions and scientists. The problem arises from the nature of these products. For some reason some of the parts inside the assemblies should or must not be destroyed along with the whole product. Some parts from the product are valuable for reuse, remanufacturing or recycling and should not be deposited, this means that the component can be reused avoiding the whole refabricating of the component. Other products cannot be discarded along with the other materials because they are toxic and need to be discarded in specialized facilities. During the last few decades, the rapid development of automobiles, electric and electronic equipment, resulted in creation of billions tons of waste. For instance, "around 3 billion tons of waste are generated in the EU each year - over 6 tones for every European citizen [1]." The extensive usage of personal computers arises the question for the privacy of the data discarded along with the device. Some companies acquire certificate for proper data destruction. The list goes on and every product may or may not have some part that needs to be extracted by hand before it is all discarded or recycled for reuse of the materials. Facilities for proper recycling of this assemblies are created that will discard or obtain these parts in a proper manner. Because of the different nature of different products there are facilities specialized for each of the products. For example facility for batteries, facility for recycling of computers and other IT equipment, facilities for recycling refrigerators because of the environmentally hazardous CFC-12 or other materials used in the cooling process etc. We believe that there is place for improvement in this process.

Current legal regulations clearly indicate that the technical products should be designed considering the recovery of the product at the end-of-life stage. In Europe, the designers have to follow European directives for environment protection such as Directive 2000/53/EC for end-of-life vehicles [2] and 2002/96/EC for waste electrical and electronic equipment (WEEE) [3]. The designers have to incorporate the directives into the product design in order not to pollute the environment or reduce the impact of pollution to a minimum level.

BACKGROUND

This paper deals with problems on how to reduce hazardous substances in products, to prevent pollution of the environment and to incorporate design for the environment early in the product design stage in order to facilitate product dismantling and recovery, and to achieve the quantified targets for reuse, recycling and total recovery.

Augmented Reality (AR) points out to be a good technology for training in the field of maintenance, assembly and disassembly, as instructions or rather location-dependent information can be directly linked and/or attached to physical objects. The products contain a large number of components, such us screws, plugs, etc., and their location is important from aspect of the product assembly and disassembly. AR-based training takes place with the real physical devices of the training scenario [4]. Based on the principle of perspective projection, the 3D virtual scene in AR-based assembly and disassembly guiding system is positioned into the virtual world and displayed the specified viewpoint on the specified screen area. All algorithms proposed in this paper [5] are utilized by automatically extracted CAD feature's bounding box model of part as input data so they could be implemented for online planning of 3D assembly guiding scenes. One of the most industrial applications in which augmented reality can be applied is disassembly process. In the paper [6], the authors introduce the possibilities of the implementation of augmented reality concept in the disassembly process with goal of shortening the overall duration of the disassembly process of heating circulation pump assembly.

Zhang et al. [7] proposed a RFID-assisted assembly guidance system in an augmented reality environment. The paper presented a novel research aiming at providing just-in-time information rendering and intuitive information navigation, methodologies of applying RFID, infrared-enhanced computer vision, and inertial sensor. Stankovski et al. in the paper [8,9] presented a new way for identification of products/parts and their tracking during the whole life cycle, from the manufacture and assembly phase to the disassembly phase. RFID technology is applied on a chosen product, an in-mould labelling (IML) robot. RFID-based integrated method for electromechanical products disassembly decision-making was presented in the paper [10]. Chen et al. shows how RFID technology can be utilized to record and trace the lifecycle information, hence optimizing disassembly process and improving recovery efficiency. This integrated method is highly extensible, and it can be applied to various types of electromechanical products. Mircheski et al. in the paper [11] presented a method for improving the process and cost of nondestructive disassembly of a final product. The method analyzes the nondestructive disassembly by determining a disassembly interference matrix, feasible disassembly sequences, and improved nondestructive disassembly sequences. The innovative element of the nondestructive disassembly method proposed in the paper is integrating the generated conceptual design solutions for a given technical device with a software package developed for determining its improved disassembly sequence embedded within a 3D CAD platform.

In this article, a nondestructive disassembly process of a technical device supported with augmented reality and RFID technology is proposed. Different from other methods and strategies, this method uses system which marks the components of interest from the product by using a RFID tag which contains the ID of the product design in the centralized database. The system is modular and extensible in terms of the services and re-manufacture offered. The overall system has a forum that is helpful in communication between recycling/reuse facilities and product designers. Augmented reality system offers video presentation when possible to visualize the disassembly process. Main objective of this paper is the development of a new recycling/reuse concept by using the nondestructive disassembly process supported with augmented reality and RFID technology.

THE STRUCTURE OF THE MODEL

The research presented in this paper is oriented into creating and implementing of useful novel model for easy nondestructive disassembly process of technical device supported with augmented reality and RFID technology. In this context, the novel model is intended for end-of-life products which consist valuable components or component of interest. The novel model for nondestructive disassembly includes innovative elements such as: planning of nondestructive disassembly process in the early stages of the design process; connecting with the production process and product marking with RFID tag which will indicate that the product consists a valuable component of interest; and into the end-of-life stage of the product will give procedure and order for nondestructive disassembly supported with augmented reality. The overall model is an iterative process that improves the product structure and some valuable components will be reused or recycled. As depicted in Figure 1, the proposed model is performed in three main phases.

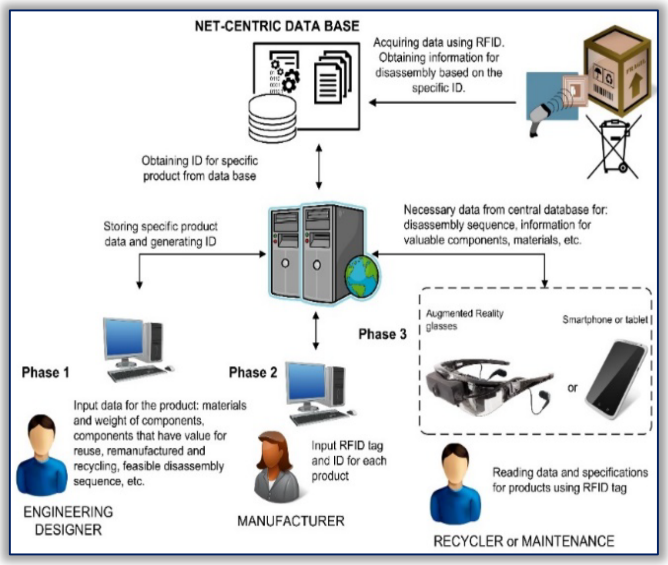

Figure 1. Flowchart of the proposed model for nondestructive disassembly using augmented reality and RFID technology

— Phase 1: Planning of the nondestructive disassembly process in the early stages of the design process which includes identification of fastener, component, contacts between parts, materials and weight for the parts by using of 3D CAD file as an input in SolidWorks assembly file of product with extension ".SLDASM". Also, this phase includes the automatic determination of the contact matrix between fasteners and components (FC), automatic determination of the contact matrix between components (CC) for all subassemblies (SA) within the product assembly (A), the disassembly operations, the disassembly interference matrix, all possible disassembly sequences, the improved disassembly sequence by using of developed software presented in the paper [11].

In order to demonstrate the proposed model, the product hair-dryer is used as an example. The main goal of the model is the presentation of the improved non-destructive disassembly sequence supported with augmented reality and RFID technology. Constituent components of the hair-dryer are: C_1=Holder, C_2=Exit part, housing which is consisted of two components (called C_3=Body part and C_4=Back part), C_5=Propeller, C_6=Electric motor, C_7=Heating element. A discrete fasteners in the hair dryer are: F_1=F-Bolt M2x8-3, F_2=F-Bolt M2x8-1, F_3=F-Bolt M2x8-2, F_4=F-Bolt M2x28-1, and non-discrete fasteners are: F_5=F5-Virtual (between C1,C3), F_6=F6-Virtual (C1,C6) and F_7=F7-Virtual (C2,C3). In the Figure 2, the CAD model of the product assembly for hair-dryer and its constituent elements is shown with exploded view. For simplicity of calculations the abbreviation names for components and fasteners (C_1, C_2, … and F_1, F_2, …) are applied.

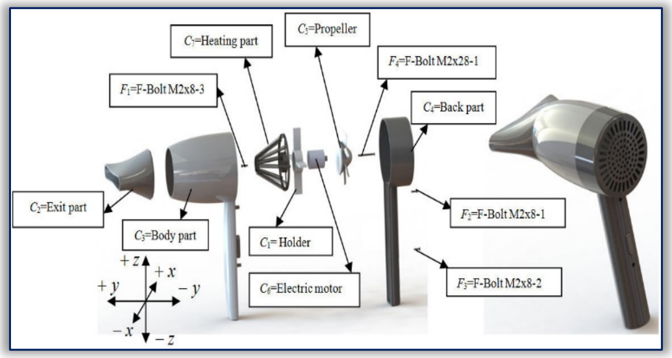

Figure 2. Exploded view and assembly of hair-dryer

The electric motor as valuable component of interest for reuse is aim for the disassembly process. The optimal disassembly sequences in according with methodology presented in the paper [11] are:

F2(-y), F3(-y), C4(-y), F4(-y), C5(-y), C6(-y)

F3(-y), F2(-y), C4(-y), F4(-y), C5(-y), C6(-y)

The optimal nondestructive disassembly sequence is usually a partial disassembly sequence, because not all disassembly operations return profit. The optimal nondestructive disassembly sequence gives insight into the disassembly cost, the percent of recovered material and other characteristics of the product. The lower the disassembly cost, the higher is the economic effect of the product recovery. The higher is the weight and volume of the recovered materials, the higher is the environmental benefit. These criteria can give important information to the designer in order to compare the design variants and select those that return higher value at product end-of-life and have lower negative effect to the environment.

- Phase 2: The model for nondestructive disassembly process of technical device utilizes RFID technology. Radio Frequency Identification (RFID) is a wireless identification technology consisted of a RFID tag, RFID reader/writer, a RFID antenna and related software. The key advantages of this technology compared to other identification technologies, like for example the barcode are: noncontact identification; long-distance reading of tags; simultaneous reading of multiple tags; high automation of the procedure; huge quantity of data can be processed very fast. The main disadvantages of the RFID technology is the limited amount of data that can be stored on a single tag and the price of a tag compared to a barcode sticker.

The developed model operates using a Neology Ultra High Frequency (UHF) Class-1 Gen-2 96 bit RFID tag containing a code in XML format. The products are marked with the appropriate RFID tag. The system is based on the software package of Inner Circle Logistics using the software Circus^{SM}, Jester^{SM}, Ringmaster^{SM} and Scarborough Fair^{SM} as is presented in Figure 3.

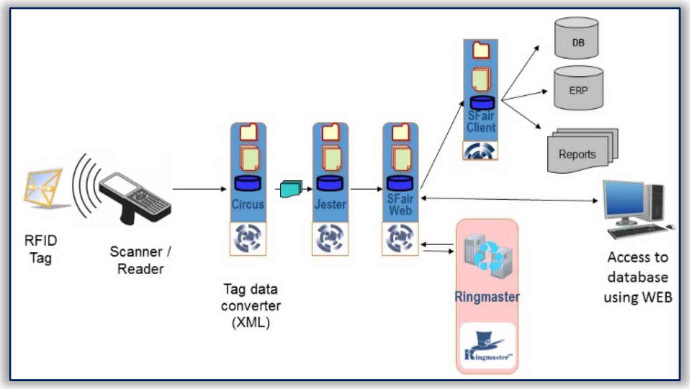

Figure 3. Diagram of the RFID software system architecture

Circus^{SM} is a RFID interface software that provides the ability to tie passive RFID tag data to the database utilizing next generation security protocols. Jester^{SM} is an automated data exchange application designed to post data to a net-centric virtual relational database. In the same way that Scarborough Fair^{SM} makes data available to a variety of audiences, Jester^{SM} runs in the background and enables smart data transfer capabilities that tie directly to virtually any database. Ringmaster^{SM} provides the authentication and control functions for the systems as well as the domain name system (DNS) lookup and other web services. It guarantees the security of the system, ensuring that only those with proper authority can access the information.

When the RFID tag is read by a RFID reader (Figure 4), the read information is transformed in order to access the centralized database and obtain the product ID code and the product design datasheet, such as shown in the Figure 1. The database can be designed in a way to satisfy the needs of each member of the product lifecycle chain. At this point, the product design sheet contains data elements for the product name, manufacturer, dimensions, number of parts, materials of parts, whether the product contains hazardous materials, components of interest, and the most important the disassembly sequence. The recycling facilities can use this ID to download data relevant for nondestructive disassembly of the product and obtaining the components of interest. The manufacturer inputs the necessary data in the database. The design of the database can be adopted to various requirements.

The proposed model is modular and extensible in terms of the services offered. The system may have forums that will be helpful in communication between recycling facilities and product designers.

This form of the system design provides the necessary security of the proposed model. The RFID tag contains only non-sensitive information that can be utilized after accessing a secure database. In that way, reading the information written on the tag during the lifecycle of the product does not present a security risk for the any of the involved parties.

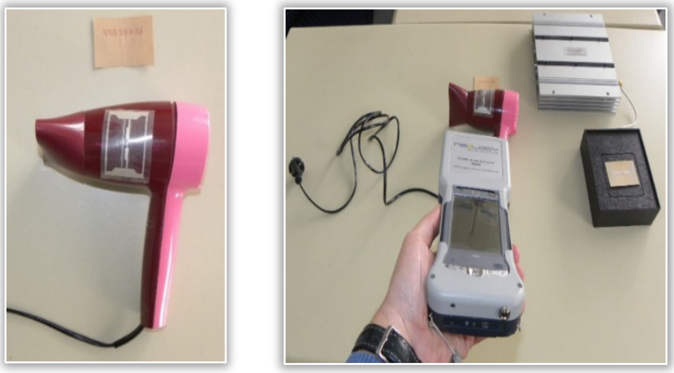

Figure 4. Placement of RFID tag and tag reading

— Phase 3: The system offers interactive video tutorials of nondestructive disassembly process and disassemble of valuable components of interest with visualization of the disassembly process supported with augmented reality.

Augmented reality (AR) is a technology that enables digitally stored spatial information to be overlaid graphically on views of the real world [12]. AR allows the user to see the real world, with virtual objects superimposed upon or composited with the real world. Ideally, it would appear to the user that the virtual and real objects coexisted in the same space. Augmented Reality enhances a user's perception of and interaction with the real world [13]. The virtual objects display information that the users cannot directly detect with their own senses. The information conveyed by the virtual objects helps a user perform real-world tasks.

The usual 2D technical drawings or 3D video animations of the disassembly process are difficult to understand and challenging to follow. The proposed model uses an interactive video guide superimposed on the real product. The system requires a hand-held device equipped with rear mounted camera, Android or iOS operating systems and access to internet. An animation of the disassembly process is created for the defined optimal nondestructive disassembly sequence from phase 1.

Using the Augment software platform the animation is uploaded to the Augment Manager providing the necessary information and tags. Using the data read from the RFID tag, a link to the 3D model in Augment Manager is generated and the animation is loaded on the hand-held device. The superimposed model in augmented reality is displayed on the screen.

The animation guides the recycler in the process of the nondestructive disassembly step-by-step as shown in Figure 5. The system provides with corresponding views as the user changes the viewing angle and position relative to the product with real motion. The component of interest is highlighted and the corresponding information is displayed. In case of presence of hazardous materials, the animation will provide the procedures for secure disposal. The systems is designed to operate using a hand-held device or a Head-Mounted Display (HUD).

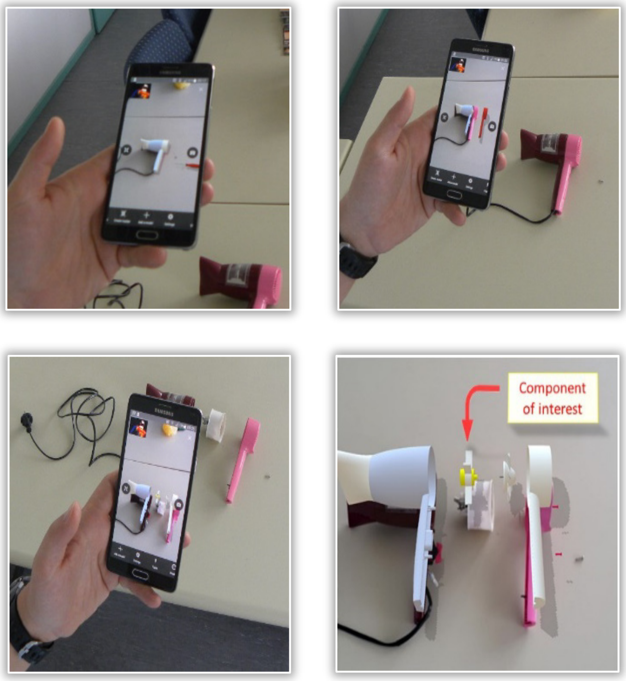

Figure 5. Step-by-step visual guide for nondestructive disassembly operations in Augmented Reality

CONCLUSION

In this paper, a novel model for nondestructive disassembly process of end-of-life product supported with augmented reality and RFID technology is proposed. Using this model, the information about the nondestructive disassembly process of end-of-life product and information regarding the valuable component of interest can be delivered directly via net-centric database by using of RFID tag and the nondestructive disassembly process will be shown with video presentation in augmented reality.

The model provides the necessary security of the product information by not storing real information to the RFID tag. As a result, this proposed model can improve the percent of recovered material, recovered valuable functional component of interest for reuse, lower negative effect to the environment, biggest recovery profits, easy disassembly process by using of video presentation and augmented reality.

Note

This paper is based on the paper presented at 13th International Conference on Accomplishments in Mechanical and Industrial Engineering – DEMI 2017, organized by University of Banja Luka, Faculty of Mechanical Engineering, in Banja Luka, BOSNIA & HERZEGOVINA, 26 - 27 May 2017.

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