AUTOMATION OF SMARTPHONE DISASSEMBLY: COLLABORATIVE APPROACH

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Abstract: The existing recycling technologies for electronics scrap focus on shredding devices into smaller fractions for recovery of prevailing valuable materials from integrated printed circuit boards (PCBs). By using metallurgic processes, many low volume materials such as rare earths metals and valuable still functioning integrated circuits (ICs) are lost during treatment.
The approach developed in the sustainablySMART project implies a collaborative disassembly unit which can be re-arranged and adapted to different types of mobile phones and combines less invasive technology with manual labor. In the sustainablySMART project [1], a demonstrator was developed and tested using different smartphones.
The paper presents research results obtained during the development of a collaborative disassembly cell for mobile phones and shows the possibilities of the newest automation technology. Additionally, the environment impact of the disassembly cell will be assessed and it is outlined to which business models and value chains the developed technology contributes to.

1. INTRODUCTION

The existing recycling technologies for electronics scrap focus on shredding devices into smaller fractions for recovery of prevailing valuable materials from integrated PCBs. By using metallurgic processes, many low volume materials such as rare earths metals and valuable still functioning ICs are lost during treatment.
The approach developed in the sustainablySMART project implies a modular collaborative disassembly unit which can be re-arranged and adapted to different types of mobile phones and combines less invasive technology with manual labor. The interaction between robots and humans makes it possible to combine disassembly steps in an effective manner to gain batteries and PCBs therefrom for further processing while keeping investments low. The integration of automated machines for unsoldering and reworking of ICs has enabled the development of an effective line for the disassembly of phones, unsoldering and reworking of valuable memory chips, CPUs and other potentially interesting BGA and LGA components. In the sustainablySMART project [1], a demonstrator was developed and tested using different smartphones.
Moreover, the business case for this collaborative disassembly machinery was assessed: The approach focusses on handling lower numbers of devices as can be found at medium sized recycling companies in the market which can benefit from lower invest costs of the machinery compared to higher volume approaches. Thereby this approach complements fully automatic disassembly processes and machinery, e.g. as developed in the ADIR project [2, 3], which use cutting methods to extract valuable materials from PCBs for further treatment.

Additionally, the environmental impact in terms of energy consumption will be measured and evaluated according to ISO 14955 [4]. The measurements are used to identify the most energy intensive process steps and improve them.
The paper presents research results obtained during the development of a collaborative disassembly cell for mobile phones and shows the possibilities of the newest automation technology. Additionally, a possible business model for remanufacturing approaches is introduced.

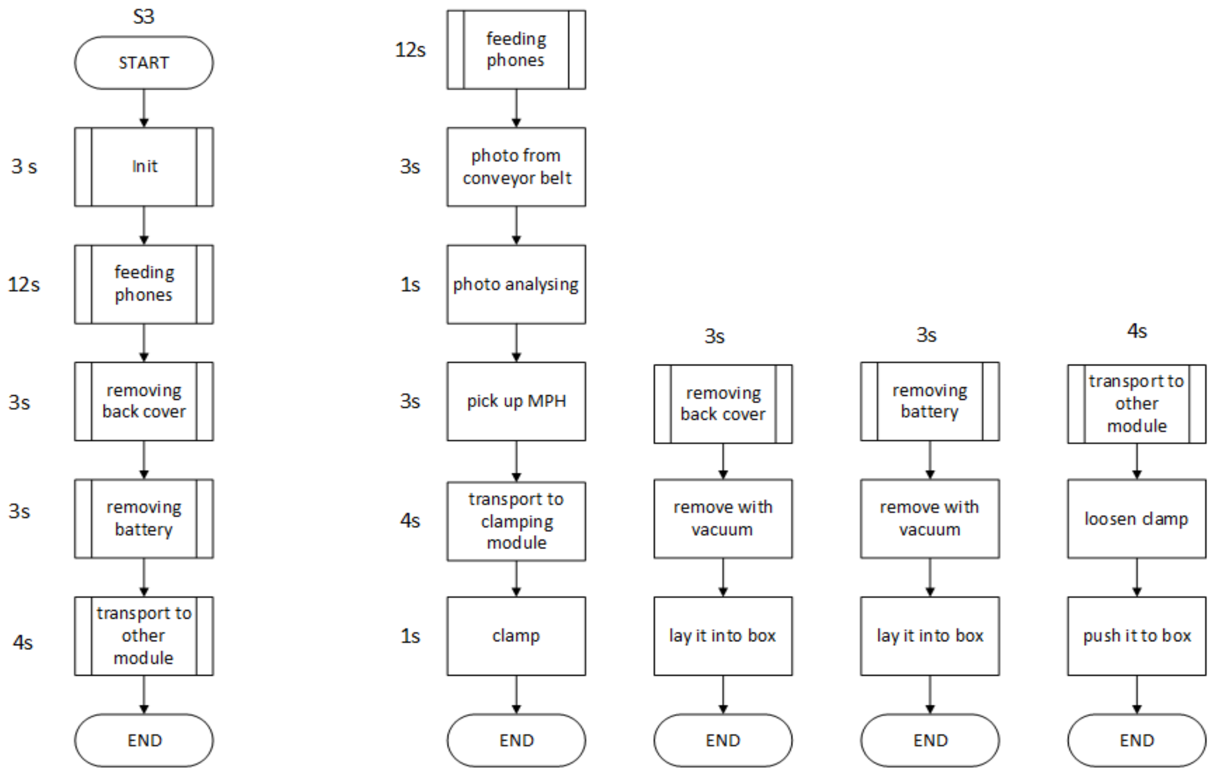

Figure 1: automatic dismantling process for a smart phone

2. TECHNICAL APPROACH

Within the demonstrator, a collaborative robot – in this case SAWYER [5] was used as a central handling unit operating with additional, interchangeable modules. The robot recognizes different taught-in mobile phones on a running belt and picks them. For the teach-in of phones the already implemented pattern matching of the robot's camera was used to detect different phone types and their respective positions in space. A collaborative parallel gripper grips the objects while monitoring the gripping force to ensure safety during the whole process.

The gripped phones are either put into a clamping module or a heating module, depending on the phone type. Phones having glued back covers are heated to minimize the bonding of the used glue. This process is done by the robot, as it involves manipulating parts heated up to 85 °C. After the removal of the back cover and the battery, the remaining phone is either placed into the manual work unit or the automatic unscrewing unit. Depending on the complexity of the phone's internal assembly, either a manual operator removes the PCB or an automatic unscrewing portal unscrews the tightened screws.

Finally, a manual worker takes out the PCB and hands it back to the robot for further operations or puts it in a box for the remanufacturing of components from the PCB. An example of a dismantling process is shown in Figure 1.

The demonstrator (as seen in Figure 2) can be easily reconfigured, depending on the internal assembly structure of the upcoming devices and new phones can be taught-in using the direct teach-in method. This allows end-users to teach-in new recipes within several hours and ensures high flexibility of the process.

All modules are designed using simple modular mechanical bases and are quickly exchangeable.

The robot is able to work collaboratively with a human operator, supporting operations in hazardous situations such as heated zones, and works as an interface to other parts of the system such as a feeding belt. Moreover, it is able to control the cycle time by dynamically assigning tasks to the operator.

Figure 2: picture of demonstrator; bottom: clamping unit, right top: heating unit, right bottom: screwing unit, center: robot

3. BUSINESS MODELS FOR AUTOMATED DISASSEMBLY

The sustainablySMART project combines technological with business model innovation. Focus is on exploring new value propositions, defining how this value can be created and captured by involved companies [6]. The value proposition of ProAutomation to customers is rooted in innovativeness as well as both operational effectiveness and cost efficiency of the automated disassembly machinery. Additionally the value proposition of this machinery builds upon the modular design of sub-processes and thereby in the flexibility of the whole system boosting its economic efficiency. The developed technology is modular and therefore enables different degrees of disassembly, see Figure 3:

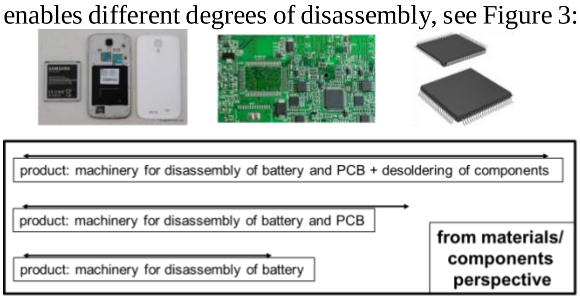

Figure 3: modularity of automation solution

Target customers are medium sized recyclers of smartphones. They benefit from lower initial invest or lesser leasing rates for machinery compared to high volume automation solutions. Recyclers of smartphones should then assess which solution best fits their value chain, also compared to their status quo (shredding of devices). Profitability can be compared for:

- automated disassembly of battery vs. manual disassembly of battery by remarketing to smelters/ battery recycling
- automated disassembly of PCB and separated remarketing of PCBs, batteries and housing
- remarketing of components, PCBs, battery and housing

The automation technology targets markets with high labour costs and recycling policies, in particular in Europe and North America. Automation technology is an enabler in these markets for economically viable sorting and disassembly of (waste) electronics products such as mobile phones.

4. ENVIRONMENTAL EVALUATION

As mentioned in the Chapter 1, the existing recycling technologies for electronic scrap focuses on shredding and recovery of prevailing materials and many rare earths metals and still working parts are lost during that treatment.

New end of life approaches for mobile phones, like device remanufacturing, component harvesting, or even advanced recycling processes with improved material recovery rates, enabled by the presented collaborative disassembly cell, will improve this situation.

Taking a look at the environmental aspect, one must assure that this new end of life approaches for mobile phones will result in environmental benefits compared to the common end of life treatments of mobile phones. For example, questions like how big is the environmental impact of an extracted and reused mobile phone camera component, compared to a new one, has to be answered.

To answer such questions, the whole reuse process (of the new end of life approaches) needs to be assessed. Every additional process step (collection of discarded mobile phones, distribution activities, sorting, disassembly, part extraction, functionality checks, etc.) corresponds to a specific environmental Impact.

One contributor in this process chain is the disassembly and part extraction fulfilled by the presented collaborative disassembly cell. In order to evaluate such kind of new end of life scenarios, it is of interest to know the environmental impact caused by this process steps.

In general, when investigating the environmental impact of products (e.g. machine tools), the system boundaries covers the full products life cycle. From the use of raw materials, the manufacturing, the distribution, the use to the end of life of the product [7].

If the environmental impacts of machine tools are compared in the different life cycle stages, the typical profile is "use-intensive" [8], meaning the use stage cause the biggest impact and the largest contributor is the energy consumption.

Considering the question, how big the environmental impact of one extracted mobile phone camera component is, the share caused by the collaborative disassembly cell along the full life cycle have to be included. Having in mind that such "machine tools" are very use intensive, and large quantities are handled over the lifetime, all life cycle phases except the use phase will become relatively insignificant. Meaning that just the use phase in terms of energy consumption is relevant when considering the environmental impact of the collaborative disassembly cell extracting mobile phone cameras.

This approach is also taken within the ISO 14955 framework where just the use phase respectively the energy efficiency of machine tools during the use stage is considered. The first part of the ISO 14955-1 standard, outlines how to measure the energy consumption of machine tools in order to gain measures to improve the energy consumption [8], see Figure 4.

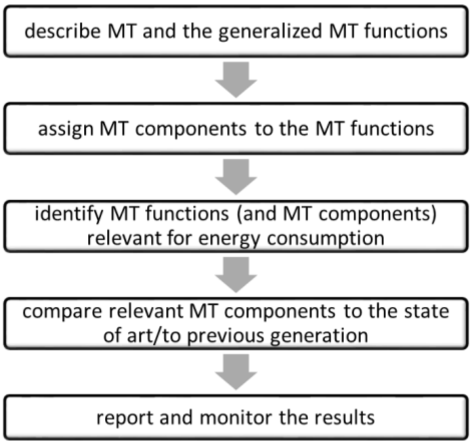

Figure 4: Design methodology for energy-efficient machine tools according to ISO 14955-1

Although this automated disassembly cell for mobile phones is not directly a machine tool in first hand, but very close to it and machine tool modules can be integrated. Therefore the ISO 14955 as a useful guideline to measure the energy consumption and to find improvement potentials regarding the energy consumption is applied.

5. SUMMARY AND CONCLUSIONS

The development of the automatic disassembly processes has confirmed that there is a demand for both fully-automatic and semi-automatic dismantling. Thus, fully-automatic dismantling is deemed reasonable if larger numbers of the same phones are available and most of the models are known. Collaborative dismantling is more preferable when there are rapid changes in mobile phone models and the new ones have to be quickly taught-in. Additionally, this approach is considered a better alternative when certain dismantling steps are too expensive to automate. The collaborative approach offers a low invest solution for automated disassembly and unlocks this business model for medium sized recyclers,

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