Robotized End-of-Life Product Disassembly

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Industrial robots have become one of the major components in automated products assembly due to their efficiency and ability to increase productivity and reduce manufacturing time and thus to improve the overall performance of manufacturing operations.

There are various types of industrial robots. One of these is the industrial micro-manipulator which has been utilized extensively in both academic and industrial applications. Our recent research utilizes this robot manipulator in a relatively new application; namely, automated disassembly of end-of-life (EOL) products.

Studies seeking sustainable solutions for accumulating waste have been growing in recent years. Electronic waste constitutes a major part in these studies since their recovery involves significant economic and environmental gains. Furthermore, electronic products enter the waste stream much faster than many other products due to the rapid pace of technological innovation. These products are classified as end-of-life (EOL) products and contain valuable materials as well as reusable components in their bills-of-materials (BOMs). In many cases, reused electronic components are considered more reliable compared to their newly manufactured counterparts since they have already survived the “burn-out” period. Electronic products may also contain hazardous materials, which require special handling. Therefore, EOL products recovery mainly involves one or more of the following processing options: (1) recycling operations to regain the material value, (2) reuse operations with additional refurbishing or remanufacturing to regain the technological value and (3) proper disposal operations to prevent environmental hazards. Storage could also be included as yet another alternative for components that are not reusable at the moment due to lack of demand or financial considerations.

Using industrial manipulators can help improve the disassembly of EOL product process, by allowing an increased number of products to be disassembled and improving the process speed via adaptive and intelligent techniques that make the process safer and faster by choosing the correct disassembly tools. However, there are some challenges in using an industrial manipulator in the disassembly operations. Similar to the assembly process, determining the robot path optimization that provides the minimum travel time while achieving maximum possible tasks is a difficult task. The solution lies in planning the disassembly sequence of the required parts for the best possible performance. The second challenge is the selectivity; implying, if there are only some required parts to be removed for reuse or recycling, the remaining parts are to be stored. This problem requires the optimization algorithm to be adaptive and adjustable for the removal of only selected items. In addition, the algorithm should take into account the physical constraints in removal (e.g., to remove the CPU of the Desktop PC, the case power supply should be removed first, even if it is not required for reuse or recycling). The final challenge in the disassembly process is the uncertainty. Since in most of the EOL products (such as used PCs) many of the items added by the manufacturers do not remain in their original places or they had been modified for maintenance or upgrading purposes (e.g., adding or removing RAM slots, new hard drive, changing the slot of the VGA card or sound card, etc.).

To be able to handle all these challenges, Genetic Algorithms (GA) have been used in [1][2] to detect the optimum disassembly sequence for the robot arm. In this algorithm the travel time to remove the required parts from an EOL product (e.g. old used PC) uses the actual Cartesian coordinates of the parts to be disassembled, and takes into account the arm speed factor and parts dependency. The part coupling has also been taken into account. For example, in the case of two adjacent parts that have similar material and will be removed for recycling, the action plan will not remove each part separately, but remove them together in the same step.

To handle the second challenge, a selective method has been developed in [3] to provide the user the choice of selecting specific items to be removed. Here, the system handles the part dependency and provides the required sequence for the robot to optimize its travel path during all disassembly operations. Figure 2 shows the hierarchical dependency chart and the related bill of materials (BOM).

The last problem faced during the disassembly process is the part and location uncertainty. To handle this problem, in [4] and [5], a 2.5D recognition system has been developed and a real time optimum sequence is generated. The system consists of a laser range finder to detect the Z coordinates of the parts required in the PC under testing. A web cam is used for detection of the required parts to be disassembled. If these parts exist, then the system determines the X, Y coordinates of the part. A simple template matching algorithm (simple normalized cross-correlation) is used in the detection process. Figure 3 shows a sample of the detection process of some of the required parts.

This system can further be improved by adding a decision-making algorithm to decide which parts are proper for the disassembly process following the detection of the available parts in the product. In addition, parallel robots can be used to share and to divide the disassembly tasks to be able to improve the overall performance of the process. Other computational models, such as parallel computation or a client server model, can also be implemented to improve the computational power of the optimization algorithm.