Graph based automatic computation of product disassembly time from assembly models

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Introduction

Four major processing options at the end-of-life of products are: reuse, recycle, remanufacture and disposal.

- Before end-of-life product entering recycle process or remanufacture process, sorting and disassembly are needed previously.
- Considering the cost effective on both recycle and remanufacture disassembly time is a critical factor[1-3].
- Selective disassembly is helpful in saving cost and time when manufacturers want to remove some specific parts from retired products.[4-6]

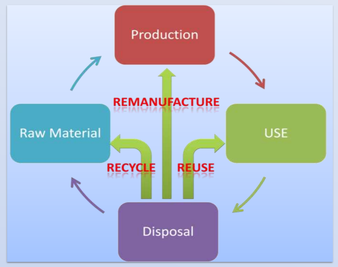


Fig1. Product life cycle with end-of-life options

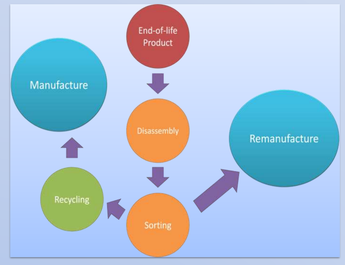


Fig2. End-of-life product processes for recycle and remanufacture

Assumption

- Disassembly time estimation in the design stage will help designers to create products with lower disassembly time.
- Disassembly is considered as the inverse of assembly processes so that disassembly time can process using assembly time estimation equation[7].

Objectives

- Develop a generic method for estimating selective disassembly time and plans for selective disassembly for a given CAD assembly model

Methods

- Utilize assembly graphs from the CAD model to obtain connective complexity metrics.
- Compute disassembly time utilizing the connective complexity metrics through an equation(1), whose reliability is 85% according to result of refinement on 9 cases in [7].

$$t_d = (APL \times n^{(1.185+PLD)}) \quad \text{.....(1)[7]}$$

where, $$APL = \frac{TPL}{n \times (n-1)} \quad \text{.....(2)[7]}$$

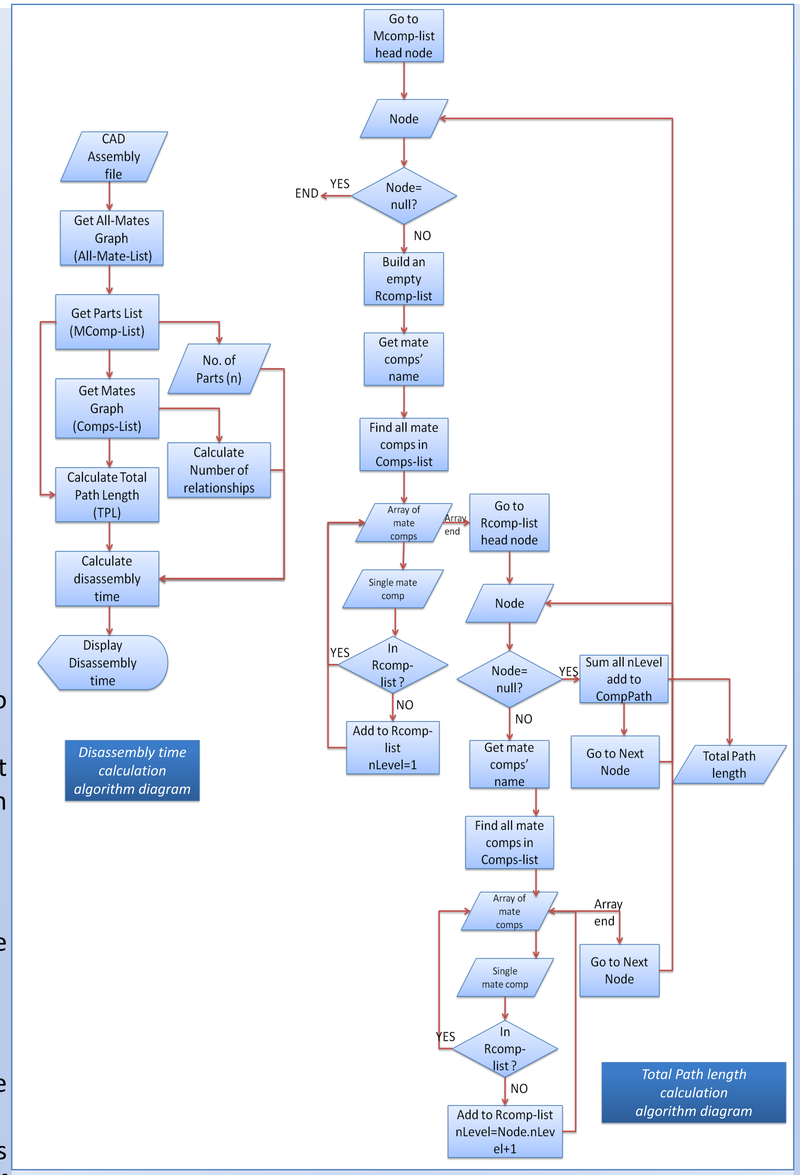
and, $$PLD = \frac{APL}{N} \quad \text{.....(3)[7]}$$

Symbols' definition are shown in Table 1.

- Modify assembly graph nodes based on recovery of specific parts that might be costly, hazardous, separated easily ,etc,.
- Utilize modified graph to estimate selective disassembly time automatically.

Case Study

- Automatic disassembly time computation will be performed in three test cases through the program developed using Solidworks API; electric eraser, toaster and TV remote.
- Electric eraser and toaster are given CAD assembly models.
- TV remote is an actual product whose CAD assembly model is constructed through symbolic components with same assembly graph as real product.



Result

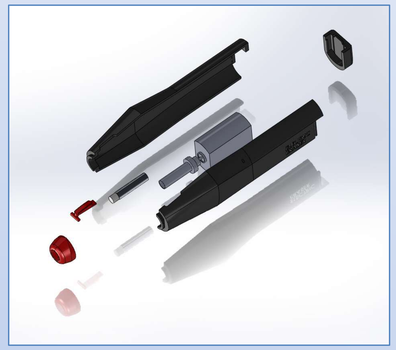
Table 1. Disassembly time computation results of case study

	Electric Eraser	TV Remote	Toaster
Number of parts (n)	10	11	34
Total Path Length (TPL)	196	224	3676
No. of Relationships(N)	18	19	56
Average Path Length (APL)	2.2	2.0	3.3
Path Length Density (PLD)	0.1	0.1	0.1
Disassembly Time (t_d)/s	44.0	45.1	262.9

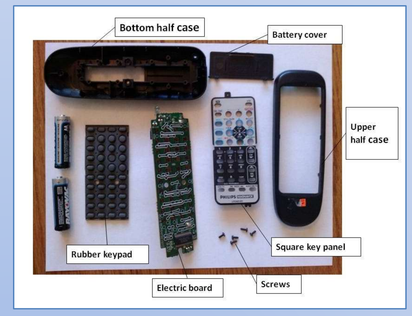
Conclusion

- This program can compute the disassembly time for Solidworks assembly files.
- For actual products, this program can obtain the connective complexity metrics from symbolic parts assembly CAD model, which could save time when analyzing an already exist product.
- The results imply that longer disassembly time is needed for CAD assembly models that have more complex assembly graph.

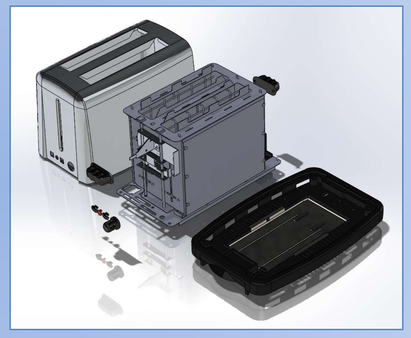
Case 1: Electronic Eraser



Case 2: TV Remote



Case 3: Toaster



Future Work

- Construct algorithms that could be able to modify CAD model graph based on certain criteria .
- Through analyzing graph obtained from CAD model the program could be able to give modification suggestions for designer on parts assembly.

Reference

[1] Navin-Chandra, D., 1994, The recovery problem in product design. Journal of Engineering Design, 5, 65-86.

[2] DeRon,A. and Penev,K., 1995, Disassembly and recycling of electronic consumer products: an overview. Technovation, 15, 363-374.

[3] Penev, K.D. and deRon, A. J., 1996, Determination of a disassembly strategy. International Journal of Production Research, 34, 495-506.

[4] Kara, S., Pornprasitpol, P., and Kaebernick, H., 2005, "A Selective Disassembly Methodology for End-of-Life Products," Assem. Autom., 252, pp. 124– 34.

[5] Behdad, S., Kim, H., and Thurston, D., 2010, "Simultaneous Selective Disassembly and End-of-Life Decision Making for Multiple Products That Share Disassembly perations," ASME J. Mech. Des., 132(4), p. 041002

[6] J Yi, B Yu, L Du, C Li, D Hu, 2008, "Research on the selectable disassembly strategy of mechanical parts based on the generalized CAD model", Int J Adv Manuf Technol (2008) 37:599–604

[7] J. Mathieson, B. Wallace, J. Summers, "Assembly Time Modeling through Connective Complexity Metrics," in 2010 International Conference on Manufacturing Automation