Disassembly Modeling for Assembly, Maintenance, Reuse, and Recycling

A. J. D. Lambert, Technische Universiteit Eindhoven, The Netherlands
and
Surendra M. Gupta, Northeastern University, Boston, Mass. USA

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Dedicated to Our Families

Teuntje, Henrike, Florian, and Frans

-AJDL

Sharda, Monica, Neil, and my parents Mam and Sarla

-SMG

Preface

Human beings have been using a variety of products for a long time. In the beginning, they made simple products such as utensils, jewelry, and ordinary tools. As time passed, the products became more sophisticated. Initially, the substance used principally consisted of organic materials. For example, early models of looms were made entirely of wood. Their construction and repair depended on the craftsmanship and skills of a few talented people. The discovery and availability of numerous other materials, chiefly metals, enhanced the variety and complexity of products. Craftsmanship was replaced by industrial production. New and intricate functionalities became available. As of late, information technology has led to the present day situation where millions of complex products are available to billions of consumers with an assortment of new products, materials, and techniques introduced daily. Today, with the advancement of technology, sophisticated products are assembled in a variety of ways. Similarly, when a product needs repairs or reaches its end-of-life, it might require efficient disassembly to replace/retrieve parts or materials. Because of the complex nature of assembly and disassembly, the need for a scientific approach to both processes is obvious.

Evidently, designing disassembly processes with minimum damage and cost has always played a crucial role in maintenance and repair. Rationalization of the production challenged the design of products and production processes that has ultimately resulted in concepts such as design for assembly and concurrent engineering. Scientific methods for assembly optimization that have been stimulated with the advent of computers and robots have played a key role for decades. Surprisingly, a breakthrough in this domain came by considering the assembly process as a reverse of disassembly, which is valid under some specific assumptions.

It is clear that scientific consideration of assembly and disassembly processes is needed when operating in harsh (or hazardous) and inaccessible environments, such as in nuclear reactors and in space. In addition, the need for planning under time pressure and the desire for profit maximization further highlight the importance of scientific methods. All these aspects compel the deployment of optimization methods that are based on mathematical modeling of products and processes. Various methods ranging from network theory to mathematical programming have become available in this domain. Numerous applications of network theory that have already been introduced in activities such as task planning and assembly line balancing, can also be adapted and applied in assembly and disassembly studies. Mathematical programming has also been used for selecting the best sequence of (dis)assembly operations from a large number of possible sequences that are usually viable in such problems.

In more recent times, additional challenges in disassembly theory started to emerge due to the growing need for end-of-life processing. This subject became increasingly important during the last decade of the 20th century. The systematic approach of disassembly processes was fueled by both the desire for precious and valuable materials recovery and the challenge for environmentally benign processing of postconsumed products. This resulted in the discovery of new types of problems that had to be solved, such as those related to the optimum disassembly level and the optimum clustering of waste streams.

Although much work has been done in recent years, a systematic and integrated approach of the various aspects of disassembly theory has never resulted in a coherent body of knowledge. Indeed, several review papers on disassembly have appeared recently. However, they merely make the reader aware of their existence rather than attempting to integrate various approaches of disassembly theory.

This book is written with the intention to fill this gap with a presentation of a coherent and comprehensive discussion of disassembly planning theories and methodologies. Firmly based on hundreds of papers that have been published that reflect various approaches to disassembly theory, the authors present an overview of the state-of-the art in this field, frequently adding new materials that enhance the transparency of the methodology that is discussed. Although the subject that is dealt with seems restricted, completeness cannot be pursued to its full extent, for open ends are present both in the chain approach and in the aggregation level. This implies that the theory on a low level of aggregation, which corresponds to a purely physical and mechanical approach, is not addressed. Theory on a high level of aggregation, which embraces scheduling and reverse logistics issues, is also not included to its full extent. The product life cycle is discussed within the framework of industrial ecology, but phases other than the disassembly phase are not fully expounded upon.

From a methodological point of view, there are three main approaches to disassembly planning; exact methods, heuristics, and metaheuristics. From these, the emphasis will be on the exact methods, which are widely applicable in various disassembly planning problems. Heuristics and metaheuristics are discussed without the details of the multiple methods that have been reported thus far.

For the same reason, the modeling theory is confined to various network approaches and related matrix representations. This book does not deal with a detailed discussion of the different models that are based on Petri nets, for these are essentially analogous to the network approach. It does, however, engage the three main applications of disassembly theory, which include assembly optimization, maintenance and repair, and end-of-life processing.

In the last decade, much optimism existed with regard to the possibility of robotically operated disassembly lines for end-of-life products. This initial optimism, however, has since been mitigated to some extent, mainly because uncertainties in supply and quality of those products put to rigorous challenges to robotic operation. Even so, the development of disassembly theory has made significant progress since then, which has been fruitful in all the phases of complex product life cycle including aspects of reverse logistics.

The optimization of disassembly processes remains an important and promising field of research. Integrated design, resulting in design for life cycle, might eventually result in a renaissance of the robotic disassembly line. This is desirable from both the environmental and the working condition points of view as high labor costs are presently impeding in exploiting the full benefits of end-of-life disassembly. The authors express their hope that this book will contribute to the establishment of environmentally sound and economically feasible product design and end-of-life processing.

About the Authors

Dr. ir. A.J.D. (Fred) Lambert is an Assistant Professor of Industrial Ecology in the Department of Technology Management at the University of Technology at Eindhoven, The Netherlands. He received his B.S. in Electrical Engineering from the Technical College at Vlissingen, his M. Sc. in Technical Physics and his Ph.D. in Theoretical Plasma Physics from the University of Technology at Eindhoven, all in The Netherlands. In addition to the University of Technology at Eindhoven, Dr. Lambert has participated in research projects at the Philips Company, the University of Greifswald (Germany), the University of Trieste (Italy), the Technical University at Lausanne (Switzerland), and the FOM Institute for Plasma Physics at Rijnhuizen (The Netherlands). Dr. Lambert has published papers on many different topics, including nuclear fusion, nonequilibrium thermodynamics, MHD power generation, energy systems modeling, process integration, materials flow modeling, and more recently on disassembly sequencing. He has published more than 30 research papers in various scientific journals and has made contributions to numerous books, conference proceedings, and professional papers. Dr. Lambert teaches undergraduate classes on energy efficiency, managerial aspects of reuse and recycling, and supervises group projects on industrial ecology related topics. He coaches graduate students on such topics as energy and waste management in industry, and sustainable energy resources. His recent activities can be viewed at <http://www.tm.tue.nl/vakgr/aw/> (technology studies). Dr. Lambert can be reached via e-mail at <A.J.D.Lambert@tm.tue.nl>.

Dr. Surendra M. Gupta, P.E. is a Professor of Mechanical and Industrial Engineering and Director of the Laboratory for Responsible Manufacturing at Northeastern University in Boston, Massachusetts. He received his BE in Electronics Engineering from Birla Institute of Technology and Science, Pilani, India; MBA from Bryant College, Smithfield, Rhode Island; and MSIE and Ph.D. in Industrial Engineering from Purdue University, West Lafayette, Indiana. Dr. Gupta's research interests are in the areas of production/manufacturing systems and operations research. He is mostly interested in environmentally conscious manufacturing, electronics manufacturing, MRP, JIT, and queueing theory. He has authored and coauthored more than 275 technical papers published in prestigious journals, books, and international conference proceedings. He has traveled widely and presented his work at international conferences in Africa, Asia, Australia, Europe, North America, and South America. Dr. Gupta has been elected to the membership of several honor societies and is listed in various Who's Who publications. He is a registered professional engineer in the State of Massachusetts and a member of ASEE, DSI, IIE, INFORMS, and POMS. Dr. Gupta is a recipient of the Outstanding Research Award and the Outstanding Industrial Engineering Professor Award (in recognition of Teaching Excellence) from Northeastern University. His recent activities can be viewed at <http://www.coe.neu.edu/~smgupta/> and he can be reached via e-mail at <gupta@neu.edu>.

Acknowledgments

We have worked in the field of disassembly for more than a decade. However, to the best of our knowledge, this is the first book written solely on disassembly. As such, it is somewhat bewildering to write the first book in any area, because it is difficult to know how one should harness and organize some important topics without ignoring some others; there are no precedents available that could serve as guides. We, therefore, started pondering with ideas of how to explain to the new generation of students, researchers, and practitioners the general concepts of disassembly. The obvious starting point was to explore the history and reason for disassembly. However, as we started to dig deeper, we realized that the field of disassembly has latently grown quite vast without anyone taking the initiative to organize it. This book is an attempt to start this process.

This book would not have been possible without the encouragement of many people. We would like to thank hundreds of researchers, colleagues, and graduate students whose works we have read and benefited from and whom we have met and interacted with, at conferences around the world. Therefore, the knowledge in this book is a collective effort of many people working in this field. We especially thank the people of the joint European REVLOG (Reverse Logistics) project, and in particular Dr. ir. S.D.P. Flapper, whose fellowship and enthusiasm substantially influenced this book. In addition, we thank our current students who continually help us propel toward future discoveries.

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A. J. D. (Fred) Lambert, Eindhoven, The Netherlands
Surendra M. Gupta, Boston, Massachusetts, U.S.A.

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