ME – PhD Thesis Defence

MECHANICAL ENGINEERING
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On Topological Approaches for Planning Electro-Mechanical Assemblies

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ABSTRACT

Assembly planning involves creating a complete plan for assembling the product from its constituent parts. Complex electro-mechanical products constitute many systems and sub-systems that employ electrical and mechanical processes; they contain multiple functional elements connected by cables and pipes for transferring electricity and fluid. The assembly planning of electro-mechanical products, especially with the propagation of electric vehicles and more electric aircraft, has increasingly become more and more significant and challenging. However, the methods in the literature are still unable to handle complex, realistic products with many parts. Current industry practice is to generate assembly plans manually; this is time-consuming, expensive, and error-prone. Therefore, considering today's competitive market, planning automation is crucial. With this motivation, we develop a topological computational framework for the automated planning of electro-mechanical assemblies.

Firstly, we address the disassembly sequencing of rigid assemblies. Recognizing the often-overlooked importance of part accessibility, we develop a systematic topological analysis of surfaces in assemblies. This leads to the notion of shell structures associated with assemblies. A graph-based representation of shells enhances the efficiency of accessibility analysis, facilitating an efficient assembly partitioning scheme for disassembly sequencing. Our method involves a onetime shell computation and efficient updating of accessibility information throughout disassembly. Extending the utility of shell structures, we showcase applications in subassembly identification and parallel disassembly, which are crucial for maintenance planning and end-of-life processing. We propose a grid-based method for constructing the shell structure from the tessellated model of the assembly.

Secondly, we address the wire harness routing problem. We show that to generate the desirable bundles of wires automatically, we must consider all the non-homotopy classes of paths. We introduce routing graphs derived from nontrivial loops in the first homology group associated with the product's surface, providing a one-time construction that encodes the homotopy of the routing environment. This facilitates the identification of all non-homotopic paths between multiple terminal pairs. Classifying the routing paradigms as on-surface and in-air categories, we define routing graphs based on handle and tunnel loops for on-surface routing and handle loops for in-air routing. We developed a linking number-based strategy for computing the handle and tunnel loops. Our methods extend to routing in assemblies utilizing shell structures. Shell structures represent a suitable solution space for routing and offer an immediate path verification method, eliminating the need for exhaustive traversal of the entire assembly. Thirdly, we address the problem of automatically generating wire harness designs. We use routing graphs to derive all the possible electrically admissible but topologically distinct harness system layouts that can be used to connect the specified terminals. Each generated layout represents a possible harness design. For the geometric embedding of the generated harnesses, we present an optimization-based methodology that simplifies the harness and determines the optimum lengths of the segments over which the wires should be bundled.

The methods were used for the assembly planning of multiple realistic products. The results demonstrate the efficiencies and efficacy of the developed methods.

ABOUT THE SPEAKER

Arun Rehal is a PhD student in the Department of Mechanical Engineering, IISc, Bangalore. He works with Prof. Dibakar Sen at the Applied Geometry and Mechanisms Lab (AGML Lab). He graduated with a Bachelor's degree in Mechanical Engineering from the Jawaharlal Nehru Govt. Engg. College, Himachal Pradesh, and obtained his Master's degree from the PEC University of Technology, Chandigarh. His broad research interests include assembly planning, path planning, computational geometry, topological modelling, and computational topology.