Automating Reasoning about Mechanical Devices

Leo Joskowicz
IBM T. J. Watson Research Center
P.O. Box 704, Yorktown Heights, NY 10598
josko@watson.ibm.com, 914-784-7062

Our long term research goal is automating various aspects of reasoning about mechanical devices. Our aim is to develop computational tools to assist in the analysis, simulation, design, validation, and cataloging of devices such as door locks, brakes, and transmissions. Modeling mechanical devices requires reasoning about the geometry of parts and the physics of their interactions. Traditional formulations in terms of mixed algebraic and differential equations have limited or no use in supporting many of the above tasks. To make the task feasible, it is necessary to find appropriate domain dependent approximations and abstractions.

Earlier work explored the design part shapes from functional specifications. We showed how pairs of objects – the basic building blocks of mechanical devices – can be created and modified to achieve a desired behavior. This non-parametric design method creates and modifies shapes by adding and deleting line and arc segments to the part's contours. The modifications are guided by a configuration space representation of the desired behavior.

Subsequent work presented a method for mechanism comparison and classification for redesign. We developed a set of approximation and abstraction operators that create multi-perspective, multi-resolution descriptions of devices' kinematic behavior. The operators create symbolic kinematic descriptions by modifying the underlying configuration space of mechanisms. The resulting description hierarchy supports the design process throughout its evolution, from the conceptual to the detailed phase.

Automating conceptual mechanism design requires developing a representation language. Recently, we have developed a simple and expressive language for describing the structure and behavior of *fixed axes* mechanisms. The language uses a mixture of predicates and algebraic relations to describe the mechanism's parts, their positions, their motions, and the relationships between them. It allows both abstract, incomplete, and underspecified behavioral descriptions, and accurate and complete descriptions. We are implementing a design verification algorithm that determines if a mechanism structure matches desired structural and behavioral specifications.