First Steps toward Automated Design of Mechatronic Systems Using Bond Graphs and Genetic Programming

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1 OVERVIEW OF THE WORK

This paper suggests a method for automatically synthesizing designs for mechatronic systems. The domain of mechatronic systems includes mixtures of, for example, electrical, mechanical, hydraulic, pneumatic, and thermal components, making it difficult to design a system to meet specified performance goals with a single design tool. Bond graphs are domain independent, allow free composition, and are efficient for classification and analysis of models, allowing rapid determination of various types of acceptability or feasibility of candidate designs (Karnopp *et al*). This can sharply reduce the time needed for analysis of designs that are infeasible or otherwise unattractive. Genetic programming is well recognized as a powerful tool for open-ended search (Koza et al). The combination of these two powerful methods is therefore an appropriate target for a better system for synthesis of complex multi-domain systems. The approach described here will evolve new designs (represented as bond graphs) with ever-improving performance, in an iterative loop of synthesis, analysis, and feedback to the synthesis process.

2 BOND GRAPHS AND GP

Bond graphs consist of elements and bonds. There are several types of elements, each of which performs analogous roles across energy domains.

Bond graphs are "grown" by executing the sequence of GP functions and terminals specified by the tree (at specific bonds or nodes of the bond graph), using the embryo as the starting point. In our initial approach, the GP tree represents a program to construct a bond graph, not the bond graph *per se*. The initial studies reported here use the following set of bond graph elements: {C, I, R; 0, 1, S_f, S_e}, representing generalized capacitances, inductances, resistances, parallel and series connections, and sources of flow and effort. This set is sufficient to allow us to achieve designs that have practical meaning in engineering terms, while still permitting other methods to be used for comparison, to help to assess our initial work.

3 EXAMPLE: EIGENVALUE SEARCH

In this case, a set of target eigenvalues is given and a bond graph model with those eigenvalues is desired. The embryo model used is shown in Figure 1. The dotted box represents the initial modifiable site ("writehead"). The construction steps specified in the GP tree are executed at that point. The numbers in parentheses represent the parameter values specified (or found) for the elements.

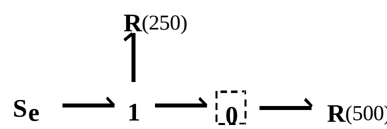

Figure 1: Embryo bond graph model

As a proof of concept for this approach, evolution of a limited set of bond graphs with specified target eigenvalues was tested, with good results produced rapidly using very limited computing resources. This provides some support for the conjecture that much more complex multi-domain systems with much more detailed performance specifications can be automatically designed, given longer execution times and/or using inexpensive cluster computing facilities.

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