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CONCURRENT CONCEPTUAL DESIGN THROUGH ONTOLOGY DEFINITIONS AND DECLARATIVE MODEL SOLVER

Abstract

During the early stage conceptual design of any new spacecraft mission, sizing relationships are normally encoded across different sets of computational tools. In the context of concurrent design, there is generally a centralized database where information is updated as the design team changes assumptions and updates computations. Each domain expert will build their internal design models and interface with variables from a few other domain-specific models. However, the data exchange often happens in formats that are very hard to change from mission to mission. From the system engineer's perspective, if a new type of Roll-Up that is not already standardized through the central database needs implementing, it needs to be implemented from scratch. This paper describes a method that creates much greater formulation flexibility and change readiness. The method's key element consists of creating a problem-specific ontology as part of the conceptual design formulation phase. The ontology lists the types of things that can exist in the design and what properties we expect them to have; for example, any physical component of the spacecraft would exhibit the property of mass, a subset of the components would exhibit power properties, and in the case of a propulsion system, delta-v properties. The second key element of this method is the implementation of sizing relationships that impose constraints on the type of variable that can be used (delta-v would work with the so-called rocket equation, and mass roll-ups would work on the whole tree of physical components with mass). The ontology also enables domain experts to describe the specific properties belonging to their domain while inheriting properties from the systems level ontology. Finally, we allow for the specification in this ontology of mathematical sizing relationships in a declarative fashion. We describe the implementation of a solver that, based on this declarative model, gives the designer immediate sets of feasible candidate designs, thus enabling the rapid exploration of the design space. We apply the method to an Earth observation satellite design example, generating a simple ontology that captures the design problem and the sizing equations, and finally, run the solver on the problem to explore the design space.