Why are intervals and imprecision important in engineering design?

J. M. Aughenbaugh and C. J. J. Paredis

Georgia Institute of Technology
Atlanta, GA 30308
email: gtg224k@mail.gatech.edu
chris.paredis@me.gatech.edu

Abstract

The goal of this paper is to introduce the Reliable Engineering Computing community to the needs of the engineering design community for interval methods and imprecision probabilities [1]. While the community is familiar with those tools, it is not necessarily as familiar with the structure and assumptions of the engineering design process. Earlier work has demonstrated the value of using imprecise probabilities in engineering design [2], the role of imprecise probabilities in applying information economics [3], and the provided an example of interval comparisons [4]. However, significant computational challenges have been faced in implementing these methods. By introducing the needs and context of the engineering design community, we hope to foster future collaboration between the communities.

Engineering design is a process of converting information about requirements into a specification of a product. The complexity of the design problem, including the presence of uncertainty, makes it impossible to arrive at an optimal design in one step. For example, a set of design alternatives is the output of a creative process. It would be prohibitively expensive to enumerate all design alternatives by considering all possible combinations of all solution principles for all the subsystems of a complex product. Even if such a set existed, it would be impractical to evaluate and compare all alternatives. Consequently, the design process is broken down into a sequence of decisions.

Note that it is important to distinguish clearly between *decision* alternatives and *design* alternatives. A design alternative is one of the possible complete product design specifications, while each decision alternative corresponds to a set of design alternatives. For example, when choosing a vehicle type, assume the decision maker has two *decision alternatives*: car or bike. Each of these decision alternatives actually corresponds to a *set* of *design alternatives*—the choice of vehicle type *car* includes the gas car, diesel car, and electric car, because the vehicle type decision will be followed by the engine type decision. In this manner, the decision alternative *car* includes a set of designs, and the characterization of the performance of the *car* is imprecise—it cannot be expressed as single, crisp number. For example, the horsepower of the set of all cars is an interval or set of values rather than a precise value.

The use of sequential decision making and existence of sets of design alternatives is just one example of the need for interval computations in engineering design. In this paper, we summarize the design process and describe five sources of imprecision in engineering design:

- Future design decisions introduce imprecision because the design alternatives are imprecisely defined sets of alternatives.
- Behavioral simulations are imprecise abstractions of reality.
- Environmental factors are imprecise estimates based on limited measurements.
- Preferences are not fully elicited and therefore imprecise.
- Numerical implementation of these models introduces additional imprecision.

Given the existence and importance of these sources of imprecision, it is clear that engineers require reliable computing methods that can handle intervals efficiently. This paper presents the context of these needs and suggests areas for future collaboration and research.

References

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