Research Summary: Interaction-based Design

Brian C. Williams
Xerox Palo Alto Research Center
3333 Coyote Hill Road, Palo Alto CA 94304
bwilliams@parc.xerox.com

A device is often considered novel if it works in a way qualitatively different from those seen before. Furthermore, a designer relies heavily on this qualitative understanding of device behavior when making substantial changes to a design. Thus an approach to design innovation should capture, at its foundation, an engineer's ability to identify and reason about a device's salient features with respect to how it works. At the center of my research is a set of representations for capture these salient features for continuous systems (i.e., interaction topologies), a set of reasoning techniques for constructing and manipulating these representations (e.g, temporal qualitative analysis, temporal constraint propagation, the symbolic algebra system Minima, and the terminological reasoning system Iota) and a set of strategies for constructing designs based on these representations (interaction-based design). These have been developed in the context of designing and analyzing simple feedback control systems.

With respect to representations, we have taken the perspective that a device works by constructing a topology of continuous interactions between quantities and modulating these interactions over time. [AIJ84] studied the process of constructing qualitative explanations of how continuous, time-varying systems work, developing qualitative, causal and temporal aspects of interaction representations, and exploring the role of continuity and feedback in qualitative explanation. [AAAI86] examined in more detail the temporal aspects of interactions, exploring the use of local interactions to identify the salient temporal features of behavior with respect to how devices work. The result was a dynamic interaction representation, called concise histories, and a simulation technique, called temporal constraint propagation. [AIJ91] examined in detail the qualitative/quantitative aspects of interactions, developing and formalizing an algebra, called SR1, that is able to describe interactions at many points along a spectrum between traditional qualitative and quantitative representations. A symbolic algebra system for SR1 was developed, called Minima.

In the context of design, [PhD89, AAAI90, WS90] present a technique, called interaction-based design, and a system, Ibis, which constructs simple control systems from first principles. A topology of a system's existing interactions is used to identify points of sensing and control. A compact representation of the first principles, called a topology of potential interactions, is then used to establish a control loop between the sensing and control interactions. Finally Minima is used to perform the symbolic algebra necessary to ensure that the control loop is stable. Current work extends these ideas in the context of optimization and non-linear control.

References

B. Williams, "Qualitative Analysis of MOS Circuits," Artificial Intelligence, 24(1-3):281-346, January 1984.

B. Williams, "Doing Time: Putting Qualitative Reasoning on Firmer Ground," AAAI, 1986.

J. de Kleer and B. Williams, "Diagnosing multiple faults," Artificial Intelligence, 32 (1987) 97-130.

J. de Kleer and B. Williams. "Diagnosing with Behavioral Modes." IJCAI, 1989.

B. Williams. "Invention from First Principles via Topologies of Interaction" PhD, MIT, June 1989.

B. Williams. "Invention from First Principles: An Overview" In P. Winston and S. Shellard (Eds.), Artificial Intelligence at MIT: Expanding Frontiers. MIT Press, 1990.

B. Williams. "Interaction-based Invention: Designing Novel Devices from First Principles," AAAI, 1990.

B.C. Williams. "A Theory of Interactions: Unifying Qualitative and Quantitative Algebraic Reasoning." Artificial Intelligence, 51(1-3):39-94, October 1991.

B. Williams. "Capturing How Things Work: Constructing Critical Abstractions of Local Interactions." AAAI Wkshp on Abstraction & Approximation, 1990.

O. Raiman and B. Williams. "Caricatures: Generating Models of Dominant Behavior." AAAI Wkshp on Abstraction & Approximation, 1992.