Thesis Evaluation: A Foundation for the Design and Analysis of Robotic Systems and Behaviors

by

Zhang Ying

Written by: Amir Pnueli

The thesis contains a huge amount of material. It provides a general introduction (including a detailed presentation of the required mathematical preliminaries) to dynamic and hybrid systems, presents the hybrid system descriptive model of *constraint nets*, including a full domain-theoretic denotational semantics, it presents two distinct formalisms for requirement specification of hybrid systems: a *timed temporal logic* and a timed variant of $\forall$-*automata*, and discusses some approaches to their verification. Finally, part III of the thesis presents an interesting approach to the synthesis of controllers based on on-line constraint solving, using a host of methods for discrete and continuous constraint solving. To top it off, Appendix B presents a visual programming and simulation environment ALERT that seems to have been developed as part of the thesis

This amazing wealth of material has two consequences.

First, it was humanly impossible to read the complete thesis at the same level of detail and do equal justice to all parts. Instead, my approach has been to adopt a sampling technique of selecting parts and reading them in greater detail, going backwards for definitions and previous discussions. The selection of parts to be considered in greater detail was half random, and half based on parts with which I was more familiar, and where I expected serious pitfalls or difficulties. My evaluation is based on this reading mode. Consequently, even though my overall summary is positive, I cannot vouch for the full correctness of all 245 pages of the thesis.

A second consideration concerning the size of the thesis is the following. In many cases, too much material in the thesis leads to a negative evalu-

ation. Often, it may point to the fact that the student is covering up for not being able to say a single or two important things by saying, instead, many insignificant things. This is often evident by the fact that a lot of the presented material is a background material that could be easily found in standard textbooks.

This is *definitely* not the case with this thesis, in spite of its extraordinary size. The many parts of the thesis fit well together and present an interesting journey through the world of hybrid systems with their intended robotic applications. Even the sections dedicated to background mathematical material present a useful selection of just the material that is relevant to the thesis. Perhaps I was influenced by the quotations from Lao Tzu to adopt a holistic view and suggest that no parts be removed from the thesis, and that it be accepted as a satisfactory fulfillments of a Ph.D. dissertation requirements.

To continue my evaluation, I did not find any major breakthroughs in the thesis. However, it does contain several innovative elements that, together, accumulate to a meaningful contribution. The main new ideas are the Constraint Network model for hybrid systems with its denotational semantics, the extension of ∀-automata to include timing elements, the corresponding generalization of the verification methods, using Liaponov functions and, finally, the idea of hybrid controllers based on on-line constraint solving.

There is no question that these ideas contribute to the field of hybrid systems and its application to robotics. Consequently, I strongly recommend accepting the thesis, with no modifications, as a satisfactory Ph.D. thesis.

Sincerely Yours

A. Pnueli

Amir Pnueli