Decentralized Discrete Event Systems: Structure, Communication, and Control

Peter Caines (McGill University),
Stéphane Lafortune (University of Michigan),
Laurie Ricker (Mount Allison University),
Iakov Romanovski (Queen's University),
Karen Rudie (Queen's University),
John Thistle (University of Waterloo)

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The workshop themes of structure, communication and control in decentralized discrete event systems were addressed through examinations of modular and hierarchical architectures, language-based theories of distributed control synthesis, and logics for specification, synthesis and verification of control and communication structures. Potential applications were presented in the fields of distributed control of air and watercraft, distributed robotic self-assembly and power system fault detection. Throughout the two-day meeting the sessions were notable for the informal and lively discussions that accompanied essentially all of the talks. From both the presentations and the discussions several key issues emerged, and these are summarized below.

Modularity and Structure:

New unpublished results about the implications of modular structure on the computational complexity of certain verification and control problems were presented. It became apparent that computational issues associated with modular systems are highly sensitive to the inherent symmetry in the system components. In particular, a new undecidability result for certain classes of symmetric modular systems was presented. This result generated considerable discussion among the attendees. On the other hand, it was demonstrated that for another class of symmetric modular systems, significant computational savings could be achieved in solving verification and control problems by exploiting symmetry and building quotient transition structures, reminiscent of partial-order methods in field of formal verification in computer science. It became apparent that these issues are worthy of future investigations, especially regarding the boundary between decidability and undecidability as well as the robustness of quotient structures to the symmetry assumptions.

New work was presented on fundamental properties (controllability, observability, etc.) underpinning control synthesis for multi-agent systems; this included the topic of controller synthesis for vector discrete event systems under partial observations. A promising approach in this direction is the use of hierarchical control architectures presented during the workshop. This method can be effectively used to reduce the computational complexity of various architecturally complex systems.

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Logics for Synthesis of Decentralized/Distributed Controllers:

Exciting new results on the use of special logics that allow the solution of controller synthesis problems as certain types of verification problems were presented. These results are very elegant from a theoretical standpoint. They also appear to offer new possibilities for synthesizing control strategies for problems with partial observation. There was a feeling among attendees that this is a promising new avenue, although the computational properties of the approach remain largely unexplored.

Related work on solving control problems for continuous-variable systems subject to temporal logic specifications was presented. In this case, it was shown how the (discrete) specification drives the abstraction of the continuous-variable system to a discrete event system that is sufficiently detailed for controller synthesis purposes.

The use of a special logic for addressing decentralization of information in distributed systems was also presented. This method uses a modal logic for ascribing knowledge to agents and relates the field of discrete-event systems control to recent work in theoretical computer science on formal reasoning about knowledge. One of the goals is to use the knowledge theory approach to aid in the synthesis of communication strategies between controllers in a distributed control setting.

Application Areas:

A grammar-based approach to problems in distributed robotic self-assembly was presented, and various discrete-event control problems associated with Uninhabited Air Vehicles (UAVs) and distributed ship control were discussed. A Petri-net based method of fault detection in electric power distribution system protection networks was proposed. In general, it was felt that in further theoretical developments of existing theories special attention should be paid to applications. For example, more experience with applications could lead to a better understanding of the modelling of incomplete or imperfect system descriptions. It was suggested that a set of benchmark applications be assembled, and that additional energy be devoted to the development of software tools.

Discussion Topics

At the end of the workshop, a free-form session was held to discuss the common themes, open research problems, and debated ideas that arose during the workshop. In addition to the topics and areas in the aforementioned sections of this report, some of the other issues that arose include the following: the tradeoff between expressiveness of a model and its computational capabilities; uncertainty, robustness, unmodelled dynamics and the need to design systems which can tolerate imperfections; the desire for a simple characterization of the fundamental system-theoretic properties of decentralized discrete-event systems; and the relationship between theory and application and to what degree applications should drive future theory.

Future Workshop:

The workshop underlined the vitality, the variety and the pertinence of research on the three broad issues of structure, communication and control. It also highlighted other themes – such as the increasing rapprochement between discrete event control and computer science, which recurred throughout. The attendees unanimously support holding a similar workshop in 2006 to discuss progress made on the key issues summarized above and to identify new strategic research directions in decentralized control of discrete event systems.