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HYBRID SUPERVISORY CONTROL IN INTELLIGENT AUTONOMOUS SYSTEMS

Panos J. Antsaklis

Department of Electrical Engineering
University of Notre Dame
Notre Dame, IN 46556 USA
mail: antsaklis.1@nd.edu
http://www.nd.edu/~pantsakl/

Abstract: It is shown that the quest for autonomy in engineering systems leads to intelligent control and to approaches that combine methodologies from the control, computing and communication networks areas and to hybrid system methodologies. The area of hybrid dynamical systems is of particular importance to intelligent control and several approaches to modeling and control of such systems are briefly discussed, with emphasis on supervisory control approaches that are based on discrete abstractions.

Keywords: Autonomous control, Intelligent control, Supervision

SUMMARY

An introduction to the area of intelligent autonomous control is first presented. Fundamental issues rather than techniques are emphasized and examples are used to illustrate the concepts. Highly demanding autonomous control requirements in modern control systems, coupled with the complexity and uncertainty of models require the use of sophisticated control methods; and this is the driving force behind intelligent control. Examples of systems where intelligent control is of great importance include flexible manufacturing and chemical process control systems, robotic systems, interconnected power systems, intelligent vehicle highway systems, air traffic management systems and computer communication networks. The evolution from conventional control to intelligent control methodologies is discussed and a hierarchical intelligent functional control architecture is presented.

Recent technological advances make feasible the deployment of large numbers of distributed embedded processors that cooperate towards achieving common goals. This can be seen as a way to realize autonomous intelligent systems. In general, embedded digital devices that interact with the physical world via sensors and actuators that are widely distributed and linked via a communication network, and which coordinate their actions towards some common goal are expected to proliferate in commercial and military applications. These applications range from manufacturing, chemical process and medical applications, to autonomous robotic space, air and ground vehicles. The embedded systems may implement a control system or the behavior of existing embedded systems may need to be better understood and managed via systems and control methodologies. When embedded digital processors interact with the physical world, hybrid dynamics play an important role particularly in the design of high performance systems. So the area of hybrid embedded systems has significant potential for growth and impact and holds great promise.

Hybrid systems are dynamical systems the behavior of which is determined by interacting continuous and discrete dynamics. To fully understand

the system's behavior and meet high performance specifications one needs to study all dynamics together with their interactions. Only then problems such as optimization of the whole process may be addressed in a more meaningful manner. There are many application areas where hybrid dynamics arise. For example, the need for advanced computer control of continuous processes in areas such as manufacturing, communication networks and industrial processes provides strong motivation for the study of modeling, design, verification and control of hybrid dynamical systems that include both continuous and discrete dynamics that interact with each other. In some cases the continuous and discrete parts of the process of interest may be studied independently, but when there are strong interactions among these continuous and discrete components or tight design specifications to be met, the hybrid nature of the process must be taken explicitly into account.

In the supervisory approach to hybrid control, a discrete event system (DES) model of the continuous dynamics is extracted and used to design supervisors that satisfy the original specifications on the hybrid system. It is important to recognize the fundamental importance of the hybrid interface and to identify key fundamental concepts, such as non-determinism in the DES models of the continuous dynamics derived using discrete abstractions. A control synthesis approach where hybrid system supervisors are designed by extending the logical supervisory DES control approach is briefly presented. In recent work to analysis and synthesis of hybrid systems the supervisory control methodologies have been refined and extended. This approach is based on a systematic methodology for refinement of the state space partition and uses the available control inputs in order to simplify the continuous dynamics. The approach focuses on discrete-time, piecewise linear systems and develops strong theoretical results and efficient algorithms.

Details of our approach to intelligent control and to hybrid control systems may be found in the references below.

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