C O N 4 C O O R D

Control for Coordination of Distributed Systems

The project aims at developing controllers of distributed systems for five case studies and at developing theory for control, communication, informatics, and tools of such distributed systems.

KEYWORDS: Control, coordination, cooperation, hierarchical control, communication, informatics, tools, distributed systems, uninhabited underwater vehicles, uninhabited aerial vehicles, control of road networks, complex machines, automated guided vehicles.

At A Glance: CON4COORD

Control for coordination of distributed systems.

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University of Cyprus (Cyprus)
Ghent University (Belgium)
University of Porto (Portugal)
University of Verona (Italy)
Hesse-Noord Natie (Belgium)
Marine Systems Technology (Portugal)
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Duration: *36 months*

Start: 2008.05.01

Total Cost: € 3.994.584

EC Contribution: € 2.900.000

Main Objectives

The aim of the project is to develop control theory and control engineering for coordination control of distributed engineering systems.

The motivation for studying control for coordination of distributed systems is exemplified by the project's five case studies: control for underwater vehicles, for aerial vehicles, for a road control and communication network, for automated guided vehicles, and for complex machines.

CON4COORD aims at control design and at theory development for distributed systems.

The research thrust of the project is in control design and control synthesis. There are four main themes: control synthesis of a global coordinator of a distributed system, in communication for control, in informatics for control, and in tools for control design. Control design for the case studies based on the research thrust will form the main effort of the project and will be disseminated to the user partners.

The researchers find it useful to work on these case studies and on the theoretical issues simultaneously so as to compare the case studies and to learn from the algorithms and methods in the areas of the case studies.

The consortium consists of four user partners and eight academic partners which combined have a very wide and very deep expertise in the many topics required for the proposed project.

Technical Approach

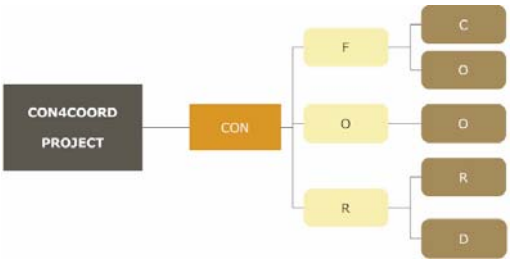
The problem of control of distributed systems is to synthesize and to design a control law, and to evaluate the performance of the resulting closed-loop system. The performance evaluation determines to which degree the closed-loop system meets the set of control objectives. In this investigation major attention is devoted to the control synthesis at the global level for the coordinator. The control synthesis at the local level is assumed to be solved satisfactorily by existing methods. This problem is very difficult because of:

(1) the distributed character of the system and

(2) the partial observations of the state available for control where the partial observations differ by subsystem.

Control for Coordination

There are known examples of control problems for distributed systems which cannot be solved using local control laws exclusively. It is therefore necessary to have a control law at the global level which will be called the *coordinator* of the distributed system. That coordinator receives partial information of all subsystems and facilitates cooperation between local subsystems. Physically the coordinator is often located at one of the subsystems.



It is clear from examples of coordinators that the time scale of the dynamics of a coordinator is much slower than that of the subsystems. But the interaction of the coordinator and the subsystems depends on the problem, it can be tight or slow. In case of a time scale separation the problem has a natural hierarchical structure with the coordinator at the highest level and the subsystems at the lower level. For particular case studies it may be useful to distinguish more levels of the hierarchical system.

Control with communication between controllers of the subsystems

In addition to the progress on the control issues discussed above, progress is envisioned on the research topic of control via a communication network. When control of a distributed system takes place via a communication network then the control law has to take account that the communication of information is unreliable, the communication channels have limited capacity, and information arrives with a delay.

The progress is expected to consist of procedures and algorithms to cope with the communication delays and the limited capacities. This amounts to a trade-off between the control objectives and the performance of the communication network which can be partly done by optimization techniques. It is a fact of life that communication channels are unreliable. Total breakdown can occur at any time. Therefore procedures on what to do have to be defined at every subsystem if the communication network fails to function over a long period of time.

Informatics

Distributed algorithms for control of distributed systems will receive attention. Tools for control design like Ariadne will be further developed.

Key Issues

The particular research issues are:

- *Case study. Control of underwater vehicles*. Control for coordination of three or more underwater vehicles for surveillance or environmental monitoring missions.

- *Case study. Control of aerial vehicles*. Control for coordination of several aerial vehicles for missions of environmental monitoring.

- *Case study. Control on road networks*. Design of a control system for a road network with information from many vehicles in a hierarchically structured control and communication network to meet objectives of safety and the environment.

- *Case study. Control for coordination of automatic guided vehicles*. Control design for vehicles which are transporting containers to or from a warehouse at a container terminal.

- *Case study. Control of complex machines*. Control design for complex machines such as high speed printers which use distributed control and information processing to achieve an optimum between performance and cost.

- *Control*. Control for coordination of distributed systems by a global coordinator which achieves a trade-off between the control objectives and the cost.

- *Communication networks for control*. Synthesis and performance analysis of protocols for communication networks used for control including dynamically changing networks.

- *Informatics for control of distributed systems*. Synthesis and design of distributed algorithms for control and failure detection of distributed systems.

- *Tools*. Computer programs to compute control laws with guaranteed performance bounds for hybrid systems by methods of mathematics and of computer science.

Expected Impact

The contribution of the project to the European Commission's Work Program are in control of large-scale complex distributed systems (ICT-2007.3.7.(c)). The expected impacts are:

(1) enabling low cost monitoring for the environment and for natural resources by underwater and aerial vehicles;

(2) new services and applications for new markets

in particular for automated guided vehicles at container terminals, and for control and communication networks of road networks; and

(3) improved performance of distributed systems.