Report on the First European Laboratory on Real-Time Embedded Systems

RETIS Lab
Scuola Superiore Sant'Anna, Pisa (Italy)
Pisa, July 10-14, 2006

URL: http://www.artist-embedded.org/FP6/ARTIST2Events/Events/RT-Control/

1. Introduction

The First European Laboratory on Real-Time Embedded Systems (called the Eurolab in the following) was an initiative of the ART cluster of the ARTIST2 NoE, organized in collaboration with the Control Cluster. The purpose of this course was twofold:

- The first objective was to provide the most important concepts and methodologies used in developing real-time embedded systems, including fundamentals of real-time scheduling, operating systems, distributed systems, and control theory.
- The second and more challenging goal was to show how to apply theory into practice, teaching students how to develop simple real-time distributed control applications using the state-of-the-art technologies available into the Shark kernel

The course was hosted by the Laboratory on Real-Time and Embedded Systems (RETIS Lab) of the Scuola Superiore Sant'Anna, located in Pisa (Italy), from July 10 to July 14, 2006.

Organizing Committee

- Giorgio Buttazzo (Scuola Superiore Sant'Anna, Italy)
- Karl-Erik Årzén (University of Lund, Sweden)
- Luis Almeida (University of Aveiro, Portugal)
- Anton Cervin (University of Lund, Sweden)

Local Arrangements

- Giorgio Buttazzo (Scuola Superiore Sant'Anna, Italy)
- Ettore Ricciardi (ISTI-CNR, Pisa)
- Mara Gandolfo (RETIS Lab, Scuola Superiore Sant'Anna, Pisa)

Teachers

- Giorgio Buttazzo (Scuola Superiore Sant'Anna, Italy)
- Luis Almeida (University of Aveiro, Portugal)
- Anton Cervin (University of Lund, Sweden)
- Paolo Gai (Evidence S.r.l., Italy)

Technical Assistants

- Tullio Facchinetti (University of Pavia, Italy)
- Mauro Marinoni (University of Pavia, Italy)
- Gianluca Franchino (University of Pavia, Italy)
- Paulo Pedreiras (University of Aveiro, Portugal)
- Ricardo Marau (University of Aveiro, Portugal)

2. Course structure

The school was structured as a five day course with lectures and laboratory exercises. For the first four days, mornings were dedicated to theory and afternoons to practical experience. The last day was entirely dedicated to practice. The goal of the lectures was to introduce the fundamentals on real-time systems in scheduling, control, and networks, and to provide a detailed presentation of the Shark operating system, used for the practical laboratory part. Each day was dedicated to a specific topic:

1. The first day introduced the basic principles of real-time computing and illustrated the most significant results on real-time scheduling and resource management.
2. The second day was entirely devoted to the Shark kernel, to enable participants to quickly write a simple real-time demo, using the methodologies they learnt in the previous day. During the second day, 15 possible projects were presented by the teachers to the participants, who divided in groups of 2-3 people and selected a project to develop in the next days.
3. The third day was focused on real-time control and explained how to design control applications taking timing constraints into account, and how to use control techniques to make real-time systems more adaptive to dynamic changes.
4. The forth day was dedicated to real-time networks and addressed the problems of synchronization and medium access control that are encountered in distributed embedded systems, together with an analysis of end-to-end latencies.
5. The fifth day was entirely dedicated to practical experience and implementation. The participants interacted with the teachers and lab assistants to propose a real-time control application, preferably distributed, either in a simulated environment or for controlling one of the platforms that will be provided by the teachers.

3. Practical laboratory experience

The practical part of the course required the participants to develop a real-time control application, using a number of simple robotic devices prepared by the organizers. The available systems included an inverted pendulum, a ball and plate device with video feedback, a 5 d.o.f. robot arm with a videocamera on its wrist, a robot veicle with a wireless camera, a pan and tilt laser pointer, two light guns, a data glove, and a number of distributed applications that had to be developed on a different PC's connected through Ethernet under UDP/IP.

Each control application had to be developed under the Shark operating system, using a number of concurrent threads, with periodic and aperiodic nature, interacting through shared buffers or message passing communication channels. The low level code for accessing the hardware was already provided as a number of library functions, so the participants had to develop only the code for sensory data processing and control.

The participants had the unique opportunity to use and test different advanced kernel mechanisms, like Rate Monotonic, EDF, Aperiodic Servers, Resource Reservation, Admission Control, Priority Inheritance, and several types of communication mechanisms.

4. Participants

The course hosted thirty participants, from universities, research centers and industries, coming from 10 different countries. Figure 1 and Figure 2 show them attending the lectures and working in the lab.

1.	Prashant Batra	IIT Bombay, India
2.	Jerker Bengtsson	Halmstad University, Sweden
3.	Menouer Boubekeur	University College Cork, Ireland
4.	Gabriele Cecchetti	Scuola Superiore Sant'Anna, Italy
5.	Niharendu Chandra	Chalmers University of Technology, Sweden
6.	Fabio Checconi	Scuola Superiore Sant'Anna, Italy
7.	Francesco Focacci	Scuola Superiore Sant'Anna, Italy
8.	Ning Gui	University of Antwerpen, Belgium
9.	Jean-Claude Habumuremyi	Royal Military Academy, Belgium
10.	Thomas Heinz	Bosch GmbH / Saarland University, Germany
11.	Dave Hickey	University College Cork, Ireland
12.	Hoai Hoang	Halmstad University, Sweden
13.	Danilo Iovino	Ansaldo Segnalamento Ferroviario, Italy
14.	Panagiotis Katsaros	Aristotle University of Thessalonkiki, Greece
15.	Omar Kermia	INRIA Rocquencourt, France
16.	Francesco Leonardi	University of Trento, Italy
17.	Carlos Martinez Belinchon	Universidad Politecnica de Madrid, Spain
18.	James Mc Enery	University College Cork, Ireland
19.	Ahlem Mifdaoui	ENSICA Toulouse, France
20.	Paolo Pagano	Scuola Superiore Sant'Anna, Italy
21.	Kunal Raheja	Chalmers University of Technology, Sweden
22.	Antonio Romano	Scuola Superiore Sant'Anna, Italy
23.	Anna Lina Ruscelli	Scuola Superiore Sant'Anna, Italy
24.	Anna Salzo	Ansaldo Segnalamento Ferroviario, Italy
25.	Salvatore Scafidi	Ansaldo Segnalamento Ferroviario, Italy
26.	Ramon Serna Oliver	TU Kaiserslautern, Germany
27.	Alena Simalatsar	University of Trento, Italy
28.	Nikolay Stoimenov	ETH Zurich, Switzerland
29.	Hong Sun	University of Antwerp, Belgium
30.	Yifan WU	Scuola Sant'Anna, Italy

Figure 1: Participants following the theoretical lectures.

Figure 2: Participants working in the lab.

5. Projects

During the course, a number of real-time control applications have been developed by the participants, who have been divided into groups of 2, 3, or 4 people. Each group had to select a control system among those provided by the organizers and develop the acquisition and control software using the real-time features available into Shark. Considering the limited time available for programming, the low-level code for accessing the hardware was already provided as a number of library functions, so the participants had to develop only the code for sensory data processing and control.

The following projects have been selected by the participants:

	Project	Participants
1.	**Robot Goalkeeper**	Salvatore Scafidi, Ramon Serna Oliver, Ahlem Mifdaoui, Omar Kermia
2.	**Inverted pendulum**	Nikolay Stoimenov, Carlos Martinez Belinchon
3.	**Ball and plate by vision**	Danilo Iovino, Anna Salzo
4.	**Vehicle following a target by vision**	Yifan Wu, Paolo Pagano, Prashant Batra Antonio Romano, Anna Lina Ruscelli
5.	**Robot arm: grasping by vision**	Ning Gui, Hong Sun Jean-Claude Habumuremyi
6.	**Light gun**	Thomas Heinz, Dave Hickey, Menouer Boubekeur, James Mc Enery
7.	**Laser pointer with mouse control**	Niharendu Chandra, Kunal Raheja
8.	**Data glove**	Francesco Leonardi, Alena Simalatsar
9.	**Distributed ping pong**	Panagiotis Katsaros, Francesco Focacci
10.	**Distributed car race**	Jerker Bengtsson, Hoai Hoang, Fabio Checconi, Gabriele Cecchetti

6. Presentations

The last day (Friday, July 14), each group gave a short (10 minutes) presentation to all the other participants, explaining the proposed ideas and solutions. A demo of the developed system was also shown if possible.

7. Diploma

At the end of school, each participant received a diploma certifying his/her attendance to the course:

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First European Laboratory on Real-Time Embedded Systems

Pisa, July 10-14, 2006

We hereby declare that _____

attended the First European Laboratory on Real-Time Embedded Systems, held in Pisa, on July 10-14, 2006.

The course included 20 hours of lectures and 20 hours of laboratory experience divided in the following topics:

"Real-Time Scheduling"	by Prof. Giorgio Buttazzo (Scuola Superiore Sant'Anna, Italy)
"The SHARK Kernel"	by Dr. Paolo Gai (Evidence S.r.l., Italy)
"Real-Time and Control Issues"	by Dr. Anton Cervin (Lund University, Sweden)
"Real-Time Networks"	by Prof. Luis Almeida (University of Aveiro, Portugal)

Pisa, July 14th, 2006

The Course Coordinator
Prof. Giorgio Buttazzo

8 Conclusions

All the participants highly appreciated the course, since they learned not only novel methodologies in the field of real-time embedded systems, but also had the unique opportunity to apply theory into practice, by developing a real control application.

In spite of some initial difficulties in getting all hardware devices working, most of the participants had the possibility of programming periodic control threads, reading sensors, performing some simple image processing, writing PID controllers, acquiring data from a serial line, exchanging data packets through an UDP/IP network, and controlling servomotors.

Setting up the control devices for the practical experiments took the major effort in the preparation of the course and was underestimated at the time of the proposal. Sensory acquisition interfaces and servomotor control boards had to be developed and tested for each robot device and the total cost required for this phase was significantly higher than the allocated budget. This course could have never be implemented so successfully without the extremely helpful support of the laboratory assistants, who worked hard, before and during the course, to facilitate the job to the participants and guarantee that all hardware devices were fully operational.