# Fourth ARTIST2 graduate school on Embedded Control Systems, May 26-30 at KTH - Conclusions

The fourth Artist2 graduate school on was given in Stockholm at KTH, May 26-30, 2008, in the series of graduate schools arranged by the Control for Embedded systems cluster (Lund 2007, Prague 2006, Valencia 2005). The school was this time organized by KTH, and the local organizer was Prof. Martin Törngren. The lectures were given by representatives of the four cluster partners (KTH, LTH, UPV and CTU) and invited industrial presenters from ABB, Ericsson, Scania, and the Swedish Space Corporation. See the appendix for the full program.

## Changes compared to previous school

No major changes were performed but comparing with the previous course the following changes were made:

- The foundational first day, providing introductory crash courses, was augmented by one additional introductory lab to complement the theoretical introduction such that participants with a computing background were given basic exercises on Matlab/Simulink/Stateflow/Control, and participants with a control background were given an introduction to microcontroller programming and integrated development environments.
- A first common dinner was scheduled the first day to stimulate interactions among the participants.
- A special tour of the Department was included where results from MSc level capstone projects in Mechatronics were presented.

Most of the labs were this time taken from existing courses at KTH, basically corresponding to the labs given during the previous course. In addition the complete set of material was revised taking previous years evaluation into account.

The only logistical problem encountered was the fact that the course took place during a busy time at KTH coinciding with the peak of a KTH exam period (the date was chosen based on the availability of lecturers and to avoid clashes with other events). The result was that three different lecture rooms had to be used. Although they are located closely to each-other, the house layout made orientation a little difficult.

## Participants

Due to physical constraints in the lab, the no. of participants was limited to 35, out of which 34 persons eventually participated. The participants came from Austria, Finland, France, Germany, Italy, Korea, Rumania, Spain, Sweden and the UK (see the list of participants, appended to this report). The course became full prior to the deadline, approx. one month before the course. The waiting list contained five persons, of which two were accepted in a late stage when already accepted persons informed us they were not coming. It should be noted that there was only ONE major call issued through email informing about the event. The event was visible through the ARTIST2 web page.

The school was free of cost for all participants. The PhD student participants were also offered full support for accommodation at youth hostels in Stockholm. One dinner was included as part of the ARTIST2 course. A second complimentary dinner was supported by KTH and industrial sponsors.

## Conclusions

Overall the course was a success. The feedback from the participants was highly positive both with respect to the course content and its organization. One reason for the success is the experience gained during the series of ARTIST2 courses undertaken by the Control for embedded systems cluster. However there are still ways in which the course can be improved even further. The improvement possibilities are strongly connected to the challenges inherent in organizing this type of interdisciplinary and intensive course.

*Heterogeneous topics and participants*. The course focus on the intersection of control and embedded systems has several implications. First of all, there is a large number of potential topics that may be covered. This means that a selection is required. Secondly, the interdisciplinarity means that the participants also have widely varying backgrounds such as computer science, automatic control, or software engineering.

*Intensive course*. During one week the students are exposed to a large number of topics that span several disciplines. The overall goal is to provide the students with better overview of the area and a better understanding of the connections between the involved theories/disciplines. However, having such a concentrated interdisciplinary course means that the approach has to be chosen such that the participants are not overwhelmed with material, and ideally such that they are supported in follow-up studies after the course.

The heterogeneity of the participants is clearly reflected in their answers (for example with some stating that the labs were too simple, whereas others stating that the labs were too advanced).

To handle these challenges, the course strategy was to provide

- An introductory day, providing in parallel crash courses and labs in Control as well as real-time embedded systems.
- Choices to the participants meaning that the participants for each lab section could focus on more embedded systems or control intensive tasks, and proceed from simpler to more advanced tasks.
- A balance between theory and practice (labs) to enhance learning.
- All material accessible on the web.

Excellent suggestions were provided by the course participants to strengthen the course further. These together with our own observations provide the following suggestions for improvements.

- Make the introductory day optional - and thus available for those that demand it.
- Add a poster session were the participants present their research in order to stimulate for exchange and discussions among participants.
- The lab material/exercises in this course were to a large extent taken from final year MSc courses at KTH. Given the time and resources, these should be optimized for this kind of intensive PhD level course. The short amount of time is the key constraint, requiring focused labs.
- The labs or related exercises could be distributed prior to the course with demands for preparation.

The continuation of the course is currently undetermined but given the feedback over the four years, and the limited marketing effort, there are substantial indications that there is a demand and interest for the course. It seems highly plausible that the course would attract participants also without being free of charge. The course may be continued within the context of the ArtistDesign network or possibly as a stand-alone course.

## Course evaluation: Feedback from the participants

The replies are taken from the course questionnaire representing summaries of the replies of the participants to the stated questions. 20 replies (out of 34) were received. Similar answers have been grouped with the number of similar answers given in parenthesis.

*WHAT WAS THE BEST THING WITH THE COURSE?*
- The organization of the course (11)
- Overview of the area (5)
- The high qualitification of the professors and lecturers who teached (5)
- Location (KTH campus) and KTH specific arrangements including Dept. and project tour (3)
- Lab activities (3)
- Combination of practical and theoretical issues (2)
- Guest lectures from industry (2)
- Theoretical lectures and lecturers (1)
- Best lectures: RT computing (1), Fixed point (2), off-line scheduling for FPGA (1)
- Industry talks (1)
- Real-time systems part (1)
- Lectures from people presenting their research activity and results (1)
- Good management of lectures & labs (1)
- The ideas exchange with many people from all of the world that give their contribution to knowledge (1)

*WHAT WAS THE WORST THING WITH THE COURSE?*
- Industrial lectures (vague content stated for one, too long stated for one) (2)
- A large quantity of information and new knowledge which was covered in a short time (1)
- Too much emphasis on time scheduling with too much overlap between lectures.
  Suggestion: Check overlap and Cover within fewer lectures (1)
- Too much changing rooms (1)
- Dividing into parallel parts the first day (1)
- The hostel is terrible (1)
- Dividing lectures and lab exercise in two parallel tasks (1)
- Although very useful, the labs were a bit abstract for me (1)

*WHICH PARTS SHOULD WE REMOVE AND/OR SUBSTANTIALLY UPDATE FOR A FOLLOW-UP COURSE?*
- Lab time was not enough (too comprehensive labs, too much to read, too advanced tools): (7)
- Reduce lab time, increase lecture time (1)
- Labs were too student oriented (copy and paste) (3)
- Strengthen connection between FPGA part and other parts of the course (2)
- Too advanced labs (2)
- More labs oriented towards analysis (1)
- Too basic labs (1)

- Lab material/exercises should be distributed prior to the course with demands for preparation (1)
- Some of the problems discussed were engineering problems rather than research. Would like to have more emphasis on theory and research. Would have been good to have more of open research problems and their relevance (1)
- Topic selection was good but more theoretical results with people also presenting their leading edge research results are welcome (1)
- Lab: Suggestion to focus on a single "argument" and explore it in detail during the whole week (1)
- Maybe it would have been better to have one single lab project during the whole week (1).
- Add a poster session were the participants present their research in order to provide opportunities for interaction and coop. can be found/better exploited (1)
- The course could start with a short intro, of every participant (1)
- Many of the students participating because they are working in the area of the course, so many do not need the introductions to control and RT parts during the first day (1)
- The topics are more about control. Possible add more about real-time system and scheduling algorithms in the future. (1)
- Provide a CD or USB with all course material (1).
- Maybe a scope of current commercial embedded solutions with their features (1)
- Computers in the lab should be available for each one, not in pairs of two or three (1)

*ARE THERE SOME TOPICS YOU THINK WERE MISSING?*
*(comments on the selection of topics and theory vs. practice, are also most welcomed)*
- Robust control for NCS, and control over sensor nets (1)
- Hardware issues, power, HW components, reliability (1)
-A/D, D/A, quantization (1)
- Safety critical systems aspects (1)
- More on real-time systems, in particular open source RTS, e.g. RTLinux/GPL, RTAI, etc. (1)
- More about the actual implementation of control on hardware and its related problems (1)

*COMMENTS ON THE PRACTICAL ARRANGMENTS?*
- Too much room changing, try to keep in the same room (3)

*SPECIFIC COMMENTS TO THE LECTURES AND LABS*
- International students need more practical info regarding accommodation (1)
- Very nice to have accommodation arranged (1)
- Some of the hostels were in themselves not well arranged (1)
- Would be better to have the lectures between 8-16 to give room for sightseeing (1)
- The hostel is a bit far from the Univ. Would be better to stay closer (1).
- Most of students are from abroad. Giving more details about hostels would be helpful (1)

*OTHER COMMENTS*
"- I consider it has been a very instructive course, and I've learnt a lot. It would be nice to keep it for several years to make more people able to take part in it."
- "See u again if you accept my application next course, thank you."
- "Cool lab sessions"
- "Good balance between topics" (5)
- "The presentation of projects on Thursday was great." (1)
Many dedicated thanks were included to the KTH organizers and ARTIST2! (7)

## Appendices

- Course program
- List of participants

## Course program

**Monday, May 26 – *Room M37***

| | | |
|---|---|---|
| 09.00 – 09:15 | Welcome | Martin Törngren |
| 09:15 – 10.15 | Embedded control systems: Intro&Overview | Martin Törngren |
| 10:15 – 10.30 | Coffee | |
| 10:30 – 12.30 | Parallel tracks | |
| | Introduction to Control | Jan Wikander/Bengt Eriksson |
| | Introduction to Real-time computing | Alfons Crespo |
| 12:30- 13.30 | Lunch | |
| 13:30 – 14.30 | Parallel tracks continued | Jan Wikander/Alfons Crespo |
| 14.30 – 15.30 | Example flow: PID control to implementation | Lei Feng |
| 15:50 – 18.00 | Lab 1: Matlab/Simulink and 32 bit microcontroller development environment | |
| 19.00 - | JOINT DINNER AT KTH! | |

**Tuesday, May 27 – *Room M36***

| | | |
|---|---|---|
| 09.00 – 11:00 | Control and Real-time issues | Pedro Albertos, Alfons Crespo |
| 11:00 – 11.15 | Coffee | |
| 11:15 – 12:30 | Integrated control and scheduling | Karl-Erik Årzen, Anton Cervin |
| 12:30 - 13.30 | Lunch | |
| 13:30 – 14:15 | Integrated control and scheduling cont. | Karl-Erik Årzen, Anton Cervin |
| 14:15 – 17:15 | Lab2: PID control of DC servo and RTOS implementation | KTH Mechatronics |

**Wednesday, May 28 – *Room M36***

| | | |
|---|---|---|
| 8.30 – 10.30 | Control of computer systems | Karl-Erik Årzen, Anton Cervin |
| 10:45 - 11.45 | Fixed point arithmetics | Anton Cervin |
| 11:45 – 12:30 | Lunch | |
| 13:00 - 17.00 | Lab3: | |
| | Control over the CAN network | KTH mechatronics |
| | FPGAs: Brief intro and lab | KTH ICT |

**Thursday, May 29 – *Room M22***

| | | |
|---|---|---|
| 09:00 – 10.00 | Networked control systems | Karl Henrik Johansson |
| 10:00 – 11:00 | Integrating multiple models and tools in embedded control systems development. | Martin Törngren |
| 11:00 – 11.15 | Coffee | |
| 11:15 – 12:30 | Offline scheduling for FPGAs | Premysl Sucha |
| 12:30 - 13:30 | Lunch | |
| 13:30 – 17:00 | Lab4: Truetime and TORSCHE | KTH and Premysl Sucha |

**Friday, May 30 - Industrial guest lectures – *Room M36***

| | | |
|---|---|---|
| 09:00 – 09:55 | Engine control systems | Mats Jennische, Scania |
| 9:55 – 10:50 | Embedded control systems in Industrial robotics | Peter Ericsson, ABB |
| 11:10 – 12:05 | Design for redundancy and high reliability, with examples from spacecraft development | Gunnar Andersson, Swedish Space Corporation |
| 12:05 – 13:00 | Control problems in wireless networks | Fredrik Gunnarsson, Ericsson |

## List of participants

| | | | | |
|---|---|---|---|---|
| **Assad** | **Al Alam** | Systems developer | Scania | Sweden |
| **Ashraf** | **Armoush** | PhD | RWTH-Aachen University | Germany |
| **Fatima** | **Barcelo Rico** | PhD | UPV | Spain |
| **Meysam** | **Basiri** | (start) PHD | KTH | Sweden |
| **Moris** | **Behnam** | PhD | Mälardalen university | Sweden |
| **Ignacio** | **Benitez Sanchez** | PhD | Polytechnic University of Valencia | Spain |
| **Mangesh** | **Chitnis** | Phd | Scuola Superiore Sant'Anna, Pisa | Italy |
| **Silviu** | **Craciunas** | PhD | University of Salzburg | Austria |
| **Antonio** | **Del Giudice** | Electronic engineer | University of Salerno | Italy |
| **Piergiuseppe** | **Di Marco** | Master Student | KTH | Sweden |
| **Wassim** | **El Hajj Chehade** | PhD | CEA Saclay France | France |
| **Mohammed** | **Elmusrati** | researcher | Helsinki University of Technology | Finland |
| **Florin** | **Enache** | PhD | Military Technical Academy | Romania |
| **Dario** | **Faggioli** | PhD | Scuola Superiore Sant'Anna | Italy |
| **Pan** | **Gun Park** | PhD | KTH | Sweden |
| **Magnus** | **Lindhé** | PhD | KTH | Sweden |
| **Diego** | **Martínez Castro** | PhD | Universidad Politécnica de Valencia | Spain |
| **Manuel** | **Muñoz Alcobendas** | PhD | Polytechnic University of Valencia | Spain |
| **Vicente** | **Nicolau** | PhD | Politechnic University of Valencia | Spain |
| **Javier O. Coronel** | **Parada** | PhD | Universidad Politécnica de Valencia | Spain |
| **Sang-Kyun** | **Park** | Control engineer | Hyundai Heavy Industries Co. | Korea(South) |
| **Florin** | **Popescu** | PhD | Military Technical Academy | Romania |
| **Mitra** | **Pourabdollah** | Master Student | KTH | |
| **Sergiu** | **Rafiliu** | PhD | Linköping University | Sweden |
| **Chithrupa** | **Ramesh** | researcher | KTH | Sweden |
| **Zhou** | **Rui** | PhD | Universidad Politécnica de Valencia | Spain |
| **Zhitao** | **He** | PhD | KTH/Kista | Sweden |
| **Soheil** | **Samii** | PhD | Linköping University | Sweden |
| **Luca** | **Santinelli** | Ph.D. | Scuola Superiore Sant'Anna in Pisa | Italy |
| **Mohammad** | **Sohani** | Master Student | KTH | Sweden |
| **Andre** | **Stollenwerk** | PhD | RWTH Aachen University | Germany |
| **Ekarin** | **Suethanuwong** | PhD | Institute of Computer Engineering | Austria |
| **Huiyan** | **Wang** | PhD | University of Leicester | England |
| **Zeashan Hameed** | **KHAN** | PhD | Domaine Universitaire | France |