

Year 2 Review
Paris, November 8th and 9th, 2006

Achievements and Perspectives :

Control for Embedded Systems

Cluster leader : Karl-Erik Årzén
Lund University



Presentation of the Cluster - Partners

Core partners:

- Lund University – Karl-Erik Årzén
- KTH – Martin Törngren
- UPVLC – Alfons Crespo
- CTU – Zdenek Hanzalek



Affiliated international partners:

- Lui Sha – Univ of Illinois
- Tarek Abdelzaher – Univ of Illinois



Presentation of the Cluster

Affiliated industrial partners:

- dSpace (Joachim Stroop)
- ABB Automation Technology Products (Göran Arinder)
- Honeywell Prague Laboratory (Vladimir Havlena)
- Volvo Car Corporation (Jakob Axelsson)
- Volvo Technology Corporation (Magnus Hellring)
- Maquet Critical Care (Klas Engwall)
- Ericsson (Johan Eker)



Presentation of the Cluster - Activities

Cluster Integration Activities:

- Control for Real-Time Computing (**CREATE**) – Karl-Erik Årzén
- RT Techniques in Control System Implementation (**RTC**) – Alfons Crespo

NoE Integration Activities:

- Adaptive RT, HRT and Control (**HARTCON**) – Karl-Erik Årzén

Platform Activity:

- Design Tools for Embedded Control (**ECS-Tools**) – Martin Törngren

High-Level Objectives

- Long Term Scientific Objectives

*Development of methods, tools and theory that allow faster and more efficient development of **networked embedded control** systems that are **safer**, more **flexible**, more **predictable**, have higher degree of **resource** utilization, and better **performance** than what is possible today*

*Advance the state of the art in applying **control methods** for providing **flexibility** and **robustness** and manage **uncertainty** in **embedded computing and communication systems**.*

High-level Objectives: Year 2

- **Design Tools for Embedded Control:**
 - **Objectives:** Tool integration, coordination with other clusters, and further development, coordination, and promotion of individual tools.
 - **Status:** The objectives have been achieved

- **Control in Real-Time Computing (CREATE):**
 - **Objectives:** Advance state of the art in applying control methods in embedded computing and communication systems.
 - **Application areas:** Performance control of web server systems, feedback-based reservation management in embedded real-time systems, feedback scheduling of control systems, and control of communication and sensor networks
 - **Status:** The objectives have been achieved
 - The followup to the Lund Workshop postponed until Spring 2007
 - Urbana-Champaign (May 31 – June 1)

High-Level Objectives: Year 2

- **Real-Time Techniques in Control System Implementation (RTC):**
 - **Objectives:** Advance the state of the art in applying real-time system methodology for embedded control system implementation, develop a common framework of control parameters and real time operating systems criteria
 - **Status:** Most of the objectives have been fulfilled.
 - The work on a common framework is ongoing
 - A planned joint meeting with HYCON had to be cancelled by HYCON
- **Adaptive RT, HRT and Control :**
 - **Objectives:** The union of the objectives for RTC and CREATE, but on a network-wide level involving the RT Components and the ART clusters.
 - **Status:** The objectives have been fulfilled.
 - Several joint research projects between the Control and the ART cluster
 - Joint Industrial Workshop organized between the Control and the RT Components cluster

Expected Impacts on Industry

- **Control is cross-cutting** in embedded systems
 - The results from the cluster can potentially influence most industry sectors, e.g. automotive, aerospace, industrial automation, medical systems, telecom, ...
- **Resource constraints** are a common characteristic of embedded systems
 - New theory, methodology and tools for embedded control system design and implementation can be expected to have a strong impact on industry
 - **Integration-based approaches** as well as **separation-of-concern based approaches**
- The use of feedback-based (adaptive) resource management is of particular interest in **soft and adaptive** real-time application areas, e.g.. multimedia, telecom, web services, ...

State of the Art - Research Trends

- **Increased awareness within the control community of the necessity to consider implementation-related resource constrains**
 - Pervasive embedded systems, e.g., sensor/actuator networks
 - Networked embedded systems, in particular wireless
 - Limited bandwidth, varying latencies, lost packets,
 - Resource-aware, implementation-aware, network-aware control
- **The true timing demands of control applications are to a higher degree considered in the real-time community**
- **Model-based control design integrated with model-driven software development**
 - Model management and tool integration important
- **Increased emphasis on large scale applications and experimental verification in control of computer systems**

Aim of the Cluster

- **Unite the best European groups** in the field and create a strong European research network on control for embedded systems.
- **Integrate the cluster with the other Artist2 clusters,**
 - increasing the awareness concerning the true computing and communication requirements of networked embedded control applications, and of
 - how control techniques can be used in the design of embedded systems to achieve increased robustness and flexibility.

Aim of the Cluster

- **Link the control and the embedded systems communities**
 - Very strong connections to the hybrid control community (HYCON)
 - Several of the cluster members are also active in HYCON
 - Lund hosted the HYCON general meeting in June
 - Årzén will give the first course on Embedded Control at the HYCON/“European Embedded Control Institute”, Supelec, March 12-16
 - Årzén and Cervin have been invited to lecture at the 2nd HYCON PhD School on Hybrid Systems, Siena, July 16-19, 2007
 - Very strong connections to the sensor networks & control community (RUNES)
 - Several of the cluster members are also members of RUNES
 - Controller components for MANET / sensor network applications
- **Provide a link between the network and the best US groups within the field**
 - UIUC, Caltech, Berkeley
 - International ARTIST2 Workshops
 - Lund 2005
 - Urbana – Champaign 2007

Interaction and Excellence Building: Year 2

- Numerous joint research activities
- Graduate Course on Embedded Control, Prague, 3-7 April 2006
- Jointly organized session on co-design tools at the IEEE CACSD conference, Munich, Oct 5
- Co-organized the First European Laboratory on Real-Time and Control for Embedded Systems, July 10-14th, 2006, Pisa, Italy with the ART cluster
- The workshop **Interaction between control and embedded electronics in the automotive industry** was jointly organized with the RT Components cluster in Innsbrück, March 23.
- Participated in the establishment of the FeBID workshop series on *Feedback Control Implementation and Design in Computing Systems and Networks*
- Organized the Scandinavian ARTIST2 Day in Stockholm, 21 August 2006
- Joint curriculum and textbook development in embedded control
- Several new EU projects involving partners from this clusters
- An invited session involving work from the RUNES and the ARTIST2 projects were held at the CDC-ECC conference in Sevilla in December, 2005
- A special issue of the Journal “Revista de Automática e Informática Industrial” (in Spanish) about real-time and control systems
- Presentation of ARTIST2 project at two workshops organized by EMTECH
- Co-organized track on Model-Based Design of Embedded Systems at DATE’07
- Three internal cluster meetings
- ...

Assessment at Y0+2

- Year 1 was characterized by roadmap development
- Year 2 more focus on dissemination and joint research along the lines of the roadmaps
 - More work to do on the roadmap dissemination
- More integration within the cluster and within the network
 - Several active research collaborations
 - 19 joint publications and a huge number of individual publications
 - Both journal and conference
 - Collected at <http://www.md.kth.se/RTC/ARTIST2/publications.html>
 - Jointly organized events (workshops, summer schools, sessions)
 - Invited keynote presentations
 - Project proposals
- PhD student mobility has decreased
 - Natural reasons
- A more realistic view on what can be achieved within a NoE

Future Work

Control of Real-Time Computing Systems:

- Progress on: Decreased requirements on prior knowledge about resource utilization, increased possibilities to use COTS implementation platforms, and enhanced robustness towards load variations
- Increase our international and industrial visibility. A good means for this is through the organization of and the participation in the FeBID workshops.
 - Munich, May 2007

Real-Time Techniques in Control System Implementation:

- Define common framework model in order to facilitate the control and computing co-design
- Organization of an annual Graduate School on Embedded Control Systems
 - May 7-11, Lund
- Organization of a follow-up of the Lund Workshop on Control for Embedded Systems
 - Urbana-Champaign, May 31 – June 1
- RTC 2007 Workshop attached to ECRTS'07 in Pisa

Future Work

Adaptive RT, HRT and Control:

- Demonstrate that scheduling algorithms can be made adaptive by means of control schemes
- The organization of a new industrial workshop together with the RT Components cluster
 - Co-located with the Integrated Modular Avionics workshop
- Urbana-Champaign workshop

Design Tools for Embedded Control:

- Further development of partner's individual tools
- Further work on model and tool integration including
 - Development of integration scenarios
 - Case studies involving integrating of tool functionalities developed by cluster partners
 - Case studies providing integration with UML tools
 - Case studies providing integration with tools for system safety analysis
- Further dissemination of results

Summary of Planned Events

- International ARTIST2 Workshop on Control for Embedded Systems
 - Urbana-Champaign, May 31 – June 1
- Graduate School on Embedded Control Systems
 - May 7-11, Lund
- Co-organization of the *Feedback Control Implementation and Design in Computing Systems and Networks* (FeBID) workshop, Munich 25 May, 2007 in Munich, (in conjunction with the 10th IFIP/IEEE Symposium on Integrated Management (IM 2007))
- Industrial Workshop co-organized with the RT Components cluster, Summer 2007
- Co-organization of the Second European Laboratory on Real-Time and Control for Embedded Systems, Pisa, July
- RTC'07 Workshop in connection with ECRTS'07
- Participation in the ARTIST2 China Workshop
- Participation in the ARTIST2 Platform Workshops (DATE, CAV, ..)
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Future Work: BRIDGIT

- Definition of embedded control case studies / benchmarks
- Control design **and real-time implementation**
 - Task structure
 - Real-Time Networks
 - Task allocation
- Matlab/Simulink + TrueTime
- Objectives
 - to share control&RT parameters of complex mechatronic systems
 - to compare various controllers designed and simulated in Matlab/Simulink
 - to simplify joint experiments on real plants
- “Unified” description of shared models
 - Control System Hardware
 - Control System Software
 - Experiments & Data
 - Mathematical Models & Controllers
 - Visualization
- First example: Helicopter from CTU

