IST-004527 ARTIST2
Network of Excellence
on Embedded Systems Design

Activity Progress Report for Year 3

JPRA-Cluster Integration
Control in real-time computing

Clusters:

Control for Embedded Systems

Activity Leader:

Professor Karl-Erik Årzén, Lund University

http://www.control.lth.se/user/karlerik/

Policy Objective (abstract)

The overall objective of this activity is to advance the state of the art in applying control methods for uncertainty handling and as a way to provide flexibility and improved performance in embedded computing and communication systems. This report summarizes the achievements obtained during the third year of ARTIST2.

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1.　Overview of the Activity

1.1　ARTIST Participants and Roles

Professor Karl-Henrik Johansson – KTH (Sweden)
Role: Provides expertise in applying control techniques to communication networks, including sensor networks.

Associate Professor Anders Robertsson – LUND (Sweden)
Role: Provides expertise in performance control of server systems.

Professor Karl-Erik Årzén – LUND (Sweden)
Role: Provides expertise on feedback-based scheduling of control systems.

Professor Alfons Crespo – UPVLC (Spain)
Role: Provides expertise on embedded computing.

Professor Martin Törngren – KTH (Sweden)
Role: Provides expertise in architectural design and automotive embedded system applications involving dynamic configuration.

1.2　Affiliated Participants and Roles

Dr Johan Eker – Ericsson (Sweden)
Role: Provides expertise on reservation-based scheduling in mobile terminals.

Professor Lui Sha - University of Illinois (US)
Role: Provides expertise on error control of software systems.

Professor Tarek Abdelzaher - University of Illinois (US)
Role: Provides expertise on feedback scheduling.

1.3　Starting Date, and Expected Ending Date

The activity started September 1, 2004. Since the overall status of the activity is to enhance the state of the art in applying control techniques to real-time control and computing systems the activity will run over the entire life-time of the network, and will continue after the termination of Artist2 within the ArtistDesign NoE.

1.4　Baseline

Before this activity started the different groups performed individual research on applying control-based approaches to embedded and real-time systems, e.g., feedback scheduling of servers, feedback scheduling of control systems, and control-based approaches in networking. The research area was strongly dominated by US research groups.

1.5   Problem Tackled in Year 3

The overall objective of this activity is to advance the state of the art in applying control methods for uncertainty handling and as a way to provide flexibility and improved performance in embedded computing and communication systems. The application areas include performance control of web server systems, feedback-based reservation management in embedded real-time systems, feedback scheduling of control systems, dynamically configurable automotive systems and control of communication and sensor networks.

This objective has been achieved in a nice way through the large amount of research that has been performed within and between the partners. The planned meetings have all been held, including the follow-up workshop to the Lund Workshop on Control for Embedded Systems.

During Year 3 writing research proposals has been a major activity. This work has been successful with several new both national and European projects in this area.

1.6   Comments From Year 2 Review

1.6.1   Reviewers' Comments

The Year 2 deliverable was accepted without any specific comments.

1.6.2   How These Have Been Addressed

Since the reviewer's were very positive both after the Year1 and the Year 2 review we have tried to continue along the same lines as previous year. As an example of this a special Artist2 poster session was organized at FeBID'07, the Second International Workshop on Feedback Control Implementation and Design in Computing Systems and Networks that was held in Munich in May 2007. In parallel with this the research within the groups and in collaboration between the groups has continued.

2. Summary of Activity Progress

2.1 Previous Work in Year 1

Since this is a rather new research area it was decided at the beginning of year1 that the main activity should be the creation of a research roadmap. The aim of the roadmap was to chart the area, provide a common platform for the coming work, and to identify the most important research directions.

- The first version of the roadmap was completed.

- A new feedback scheduling method was developed for control loops by Dan Henriksson and Anton Cervin (LUND). A paper was presented at the CDC-ECC'05 in Sevilla - LUND

- An international workshop in Control for Embedded Systems was held in Lund with 20 participants. The international affiliates Lui Sha and Tarek Abdelzaher participated and gave valuable input. A separate research agenda for the work within Artist2 was written as the output from the workshop.

- Karl-Erik Årzén and Anders Robertsson were invited to participate as the only non-US participants at a workshop on the future of control of computing systems organized by NFS and held at IBM, May 3-4, 2005

- KTH has been working on control-based error-correction in packet-switched networks, on the use of radio network feedback to improve TCP performance over cellular networks, and on network state estimation.

2.2 Previous Work in Year 2

Achievement: Dissemination of Roadmap Material

The conclusions from the roadmap developed during year1 were summarized into a conference paper that was presented as an invited talk at FeBID'06, the First International Workshop on Feedback Control Implementation and Design in Computing Systems and Networks that was organized in Vancouver in April 2006. An extended version of this paper has also been published in the ACM SIGBED Review. The creation of the FeBID workshop series can potentially be very important for the future development of the area. The followup workshop FeBID'07 will be organized in Munich in May 2007, with a member of the Lund group as a technical co-chair and with another member of the Lund group in the IPC. (constituting two of the only three European members of the organizing committee – compared to 26 members from the US!).

Achievement: Control of Server systems

Control of server systems is the subject of research in Lund and University of Illinois. Lund is working on improved models for feed-forward based queing control systems and on providing reservation-based scheduling in Linux systems using the nice value as the control signal. A natural application for the latter is web servers. The work at University of Illinois is focused on content distribution, adaptive rate allocation, and delay control. Dan Henriksson from Lund is spending the year 2006-2007 as a postdoc at University of Illinois working with Tarek Abdelzaher. The new model types derived for queing control are also applied to traffic flow control in collaboration between CTU and LUND.

In a complementary activity at KTH, the automatic control group has been investigating distributed resource allocation mechanisms for large-scale server clusters. Optimal off-line

solutions and high-performing distributed heuristics have been developed and evaluated in detailed system-level simulators of the Chameleon architecture.

Achievement: Feedback Scheduling of Control Systems
In our previous work on feedback scheduling of linear controller tasks it has been assumed that the amount of disturbances entering the control loops is constant over time. The inital states of the controlled plants are taken into account by the feedback scheduler by including the inital state in the cost function. The motivation for this is that a plant with a large error should receive more resources in order to better cope with the disturbance. However, in all but extreme cases it is the expected future disturbances that completely dominate the cost function. In [6], we have explored how one can obtain a more reactive feedback scheduler by estimating the amount of noise in the various control loops. We have also extended the cost functions to take a constant delay (obtained using Control Servers) into account. This work has been performed in collaboration with UPC.

Achievement: Control of Communication Networks
The automatic control group at KTH has been working on theory and engineering principles for cross-layer optimization of wireless networks. Specific achievements include a theoretical framework for self-regulating protocol design, as well as detailed resource control strategies for specific network technologies. The KTH group has also worked on on-line error control adaptation in networked applications, feedback-based error-correction in feedback-based networks, stability of window-based queue control with applications to mobile terminal download, models for network congestion control, and distributed consensus algorithms.

2.3 Current Results

The results generated in this activity consist of technical achievements and jointly organized events. Technical achievements have been done within control of server systems, feedback-based resource management in cellular devices, control of communication networks, adaptive resource management in wireless networked embedded systems, in particular sensor networks, and in dynamically configurable automotive embedded systems, see below for more details. Three main events have been organized that are related to this cluster: the 3rd Graduate Course on Embedded Control, the 2nd Internatioal ARTIST2 Workshop on Control for Embedded Systems, and an Artist2 poster session at the Second International Workshop on Feedback Control Implementation and Design in Computing Systems and Networks.

2.3.1 Technical Achievements

Achievement: Control of Server systems (LUND, UIUC)
Control of server systems is the subject of research in Lund and University of Illinois. Lund has continued its workon improved models for feed-forward based queing control systems and on providing reservation-based scheduling in Linux systems using the nice value as the control signal. A natural application for the latter is web servers, see [1]. In [2] a feedback–based prediction scheme for controlling the response times in a single server queue is investigated. This control structure has the benefit over other previously suggested control structures that no measurement of the required work of each job is needed. However, the new solution maintains the same attractive properties, regarding average response time and variance as previously suggested solutions.

The work at University of Illinois is focused on content distribution, adaptive rate allocation, and delay control. Dan Henriksson from Lund has spent the year 2006-2007 as a postdoc at University of Illinois working with Tarek Abdelzaher.

In parallel with this KTH has continued their work on control of server farms described in Section 2.2, see [10].

Achievement: Feedback-Based Resource Management in Cellular Devices (Ericsson, LUND)

Lund and Ericsson have received fudning from the Swedish funding agency VINNOVA for the joint project "Feedback Based Resource Management and Code Generation for Soft Real-Time Systems". The project will provide funding for one researcher from Lund University and one researcher from Ericsson over three years. A related EU FP7 STREP project coordinated by Ericsson has also been approved. This will, however, be reported in the activity report for the NoE integration activity Adaptive Real-Time, HRT and Control.

Achievement: Control of Communication Networks (KTH, Ericssom, ABB)

The networked control group at KTH has continued their research on analysis and synthesis of networked control systems, including resource allocation, traffic control and routing for wireless networks and distributed control and estimation. The work includes laboratory implementations and testing as well as industrial dissemination trough collaborative projects with ABB, Ericsson, Scania etc. KTH participated in the 2nd International ARTIST Workshop on Control for Embedded Systems in Urbana-Champaign, where samples of these results were presented.

Achievement: Adaptive Resource Management in Wireless Networked Embedded Systems (KTH, LUND, Ericsson)

Resource control in wireless networked embedded systems has been the subject for the collaboration between KTH, Lund and Ericsson funded by the RUNES IP during the year; see [14] and [15]. A challenging demonstrator scenario has been developed and implemented involving mobile robots and sensor network nodes, in which control and localization techniques closed over a wireless network were combined with feedback-based radio transmit power control

Achievement: Dynamically Configurable Automotive Embedded Systems (KTH, Volvo)

Within the newly started project Dyscas (www.dyscas.org), KTH in cooperation with European automotive industries (including ARTIST2 affiliated partners Volvo, and DaimlerChrysler), Enea (providing the OSE real-time operating systems), Univ. of Paderborn and Univ. of Greenwich, have spent considerable efforts on dynamically configurable automotive embedded systems The goals are to provide new platforms and methods that support scenarios such as software download (also during run-time), flexible internal resource configuration schemes (for availability or performance purposes), and flexible connectivity with external devices such as PDA's (for functionality and performance purposes). The main emphasis is on non-safety critical functions related to the telematics/infotainment domains, but in a connected Swedish national project the same scenarios are also considered for more safety critical functions. The challenge is to be able to fully exploit the flexibility of software while guaranteeing performance and dependability (including not distracting the driver).

2.3.2   Individual Publications Resulting from these Achievements

LUND

[1] Martin Ohlin, Martin Ansbjerg Kjær. Nice Resource Reservations in Linux. In Proceedings, Second IEEE International Workshop on Feedback Control Implementation and Design in Computing Systems and Networks (FeBID'07), Munich, Germany, May 2007.

[2] Martin Ansbjerg Kjær, Maria Kihl, Anders Robertsson. Response–Time Control of Single Server Queue, In Proceedings, 46th IEEE Conference on Decision and Control, New Orleans, LA, accepted for publication, December 2007.

[3] Sven Gestegård Robertz, Dan Henriksson, Anton Cervin. Memory-Aware Feedback Scheduling of Control Tasks, In Proceedings of the 11th IEEE International Conference on Emerging Technologies and Factory Automation (ETFA06), Prague, Czech Republic, September 2006.

KTH

[4] K. Jacobsson, L. L. H. Andrew, A. Tang, K. H. Johansson, H. Hjalmarsson, S. H. Low, ACK-clock dynamics: modeling the interaction between ACK-clocks and the network, IEEE Infocom, Phoenix, AZ, USA, 2008. Submitted.

[5] A. Tang, L. L. H. Andrew, K. Jacobsson, K. H. Johansson, S. H. Low, H. Hjalmarsson, Window flow control: macroscopic properties from microscopic factors, IEEE Infocom, Phoenix, AZ, USA, 2008. Submitted.

[6] L. Shi, K. H. Johansson, and R. M. Murray, Change sensor topology when needed: how to efficiently use system resources in control and estimation over wireless networks, IEEE CDC, New Orleans, LA, USA, 2007. To appear.

[7] B. Zurita Ares, C. Fischione, A. Speranzon, K. H. Johansson. On power control for wireless sensor networks: system model, middleware component and experimental evaluation, ECC, Kos, Greece, 2007.

[8] O. Flärdh, C. Fischione, K. H. Johansson, and M. Johansson, Analysis of a simple feedback scheme for error correction over a lossy network, IEEE International Conference on Networking, Sensing and Control, London, UK, 2007. Best Student Paper Finalist.

[9] B. Zurita Ares, C. Fischione, and K. H. Johansson, Energy consumption of minimum energy coding in CDMA wireless sensor networks, In Wireless Sensor Networks. Vol. 4373 of Lecture Notes in Computer Science. Springer-Verlag. 2007. Presented at EWSN, Delft, The Netherlands, 2007.

[10] B. Johansson, C. Adam, M. Johansson and R. Stadler, "Resource allocation for achieving quality-of-service objectives in server clusters", IEEE CDC, San Diego, December 2006.

[11] Chen et al (2007). DeJiu Chen, Richard Anthony, Martin Torngren, Gerrit de Boer. Developing a context-aware architecture in DySCAS. Accepted for the DASIP 2007 Workshop. November 27-29, 2007 - Grenoble, France.

[12] Larses et al (2007). Ola Larses, Carl-Johan Sjöstedt, Martin Törngren, Ola Redell. Experiences from Model supported Configuration Management and Production of Automotive Embedded Software. In Proceedings of the SAE World Congress, In-Vehicle Software session, Detroit, USA, 2007.

[13] Axelsson et al (2007). Martin Axelsson, Magnus Eriksson, Thomas Francke, Felix Hammarstrand, Andreas Lindell, Oskar Nyqvist, Erik Persson, Martin Svensson, Christoffer Strömberg, Niklas Thörnqvist, Magnus Persson, Martin Törngren. The Saint3 automotive embedded systems demonstrator. Technical report, Department of Machine Design, KTH, 2007 (in print).

2.3.3 Interaction and Building Excellence between Partners

There are interactions between all core partners in the activity and with several of the associated partners. These are of several types, including participation in the same European projects, joint participation in national projects, participation in meetings organized by this cluster, and joint execution of the Graduate Course on Embedded Control (which includes control of computer systems as one of the topics). Most of the interactions are bilateral or trilateral, with only the joint organization of the Graduate Course involving all the core partners. The reason for the difficulties of integration all the partners is explained in the corresponding cluster report.

The following is a list of the major collaborations, except the Graduate Course on Embedded Systems between partners in the Control in Real-Time Computing activity as well as with partners outside the activity which has contributed to creation of excellence between partners.

Activities within the activity:

- KTH and Volvo are working together within the Dyscas project on Dynamically Configurable Automotive Embedded Systems, together with DaimlerChrysler, Enea, Univ. of Paderborn and Univ. of Greenwich has led to five joint publications this year.

- KTH, Lund, and Ericsson are working together on resource-control in sensor networks and component technologies for wireless networked embedded systems within the context of the RUNES project. This has led to two joint publications this year. Withn RUNES KTH and Lund also collaborate with UPisa, UPatras, and ETH.

- KTH and Ericsson are collaborating on control of communication networks.

- UPVLC and CTU are collaborating on contract-based adaptive reservation techniques within the FRESCOR project together with SSSA/Pisa, UYork, UCantabria, TUKL, Enea, Thales, Visual Tools, Rapita Systems, and Evidence.

- Ericsson and Lund have jointly applied for a Swedish VINNOVA project on Feedback Based Resource Management and Code Generation for Soft Real-Time Systems. The project will be performed by one research at Ericsson and one PhD student at Lund. The projefct started during Spring 2007 and will continue for 3,5 years.

- Dan Henriksson from Lund has been doing a post doc at UIUC working on control aspects in sensor networks and in client-server systems during 2006-2007.

Activities with partners outside the activity:

- Lund and UPC are continuing their collaboration on feedback-based scheduling of control systems.

- Lund are working with Washington Univ, St Louis on applying event-based control techniques to control of distributed client-server systems.

2.3.4 Joint Publications Resulting from these Achievements

[14] Karl-Erik Årzén, Antonio Bicchi, Gianluca Dini, Stephen Hailes, Karl Henrik Johansson, John Lygeros, Anthony Tzes. A component-based approach to the design of networked control systems, In Proceedings of the European Control Conference, July 2007.

[15] Karl-Erik Årzén, Antonio Bicchi, Gianluca Dini, Stephen Hailes, Karl Henrik Johansson, John Lygeros, Anthony Tzes. A component-based approach to the design of networked control systems. European Journal of Control, 13:2-3, June 2007. (Extended journal version of [3])

[16] Anthony et al (2007a). Richard Anthony, Achim Rettberg, Isabell Jahnich, DJ Chen, Cecilia Ekelin: Towards a Dynamically Reconfigurable Automotive Control System Architecture, at "International Embedded Systems Symposium" in Irvine, CA, USA, May 29-June 1 2007

[17] Anthony et al (2007b). Richard Anthony, Achim Rettberg, Ola Redell, Tahir Naseer Quereshi, Martin Törngren, Cecilia Ekelin, Gerrit de Boer: "Dynamically Reconfigurable Automotive Control Systems" at "Advanced Automotive Electronics" in Gaydon, UK, January 31 2007.

 [18] Sjöstedt et al (2007). Carl-Johan Sjöstedt, DeJiu Chen, De-Jiu Chen, Phillipe Cuenot, Patrick Frey, Rolf Johansson, Henrik Lönn, David Servat, Martin Törngren. Developing Dependable Automotive Embedded Systems using the EAST-ADL; representing continuous time systems in SysML. In Proc. of EOOLT'2007. 1st Int. Workshop on Equation-Based Object-Oriented Languages and Tools.

[19] Shi et al (2007). Jianlin Shi, Martin Törngren, David Servat, Carl-Johan Sjöstedt, DeJiu Chen, Henrik Lönn. Combined usage of UML and Simulink in the Design of Embedded Systems: Investigating Scenarios and Structural and Behavioral Mapping. To appear in Proc. of OMER 4 workshop on Object-oriented modeling of embedded real-time systems, Oct. 30-31, 2007.

[20] Cuenot et al (2007a). Philippe Cuenot, DeJiu Chen, Sébastien Gérard, Henrik Lönn, Mark-Oliver Reiser, David Servat, Ramin Tavakoli Kolagari, Carl-Johan Sjöstedt, Martin Törngren, Matthias Weber. Managing Complexity of Automotive Electronics Using the EAST-ADL. Accepted for the 2nd Int. UML&AADL Workshop (UML&AADL'2007) at the 12th Int. Conf. On Engineering of Complex Computer Systems, Auckland, New Zealand, July 11 - 14, 2007.

2.3.5   Keynotes, Workshops, Tutorials

Keynote: Real-Time Aspects in Control,. By Karl-Erik Årzén
Conference name: ANIPLA, November 15 2006, Rome, Italy

Workshop: Control of Real-Time Computing in Artist2
Conference name: FeBID'07 (Second International Workshop on Feedback Control Implementation and Design in Computing Systems and Networks), Munich, Germany – May 25, 2007

A poster session presenting the work related to this workshop within Artist2 was organized. The session contained contributions from LUND, Aveiro, UPC, and SSSA/Pisa. A negative factor that limited the participation both in this poster session and at the entire workshop was the high conference fee enforced by the 10th IFIP/IEEE Symposium on Integrated Management (IM 2007) which the workshop was co-located with.

Workshop : 2nd Int'l ARTIST Workshop on Control for Embedded Systems
Location: University of Illinois, Urbana-Champaigne, Illinois, US, May 31 – June 1, 2007

The second in the series of International Workshops in Control for Embeded Systems was organized by the cluster at Urbana-Champaigne is Illinois with Tarek Abdelzaher as the local host. The formal topics of the workshop were Real-Time and Control in Sensor/Actuator Network, Control in Cyber-Physical Systems, Event-Based Control and Computing, and Control of Software Errors. However, several of the presentations given were very relevant also for this activity. This cluster was represented by LUND, KTH and UPVLC. More information about the workshop including the conclusions are available at

http://www.artist-embedded.org/artist/-Control-for-Embedded-Systems,810-.html

Tutorial Session: Toward a Component-Based Framework for Networked Control, **Conference name:** European Control Conference, Kos, Greece, July 2-5.

An invited tutorial session about control-related issues in wireless networked embedded systems was held as a part of the ECC conference. The session contained three presentations authored by members of this cluster.

3. Future Work and Evolution

3.1 Problem to be Tackled over the next 12 months (Sept 2007 – Aug 2008)

The work during the final year of this activity will be focused on completing the work performed during the previous three years and disseminate it through journal articles and presentations at Artist events. In parallel with this the individual and joint research will continue. The focus will continue to be control-based models and methods for queuing systems with applications in server systems, control of multi-tier server systems, feedback scheduling of control systems, feedback-based and hierarchical resource reservation schemes for embedded systems, control of communication networks in different settings, dynamic configuration of automotive embedded systems. Special emphasis will be given to feedback-based reservation scheduling in mobile devices, and area where new projects have been approved both nationally and within EU.

An important issue for this activity is also how the work can be carried over to the new Design for Adaptivity activity within the new ArtistDesign Noe.

3.2 Current and Future Milestones

Year1 Milestone:
- Roadmap describing the current state-of-the-art and the important research issues *(Achieved)*

Year2-4 Milestones:
- Progress made on the fundamental underlying issues: decreased requirements on prior knowledge about resource utilization, increased possibilities to use COTS implementation platforms, and enhanced robustness towards load variations (*Achieved to 30 % currently after Year 2)*

  The research performed during Year 2-3 has contributed to the solution of several of the above items. For example, the work on feedback control of Linux scheduling is a step towards being able to utilize COTS implementation platforms, and the work on queueing system models is motivated by the aim to be robust against load variations. (Achieved to 60% after Year 3)

Year 3-4 Milestone:
- Increase our international and industrial visibility. A good means for this is through the organization of and the participation in the FeBID workshops.

  Achieved. We participated at FeBID 2007 in Munich and also organized a special Artist2 poster session there.

Updated Milestones for Year 4:

- Disseminate the total amount of work done during the four years in this activity at Artist and ArtistDesign organized events.
- Continue our presence at workshops and conferences in the area.
- Continue the research performed within control of server systems, in control-based reservation management and feedback-based scheduling, on applying control to

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communication networks and sensor networks, and dynamically configurable embedded systems.

3.3 *Indicators for Integration*

Joint research work indicated by joint high-quality publications, mobility of team members among the teams, and jointly organized workshops and sessions.

3.4 *Main Funding*

The main sources of funding for this work are:

- Nationally funded projects. For the Swedish partners these include grants funded by the Swedish Research Council, the Swedish Foundation for Strategic Research, VINNOVA and the Swedish Programme Council for Vehicle Research. For example during 2007 LUND has obtained one new project from the Swedidh Resarch Council on control of server systems and one new VINNOVA project om feedback-based resource management. For the partners from other countries the situation is similar.

- EU projects. The following are examples of currently running or recently completetd EU FP6 projects that to some extent cover these acivities: RUNES, SOCRADES, DYSCAS, CEMACS, and FRESCOR.

- New EU FP7 projects. This includes the ArtistDesign NoE and ACTORS.

4.   Internal Reviewers for this Deliverable

Zdenek Hanzalek, CTU