IST-214373 ArtistDesign
Network of Excellence
on Design for Embedded Systems

Cluster Progress Report for Year 1

Cluster:
Operating Systems and Networks

Cluster Leader:

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Policy Objective (abstract)
The objective of this cluster is to build the fundamental basis of a new real-time software technology that can provide a more efficient and predictable support to the development of future embedded systems, characterized by high complexity dynamic behaviour and distributed organisation. In particular, the new software technology should:

- simplify the management of resources to control the growing complexity and distribution of embedded systems;
- take advantage of parallel processing platforms, such as multicores, in order to satisfy timing and adaptivity requirements;
- support distributed computing to deal with the dynamics and ubiquitous nature of the computing infrastructure;
- increase system adaptivity to react to environmental changes, still providing a sufficient level of performance;

To cover these issues, the cluster is organized into 3 activities:

1. JPRA Cluster: Resource-Aware Operating Systems
2. JPRA Cluster: Scheduling and Resource Management
3. JPRA Cluster: Real-Time Networks

Versions

number	comment	date
1.0	First version delivered to the reviewers	December 19th 2008

Table of Contents

1. Overview

1.1 High-Level Objectives

The high level objective of this cluster is to build the fundamental basis of a new real-time software technology that can provide a more efficient and predictable support to the development of future embedded systems, characterized by high complexity dynamic behaviour and distributed organisation. In particular, the new software technology should:

- support scalability to facilitate the porting of control applications to different platforms;
- simplify the management of resources to control the growing complexity and distribution of embedded systems;
- take advantage of parallel processing platforms, such as multicores, in order to satify timing and adaptity requirements;
- be light-weight to opimize the usage of scarce resuources in tiny embedded computing devices;
- increase programming flexibility, for specifying functional and performance requirements to simplify test and verification;
- enable run-time reconfigurability and functionality updates to deal with the dynamics and ubiquitous nature of the supporting computing infrastructure;
- increase programming productivity, by raising the level of abstraction of the resource management services;
- increase system adaptivity to react to environmental changes, still providing a sufficient level of performance;
- be robust to tolerate transient and permanent overload conditions due to wrong design assumptions or unpredictable changes.

Such features would have a concrete impact on European industry to reduce time to market, and improve software reliability and testability. To support industry in such a transition phase, new tools, algorithms and kernel mechanisms must be also provided. In this respect, this cluster is playing an active role, acting as a bridge between the academic and the industrial world, especially in the domain of consumer electronics, robotics, industrial automation, telecommunications, and the so called cyber-physical systems.

A means to achieve such a goal is to develop a research platform for real-time systems to share competencies, resources, and tools targeting at the development of applications, such as control systems, with performance and timing requirements. The use of a shared platform is essential for experimenting new real-time software technology, including novel scheduling algorithms, resource management techniques, communication paradigms, energy-aware policies and overload handling approaches to increase robustness and predictability. A shared platform also facilitates the transfer of research results to industry, as it allows teaching practical knowledge of concepts and techniques. In addition, several solutions can be developed and tested in parallel in different partner sites, allowing the evaluation of the most appropriate approach for specific applications.

Specific research topics addressed in this cluster are related to operating systems and networks, with particular emphasis on scheduling and resource management, including energy-aware strategies and exploitation of parallelism in multicores.

1.2 Industrial Sectors

The industrial sectors that can benefit from adaptive real-time technology include Consumer Electronics, Industrial Automation, and Telecommunications.

Consumer Electronics (CE) products range from miniature cameras and MP3 players to advanced media servers and large displays. Mainly driven by Moore's law, the evolution in the CE industry is very fast [Bou05]. Utilizing available hardware and software resources in an optimal fashion is crucial both to save costs and to keep the competitive edge. Moreover, multimedia systems exhibit a highly dynamic behavior, since task execution times are often dependent on input data that are difficult to predict [Riz06]. As a consequence, these systems are prone to intermittent overload conditions that could degrade the performance in an unpredictable fashion [Wus05, Loo03]. To address these problems, the cluster aimed at integrating the most recent research results achieved in the real-time community to build flexible as well as predictable real-time systems that can react to load changes and perform QoS adaptation in a controlled fashion.

In the area of Industrial Automation there is a trend to use distributed solutions for connecting the general plant actuators, sensors and the controllers. At the same time, there is an increase of demands for new options and improvements in the automation results, fetching more control of plant secondary data. This imposes a continuous increment in processing power and memory capacity that requires adaptivity at different levels of system operation. The contribution of the cluster in this domain was to investigate how to achieve predictability and adaptivity in distributed systems.

Embedded systems for telecommunications applications are mainly targeted to the interfaces between communication technologies and to coding/decoding operations. They may be considered real-time as they have timeliness requirements for some of the critical operations they must perform. The referred systems are microprocessor based platforms, often integrating a second processor (e.g., a DSP) devoted to specific functions, like MPEG coding. From the software point of view, a modern mobile phone typically consists of several million lines of code with use-cases involving large number of concurrent activities. A system supporting ``memory and temporal protection'' would allow safely mixing real-time and non real-time applications with the benefit of achieving a more scalable platform. The work on resource reservation carried out in the cluster was of crucial importance to manage the increased complexity of the applications in this domain.

1.3 Main Research Trends

Today's embedded systems are required to work in dynamic environments, where the characteristics of the computational load cannot always be predicted in advance. The combination of real-time features in dynamic environments, together with cost and resource constraints, creates new problems to be addressed in the design of such systems, at different architecture levels.

To efficiently operate in dynamic environments, a system must be adaptive; that is, it must be able to adjust its internal strategies in response to a change in the environment, to keep the system performance at a desired level [Loo03, Eke05]. Implementing adaptive embedded systems requires specific support at different levels of the software architecture. The most important component affecting adaptiveness is the kernel, hence specific research efforts are being devoted to flexible, as well as predictable real-time scheduling and resource management policies [But06]. However, flexibility can also be introduced above the operating system, in a software layer denoted as a middleware. To investigate such a possibility, other research groups are working on this level to introduce adaptivity and QoS management [Sch03, Wan05, Sch06, Gar02].

Some embedded systems are large and distributed among several computing nodes. In these cases, special network methodologies are investigated to achieve adaptive behavior and predictable response [Alm03] [Ped05]. Several research efforts have also been placed in addressing wireless sensor networks (WSN) [Sta03], mobile ad-hoc networks MANET [Joh96, Wu04, Fac05] and other networked systems for which, albeit the dynamic nature and resource scarcity of the infrastructure, timeliness is still a requirement.

Finally, as the complexity of real-time systems increases, high demand will be placed on the programming abstractions provided by languages. Unfortunately, current programming languages are not expressive enough to prescribe certain timing behavior and hence are not suited for realizing predictable real-time applications. As a consenquence, most of the work on programming languages for real-time applications is aimed at providing real-time functionality via language constructs rather than operating system calls.

2. State of the Integration in Europe

2.1 Brief State of the Art

The main reason for investigating adaptive real-time systems is to provide predictability and flexibility for systems and environments where requirements on resources are inherently unstable and difficult to predict in advance. Such a difficulty is due to different causes. First of all, modern computer architectures include several low-level mechanisms that are designed to enhance the average performance of applications, but unfortunately introduce high variations on tasks' execution times. In other situations, as in multimedia systems, processes can have highly variable execution times that also depend on input data [Riz06]. As a consequence, the overall workload of a computing system is subject to significant variations, which can produce an overload and degrade the performance of the entire system in an unpredictable fashion [Loo03, Eke05]. This situation is particularly critical for small embedded devices used in consumer electronics, telecommunication systems, industrial automation, and automotive systems. In fact, in order to satisfy a set of constraints related to weight, space, and energy consumption, these systems are typically built using small microprocessors with low processing power and limited resources.

For most of these systems, the classical real-time approach based on a rigid off-line design, worst-case assumptions and a priori guarantee would keep resources unused for most of the time, therefore it is not acceptable for efficiency reasons. When resources are scarce, they cannot be wasted. On the other hand, an off-line design based on average-case behavior is also critical, because it would be difficult to guarantee timing constraints when resources are overloaded.

To prevent unpredictable performance degradations due to overloads, a real-time system must react to load variations, degrading its performance in a controlled fashion acting on system, as well as application parameters. The process of controlling the performance of a system as a function of workload variations is referred to as Quality of Service (QoS) Management. Performing efficient QoS management requires specific support at different levels of the system architecture. Hence, new software methodologies are emerging in Embedded Systems, which strictly relate to Real-Time Operating Systems (RTOS), Middleware, and Networks.

Real-time scheduling is the kernel mechanism having the most impact on RTOS performance. Most scheduling algorithms have been developed around one of three basic schemes: table driven [Foh95], fixed priority [Aud95], or dynamic priority [Spu96]. Depending on whether scheduling decisions are resolved before or during runtime, they are classified as offline or online.

Adapting to changing environmental situations may involve changes to task parameters at runtime. System wide changes, e.g., for changing operational modes in the system, have been addressed by mode change algorithms [Foh93].

Feedback scheduling changes task parameters, in particular periods [But02], to respond to online variations in the environment and current load conditions of the system. As both conditions can vary frequently, too frequent responses, which in turn influence the conditions, can introduce instability in the system. Feedback control scheduling applies control theory to estimate effects of changes and to choose parameters to provide for smooth responses and avoid instability [Cas06].

Each of the basic scheduling paradigms has specific advantages. When advantages of different schemes are demanded in the same system, more than one scheme could be used for different tasks. For example, in a complex system including hard periodic and soft aperiodic tasks, two scheduling schemes need to be integrated for satisfying the different requirements of each task class.

In hierarchical scheduling [Reg01] a meta algorithm arbitrates between a set of diverse scheduling algorithms. Thus, it can appear to the individual scheduling algorithms and their applications that they execute alone in the system. Furthermore, the amount of the CPU portion can be set individually for each scheduler and application. Special attention has to be given to shared resources.

In those systems subject to higly varialble workload, an overload condition could degrade the system performance in an unpredictable fashion. Novel scheduling methodologies have been recently proposed to cope with transient and permanent overload conditions. Transient overloads due to execution overruns can be effectively handled using resource reservation techniques [Mer94], according to which each activity consumes a fraction of the processing resource, independently of the actual execution demand. Permanent overload conditions, typically occurring in a periodic environment, can be efficiently handled by sporadic job skipping [Kor95] or by rate adaptation techniques (like elastic scheduling) [But02], which keep the load below a given threshold by acting on task periods.

Major needs for flexible scheduling techniques are typical of industries working in consumer electronics, industrial automation, and telecommunications, as resulted from a study carried out within the ARTIST 5FP project [Bou05].

For example, mobile terminals today are getting more and more advanced and their source code consists of several million lines of code involving a large number of parallel activities. For these applications, the use of flexible real-time scheduling techniologies would allow to safely mix real-time and non real-time processes. The benefit of such a solution would be a much more scalable platform. Adding and removing features would become predictable and less hazardous, allowing configuring the system without worrying about unpleasant surprises.

In the area of Industrial Automation, the continuous increment in processing power and memory capacity in local processors gives the opportunity to add new tasks into them, increasing system complexity in terms of supervision, diagnostics, presentation, communication, etc. Adaptive tasks scheduling that preserves the real-time constraints is a possible way to handle such situation and manage the complexity of the application.

In telecommunication companies, the main current interest seems to be in exploring the use of real-time extensions for the Linux OS. It also seems that QoS mechanisms are starting to be recognized as important for these embedded applications to increase the efficiency of subsystems and to support the possibility to serve more clients with similar levels of resources.

2.2 Main Aims for Integration and Building Excellence through ArtistDesign

Achieving adaptivity in embedded real-time systems is a complex task that requires expertize from several disciplines, including operating systems and kernels, scheduling theory, distributed systems, network communication, control theory, quality of service management, and programming languages. Combining the results achieved in such different domains and orchestrating the various groups active in these fields is only possible by a tight interaction among the cluster participants. Hence, the aim of the integration through ArtistDesign is to facilitate communication among cluster members in order to:

- Improve the understanding of the key features to be added at different architecture levels (operating system, network, middleware, and language) to support adaptive real-time systems;
- Clarify the terminology to provide a common language for exchanging information between different cluster and research communities;
- Build a common operating system platform to perform experiments and develop tools that can be shared by the different research teams;
- Identify new research directions aimed at overcoming the problems encountered during the integration phase;
- Interact with industries to understand their problems and identify possible solutions;
- Form new consortia and make concrete project proposals to address specific research problems or develop critical applications of industrial interest.

2.3 Other Research Teams

The cluster had several interactions with the following research teams:

- University of Illinois at Urbana Champagne (reference persons: Prof. Lui Sha, Prof. Tarek Abdelzaher, and Prof. Marco Caccamo) on wireless communication protocols for real-time distributed emebedded systems.
- University of Virginia (reference persons: Prof. John Stankovic and Prof. Sang Son) on adaptive real-time systems for sensor networks.
- University of Lund (reference persons: Karl-Erik Arzen and Anton Cervin) on feedback control tecniques for adaptive real-time systems.
- University of California at Berkeley (reference person: Alberto Sangiovanni Vincentelli) on the design of component-based operating systems.
- Philips Research Eindhoven (reference persons: Dr. Sjir van Loo) on resource management for consumer electronics.
- NXP (reference persons: Dr. Liesbeth Steffens) on resource management for consumer electronics.
- Ericsson Mobile Platforms (reference person: Dr. Johan Eker) on resource reservation and adaptive QoS management.
- Microchip Technology (reference person: Dr. Antonio Bersani) on real-time embedded platforms for monitoring and control.
- Carnagie-Mellon University (reference person: Prof. Raj Rajkumar) on wireless sensor networks, cooperative computing, andQoS adaptation.
- Seoul National University (reference persons: Dr. Jungkeun Park, Dr. Kanghee Kim) on distributed embedded systems and stochastic analysis of periodic task sets.
- Malardalen University, Sweden (reference person: Dr. Thomas Nolte) on integration of networked subsystems in resource constrained environments and on stochastic analysis of hybrid task sets.

2.4 Interaction of the Cluster with Other Communities

Interaction with the control community

There are at least two reasons that motivate a tight collaboration of the cluster with the control community. From the operating system prespective, the use of feedback control techniques allow making real-time embedded systems more reactive to environmental changes, hence system adaptivity can be improved by integrating control theory and real-time scheduling [Sta99]. From the control perspective, using flexible scheduling technologies allows making control systems more robust and predicatable: integrating feasibility analysis in the design of complex control systems allows the system designer to better analyze/control/compensate for delays and jitter caused by concurrency and intertask interference [Arz00].

A joint work involving people from Pavia, Pisa and Lund has been carried out on feedback control schemes to investigate the effects of different scheduling policies on delays and jitter in control loops.

Another strong collaboration has been established with the hybrid systems community. As a result of this connection, Giorgio Buttazzo has been invited as a co-Program Chair to organize the International Conference on Hybrid Systems: Computation and Control (HSCC 2007).

A joint work involving people from UPC (affiliated to TUKL) and Lund has been carried out to investigate feedback scheduling techniques. A PhD student from UPC spent 5 months in Lund working on the project.

Interaction with the cluster on compilers and timing analysis

A collaboration has been started with the cluster on compilers and timing analysis to investigate the problem of enhancing the predictability of real-time systems by reducing the variability of task execution times. In fact, internal kernel mechanisms, such as scheduling, mutual exclusion, interrupt handling and communication, can heavily affect task execution behaviour and hence the timing predictability of a system. For example, preemptive scheduling reduces program locality in the cache, increasing the worst-case execution time of tasks compared with non preemptive execution.

To address these issues, a new research was initiated that looks at predictability and efficiency in a synergistic manner and that involves all levels of abstraction and implementation in embedded-system design.

Thanks to the ArtistDesign NoE, the cluster got in contact with the cluster on Compilers and Timing Analysis. The two clusters started working together to develop a new approach consisting of a combination of several methods, including (a) design-space exploration on the hardware architecture level to identify good designs offering combinations of strong performance with good predictability, (b) appropriate kernel mechanisms for task and resource management that are predictable and analyzable, and (c) a synergistic development of models, design methods and matching analysis tools that extract precise system-behaviour properties.

Interaction with the consumer electronics industry

Thanks to the ArtistDesign NoE, the cluster got in contact with two major companies, Philips and Ericsson, acting in the domain of consumer electronics. After a tight interaction with the engineers responsible for the software development process, a number of industrial needs have been identified, that would make new generation products more robust and flexible.

To cope with a constantly increasing complexity of software applications (already consisting of several million lines of code and hundreds of concurrent activities), a system supporting memory and temporal protection would allow safely mixing real-time and non real-time applications with the benefit of achieving a more scalable platform. Therefore, the work on

resource reservation carried out within the cluster is of crucial importance to manage the increased complexity of the applications in this domain.

In addition, multimedia systems exhibit a highly dynamic behavior, since task execution times are often dependent on input data that are difficult to predict. As a consequence, these systems are prone to intermittent overload conditions that could degrade the performance in an unpredictable fashion. Again, the expertize existing in the cluster on overload management is of high interest for these companies, since it allows building flexible as well as predictable real-time systems that can react to load changes and perform QoS adaptation in a controlled fashion.

Interaction with the electronics industry

A new interaction of the cluster with Microchip Technology has been started on real-time embedded platforms for monitoring and control. In particular, the expertize existing in the cluster on real-time embedded control applications and real-time operating systems is extremely actractive for Microchip, who is interested in pushing the development of real-time embedded applications using 16-bit microcontrollers (as the dsPIC30 and the dsPIC33).

In this context, a big opportunity for the cluster is to find an agreament with Microchip to define the characteristics of a small real-time embedded platform for sensory acquisition and motor control that can be used (in conjunction with a wireless card) as a node of a mobile wirelss network. This unit would be more powerful and flexible than a mote and could be used to carry out experiments on sensor networks, embedded control, mobile robot teams and distributed control systems.

Interaction with the real-time components community

A collaboration between the clusters on components and adaptive real-time has been carried out along the ArtistDesign project. The main goal is to provide support for dealing QoS aspects in component-based systems. This technology is a relevant approach to complex system development and to allow a smooth integration of software from different vendors. QoS management is an adequate mean to provide a predictable quality to end-users. The collaboration between those clusters has brought competencies in component-based design for hard and adaptive real-time systems, to produce advances that would be difficult to achieve without all three.

This cooperation has facilitated the development of a number of technical achievents along four research lines: a) specification of QoS properties using UMNL profiles and aspect-based approachs, b) generation of analyzable models from the UML models, c) composition of QoS-aware components and adaptability, and d) QoS support in run-time components frameworks. The participants in this activity have actively participated in the development of a number of OMG standards

Dissemination

The cluster has been quite active in disseminating the research results achieved in the context of the ArtistDesign network of excellence, as an overall strategy for reaching other research/academic/industrial communities with related interests.

The platform developed in the context of the activity on Resource-Aware Operating System has been extensively used in graduate courses to teach how to develop embedded applications with real-time and performance requirements.

In addition, several scientific papers have been published and a number of workshops, and conferences have been organized by the cluster to spread the acquired knowledge in the

scientific community. The conferences and workshops in which the cluster has been involved include:

- OSPERT: Workshop on Operating Systems Platforms for Embedded Real-Time applications.
- ETFA: IEEE International Conference on Emerging Technologies and Factory Automation.
- RTSS: IEEE Real-Time Systems Symposium.
- ECRTS: Euromicro Conference on Real-Time Systems.
- RTAS: IEEE Real-Time and Embedded Technology and Applications Symposium.
- HSCC: ACM International Conference on Hybrid Systems: Computation and Control.
- RTCSA: IEEE International Conference on Embedded and Real-Time Computing Systems and Applications.
- IFAC World Congress.
- IECON: Annual Conference of the IEEE Industrial Electronics Society.
- WFCS: IEEE International Workshop on Factory Communication Systems.
- IECON: Annual Conference of the IEEE Industrial Electronics Society.
- RTN: International Workshop on Real Time Networks.
- OSERTS: Workshop towards Off-the-Shelf Embedded Real-Time Software.
- WPDRTS: International Workshop on Parallel and Distributed Real-Time Systems (In conjunction with IPDPS).
- Ada Europe: International Conference on Reliable Software Technologies.
- ISORC: IEEE International Symposium on Object and component-oriented Real-time distributed Computing.
- DIPES: IFIP Working Conference on Distributed and Parallel Embedded Systems.
- WTR: Brazilian Workshop on Real-Time Systems.
- RTNS: Int. Conf on Real-Time and Networked Embedded Systems.
- INCOM: IFAC Simposium on Information Control for Manufacturing.
- SAE World Congress.

Participation in Standards

Some cluster members are actively involved in the following standardization activities:

UML Profile QoS and Fault Tolerance

URL: http://www.artist-embedded.org/artist/UML-Profile-QoS-and-Fault.html

Member: Miguel A. de Miguel, UP Madrid.

Ada

URL: http://www.artist-embedded.org/artist/UML-Profile-QoS-and-Fault.html

Member: Alan Burns, Univ. of York.

POSIX 1003

URL: http://www.artist-embedded.org/artist/POSIX-IEEE-1003.html
Member: Michael Gonzalez Harbour, Univ. of Catabria.

MPEG Multimedia Middleware (M3W)

URL: http://www.artist-embedded.org/artist/MPEG-Multimedia-Middleware-M3W.html
Member: Alejandro Alonso, UP Madrid.

ETHERNET powerlink

URL: http://www.artist-embedded.org/artist/ETHERNET-Powerlink.html
Member: Lucia Lo Bello, Univ. of Catania (affiliated to Pisa).

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3. Overall Assessment and Vision for the Cluster

3.1 Assessment for Year 1

The integration activities among the cluster participants is demonstrated by the number of joint publications, projects and events organized within the cluster. The main examples are our workshops, graduate courses, and the various research consortia that have led to new European projects, like FRESCOR, ACTORS, and PREDATOR.

3.2 Overall Assesment since the start of the ArtistDesign NoE

The overall assessment of the work carried out by the cluster within this first year is very good. The major benefit of the ArtistDesign NoE was to act as a large scientific arena, where different research groups had the possibility to discuss, interact, and collaborate for addressing challenging research problems in the complex domain of embedded systems. Such a collaborative work produced the following significant results:

- Education. A number of graduate courses, workshops and training laboratory activities have been organized to disseminate the knowledge of the cluster to graduate and PhD students.
- Challenging research issues. Different collaborations took place within the cluster that allowed exploiting complementary expertize available among the partners to address complex problems and propose interesting solutions. This can be assessed by the large number of joint papers produced by the cluster members.
- European projects. Several European projects started thanks to the integration activities triggered by ArtistDesign. Examples are ACTORS, PREDATOR, MORE, and INTERESTED.
- Bridge bewteen Industry and Academia. Several contacts with the industry have been established within ArtistDesign, which contributed to reduce the huge gap existing between the theoretical work carried out in the university and the applications developed by the companies. A significant effort has been made by the cluster to precisely define a common language between industry and academia.

3.3 Indicators for Integration

Interactions planned between partners include:

- 10 Joint publications / year in international journals and proceedings related to realtime and embedded computing systems;
- Organization of joint educational activities on real-time operating systems and networks, like training courses, summer schools, or student competitions;
- Organization of 3 workshops / year for discussing new trends and solutions on operating systems and networks;
- Creation of a repository for relevant publications, algorithms, and libraries related to real-time operating systems.

All these objectives has been achieved by the cluster in the first year, as reported in this deliverable.

3.4 Long-Term Vision

The long-term vision of the cluster is to build a significant amount of knowledge on problems, methodologies, techniques, and tools for embedded systems with highly dynamic behavior, so that it can be disseminated in the industry and in the academia to educate next generation engineers to make embedded systems more robust, more efficient, more flexible, and more predictable than what is possible today.

There are strong indications that adaptive real-time techniques will continue to be important for the embedded systems community. Scheduling and resource management must allow a higher flexibility to handle future applications, which are going to be more dynamic in terms of resource requirements.

The current industrial trend of developing multi-core platforms is introducing a higher degree of complexity that is pushing the research community towards new approaches and methodologies. In fact, the traditional programming model used so far in uniprocessor platforms is quite inadequate for systems consisting of multiple cores and needs to be completely revisited.

4. Cluster Participants

4.1 Core Partners

Cluster Leader **Activity Leader for "Resource-Aware Operating Systems"**	
	Prof. Giorgio Buttazzo Scuola Superiore Sant'Anna (SSSA), Pisa (Italy) URL: http://feanor.sssup.it/~giorgio/
Technical role(s) within ArtistDesign	Coordinating the cluster on Operating Systems and Network and the activity entitled "Resource-Aware Operating Systems". Providing support on real-time scheduling, operating systems, resource management, overload handling, energy aware algorithms, and quality-of-service strategies.
Research interests	Real-time operating systems, dynamic scheduling algorithms, quality of service control, multimedia systems, advanced robotics applications, and neural networks.
Role in leading conferences/journals/etc in the area	Editor-in-Chief of the Journal of Real-Time Systems (Springer). Associate Editor of the Journal of Embedded Computing (Cambridge International Science Publishing). Executive Board Member of the Euromicro Conference on Real-Time Systems. Program Chair of RTSS'01, ECRTS'03, EMSOFT'04, HSCC'07. General Chair of RTSS'02, EMSOFT'04, ECRTS'07. Reviewer for Real-Time Systems, IEEE Transactions on Computers, ACM Transactions on Embedded Computing. Program committee member of most real-time related conferences.
Notable past projects	"FIRST: Flexible Integrated Real-time Systems Technology", IST-2001-32467 (2002-2005) investigated advanced scheduling for handling applications with various real-time requirements. "OCERA: Open Components for Embedded Real-time Applications", IST-2001-35102 (2002-2005) integrated advanced real-time mechanisms in open-source kernels. "FABRIC: Federated Applications Based on Real_time Interacting Components", IST-2001-37167 (2002-2003) investigated QoS management methods for home networks.

	"ARTIST: Advanced Real-Time Systems", IST-2001-34820 (2002-2005) investigated adaptive real-time systems for QoS management. "TRACS - Flexible Real-Time Architecture for Traffic Control Systems", ESPRIT III project No. 6373 (1992-1995) investigated real-time techniques for vessel control systems.
Awards	Best paper Award at the 10th Int. Conference on Real-Time and Embedded Computing Systems and Applications (RTCSA 2004), Gothenburg, Sweden, August 2004. Paper: "The Jitter Margin and Its Application in the Design of Real-Time Control Systems". Award for the best paper and presentation at the ANIPLA Workshop on Operating Systems for Industrial Control Applications, Milan, November 18, 1999. HUSPI Award given by Honeywell for the best journal publication on robotic systems, November 1987.
Further Information	Senior Member of IEEE

Team Leader **Activity Leader for "Scheduling and Resource Management"**	
	Professor Alan Burns University of York, UK URL: www.cs.york.ac.uk/~burns
Technical role(s) within ArtistDesign	Undertakes research in real-time systems scheduling, particularly for flexible systems. Also concerned with the development of programming languages for this domain.
Research interests	Scheduling, languages, modelling and formal logics.
Role in leading conferences/journals/etc in the area	Previous Chair of the IEEE Technical Committee on Real-Time Systems. Edited special issue of ACM Transactions on Embedded Systems (on education).
Notable past projects	DIRC – Dependability Interdisciplinary Research Collabroations – A large, UK, 6-year, multisite project looking at dependability of computer-based systems. Burns was a PI and manged the work on temporal aspects of dependability. FIRST – EU funded project concerninf flexibile scheduling FRESCOR – EU follow on project to FIRST

Team Leader	
	Prof. Gerhard Fohler Technical Univeristy of Kaiserslautern (TUKL) URL: www.eit.uni-kl.de/fohler
Technical role(s) within ArtistDesign	The role of TUKL is to investigate resource management policies for controlling the quality of service in multimedia applications. The team is leading the activity on Adaptive Resource Management for Consumer Electronics and is involved in the development and analisys of algorithms for video streaming applications. A further focus is on flexible scheduling, with the aim of integrating offline and online approaches.
Research interests	Real-time scheduling, integration of offline and online scheduling, QoS management, video streaming and media processing.
Role in leading conferences/journals/etc in the area	Chairman, technical committee on real-time systems, Euromicro Member of executive board technical committees on, IEEE real-time systems, IE embedded systems Area editor real-time, Journal of System Architecture, Elsevier Program chair, IEEE Real-Time Systems Symposium, 2006 Program chair, subtrack real-time systems, DATE 2005-2007 Program committee member of most real-time related conferences
Notable past projects	FRESCOR - Framework for Real-time Embedded Systems based on COntRacts, EU IST STREP WASP - Wirelessly Accessible Sensor Populations, EU IST IP BETSY - BEing on Time Saves energY continuous multimedia experience with low battery power, EU IST STREP FIRST - Flexible Integrated Real-Time System Technology, EU IST STREP FABRIC: “Federated Applications Based on Real_time Interacting Components”, IST-2001-37167 (2002-2003) investigated QoS management methods for home networks.

Team Leader	
	Prof. Michael González Harbour Universidad de Cantabria http://www.ctr.unican.es/
Technical role(s) within ArtistDesign	The role of University of Cantabria is to provide support for schedulability analysis of embedded distributed systems with real-time requirements. The Group has also developed methodologies and tools for software engineering of real-time systems in which a mixture of soft and hard deadlines can be found and as such is leading the activity on Flexible Scheduling Technologies. The group is also actively participating in the development of the Real-time POSIX operating systems standards, and is active in real-time languages, (Ada) and therefore contributing to the platform being used in the Real-Time Languages activity. One important goal of the Group has always been to test the results of basic research in practical applications. As a consequence, the Group has contacts with industrial companies in the field of industrial automation.
Research interests	Real-Time Schedulability Analysis, Real-Time Operating Systems, Real-Time Languages, Real-Time networks
Role in leading conferences/journals/etc in the area	Program chair of ECRTS 07, Program Co-Chair of the International Conference on Reliable Software Technologies 2006, Program Committee Member of RTAS, RTSS, ECRTS, and various Workshops on real-time systems.
Notable past projects	FRESCOR, Framework for Real-time Embedded Systems based on COntRacts. The FRESCOR project is aimed at developing a framework that integrates advanced flexible scheduling techniques directly into an embedded systems design methodology, covering all the levels involved in the implementation, from the OS primitives, through the middleware, up to the application level (www.frescor.org)

Team Leader **Activity Leader for "Real-Time Networks"**	
	Prof. Luis Almeida University of Aveiro URL: http://www.ieeta.pt/lse
Technical role(s) within ArtistDesign	Leader of the team from the University of Aveiro.
Research interests	Real-time communication (traffic scheduling, protocols,…) Flexible architectures for distributed embedded systems
Role in leading conferences/journals/etc in the area	Usually participates in the Organizing and /or Program Committees of conferences in the fields of Real-Time Systems (e.g., RTSS, ECRTS, RTAS) and industrial communications (e.g., WFCS, ETFA, FET). Has chaired several workshops (e.g., RTN, WTR, WiP sessions). Reviewer for several related journals (e.g., IEEE TII, TIE, TC, ACM TECS, Kluwer JRTS)
Notable past projects	ARTIST (FP5 accompaning measure). CAMBADA – Cooperative Autonomous roBots with Advanced Distributed Architecture. Specification and development of a team of cooperating autonomous robots for the Robocup Middle-Size Soccer League. Particular focus has been devoted to the architecture of each robot and their communication for information sharing. http://www.ieeta.pt/atri/cambada/ DISCO, DIStributed embeddable systems for COntrol applications. The objectives of the project were to investigate techniques and to develop solutions to improve flexibility and adaptability in distributed embedded control systems in order to reduce operation and maintenance costs while maximising the utilisation of system resources. http://www.ieeta.pt/lse/DISCO_web.pdf CIDER, Communication Infrastructure for Dependable and Evolvable Real-time systems. The project pursued two objectives: to analyse the usability of Ethernet in dependable applications (static set-up) and to devise the necessary mechanisms to allow the set-up to change dynamically (dynamic set of services and hosts) while providing the required dependability. http://www.hurray.isep.ipp.pt/activities/cider/
Awards	Best Paper Award in WFCS 2004 Best Paper Award in SICICA 2000

Team Leader	
	Prof. Eduardo Tovar Polytechnic Institute of Porto (ISEP-IPP), Porto (Portugal) URL: http://www.hurray.isep.ipp.pt/asp/show_people.asp?id=1
Technical role(s) within ArtistDesign	The role of ISEP-IPP team is to investigate distributed embedded systems, with a particular focus on communication protocols for WSN and MANETs. The team is leading the activity on Real-Time Networks and involved in flexible scheduling technologies, resource management policies and QoS-aware collaborative computing. The team has also a strong commitment in Real-Time Languages.
Research interests	Real-time systems, wireless sensor networks, multiprocessor platforms, communication networks, factory automation and system integration.
Role in leading conferences/journals/etc in the area	Executive Board Member of the Euromicro Technical Committee on Real-Time Systems. Program Chair ECRTS'05, RTN'02, WDES'06. General Chair of WFCS'00, ECRTS'03. Program committee member in several editions of ERCTS, RTSS, RTAS, RTCSA, ICDCS, SRDS, WFCS, ETFA, EMSOFT and other IEEE, ACM and Euromicro events on real-time systems, embedded systems and factory communication systems. Reviewer for Real-Time Systems, IEEE Transactions on Computers, ACM Transactions on Embedded Computing, IEEE Transactions on Industrial Informatics.
Notable past projects	"REMPLI: Real-time Energy Management via Power-lines and Internet", NNE5-2001-00825 (2003-2006) investigated advanced scheduling and protocols for power-line communication systems (PLC). "R-Fieldbus: High Performance Wireless Fieldbus in Industrial Multimedia-Related Environment", IST-1999-11316 (2001-2003), integrated advanced real-time mechanisms in hybrid wired/wireless fieldbus neworks. Mobility protocols and end-to-end deadlines.. "CABERNET: Network of Excellence in Distributed Computing Systems Architectures", IST-2000-25088 (2001-2003). "CIDER: Communication Infrastructure for Dependable Evolvable Real-time systems", POSI/1999/CHS/33139 (2001-2003), Portuguese Science Foundation project on real-time communication networks.
Further Information	Senior Member of IEEE

Team Leader **Activity Leader for "Design for Adaptivity"**	
	Professor Karl-Erik Årzén Lund University URL: http://www.control.lth.se/user/karlerik/
Technical role(s) within ArtistDesign	Leader for the Transversal activity "Design for Adaptivity". Team leader for Lund University. Participates in the OS and Networks cluster
Research interests	Embedded control, real-time systems, adaptive resource management, veedback applied to computer systems
Role in leading conferences/journals/etc in the area	CoChair 4th Intl. Workshop on Feedback Control Implementation and Design in Computing Systems & Networks (FeBID 2009)
Notable past projects	RUNES, ARTIST2, ACTORS (ongoing)
Awards	The Dr Guido Carlo-Stella award in manufacturing automation from the World Batch Forum in 2006 for achievements in manufacturing automation and information structuring

Team Leader	
	Dr. Stylianos Mamagkakis IMEC vzw. http://www.imec.be
Technical role(s) within ArtistDesign	Representing IMEC Nomadic Embedded Systems (NES) division in: -Cluster: SW Synthesis, Code Generation and Timing Analysis -Cluster: Operating Systems and Networks -Cluster: Hardware Platforms and MPSoC Design -Intercluster activity: Design for Adaptivity -Intercluster activity: Design for Predictability and Performance -Intercluster activity: Integration Driven by Industrial Applications

Research interests	Stylianos Mamagkakis received his Master and Ph.D. degree in Electrical and Computer Engineering from the Democritus Uni. Thrace (Greece) in 2004 and 2007, respectively. Since 2006, he coordinates a team of PhD students within the NES division at IMEC, Leuven, Belgium. His research activities mainly belong to the field of system-level exploration, with emphasis on MPSoC run-time resource management and system integration.
Role in leading conferences/journals/etc in the area	Stylianos Mamagkakis has published more than 35 papers in International Journals and Conferences. He was investigator in 9 research projects in the embedded systems domain funded from the EC as well as national governments and industry.
Notable past projects	Project leader of MNEMEE IST project www.mnemee.org Project leader of OptiMMA IWT project www.imec.be/OptiMMA Participation in: 1 international IMEC project (M4), 3 European IST projects (AMDREL, EASY, ARTIST2), 2 Greek projects (PRENED, DIAS)
Awards	1st prize in 'Technogenesis' Competition for Business Innovation, Greece, June'06 3rd prize in 'Otenet Innovation 2006' Competition for Business Innovation, Greece, November'06
Further Information	http://www2.imec.be/imec_com/nomadic-embedded-systems.php

4.2 Affiliated Industrial Partners

Team Leader	
	Dr. Paolo Gai (Ph.D.) Evidence srl (Italy) URL: http://feanor.sssup.it/~pj/
Technical role(s) within ArtistDesign	Support for the SHaRK kernel maintenance, consulting on POSIX and OSEK standards, real-time kernels, design and analysis tools.
Research interests	Real-time scheduling, operating systems, design and analysis tools.
Notable past projects	FIRST: Flexible Integrated Real-time Systems Technology, IST-2001-32467 (2002-2005) investigated advanced scheduling for handling applications with various real-time requirements. OCERA: Open Components for Embedded Real-time Applications, IST-2001-35102 (2002-2005) integrated advanced real-time mechanisms in open-source kernels. ARTIST: Advanced Real-Time Systems. (http://www.artist-embedded.org)

4.3 Affiliated Academic Partners

Team Leader	
	Professor Juan A. de la Puente Universidad Politécnica de Madrid URL: http://www.dit.upm.es/jpuente
Technical role(s) within ArtistDesign	Team Leader of the Universidad Politécnica de Madrid, UPM leader on “Real-Time languages” and “Common infrastructure for Adaptive Real-Time Systems”
Research interests	Design of real-time systems, high-integrity systems, programming languages, scheduling, control systems and distributed systems

Role in leading conferences/journals/etc in the area	Associate editor of the Journal of Real-Time Systems. Participation in the Programme Committee of conferences such as Euromicro Real-Time Systems, International Conference on Reliable Software Technologies.
Notable past projects (optional – max 5)	ASSERT: Developmet of advance software techniques for high integrity systems for aerospace systems. TRECOM: Techniques for the development of advanced distributed real-time systems for safety and business critical systems. ORK (Open Ravenscar Real-TIme Kernel): Development of a kernel for safety-critical space systems.
Awards / Decorations	IFAC Fellow

Activity Leader for "Qos-aware components"	
	Prof. Alejandro Alonso Universidad Politécnica de Madrid. URL: http://www.dit.upm.es/aalonso
Technical role(s) within ArtistDesign	Activity Leader for "Qos-aware components" UPM leader on Adaptive resource management for CE"
Research interests	Design of real-time systems, programming languages, scheduling, distributed systems and quality of service
Role in leading conferences/journals/etc in the area	Participation in the Programme Committee of conferences such as Euromicro Real-Time Systems, International Conference on Reliable Software Technologies.
Notable past projects	MORE: Network-centric Middleware for GrOup communication and Resource Sharing across Heterogeneous Embedded Systems HIJA: High-Integrity Java Applications. The goal is to develop a new Java-based middleware platform fo the creation of Architecture-Neutral, high-integrity, distributed Real-Time Systems (ANRTS) ROBOCOP and Space4U. Development of component framework for embedded devices. It includes support for QoS and resource management. TRECOM: Techniques for the development of advanced distributed real-time systems for safety and business critical systems.

Team Leader	
	Prof. Hermann Härtig Dresden University of Technolgy URL: http://os.inf.tu-dresden.de/~haertig/
Technical role(s) within ArtistDesign	
Research interests	
Role in leading conferences/journals/etc in the area	
Notable past projects	

Team Leader	
	Name: Alfons Affiliation: Universidad Politécnica de Valencia, Spain URL: http://www.gii.upv.es/personal/alfons/
Technical role(s) within ArtistDesign	Real-time control on embedded platforms
Research interests	Virtualisation, hypervisor, real-time operating system, dynamic memory management
Role in leading conferences/journals/etc in the area	Program Committee member Reviewer
Notable past projects	ARTIST2: Network of Excellence on Embedded Systems Design. U.E. IST Programme - IST 004527. 2004-08 FRESCOR: Framework for Real-time Embedded Systems based on COntRacts FRESCOR. U.E. IST Programme - IST 034026. 2006-2009 THREAD: Integral support for embedded, distributed open real-time

	systems Spanish Ministry of Education, Science and Technology - TIC2005-08665-C03. 2005-2008 SENSE: Smart Embedded Network of Sensing Entities. U.E. IST Programme - IST 033279. 2006-2009 TECOM: Trusted Embedded Computing. Programme ITEA-2 and PROFIT (M. Industria, Spanish Governement). 2007-2010 OCERA: Open Components for Embedded Real-Time Applications. U.E. IST Programme (IST 35102). 2002-05

Team Leader	
	Prof. Jean-Dominique Decotignie Ecole Polytechnique Fédérale de Lausanne (Switzerland) URL: http://lamspeople.epfl.ch/decotignie/
Technical role(s) within ArtistDesign	
Research interests	
Role in leading conferences/journals/etc in the area	
Notable past projects	

Team Leader	
	Prof. Lucia Lo Bello University of Catania (Italy) – Affiliated to SSSA, Pisa URL: http://www.diit.unict.it/users/llobello/
Technical role(s) within ArtistDesign	Support for the SHaRK kernel maintenance. Implementation of industrial multimedia system using SHARK. Execution time measurement. Stochastic analysis of soft real-time tasks in the context of priority-driven soft real-time systems. Calculation of stochastic response time profiles of tasks that are hierarchically scheduled using server based techniques. Support for real-time communication in distributed embedded

	systems, with particular reference to networked embedded systems used in factory communication and in automotive environments. Real-time communication over wireless networks: modelling, timing analysis, and transmission scheduling to support soft real-time traffic over 802.11, 802.15.4 and Bluetooth networks. Design issues and protocols for wireless sensor networks and networked embedded systems.
Research interests	Real-time scheduling, overload handling, real-time communication protocols, factory communication, real-time communication over wireless networks, wireless sensor networks, automotive communications.
Role in leading conferences/journals/etc in the area	Program Chair of ETFA 05, ETFA 07. WIP Chair of ETFA 06. General Chair of ECRTS 04. PC member of many editions of ECRTS, RTSS;,RTAS,ETFA, WFCS, RTN , FET, RTNS ,WTR. Reviewer for the Real-Time Systems Journal, IEEE Transactions on Industrial Informatics, IEEE Transactions on Industrial Electronics, IEEE Transactions on Computers, Computer Standard and Interfaces, Journal of System Architectures. On the Editorial Board of the International Journal of Embedded Systems.
Notable past projects	Italian National project PRIN 04 entitled “Study and development of a realtime land control and monitoring system for fire prevention”, funded by the Italian Ministry of University and Research (http://www.prin.polito.it/) European project ESPRIT 26951 "NOAH - Network Oriented Application Harmonisation. Italian National COFIN 2001 inter-university project titled ‘’High-Performance Processing for Applications with High-Intensity Computational Requirements and Real-Time Constraints, funded by the Italian Ministry of University and Research (http://tsc.polito.it:7777/cofin2001/)
Further Information	Member of the International Electrotecnical Commission (IEC), Technical Committee SC65C, Working Group 11, Real-Time Industrial Ethernet (RTE), actively involved in standardization activities. Nominated expert member for the Italian Electrotechnical Committee (CEI-Comitato Elettrotecnico Italiano) in the Technical Committee SC65C “Digital Data Communications for Measurement and Control-Fieldbus for Use in Industrial Control Systems”, Maintenance Team 9, “High availability automation networks". Member of the Technical Committee on Factory Automation of the Industrial Electronics Society (IES). Co-chair of the Subcommittee 10 “Intelligent Sensors and Sensor Networks in Industrial & Factory Automation”.

Team Leader	
	Dr. Pau Martí Technical University of Catalonia, Barcelona, Spain URL: http://www.upcnet.es/~pmc16/
Technical role(s) within ArtistDesign	Real-time systems and control systems co-design
Research interests	Real-time and control systems, overload handling, jitter analsyis and compensation, control theory.
Role in leading conferences/journals/etc in the area	Program committee member of major real-time and control conferences. Reviewer for the Real-Time Systems Journal.

Team Leader	
	Prof. Ivo De Lotto Robotic Lab, University of Pavia, Italy http://www.unipv.it/ingegneria/servizi/scheda.php?mat=000300
Technical role(s) within ArtistDesign	Provide support for the development of real-time control applications in the domain of robotics and automation.
Research interests	Sensory systems, robotics applications, wireless communication, energy-aware computing.
Role in leading conferences/journals/etc in the area	Program committee member of major conferences on robotics. Reviewer of International journals on robotics. Member of the evaluation committee for national projects.
Awards / Decorations	Gold Medal of Italian Ministry of Education (1988)

Team Leader	
	Prof. Marisol García-Valls Universidad Carlos III de Madrid URL: http://www.it.uc3m.es/mvalls
Technical role(s) within ArtistDesign	UC3M leader on Adaptive resource management for CE”

Research interests	Distributed embedded systems, design and modelling of real-time systems, real-time programming languages, quality of service
Role in leading conferences/journals/etc in the area	Member of the Programme Committee of conferences such as ARCS 06, EstiMedia 04-06, JTRES 03-04, EUC 05, EMSOFT 03-04 Reviewer of the Real-Time Systems Journal
Notable past projects	ARTIST: Advanced Real-Time Systems. URL: http://www.artist-embedded.org MUSE: MUlti Service Access Everywhere Everyware: Personalized services in ubiquitous environments

Team Leader	
	Prof. Julian Proenza University of the Balearic Islands URL: http://dmi.uib.es/research/SRV/jpa_ppl_en.htm
Technical role(s) within ArtistDesign	Team leader of affiliated partner. Indirect participation in the Cluster, with the core team University of Aveiro
Research interests	Dependable and Real-Time Systems, in particular, on fault-tolerant distributed systems, clock synchronization and field-bus networks, like CAN (Controller Area Network).
Role in leading conferences/journals/etc in the area	Chair of several workshops in his fields of interest. Participation in several Organizing and Program Committees of related events.

4.4 Affiliated International Partners

	Professor Tarek Abdelzaher, University of Illinois at Urbana-Champaign http://www.cs.uiuc.edu/homes/zaher/

Technical role(s) within ArtistDesign	Technical expert
Research interests (optional)	Operating systems, networking, sensor networks, distributed systems, and embedded real-time systems.

	Professor Lui Sha, University of Illinois at Urbana-Champaign http://www.cs.uiuc.edu/directory/directory.php?name=sha
Technical role(s) within ArtistDesign	Technical expert.
Research interests	Distributed real-time computing systems, dynamic real-time architecture, QoS driven resource management and security and fault tolerance in networked embedded systems.

	Professor Sanjoy Baruah, University of North Carolina at Chapel Hill http://www.cs.unc.edu/~baruah/
Technical role(s) within ArtistDesign	Technical expert.
Research interests	Schedulability analysis and multiprocessor systems.

5. Internal Reviewers for this Deliverable

Karl-Erik Arzen (Univ. of Lund, Sweden)

Marco Caccamo (University of Illinois at Urbana Champaign, USA)