INSTITUT NATIONAL DE RECHERCHE EN INFORMATIQUE ET EN AUTOMATIQUE

Project-Team TRIO

Temps Réel et InterOpérabilité (Real Time and InterOperability)

Lorraine

THEME COM

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1. Team

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2. Overall Objectives

2.1. Overall Objectives

The goal of the TRIO team is to provide a set of techniques and methods that can be applied to design, validate and scale real time distributed applications. In order to tackle this problem as a whole, our work is structured along two complementary points of view:

- specification of real time on line mechanisms (protocols, schedulers, middleware) offering services to the application with a quality of service that ensures the satisfaction of real time constraints; this includes fault detection, fault indication and fault tolerance,
- modeling, analysis and evaluation of real time distributed systems for the verification of temporal properties and the optimisation of distributed deployment.

Furthemore, we keep aware on the modeling process of real-time distributed applications that allows the description of both functional and non-functional aspects of these applications and therefore a formal use of these models for quantitative evaluation and optimal scaling.

The problems to solve are mainly due to three particularities of targeted applications:

- They are discrete event systems with temporal characteristics (temporal performances of hardware support, temporal properties); this increases the complexity of their modeling and of their analysis. Hence a part of our research objectives is to master this complexity while stating a compromise between the accuracy of a model and its ability to be analyzed.
- A second aspect is the environment of these systems that can be the cause of perturbations. We need to take into account the impact of an uncertain environment (for example, the impact of electro-magnetic perturbations on a hardware support) on the required properties. Therefore we have to develop stochastic approaches.
- Finally, the main characteristic of our works is based on the fact that we consider the performances of hardware supports. Consequently, the time that we manipulate is a physical (continuous) time and the studied systems are event driven timed systems.

These above mentioned main directions contribute to cover the full spectrum from formal modeling and evaluation of real time distributed systems up to their use in industrial problems, in particular, in the field of in-car electronic embedded systems or real-time Quality of Service. Furthermore, some of our results yield to software tools and fruitful collaborations with the automotive industry.

3. Scientific Foundations

3.1. Scientific Foundations

In order to check for the timed behavior and the reliability of a distributed systems, the TRIO team developped several techniques based on deterministic approaches ; in particular, we apply and extend analytical evaluation of worst case response time and when necessary, e.g. for open communication systems as internet based applications, we use techniques based on network calculus.

When the environment might lead to hazards (e.g. electromagnetic interferences causing transmission errors and bit-flips in memory), or when some characteristics of the system are not perfectly known or foreseeable beforehand, we model and analyze the uncertainties using stochastic models, for instance, models of the frame transmission patterns or models of the transmission errors. In the context of real-time computing, we are in general much more interested by worst-case results over a given time window than by average and asymptotic results, and dedicated analyses in that area have been developed in our team over the last 10 years. An illustration, is our recent contribution to the extension of "consecutive-k-out-of-n:F" analyses, applied to the reliability evaluation of X-by-Wire systems [67], [70]. As far as the design of discrete event systems is concerned, we mainly use scheduling techniques for real time systems.
In the design of discrete event systems with hard-real time constraints, the scheduling of the system's activities is of crucial importance. This means that we have to devise scheduling policies that ensure the respect of time constraints on line and / or optimize the behavior of the system according to some other application-dependent performance criteria. A new approach to solve these problems was partially developed in our team: the trajectory approach with priority functions. This approach has been used many times to make formal proofs of schedulability results in quite general cases. Another line of research investigated in our team is the use of techniques originating from network calculus, with the aim of minimizing the set of assumptions about the system's behaviour.

Many current systems can adapt dynamically to the environment [68], [69], [65], [64]. This is why we focus on "weakly hard" real time constraints such as (m, k)-firm constraints and study their applicability in two main application fields. The first one is concerned by application under weakly hard constraints, as real time multimedia application that are deployed for example on internet; in this case, the main problem is to adapt the (m, k)-pattern to the current requirements in terms of real time Quality of Service. The second domain where these techniques are investigated is the co-design of networked control systems. It has to be noted that in this domain several approaches are developed by the community; some of them focus on the automatic control problem and try to solve it by delayed systems while other ones are concerned only by the scheduling techniques to implement in order to guarantee the timing properties required by the closed loops. In this context, we propose to specify how to scale both control law parameters and scheduling strategies for tasks and messages and, for this purpose, we integrate control theory (linear systems, multi-variables), optimisation and schedulability analysis in order to develop off-line and on-line techniques [64], [66].

4. Application Domains

4.1. Application Domains

Four main application domains can be underlined.

- **Fieldbuses and field equipments.** In this context a previous important contribution of TRIO is the participation to WorldFip protocol specification and evaluation. WorldFip Fieldbus is an IEC standard (2000) and is the only field-bus in the world which has been certified (Safety Integrity Level 3) in 2001 according to the IEC 61508 standard. Recently a new field of investigation has been started for error management mechanisms for CAN Networks.
- **In-car embedded systems.** A lot of work developed in TRIO is oriented towards these particular applications. They mainly cover two points. The first one is the specification of what must be modeled in such a system and how to reach a good accuracy of a model; this leads to investigate topics like Architecture Description Languages and automatic generation of models. The second point concerns the verification of dependability properties and temporal properties required by these applications and, consequently, the development of new fault tolerant on-line mechanisms to include in an application or the automatic generation of a standard middleware.

- **Quality of services (QoS) of protocols.** In many application domains, the evaluation and, when required, the improvement of the quality of services provided by the used communication protocols is a way to ensure the respect of dependability properties. In this context, we model and analyze some protocols for home automation application and aim to define analytically the optimal configuration of their characteristics; for example, we investigate different protocols available in Power Line Communication systems / PLC (REMPLI Project / 5th EC FP) and in wireless communication. In the same field we specify mechanisms for guaranteeing on line a required QoS for applications under weakly hard real time constraints.
- **Remote monitoring.** The research in remote monitoring follows two objectives: on one hand, the monitoring of chronic patients (kidney disease, cardiac decompensation) and, on the other hand, the remote monitoring and maintenance of physical processes. Both of these applications need real time data acquisition, modeling of the considered "objects", data fusion and decision, and obviously communication and distribution policies analysis. In this field, the interest for TRIO is the broadening of communication protocols studies and applications, and of interoperability requirements [71].

5. Software

5.1. Diatélic

Participant: Jean-Pierre Thomesse.

After having developed (in 2002) the well-suited structure for the deployment of the "Diatélic" service in Lorraine, more than 200 patients have been installed and get benefits from the remote monitoring service for peritoneal dialysis therapy. This deployment has been very rich in experience for extending an innovative system at a wide scale. In terms of medical results, the same tendencies are observed as during the experiment (1999-2002); i.e. best control of weight, of blood pressure, less consumption of drugs and important decreasing of the hospitalization duration (50 %), leading to an economy for health insurance of about 15 000 euros per year and per patient.

This year has been dedicated to the extension of the developped approach for remote monitoring of patients with cardiac insufficiencies. Both of these operations are carried in cooperation with the MAIA team of LORIA. Regarding the publications on these actions, nothing is published because the protection strategy is oriented towards patent registration.

5.2. REMPLI traffic Dispatcher

Participants: Xavier Granmougin, Liping Lu, Christiano Nemer, Pathagolusu Venkat Rao, YeQiong Song.

For supporting REMPLI applications with different timing constraints, a PLC (Power Line Communication) system must provide differentiated QoS (Quality of Service). Within REMPLI EU project, we developed and implemented a traffic dispatcher at the network layer in the kernel space of the Hynet board. It guarantees both required periodic data update and short end-to-end delay of aperiodic data request services [10]. This software, being part of the whole REMPLI SFN communication board, will be exploited by the iAd company after the achievement of the REMPLI project.

5.3. SPECO: Software Platform to Evaluate the impact of Compilation Optimizations

Participants: Dominique Bertrand, Olivier Zendra.

This platform is intended to automatically run a large number of benchmarks to make it possible to get precise concrete results over the actual impact of any compilation optimization we design in our research. The benchmarks have been chosen among the most relevant according to the bibliography, and mostly comprise multimedia and embedded systems related programs. The platform works as follows. It extracts static metrics to provide information about the structure and static complexity of the benchmarks. It compiles all the benchmarks, and runs them to extract dynamic metrics. Those comprise time, for raw performance and space (memory) information to better understand the memory behavior of the programs. The energy usage metric is also nearing completion [60].

Future development should include finishing the energy estimation part, completing the text-based results we provide with automatic generation of graphs, automating the installation of our software platform and making sure it runs on a variety of hardware platforms.

6. New Results

6.1. Real time services and protocols

In this topic, we developed, on one hand, policies for managing the quality of service of operating support (mainly, networks and protocols) in order to meet the properties required by real time applications (hard real time, weakly hard real time) and, on the other hand, strategies for scheduling activities and admission

6.1.1. Low-power and low-energy in embedded and/or real-time systems

Keywords: *adaptation*, *compilation*, *embedded systems*, *energy consumption model*, *low-energy*, *low-power*, *memory management*, *scheduling*, *scratch-pad memory*.

Participants: Dominique Bertrand, Mathieu Grenier, Nicolas Navet, Pathagolusu Venkat Rao, Olivier Zendra.

Amongst all hardware and software techniques aimed at reducing energy consumption, supply voltage reduction, and hence reduction of CPU speed, is particularly effective. This is because CPU requires a large amount of energy (e.g., 30W at maximal frequency for an Intel P4 Mobile 1.8GHz) and the energy consumption of the processor is usually at least quadratic with the speed of the processor. The aim is thus to minimize the processor frequency as much as possible while satisfying the performance constraints of the system. Many power-constrained embedded systems are built upon multiprocessor platforms because of high-computational requirements and because multiprocessing often significantly simplifies the design. Another advantage is that multiprocessor systems are theoretically more energy efficient than equally powerful uniprocessor platforms because raising the frequency of a single processor results in a multiplicative increase of the consumption while adding processors leads to an additive increase [17].

Recent work in this domain include the exploration of the state of the art about compilation issues and possible optimization for low-energy as well as low-power in embedded and or/real-time systems.

We especially focussed on data, or more precisely on memory-related issues for low-energy [59]. We concluded that scratch-pad memory (SPM) is a direction that offers great opportunities to optimize energy and/or power when considering compiler techniques and optimizations. Indeed, SPM provides a high level of control for the compiler and application over memory, which unlike caches allows us to work on more precise bases and known environment.

We thus intend to go on by working on data and memory related optimizations, such as compaction, and data placement, especially in scratch-pad memories. In the context of real-time systems, static placements will be explored, as well as dynamic (re)placements. Indeed, we think that the latter, although they are likely to make things harder to predict, offer greater optimization challenges and potential through adaptation.

As part of this work, we designed and started to build an experimental platform, termed SPECO, to benchmark the results of the compilation optimizations. Since we aim at designing new optimizations techniques and at incorporating then in existing compilers, we especially target the well-known, open source and free compiler gcc, for C and C++.

Some work has also been devoted to the ongoing study of a multiprocessor scheduling algorithm under energy constraints. This work is not finished yet.
Battery lifetime is a primary design constraint for mobile embedded systems. It has been shown to depend heavily on the load current profile (i.e. evolution of the current drawn over time). However, up to now, very few low-power scheduling policies take this fact into account. We explored in [50] how scheduling guidelines drawn from battery models can help in the extension of battery capacity. We proposed a "Battery-Aware Scheduling" methodology for periodically arriving task-graphs (Directed Acyclic Graph) with real time deadlines and precedence constraints. The methodology presented in [50] divides the problem into two steps. First, a good DVS algorithm dynamically determines the minimum frequency of execution. Then, a greedy algorithm allows a near optimal priority function to choose the task which would maximize slack recovery. Battery simulations carried out on the profile generated by our approach for a large set of task-graphs show that battery life time is extended up to 23.3% compared to existing dynamic scheduling schemes.

6.1.2. *Improving resource utilization under (m, k)-firm constraint*

Keywords: *Network*, *Non pre-emptive scheduling*, *Real-time QoS*, *weakly hard constraints*.

Participants: Jian Li, YeQiong Song.

This work aims at providing deterministic (m, k)-firm guarantee for the QoS control of packet transmissions. Hence we only interest in the non pre-emptive scheduling algorithms for sharing a common resource among multiple queues. In our early work [21], [16], we have shown that the deterministic guarantee of (m, k)-firm real-time requirement is NP-hard in general. This can lead to very low resource utilization in practice. Faced to this problem, two research directions are possible: developing heuristic approaches to obtain sub-optimal solutions or relaxing the constraint model. We worked in this second direction as the real-time applications we aimed at have certain "natural fault tolerant capability" (e.g. multimedia streams such as VOIP, Video, etc.). A relaxed (m, k)-firm constraint model has been proposed which, instead of constraining on the per-instance deadline, constrains the "per-group-of-instances" deadline. With this relaxation, we obtained general results on the resource utilization improvement for either fixed priority scheduling or dynamic one [45],[42], [43]. Moreover, for (r, b)-upper bounded input flows, a QoS control mechanism called DLB (Double Leaks Bucket) has been proposed which guarantees the relaxed (m, k)-firm constraint with high resource utilization [44].

6.1.3. *Performance and real-time QoS in wireless sensor networks*

Keywords: *MAC routing protocols*, *Real-time QoS*, *Wireless sensor network*, *performance evaluation*.

Participants: Najet Boughanmi, ChungShue Chen, Bilel Nefzi, YeQiong Song.

A new research topic has been initiated this year whose main objective is to study the possibility to support real-time applications using the state-of-the-art wireless sensor networks (WSN). For this purpose, we firstly analyzed the commonly accepted Zigbee routing and IEEE802.15.4 MAC protocols. With this preliminary work we have shown that:

- in a star topology, there is a need to introduce priorities to IEEE802.15.4 for a judicious bandwidth sharing. Moreover a deterministic MAC (Medium Access Control) protocol rather than a contention based one is preferable for reporting an event that has simultaneously be detected by several sensor nodes. For this issue, a differentiated QoS solution has been proposed which consists in only tuning the backoff interval and contention window values according to the traffic types, and this without changing the slotted CSMA/CA protocol [40].
- in a peer to peer topology, AODV (Ad hoc On Demand Distance Vector) based Zigbee routing protocol does not take into account the temporal and energy optimisation constraints. On this point, we proposed a new routing metric, which can satisfy both energy and delay constraints [25].
- in a cluster-tree organisation, synchronizing the cluster heads can largely improve the temporal performance.

In collaboration with Zhejiang university, we also showed the feasibility to use WSN for real-time fire monitoring [46]. This work is continuing as part of a postdoctoral research project (ChungShue Chen) and a PhD thesis (Najet Boughanmi). The former focuses on the communication reliability analysis facing transient errors, whilst the latter studies a sensing and actuating control loop using WSN as communication path. In addition, we can hope that our past experience and expertise on real-time wired sensor and actuator networks (i.e., fieldbus such as WorldFIP, CAN, etc.) can contribute to enhance the real-time QoS of WSN; in particular we plan to adapt the temporal and spatial consistency mechanisms of the fieldbusses to WSN.

6.1.4. Real-time scheduling

Keywords: *Fixed-Priority Preemptive*, *Posix 1003.1b*, *Round-Robin*, *Schedulability analysis*, *Scheduling*, *optimal priority assignement*.

Participants: Nicolas Navet, Mathieu Grenier.

Posix 1003.1b is the major and most widely used standard for real-time Operating Systems. Compliant systems provide two well specified scheduling policies, namely sched_rr (Round-Robin like) and sched_fifo (Fixed Preemptive Priority like). Each task is assigned not only a priority but also a scheduling policy. Up to now, little has been done to take advantage of the combination of both policies to maximize schedulability. In [31], we propose an optimal priority and policy assignment algorithm for Posix 1003.1b systems. The algorithm is shown to be optimal with regards to the power of the feasibility test (i.e. its ability to distinguish feasible and non feasible configurations). The algorithmic complexity is exponential in the number of tasks but we establish some properties on the scheduling that help to reduce drastically the search space. In practice, experiments show that the algorithm scales well with the number of tasks and allows to achieve a much higher CPU utilisation than in the plain FPP case. This study is extended in [30] to the case where the time quantum of the Round Robin tasks can be chosen on an individual basis. The algorithm remains optimal with regards to the power of the schedulability test. The efficiency is shown to be significantly better than in the system-wide quantum case at the expenses of a higher complexity.

6.1.5. Scheduling of tasks based on stochastic models

Keywords: *Markov Decision Process*, *genetic algorithm*, *scheduling*.

Participants: Bernard Chauvière, Dominique Geniet [University of Poitiers], René Schott.

Our research activities concern the development of new probabilistic and deterministic methods for task scheduling in real-time systems.
In [13], B. Chauvière and D. Geniet have developed an evaluation method for the feasability of hard real-time systems which depends on Markovian analysis. In [14], B. Chauvière, D. Geniet and R. Schott present a new method called PFX for determining fixed priority real-time policies on multiprocessor targets. PFX follows an off-line approach: the construction process uses an inductive analysis of the whole set of possibilities and the exact evolution parameters of tasks instead of response times. Recently, we started a work on task scheduling in real-time systems via Markov Decision Processes (MDPs).
Our 2007 research activities will concern the design of hybrid algorithms combining the features of genetic algorithms with MDPs, for task scheduling in real-time systems.

6.2. Evaluation and optimal scaling of real-time systems

6.2.1. Networked control systems: resource overload management using selective data dropouts according to (m, k)-firm model

Keywords: *Network*, *Networked control systems*, *Real-time QoS*, *Scheduling*, *WFQ*.

Participants: Flavia Felicioni [Rosario University, Argentina], Ning Jia, Françoise Simonot-Lion, YeQiong Song.

In networked control systems, according to their specification (see the good practices introduced by Aström), some feedback control laws can tolerate/compensate the performance degradation of the QoS of the underlying processor or communication networks under the condition that they remain within the process stability region. In this context, we consider control systems that are deployed on a distributed architecture where processors and networks can be subject to overloading situation. The first step of the PhD program of Ning JIA consists in identifying the relationship between the Quality of Control, expressed as the control stability and the control performance, and the processor or/and communication system performance degradation due to resource overload. We focused on the influence of the packet dropouts and studied how the packet drops governed by certain (m, k)-patterns could be used to optimize the Quality of Control. In [62] and [28], we identified that the parameter k of the (m, k)-firm model is related to the stability of the system. So, we determined through an analytical technique both the control law parameters and the value of k that preserve the stability. In fact, in this case, the calculated value of k is interpreted as the largest period, multiple of the Shannon sampling period that is suited. Then, the choice of the value of m and the (m, k)-pattern is discussed to minimize the LQR cost.

In [32], considering a single control loop, we investigated how to design the controller under packet drops and how to distribute the packet drops in a packet delivery sequence so that the quality of control (QoC) is optimized. We proposed a methodology for deriving the distribution of the packet drops in the packet delivery sequence so that the QoC is optimal. To reduce the computation complexity of the proposed methodology, a computationally cheaper algorithm is also given.

Finally, we extend these results in order to support the handling of n control loops implemented as a configuration of n real time tasks sharing the same processor; a configuration is defined by the number of tasks, the worst case execution time, the periodicity and the relative deadline for each tasks. Furthermore, we consider the point in time where the diagnostic and supervision activities have to switch to a new functionning mode of the system and therefore to a new task configuration. We investigated how to design the controllers and the task instance dropping strategies so that a global parameter covering all the concerned control laws is optimized. The result is a (m_i, k_i)-firm strategy for each task in the configuration. Moreover we analysed the (m_i, k_i)-firm policy for both supervision and control purposes. In this case, we determine off-line k_i and M_i, a set of possible values of m_i for each task; assuming a uniform distribution of the m mandatory instances among a sequence of k, the problem is to determine on-line the best value in M_i. For this purpose we proposed an efficient heuristic. This work is a contribution to the ARA-SSIA Safe-Necs project [61].

6.2.2. Optimal deployment of a real-time middleware

Keywords: *design pattern*, *discrete optimisation*, *frame packing*, *generalized multiframe task*, *in-vehicle embedded system*, *multiframe task*, *real time*, *schedulability*.

Participants: Nicolas Navet, Ricardo Santos Marques, Françoise Simonot-Lion, Philippe Hubert, Xavier Rebeuf.

In our early work, we defined a method for the automatic generation of the communication services of an automotive middleware, as proposed by Autosar consortium (http://www.autosar.com). The main purpose of these services is to support the signal exchanges, assumed to be periodic or sporadic and specified at applicative level, thanks to frame transmission done at network level. In order to minimize the bandwith consumption, local signals are packed into frames according to a frame packing strategy and frame sending rules that we provided formerly. The automatic generation technique separates, on the one hand, the static point of view (code sequences, local and common data) and on the other hand, the dynamic one (feasible configuration of local tasks and frames). For the static view, we proposed formerly a generic reference model of the middleware obtained by a composition of different Design Patterns. The result is a UML class diagram thanks to which software components and data can be instanciated with respect to the local application requirements. We considered also the dynamic aspect of the middleware and we identified the two tasks that realize at run time the middleware communication services and prove that the proposed solution is optimal in the automotive context (minimization of context switchs under constraints due to OSEK/VDX OS) and we determined how to evaluate the characteristics of these two tasks with respect to the applicative requirements (timing constraints

on exchanged signals, signal emission, etc.) and to the frame packing strategy. This year we achieve this work by developping a strategy for the construction of the sending task as multiframe task or, when necessary, as generalized multiframe task [19], [51], [52]. We also extended the results for other services as communication error handling. This work is a large part of the PhD thesis of Ricardo Santos Marques [11]. An implementation of this method was prototyped by Philippe Hubert during his CNAM engineer degree.

6.2.3. Schedulability analysis with real-world automotive constraints

Keywords: *CAN*, *Schedulability*, *in-vehicle embedded system*.

Participants: Liliana Cucu, Mathieu Grenier, Nicolas Navet.

Sometimes there is gap between what is hypothesized in the literature and how systems are in practice. For instance, existing schedulability analyses on priority buses (e.g., Controller Area Network) make strong assumptions about the communication controllers and the software communication layers. As an illustration, it is assumed that there are as many different buffers as frames to transmit at the communication controller level. In practice, in automotive applications, this is not the case and some frames are to be stored for some time in a queue at the microcontroller level before being moved to the communication controller. In the context of an industrial contract with PSA, we are first interested in devising the best mechanisms (e.g. protocols) for minimizing the overheads caused by such "non-ideal behaviours". The second objective is to revisit the existing literature on schedulability analysis for real-time communications and integrate our proposals. More generally, the aim of the project is to adapt timing verification techniques in such a way as to take into account the actual constraints in the design of vehicles; technical constraints, for instance dictated by the hardware, but also constraints due to the legacy in terms of usages, tools or even relationship with third-part suppliers.

6.2.4. Real-time component-based design

Keywords: *Function Blocks*, *IEC 61499*, *Real Time Component*, *off-line composition*, *on-line composition*.

Participants: Mohamed Khalgui, Xavier Rebeuf, Françoise Simonot-Lion.

Last year, we worked on the scheduling of an application specified as a Function Block Network deployed onto one resource under constraints on end-to-end response time between a periodic input event of the network and the causal output ones. The proposed strategy was an idle non preemtive fixed priority one [15]. This year, we extended this result.

Firstly, we took into account the possibility that such a static scheduling cannot be found; more precisely, we considered the case where the designer is able to produce a (m, k)-pattern specifying which m occurrences are necessarily to be treated in each sequence of k occurrences and we proposed to verify that under this new constraints, the previously proposed strategy gives a schedulable result [39]. In this case, a dropping algorithm has to be added to the static scheduler.

Secondly, we integrated the fact that nowadays, main programmable logic controllers are based on a multi-tasks operating systems. In this case, the deployement of a Function Blocks network can take profit of the pseudo-parallelism allowed by such a device. So, we defined a method that combines static and dynamic scheduling techniques [34], [37], [35]:

- the previously specified static scheduling approach is applied to the scheduling of Function Blocks algorithms inside one resource and we consider that one resource corresponds to an Operating System task (note that assuming this brings a formal semantics to the standard IEC 61499),
- once the static scheduling is done inside the resource, the problem is to propose a scheduling policy for the set of resources; for this purpose, we identified that this problem is related to the concept of recurrent and conditional tasks proposed by Sanjoy Baruah and therefore it was possible to apply the adequate schedulability condition to our initial problem.

Then, another contribution brings a solution to the deployement of a Function Blocks network onto a distributed system. In particular, we proposed to characterize each message exchanged through a given fieldbus by several attributes: its applicative emission profile (a function that gives the instants of its emission by a Function Block), its deadline and its size. Given these information, we provided an algorithm that build the correct set of messages as they will be transmitted actually on the fieldbus and so that the set is proved schedulable [36].

Finally, we proposed a heuristic that supports the allocation of Functions Blocks onto a distributed system and under some allocation constraints. This heuristic is based on the above mentionned results in order to obtain a "correct" solution [33].

The different proposal are currently applied in a case study and form a part of a collaboration between the TRIO team and the Software Engineering Software Engineering Group at Patras University (Professor Kleanthis Thramboulidis).

6.2.5. Quantitative evaluation of the safety for X-by-Wire applications

Keywords: *FlexCAN*, *IEC 61508*, *TDMA*, *X-by-Wire*, *fault tolerant architectures*, *networked controlled systems*, *reliability*, *safety*.

Participants: Juan Pimentel [University of Kettering, USA], René Schott, François Simonot, Françoise Simonot-Lion, YeQiong Song.

Last year, we developped a quantitative evaluation technique in order to verify that an in-vehicle critical system, as a Steer-by-Wire one, is compliant to a given Safety Integrity Level (SIL) as specified in the standard IEC 61508. We focused on TDMA-based communication systems and specified the formal relation between external transient faults at the communication level, due for example to Electro Magnetic Interferences, and the safety properties at the vehicle level. We identified that this problem has to be related to concept of "consecutive-k-out-of-n:F" systems, developped for the reliability evaluation of static systems. Another contribution was to find an algorithm that computes efficiently the probability of failure occurrences for any pattern of external faults occurrences under a given critical situation of the vehicle represented by the corresponding control laws and the corresponding model of the vehicle [54], [56], [55], [53]. This year, during the visit of Juan Pimentel, we extended these results in order to obtain the evaluation of the safety of a vehicle whose embedded electronic systems is based on a FlexCAN protocol. This protocol, proposed by Juan Pimentel, is based on the CAN one and specifies a upper layer that integrates both TDMA approach (time windows) and, inside the time windows maintains the CAN Medium Access Control protocol for messages allocated to this window. So, the safety evaluation has to take into account results obtained previously by Nicolas Navet in his PhD thesis and extended later by Ian Broster and the method that we proposed on for TDMA-based network [63].

This kind of problem constitutes the heart of the proposal of QSL operation TT_SAFETY ("Evaluation of the Safety of Systems Distributed onto a TDMA-Based Network and Subject to Agressive Environment"). We intend to look for a safety evaluation method when the system is distributed onto a FlexRay or a TTCAN protocol. Two main complementary directions are to be investigated: the first one consists in the identification process of external fault occurrences profile and the second one in the safety evaluation method itself. This operation was accepted at the end of October 2006 and is a joint project between IECN and TRIO.

6.2.6. Computational Intelligence in Finance

Keywords: *Computational Intelligence*, *Data-Mining*, *genetic programming*, *high-frequency finance*, *market efficiency*.

Participant: Nicolas Navet.

We are interested in studying the efficiency of high-frequency markets, that is, roughly, their ability to confront in a fair manner offer and demand. The aim is twofold: on the investors point of view, it is about limiting the investment risks while on the side of the market regulation organisms, the aim is to detect sub-optimal functioning phases and possibly come up with better regulation rules. In financial engineering, techniques originating from AI are increasingly experimented, particularly techniques belonging to the emerging field of Computational Intelligence. A typical problem is how to best compose a portfolio given the investor's objectives. Literature in this field is plethoric but typically published results are unconvincing and do not give clear-cut answers regarding the efficiency of the techniques. The basic reason is that it is never distinguished between the two root causes of failures: markets that would be efficient or inefficient algorithms. We propose in [49], [27] a series of pretests, similar in the spirit to pretests in econometrics, that allow to answer to these questions with statistical confidence. The idea is to observe the behaviour of an investor acting according to an AI algorithm and introduce progressively some randomness in its behaviour (to the point where he acts fully at random, dubbed "lottery trading"). By analysing the results at each step and comparing them using statistical hypothesis tests, one can draw conclusions about the efficiency of the market and the AI technique under consideration. Preliminary experiments on 9 different markets show that, on average, markets are very efficient and our implementation of the AI technique tested (i.e. Genetic Programming) is often only marginally better than random search.

It has to be noted that despite this domain does not belong to the usual application domains of TRIO team, these works open some new perspectives in the real-time context. In particular, due to the quasi unfeasibility of a deterministic behaviour of an industrial application (in-vehicle embedded systems, remote monitoring, real time wireless sensor networks), we think that a large place has to be done for research in adaptive systems. The research started by Nicolas Navet is one of the inputs of this new research direction. For instance, by studying the traces of execution within an embedded system, one may obtain some insight into the dynamics of the system and the role of the entities involved. As an illustration, the off-line or on-line analysis of the instants at which frames are transmitted (i.e. the pattern of transmission) on an in-vehicle network may help us to identify bottlenecks and improve transmission protocols accordingly. Other inputs are the involvement of the team in (m, k)-firm approach for QoS service management or networked control systems and some works that are initiated with the MAIA team on the co-design of algorithms as developped by the Artificial Intelligence community and the monitoring on-line of their real-time properties. This last point will be studied in the context of the CRISTAL project.

7. Contracts and Grants with Industry

7.1. PSA-Peugeot Citroën contracts - Verification of embedded real-time communications

Participants: Nicolas Navet, Françoise Simonot-Lion, Liliana Cucu, Mathieu Grenier.

The aim of this collaboration (September 2006-July 2007) between TRIO and PSA Peugeot-Citroën is to provide a technique for the verification of an embedded real-time communication architecture (set of real-time frames). A further objective of this contract is to specify a method, based on the developped verification techniques for the optimal deployment of an embedded real-time set of frames (queueing handling policies, fault tolerance strategies, etc.)

8. Other Grants and Activities

8.1. Regional actions

8.1.1. QSL Operation TT_SAFETY - Evaluation of the Safety of Systems Distributed onto a TDMA-Based Network and Subject to "Agressive Environment"

Participants: René Schott, François Simonot, Françoise Simonot-Lion, YeQiong Song.

This project aims to define a safety evaluation method for systems that are distributed onto a TTP/C, a FlexRay or a TTCAN protocol. Two main complementary directions are to be investigated: the first one consists in the identification process of external fault occurrences profile and the second one in the safety evaluation method itself. This operation was accepted at the end of October 2006 and is a joint project between IECN and TRIO.

8.2. National Grants

8.2.1. ANR - PREDIT Project SCARLET

Participants: Xavier Rebeuf, Françoise Simonot-Lion.

This project proposed by the competitivity pole System@tic / Num@tec Automotive will be financed by ANR / PREDIT Program. It will start in January 2007. The purpose of this project is to define methods and services that ensure the reliability of software COTS when integrating them in a critical embedded system. In SCARLET, TRIO will be involved in tasks that aim to specify a methodology for the correct and optimal deployement of a real-time systems. A good input of this research are the works done by Mohamed Khalgui and Ricardo Santos Marques during their PhD.

8.2.2. ARA SSIA SAFE_NECS

Participants: Flavia Felicioni, Ning Jia, Françoise Simonot-Lion, YeQiong Song.

Since December 2005, TRIO participates to the ARA SSIA Safe_NECS national project under ANR grant n° ANR-05-SSIA-015. The context of this project is the design of embedded systems whose function is the fault tolerant control of continuous process and whose implementation is done onto a distributed platform (Networked Control Systems). One of the main specificities in this context arises from the autonomous aspect of these systems and, more precisely from the resource constraints (network bandwidth, processor power, etc.). In particular, the project aims to develop a "co-design" approach that integrates in a coordinated way several kinds of parameters: the characteristics modelling the Quality of Control (QoC) as given by automatic control specialists, the dependability properties required on a system and the parameters of real-time scheduling (tasks and messages). The advantage of this integrated approach is mainly the minimisation of the resources necessary for meeting the required Quality of Control. This minimisation is of great significance for autonomous embedded systems. The usual approach based on off-line schedulability analysis leads to unavoidable system over sizing. Therefore it is necessary to develop techniques enabling on-line the adaptation of scheduling parameters with respect to the state of the process to control and of the controller (Adaptive systems). The aim of the project is twofold. Firstly, we plan to concentrate the studies to the specification of the above-mentioned parameters and to identify their relations thanks to performance evaluation techniques. Secondly, we will develop feedback scheduling algorithms, graceful degradation mechanisms, diagnosis / reconfiguration techniques as well as their implementation strategies (allocation, configuration). The challenge in this project is the mastering of three levels of regulation: the control closed loop, the supervision closed loop and the feedback scheduling closed loop. This year, we proposed several techniques for the co-design of control laws and scheduling strategies.

8.3. European Projects

8.3.1. European Program NNE 2001-00825, REMPLI

Participants: Xavier Granmougin, Liping Lu, Christiano Nemer, Pathagolusu Venkat Rao, YeQiong Song.

The major goal of the European project REMPLI (Real-time Energy Management via Power Line communication and Internet) is to provide real-time data collection and equipment control for efficient energy distribution and consumption. The project has been extended until January 2007. TRIO has focused on the REMPLI power line communication protocol design and implementation. Much effort has been paid on the protocol implementation in a linux kernel. In parallel, the whole REMPLI power line communication network has been evaluated by simulation showing its satisfying performance with respect to the application requirements (e.g., power distribution and demand side management, substation automation) [47], [48]. Our contributions to the REMPLI project has led to the PhD thesis defence of Liping Lu.

8.4. International Cooperations

- PRA SI03-02 is a biannual bilateral research program co-funded by AFCRST in France and the Chinese ministry of the science and technology. It aims to develop the (m, k)-firm based QoS management in multimedia networks. The two partners are the TRIO team of the LORIA and the National Laboratory of Industrial Control Technology of Zhejiang university. This year was organised a workshop at Zhejiang University during which were summarized the main contributions of this project [54], [35], [57], [41].
- This year we started a cooperation between TRIO and the team MOSIC, University of Tunis El Manar. The purpose of this cooperation is to develop a set of methodological tools for the component-based design of critical real-time applications. Two complementary competencies are required: software engineering from MOSIC team and real-time from TRIO. The studies focus on the Function Block specifications and the standard 61499. Two PhD students and one assistant professor from University of Tunis El Manar visited the team in September and November 2006. Xavier Rebeuf and Françoise Simonot-Lion visits MOSIC team in December 2006. A Workshop was organized in December, 12 2006 at University of Tunis El Manar. It gathered both PhD students, researchers and industrial partners of MOSIC team. The proceedings will be edited by this university.
- An informal collaboration was intiated this year between the TRIO team and the Software Engineering Software Engineering Group of University of Patras (Greece); more precisely we intend to join our complementary competencies in order to gather some methods for the design of application based on Function Blocks concepts. The first result of the collaboration is to apply our techniques on a case study furnished by our partners.

8.5. Visits

In 2006 TRIO has invited the following researchers for short or long term visits

- Liliana Cucu, Post-Doctorant, Université Libre de Bruxelles, Belgium (May 2006).
- Juan Pimentel, Professor, Kettering University, Flint, USA (April-June 2006).
- Adel Khalfallah, Assistant Professor, Université de Tunis El Manar, Tunisia (November 2006).

8.6. Action for the research community

- Several members of TRIO participate actively to the GDR ASR/ASERT, action CNRS/ASFEC, GDR SOC/SIP, GDR ASR/GSP and RGE.
- Françoise Simonot-Lion is member of the expert committee of the GDR ASR/ASERT,
- Françoise Simonot-Lion is member of the CNRS “Diagnostic et Sûreté de fonctionnement” expert group,
- Jean-Pierre Thomesse is Deputy President of Institut National Polytechnique de Lorraine.
- Xavier Rebeuf is elected member of the administration board of Institut National Polytechnique de Lorraine.
- Françoise Simonot-Lion is elected member of the administration board of École Nationale Supérieure des Mines de Nancy.
- Françoise Simonot-Lion and Olivier Zendra are elected members of LORIA Laboratory Council.
- Françoise Simonot-Lion is member of the Program committee of INRIA-Lorraine
- YeQiong Song is member of operation committee of QSL action.
- Olivier Zendra is Head of Documentation Committee of INRIA-Lorraine.
- Members of TRIO are elected to CSE of sections 27 and / or 61.

- Nicolas Navet was assessor for a Phd grant of the "Fonds pour la Formation à la Recherche dans l'Industrie et dans l'Agriculture" (Belgium) and "Programme Blanc" of ANR and Françoise Simonot-Lion was expert evaluator for a Professor position at Mälardalen University (Sweden).
- Françoise Simonot-Lion was expert evaluator of a project submitted to the Université de Paris-Sud and an Eureka project.
- Olivier Zendra is the main writer for a cluster proposal "Architecture aware compiler solutions for energy issues in embedded systems" inside HiPEAC NOE.
- Françoise Simonot-Lion chairs the subcommittee "Automotive Electronic and Embedded Systems" (part of the Technical Committee on Factory Automation) of the IEEE Industrial Electronics Society.
- Françoise Simonot-Lion is Member of the Advisory Board of the "Embedded Systems Hanbook" at CRC Press.

8.7. Colloquium, seminars, invitations

- Mathieu Grenier, Joël Goossens, Nicolas Navet received the "best paper award" of the Conference RTNS'06.
- During his Delegation at the AI-ECON Research Center, Nicolas Navet was invited to give a tutorial on Genetic Programming for Financial Trading at the 5th International Conference on Computational Intelligence in Economics and Finance (CIEF'2006), October 8, 2006, Kaohsiung, Taiwan [49].
- Françoise Simonot-Lion was invited keynote speaker at the 1st IEEE Symposium on Industrial Informatics, IES'2006 in Antibes, France [55].
- Jean-Pierre Thomesse was invited keynote speaker at the workshop RTN'06, satellite of Euromicro'2006, Dresden, Germany .
- Jian Li, Xavier Rebeuf, Françoise Simonot-Lion and YeQiong Song were invited to give seminars at the Workshop of Real-Time and Embedded Systems, Zhejiang University, Hangzhou, China [41], [35], [54], [57].
- Xavier Rebeuf and Françoise Simonot-Lion were invited to give seminars at the Workshop of "Approches formelles pour la génération d'applications temps réel par intégration de composants" [37], [38], [52], [53]
- Nicolas Navet was organiser of the special session on "Computational Intelligence in Economics and Finance" at 13th International Conference on Neural Information Processing (ICONIP2006), Hong-Kong, October 4-6, 2006 and of the special session on "Computational Intelligence in Economics and Finance" at 6th International Conference on Simulated Evolution and Learning (SEAL'06), Hefei, Chine, October, 15-18, 2006.
- Nicolas Navet and Françoise Simonot-Lion are organisers of the 15th International Conference on Real-Time and Network Systems, RTNS'2007, March 29-30, 2007, Nancy, France
- Nicolas Navet was program chair with Tei-Wei Kuo (NTU Taipei) of the track on Real-Time and (Networked) Embedded Systems at the 11th IEEE International Conference on Emerging Technologies and Factory Automation (IEEE ETFA 2006), September 20-22 2006 and is the program chair with Luis Gomez (UNINOVA, Portugal) of the 2nd IEEE Symposium on Industrial Informatics, Lisbon, Portugal, July 2007; he will be vice-program chair of the 2007 IFIP International Conference on Embedded and Ubiquitous Comuting (EUC 2007).
- Jean-Pierre Thomesse was organiser of a special session at the 11th IEEE International Conference on Emerging Technologies and Factory Automation (IEEE ETFA 2006), September 20-22 2006 and at IFAC INCOM, September 2006.
- Françoise Simonot-Lion was program chair with Charles André (Université de Nice) of the IEEE International Symposium on Industrial Informatics (IEEE IES'2006), October 18-20 2006.

- Olivier Zendra was organiser and program chair of the satellite workshop ICOOOLPS at the European Conference on Object-Oriented Programming, 20th edition,July 3-7, Nantes (France)
- Jean-Pierre Thomesse is member of the steering committee of FET'07.
- Françoise Simonot-Lion is member of the International Advisory Committee of SIES'2007 and is program chair with Gianluca Cena (Politecnico Torino) of WFCS'2008
- Nicolas Navet is member of the editorial board of Journal of Embedded Computing.
- Nicolas Navet was editor of "Traité IC2 Hermès sur les systèmes temps réel", 2 volumes [9], [8],
- Nicolas Navet and Françoise Simonot-Lion are editors of the CRC Handbook on "Automotive Embedded Systems", Taylor&Francis, 2007.
- Nicolas Navet is member of program committee for the IEEE International Workshop on Models and Analysis for Automotive Systems , the International Workshop on SoC and MCSoC Design (SoC-06), the 5th International Conference on Computational Intelligence in Economics and Finance (CIEF'2006), the WIP session at 18th Euromicro Conference on Real-Time Systems (ECRTS'06), the first School on the Design of Low-Power Real-Time Systems (ECOFAC), the IEE Intelligent Environments 2006 Conference (IE 2006), the 1st International Workshop on Embedded Software Optimization (ESO 2006), the 8th Brazilian Workshop on Real-Time Systems (WTR 2006), the 3rd International Workshop on Embedded Computing (EC-06), the Workshop on Real Time Systems and Adaptive Applications (RTSAA06), the special track on Operating systems and Adaptive Applications (OSAA) at ACM Symposium on Applied Computing (ACM SAC), .
- Nicolas Navet and Françoise Simonot-Lion were program committee members of the 6th IEEE International Workshop on Factory Communication Systems (WFCS'2006), the 14th and 15th Conference on Real-Time and Network Systems (RTNS'06, RTN'07) - Poitiers - 30 et 31 Mai 2006,
- Françoise Simonot-Lion was program committee member of the 11th IEEE International Conference on Emerging Technologies and Factory Automation (ETFA 2006), third International Conference on Integrated Modeling and Analysis in Applied Control and Automation (IMAACA'07), the 5th International Workshop on Real Time Networks (RTN'06), the 25th IEEE Symposium on Reliable Distributed Systems (SRDS-25), 3rd edition of the International Workshop on Dependable Embedded Systems (WDES 2006), the Third Taiwanese-French Conference on Information Technology (TFIT'06).
- YeQiong Song belongs to the program committee of 2nd IEEE International conference on Sensor Networks and Applications (SNA 2006) and of the 11th IEEE International Conference on Emerging Technologies and Factory Automation (ETFA 2006)
- Nicolas Navet was discussant at the 4th National Taiwan University International Conference on Economics, Finance and Accounting, Taipei, Taiwan, April 13th 2007
- The permanent members of TRIO team are reviewers for several international Conferences and Workshops and for several journals TSI (Nicolas Navet, Xavier Rebeuf, Jean-Pierre Thomesse, Olivier Zendra), JESA (Françoise Simonot-Lion), IEEE Transactions on Industrial Informatics (Nicolas Navet, Françoise Simonot-Lion), IEEE Transactions on Industrial Informatics (Nicolas Navet, Françoise Simonot-Lion, Jean-Pierre Thomesse), IEE Proc. Communications (Françoise Simonot-Lion), Eurasip Journal (Françoise Simonot-Lion), Computer Communications (YeQiong Song), IEEE transaction on Vehicular Technology (Nicolas Navet), The Computer Journal (Nicolas Navet), IEEE Communication Magazine (YeQiong Song) and Computer Communications (YeQiong Song), Journal IES IEEE (Jean-Pierre Thomesse).

8.8. Teaching activities

The permanent members of TRIO are teaching in INPL and Université Henri Poincaré-Nancy 1 (engineer schools and masters). During his Delegation at the AI-ECON Research Center, Nicolas Navet was invited to give lectures at Department of Economy, Soochow University, Taipei, at National Taiwan University, Department of Computer Science and Information Engineering, Taipei and at the National Changhua University of Education, Departement of Business Administration, Taiwan.

9. Bibliography

Major publications by the team in recent years

[1] B. GAUJAL, N. NAVET, C. WALSH. *Shortest Path Algorithms for Real-Time Scheduling of FIFO tasks with Minimal Energy Use*, in "ACM Transactions on Embedded Computing Systems", Dec 2004.

[2] A. KOUBÂA, Y.-Q. SONG. *Graceful Degradation of Loss Tolerant QoS using (m,k)-Firm Constraints in Guaranteed Rate Networks*, in "Journal of Computer Communications", 2005.

[3] N. NAVET, F. SIMONOT-LION. *Fault Tolerant Services For Safe In-Car Embedded Systems*, in "The Embedded Systems Handbook", R. ZURAWSKI (editor). , CRC Press, Dec 2005.

[4] N. NAVET, Y.-Q. SONG, F. SIMONOT. *Worst-Case Deadline Failure Probability in Real-Time Applications Distributed over CAN (Controller Area Network)*, in "Journal of Systems Architecture - The EUROMICRO Journal", vol. 46, n^{o} 7, Apr 2000, p. 607-617.

[5] N. NAVET, Y. SONG, F. SIMONOT-LION, C. WILWERT. *Trends in Automotive Communication Systems*, in "Proceedings of the IEEE", vol. 93, n^{o} 6, Jun 2005, p. 1204-1223.

[6] J.-P. THOMESSE. *The WorldFIP Fieldbus*, in "Industrial Information Technology Handbook", R. ZURAWSKI (editor). , Industrial Electronics Series, CRC Press, Dec 2004.

[7] C. WILWERT, N. NAVET, Y.-Q. SONG, F. SIMONOT-LION. *Design of Automotive X-by-Wire System*, in "The Industrial Communication Technology Handbook", R. ZURAWSKI (editor). , CRC Press, Dec 2005.

Year Publications

Books and Monographs

[8] N. NAVET. , N. NAVET (editor). *Systèmes temps réel 1 - Techniques de description et de vérification*, Hermes - Lavoisier, 2006, http://hal.inria.fr/inria-00105904/en/.

[9] N. NAVET. , N. NAVET (editor). *Systèmes temps réel 2 - Ordonnancement, réseaux et qualité de service*, Traité IC2, Information - Commande - Communication, Hermès - Lavoisier, 2006, http://hal.inria.fr/inria-00105907/en/.

Doctoral dissertations and Habilitation theses

[10] L. LU. *Performances et qualité de service dans les réseaux courants porteurs pour des systèmes de distribution moyenne tension et basse tension*, Thèse d'université INPL, Nancy, 2006.

[11] R. SANTOS-MARQUES. *Méthodologie de développement des services de communication temps réel d'un intergiciel embarqué dans l'automobile*, Thèse d'université INPL, Nancy, 2006.

Articles in refereed journals and book chapters

[12] T. BANGEMANN, X. REBEUF, D. REBOUL, A. SCHULZE, J. SZYMANSKI, J.-P. THOMESSE, M. THRON, N. ZERHOUNI. *PROTEUS - Creating Distributed Maintenance Systems through an Integration Platform*, in "Computers in Industry Journal", 2006, http://hal.inria.fr/inria-00000827/en/.

[13] B. CHAUVIÈRE, D. GENIET. *Une approche markovienne pour l'étude de systèmes temps-réel à contraintes strictes*, in "Technique et Science Informatiques (TSI)", 2006, http://hal.inria.fr/inria-00115120/en/.

[14] B. CHAUVIÈRE, D. GENIET, R. SCHOTT. *A New Method for Determining Fixed Priority Configurations for Real-Time Systems on Multiprocessor Targets*, in "Real-Time Systems", 2006, http://hal.inria.fr/inria-00115123/en/.

[15] M. KHALGUI, X. REBEUF, F. SIMONOT-LION. *Postworkshop Proceedings of the 3rd Workshop on Object-oriented Modeling of Embedded Real-Time Systems*, H. GIESE, O. NIGGEMANN (editors). , chap. A static scheduling generator for the deployment of a component based application, Heinz Nixdorf Institut, 2006, http://hal.inria.fr/inria-00113450/en/.

[16] J. LI, Y.-Q. SONG, F. SIMONOT-LION. *Providing Real-time Applications with Graceful Degradation of QoS and Fault Tolerance According to (m,k)-firm Model*, in "IEEE Transactions on Industrial Informatics", vol. 2, n^{o} 2, 2006, p. 112-119, http://hal.inria.fr/inria-00113851/en/.

[17] N. NAVET, B. GAUJAL. *Systèmes temps réel 2 - Ordonnancement, réseaux et qualité de service*, N. NAVET (editor). , Traité IC2, Information - Commande - Communication, chap. Ordonnancement temps réel et minimisation de la consommation d'énergie, Hermès - Lavoisier, 2006, http://hal.inria.fr/inria-00105909/en/.

[18] S. RISHI, N. NAVET. *Frame packing algorithms for automotive applications*, in "Journal of Embedded Computing", vol. 2, 2006, p. 93-102, http://hal.inria.fr/inria-00105925/en/.

[19] R. SANTOS-MARQUES, F. SIMONOT-LION, N. NAVET. *Object-oriented Modeliing of Embedded Real-Time Systems 3*, H. GIESE, O. NIGGEMANN (editors). , HNI-Verlagsschriftenreihe, Postworkshop Proceedings of the 3rd Workshop on Object-Oriented Modeling of Embedded Real-Time Systems, chap. Development of an in-vehicle middleware, Heinz Nixdorf Institut, 2006, http://hal.inria.fr/inria-00113588/en/.

[20] F. SIMONOT-LION, N. NAVET. *Systèmes temps réel 2 - Ordonnancement, réseaux et qualité de service*, N. NAVET (editor). , Traité IC2, Information - Commande - Communication, chap. Les réseaux temps réel embarqués dans les véhicules, Hermès - Lavoisier, 2006, http://hal.inria.fr/inria-00105924/en/.

[21] Y.-Q. SONG, A. KOUBÂA, J. LI. *Systèmes temps réel 2*, N. NAVET (editor). , chap. Qualité de service temps réel selon le modèle (m,k)-firm, Hermès - Lavoisier, 2006, http://hal.inria.fr/inria-00114397/en/.

[22] J.-P. THOMESSE. *Les techniques de l'ingénieur*, chap. Les caractéristisques temporelles des réseaux industriels, Les techniques de l'ingénieur, 2006, http://hal.inria.fr/inria-00114187/en/.

[23] J.-P. THOMESSE. *Systèmes temps réel - Volume 2 Ordonnancement, réseaux, qualité de service*, N. NAVET (editor). , chap. L'accès au médium : Concepts de base des protocoles MAC temps réel, Hermès, 2006, http://hal.inria.fr/inria-00113809/en/.

[24] O. ZENDRA. *Compilation et faible consommation*, in "Techniques et Sciences Informatiques", A paraitre, 2006, http://hal.inria.fr/inria-00113532/en/.

Publications in Conferences and Workshops

[25] N. BOUGHANMI, Y.-Q. SONG. *A New routing metric for satisfying both energy and delay constraints in wireless sensor networks*, in "2nd International Conference on Sensor Networks and Applications (SNA06), 19/10/2006, Beijing/Chine", 2006, http://hal.inria.fr/inria-00105886/en/.

[26] J. CHANLIAU, P. Y. DURAND, L. VEGA, J.-P. THOMESSE, F. CHARPILLET, M. KESSLER. *PD telemedicine by DIATELIC : Preliminary results of the largest french pilot study*, in "26th Annual Conference on Dialysis, 2006, San Francisco", 2006, http://hal.inria.fr/inria-00114620/en/.

[27] S.-H. CHEN, N. NAVET. *Pretests for genetic-programming evolved trading programs: "zero-intelligence" strategies and lottery trading*, in "The 13th International Conference on Neural Information Processing, 10/2006, Hong-Kong", in: Lecture Notes in Computer Science, Neural Information Processing, n^{o} 4234/2006, Springer Berlin / Heidelberg, 2006, p. 450-460, http://hal.inria.fr/inria-00105926/en/.

[28] F. FELICIONI, N. JIA, Y.-Q. SONG, F. SIMONOT-LION. *Impact of a (m,k)-firm Data Dropouts Policy on the Quality of Control*, in "6th IEEE International Workshop on Factory Communication Systems, 28/06/2006, Torino, Italy", Factory Communication Systems, 2006 IEEE International Workshop on, IEEE, 2006, p. 353-359, http://hal.inria.fr/inria-00113827/en/.

[29] M. GRENIER, J. GOOSSENS, N. NAVET. *Near-Optimal Fixed Priority Preemptive Scheduling of Offset Free Systems*, in "14th International Conference on Real-Time and Networks Systems (RTNS'06), 30/05/2006, Poitiers/France", 2006, p. 35–42, http://hal.inria.fr/inria-00083863/en/.

[30] M. GRENIER, N. NAVET. *Improvements in the configuration of Posix 1003.1b scheduling*, in "Submitted to RTNS'2007, 2007, Nancy, France", 2006, http://hal.inria.fr/inria-00113954/en/.

[31] M. GRENIER, N. NAVET. *Optimal Priority and Scheduling policy Assignment on Posix 1003.1b compliant systems*, in "Submitted to IEEE RTAS'2007, 2007, Bellevue, WA, United States", 2006, http://hal.inria.fr/inria-00113953/en/.

[32] N. JIA, Y.-Q. SONG, F. SIMONOT-LION. *Optimal LQ-controller Design and Data Drop Distribution under (m,k)-firm constraint*, in "workshop on advanced control and diagnosis 2006, 17/11/2006, nancy, france", 2006, http://hal.inria.fr/inria-00113830/en/.

[33] M. KHALGUI, X. REBEUF, F. SIMONOT-LION. *A heuristic based method for automatic deployment of distributed component based applications*, in "IEEE Symposium on Industrial Embedded Systems - IES'2006, 18/10/2006, Nice, France", 2006, http://hal.inria.fr/inria-00113471/en/.

[34] M. KHALGUI, X. REBEUF, F. SIMONOT-LION. *A hybrid scheduling approach of centralized component based control applications*, in "6th IEEE International Workshop on Factory Communication Systems, 28/06/2006, Turin, Italie", IEEE, 2006, p. 83-86, http://hal.inria.fr/inria-00113440/en/.

[35] M. KHALGUI, X. REBEUF, F. SIMONOT-LION. *A schedulability analysis of an IEC 61499 control application*, in "Workshop of Real-Time and Embedded Systems, 13/03/2006, hang zhou, China", 2006, http://hal.inria.fr/inria-00114315/en/.

[36] M. KHALGUI, X. REBEUF, F. SIMONOT-LION. *Component based deployment of industrial control systems: a hybrid scheduling approach*, in "11th IEEE International Conference on emerging Technologies and Factory Automation, 20/09/2006, Prague, République Tchèque", 2006, http://hal.inria.fr/inria-00113460/en/.

[37] M. KHALGUI, X. REBEUF, F. SIMONOT-LION. *Déploiement d'un réseau de blocs fonctionnels (Function Blocks - IEC 61 499) : une approche hybride d'ordonnancement*, in "Approches formelles pour la génération d'applications temps réel par intégration de composants, 12/12/2006, Tunis, Tunisia", Université Tunis El Manar, 2006, http://hal.inria.fr/inria-00114332/en/.

[38] M. KHALGUI, X. REBEUF, F. ZAMPOGNARO. *Le concept de contrat OPC-XML adaptatif au trafic réseau dans un objectif temps réel.*, in "Workshop « Approches formelles pour la génération d'applications temps réel par intégration de composants », 12/12/2006, Tunis, Tunisia", Université Tunis El Manar, 2006, http://hal.inria.fr/inria-00114334/en/.

[39] M. KHALGUI, F. SIMONOT-LION, X. REBEUF. *A degraded scheduling generation of a component based application*, in "12th IFAC Symposium on Information Control Problems in Manufacturing, 17/05/2006, Saint Etienne, France", 2006, http://hal.inria.fr/inria-00113436/en/.

[40] A. KOUBÂA, M. ALVES, B. NEFZI, Y.-Q. SONG. *Improving the IEEE 802.15.4 Slotted CSMA/CA MAC for Time-Critical Events in Wireless Sensor Networks*, in "Proceedings of the Workshop of Real-Time Networks (RTN 2006), Satellite Workshop to ECRTS 2006, 05/07/2006, Dresden, Germany", Jean-Dominique Decotignie, 2006, http://hal.inria.fr/inria-00114519/en/.

[41] J. LI. *A Graceful QoS Degradation Scheme for Loss Tolerant Real-time Applications*, in "Workshop on Real-Time and Embedded Systems, 03/2006, Workshop on Real-Time and Embedded Systems", 2006, http://hal.inria.fr/inria-00115122/en/.

[42] J. LI, Y. SONG. *R-(m,k)-firm : A novel QoS Scheme for Real-time Flow Guarantee in Networks*, in "14TH International Conference on Real-Time and Network Systems, RTNS'06, 05/2006, Poitiers, France", 2006, http://hal.inria.fr/inria-00108417/en/.

[43] J. LI, Y.-Q. SONG. *A Graceful QoS Degradation Scheme for Loss Tolerant Real-time Applications*, in "Third Taiwanese-French Conference on Information Technology, 28/03/2006, Nancy/France", 2006, http://hal.inria.fr/inria-00114860/en/.

[44] J. LI, Y.-Q. SONG. *DLB: A Novel Real-time QoS Control Mechanism for Multimedia Transmission*, in "20th International Conference on Advanced Information Networking and Applications (AINA06), 04/2006, Vienna, Austria", 2006, http://hal.inria.fr/inria-00108409/en/.

[45] J. LI, Y.-Q. SONG. *Relaxed (m,k)-firm Constraint to Improve Real-time Streams Admission Rate under Non Pre-emptive Fixed Priority Scheduling*, in "11th IEEE International Conference on Emerging Technologies and Factory Automation, ETFA'06,, 09/2006, Prague, Czech Public", 2006, http://hal.inria.fr/inria-00108422/en/.

[46] Y. LI, Z. WANG, Y.-Q. SONG. *Wireless Sensor Network Design For Wildfire Monitoring*, in "6th World Congress on Intelligent Control and Automation (WCICA2006), 21/06/2006, Dalian (China)", IEEE, IEEE, 2006, http://hal.inria.fr/inria-00114523/en/.

[47] L. LU, G. LI, Y. SONG. *Powerline Communication System for Monitoring and Supervision of Feeder Equipments for MV Substation Automation*, in "IEEE Symposium on Industrial Embedded Systems, 10/2006, Antibes Juan-Les-Pins, France", 2006, http://hal.inria.fr/inria-00113787/en/.

[48] L. LU, J. ZHOU, J. HU, G. LI, Y. SONG. *Embedded Powerline Communication in Large Scale Distribution Automation and Demand Side Management System*, in "The 2nd IEEE/ASME International Conference on Mechatronic and Embedded Systems and Applications, 13/08/2006, Beijing, China", 2006, http://hal.inria.fr/inria-00113782/en/.

[49] N. NAVET. *Genetic Programming for Financial Trading : a Tutorial*, in "5th international conference on Computational Intelligence in Economics and Finance (CIEF'2006), 08/10/2006, Kaohsiung, Taiwan", 2006, http://hal.inria.fr/inria-00113706/en/.

[50] V. RAO, G. SINGHAL, N. NAVET, A. KUMART, G. VISWESWARAN. *Battery Aware Dynamic Scheduling for Periodic Task Graphs*, in "14th International Workshop on Parallel and Distributed Real-Time Systems (WPDRTS 2006), 04/2006, Island of Rhodes/Greece", 2006, http://hal.inria.fr/inria-00000463/en/.

[51] R. SANTOS-MARQUES, F. SIMONOT-LION, N. NAVET. *Optimal configuration of an in-vehicle embedded middleware*, in "Third Taiwanese-French Conference on Information Technology (TFIT 2006), 03/2006, Nancy, France", 2006, http://hal.inria.fr/inria-00105928/en/.

[52] F. SIMONOT-LION, R. SANTOS-MARQUES, N. NAVET. *Configuration optimale d'un intergiciel embarqué dans l'automobile*, in "Workshop « Approches formelles pour la génération d'applications temps réel par intégration de composants », 12/12/2006, Tunis", Université de Tunis El Manar, 2006, http://hal.inria.fr/inria-00114335/en/.

[53] F. SIMONOT-LION. *La conception de systèmes sûrs embarqués dans l'automobile : du composant au système*, in "Approches formelles pour la génération d'applications temps réel par intégration de composants, 12/12/2006, Tunis", Université de Tunis El Manar, 2006, http://hal.inria.fr/inria-00115187/en/.

[54] F. SIMONOT-LION. *Safety Evaluation of Critical Applications Distributed on TDMA-Based Networks*, in "Workshop of Real-Time and Embedded System, 13/03/2006, Hangzhou, China", 2006, http://hal.inria.fr/inria-00114313/en/.

[55] F. SIMONOT-LION. *The design of safe automotive electronic systems: some problems, solutions and open issues*, in "IEEE Symposium on Industrial Embedded Systems, IES'2006, 18/10/2006, Antibes, Juan-les-Pins", 2006, http://hal.inria.fr/inria-00114262/en/.

[56] F. SIMONOT-LION, F. SIMONOT, Y.-Q. SONG. *Safety Evaluation of Critical Applications Distributed on TDMA-Based Networks*, in "Third Taiwanese-French Conference on Information Technology , TFIT'2006, 28/03/2006, Nancy/France", 2006, http://hal.inria.fr/inria-00114266/en/.

[57] Y.-Q. SONG. *Guaranteeing real-time QoS according to (m,k)-firm model*, in "Workshop of Real-Time and Embedded Systems, 13/03/2006, Zhejiang University, Hangzhou (Chine)", Zhejiang University and LORIA, 2006, http://hal.inria.fr/inria-00114959/en/.

[58] J.-P. THOMESSE, D. REBOUL. *La Maintenance intégrée : Le projet PROTEUS*, in "Colloque EMM 4ème rencontres Européennes de Mécatronique, 18/05/2006, Saint Etienne", 2006, http://hal.inria.fr/inria-00114364/en/.

[59] O. ZENDRA. *Memory and compiler optimizations for low-power and -energy.*, in "1st ECOOP Workshop on Implementation, Compilation, Optimization of Object-Oriented Languages, Programs and Systems (ICOOOLPS'2006)., 07/2006, Nantes/FRANCE", 2006, http://hal.inria.fr/inria-00104146/en/.

Internal Reports

[60] D. BERTRAND. *Réalisation d'une plateforme d'évaluation d'optimisations*, Stage, 2006, http://hal.inria.fr/inria-00115040/en/.

[61] N. JIA, F. SIMONOT-LION, Y.-Q. SONG. *L'ordonnancement d'un ensemble de tâches de contrôle avec le modèle (m,k)*, Rapport de recherche, 2006, http://hal.inria.fr/inria-00114859/en/.

[62] N. JIA, Y.-Q. SONG, F. SIMONOT-LION. *Overload Management in Real-time Control Applications Using (m,k)-firm Constraint*, Rapport de recherche, 2006, http://hal.inria.fr/inria-00114857/en/.

[63] J. PIMENTEL. *Problem C: Calculation of Pmerr for FlexCAN*, Rapport de recherche, 2006, http://hal.inria.fr/inria-00120905/en/.

References in notes

[64] G. BERNAT, A. BURNS. *Weakly-Hard Real-Time Systems*, in "IEEE Transactions on Computers", vol. 50, n^{o} 4, April 2001, p. 308-321.

[65] A. CERVIN. *Towards the integration of control and real-time scheduling design*, Ph. D. Thesis, Lund University, Lund, Sweden, 2000.

[66] M. HAMDAOUI, P. RAMANATHAN. *A dynamic priority assignment technique for streams with (m, k)-firm deadlines*, in "IEEE Transactions on Computers", vol. 44, December 1995, p. 1443-1451.

[67] N. NAVET. *Evaluation de performances temporelles et optimisation de l'ordonnancement de tâches et de messages*, Thèse d'université INPL, Nancy, 1999.

[68] K. RAMAMRITHAM. *Where do time constraints come from and where do they go?*, in "International Journal of Database Management", vol. 7, n^{o} 2, 1996.

[69] P. RAMANATHAN. *Overload management in Real-Time control applications using (m, k)-firm guarantee*, in "IEEE Transactions on Parallel and Distributed Systems", vol. 10, n^{o} 6, June 1999, p. 549-559.

[70] F. SIMONOT, F. SIMONOT-LION, Y. SONG. *Dependability Evaluation of Real-Time Applications Distributed on TDMA-Based Networks*, in "6th IFAC International Conference on Fieldbus Systems and their Applications - FeT'2005, Puebla, Mexico", IFAC, November 2005.

[71] J. P. THOMESSE. *Diatélic, un système de télémédecine pour la prévention des aggravations de santé en dialyse péritonéale*, in "Colloque "Histoire de la médecine" , Musée de la Mine, Petite Rosselle, France", Oct 2003.