RESEARCH CENTRE

Grenoble - Rhône-Alpes

IN PARTNERSHIP WITH:

Institut polytechnique de Grenoble, Université de Grenoble Alpes

2020

ACTIVITY REPORT

Project-Team CTRL-A

Control for safe Autonomic computing systems

IN COLLABORATION WITH: Laboratoire d'Informatique de Grenoble (LIG)

DOMAIN

Networks, Systems and Services, Distributed Computing

THEME

Distributed Systems and middleware

Contents

Project-Team CTRL-A

Creation of the Team: 2014 January 01, updated into Project-Team: 2017 June 01

Keywords

Computer sciences and digital sciences

A1.1.2. – Hardware accelerators (GPGPU, FPGA, etc.)

A1.1.4. – High performance computing

A1.1.5. – Exascale

A1.1.9. – Fault tolerant systems

A1.1.10. – Reconfigurable architectures

A1.3. – Distributed Systems

A1.3.5. – Cloud

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A2.6.4. – Ressource management

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Other research topics and application domains

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B6.1.1. – Software engineering

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B6.6. – Embedded systems

B8.1. – Smart building/home

1 Team members, visitors, external collaborators

Research Scientist

- Eric Rutten [Team leader, Inria, Researcher, HDR]

Faculty Members

- Raphaël Bleuse [Univ Grenoble Alpes, Associate Professor]
- Gwenaël Delaval [Univ Grenoble Alpes, Associate Professor, (80%)]
- Stéphane Mocanu [Institut polytechnique de Grenoble, Associate Professor, HDR]

Post-Doctoral Fellow

- Sophie Cerf [Inria, from Mar 2020]

PhD Students

- Neil Ayeb [Orange Labs]
- Quentin Guilloteau [Univ Grenoble Alpes, from Oct 2020]
- Estelle Hotellier [DCNS Group, from Nov 2020]

Technical Staff

- Mahyar Tourchi Moghaddam [Inria, Engineer, from Feb 2020]

Interns and Apprentices

- Manal Benaissa [Univ Grenoble Alpes, from Feb 2020 until Jun 2020]
- Quentin Guilloteau [Institut polytechnique de Grenoble, from Feb 2020 until Jun 2020]
- Ibrahim Ibrahim [Inria, from Feb 2020 until Jul 2020]
- Fabien Lefevre [Univ Grenoble Alpes, until Sep 2020]
- Lucie Muller [Inria, until Aug 2020]
- Gaetan Sorin [Univ Grenoble Alpes, until Sep 2020]

Administrative Assistant

- Imma Presseguer [Inria]

External Collaborator

- Bogdan Robu [Univ Grenoble Alpes]

2 Overall objectives

Objective: control support for autonomic computing

CTRL-A is motivated by today's context where computing systems, large (data centers) or small (embedded), are more and more required to be adaptive to the dynamical fluctuations of their environments and workloads, evolutions of their computing infrastructures (shared, or subject to faults), or changes in application functionalities. Their administration, traditionally managed by human system administrators, needs to be automated in order to be efficient, safe and responsive. Autonomic Computing is the approach that emerged in the early 2000's in distributed systems to answer that challenge, in the form of self-administration control loops. They address objectives like self-configuration (e.g. in service-oriented systems), self-optimization (resource consumption management e.g., energy), self-healing (fault-tolerance, resilience), self-protection (security and privacy).

Therefore, there is a pressing and increasing demand for methods and tools to design controllers for self-adaptive computing systems, that ensure quality and safety of the behavior of the controlled system. The critical importance of the quality of control on performance and safety in automated systems, in computing as elsewhere, calls for a departure from traditional approaches relying on *ad hoc* techniques, often empirical, unsafe and application-specific solutions.

The main objective of the CTRL-A project-team is to develop a novel framework for model-based design of controllers in Autonomic Computing. We want to contribute generic Software Engineering methods and tools for developers to design appropriate controllers for their particular reconfigurable architectures, software or hardware, and integrate them at middleware level.

We want to improve concrete usability of techniques from Control Theory, particularly Discrete Event Systems, by specialists of concrete systems (rather than formal models) [7], and to provide tool support for our methods in the form of specification languages and compilers.

We address policies for self-configuration, self-optimization (resource management, low power), self-healing (fault tolerance) and self-protection (security).

3 Research program

Modeling and control techniques for autonomic computing

The main objective of CTRL-A translates into a number of scientific challenges, the most important of these are:

- (i) programming language support, on the two facets of model-oriented languages, based on automata [5] , and of domain specific languages, following e.g., a component-based approach [4, 1] or related to rule-based or HMI languages ;
- (ii) design methods for reconfiguration controller design in computing systems, proposing generic systems architectures and models based on transition systems [3], classical continuous control or controlled stochastic systems.

  We adopt a strategy of constant experimental identification of needs and validation of proposals, in application domains like middleware platforms for Cloud systems [3] , multi-core HPC architectures [10] , Dynamic Partial Reconfiguration in FPGA-based hardware [2] and the IoT and smart environments [8] .

Achieving the goals of CTRL-A requires multidisciplinarity and expertise from several domains . The expertise in Autonomic Computing and programming languages is covered internally by members of the Ctrl-A team. On the side of theoretical aspects of control, we have active external collaborations with researchers specialized in Control Theory, in the domain of Discrete Event Systems as well as in classical, continuous control.

Additionally, an important requirement for our research to have impact is to have access to concrete, real-world computing systems requiring reconfiguration control. We target autonomic computing at different scales, in embedded systems or in cloud infrastructures, which are traditionally different domains.

This is addressed by external collaborations, with experts in either hardware or software platforms, who are generally missing our competences on model-based control of reconfigurations.

4 Application domains

Self-adaptive and reconfigurable computing systems in HPC and the IoT

We are attacking the problem of designing well-regulated and efficient self-adaptive computing systems by the development of novel strategies for systems management.

The kind of systems we typically target involve relatively coarse grained computation tasks (e.g. image processing or HPC tasks, components or services), assembled in workflows, application dependency graphs, or composites. At that level, there can be parallel and conditional branches, as well as choices that can be made between alternative branches, corresponding to different ways to perform that part of the application. Such tasks can be achieved following a choice of implementations or versions, such as in service oriented approaches. Each implementation has its own characteristics and requirements, e.g., w.r.t. resources consumed and QoS offered. The systems execution infrastructures present heterogeneity, with different computing processors, a variety of peripheral devices (e.g., I/O, video port, accelerators), and different means of communications. This hardware or middleware level also presents adaptation potential e.g., in varying quantities of resources or sleep and stand-by modes.

The kinds of control problems encountered in these adaptive systems concern the navigation in the configurations space defined by choice points at the levels of applications, tasks, and architecture. Upon events or conditions triggering reconfiguration and adaptation, the controller has to choose a next configuration where, on the one hand, all consistency constraints are satisfied w.r.t. dependencies and resources requirements. On the other hand, it has to apply a policy or strategy deciding between correct configurations which one to chose e.g. by optimizing one or more criteria, or by insuring reachability of some later configuration (goal or fallback). This targeted class of computing systems we consider is mid-sized, in the sense that the combinatorial complexity is large enough for manual solving to be impossible, while remaining within the range where supervisory control techniques are tractable. The pace of control is more sporadic, and slower than the instruction-level computation performance within the coarse-grained tasks.

The objectives of CTRL-A will be achieved and evaluated in both of our main application domains, thereby exhibiting their similarities from the point of view of reconfiguration control. A first application domain is High Performance Computing. In this area, we currently focus especially on the management of Dynamic Partial Reconfiguration in FPGA based hardware, at the level of middleware . Here the particular application we consider is, as in our ANR project HPeC starting end of 2015, video image flow processing for smart cameras implemented on DPR FPGASs themselves embedded in drones .

A second general application domain to confront our models is the Internet of Things (IoT), more specifically self-adaptive middleware platforms for Smart Environments, or Industry 4.0 related topics, like SCADA. We focus on providing coordination components and controllers of software components and services, or rule-based middleware platforms. The adaptation problems concern both the functional aspects of the applications in a smart building, and the middleware support deployment and reconfiguration issues. We are considering perspectives concerning self-protection and security.

5 Social and environmental responsibility

5.1 Footprint of research activities

In the year 2020, the travels of the team has been drastically reduced, obviously due to sanitary restrictions.

Our activities involve running experiments on large computing infrastructures e.g., using Grid 5000, where we spend approx. 30 k hours of computing.

5.2 Impact of research results

We have research activities w.r.t. energy efficiency in computing systems, at the levels of nodes (RAPL) as well as at the higher level of grids (CiGri), which are contributing to a better mastered energy consumption in computing.

On the different aspect of sobriety concerning data and privacy, we also are interested in topics of locality of data in Fog/Edge architectures,in order to avoid, useless spreading of confidential data.

On a longer term, we are having reflexions on how to orient our research towards topics explicitely targeting environmental as well social impacts.

6 Highlights of the year

We are co-chairing, with the TIMA laboratory and CEA in Grenoble, the organization committee of the FETCH'21 summer school (École d'hiver Francophone sur les Technologies de Conception des Systèmes Embarqués Hétérogènes), postponed to 2022 due to sanitary restrictions. (https://sites.google.com/view/fetch2021/)

7 New software and platforms

7.1 New software

7.1.1 Heptagon

Keywords: Compilers, Synchronous Language, Controller synthesis

Functional Description: Heptagon is an experimental language for the implementation of embedded real-time reactive systems. It is developed inside the Synchronics large-scale initiative, in collaboration with Inria Rhones-Alpes. It is essentially a subset of Lucid Synchrone, without type inference, type polymorphism and higher-order. It is thus a Lustre-like language extended with hierchical automata in a form very close to SCADE 6. The intention for making this new language and compiler is to develop new aggressive optimization techniques for sequential C code and compilation methods for generating parallel code for different platforms. This explains much of the simplifications we have made in order to ease the development of compilation techniques.

The current version of the compiler includes the following features: - Inclusion of discrete controller synthesis within the compilation: the language is equipped with a behavioral contract mechanisms, where assumptions can be described, as well as an "enforce" property part. The semantics of this latter is that the property should be enforced by controlling the behaviour of the node equipped with the contract. This property will be enforced by an automatically built controller, which will act on free controllable variables given by the programmer. This extension has been named BZR in previous works. - Expression and compilation of array values with modular memory optimization. The language allows the expression and operations on arrays (access, modification, iterators). With the use of location annotations, the programmer can avoid unnecessary array copies.

URL: http://heptagon.gforge.inria.fr

Contacts: Marc Pouzet, Adrien Guatto, Gwenaël Delaval

Participants: Adrien Guatto, Brice Gelineau, Cédric Pasteur, Eric Rutten, Gwenaël Delaval, Léonard Gérard, Marc Pouzet

Partners: UGA, ENS Paris, Inria, LIG

8 New results

8.1 Design support for Control in Autonomic Computing

8.1.1 Discrete Control and reactive languages

Participants Gwenaël Delaval, Lucie Muller, Eric Rutten.

Our work in reactive programming for autonomic computing systems is focused on the specification and compilation of declarative control objectives, under the form of contracts, enforced upon classical mode automata as defined in synchronous languages. The compilation involves a phase of Discrete Controller Synthesis, integrating the tool ReaX, in order to obtain an imperative executable code. The programming language Heptagon / BZR (see Section 7.1.1) integrates our research results [5].

Ongoing topics are on :

- abstraction methods for compilation using discrete controller synthesis (needed for example, in order to program the controllers for systems where the useful data for control can be of arbitrary types (integer, real, ...), or also for systems which are naturally distributed, and require a decentralized controller).
- compilation and diagnosis for discrete controller synthesis. The compilation involving a phase of controller synthesis can fail to find a solution, if the problem is overconstrained. The compiler does notify so to the programmer, but the latter would need a diagnosis in order to understand where and how to debug the program. Such diagnosis is made especially difficult by the declarative nature of the synthesis.

Recent work concerns a methodology for the evaluation of controllers. We are considering that Discrete Controller Synthesis produces results that are correct by construction w.r.t. the formal specification, but in practice there remains to evaluate the obtained controller quantitatively, to check e.g., whether it is not overconstrained, and effectively producing the expected impact on the overall system behavior. We consider our work on self-protection (see Section 8.2.2) as a use case, evaluating the improvement of resilience of a system in the presence of attacks.

This was the object of the M2 internship of Lucie Muller [21].

8.1.2 Domain-specific languages

Participants Gwenaël Delaval, Eric Rutten.

Our work in Domain-specific languages (DSLs) is founded on our work in component-based programming as examplified by e.g., FRACTAL for autonomic computing systems. We consider the problem of specifying the control of components assembly reconfiguration, with an approach based on the integration within such a component-based framework of a reactive language as in Section 8.1.1 [4]. In recent work, we proposed an extension of a classical Software Architecture Description Languages (ADL) with Ctrl-F, DSL for the specification of dynamic reconfiguration behavior in a [1]. Based on this experience, we also proposed a DSL called Ctrl-DPR [6], allowing designers to easily generate Autonomic Managers for DPR FPGA systems.

Ongoing work involves considering a more general DSL, wich will gather the patterns emerging from the diversity of our experiences in Section 8.2, in terms of modelling separately resources and infrastructure, and tasks and their implementations. Also of interest is the separation of concerns between the description of the self-adaptation and configurations space at the different levels of applications or functionality on the one side, and infrastructure and resources on the other side. Each dimension can have its own dynamics, independently of the other, and can be designed separately, while both have to be coordinated.

8.1.3 Control and Machine Learning

Participants Sophie Cerf, Eric Rutten.

In the framework of our cooperation with Nokia Bell-labs (See Section 9.1), and the Dyonisos team at Inria Rennes, we are considering the management of Software Defined Networks (SDN). The main approach, considering AI / Machine Learning, is developed at Inria Rennes. An ongoing topic is to consider that these reinforcement learning based approaches involve questions of trust and explanability. In our team we propose to address them by considering their composition with controllers based on Control Theory, in order to maintain guarantees on the behaviors of the managed system. As a result we performed a survey of the state of the art in interactions between RL and control, some of them classic, ohers less explored. Perspectives involve the odentification of use-cases from our partners in the Inria/Nokia porject.

8.2 Design methods for reconfiguration controller design in computing systems

We apply different control techniques, to a range of infrastructures of different natures, but sharing a transversal problem of design of the control of their reconfigurations. From this very diversity of validations and experiences, we draw a synthesis of the whole approach, towards a general view of Feedback Control as MAPE-K loop in Autonomic Computing [7, 9].

8.2.1 Self-adaptative distributed systems and HPC

Complex Autonomic Computing Systems, as found typically in distributed systems, must involve multiple management loops, addressing different subproblems of the general management, and can be using different modeling, decision and control approaches (discrete [3], continuous, stochastic, machine-learning based, ...) They are generally addressing deployment and allocation of computations on resources w.r.t. QoS, load, faults, ... but following different, complementary approaches. The similarities and recurring patterns are considered as in Section 8.1.2 . Their execution needs to be distributed w.r.t. different characteristics such as latency (as in Fog and Edge Computing) or load. We are studying Software Architectures to address the design of such complex systems.

Self-adaptation of micro-services in Fog/Edge and Cloud computing

Participants Eric Rutten.

Fog systems are a recent trend of distributed computing having vastly ubiquitous architectures and distinct requirements making their design difficult and complex. Fog computing is based on leveraging both resource-scarce computing nodes around the Edge to perform latency and delay sensitive tasks and Cloud servers for the more intensive computation.

In this work, we present a formal model defining spatial and structural aspects of Fog-based systems using Bigraphical Reactive Systems, a fully graphical process algebraic formalism. The model is extended with reaction rules to represent the dynamic behavior of Fog systems in terms of self-adaptation. The notion of bigraph patterns is used in conjunction with boolean and temporal operators to encode spatio-temporal properties inherent to Fog systems and applications. The feasibility of the modelling approach is demonstrated via a motivating case study and various self-adaptation scenarios.

This work is done in cooperation with the Inria team Stack in Nantes (T. Ledoux, H. Sahli), and an extended paper is under reviewing.

High-Performance Grid Computing

Participants	Manal Benaissa, Raphaël Bleuse, Sophie Cerf, Quentin Guilloteau, Bashir Ibrahim, Bogdan Robu, Eric Rutten.

Cloud and HPC (High-Performance Computing) systems have increasingly become more varying in their behavior, in particular in aspects such as performance and power consumption, and the fact that they are becoming less predictable demands more runtime management [10].

A Control-Theory based approach to minimize cluster underuse One such problem is found in the context of CiGri, a simple, lightweight, scalable and fault tolerant grid system which exploits the unused resources of a set of computing clusters. In this work, we consider autonomic administration in HPC systems for scientific workflows management through a control theoretical approach. We propose a model described by parameters related to the key aspects of the infrastructure thus achieving a deterministic dynamical representation that covers the diverse and time-varying behaviors of the real computing system. We propose a model-predictive control loop to achieve two different objectives: maximize cluster utilization by best-effort jobs and control the file server's load in the presence of external disturbances. The accuracy of the prediction relies on a parameter estimation scheme based on the EKF (Extended Kalman Filter) to adjust the predictive-model to the real system, making the approach adaptive to parametric variations in the infrastructure. The closed loop strategy shows performance improvement and consequently a reduction in the total computation time. The problem is addressed in a general way, to allow the implementation on similar HPC platforms, as well as scalability to different infrastructures.

This work is done in cooperation with the Datamove team of Inria/LIG (O. Richard), and Gipsa-lab (B. Robu).

It was the topic of the Master's thesis in Control Theory of Bashir Ibrahim [20], and the Master's thesis in Computer Science of Quentin Guilloteau [19], and now also the PhD thesis of Quentin Guilloteau.

Combining Scheduling and Autonomic Computing for Parallel Computing Resource Management This research topic aims at studying the relationships between scheduling and autonomic computing techniques to manage resources for parallel computing platforms. The performance of such platforms has greatly improved (149 petaflops as of November 2019 [22]) at the cost of a greater complexity: the platforms now contain several millions of computing units. While these computation units are diverse, one has to consider other constraints such as the amount of free memory, the available bandwidth, or the energetic envelope. The variety of resources to manage builds complexity up on its own. For example, the performance of the platforms depends on the sequencing of the operations, the structure (or lack thereof) of the processed data, or the combination of application running simultaneously.

Scheduling techniques offer great tools to study/guaranty performances of the platforms, but they often rely on complex modeling of the platforms. They furthermore face scaling difficulties to match the complexity of new platforms. Autonomic computing manages the platform during runtime (on-line) in order to respond to the variability. This approach is structured around the concept of feedback loops.

The scheduling community has studied techniques relying on autonomic notions, but it has failed to link the notions up. We are starting to address this topic.

It was the topic of the Master's thesis of Manal Benaissa [18].

8.2.2 IoT and Cyberphysical Systems

Device management

Participants	Neil Ayeb, Eric Rutten.

The research topic is targeting an adaptative and decentralized management for the IoT. More precisely, it concerns Device Management (DM), which is currently industrially deployed for LAN devices, phones and workstation management. This work in an industrial environment addresses these limitations with a novel autonomic and distributed approach for the DM [11].

This work is in the framework of the Inria/Orange labs joint laboratory (see Section 9.1), and supported by the CIFRE PhD thesis grant of Neïl Ayeb, starting dec. 2017, and defended in nov. 2020 [15]. This topic continues with the post-doctoral research of Ghada Moualla at Orange labs, considering the autonomic management of DM servers and their (re-)deployment on a Fog infrastructure.

Self-adaptive support for Cyber-physical Systems

Participants Mahyar Tourchi Moghaddam, Eric Rutten.

In this work we consider self-adaptation at the level of Software Architectures, targeted at the domain of Cyber-Physical Systems.

This activity takes place in the framework of the H2020 project CPS4EU

In a preliminary phase, a systematic litterature review was undertaken, on the topic of Self-adaptive middleware support for Cyber-physical Systems, whic is currently under review [16].

We develop a generic approach to model control loops and their interaction within the Internet of Things (IoT) environments. We take advantage of MAPE-K loops to enable architectural self-adaptation. The system's architectural setting is aligned with the adaptation goals and the components run-time situation and constraints. We introduce an integrated framework for IoT Architectural Self-adaptation (IAS) where functional control elements are in charge of environmental adaptation and autonomic control elements handle the functional system's architectural adaptation. A Queuing Networks (QN) approach was used for modeling the IAS. The IAS-QN can model control levels and their interaction to perform both architectural and environmental adaptations.

As an applicative use-case, we consider Smart Grid management, in cooperation with RTE. The IAS-QN was applied on a smart grid system for the Melle-Longchamp area (France). Our architectural adaptation approach successfully set the propositions to enhance the performance of the electricity transmission system. Another application domain on which contacts are taken with ACOEM concern monitoring in Smart Cities. These industrial use-cases are a part of CPS4EU European industrial innovation pro ject.

First results were published in the ECSA2020 conference [14]

Security in SCADA industrial systems

Participants Gwenaël Delaval, Fabien Lefevre, Stéphane Mocanu, Eric Rutten, Gaetan Sorin.

We focus mainly on vulnerability search, automatic attack vectors synthesis and intrusion detection. Model checking techniques are used for vulnerability search and automatic attack vectors construction. Intrusion detection is mainly based on process-oriented detection with a technical approach from runtime monitoring. The LTL formalism is used to express safety properties which are mined on an attack-free dataset. The resulting monitors are used for fast intrusion detections. A demonstrator of attack/defense scenario in SCADA systems has been built on the existing G-ICS lab (hosted by ENSE3/Grenoble-INP). This work is in the framework of the ANR project Sacade on cybersecurity of industrial systems (see Section 10.3.1).

One of important results is the realization of a Hardware-in-the-loop SCADA Cyberange based on a electronic interface card that allows to interface real-world PLC with a software simulation. The entire system is available in open-source including the electronic card fabrication files (`http://gics-hil.gforge.inria.fr/`). Interfacing system allow connection with various commercial simulation software but also with "home made" simulators. The work is also supported by Grenoble Alpes Cybersecurity Institute (see Section 10.4) and Pulse program of IRT NANOELEC.

A study on the real-time performance and security of smard-grid protocols was published in [13].

Reverse-engineering analysis of embedded PLC firmwares and an industrial proprietary communication protocol were conducted in the Master theses of Gaëtan Sorin and Fabian Lefebvre. A Wireshark dissector was obtained and we expect a further cooperation with the manufacturer.

A cooperation is being started with Naval Group on the topic of intrusion detection in continous and hybrid industrial systems. In this framework, Estelle Hotellier will perform a PhD.

Ongoing work concerns the complementary topic of analysis and identification of reaction mechanisms for self-protection in cybersecurity, where, beyond classical defense mechanisms that detect intrusions and attacks or assess the kind of danger that is caused by them, we explore models and control techniques for the automated reaction to attacks, in order to use detection information to take the appropriate defense and repair actions. Results were published in the IFAC World Congress 2020 [12].

These activities in Cyber-Security are represented by holding a booth at FIC in Lille (Forum International de la Cybersécurité) in the last years.

9 Bilateral contracts and grants with industry

9.1 Bilateral grants with industry

Orange We have a cooperation with Orange labs, around a CIFRE PhD grant, on the topic of autonomic device management (see Section 8.2.2). This activity is part of the Inria/Orange joint laboratory.

The PhD defence was on nov. 25, 2020.

Nokia / Bell labs We have a research action with Nokia / Bell labs, in cooperation with project-team Dyonisos at Inria Rennes, on the topic of the Autonomic management in Software Defined Networks . This activity is part of the Inria/ Nokia / Bell labs joint laboratory.

10 Partnerships and cooperations

10.1 International initiatives

10.1.1 Inria International Labs

We participate in the jLESC, Joint Laboratory for Extreme Scale Computing, with partners INRIA, the University of Illinois, Argonne National Laboratory, Barcelona Supercomputing Center, Jülich Supercomputing Centre and RIKEN AICS.

We started a cooperation with Argonne National Labs, on Improving the performance and energy efficiency of HPC applications using autonomic computing techniques. https://jlesc.github.io/projects/energy_autonomic/

We are also exploring possibilities on the topic of integrating FPGAs in HPC grids. https://collab.cels.anl.gov/display/HPCFPGA/HPC-FPGA

10.1.2 Inria international partners

Informal international partners We have had ongoing relations with international colleagues in the emerging community on our topic of control for computing e.g., in Sweden at Lund (K.E. Arzen, M. Maggio), Mälardalen (A. Papadopoulos) and Linnaeus Universities (D. Weyns, N. Khakpour), in the Netherlands at CWI/leiden University (F. Arbab), in the U.K. at Liverpool U. (N. Berthier), in China at Heifei University (Xin An), in Italy at University Milano (C. Ghezzi, A. Leva), in the USA at Ann Arbor University (S. Lafortune) and UMass (P. Shenoy, E. Cecchet).

10.2 European initiatives

10.2.1 FP7 & H2020 Projects

CPS4EU

Title: Cyber Physical Systems for Europe

Duration: july 2019 - june 2022

Coordinator: VALEO

Partners:

- ABENGOA INNOVACION SOCIEDAD ANONIMA (Spain)
- ANSYS FRANCE SAS (France)
- BUDAPESTI MUSZAKI ES GAZDASAGTUDOMANYI EGYETEM (Hungary)
- CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE CNRS (France)
- COMMISSARIAT A L ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES (France)
- EMMTRIX TECHNOLOGIES GMBH (Germany)
- ETH LAB SRL (Italy)
- EUROTECH SPA (Italy)
- FUNDACION CENTRO DE TECNOLOGIAS DE INTERACCION VISUAL Y COMUNICACIONES VICOMTECH (Spain)
- GREENWAVES TECHNOLOGIES (France)
- INSTITUTO TECNOLOGICO DE INFORMATICA (Spain)
- KALRAY SA (France)
- LEONARDO - SOCIETA PER AZIONI (Italy)
- M3 SYSTEMS SAS (France)
- PROVE&RUN (France)
- SCHNEIDER ELECTRIC FRANCE SAS (France)
- SEQUANS COMMUNICATIONS SA (France)
- SHERPA ENGINEERING SA (France)
- SPINSPLIT MUSZAKI KUTATO FEJLESZTOKFT (Hungary)
- TECHNISCHE UNIVERSITAT CLAUSTHAL (Germany)
- ECNOLOGIAS SERVICIOS TELEMATICOS YSISTEMAS SA (Spain)
- THALES (France)
- UNIVERSITAET AUGSBURG (Germany)
- UNIVERSITE DE LORRAINE (France)
- UNIVERSITE GRENOBLE ALPES (France)
- VALEO COMFORT AND DRIVING ASSISTANCE (France)
- VALEO VISION SAS (France)

Inria contact: E. Rutten

Summary: CPS4EU proposes to address technical issues and organizational issues in an integrated way. Hence, CPS4EU promotes a high level of sharing, so that an operational ecosystem, with adequate skills and expertise all along the value chain can enable, at the end of the project, the European industry to lead strategic markets based on CPS technologies.

https://cps4eu.eu/

In this project, the Ctrl-A team is involved in WP4 and WP9 mainly, on topics of Software Architectures for Self-Adaptive systems in CPS, and our main industrial collaboration is with RTE.

10.3 National initiatives

10.3.1 ANR Sacade

The ANR ASTRID Sacade project is funded by DGA. Stéphane Mocanu is in charge of several workpackages including a demonstrator. An expert engineer position is funded for the implementation of attack/defense scenarios in SCADA.

The project has officially ended in January 2020.

10.3.2 IRT Nanoelec Pulse program

The Pulse program aims the development for SCADA cybersecurity demonstrators. It has funded a Master grant in 2019 and two master grants in 2020.

10.3.3 Informal National Partners

We have contacts with colleagues in France, in addition to the cooperation mentioned before, and with whom we are submitting collaboration projects, co-organizing events and workshops, etc. They feature : Avalon Inria team in Lyon (Ch. Perez, L. Lefevre, E. Caron), LIP6 (J. Malenfant), Scales Inria team in Sophia-Antipolis (L. Henrio), LIRRM in Montpellier (A. Gamatié, K. Godary, D. Simon), IRISA/Inria Rennes (J. Buisson, J.L. Pazat, ...), Telecom Paris-Tech (A. Diaconescu, E. Najm), LAAS (Thierry Monteil), LURPA ENS Cachan (J.M. Faure, J.J. Lesage).

10.3.4 Informal National Industrial Partners

We have ongoing discussions with several industrial actors in our application domains, some of them in the framework of cooperation contracts, other more informal: Eolas/Business decision (G. Dulac, I. Saffiedine), ST Microelectronics (V. Bertin), Schneider Electric (C. El-Kaed, P. Nappey, M. Pitel), and DGA.

10.4 Regional initiatives

Grenoble Alpes Cybersecurity Institute Cross-Disciplinary Project of the Idex The Grenoble Alpes Cybersecurity Institute aims at undertaking ground-breaking interdisciplinary research in order to address cybersecurity and privacy challenges. Our main technical focus is on low-cost secure elements, critical infrastructures, vulnerability analysis and validation of large systems, including practical resilience across the industry and the society.

In Ctrl-A, it funded two "alternance" inership positions, supervised bt Stéphane Mocanu.

11 Dissemination

11.1 Promoting scientific activities

11.1.1 Scientific events: organisation

General chair, scientific chair Eric Rutten is co-chairing, with Liliana Andrade (Université Grenoble Alpes, TIMA) and Pascal Vivet (CEA List), FETCH 2022 (École d'hiver Francophone sur les Technologies de Conception des Systèmes Embarqués Hétérogènes) the 15th Winter School on Heterogeneous Embedded Systems Design Technologies, postponed to 2022 due to sanitary restrictions. (https://sites.google.com/view/fetch2021/)

11.1.2 Scientific events: selection

Chair of conference program committees Mahyar Tourchi Moghaddam and Eric Rutten are co-chairing, with G. Giraud (RTE), SE4ICPS, the Workshop on Software Engineering for Industrial Cyber-Physical Systems, at COMPSAC 2021 https://ieeecompsac.computer.org/2021

Member of the conference program committees Eric Rutten is PC member for :

- international conferences
  - 15th Workshop on Discrete Event Systems, WODES 2020, Rio de Janeiro, May, 13th-15th, 2020. (https://wodes2020.eventos.ufrj.br)
  - CPS&IoT 2020 - the 8th International Conference on Cyber-Physical Systems and Internet-of-Things, Budva, Montenegro, June 8-11, 2020 (http://embeddedcomputing.me/en/cps-iot-2020)
  - (Associate Editor) 4th IEEE Conference on Control Technology and Applications, CCTA 2020, Montreal, August, 2020 (http://ccta2020.ieeecss.org/)
  - 7th International Conference on Control, Decision and Information Technologies, CoDIT20, June 29 - July 02, 2020, Prague, Czech Republic (https://codit2020.com/)
  - 1st International Conference on Autonomic Computing and Self-Organizing Systems, ACSOS 2020 ; Mon 17 - Fri 21 August 2020 Washington, DC, Washington, United States (https://conf.researchr.org/home/acsos-2020)
  - 18th High Performance Computing & Simulation Conference (HPCS 2020). Barcelona, Spain (Virtual/Online event) (http://hpcs2020.cisedu.info/)
  - PECS, the 1st Workshop on the Performance and Energy-efficiency of Concurrent Systems (https://pecs-workshop.github.io), co-located with the ACM/SPEC International Conference on Performance Engineering (ICPE) in April 2021 (https://icpe2021.spec.org/).
  - CPS& IoT'2021- the 9th International Conference on Cyber-Physical Systems and Internet-of-Things http://embeddedcomputing.me/en/cps-iot-2021
  - (Associate Editor) CCTA 2021, 5th IEEE Conference on,Control Technology and Applications, aug. 2021, San Diego, CA (http://ccta2021.ieeecss.org/)
  - 13ème Colloque sur la Modélisation des Systèmes Réactifs (MSR'21), Paris, 8 - 10 novembre 2021. (http://msr2021.cnam.fr/)

Reviewer Raphaël Bleuse is reviewer for 1st International Conference on Autonomic Computing and Self-Organizing Systems, ACSOS 2020.

11.1.3 Journal

Eric Rutten is reviewer for :

- Science of Computer Programming
- Future Generation Computing Systems (FGCS)
- journal of Discrete Event Dynamic System (jDEDS)

Mahyar Tourchi Moghaddam is reviewer for : ACM Transactions on Autonomous and Adaptive Systems.

11.1.4 Invited talks

Eric Rutten was invited to give a talk at : FETCH 2020, Ecole d'Hiver francophone sur la technologie de conception des systèmes embarqués hétérogènes, Montreal, QC, Canada janvier 2020 https://sites.google.com/view/fetch2020/accueil

11.1.5 Leadership within the scientific community

Eric Rutten is co-chair of the Technical Committee on Discrete Event Systems (DESTC), a part of the IEEE Control Systems Society (CSS) Technical Activities Board (http://discrete-event-systems.ieeecss.org/tc-discrete/home) ; and member of the IFAC Technical Committee 1.3 on Discrete Event and Hybrid Systems, for the 2017-2020 triennum (http://tc.ifac-control.org/1/3).

The (co-)chairs (Anne-Kathrin Schmuck, Eric Rutten, Xiang Yin, and Kai Cai) organize the IEEE CSS TC DES Lighening Tutorial Steries 2021, a virtual lecture series throughout 2021 (http://discrete-event-systems.ieeecss.org/tc-discrete/tutorial-series-2021)

11.1.6 Scientific expertise

Eric Rutten was reviewer for :

- the ANRT, evaluating a Cifre PhD proposal,
- the U. Verona (Italy) call for proposals for Post-Doc projects in all areas of Computer science and applied mathematics.

11.1.7 Research administration

Gwenaël Delaval is elected member at the Academic Council (Conseil Académique) of University Grenoble Alpes (UGA) for the Confédération Générale du Travail trade union.

Eric Rutten is a named member of the Laboratory Coucil (Conseil de Laboratoire) and of the Scientific Board (Bureau Scientifique) of LIG (https://www.liglab.fr).

11.2 Teaching - Supervision - Juries

11.2.1 Teaching

- Licence: R. Bleuse, C language, 12h lab, L2, Univ. Grenoble Alpes
- Licence: R. Bleuse, methodology of software development, 30h, L2, Univ. Grenoble Alpes
- Licence: R. Bleuse, network architecture, 36h lecture/tutorials/practicals, L1, Univ. Grenoble Alpes
- Licence: R. Bleuse, network architecture, 24h tutorials/practicals, L1, Univ. Grenoble Alpes
- Licence: R. Bleuse, basics of object-orientied programming, 42h lecture/tutorials/practicals, L1, Univ. Grenoble Alpes
- Licence: R. Bleuse, OOP/UI/UML project, 4h, L1, Univ. Grenoble Alpes
- Licence: R. Bleuse, advanced algorithmics/C++ language, 13h practicals, L1–2, Univ. Grenoble Alpes
- Licence : G. Delaval, Bases du développement logiciel, modularité et tests, 15h tutorials, 15h lab, L2, Univ. Grenoble Alpes
- Licence : G. Delaval, Algorithmique et programmation impérative, 18h tutorials, 18h lab, L2, Univ. Grenoble Alpes
- Master : G. Delaval, Programming languages and compiler design, 6h class, 30h tutorials, L2, Univ. Grenoble Alpes
- Master : S. Mocanu, Computer Networks and Cybersecurity, 16h class, 34h lab, M1, Grenoble-INP/ENSE3
- Master : S. Mocanu, Industriel Computer Networks, 8h class, 8h lab, niveau (M1, M2), M2, Grenoble-INP/ENSE3
- Master : S. Mocanu, Reliability, 10h class, 8h lab, M2, Grenoble-INP/ENSE3
- Master : S. Mocanu, Intrusion Detection and Defense in Depth labs, niveau M2, Grenoble-ENSE3/ENSIMAG

11.2.2 Supervision

- PhD : Neïl Ayeb ; Administration autonomique et décentralisée de flottes d'équipements de l'Internet des Objets ; nov. 2020 ; co-advised by Eric Rutten with S. Bolle, T. Coupaye (Orange labs).
- PhD in progress : Quentin Guilloteau ; Une approche autonomique de la gestion dynamique de ressources dans les clusters HPC ; oct. 20 ; co-advised by Eric Rutten with O. Richard, Datamove team Inria/LIG.

11.2.3 Juries

Eric Rutten was member of the following juries :

- PhD defense of Maverick Chardet, IMT Nantes, 3 déc. 2020. (reviewer)
- PhD thesis of Ferdie Reijnen, Eindhoven University of Technology, The Netherlands, 12 nov 2020 (reviewer)

12 Scientific production

12.1 Major publications

[1] F. Alvares, E. Rutten and L. Seinturier. 'A Domain-specific Language for The Control of Self-adaptive Component-based Architecture'. In: *Journal of Systems and Software* (Jan. 2017). URL: https://hal.archives-ouvertes.fr/hal-01450517.

[2] X. An, E. Rutten, J.-P. Diguet and A. Gamatié. 'Model-based design of correct controllers for dynamically reconfigurable architectures'. In: *ACM Transactions on Embedded Computing Systems (TECS)* 15.3 (Feb. 2016). URL: https://hal.inria.fr/hal-01272077.

[3] N. Berthier, E. Rutten, N. De Palma and S. M.-K. Gueye. 'Designing Autonomic Management Systems by using Reactive Control Techniques'. In: *IEEE Transactions on Software Engineering* 42.7 (July 2016), p. 18. URL: https://hal.inria.fr/hal-01242853.

[4] G. Delaval and E. Rutten. 'Reactive model-based control of reconfiguration in the Fractal component-based model'. In: *Proceedings of the 13th International Symposium on Component Based Software Engineering (CBSE), \em Prague, Czech Republic, 23-25 June.* \bf best paper award. 2010, pp. 93–112. URL: http://dx.doi.org/10.1007/978-3-642-13238-4%5C_6.

[5] G. Delaval, E. Rutten and H. Marchand. 'Integrating Discrete Controller Synthesis in a Reactive Programming Language Compiler'. In: *journal of Discrete Event Dynamic System, jDEDS, special issue on Modeling of Reactive Systems* 23.4 (2013), pp. 385–418. URL: http://dx.doi.org/10.1007/s10626-013-0163-5.

[6] S. M.-K. Gueye, G. Delaval, E. Rutten, D. Heller and J.-P. Diguet. 'A Domain-specific Language for Autonomic Managers in FPGA Reconfigurable Architectures'. In: *ICAC 2018 - 15th IEEE International Conference on Autonomic Computing*. Trento, Italy: IEEE, Sept. 2018, pp. 1–10. URL: https://hal.archives-ouvertes.fr/hal-01868675.

[7] M. Litoiu, M. Shaw, G. Tamura, N. M. Villegas, H. Müller, H. Giese, R. Rouvoy and E. Rutten. 'What Can Control Theory Teach Us About Assurances in Self-Adaptive Software Systems?' In: *Software Engineering for Self-Adaptive Systems 3: Assurances*. Ed. by R. de Lemos, D. Garlan, C. Ghezzi and H. Giese. Vol. 9640. LNCS. Springer, May 2017. URL: https://hal.inria.fr/hal-01281063.

[8] M. Louvel, F. Pacull, E. Rutten and A. N. Sylla. 'Development Tools for Rule-Based Coordination Programming in LINC'. In: *19th International Conference on Coordination Languages and Models (COORDINATION)*. Ed. by J.-M. Jacquet and M. Massink. Vol. LNCS-10319. Coordination Models and Languages. Part 2: Languages and Tools. Neuchâtel, Switzerland: Springer International Publishing, June 2017, pp. 78–96. DOI: 10.1007/978-3-319-59746-1_5. URL: https://hal-cea.archives-ouvertes.fr/cea-01531019.

[9] E. Rutten, N. Marchand and D. Simon. 'Feedback Control as MAPE-K loop in Autonomic Computing'. In: *Software Engineering for Self-Adaptive Systems III. Assurances.* Vol. 9640. Lecture Notes in Computer Science. Springer, Jan. 2018, pp. 349–373. DOI: 10.1007/978-3-319-74183-3_12. URL: https://hal.inria.fr/hal-01285014.

[10] N. Zhou, G. Delaval, B. Robu, E. Rutten and J.-F. Méhaut. 'An Autonomic-Computing Approach on Mapping Threads to Multi-cores for Software Transactional Memory'. In: *Concurrency and Computation: Practice and Experience* 30.18 (Sept. 2018), e4506. DOI: 10.1002/cpe.4506. URL: https://hal.archives-ouvertes.fr/hal-01742690.

12.2 Publications of the year

International peer-reviewed conferences

[11] N. Ayeb, E. Rutten, S. Bolle, T. Coupaye and M. Douet. 'Coordinated autonomic loops for target identification, load and error-aware Device Management for the IoT'. In: FedCSIS 2020 - 15th Federated Conference on Computer Science and Information Systems. Proceedings of the Federated Conference on Computer Science and Information Systems (FedCSIS). Sofia, Bulgaria, 9th Sept. 2020, pp. 1–10. URL: https://hal.inria.fr/hal-02934785.

[12] G. Delaval, A. Hore, S. Mocanu, L. Muller and E. Rutten. 'Discrete Control of Response for Cybersecurity in Industrial Control'. In: IFAC 2020 - IFAC World Congress 2020. Proc. of the 21st IFAC World Congress. Berlin, Germany: https://www.ifac2020.org/, 13th July 2020, pp. 1–8. URL: https://hal.archives-ouvertes.fr/hal-02569406.

[13] S. Mocanu and J.-M. Thiriet. 'Experimental study of performance and vulnerabilities of IEC 61850 process bus communications on HSR networks'. In: 2020 IEEE European Symposium on Security and Privacy Workshops (EuroS&PW). Gênes, Italy, 7th Sept. 2020. DOI: 10.1109/EuroSPW51379.2020.00085. URL: https://hal.archives-ouvertes.fr/hal-02921495.

[14] M. T. Moghaddam, E. Rutten, P. Lalanda and G. Giraud. 'IAS: an IoT Architectural Self-adaptation Framework'. In: 14th European Conference on Software Architecture (ECSA). L'Aquila, Italy: https://ecsa2020.disim.univaq.it/, 14th Sept. 2020. URL: https://hal.inria.fr/hal-02900674.

Doctoral dissertations and habilitation theses

[15] N. Ayeb. 'Autonomic and decentralized device management for the Internet of Things'. Université Grenoble Alpes [2020-....], 25th Nov. 2020. URL: https://tel.archives-ouvertes.fr/tel-03152166.

Reports & preprints

[16] M. T. Moghaddam, E. Rutten and G. Giraud. *Protocol for a Systematic Literature Review on Adaptative Middleware Support for IoT and CPS.* 24th Sept. 2020. URL: https://hal.inria.fr/hal-02948347.

Other scientific publications

[17] Q. Guilloteau. 'Minimizing Cluster Under-use using a Control-Based Approach'. Grenoble INP Ensimag; Université Grenoble Alpes, 25th June 2020. URL: https://hal.archives-ouvertes.fr/hal-03167242.

12.3 Cited publications

[18] M. Benaissa. 'Relationships between Scheduling and Autonomic Computing Techniques Applied to Parallel Computing Resource Management'. MA thesis. France: Masters Thesis, M2R MOSIG, Université Grenoble Alpes, 2020.

[19] Q. Guilloteau. ‘Minimizing Cluster Under-use using a Control-Based Approach’. MA thesis. France: Masters Thesis, M2R MOSIG, Université Grenoble Alpes, 2020.

[20] B. Ibrahim. ‘Control Approaches for Minimizing Unused Computing Grid Resources with Overload Avoidance’. MA thesis. France: Masters Thesis, M2R MISCIT, Université Grenoble Alpes, 2020.

[21] L. Muller. ‘Processus de tests et d’intégration continue pour le langage Heptagon’. MA thesis. France: M2 Report, Université Grenoble Alpes, 2020.

[22] E. Strohmaier, J. Dongarra, H. Simon and M. Meuer. *TOP500 list*. URL: https://www.top500.org/lists/ (visited on 07/01/2020).