IN PARTNERSHIP WITH:
Université des sciences et technologies de Lille (Lille 1)

Activity Report 2015

Project-Team SPIRALS

Self-adaptation for distributed services and large software systems

IN COLLABORATION WITH: Centre de Recherche en Informatique, Signal et Automatique de Lille

RESEARCH CENTER
Lille - Nord Europe

THEME
Distributed Systems and middleware

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Project-Team SPIRALS

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2. Overall Objectives

2.1. Introduction

Our research is based on two complementary fields: distributed systems and software engineering. We aim at introducing more automation in the adaptation processes of software systems, that is, transitioning from the study of adaptive systems to self-adaptive systems. In particular, we work towards two directions: self-healing software systems with data mining solutions, and self-optimizing software systems with context monitoring. These two objectives are declined for two target environments: mobile computing and cloud computing.

2.2. Scientific Foundations

Distributed software services and systems are central to many human activities, such as communication, commerce, education, defense, etc. Distributed software services consist of an ever growing number of devices, often highly heterogeneous, from cloud platforms, sensor networks, to application servers, desktop machines, and mobile devices, such as smartphones. The future of this huge number of interconnected software services has been called the Internet of Services, a vision *"where everything that is needed to use software applications is available as a service on the Internet, such as the software itself, the tools to develop the software, the platform servers, storage and communication to run the software."* [1] This pervasiveness continuously leads to new usages that in turn foster the emergence of novel requirements and concepts for new software services. Hence, it is necessary to establish new paradigms to design and execute software programs in these highly

[1] http://cordis.europa.eu/fp7/ict/ssai

interconnected and heterogeneous environments, and it is necessary to ensure not only that these software systems can be adapted to new usages, new infrastructures, and new execution environments in the long term, but also that after the adaptation process the services still perform as expected.

This research project focuses on defining *self-adaptive* software services and middleware. From the perspective of the Internet of Services, this project fits in the vision sketched by *e.g.*, the FP8 Expert Group Services in the Future Internet [85], the NESSI Research Priorities for the next Framework Programme for Research and Technological Development FP8 [89], the Roadmap for Advanced Cloud Technologies under H2020 [86], and research roadmaps, such as [95], [84], [72].

3. Research Program

3.1. Introduction

Our research program on self-adaptive software targets two key properties that are detailed in the remainder of this section: *self-healing* and *self-optimization*.

3.2. Objective #1: Self-healing - Mining software artifacts to automatically evolve systems

Software systems are under the pressure of changes all along their lifecycle. Agile development blurs the frontier between design and execution and requires constant adaptation. The size of systems (millions of lines of code) multiplies the number of bugs by the same order of magnitude. More and more systems, such as sensor network devices, live in "surviving" mode, in the sense that they are neither rebootable nor upgradable.

Software bugs are hidden in source code and show up at development-time, testing-time or worse, once deployed in production. Except for very specific application domains where formal proofs are achievable, bugs can not be eradicated. As an order of magnitude, on 16 Dec 2011, the Eclipse bug repository contains 366,922 bug reports. Software engineers and developers work on bug fixing on a daily basis. Not all developers spend the same time on bug fixing. In large companies, this is sometimes a full-time role to manage bugs, often referred to as *Quality Assurance* (QA) software engineers. Also, not all bugs are equal, some bugs are analyzed and fixed within minutes, others may take months to be solved [92].

In terms of research, this means that: (i) one needs means to automatically adapt the design of the software system through automated refactoring and API extraction, (ii) one needs approaches to automate the process of adapting source code in order to fix certain bugs, (iii) one needs to revisit the notion of error-handling so that instead of crashing in presence of errors, software adapts itself to continue with its execution, *e.g.*, in degraded mode.

There is no one-size-fits-all solution for each of these points. However, we think that novel solutions can be found by using **data mining and machine learning techniques tailored for software engineering** [93]. This body of research consists of mining some knowledge about a software system by analyzing the source code, the version control systems, the execution traces, documentation and all kinds of software development and execution artifacts in general. This knowledge is then used within recommendation systems for software development, auditing tools, runtime monitors, frameworks for resilient computing, etc.

The novelty of our approach consists of using and tailoring data mining techniques for analyzing software artifacts (source code, execution traces) in order to achieve the **next level of automated adaptation** (*e.g.*, automated bug fixing). Technically, we plan to mix unsupervised statistical learning techniques (*e.g.* frequent item set mining) and supervised ones (*e.g.* training classifiers such as decision trees). This research is currently not being performed by data mining research teams since it requires a high level of domain expertise in software engineering, while software engineering researchers can use off-the-shelf data mining libraries, such as Weka [70].

We now detail the two directions that we propose to follow to achieve this objective.

3.2.1. Learning from software history how to design software and fix bugs

The first direction is about mining techniques in software repositories (*e.g.*, CVS, SVN, Git). Best practices can be extracted by data mining source code and the version control history of existing software systems. The design and code of expert developers significantly vary from the artifacts of novice developers. We will learn to differentiate those design characteristics by comparing different code bases, and by observing the semantic refactoring actions from version control history. Those design rules can then feed the test-develop-refactor constant adaptation cycle of agile development.

Fault localization of bugs reported in bug repositories. We will build a solid foundation on empirical knowledge about bugs reported in bug repository. We will perform an empirical study on a set of representative bug repositories to identify classes of bugs and patterns of bug data. For this, we will build a tool to browse and annotate bug reports. Browsing will be helped with two kinds of indexing: first, the tool will index all textual artifacts for each bug report; second it will index the semantic information that is not present by default in bug management software—*i.e.*, "contains a stacktrace"). Both indexes will be used to find particular subsets of bug reports, for instance "all bugs mentioning invariants and containing a stacktrace". Note that queries with this kind of complexity and higher are mostly not possible with the state-of-the-art of bug management software. Then, analysts will use annotation features to annotate bug reports. The main outcome of the empirical study will be the identification of classes of bugs that are appropriate for automated localization. Then, we will run machine learning algorithms to identify the latent links between the bug report content and source code features. Those algorithms would use as training data the existing traceability links between bug reports and source code modifications from version control systems. We will start by using decision trees since they produce a model that is explicit and understandable by expert developers. Depending on the results, other machine learning algorithms will be used. The resulting system will be able to locate elements in source code related to a certain bug report with a certain confidence.

Automated bug fix generation with search-based techniques. Once a location in code is identified as being the cause of the bug, we can try to automatically find a potential fix. We envision different techniques: (1) infer fixes from existing contracts and specifications that are violated; (2) infer fixes from the software behavior specified as a test suite; (3) try different fix types one-by-one from a list of identified bug fix patterns; (4) search fixes in a fix space that consists of combinations of atomic bug fixes. Techniques 1 and 2 are explored in [64] and [91]. We will focus on the latter techniques. To identify bug fix patterns and atomic bug fixes, we will perform a large-scale empirical study on software changes (also known as changesets when referring to changes across multiple files). We will develop tools to navigate, query and annotate changesets in a version control system. Then, a grounded theory will be built to master the nature of fixes. Eventually, we will decompose change sets in atomic actions using clustering on changeset actions. We will then use this body of empirical knowledge to feed search-based algorithms (*e.g.* genetic algorithms) that will look for meaningful fixes in a large fix space. To sum up, our research on automated bug fixing will try not only to point to source code locations responsible of a bug, but to search for code patterns and snippets that may constitute the skeleton of a valid patch. Ultimately, a blend of expert heuristics and learned rules will be able to produce valid source code that can be validated by developers and committed to the code base.

3.2.2. Run-time self-healing

The second proposed research direction is about inventing a self-healing capability at run-time. This is complementary to the previous objective that mainly deals with development time issues. We will achieve this in two steps. First, we want to define frameworks for resilient software systems. Those frameworks will help to maintain the execution even in the presence of bugs—*i.e.* to let the system survive. As exposed below, this may mean for example to switch to some degraded modes. Next, we want to go a step further and to define solutions for automated runtime repair, that is, not simply compensating the erroneous behavior, but also determining the correct repair actions and applying them at run-time.

Mining best effort values. A well-known principle of software engineering is the "fail-fast" principle. In a nutshell, it states that as soon as something goes wrong, software should stop the execution before entering incorrect states. This is fine when a human user is in the loop, capable of understanding the error or at

least rebooting the system. However, the notion of "failure-oblivious computing" [83] shows that in certain domains, software should run in a resilient mode (*i.e.* capable of recovering from errors) and/or best-effort mode—*i.e.* a slightly imprecise computation is better than stopping. Hence, we plan to investigate data mining techniques in order to learn best-effort values from past executions (*i.e.* somehow learning what is a correct state, or the opposite what is not a completely incorrect state). This knowledge will then be used to adapt the software state and flow in order to mitigate the error consequences, the exact opposite of fail-fast for systems with long-running cycles.

Embedding search based algorithms at runtime. Harman recently described the field of search-based software engineering [71]. We think that certain search based approaches can be embedded at runtime with the goal of automatically finding solutions that avoid crashing. We will create software infrastructures that allow automatically detecting and repairing faults at run-time. The methodology for achieving this task is based on three points: (1) empirical study of runtime faults; (2) learning approaches to characterize runtime faults; (3) learning algorithms to produce valid changes to the software runtime state. An empirical study will be performed to analyze those bug reports that are associated with runtime information (*e.g.* core dumps or stacktraces). After this empirical study, we will create a system that learns on previous repairs how to produce small changes that solve standard runtime bugs (*e.g.* adding an array bound check to throw a handled domain exception rather than a spurious language exception). To achieve this task, component models will be used to (1) encapsulate the monitoring and reparation meta-programs in appropriate components and (2) support runtime code modification using scripting, reflective or bytecode generation techniques.

3.3. Objective #2: Self-optimization - Sharing runtime behaviors to continuously adapt software

Complex distributed systems have to seamlessly adapt to a wide variety of deployment targets. This is due to the fact that developers cannot anticipate all the runtime conditions under which these systems are immersed. A major challenge for these software systems is to develop their capability to continuously reason about themselves and to take appropriate decisions and actions on the optimizations they can apply to improve themselves. This challenge encompasses research contributions in different areas, from environmental monitoring to real-time symptoms diagnosis, to automated decision making. The variety of distributed systems, the number of optimization parameters, and the complexity of decisions often resign the practitioners to design monolithic and static middleware solutions. However, it is now globally acknowledged that the development of dedicated building blocks does not contribute to the adoption of sustainable solutions. This is confirmed by the scale of actual distributed systems, which can—for example—connect several thousands of devices to a set of services hosted in the Cloud. In such a context, the lack of support for smart behaviours at different levels of the systems can inevitably lead to its instability or its unavailability. In June 2012, an outage of Amazon's Elastic Compute Cloud in North Virginia has taken down Netflix, Pinterest, and Instagram services. During hours, all these services failed to satisfy their millions of customers due to the lack of integration of a self-optimization mechanism going beyond the boundaries of Amazon.

The research contributions we envision within this area will therefore be organized as a reference model for engineering **self-optimized distributed systems** autonomously driven by *adaptive feedback control loops*, which will automatically enlarge their scope to cope with the complexity of the decisions to be taken. This solution introduces a multi-scale approach, which first privileges local and fast decisions to ensure the homeostasis [2] property of a single node, and then progressively propagates symptoms in the network in order to reason on a longer term and a larger number of nodes. Ultimately, domain experts and software developers can be automatically involved in the decision process if the system fails to find a satisfying solution. The research program for this objective will therefore focus on the study of mechanisms for **monitoring, taking decisions, and automatically reconfiguring software at runtime and at various scales**. As stated in the self-healing objective, we believe that there is no one-size-fits-all mechanism that can span all the scales of

[2] Homeostasis is the property of a system that regulates its internal environment and tends to maintain a stable, relatively constant condition of properties [Wikipedia].

the system. We will therefore study and identify an optimal composition of various adaptation mechanisms in order to produce long-living software systems.

The novelty of this objective is to exploit the wisdom of crowds to define new middleware solutions that are able to continuously adapt software deployed in the wild. We intend to demonstrate the applicability of this approach to distributed systems that are deployed from mobile phones to cloud infrastructures. The key scientific challenges to address can be summarized as follows: *How does software behave once deployed in the wild? Is it possible to automatically infer the quality of experience, as it is perceived by users? Can the runtime optimizations be shared across a wide variety of software? How optimizations can be safely operated on large populations of software instances?*

The remainder of this section further elaborates on the opportunities that can be considered within the frame of this objective.

3.3.1. Monitoring software in the wild

Once deployed, developers are generally no longer aware of how their software behave. Even if they heavily use testbeds and benchmarks during the development phase, they mostly rely on the bugs explicitly reported by users to monitor the efficiency of their applications. However, it has been shown that contextual artifacts collected at runtime can help to understand performance leaks and optimize the resilience of software systems [94]. Monitoring and understanding the context of software at runtime therefore represent the first building block of this research challenge. Practically, we intend to investigate crowd-sensing approaches, to smartly collect and process runtime metrics (*e.g.*, request throughput, energy consumption, user context). Crowd-sensing can be seen as a specific kind of crowdsourcing activity, which refers to the capability of lifting a (large) diffuse group of participants to delegate the task of retrieving trustable data from the field. In particular, crowd-sensing covers not only *participatory sensing* to involve the user in the sensing task (*e.g.*, surveys), but also *opportunistic sensing* to exploit mobile sensors carried by the user (*e.g.*, smartphones).

While reported metrics generally enclose raw data, the monitoring layer intends to produce meaningful indicators like the *Quality of Experience* (QoE) perceived by users. This QoE reflects representative symptoms of software requiring to trigger appropriate decisions in order to improve its efficiency. To diagnose these symptoms, the system has to process a huge variety of data including runtime metrics, but also history of logs to explore the sources of the reported problems and identify opportunities for optimizations. The techniques we envision at this level encompass machine learning, principal component analysis, and fuzzy logic [81] to provide enriched information to the decision level.

3.3.2. Collaborative decision-making approaches

Beyond the symptoms analysis, decisions should be taken in order to improve the *Quality of Service* (QoS). In our opinion, collaborative approaches represent a promising solution to effectively converge towards the most appropriate optimization to apply for a given symptom. In particular, we believe that exploiting the wisdom of the crowd can help the software to optimize itself by sharing its experience with other software instances exhibiting similar symptoms. The intuition here is that the body of knowledge that supports the optimization process cannot be specific to a single software instance as this would restrain the opportunities for improving the quality and the performance of applications. Rather, we think that any software instance can learn from the experience of others.

With regard to the state-of-the-art, we believe that a multi-levels decision infrastructure, inspired from distributed systems like Spotify [66], can be used to build a decentralized decision-making algorithm involving the surrounding peers before requesting a decision to be taken by more central control entity. In the context of collaborative decision-making, peer-based approaches therefore consist in quickly reaching a consensus on the decision to be adopted by a majority of software instances. Software instances can share their knowledge through a micro-economic model [63], that would weight the recommendations of experienced instances, assuming their age reflects an optimal configuration.

Beyond the peer level, the adoption of algorithms inspired from evolutionary computations, such as genetic programming, at an upper level of decision can offer an opportunity to test and compare several alternative decisions for a given symptom and to observe how does the crowd of applications evolves. By introducing some diversity within this population of applications, some instances will not only provide a satisfying QoS, but will also become naturally resilient to unforeseen situations.

3.3.3. Smart reconfigurations in the large

Any decision taken by the crowd requires to propagate back to and then operated by the software instances. While simplest decisions tend to impact software instances located on a single host (*e.g.*, laptop, smartphone), this process can also exhibit more complex reconfiguration scenarios that require the orchestration of various actions that have to be safely coordinated across a large number of hosts. While it is generally acknowledged that centralized approaches raise scalability issues, we think that self-optimization should investigate different reconfiguration strategies to propagate and apply the appropriate actions. The investigation of such strategies can be addressed in two steps: the consideration of *scalable data propagation protocols* and the identification of *smart reconfiguration mechanisms*.

With regard to the challenge of scalable data propagation protocols, we think that research opportunities encompass not only the exploitation of gossip-based protocols [65], but also the adoption of publish/subscribe abstractions [73] in order to decouple the decision process from the reconfiguration. The fundamental issue here is the definition of a communication substrate that can accommodate the propagation of decisions with relaxed properties, inspired by *Delay Tolerant Networks* (DTN), in order to reach weakly connected software instances. We believe that the adoption of asynchronous communication protocols can provide the sustainable foundations for addressing various execution environments including harsh environments, such as developing countries, which suffer from a partial connectivity to the network. Additionally, we are interested in developing the principle of *social networks of applications* in order to seamlessly group and organize software instances according to their similarities and acquaintances. The underlying idea is that grouping application instances can contribute to the identification of optimization profiles not only contributing to the monitoring layer, but also interested in similar reconfigurations. Social networks of applications can contribute to the anticipation of reconfigurations by exploiting the symptoms of similar applications to improve the performance of others before that problems actually happen.

With regard to the challenge of smart reconfiguration mechanisms, we are interested in building on our established experience of adaptive middleware [8] in order to investigate novel approaches to efficient application reconfigurations. In particular, we are interested in adopting seamless micro-updates and micro-reboot techniques to provide in-situ reconfiguration of pieces of software. Additionally, the provision of safe and secured reconfiguration mechanisms is clearly a key issue that requires to be carefully addressed in order to avoid malicious exploitation of dynamic reconfiguration mechanisms against the software itself. In this area, although some reconfiguration mechanisms integrate transaction models [74], most of them are restricted to local reconfigurations, without providing any support for executing distributed reconfiguration transactions. Additionally, none of the approached published in the literature include security mechanisms to preserve from unauthorized or malicious reconfigurations.

4. Application Domains

4.1. Introduction

Although our research is general enough to be applied to many application domains, we currently focus on applications and distributed services for the retail industry and for the digital home. These two application domains are supported by a strong expertise in mobile computing and in cloud computing that are the two main target environments on which our research prototypes are build, for which we are recognized, and for which we have already established strong collaborations with the industrial ecosystem.

4.2. Distributed software services for the retail industry

This application domain is developed in relation with the PICOM (*Pôle de compétivité Industries du Commerce*) cluster. We have established strong collaborations with local companies in the context of former funded projects, such as Cappucino and Macchiato, which focused on the development of a new generation of mobile computing platforms for e-commerce. We are also involved in the Datalyse and OCCIware funded projects that define cloud computing environments with applications for the retail industry. Finally, our activities in terms of crowd-sensing and data gathering on mobile devices with the APISENSE® platform share also applications for the retail industry.

4.3. Distributed software services for the digital home

We are developing new middleware solutions for the digital home, in particular through our long standing collaboration with Orange Labs. We are especially interested in developing energy management and saving solutions with the POWERAPI software library for distributed environments such the ones that equip digital homes. We are also working to bridge the gap between distributed services hosted on home gateways and distributed services hosted on the cloud to be able to smoothly transition between both environments. This work is especially conducted with the SALOON platform.

5. Highlights of the Year

5.1. Highlights of the Year

5.1.1. Awards

In 2015, we are particularly proud that our project-team received four awards. We are all the more proud of the fact these awards have been granted to PhD students and to young engineers involved in transfer activities.

Clément Quinton received the Best thesis award from the CNRS GDR GPL (*Génie de la programmation et du logiciel*). Clément Quinton PhD thesis [82] proposes an innovative solution for configuring and deploying software systems on cloud computing environments with software product lines and ontologies. The work of Clément Quinton led to the implementation of the Saloon software system (see Section 6.3) and contributed to the FP7 PaaSage project (see Section 9.3).

Maria Gomez Lacruz received an award in the ACM Best Student Research Competition for her paper [26] at the ACM MobileSoft conference on mobile software engineering and systems. Maria Gomez Lacruz proposes a solution for detecting buggy applications with a recommendation system that learns from software available on mobile application stores.

Gérard Paligot received two awards at the STAF Transformation Tool Contest for his work on the Spoon (see Section 6.4) library for Java source code analysis and transformation. The two awards were in the categories Java refactoring, and Java annotation processing live, respectively.

Nicolas Petitprez received the Bpifrance award in the *Création d'entreprise innovante* contest in the category *Emergence*. This award is linked to the work of Nicolas Petitprez and Martin Monperrus towards the creation of the Makitoo start-up company that is planned to be launched in 2016. This transfer project is built around the Spoon (see Section 6.4) library for Java source code analysis and transformation.

BEST PAPER AWARD:

[26]
M. GOMEZ, R. ROUVOY, M. MONPERRUS, L. SEINTURIER. *A Recommender System of Buggy App Checkers for App Store Moderators*, in "2nd ACM International Conference on Mobile Software Engineering and Systems", Firenze, Italy, D. DIG, Y. DUBINSKY (editors), IEEE, May 2015, https://hal.inria.fr/hal-01117376

6. New Software and Platforms

6.1. APISENSE®

Participants: Clive Ferret-Canape, Julien Duribreux, Maria Gomez Lacruz, Christophe Ribeiro, Romain Rouvoy, Antoine Veuiller.

- Contact: Romain Rouvoy
- URL: https://bil.inria.fr/fr/software/view/614/tab

In 2015, APISENSE® has been extended to include the support for iOS smartphones and tablets. The infrastructure, hosted by the LHS (*Laboratoire Haute Sécurité*), is now fully secured to protect the privacy of contributors.

APISENSE® is a distributed platform dedicated to crowd-sensing activities. Crowd-sensing intends to leverage mobile devices to seamlessly collect valuable dataset for different categories of stakeholders. APISENSE® intends to be used in a wide variety of scientific and industrial domains, including network quality monitoring, social behavior analysis, epidemy predictions, emergency crisis support, open maps initiatives, debugging of applications in the wide. APISENSE® is composed of HIVE delivered as a *Platform-as-a-Service* (PaaS) to the stakeholders who can pilot and customize their own crowd-sensing environment [79], and *Bee* supporting participants with a mobile application to control the sensors to be shared with the rest of the world [68], [69]. The platform is used by the Metroscope consortium, an Internet scientific observatory initiative supported by Inria. APISENSE® originates as the output of Nicolas Haderer PhD thesis [67].

APISENSE® is at the core of the Inria ADT Focus CrowdLab project (see Section 9.2) and of an industrial transfer action that aims at creating the Crowdify spin-off company.

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6.2. PowerAPI

Participants: Maxime Colmant, Loïc Huertas, Romain Rouvoy.

- Contact: Romain Rouvoy
- URL: https://bil.inria.fr/fr/software/view/1642/tab

In 2015, POWERAPI has been further extended to support the monitoring of *Software-as-a-Service* (SaaS) [23] by including a support for hypervision technologies like KVM (*Kernel-based Virtual Machine*), and Docker.

POWERAPI is a Scala-based library for monitoring energy in software systems. It is based on a modular and asynchronous event-driven architecture using the Akka library. POWERAPI differs from existing energy process-level monitoring tool in its pure software, fully customizable and modular aspect which let users precisely define what they want to monitor, without plugging any external device. POWERAPI offers an API which can be used to express requests about energy spent by a process, following its hardware resource utilization (in terms of CPU, memory, disk, network, etc.). Its applications cover energy-driven benchmarking [75], [62], [60], [61], energy hotspots and bugs detection [76], [77], and real-time distributed system monitoring. POWERAPI originates as the output of Adel Noureddine PhD thesis [78].

POWERAPI is at the core of the Inria ADT eSurgeon project (see Section 9.2).

Web site: http://www.powerapi.org. Registered with the APP (Agence pour la Protection des Programmes) under reference IDDN.FR.001.400015.000.S.P.2012.000.10000. License: AGPL.

6.3. Saloon

Participants: Laurence Duchien, Daniel Romero Acero, Lionel Seinturier [correspondant].

- Contact: Lionel Seinturier
- URL: https://bil.inria.fr/fr/software/view/1492/tab

In 2015, SALOON was extended to fit with the requirements of the FP7 PaaSage project (see Section 9.3). New mechanisms were added to deal with ontologies for describing cloud computing commercial offers.

SALOON is a framework for the selection and configuration of Cloud providers according to application requirements. The framework enables the specification of such requirements by defining ontologies. Each ontology provides a unified vision of provider offers in terms of frameworks, databases, languages, application servers and computational resources (i.e., memory, storage and CPU frequency). Furthermore, each provider is related to a Feature Model (FM) with attributes and cardinalities, which captures its capabilities. By combining the ontology and FMs, the framework is able to match application requirements with provider capabilities and select a suitable one. Specific scripts to the selected provider are generated in order to enable its configuration. SALOON originates as the output of Clément Quinton PhD thesis [82].

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6.4. Spoon

Participants: Thomas Durieux, Matias Martinez, Martin Monperrus, Gérard Paligot, Nicolas Petitprez.

- Contact: Martin Monperrus
- URL: https://bil.inria.fr/fr/software/view/251/tab

SPOON is a library for analyzing and transforming Java source code [18] [80]. In 2015, there was one engineer (Géradar Paligot) working full-time on Spoon. This has incredibly boosted the project. In particular, the new features of SPOON are: a) the complete support for Java 8 (incl. lambda expressions) b) the support for Maven and Gradle build systems. Also, a major testing effort has been done and consequently, the code quality now meets the highest standards, using a comprehensive test suite as well three continuous integration servers (incl. the Inria one). Spoon has an an international community of users and contributors, which is very active on the Github project.

SPOON is at the core of the Inria ADT Spoon3R project (see Section 9.1) SPOON is the foundation behind an industrial transfer action that aims at creating the Spoonware spin-off company on automatic hot patching.

Web site: http://spoon.gforge.inria.fr. Registered with the APP (Agence pour la Protection des Programmes) under reference IDDN.FR.001.070037.000.S.P.2007.000.10600. License: CeCILL-C.

7. New Results

7.1. Traceability of Concerns in Large Software Systems

In 2015, we obtained new results in the domain of the analysis of large software systems. The purpose is to be able to deal the complexity of such systems by slicing them depending on different concerns. The slicing enables to gain a view and a better understanding on how the concern evolves over time and through the different refinement layers of the software system. For that, we present a systematic approach based on model driven engineering and basic models of software components, in order to better manage software complexity and traceability of functional and non-functional requirements. We provide in particular three major contributions. First, we provide an integrated set of meta-models for describing the concerns of software requirements, software components, and traceability between the concerns and software components. By providing an abstract model, we are independent of any implementation and thus allow existing approaches relying on that model to expand their support. With the second contribution, we propose a formal support of our model to allow formal verification. We focus on temporal property verification. For this, our design model is translated into timed automata for which we can apply a timed model checker. Instead of using temporal logic, which is difficult to handle by non-experts, we use patterns of temporal properties. For each pattern, we propose timed automata that can be applied directly into a timed model checking tool. These timed automata are seen as observers or watch dogs that check the system under observation. Finally, with the last

contribution, we propose a software component-based development and verification approach, called SARA, and included in V-lifecycle widely used in the railway domain. These contributions have been validated with case studies from the domain of railway control systems especially for the new European train control system ERTMS/ETCS. These results contribute to our objective on self-optimizing software systems (see Section 3.3) and are part of the PhD thesis by Marc Sango [13].

7.2. Automatic Analysis and Repair of Exception Bugs for Java Programs

In 2015, we obtained new results in the field of automated software repair, that is a new and emerging domain of software engineering. The goal of automatic repair is to increase the quality of software systems by automatizing tasks related to fixing of defects and bugs. The new results that we bring are related with the management of runtime exceptions. These results contribute to our objective on self-healing software systems (see Section 3.2) and are part of the PhD thesis by Benoit Cornu [11], defended on 26 November 2015. To improve the available information about exceptions, we have presented a characterization of the exceptions (expected or not, anticipated or not), and of their corresponding resilience mechanisms [16]. We have provided definitions about what is a bug when facing exceptions and what are the already-in-place corresponding resilience mechanisms. We have formalized two formal resilience properties: source-independence and pure-resilience as well as an algorithm to verify them. Then, we have presented two dynamic analysis techniques based on code transformation for analyzing exceptions. Casper is an approach to make bug fixing easier by providing information about the origin of null pointer dereferences. NpeFix is a system to tolerate null pointer dereferences. Both systems are empirically validated on real-world null dereference bugs from large-scale open-source projects

8. Bilateral Contracts and Grants with Industry

8.1. ip-label

Participants: Christophe Ribeiro, Romain Rouvoy [correspondant].

A software exploitation license of the APISENSE® crowd-sensing platform has been sold to the ip-label company. They use this platform as a solution to monitor the quality of the GSM signal in the wild. The objective is to provide developers and stakeholders with a feedback on the quality of experience of GSM connection depending on their location.

8.2. Orange Labs

Participants: Laurence Duchien [correspondant], Amal Tahri.

This collaboration aims at bridging the gap between home networks and cloud environments for the design, the provisionning and the administration of distributed services. The purpose is to define solutions, essentially software design tools and runtime infrastructures, for the seamless migration of distributed applications and services between home networks and cloud environments. The envisioned approach is based on the research activities that we are conducting in the domain of software product lines.

This collaboration is conducted in the context of the ongoing PhD thesis of Amal Tahri.

8.3. Scalair

Participants: Yahya Al-Dhuraibi, Philippe Merle [correspondant].

This collaboration aims at proposing a framework to deal with elasticity in cloud computing environments. This framework must cover all kind of resources, IaaS, PaaS, SaaS, must provide a solution for interoperability between different clouds and virtualization technologies, and must enable the specification and composition of reactive and predictive strategies.

This collaboration is conducted in the context of the ongoing PhD thesis of Yahya Al-Dhuraibi.

9. Partnerships and Cooperations

9.1. Regional Initiatives

9.1.1. Région Nord-Pas De Calais

9.1.1.1. Citizen Awareness and Contribution to Air Quality Monitoring

Participants: Daniel Romero Acero, Romain Rouvoy [correspondant], Lionel Seinturier.

This is a 3-year granted in the context of the so-called "Chercheur citoyen" program that started in 2015. The partners are LISIC/Université Côte d'Opale (leader), ATMO Nord-Pas De Calais, Association Bâtisseurs d'Economie Solidaire. This project targets the distributed monitoring of air quality with crowd-sensing solutions obtained via sensors connected to smart devices. We aim at inciting citizens to perform their own measures, and to obtain thanks to GPS geo-localisation a large-scale database and a dynamic fine-grained cartography of air quality. This project takes advantage of the APISENSE® crowdsensing platform (see Section 6.1).

9.1.2. Inria Lille - Nord Europe

9.1.2.1. ADT eSurgeon

Participants: Maxime Colmant, Loïc Huertas, Romain Rouvoy [correspondant].

ADT eSurgeon (2013–15) is a technology development initiative supported by the Inria Lille - Nord Europe Center that aims at supporting the development of the POWERAPI software library (see Section 6.2) for measuring and monitoring the energy consumption of middleware and software systems.

9.1.2.2. ADT Spoon3R

Participants: Gérard Paligot, Martin Monperrus [correspondant].

ADT Spoon3R (2014–16) is a technology development initiative supported by the Inria Lille - Nord Europe Center that aims at supporting the development of the SPOON software library. (see Section 6.4) Spoon3R aims at extending SPOON with the features defined in the context of our research activities on automated software repair.

9.1.2.3. North European Lab LLEX

Participants: Benoit Cornu, Martin Monperrus [correspondant], Lionel Seinturier.

North European Lab LLEX (2015–17) is an international initiative supported by the Inria Lille - Nord Europe Center that takes place in the context of a collaboration between Inria and University College London. LLEX deals with research on automatic diagnosis and repair of software bugs. Automatic software repair is the process of fixing software bugs automatically An automatic software repair system fixes software bugs with no human intervention. The goal of automatic software repair is to save maintenance costs and to enable systems to be more resilient to bugs and unexpected situations. This research may dramatically improve the quality of software systems. The objective of the partnership is to work on the automated diagnosis of exceptions with a focus on null pointer exceptions.

9.1.2.4. North European Lab SOCS

Participants: Maria Gomez Lacruz, Christophe Ribeiro, Romain Rouvoy [correspondant], Lionel Seinturier.

North European Lab SOCS (2013–15) is an international initiative supported by the Inria Lille - Nord Europe Center that takes place in the context of a well-established collaboration between Inria and *Universitetet i Oslo* (UiO) initiated in 2008. SOCS (Self-Optimization of Cyber-physical Systems) focuses on the self-optimization issues in cyber-physical systems. Cyber-Physical Systems (CPS) are complex systems-of-systems that blend hardware and software to fulfill specific missions. However, traditional CPS are statically configured to achieve predefined goals, which not only limit their sharing and their reuse, but also hinder their sustainability. We believe that this waste of resources stems from the lack of agility of CPS to adapt to change in their environment or objectives. The SOCS Inria Lab takes advantage of the technologies developed as part of the APISENSE® crowd-sensing platform (see Section 6.1) to leverage the development of agile CPS.

9.1.2.5. LEDA

Participant: Philippe Merle [correspondant].

LEDA (2013–16) Laboratoire d'Expérimentation et de Démonstrations Ambiantes is a demonstration space allocated by the Inria Lille - Nord Europe Center whose goal is to show the scientific results of the Spirals team in the domains of distributed systems, adaptable middleware, software product lines, green computing, and ambiant computing. These results are illustrated around the scenario of a mock digital home.

9.2. National Initiatives

9.2.1. ANR

9.2.1.1. ANR BottleNet

Participants: Romain Rouvoy [correspondant], Walter Rudametkin Ivey, Lionel Seinturier.

BottleNet is a 48-month project funded by ANR that started on October 2015. The objective of BottleNet is to deliver methods, algorithms, and software systems to measure Internet Quality of Experience (QoE) and diagnose the root cause of poor Internet QoE. Our goal calls for tools that run directly at users' devices. We plan to collect network and application performance metrics directly at users' devices and correlate it with user perception to model Internet QoE, and to correlate measurements across users and devices to diagnose poor Internet QoE. This data-driven approach is essential to address the challenging problem of modeling user perception and of diagnosing sources of bottlenecks in complex Internet services. BottleNet will lead to new solutions to assist users, network and service operators as well as regulators in understanding Internet QoE and the sources of performance bottleneck.

9.2.1.2. ANR SATAS

Participants: Philippe Merle [correspondant], Romain Rouvoy, Lionel Seinturier.

SATAS is a 48-month project funded by ANR that started on October 2015. SATAS aims to advance the state of the art in massively parallel SAT solving with a particular eye to the applications driving progress in the field. The final goal of the project is to be able to provide a "pay as you go" interface to SAT solving services, with a particular focus on its power consumption. This project will extend the reach of SAT solving technologies, daily used in many critical and industrial applications, to new application areas, which were previously considered too hard, and lower the cost of deploying massively parallel SAT solvers on the cloud.

9.2.2. Competitivity Clusters

9.2.2.1. FUI Hermes

Participants: Laurence Duchien, Romain Rouvoy, Lionel Seinturier [correspondant].

Hermes is a 41-month project funded by FUI and labelized by the PICOM (Pôle des Industries du COMmerce) competitivity cluster which has started in August 2012. The partners are Norsys (leader), Keynosoft, Numsight, Cylande, Auchan, Brand Alley, Kiabi, Leroy Merlin, Univ. Lille 1, LIPN, LITIS. The goal of the project is to define a modular and context-aware marketing platform for the retail industry. The focus is put on the interactions with customers in order to extract and mine relevant informations related to shopping habits, and on a multi-device, cross-canal, approach to better match customer usages.

9.2.3. Programme Investissement d'Avenir (PIA)

9.2.3.1. PIA Datalyse

Participants: Filip Krikava, Romain Rouvoy, Lionel Seinturier [correspondant], Bo Zhang.

Datalyse is a 42-month project of the Programme Investissement d'Avenir Cloud Computing 3rd call for projects. The project started in May 2013. The partners are Eolas (leader), Business & Decision, Groupement des Mousquetaires, Université Grenoble 1, Université Lille 1, Inria, Université Montpellier 2. The project aims at defining an elastic cloud computing infrastructure for processing big volumes of data. The originality of the project is to consider jointly data generated by users and by the infrastructure, and to correlate data at these two levels.

9.2.3.2. PIA OCCIware

Participants: Romain Rouvoy, Philippe Merle [correspondant], Lionel Seinturier.

OCCIware is a 36-month project of the Programme Investissement d'Avenir Cloud Computing and Big Data 4th call for projects. The project started in December 2014. The partners are Open Wide (leader), ActiveEon SA, CSRT, Institut Mines-Télécom/Télécom SudParis, Inria, Linagora GSO, Obeo, OW2 Consortium, Pôle Numérique, and Université Joseph Fourier - Grenoble. The project aims at defining a formal framework for managing every digital resources in the clouds, based on *Open Cloud Computing Interface* (OCCI) recommendations from *Open Grid Forum* (OGF).

9.2.4. Inria National Initiatives

9.2.4.1. Inria ADT Focus CrowdLab

Participants: Clive Ferret-Canape, Julien Duribreux, Maria Gomez Lacruz, Christophe Ribeiro, Romain Rouvoy [correspondant], Antoine Veuiller.

The purpose of the ADT Focus CrowdLab (2014–2016) is to strengthen the technological part of the Metroscope consortium and to promote the APISENSE® crowd-sensing platform (see Section 6.1) as a reference platform fo gathering mobile data within the scientific community. The CrowdLab project focuses on three stringent goals: (1) consolidating the current technological solutions, (2) technical and logistical support of the research activities initiated in different scientific domains, and (3) the improvement of security and anonymity of collected data. In addition to the Metroscope consortium, the Inria research teams participating of the ADT Focus CrowdLab project are: Spirals (coordinator), Madynes, Diana, Muse.

9.2.5. Other National Initiatives

9.2.5.1. ADEME Web Energy Archive 2

Participants: Maxime Colmant, Loïc Huertas, Filip Krikava, Romain Rouvoy [correspondant], Lionel Seinturier.

Web Energy Archive 2 (WEA2) is a 12-month project funded in 2015 by ADEME. The purpose of the project is to define innovative solutions for measuring the energy consumption of web sites as experienced by users. The output of the project can be consulted on http://webenergyarchive.com where web sites are ranked based on their energy profile (from A to G, where A denotes web sites that are the more energy friendly). This project contributes to the development of our PowerAPI library (see Section 6.2).

9.3. European Initiatives

9.3.1. FP7 & H2020 Projects

Program: FP7 ICT.

Project acronym: PaaSage.

Project title: Model Based Cloud Platform Upperware.

Duration: October 2012–September 2016.

Coordinator: ERCIM.

Other partners: ERCIM (Fr), SINTEF (No), STFC (UK), U. of Stuttgart (De), Inria (Fr), CETIC (Be), FORTH (El), Be.Wan (Be), EVRY Solutions (No), SysFera (Fr), Flexiant (UK), Lufthansa Systems AG (De), Gesellschaft fur wissenschaftliche Datenverarbeitung mbh Gottingen (De), Automotive Simulation Center Stuttgart (De).

Abstract: Cloud computing is a popular and over-hyped concept in ICT. The concept of infinitely scalable elastic resources changing without complex systems administration and paying only for resources used is attractive. These benefits are not immediately realizable. Within organisation benefits are realizable at considerable cost. IaaS (*Infrastructure-as-a-Service*) public Clouds have different interfaces and conditions of use thus for an organisation to "scale out" requires considerable investment using skilled technical staff. The business need is to allow organisations to "scale out" from their private Cloud to public Clouds without a technical chasm between. This cannot easily be achieved. Aligned with the EU strategic direction of an open market for services, SOA (*Service-Oriented architecture*) offers a way to virtualize across heterogeneous public Clouds and organizational private Clouds. It opens a market for European SMEs to provide services to be utilized (and paid for) by business applications and for all organisations to benefit from a catalogue of services that can be used across the environment. PaaSage will deliver an open and integrated platform, to support both deployment and design of Cloud applications, together with an accompanying methodology that allows model-based development, configuration, optimisation, and deployment of existing and new applications independently of the existing underlying Cloud infrastructures. Specifically it will deliver an IDE (*Integrated Development Environment*) incorporating modules for design time and execution time optimisation of applications specified in the Cloud Modeling Language (Cloud ML), execution-level mappers and interfaces and a metadata database.

Participants: Laurence Duchien, Daniel Romero Acero [correspondant], Romain Rouvoy, Lionel Seinturier.

Program: FP7 FET.

Project acronym: DIVERSIFY.

Project title: More software diversity. More adaptivity in CAS.

Duration: 36 months (2013–16).

Coordinator: Inria.

Other partners: SINTEF (Norway), Trinity College Dublin (Ireland), University of Rennes 1 (France).

Abstract: DIVERSIFY explores diversity as the foundation for a novel software design principle and increased adaptive capacities in CASs (*Collective Adaptive Systems*). Higher levels of diversity in the system provide a pool of software solutions that can eventually be used to adapt to unforeseen situations at design time. The scientific development of DIVERSIFY is based on a strong analogy with ecological systems, biodiversity, and evolutionary ecology. DIVERSIFY brings together researchers from the domains of software-intensive distributed systems and ecology in order to translate ecological concepts and processes into software design principles.

Participants: Martin Monperrus [correspondant], Matias Martinez.

9.4. International Initiatives

9.4.1. Inria Associate Teams not involved in an Inria International Labs

9.4.1.1. SOMCA

Title: Self-Optimization of Service Oriented Architectures for Mobile and Cloud Applications

International Partner (Institution - Laboratory - Researcher):

Université du Québec À Montréal (Canada) - LATECE - Naouel MOHA

Start year: 2014

See also: http://sofa.uqam.ca/somca.php

The long-term goal of this research program is to propose a novel and innovative methodology embodied in an software platform, to support the runtime detection and correction of anti-patterns in large-scale service-oriented distributed systems in order to continuously optimize their quality of service. One originality of this program lies in the dynamic nature of the service-oriented environments and the application on emerging frameworks for embedded and distributed systems (*e.g.*, Android/iOS for mobile devices, PaaS/SaaS for Cloud environments), and in particular mobile systems interacting with remote services hosted on the Cloud.

9.4.2. Inria International Partners

9.4.2.1. Declared Inria International Partners

9.4.2.1.1. University of Los Andes, Bogota, Colombia

We have a long term collaboration since 2005 with this university. Over the years, four PhD thesis (Carlos Noguera, Carlos Parra, Daniel Romero Acero, Gabriel Tamura) have been defended in our team with students who obtained their MSc in this university. The first three were full French PhD, whereas the last one was a co-tutelle with this university. Professor Rubby Casallas from University of Los Andes is frequently visiting our team. The most recently defended PhD thesis, that of Gabriel Tamura, deals with QoS (quality-of-service) contract preservation in distributed service-oriented architectures. A formal theory to perform, in a safe way, the process of self-adaptation in response to quality-of-service (QoS) contracts violation has been proposed. The results have been published in [90], [88] and in the PhD thesis document itself [87].
Participants: Laurence Duchien [correspondant], Daniel Romero Acero, Romain Rouvoy, Lionel Seinturier.

9.4.2.1.2. University of Oslo, Norway

The scientific collaboration with this international partner deals with complex distributed systems that have to seamlessly adapt to a wide variety of deployment targets. This is due to the fact that developers cannot anticipate all the runtime conditions under which these systems are immersed. A major challenge for these software systems is to develop their capability to continuously reason about themselves and to take appropriate decisions and actions on the optimizations they can apply to improve themselves. This challenge encompasses research contributions in different areas, from environmental monitoring to real-time symptoms diagnosis, to automated decision making. The collaboration has been supported by the SEAS Inria associated team (2012-14).
Participants: Maria Gomez Lacruz, Daniel Romero Acero, Romain Rouvoy [correspondant], Lionel Seinturier.

9.4.3. Participation In other International Programs

9.4.3.1. STIC AmSud - Project MineAPI

Participants: Benoit Cornu, Maria Gomez Lacruz, Matias Martinez, Martin Monperrus [correspondant], Vincenzo Musco, Gérard Paligot, Romain Rouvoy.

MineAPI is a STIC AmSud project (2015–16) between with University Diego Portales, Santiago, Chile, and Federal University of Uberlândia, Brazil. The coordinator on the French side is Damien Cassou from the Inria/Lille1 project-team Rmod. The project aims at facilitating the usage of frameworks and application programming interfaces (APIs) by mining software repositories. Our intuition is that mining reveals how existing projects instantiate these frameworks. By locating concrete framework instantiations in existing projects, we can recommend to developers the concrete procedures for how to use a particular framework for a particular task in a new system. Our project also tackles the challenge of adapting existing systems to new versions of a framework or API by seeking repositories for how other systems adapted to such changes.

9.5. International Research Visitors

9.5.1. Visits of International Scientists

9.5.1.1. Internships

Mayank Gupta

Date: May 2015 - Jul 2015

Institution: Indian Institute of Technology Delhi (India)

Supervisor: Romain Rouvoy

Spyros Lalos

Date: August 2015 - October 2015

Institution: Technical University Munich (Germany)

Supervisor: Romain Rouvoy

10. Dissemination

10.1. Promoting Scientific Activities

10.1.1. Scientific events organisation

10.1.1.1. General chair, scientific chair

Martin Monperrus has been General Chair of the 2nd European Open Symposium on Empirical Software Engineering (EOSESE'2015), organized in Lille on 3 December 2014 in the context of EvoLille 2015.

Romain Rouvoy has been General Chair of (Compas'2015), that is the national research conference on parallelism, architecture, and system. The conference was held in Lille from 30 June to 3 July 2015.

10.1.1.2. Member of the organizing committees

Martin Monperrus has been member of the organization committee of the EvoLille'2015 scientific conference on software evolution and empirical software engineering that was held in Lille from 2nd December to 4th December 2015.

10.1.2. Scientific events selection

10.1.2.1. Chair of conference program committees

Romain Rouvoy is member of the Steering Committee of the IFIP International Conference on Distributed Applications and Interoperable Systems (DAIS) and the French conference Compas.

10.1.2.2. Member of the conference program committees

Laurence Duchien

International Software Product Line Conference (SPLC), track Vision

International Workshop on Software Engineering Research and Industrial Practice (SER&IP) at the ACM/IEEE International Conference on Software Engineering

European Conference on Software Architecture (ECSA)

IEEE International Conference on Cloud and Autonomic Computing (ICCAC)

BElgian-NEtherlands software eVOLution seminar (BENEVOL)

IEEE International Conference on Software Analysis Evolution and Reengineering Committee for Female Student Funding

Filip Krikava

Transformation Tool Contest (TTC) at the Software Technologies Applications and Foundations (STAF) International Conference

Philippe Merle

International Workshop on Combining Model-Driven Engineering and Cloud Computing (Cloud-MDE)

Intelligent Service Clouds Workshop (ISC) at the International Conference on Services Oriented Computing

International Symposium on Security in Computing and Communications (SSCC)

International Workshop on Adaptive and Reflective Middleware (ARM)

Conférence en Ingénierie Logicielle (CIEL)

Martin Monperrus

ACM /IEEE nternational Conference on Software Engineering (ICSE)

International Conference on Software Maintenance and Evolution (ICSME)

International Workshop on Computational Antifragility and Antifragile Engineering (ANTIFRAGILE)

Daniel Romero Acero

IEEE International Conference on Enabling Technologies: Infrastructure for Collaborative Enterprises (WETICE), track on Adaptative and Reconfigurable Service-Oriented and Component-Based Applications and Architectures (AROSA)

Romain Rouvoy

ACM/IFIP/USENIX International Middleware conference (Middleware)

Dependable and Adaptive Distributed Systems track (DADS) at the Annual ACM Symposium on Applied Computing (SAC)

Distributed Computing track (DC) of the International Symposium on Symbolic and Numeric Algorithms for Scientific Computing (SYNASC)

Vision Track of the International Software Product Line Conference (SPLC)

International Conference on Computer Communications and Networks (ICCCN)

International Conference on Ambient Systems, Networks and Technologies (ANT)

IEEE International Workshop on Big Data Management for the Internet of Things (BIOT)

International Workshop on Adaptive and Reflective Middleware (ARM)

International Workshop on Adaptive Services for the Future Internet (WAS4FI)

International Workshop on Software Architectures for Next-generation Cyber-physical Systems (SANCS)

International Workshop on Self-aware Internet of Things (Self-IoT)

International Workshop on Scalable Computing For Real-Time Big Data Applications (SCRAMBL)

Lionel Seinturier

IEEE/IFIP Conference on Software Architecture (WICSA)

International ACM Symposium on Component-Based Software Engineering (CBSE)

ACM Symposium on Applied Computing (SAC), tracks Software Architecture Theory Technology and Applications (SA-TTA), Operating Systems (OS), Software Engineering Aspects of Green Computing (SEGC)

International Workshop on Software Engineering for Smart Cyber-Physical Systems (SEsCPS) at the ACM/IEEE International Conference on Software Engineering

IEEE International Symposium on Software Crowdsourcing (ISCC)

IEEE International Conference on Service Oriented Computing & Applications (SOCA)

Australasian Software Engineering Conference (ASWEC)

International Workshop on Model-Driven Engineering for Component-Based Software System (ModComp)

Euromicro Conference on Software Engineering and Advanced Applications (SEAA), track Model-based development Components and Services (MOCS)

IEEE Service Visionary Track on Service Composition for the Future Internet (SCFI)

IEEE/ACIS International Conference on Software Engineering Research Management and Applications (SERA)

IEEE International Conference on Enabling Technologies: Infrastructure for Collaborative Enterprises (WETICE), track on Formal Verification of Service Based Systems (FVSBS)

Workshop on Patterns Promotion and Anti-patterns Prevention (PPAP)

Conférence francophone en sur les Architectures Logicielles (CAL)

10.1.2.3. Reviewer

Philippe Merle has reviewed papers for the International ACM SIGSOFT Symposium on Component-Based Software Engineering (CBSE).

10.1.3. Journal

10.1.3.1. Member of the editorial boards

Laurence Duchien is member of the editorial board of the journal Lavoisier Technique et Science Informatiques (TSI).

Martin Monperrus is member of the editorial board of the international journal Springer Empirical Software Engineering (IF-2014: 2.161).

Lionel Seinturier is editor for software engineering of the ISTE-Wiley Computer Science and Information Technology book collection.

10.1.3.2. Reviewer - Reviewing activities

Laurence Duchien: Elsevier Science of Computer Programming (SCP), Elsevier Journal of Systems and Software (JSS), Wiley Software Practice and Experience (SPE).

Philippe Merle: Elsevier Journal of Systems and Software (JSS), Lavoisier Technique et Science Informatiques (TSI), IEEE Cloud Computing.

Martin Monperrus: IEEE Transactions on Dependable and Secure Computing (TDSC), Wiley Journal of Software Testing, Verification and Reliability (STVR), Software Quality Journal (SQJ), Springer Empirical Software Engineering (EMSE), Communications of the ACM (CACM).

Romain Rouvoy: IEEE Computer, IEEE Internet of Things Journal, Lavoisier Technique et Science Informatiques (TSI), Journal of Network and Computer Applications (JNCA), Elsevier Computer Communications (COMCOM), Elsevier Science of Computer Programming (SCP), IEEE Journal of Software: Evolution and Process (JSME).

Lionel Seinturier: Elsevier Journal of Systems and Software (JSS), Elsevier Journal of Network and Computer Applications (JNCA), Science China Information Sciences (SCIS), Springer Journal of Internet Services and Applications (JISA), Wiley Software Practice and Experience (SPE).

10.1.4. Invited talks

Martin Monperrus gave on keynote in Barcelona at IEEE CNSM 2012, and an invited course on automatic repair at the Escuela de Ciencias Informáticas, a winter school held in Buenos Aires (Argentina).

10.1.5. Leadership within the scientific community

Laurence Duchien is the head of the CNRS GDR GPL (Génie de la Programmation et du Logiciel). GDR GPL gathers 700 researchers from 90 teams in the domain of software engineering and programming languages.

Martin Monperrus is the co-head of the "Groupe de Travail Génie Logiciel Empirique" of the GDR GPL.

Romain Rouvoy is the co-head of the "Groupe de Travail Composants Objets Services : Modèles, Architectures et Langages" of the GDR GPL.

10.1.6. Scientific expertise

Laurence Duchien was member of a recruitment committee for a Senior Research Scientist position at the University of Luxembourg, for a Full Professor Position at the University of Montpellier and at the University of Bordeaux, for a Full Professor and an Inria Chair at Ecole des Mines de Nantes. She is expert for Program Hubert Curien.

Philippe Merle was member of the recruitment committee for research engineers for Inria SED Lille and Grenoble.

Martin Monperrus has been expert for the Natural Sciences and Engineering Research Council of Canada (NSERC/CRSNG).

Romain Rouvoy has been expert for the Natural Sciences and Engineering Research Council of Canada (NSERC/CRSNG).

Lionel Seinturier has been expert for the EU COST program, the Swiss National Science Foundation, the Qatar National Research Fund, and the French DRRT. He was member of a recruitment committee for a Senior Research Scientist position at the University of Luxembourg.

10.1.7. Research administration

Laurence Duchien is member of the Scientific Advisory Board for the Certus Center of the Simula Lab Norway (2014-2016). She is member of the CNRS PEDR committee.

Philippe Merle is member of the scientific board of Inria. He is in charge of creating the Lille's instance of the Irill research and innovation institute on free software. He is vice-president of the CUMI (Comité des Utilisateurs des Moyens Informatiques), alternate member of the Comité de centre, member of the CLHSCT (Comité Local d'Hygiène, de Sécurité et de Conditions de Travail).

Romain Rouvoy is president of the CLDD (Commission Locale de Développement Durable), member of the CUB (Commission des Utilisateurs du Bâtiment), and member of the Horizon Startup committee for the Inria Lille - Nord Europe research center.

Lionel Seinturier is member of the CDT (Commission Développement Technologique), member of the CER (Commission Emplois Recherche), and scientific correspondant for DPEI (Direction Partenariat Europe et International), for the Inria Lille - Nord Europe research center. He heads the committee (so-called "vivier 27 rang A") that selects members of recruitment committees in Computer Science at University of Lille 1.

10.2. Teaching - Supervision - Juries

10.2.1. Teaching

Laurence Duchien teaches at the University of Lille 1, IEEA faculty. She heads the research program in Master of Computer Science at University Lille 1. She heads the Carrières et Emplois service and is referent for the professional insertion in the PhD program in Computer Science at ComUE University Lille Nord de France. She is also Director of Doctoral Studies for Computer Science in Doctoral School Engineering Science (SPI) - ComUE Lille Nord de France.

Software Project Management, 50h, Level M2, Master MIAGE,

Design of distributed applications, 42h, Level M1, Master of Computer Science,

Software Product Lines, 8h, Level M2, Master of Computer Science,

Research and Innovation Initiation, 22h, Level M2 IAGL, Master of Computer Science,

Tutoring Internship, 16h, Level M2, Master of Computer Science.

Martin Monperrus teaches at the University of Lille 1, IEEA faculty.

Introduction to programming, 48h, Level L1, Licence of Computer Science,

Object-oriented design, 39h, Level L3, Licence of Computer Science,

Automated software engineering, 40h, Level M2 IAGL, Master of Computer Science.

Romain Rouvoy teaches at the University of Lille 1, IEEA faculty. He heads the IAGL specialty of the Master of Computer Science at the University Lille 1. He supervises the Agil-IT Junior Enterprise.

Infrastructures et Frameworks Internet, 32h, Level M2 IAGL, Master of Computer Science,

Innovation & Initiation à la Recherche, 14h, Level M2 IAGL, Master of Computer Science speciality,

Outils pour la Programmation des Logiciels, 12h, Level M2 IAGL, Master of Computer Science,

Suivi de projets, 20h, Level M2, Master of Computer Science,

Suivi d'alternants, 20h, Level M2, Master of Computer Science.

Walter Rudametkin Ivey teaches at the University of Lille 1, Polytech engineering school.

GIS4 Programmation par Objets

GIS4 Architectures Logicielles

GIS2A3 (apprentissage) Projet programmation par Objet

IMA2A4 (apprentissage) Conception Modélisation Objet

GBIAAL4 Bases de données

Lionel Seinturier teaches at the University of Lille 1, IEEA faculty.

Conception d'Applications Réparties, 18h, Level M1, Master of Computer Science,

Infrastructures et Frameworks Internet, 6h, Level M2 E-Services and TIIR, Master of Computer Science.

10.2.2. Supervision

Defended HdR: Philippe Merle, Intergiciel d'intergiciels adaptable à base de services, composants et aspects, University Lille 1, 24 September 2015.

Defended PhD: Benoit Cornu, Automatic Analysis and Repair of Exception Bugs for Java Programs, 26 November 2015, Lionel Seinturier & Martin Monperrus.

Defended PhD: Marc Sango, Traceability of Concerns and Observer-Based Verification for Railway Safety-Critical Software, 18 September 2015, Laurence Duchien & Christophe Gransart.

In progress PhD: Yahya Al Dhuraibi, Un cadre flexible pour l'élasticité dans les nuages, October 2015, Philippe Merle.

In progress PhD: Stéphanie Challita, Un cadre formel et outillé pour la gestion de toute ressource en nuage, October 2015, Philippe Merle.

In progress PhD: Thomas Durieux, Search-based Monitoring and Root Cause Diagnosis in Production, September 2015, Lionel Seinturier & Martin Monperrus.

In progress PhD: Maria Gomez Lacruz, Self-Optimization of Software Systems Driven by Wisdom of the Crowds, October 2013, Lionel Seinturier & Romain Rouvoy.

In progress PhD: Geoffrey Hecht, Auto-optimisation des architectures orientées services : Application aux applications mobiles et Cloud, October 2013, Romain Rouvoy.

In progress PhD: Vincenzo Musco, Etude de la topologie et de l'évolution des graphes logiciels, October 2013, Philippe Preux (Inria SequeL) & Martin Monperrus.

In progress PhD: Gustavo Sousa, Towards dynamic software product lines to optimize management and reconfiguration of cloud applications, October 2012, Laurence Duchien & Walter Rudametkin Ivey.

In progress PhD: Amal Tahri, Evolution logicielle multi-vues, des réseaux domestiques au Cloud, March 2013, Laurence Duchien.

In progress PhD: Bo Zhang, Elasticité spontanée des services et infrastructures dans le Cloud, October 2013, Lionel Seinturier & Romain Rouvoy.

10.2.3. Juries

Laurence Duchien

HDR Reda Bendraou (Université Paris 6), reviewer

HDR Jean-Rémy Falleri (University of Bordeaux), reviewer

HDR Anis Sharfi (Université of Nice-Sophia Antipolis), reviewer

Marc Sango (University Lille 1), director

Jonathan Aceituno (University Lille 1), chair

Radu Ciucanu (University Lille 1), chair

Fabien Gilson (University of Namur), reviewer

Sam Rottenberg (Telecom SudParis), reviewer

Shuai Wang (University of Oslo), reviewer

Jakub Zwolakowsi (University Paris VII), reviewer

Jacob Geisel (Université of Toulouse), examiner

Vincent Lanore (ENS Lyon) Dec 2015, examiner

Martin Monperrus

Benoit Cornu (University Lille 1), co-supervisor

Romain Rouvoy

Codé Diop (INSA Toulouse), reviewer

Ivan Paez (University of Rennes 1), reviewer

Paul van der Walt (University of Bordeaux), reviewer

Lionel Seinturier

HDR Rémi Douence (University of Nantes), reviewer
HDR Patricia Stolf (University of Toulouse), reviewer
HDR Philippe Merle (University Lille 1), examiner
Benoit Cornu (University Lille 1), director
Damien Riquet (University Lille 1), chair
Nour Assy (Telecom SudParis), reviewer
Thomas Calmant (University of Grenoble), reviewer
Cédric Eschler (University of Toulouse), reviewer
Leandro Fountoura-Cupertino (University of Toulouse), reviewer
Ilias Gerostathopoulos (Charles University Prague), reviewer
Pierre Samson (University of Pau), reviewer
Abderrahmane Seriai (University Bretagne Sud), reviewer
Borjan Tchakaloff (University Bretagne Occidentale), reviewer
Ghada Ben Nejma (University of Pau), examiner

10.3. Popularization

Julien Duribreux and **Antoine Veuiller** has given a demonstration of the APISENSE® crowd-sensing platform (see Section 6.1) at the RIC day in September. The event targets students from computer science master programs and engineering schools in Lille.

Loïc Huertas has participated in June to Rencontres Inria Industries (RII) Futur en Seine organized by the Paris Rocquencourt research center where he presented the PowerAPI software library (see Section 6.2) for energy monitoring of software systems.

Lionel Seinturier has participated in October to the event Chercheur itinérant organized by the Inria Lille Nord Europe research center in the context of La Fête de la science. Two classrooms (2nde and 1ère) have been visited. The theme of the visit was crowd-sensing and data gathering from mobile devices.

11. Bibliography

Major publications by the team in recent years

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[2] M. COLMANT, M. KURPICZ, P. FELBER, L. HUERTAS, R. ROUVOY, A. SOBE. *Process-level Power Estimation in VM-based Systems*, in "European Conference on Computer Systems (EuroSys)", Bordeaux, France, T. HARRIS, M. HERLIHY (editors), EuroSys'15: Proceedings of the Tenth European Conference on Computer Systems, ACM, April 2015, 14 p. [*DOI :* 10.1145/2741948.2741971], https://hal.inria.fr/hal-01130030

[3] G. HECHT, B. OMAR, R. ROUVOY, N. MOHA, L. DUCHIEN. *Tracking the Software Quality of Android Applications along their Evolution*, in "30th IEEE/ACM International Conference on Automated Software Engineering", Lincoln, Nebraska, United States, L. GRUNSKE, M. WHALEN (editors), Proceedings of the 30th IEEE/ACM International Conference on Automated Software Engineering (ASE 2015), IEEE, November 2015, 12 p. , https://hal.inria.fr/hal-01178734

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M. GOMEZ, R. ROUVOY, M. MONPERRUS, L. SEINTURIER. *A Recommender System of Buggy App Checkers for App Store Moderators*, in "2nd ACM International Conference on Mobile Software Engineering and Systems", Firenze, Italy, D. DIG, Y. DUBINSKY (editors), IEEE, May 2015, https://hal.inria.fr/hal-01117376.

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