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2015: A pivotal year for Certus

Certus was due for its midway evaluation in 2015, and after a thorough and rigorous process led by the Research Council of Norway, the Certus Centre was given the green light to continue its operations. This is the result not only of the strong effort from our researchers and engineers in collaborative research and innovation projects, but also of the support of the Certus board, which must be congratulated for its decisive role in the process. The international evaluation panel recognized the quality of our research activities and encouraged us to increase our effort to consolidate the future of the Centre. The recommendations of the panel were carefully analysed and answered, ensuring that our plans for the upcoming three years are clear and ambitious. The year also saw the start of the European U-TEST project, studying the testing of cyber-physical systems in uncertain environments, funded through the H2020-LEIT programme. This project builds on advanced research results on the modelling and testing of highly-configurable systems obtained within Certus. In 2015, we were also honoured by the successful defence of three PhD students funded through Certus or related projects, on scientific topics directly related to software validation and verification.



For these reasons, amongst others, 2015 can be seen as a pivotal year for Certus, as it closes one period and embarks on a new era, where new and ambitious research projects will be launched. In particular, we have decided to open up three PhD positions in strategic scientific directions, namely, validation and verification of data-centric systems using collective intelligence, constraint-based validation, and verification of robotic systems and machine-learning to ensure anti-fragile systems. Building on our exploitation policy, Certus will also continue to foster innovation through the realization and deployment of tools and methodologies developed in the Centre. The DEPICT tool for assessing the quality of test campaigns will be deployed on a larger scale in 2016, and the CRYSTAL platform, through a stronger development process, will be put to work in the hands of the Certus partners. As part of the European strategy of Certus, the partners will establish stronger partnerships with European research institutions and companies in 2016. Building on its national success stories, Certus will benefit from its de-facto leading status to attract highly qualified personnel, scientific collaboration, and funding from European institutions. On the industrial side, in addition to partnerships with major companies entered into during the writing of H2020 proposals, Certus will increase its knowledge and development network in Europe. In 2016, a strong effort will be undertaken to reinforce the participation of Certus researchers and engineers with promising European consortia, and the partners will be encouraged to lead European initiatives. I strongly believe that the time has come to engage the Centre in a larger effort of dissemination and communication of its strong research and innovation results, at the European level.

Arnaud Gotlieb Leader of Certus SFI "Building on our exploitation policy, Certus will also continue to foster innovation through the realization and deployment of tools and methodologies developed in the Centre"

Shifting gears

During 2015, Certus went through its obligatory mid-term evaluation, organised by the Research Council of Norway (RCN) and conducted by international experts. This process gave a valuable opportunity to contemplate the past and create a roadmap towards the future. In such evaluations, the RCN explicitly asks for the centre's exit strategy. Although we are talking about the exit from the rather safe (but temporary) haven of a largely publicly funded project, a more appropriate order would be to really flesh out the centre's exploitation strategy. Because that is what it is all about: How should we manoeuvre to best possible harvest the fruits of eight years hard work and the investments in personal and organisational relationships within the consortium?

In its plans for the remaining project period, Certus puts particular emphasis on building a hub of technology and competence that is capable of serving and being attractive to a variety of software-demanding industries and public agencies. One particularly strong undercurrent that will help us get there is to continuously involve the centre in strategically important collaborations through H2020 projects and national funding instruments that supports industrial and public sector R&D collaboration. Observing that the Norwegian economy is taking a tough blow these days, due to the downhill slide of oil and gas prices, this shift of gears is needed more than ever. While there has been much talk about Norway moving more into knowledgebased industries in a post-oil reality, the boundary conditions have changed so rapidly that it is now really need for action and not only speeches. Certus is determined to be part of this transformation.

With its four past years of industrial collaboration on how to make software systems more safe and robust, Certus is now moving into a new phase. The user partners will be challenged to more actively drive the research and innovation processes. In Certus, this is also reflected in a deliberate change of leadership in the board. Professor Are Magnus Bruaset, who chaired the Certus Board for the first four years, puts it this way: "Now that the research foundation of Certus is in place, the time has come to increase the dosage of industrial leadership in the centre". The new Chair of the Board, Director Jan Christian Kerlefsen from the Certus partner ABB Robotics takes over from January 1, 2016. He brings deep insight in business and market needs, while at the same time he has his origin in research at the Norwegian Computing Center and at Sony in Japan.



Pictured from left to right: Katrine Langset, Customs and Excise; Bjørn Ove Olafsen, Kongsberg Maritime; Are Magnus Bruaset, Simula; Jan-Christian Kerlefsen, ABB Robotics; Marius Liaaen, Cisco; Arnaud Gotlieb, Centre leader.

"Coming from an applied research background, I am excited about the SFI instrument and the possibilities to leverage on the cooperation between world class research and world class industrial software development. I am really looking forward to continue the fruitful cooperation with the centre leader Arnaud Gotlieb and the consortium.

During the lifetime of the centre, we produce research, we arrange workshops and we run value-creating projects for the partners. With all the public funding given to the centre, I also feel a strong obligation to create something that will continue to deliver value after the SFI period. In the exit strategy, we are discussing a Certus Testing Laboratory. We do not yet have a clear picture of what this will be, but we will continue to discuss this and other ideas in the consortium", says Kerlefsen. (second from the right). In the mid-term evaluation report, the centre was especially acknowledged for the quality of its research. Going forward, we want to make sure we transform the research into notable contribution to the industrial and public administration domains, also after the SFI period. We know that this is not straight forward, but we also know that we have the best possible team to achieve this target.

Professor Are Magnus Bruaset Chair of the Certus Board, 2011 – 2015 Director of Computing and Software Simula Research Laboratory

Jan Christian Kerlefsen

Chair of the Certus Board from 2016 Managing director and R&D Manager ABB Robotics

The Certus Centre: Purpose and vision

Certus is a research-based innovation centre that unites some of the brightest minds in software validation and verification research. The centre has evolved since its founding in 2011, but its key goals remain intact.

For the uninitiated, software validation and verification may seem hard to pin down. But for industry and the public sector, these are highly specific, mission- critical tasks. A common definition of so-called 'V&V' refers to the process of ensuring that software systems meet their specifications, and that they are capable of fulfilling their intended purpose.

Software failures in industry and the public sector do occur, despite the vast resources dedicated to their development and implementation. Even the best are susceptible to breakdowns, and the high cost of repair is often matched by the damage to reputation that enterprises suffer when failsafe systems actually do fail.

For every such failure there is a reason, and Certus believes these reasons are knowable, and preventable, given the proper perspectives and insight. One of the key contributions that Certus is making to prevention of systems failure is ensuring the necessary technology transfer from the research community to industrial practice.

Lack of communication between research and industry goes both ways: academic researchers may possess only a superficial understanding of the challenges faced by industry in software validation and verification, while software engineers may not be properly trained or sufficiently equipped with methodologies and tools to enable them to prevent the introduction of software faults.

To overcome these challenges, the Certus partners maintain communication at a high level between the core group of academic researchers based at the host partner, Simula Research Laboratory, and industry and public sector partners. The user partners employ a representative cross-section of industry and public sector software applications. Certus' goal is to produce research that results in useable methodologies and tools for all the partners, with the ultimate goal of ensuring robust software operations.

The Certus centre has established a body of methods and tools for the validation and verification of softwareintensive systems.

Three types of system have evolved as the main focus areas for innovative V&V methods:

- Real-time embedded software systems, or software and hardware integrated systems with limited resources and means of communication with their environment. Typically, these systems embed a set of dedicated applications running over a real-time operating system and are subject to real-time constraints.
- 2) Highly configurable software systems, or families of software and hardware systems for which software reuse is a major concern. Many commonalities and variables exist between products in such a family. Facilitating reuse will significantly improve the overall quality and productivity of product development.
- **3**) Data-intensive software systems, or software applications built on one or more database management systems that deal with large amounts of data. These applications typically have to store, retrieve, and process millions of data entries.



The Certus centre's scientific activities are focused on four projects, addressing 1) model-based engineering for highly configurable systems 2) testing of data-intensive systems 3) testing of real-time embedded systems, and 4) smarter testing of evolving software systems. In addition, there are three other projects dedicated to administration, communication, and dissemination. A final project is related to industrial exploitation.

Now in its fifth year of operation, Certus can claim not only that its partners have implemented prototype tools and performed experimental studies, but also that some of these tools have been deployed and are running on-going exploitation. Five technologies were already promoted as exploitable tools and methods and three of them deployed in the software development processes of some of the partners of the Certus consortium (TITAN, DEPICT and ABB's Constraint Model).

Key Figures

The Certus Centre annual accounts for 2015 are presented below. The funding is presented in standard setup used by the Research Council of Norway where "Own financing" refers to funding provided by the host institution, other "public funding" refers to funding provided by the Norwegian Customs and Excise while "other private funding" refers to funding provided by the remaining user partners.

Cost in NOK 2015	
Payroll / indirect expenses	19 842 976
Equipment	122 918
Other operating expenses	1 311 461
Totals	21 277 355
Eunding in NOK 2015	
Funding in NOR 2015	
Own financing	5 754 072
Own financing Other public funding	5 754 072 895 400
Own financing Other public funding Other private funding	5 754 072 895 400 4 617 883
Own financingOther public fundingOther private fundingFrom the Research Council	5 754 072 895 400 4 617 883 10 010 000

The Certus midway evaluation: Passing the halfway marker

The Certus Centre is a centre for research-based innovation (SFI in Norwegian), awarded by the Research Council of Norway (RCN). Halfway through its funding period, every RCN-funded centre goes through a thorough midway evaluation, which took place in early 2015 for Certus. The purpose of the midway evaluation is to aid the Research Council in determining whether the centre in question should continue for the full eight-year term, or if it should wind down after just five years of running time. Another purpose of the evaluation is to give general advice to the Centre, based on its performance, strengths and weaknesses at the important middle stage.

The evaluation was based on written reports by key Certus personnel, which were approved by the Certus Board, and on the interviews that took place during the evaluation meeting on March 11th, 2015. Centre Leader Arnaud Gotlieb, along with some project leaders, PhD students, postdoctoral candidates, representatives of Simula, and the user partners, were present for the occasion, and the evaluation committee was composed of an international panel of four renowned experts specialising in Software Engineering and Innovation.

Certus was congratulated on generating high quality research, which has been disseminated appropriately, and further praise was given for the high level of conferences and publication in journals by its researchers. In a fast moving field of research and industry, the evaluation committee underlined the importance of keeping up to date, also for PhD students and post docs, and the committee found that this was the case within Certus. With regards to innovation, Certus was congratulated on the high quality of its collaborative activity among the partners, and the production of strong innovative tools in the domain of software validation. However, the committee recommended that more PhDs should be recruited in order to increase the capacity of the Centre, and to strengthen international competitiveness. Appropriately, Certus had already started the recruitment of three additional PhD students when the evaluation feedback was returned. The Centre was carrying out its plans for expanding the number of research topics with these new hires, which aligned nicely with the recommendation made by the committee.

Further recommendations from the committee included strategic collaboration with key international centres and inclusion of Norwegian universities as partners of the consortium. In keeping with the aim of centralising Certus' leadership, and maintaining the Centre's focus squarely on industry-related scientific innovation and results, the Centre has decided to prioritize the recommendation to establish strategic collaboration with other international similar centres. Although Certus is already engaged in collaboration with some international key centres, expanding on this work would give new perspectives on how to further build on Certus' exit strategy.

The last recommendation made by the evaluation committee is that the business model for the second chapter of Certus' existence as an SFI be re-evaluated, and that the Centre should consider appointing a Chair of the Board, and a Scientific Advisory Board, that are separate from the host institution. Tighter industrial bonds will arguably strengthen Certus as the Centre disconnects from RCN funding. Certus had anticipated this recommendation, and had already appointed Jan-Christian Kerlefsen to be named as Chair of the Board from 01.01.2016. In addition to this change, the SAB of Certus will be separated from that of Simula.

As a final remark, Certus board members and management, researchers and engineers involved in the midway evaluation acknowledged the high quality of the evaluation process carried out by the Research Council, and expressed appreciation for the effectiveness of the review in delivering highly relevant appreciations and recommendations. **Tighter industrial bonds will** arguably strengthen Certus as the Centre disconnects from RCN funding.

Innovation results

Industrial exploitation in Certus continues to focus on developing research results into tools of value for the industrial and public administration sectors. Several tools have sprung out from this collaborative effort, and in 2015, we continued the development of our established technologies while developing new tools to face the ever-evolving challenges of large-scale data.

HaRT

Regression testing is performed after a software system has been changed, to provide confidence that the changes do not negatively affect the behaviour of unchanged parts in the software. Typically, a test suite is executed on a system before and after changes are made, with the explicit requirement that tests should have similar outcomes in both cases. However, as the software evolves, test suites tend to grow in size, become outdated, or overlap with other parts, rendering it prohibitively costly to retest a complete test suite.

In response to this challenge, we have developed HaRT (History-based Recommendations for Testing), a novel technology that uses machine learning to recommend relevant test cases to execute based on changes made to the system, effectively maximizing the value of the test suite while reducing overall testing costs. Preliminary experiments carried out in collaboration with Cisco Norway and Kongsberg Maritime showed that HaRT is efficient and effective in deriving relevant test recommendations for industrial systems.

Activities for 2016 and onward include refining the technology to make it more universally applicable, further improving the prioritization of recommendations so that the most relevant tests can be executed first, and investigating opportunities to integrate the technology in our partners' software development processes.

Depict

Depict – Discovering Patterns and Interactions in Databases – was initially created by the Certus Centre in collaboration with the Directorate of Norwegian Customs (TOD), formerly Directorate of Customs and Excise (TAD). TOD has continued to use Depict in 2015 to verify the completeness of some of their testing efforts.

At TOD, Depict is used for a specific monitoring task of test environments during test phases. The model used provides information about the level of input data for batch jobs archiving this data. The result from Depict is used to evaluate which batch job to run so that the amount of data in the main databases is at all times optimized and kept as low as possible.

SQL queries used for this purpose are usually created and stored individually, and people tend to rewrite them each time instead of reusing old ones. Depict offers validation engineers a better overview, as it is a tool where a correct set of queries (models) are made available to everyone. The tool is easy to use, and results from executions can be saved. The potential for exploitation is great, both in "ordinary unit and system test" and in more specialized tests, such as comparison tests. Depict stands out as a robust tool for extracting data from large relational databases based on the idea of detecting interactions.

At ESITO, other usages of Depict have been explored. Because many systems are tested using live data, finding a way for developers and testers to use Depict to discover relevant test data and pinpoint test cases for which no relevant data exists in the current database, is promising. Another possible usage of Depict is to regularly verify data completeness according to a set of (complex) business rules. These promising exploitations of Depict will continue to be explored and experimented with in 2016.

Crystal

Crystal aims to provide some answers to the following challenges: How to improve software functionality sharing and reuse in the context of different applications; and how to guarantee access to data from heterogeneous sources?

Complex configurations, where parts of a system are deployed on several machines, can be easily obtained. They are most often used when an interaction between an isolated environment and an external system is needed for some specific computations. Crystal is a versatile platform, and its underlying model may be exploited in many different contexts. We are currently implementing a software collaborative testing platform on top of the Crystal platform. In 2015 we started the design of the overall architecture and the implementation of a first prototype of a set of services related to test suite sub-setting and minimization. Plans for 2016 are to add more services and high-level functionalities.

TITAN

With the increase of software complexity and size, followed by the increase of user expectations, companies are constantly facing challenges of implementing efficient test strategies able to fit limited test budgets, and ever-shortening test cycles. The TITAN project is developing an innovative software testing technology intended for companies with limited testing resources, and high requirements for software quality. The technology was initially developed in interaction with the Certus partners, and later in collaboration with external partners. Through efficient test optimization techniques, TITAN technology helps enhance product quality, reduce risks and control testing costs. The technology automates and optimizes several stages in software testing processes, balancing expenditure and quality of testing.

In 2015, the technology was pilot-tested and proved its viability in a commercial setting. Our plans going forward include further technical development and business modelling, towards a unique value proposition and the best product-market fit. The TITAN project is supported by the Research Council of Norway through the FORNY2020 program, which aims at creating value and benefits for society from research results. The program funds the results from projects conducted at publicly funded research institutions, and helps bringing them closer to the market.

Certus Centre partners

Scientific Projects

Project 2: Industrial Exploitation
Project 5: Model-Based Engineering for Highly Configurable Systems
Project 7: Testing of Data-Intensive Systems
Project 8: Testing of Real-Time Embedded Systems (RTES)
Project 9: Smarter Testing of Evolving Software Systems

User partners

[simula . research laboratory]

Projects: 2, 5, 7, 8, 9

Simula Research Laboratory is a non-profit public utility enterprise that performs leading international research within selected fields of information and communications technology (ICT). In 2012, Simula was ranked first in the national evaluation of ICT research conducted by the RCN. Certus' long-term perspective and strong industrial profile give Simula a unique opportunity to further expand and enhance its position as a leader in software validation and verification research. The Certus centre is one of several research-based innovation projects at Simula within this field.

ABB

Projects 7, 8

ABB Robotics is a leading supplier of industrial robots and modular manufacturing systems and services. Their work in the Certus centre focuses on painting systems embedded in industrial robots. Robotics software is a complex, configurable, and highly distributed embedded system. As with other technologies and domains, there is a trend to implement more functionality in software running on general hardware. One of the areas identified for adaptation to new requirements is the improvement of testing speed and quality. ABB Robotics believes that the key features of a new testing infrastructure should include extensive automatic testing, continuous integration, and the smart selection of test cases. To address this, an ABB Robotics principal engineer started an industrial PhD in 2012 as part of a Certus project, supervised by the Certus centre and University of Stavanger. The PhD concluded in 2015 and the results were exploited at ABB Robotics. Moreover, ABB is also aiming at implementing this research within ABB Robotics' global research and development organization. ABB Robotics became a full partner of Certus in 2014 and will rely on continuous support from researchers at the centre for its implementation project.

Projects: 2, 7, 8, 9

Cisco Systems Norway specializes in videoconferencing systems (VCSs) and manufactures a broad selection of products designed to achieve telepresence. Cisco's communication systems play a central role in several business and safety-critical domains, including healthcare and energy. As companies become more global, effective ways to support remote collaboration and minimize travel become essential.



Projects: 2

ESITO is an ICT company that develops and market software tools supporting domain driven design and development. "g9" is a tool that mainly is used in development of mission-critical applications. ESITO's vision is to utilize domain knowledge captured in models and offer its customers tools that give lower lifetime cost and better quality by utilizing models and domain driven design in their application development.



KONGSBERG

Projects: 5, 8, 9

Kongsberg Maritime is one of the largest suppliers of programmable marine electronics worldwide. They deliver systems for dynamic positioning and navigation, marine automation, cargo management and level sensors, maritime training simulators, and position reference systems. These products are paramount in ensuring the reliability and correct functioning of offshore and shipyard systems.

TOLL CUSTOMS

Projects: 2, 7

Customs is an agency under the Ministry of Finance. Customs carries out a number of enforcement tasks related to the import and export of goods. Customs delivers and maintains a large portfolio of systems for handling customs in Norway. Their systems have high requirements regarding data integrity, availability, and security.

Certus 2015 highlights

Shuai Wang successfully defended his PhD thesis titled "Systematic Product Line Testing: Methodologies, Automation, and Industrial Application". His research activity was fully developed in the context of Project 8 at Certus. After his defense, Wang started working as a Postdoctoral Fellow in the Certus-adjacent RCN-supported MBE4CRN project.

Morten Mossige successfully defended his PhD thesis titled "Testing Robotics Software using Constraint Programming in a Continuous Integration Process", related to task 8.3 of Project 8. This work, organized as a collaboration between ABB Robotics, Simula Research Laboratory and the University of Stavanger, is also the main result of a Certusadjacent RCN-supported 'Nærings-PhD' project at ABB Robotics. Since his defense, Mossige has been promoted to senior principal engineer at ABB.

Stefano Di Alesio successfully defended his PhD thesis "Supporting Stress Testing of Real-Time Systems with Constraint Programming". The work has been conducted at Simula Research Laboratory in collaboration with the Interdisciplinary Centre for Reliability, Security and Trust (SnT) at the University of Luxembourg. Following his defense, Di Alesio started working as a Postdoctoral Fellow in the RCN-supported EvolveIT project that is closely aligned with Certus Project 9. Dr. Leon Moonen, senior research scientist and leader of Project 9, organized the second High Integrity Systems Symposium (HISS 2015). HISS 2015 brought together researchers and practitioners from various domains, such as air traffic control, space, e-health, robotics, e-voting/egovernment, energy/nuclear, railways, and communication infrastructure, creating a platform where industry and research can meet and discuss needs, challenges and opportunities in the area of high integrity systems. As part of HISS 2015, the Norwegian High Integrity Systems Forum (HISF) was launched. HISF is a national network to organize practitioners and researchers interested in discussing the challenges and opportunities in high integrity software and system engineering.

Dr. Arnaud Gotlieb, leader of the Certus Centre published a chapter entitled "Constraint-based testing: An emerging trend in software testing" in the book Advances in Computers, edited by Atif Memon, Elsevier, 2015. The chapter reports on the most promising advances of constraint-based testing partly developed as a Certus scientific activity. The collaborative research activities performed in the Certus projects with two of the partners in the consortium, ABB and Cisco, offered the centre leader the opportunity to explore in depth the industrial adoption of the constraint-based testing technology.

From July to September 2015, an ABB advanced industrial robot was demonstrated in Simula's facilities at Fornebu. The robot ran an activity programme showing the capabilities of constraint programming for test case generation and software testing. A video for demonstrating the constraint-based testing approach designed for the robot was created and made available on the Certus website.

Chairs & scientific activities

Chairs

Certus researchers have been selected to chair and participate in prestigious scientific committees. Committee membership is not merely volunteer work. Membership is by invitation only, and these invitations are some of the hardest to come by in the software engineering world.

Arnaud Gotlieb

Program committee member:

- CP'15 21st International Conference on Principles and Practice of Constraint Programming. August 31-September 04, 2015, Cork, Ireland.
- IJCAI'15 International Joint Conference on Artificial Intelligence. July 25-31, 2015, Buenos Aires, Argentine.
- TAP'15 10th Int. Conf. on Tests and Proofs. July 20-24, 2015, L'Aquila, Italy.
- LOPSTR'15 25th Int. Symp. on Logic-Based Program Synthesis and Transformation. July 13-15, 2015, Siena, Italy.

PhD symposium co-chair (and Program committee member):

 ICST'15 - IEEE Intl Conf. on Soft. Testing, Verif. and Valid. April 13-17, 2015, Graz, Austria.

Finance co-chair:

FM'15 - 20th International Symposium on Formal Methods. June 22-26, 2015, Oslo, Norway.

Tao Yue

Program Committee Member:

- MODELS'15 ACM/IEEE 18th International Conference on ModelDriven Engineering Languages and Systems. September 30-October 02, 2015, Ottawa, Canada.
- RE'15 23rd International Conference on Requirements Engineering. August 24-28, Ottawa, Canada.
- QRS'15 IEEE International Conference on Software Quality, Reliability & Security. August 03-05, 2015, Vancouver, Canada.
- COMPSAC'15 IEEE 39th Annual International Computers, Software & Applications Conference. July 01-05, 2015, Taichung, Taiwan.
- SPLC'15 20th International Systems and Software Product Line Conference. July 20-24, 2015, Nashville, USA.

Dusica Marjan

Program Committee Member:

- QRS'15 IEEE International Conference on Software Quality, Reliability and Security. August 03-05, 2015, Vancouver, Canada.
- COMPSAC'15 IEEE Annual International Computers, Software & Applications Conference. July 01-05, 2015, Taichung, Taiwan.
- CAISE'15 International Conference on Advanced Information System Engineering. June 08-12, 2015, Stockholm, Sweden.

Chairs & scientific activities

Shaukat Ali

Program Committee Member:

- MODELS'15 ACM/IEEE 18th International Conference on ModelDriven Engineering Languages and Systems. September 30-October 02, 2015, Ottawa, Canada.
- ECMFA'15 European Conference on Modelling Foundations and Applications. July 20-24, 2015, L'Aquila, Italy.
- ICST'15 IEEE International Conference on Software Testing, Verification, and Validation. April 13-17, 2015, Graz, Austria.
- SPLC'15 20th International Systems and Software Product Line Conference. July 20-24, 2015, Nashville, USA.

Program Co-Chair (and Program Committee membership):

A-MOST'15 - Workshop on Advances in Model Based Testing. April 17, 2015, Graz, Austria.

Sagar Sen

Program Committee Member:

 ISSRE 2015 - 26th International Symposium on Software Reliability Engineering. November 02-05 Ottawa, Canada.

Leon Moonen:

General Chair:

 HISS'15 - 2nd High Integrity Systems Symposium. June 03, 2015, Oslo, Norway.

Program Committee Member:

- SANER'15 22nd IEEE International Conference on Software Analysis, Evolution, and Reengineering. March 02-06, 2015, Montréal, Canada.
- BENEVOL'15 14th BElgian-NEtherlands software eVOLution seminar. December 03-04, 2015, Lille, France.

Program Chair (And Steering Committee membership):

- ICPC'15 IEEE International Conference on Program Comprehension. May 18-19, 2015, Florence, Italy.
- SCAM'15 IEEE International Working Conference on Source Code Analysis and Manipulation. September 27-28, 2015, Bremen, Germany.

Other Scientific Activities

- At the beginning of 2015, Shuai Wang visited Professor Enrique Alba (University of Malaga) for broadcasting the work of Testing of Real-Time Embedded Systems and discussed potential collaboration possibilities.
- In November 2015, Certus Center leader Arnaud Gotlieb visited CRIM (Centre de Recherche en Informatique de Montréal) in Canada, where he met the current leader for CRIM, discussing possible synergetic collaborations at the international level.
- On proposition of the Certus Centre, Shuai Wang, who is the appointed leader of Project 8, was nominated for COST Action CA15140: Improving Applicability of Nature-Inspired Optimisation by Joining Theory and Practice (ImAppNIO) management committee (MC) membership.
- As part of HISS 2015, organised and chaired by Leon Moonen, leader of Project 9, the Norwegian High Integrity Systems Forum (HISF) was launched. HISF is a national network to organize practitioners and researchers interested in discussing the challenges and opportunities in high integrity software and system engineering.
- Sagar Sen, leader of Project 7, with the help of Dusica Marijan and Arnaud Gotlieb, wrote an article portraying how Certus is organised as a centre, including its methods for collaboration with industry partners. The objective of this article is the belief that it would be beneficial for people who would like to set up similar centres.

- Adjacent to Project 7 under the lead of Sagar Sen, the SOIGNONS project conducted with the Cancer Register of Norway, was launched in 2015. In this context, two master's students, Waqas Moazzam Butt and Marek Machnik, presented their work on social mobile apps to engage people into addressing societal challenges. These works were in inter-departmental collaboration with Michael Riegler of the multimedia department in Simula who assisted Sagar Sen in the supervision of the students.
- In collaboration with Inria Rennes, France, Arnaud Gotlieb has published a paper on the synthesis of variability models from product descriptions at SPLC'15.
- In collaboration with University of Nantes, France, Sagar Sen, leader of Project 7, presented his work with Jean-Marie Mottu of the University of Nantes on precondition discovery through automated test generation at ISSRE'15.
- In the context of Project 9, Prof. Dave Binkley from Loyola University of Maryland, USA, was invited by Leon Moonen for a 3-month visit at Simula during summer 2015.
- In the context of Project 8, Centre leader Arnaud Gotlieb visited Professor Camille Salinesi and his research group at University of Paris 1 (Panthéon – La Sorbonne). The centre leader gave a seminar talk at this occasion on Certus and some of its upmost recent results. In return, Professor Salinesi visited Certus researchers at Simula at the end of 2015 and discussed possible opportunities for collaboration.

Project 5: Model-Based Engineering for Highly Configurable Systems

Description

Model-Based Engineering (MBE) technologies make it possible to reduce the complexity of developing highly configurable systems by capturing information at a higher level of abstraction, providing a knowledge-sharing mechanism for communication between stakeholders, and enabling automated analysis. The project aims to develop MBE methodologies to support requirements in engineering, product line engineering, and testing platforms by utilizing Norwegian national research infrastructures.

Goals

In 2015, the Certus Model Based Engineering project had the following objectives:

- Evaluate model-based requirements and repository engineering approaches for managing, specifying and analyzing large-scale and highly-configurable systems.
- Devise model-based solutions for long-standing development and maintenance of the automated Cancer registry system.
- Develop an infrastructure relying on existing national resources for verifying and validating highly configurable systems.

Impact

MBE technologies have been proven cost-effective in terms of improving product quality and development productivity, and reducing development costs. MBE methodologies customized or tailored to industrial partner needs should therefore have a highly positive impact on the industry and society in general. A practical example of this would be to improve the quality and productivity of the evolving Cancer Registry System (ACRS) through automated, systematic, and cost-effective model-based approaches for improving system efficiency.

Partners

The Certus MBE project is affiliated with several other EU and national projects led by senior Simula scientists Tao Yue and Shaukat Ali. Partners are selected primarily based on whether their objectives align well with those of the MBE project. Current industry collaborators include Cisco and The Cancer Registry of Norway. The project aims to develop MBE methodologies to support requirements in engineering, product line engineering, and testing platforms.

Project 7: Testing of Data-Intensive Systems

Description

Data-Intensive Systems (DIS) collect and analyze data in varying degrees of structure and volume. For instance, transactional data may be structured and semi-structured data collected in a medium-high volume database, such as that of Norwegian Customs and Excise. Similarly, the popular term Big Data represents large quantities of unstructured, semi-structured, and structured data from multiple sources such as sensors, cameras, transactions, and logs.

A DIS must also collect and accurately analyze significant variability in data elements. For instance, TVINN, the DIS for customs declarations at Norwegian Customs and Excise, processes about 30,000 transactions a day. These declarations are verified for their conformance to customs laws and regulations. The laws are expressed using a combination of numerous factors, including:

- 260 countries of origin divided into 88 country groups
- 160 currencies
- > Taxes based on about 900 tax code groups
- Selected additional factors

Complex functionality in TVINN validates customs laws through combinations and variations of these factors. A small team currently tests these data-intensive systems, searching for bugs in the database using a manually compiled checklist and domain knowledge.

Goals

The goal of the project is to increase the efficiency of testing data-intensive systems by at least 20% using modeling and verification tools to capture and reuse domain knowledge. The aim is to resolve the following issues:

- Ensure coverage guarantee: Does the database cover all possible customs regulations?
- Selection of test data: A minimal test database is required, with properties adequate to find most bugs.
- Protect the confidentiality of customers and users.
- Deal with constantly changing system rules: The testing approach must be easily adaptable to systems that change regularly, thus affecting how data is processed.



Impact

Testing data-intensive systems at Norwegian Customs and Excise has the following societal benefits:

- Better border control: Improving the quality of and reliance on automated e-governance system at Customs and Excise can help direct efforts towards improving border control. This is in line with their current goals. Improved information systems will alert and guide customs officers toward making clearer and quicker decisions.
- Increase trust in government: High quality systems will ensure that computer or human errors do not affect users negatively, such as by charging too much tax. An errorfree information system will also communicate laws to customers using clear semantics with little ambiguity.
- Improving testing and other public service information systems: the techniques and tools developed to test the data-intensive system in this project are highly applicable for testing and verifying databases in many public service organizations. For instance, the Certus-developed Depict system is already used on the Cancer Registry of Norway's database to enhance data quality and security.

Partners

Norwegian Customs and Excise is a critical public service, accounting for 20% of the nation's GDP. The Certus Centre shares their commitment to the highest quality, corruptionfree e-governance. The information systems at Customs and Excise also set a very good example for border control and customs work worldwide. The experience gathered through our collaboration will lay the foundation for the next generation of Norwegian customs information systems.

Project 8: Testing of Real-Time Embedded Systems

Description

Real-time and embedded systems (RTES) are used extensively in varied application domains including communication, aerospace, transport, maritime and energy. RTESs are increasingly employed as business, safety, and mission critical systems. A typical RTES environment may consist of several physical components (e.g. sensors) and may even consist of other RTES. RTES are required to fulfil several properties of dependability including safety, robustness, security, and trustworthiness, in order to ensure that these systems do not harm users when operational. Automated testing of RTES is one way to improve their dependability, but often presents challenges, including:

- Physical components interacting with an RTES or the hardware of the RTES may not be available during early testing. Alternately, it may not be safe to test the RTES with real physical components.
- Coupling of hardware and software.
- RTES may have soft or hard time deadlines.
- RTES usually operate with limited resources, such as memory size and CPU speed.

Model-based testing (MBT) techniques focus on the use of models to perform a variety of testing activities, such as test optimization. A large body of existing work has shown good benefits from applying MBT to address the abovementioned challenges.

Goals

This project aims to devise practical, scalable, cost-effective, automated, and optimized model-based testing techniques for RTES that meet the requirements of industrial systems. Targets include:

- Devising a set of novel techniques for testing to significantly improve the quality of industrial RTES.
- Developing multi-objective test optimization testing techniques.
- Empirically evaluating cost, effectiveness, and scalability of testing techniques using well-established methods including controlled experiments, case study research, and surveys.
- Demonstrating the applicability of testing techniques on industrial case studies with the help of proof of concept tools.



Impact

Scientific achievements from this project (e.g. testing techniques with tool support), are expected to help Certus' industrial partners to improve their current testing practices, including strengthening the robustness of video conferencing systems (VCSs) produced by Cisco, and optimizing the testing process of painting systems produced by ABB Robotics.

In addition, demonstrating the generality and applicability of developed testing techniques should allow other industrial companies to benefit from the project when facing similar problems during the testing phase.

Partners

Cisco Norway is a worldwide VCS leader, facilitating highquality face-to-face meetings without gathering participants physically. VCSs are highly configurable embedded systems, each with 4-5 million items of code.

ABB Robotics is the market leader in painting systems embedded into complex industrial robotics.

The systems produced by Cisco and ABB require thorough testing, providing vast opportunities for:

- Identifying significant research challenges shared by industry.
- Devising novel testing techniques to address research challenges.
- Empirical evaluation of developed techniques in real industrial settings.

Project 9: Smarter Testing of Evolving Systems

Description

Software systems involved in real-world activities must continually adapt in order to satisfy the increasing demands of their users. Evolving systems are typically validated through regression testing, which aims at ensuring that new changes in a system do not negatively affect the behavior of unchanged parts. Traditionally, regression testing is performed by comparing test results before and after changes are made, under the assumption that different outcomes imply that the changes had negative effects. As the software evolves, test suites of large systems tend to grow in size, and may become partly outdated or contain redundant test cases. Over time, it becomes prohibitively expensive to execute the entire test suite available for a system, rendering traditional regression testing highly inefficient. This project investigates an alternative approach, based on analysis of historical data on past changes in a software project, in order to predict the parts of the system affected by a given change. This is based on the notion that software artifacts that often changed together in past releases are likely to be interdependent, and hence are also likely to continue changing together. This knowledge allows regression testing to focus only on the software artifacts impacted by the changes, without having to execute the entire suite of tests.

Goals

The Certus project 'Smarter testing of evolving systems' aims at devising practical, scalable, cost-effective automated techniques that empower current industrial practices in regression testing. The goal of the project is threefold: 1) to develop advanced techniques to mine knowledge about past changes from software repositories, enabling the tester to 2) identify the parts of the system affected by a given change, and 3) prioritize the execution of test cases that exercise the changed parts, so that the most vulnerable parts of the system are tested as soon as possible.

Impact

Software systems are pervasive in our society, and are destined to fully integrate into all aspects of life. Increasing user demand for software functionality and reliability represents a significant challenge when delivering highquality software products. More time-efficient and costeffective regression testing allows our partner companies to significantly improve their software quality assurance processes. In particular, smarter testing of evolving systems allows for reallocation of regression testing resources to other key phases of software development, while keeping pace with fast-growing user demands. This ultimately allows our partners to increase their competitiveness in the market by delivering better products.

Partners

Our partners Kongsberg Maritime and Cisco Norway are world leaders in the development of high-quality evolving software systems in their respective sectors. However, due to the increasing software complexity, our partners face severe challenges when testing regressions in their own products. Specifically, reducing the time needed for investigating regressions in a set of changes, while thoroughly verifying that those changes do not yield any unintended effects, is among their top priorities in improving testing processes. For these reasons, both Kongsberg Maritime and Cisco Norway constitute ideal partners for devising advanced techniques for regression testing scaled to large and complex industrial systems. More time-efficient and cost-effective regression testing allows our partner companies to significantly improve their software quality assurance processes.

Interacting with industry

Description

The Certus Centre develops research output in the form of scientific papers and technical reports, practice guidelines, and software prototype tools. Many of these research results have the potential to be further developed for use in industry, in the form of software tools or research expertise captured in methodology documents. The Industrial Exploitation Project is designed to identify results with potential for industrial development, and manage their transformation into practically relevant tools.

Industrial exploitation activities in 2015 were marked by a strong focus on further strengthening the exploitation of TITAN, a technology developed in cooperation with the Cisco and ABB user partners. TITAN technology automates and optimizes several stages in software testing processes, helping to balance costs with quality of testing. The further development of TITAN is supported by the Research Council FORNY2020 program, helping to bring results from projects conducted at publicly funded research institutions closer to the market.

Also in 2015, Certus started the development of Crystal, a platform that proposes a unifying approach to the development of research tools, easing the sharing of basic services, complex tools and data produced by experiments.

Goals

The Industrial Exploitation Project aims to create high industrial impact from research results produced at the Certus Centre. One key to reaching this goal is Certus' Exploitation Policy, a set of comprehensive guidelines for organizing technology transfer and exploitation activities. The policy guides the Industrial Exploitation Project in reaching its primary goal of transforming research results into tools with practical relevance and benefit for user partners, and the partners' subsequent exploitation of these tools.

Impact

Activities in the Exploitation Project demonstrate Certus' commitment to research-based innovation, offering benefits to the local economy and society in general. The user partners benefit directly through access to new ideas, technology, and know-how, ultimately enhancing competitiveness and bringing financial benefits to the local economy. In its four years of operation, the Industrial Exploitation Project has managed the exploitation of three innovative technologies: TITAN, DEPICT, and DART, and will strive to extend activities in the coming years to include new research results with promising exploitation potential.

Partners

The Industrial Exploitation Project is based on active relationships and interaction with all Certus user partners, ensuring that their opinions and goals are reflected in exploitation activities. One example is the Exploitation Policy, defined in iterative joint and individual meetings with the user partners, with the aim of identifying common areas of interest and defining an effective exploitation strategy for the Certus Centre.

The Certus Centre

The Industrial Exploitation Project is designed to identify results with potential for industrial development, and manage their transformation into practically relevant tools.

Adjacent activities launched in 2015

U-Test

U-Test is a European H2020 project on Testing Cyber-Physical Systems under Uncertainty: Systematic, Extensible, and Configurable Model-based and Search-based Testing Methodologies. It was launched 1 January 2015, and is set to last to 31 December 2017.

The overall goal for U-test is to improve the dependability of Cyber-Physical Systems (CPSs), via cost-effective modelbased and search-based testing of CPSs under uncertainty, by defining an Uncertainty Taxonomy and holistic modelling and testing frameworks with considerable reliance on standards. The project has several partners from different fields, such as medical technology, logistics, and advanced technology transfer to industry. Oslo Medtech is the Project Coordinator, and Simula Research Laboratory is the Technical Project Coordinator.

Model-Based Testing For Cyber-Physical Systems (MBT4CPS)

MBT4CPS is an RCN-funded project aiming to devise novel model-based testing techniques to support functional and non-functional testing of CPSs with the specific focus on risky uncertain behaviors. The ultimate goal of the project is to improve the quality and dependability of CPSs, highly critical since these systems have safety and mission critical applications. Sponsored by the Research Council of Norway's FRINATEK framework, the project started on 1 July 2015, and is scheduled to run until 30 June 2018.

Zen-Configurator: Interactive and Optimal Configuration of Cyber Physical System Product Lines

The goal of the Zen-Configurator project is to increase the efficiency and effectiveness, and thereby reduce the cost, of configuring large-scale Cyber Physical System (CPS) product lines. To achieve this goal, we maximally automate error-prone and costly manual configuration activities and optimally assist the interactive configuration process. The project relies on advanced technologies of constraint solving/evaluation, optimization using search algorithms, and propose state-of-art algorithms to enable automated configuration activities. Additionally, the project addresses real challenges faced by industry, proposes a practical and applicable solution, and applies it in at least one application domain. Sponsored by the Research Council of Norway's FRINATEK framework, the project started on 1 July 2015, and is scheduled to last until 30 June 2018.



SOIGNONS: SOCIETAL Games to promote social Nudging in cervical cancer Screening

SOIGNONS is a project in collaboration with Mari Nygård of the Cancer Registry of Norway (CRN). CRN will coordinate SOIGNONS with two partners: Simula Research Laboratory and the Icelandic Cancer Registry (ICR). The duration of the project is January 2015 to December 2017.

Social nudging is a concept in behavioural sciences which argues that positive reinforcement and indirect suggestions to try to achieve non-forced compliance can influence the motives, incentives and decision making of groups and individuals, at least as effectively – if not more effectively than direct instruction, legislation, or enforcement. Can we leverage social nudging via gamification to boost coverage of cervical cancer screening? This is the question that SOIGNonS aims to address. SOIGNonS in French means "to heal together". The goal of SOIGNONS is to virally communicate health information concerning cervical cancer via gamification in mobile games. Games will present information as thoughtprovoking puzzles and incentives to the younger generation and actively involve them in order to improve health related behaviour of their mothers or grandmothers. The success of gamification will be evaluated using registry linkages available in Nordic countries. For instance, in Norway we intend to link the population registry and the cancer registry's databases to observe long-term improvement in screening attendance due to gamification.

SOIGNONS is a first step towards exploring V&V of Socio-technical Systems thanks to the social behaviour data available at the Cancer Registry of Norway. The goal will be to see if software developed and implemented realise certain social functions.

In 2016, we aim to release an app called FightHPV to educate adolescents about the risks of cervical cancer through gaming, and evaluate the impact through registry linkage data and data from Google Analytics.

Finding purpose in partnerships

When Shuai Wang decided to come to Norway to complete his PhD, it was not just for the academics. "Mostly I was interested in the way of working here, bringing research and innovation together," Wang says. "The main attraction was the model of industrial collaboration."

According to Wang, good software engineering is built on strong theory, but dependent on practical application. "If you don't take your work out of the lab, it's hard to know what to do with the research. For me, being able to work together with industrial partners was like opening a new window."

Of all the partners in the Certus portfolio when he arrived in 2011, Wang was drawn to the Cisco case. Cisco had bought up Tandberg, the Norwegian supplier of videoconference systems, and had a need for reliable and affordable testing of their real-time embedded systems. "Cisco's challenge was interesting because they have hardware, software and networks all interconnected, and they all have to work together in real time."

The challenge is addressed in Project no. 8 at Certus, Testing of real-time embedded systems, with the ultimate goal of improving the quality of conference calls. During the course of completing his PhD, Wang has had three years of close collaboration with Cisco: "Initially I was on site at Cisco for three months learning their code for use in test cases," he relates.

Testing for real-time reliability

Testing is understandably important in a real-time system, as even a small error can disrupt the service and ruin the customer's experience, and their faith in the product. But as with any labour-intensive effort, testing can also be costly. "My job is to test different systems cost-effectively. We have to find as many bugs in as short a time as possible. Reduce time, but increase effectiveness."

Reuse of tests across a range of systems is also a priority. "Obviously this can save a lot of time," Wang states. "The challenge is that no two systems are completely alike, but they still share common traits. In order to get a broader perspective, we try to share problems with the different groups. The common goal is always better quality testing for less money."

Delivering added value is goal Certus shares with Cisco. "When clients use Cisco products, helps them do better business," Wang points out. "Cisco has big clients with global activities, many employees. The product helps people to connect, while saving travel cost and reducing environmental impact. The effect is the same, a real face-toface meeting, just without physically gathering people."

Finding warmth in a cold climate

After three years, Shuai Wang seems happy with his decision to move to Norway. "It's cold in the winter, and dark, but the summers in Norway are really special," he says. "And I like the office location, with the fjord and the parks around."

As for the Certus Centre, has it fulfilled Shuai's expectations? "I finished my PhD within the given time limit, and not everyone is fortunate enough to do that. I got a lot of great support from my supervisors, and I enjoy the working environment. The close connection with companies and other PhD candidates, in Simula and at the University of Oslo, is also good. We can learn a lot from each other," Wang maintains.

"I think the Simula environment is good for young people. They offer the same benefits to students as to employees, and that means a lot to young students."

"I would recommend others to come here. Most important of all are the people. From my advisors I learned not just how to research and write, but also how to present. Communicating results is a key factor in adding value to research," he adds.

"Communicating results is a key factor in adding value to research"

The next phase, and beyond

Shuai Wang finished his doctoral dissertation and defence in April 2015, and has plans to continue at Certus. "I will be post-doc from February 2016," he tells, "and I will take over the lead in two projects: working on modeldriven engineering for the Norwegian Cancer Registry, and continuing with improving testing efficiency for Certus. Also I will become supervisor for a new PhD candidate."

One might think that systems testing is a finite task, but Wang knows otherwise: "Testing can never be finished," he assures. "New challenges come up, and the system is constantly being perfected, so testing has to evolve too."

Now in the second phase of his work, Wang is looking forward to sharing his experiences. "But I have to finish the work first. I know I can improve on my PhD topic, even while acting as supervisor."

And if he returns to China one day, will he take Certus experience with him? "The way of working here is different than in China. There is less hierarchy, and that appeals to me. And even though people might not spend as many hours at work, they tend to be more effective for the time they are here."

"Everyplace in the world has different ways of working, but I would want to share the Nordic model that we use at Certus anywhere I end up," Wang concludes.



Embracing the human element in software testing

No matter how committed you are to the power of technology, the human element will always be a major factor in the success or failure of software, and software testing.

"The human aspect is the key to success in information technology," maintains Carlo Ieva, senior researcher at the Certus Center, and project leader for the new Crystal software testing platform. "Certus researchers and our partners live in different worlds. Typically, they want to sell, and we want to publish," he relates, in a nod to the inherently academic nature of R&D work. "But at Certus, we strive to achieve balance between the two objectives. We are more focused on relating to the real life situations of our partners. And if we want our collaborative projects to succeed, we need to find common ground."

What is Crystal?

An industry within the industry, software testing seeks to ensure robust and reliable performance in software intensive systems. Crystal is not a software testing program, but rather a framework designed to enable more efficient construction of testing software. The added value proposition behind the Crystal platform is its modular architecture and sharing-based philosophy.

"Crystal is an agnostic platform," Carlo Ieva says. "Its purpose is to allow sharing of any component of functionality or data in a safe environment, running alongside open environments." This stands in opposition to the more established method of bundling components in closed, monolithic solutions.

The Crystal philosophy, based on the microservice architectural design pattern, is widely acknowledged, but not yet widely applied. "With Crystal, we take the most robust elements of testing software and re-use them in new ways. We call the individual elements bricks," Ieva says, adding that Crystal offers a total separation of concerns: basic ingredients (or bricks) used for many purposes, and graphical flows that assemble bricks in order to realize actual tools using a visual, but executable language (BPMN 2.0).

The human element in Crystal

"We were looking for a different way to develop testing software," Ieva says. "Our goal was to connect the research, business and engineering communities in the development process." He reports that people with varying backgrounds are engaged in creating basic work flow diagrams to map out requirements along the software development chain. Successively, the concrete implementation of the workflow is obtained either through the reuse of already existing bricks, whose presence is indicated by a catalogue, or by implementing new bricks.

Crystal also allows improved sharing of research outcomes. "It encourages reuse of technology, which is a key element in accelerating the development of experimental but robust tools adhering to good design practices," Ieva relates, making Crystal an ideal R&D subject for his on-going PhD in machine learning for software testing.

Why Certus?

The human element was also the impetus for Carlo's residence in Norway. Simula and the University of Rome (Tor Vergata) have a collaboration agreement, and Carlo was invited to Oslo to give a presentation on "Variability modelling and stochastic simulation: a combination for risk assessment". Following the presentation, Certus director Arnaud Gotlieb invited Carlo to bring his family and work in Norway. "We were ready for a change, and the work environment in Norway is more accommodating than in Italy, so we have been happy with the move," Carlo says.

He brings a strong industry background to Simula and Certus, with his history in Italy as a software consultant for Johnson & Johnson, Abbott, Telecom Italia, and others. "My job there was typically to take care of the entire software life cycle. In that way I suppose I am unique in Simula, with a background in both industry and software engineering."

The future of Crystal

"I believe Crystal could be a useful tool for all those operating in the software testing domain, improving the process of developing new products," Ieva says. "Or for a software house, using it to accelerate development of software testing tools."

Ultimately, Carlo Ieva considers Crystal to be among the family of testing tools that are opening up a new world of testing based on collaboration-friendly technology. "We are still working on achieving adaptation by a partner, and when that happens, I think we will see rapid progress. Our next goal is to locate a concrete example to work with." Emphasizing the long-term potential of Crystal, Carlo confirms that the platform has been adopted as a central element in the future of Certus.



Certus and Crystal: a good fit

Coming from a commercial R&D culture, how does Carlo Ieva judge Simula and Certus as hosts for innovative testing software development? "It's a totally different environment from the business community," he says. "The Certus model allows us to focus on innovation. The time-to-market constraint you have in a commercial enterprise isn't there, and this allows us to search more freely for new and better solutions."

But even the solid support that the Certus business model provides is no guarantee of industrial partner uptake for new testing tools. "It takes time to win acceptance for new solutions, but awareness is growing, and we see user partners becoming gradually more willing to commit to the Crystal project."

Certus is well positioned to drive the further development of Crystal, Carlo Ieva believes, thanks to its collaborative model that weds research and industry. But that in turn demands that distinctly different professional communities acquire a common language.

"To ensure progressive R&D, we have to move out of our comfort zone and adopt the language of our partners. It feels odd to have to find other terms to communicate something we know so well, but it is necessary if we want to enhance the transfer of knowledge produced in the Centre to industry end users. And the more we work together, the easier it gets to understand each other. If we want successful collaboration, we can't ignore the human element."

"It takes time to win acceptance for new solutions, but awareness is growing, and we see user partners becoming gradually more willing to commit to the Crystal project"

Personnel in 2015

Certus Leader

Arnaud Gotlieb

Administrative personnel

- Christian Hemmestad Bjerke Administrative Manager
- Karoline Hagane Advisor (30%)

Key researchers

- Shaukat Ali Senior Research Scientist
- Razieh Bejati Postdoctoral fellow until 01.08.15. Presently: Adjunct Research Scientist in 20% position
- Carlo Ieva Senior Research Engineer
- Dusica Marijan Research Scientist
- Leon Moonen Senior Research Engineer
- Sagar Sen Research Scientist
- Tao Yue Senior Research Scientist

Postdoctoral researchers with financial support from the Certus Centre budget

Shuai Wang¹

Postdoctoral researchers working on projects in the Certus Centre with support from other sources

- Stefano Di Alesio Postdoc
- Phu-Hong Nguyen Postdoc

PhD students with financial support from the Certus Centre budget

- Alexandre Petillon²
- Dipesh Pradhan ³
- Shuai Wang

PhD students working on projects in the Certus Centre with financial support from other sources

- Safdar Ageel Safdar ⁴
- Erik Rogstad
- Thomas Gramstad Rolfsnes
- Tao Ma 5
- Man Zhang ⁶

Research Trainees working on projects in the Certus Centre with financial support from other sources

- Hong Lu⁷
- Mathieu Collet ⁸

External consultants

Bran Selic

¹ Shuai Wang was a PhD student with 100% support from Certus, and on 01.03.2015 became a postdoctoral fellow with split funding.

- ² Alexandre Petillon terminated his position 30.09.15
- ³ Dipesh Prathan started out as a Research Trainee, and became a PhD student on 01.09.15.
- ⁴ Safdar Aqeel Safdar started as a PhD student on 01.07.15
- ⁵ Tao Ma started on 01.08.15
- $^{\rm 6}$ Man Zhang started as a Research Trainee from 01.02.15, and became a PhD student from 01.08.15
- ⁷ Hong Lu was a Research Assistant in a 30% position, and became a Research Trainee on 01.07.15 in a 40% position.
- ⁸ Mathieu Collet worked in a three month summer internship from 01.06.2015-31.08.2015.

Gender distribution

The Certus Centre shares its host institution's vision and action plan to increase the share of women in scientific positions in the organisation. Host institution Simula Research Laboratory originally aimed to increase the percentage of women in the scientific staff to 25 per cent in the time period 2010-2015. Simula hit their target in 2013, and received the Gender Equality award from the Ministry of Research and Education in 2014 – which is the first time a research institution has ever received this award. Inspired by this recognition, Simula aimed even higher. The new goal is to increase the percentage of women in scientific positions to 30 per cent by 2017. The infrastructure, experience and ambition provided by the host institution massively benefits the Certus Centre, and assists our own organisation's aim to create a gender balanced work environment.

The Norwegian Association of Researchers cite new knowledge indicating that the lack of female role models in male dominated areas such as science and technology is an important reason for the lack of women in the field. Additionally, there is the fact that the percentage of women decreases further up in the hierarchy due to the "leaky pipeline" effect. The Certus Centre has therefore made an effort to have a high female percentage amongst the scientific staff (33 per cent), the project leaders (42 per cent), and on the board (33 per cent) in order to achieve a continual focus on creating a gender balanced work environment, and to have solid female role models for students and researchers in recruitment positions. It is the aim of Certus to promote a culture that is attractive for young, female researchers, as a recruitment platform, and a long-term career choice. Certus' activities and measures for improving the gender balance has already contributed to realising Simula's goal of 30 per cent women in scientific positions. In 2015 Certus recruited two additional women on the junior level to adjacent research projects in the Certus centre. Lu Hong was appointed as a Research Trainee on the MBE-CR project, and Man Xhang was hired as a PhD student on the Horizon2020 financed "U-Test" project.

In 2016, Certus is going to hire three new PhD candidates, and the recruiters are working hard to identify female candidates who can fill these positions. The gender dimension is also a factor in ongoing discussions of promotions and permanent positions. That being said, we experience challenges in finding and recruiting talented female candidates in a field where only 15 per cent of master students are female. All the positions at the Centre are announced internationally, in order to recruit from the largest possible number of female candidates.

"The new goal is to increase the percentage of women in scientific positions to 30 percent by 2017"

Collaborations

European Collaborations

Inria (France)

This long-term fruitful collaboration between Certus and Inria continued in 2015 with new scientific developments on feature models extraction from product descriptions and solver combinations leading to new Certus publications. Throughout the year, Assistant Pr. Mathieu Acher, a specialist in product-line engineering, has regularly invited Certus Centre leader Arnaud Gotlieb at Inria to participate in several ambitious research activities. Assistant Pr. Jean-Marie Mottu, an external collaborator with Inria, and located in Nantes, has collaborated with research scientist Sagar Sen on model transformation testing. In addition, in 2015, Certus was introduced to two distinct Inria research centres (Paris and Rennes) during institutional visits.

University of Luxembourg, SnT Centre (Luxembourg)

Since 2012, Certus and SnT have engaged in intensive scientific collaborative activities on software validation and verification. In 2015, Prof. Lionel Briand from SnT and Centre leader Arnaud Gotlieb participated as co-supervisors for the PhD disputations of two PhD students, Stefano Di Alesio, attending the University of Luxembourg, and Erik Rogstad attending the University of Oslo, both working on adjacent projects related to software testing with partners of Certus.

SICS (Sweden)

In 2015, Certus Centre leader Arnaud Gotlieb was invited to present Certus and some advanced results in test suite optimization at the Swedish Institute in Computer Science (SICS), as a consequence of a newly established scientific collaboration with senior research scientist Mats Carlsson. This collaboration has already produced published results.

University of Malaga (Spain)

Collaboration with Prof. Enrique Alba from the University of Malaga started in 2015 with a short-term visit of PhD candidate Shuai Wang to strengthen Certus' knowledge in meta-heuristics searching. Prof. Alba was then invited to Simula as an opponent in Wang's PhD disputation. This collaboration aims to investigate the applicability of searchbased techniques for solving software validation problems.

International Collaborations

Beihang University (China)

This long-standing collaboration has been continuously strengthened in several research perspectives, such as empirical software engineering, requirements engineering and model-based engineering, since the start of Certus. In 2015, the collaboration particularly focused on model-based product line engineering and model-based requirements engineering. Three PhD students from Beihang University visited Simula to work on their PhD theses in the scope of these two research directions, under the supervision of Tao Yue and Shaukat Ali. Several peer-reviewed conference papers and journals have been either published or submitted.

Loyola University, Maryland (USA)

Prof. Dr. David Binkley visited Certus for three months during the summer of 2015, under the umbrella of the Fulbright Scholar program. Prof. Binkley collaborated with Leon Moonen on an international project on the evolution of software intensive safety-critical systems. The project identified synergies between Binkley's research, which focuses on semantic-based software tools that deeply analyse the meaning of small programs to identify potential issues in the code, and Moonen's research, which focuses on techniques and tools to support the evolution of large industrial software systems. Collaboration continued after Binkley's return to the USA and has resulted in two accepted papers.



Visitors

In 2015, Certus received several researchers from all around the world:

Name	Organisation	Country
Enrique Alba	University of Malaga	Spain
David W. Binkley	Loyola University	USA
Kathryn Francis	University of Melbourne	Australia
Lori L. Pollock	University of Delaware	USA
Camille Salinesi	University of Paris 1 Pantheon- Sorbonne	France
Jurgen J. Vinju	Centrum Wiskunde & Informatica	Dutch
Jean-Marie Mottu	Université de Nantes	France
Adebola Adedimeiji	Albert Einstein College of Medicine, New York	USA
Philip Castle	Albert Einstein College of Medicine, New York	USA
Sharon Skapambwe	Centre for Infectious Disease Research	Zambia

Looking ahead: Opportunities for Certus after 2019

Even though Certus has until 2019 to reach its full potential as an SFI, serious consideration has been given to the future of the research centre. Certus is presently a leading international research-based innovation centre, and the strong expertise that combines scientific and innovative thinking has led to its recognition as a major European partner. This competitive positioning and level of achievement deserves a legacy worthy of the Certus name.

In recent years, Norwegian society has engaged in extensive modernisation of national and industrial infrastructure, and the need for expertise within the field of software engineering has increased accordingly. Efficient methodologies for software validation and verification are crucial tools in society-wide technological upgrades. The partners of Certus are all engaged in this movement, one way or another, and they wish to carry out the original plan of leveraging Certus' unique position to become a testing laboratory for the large-scale technological advancements to come. This continuation after 2019 has tentatively been named Certus Testing Laboratory, or CT-Lab.

The key concept of CT-lab is to build on the strengths of Certus, which lie within three main areas:

- As a research-based innovation centre, where the future of V&V research will be explored, and Master's and PhD students will be educated through the most advanced tools and relevant industrial case studies.
- As a centre of expertise for industrial and public partners.
- As a test facility, with the opportunity to test and evaluate the large-scale software systems of their partners.

Concrete plans for establishing CT-Lab as a self-sustained research-based innovation centre include a revitalisation of its research interests through the development of expert knowledge in the application domain, aimed at finding effective solutions to user partners issues, and a strong dedication to Machine Learning techniques for software validation problems. By aggregating research plans around the software development platform CRYSTAL and its automated learning capabilities, Certus will hopefully place the host partner in position to attract interest and largescale funding from industry and public administration. The ambition of CT-Lab is to operate in close collaboration with industry, with strategic guidance from an industrial advisory board comprised of key collaborators and stakeholders. The last three active years of the Centre will be spent establishing the CT-Lab as a well-functioning entity, strengthening international industrial collaboration, and recruiting funding from national and international sources, including the European H2020 programme and private revenue. By accessing national infrastructures in healthcare, planned for the upcoming three years through new projects such as the Horizon 2020 (H2020) U-Test, the CT-Lab will also be ideally placed to realise breakthrough innovations with highpotential value creation.

Certus is presently a leading international research-based innovation centre, and a major European partner.

Supervision of Master's students

An important part of the Certus concept is to support research in higher education. To that end Certus researcher supervise Master's students in the field of software engineering. The Centre also offers summer internship positions through Simula Research Laboratory.

Master students 2015

Name	Supervisor
Dipesh Pradhan	Tao Yue, Shaukat Ali, Magne Jørgensen
Machnik Marek	Sagar Sen, Magne Jørgensen
Mathieu Collet	Arnaud Gotlieb
Wagas Moazzam Butt	Sagar Sen

Summer interns 2015

Name	Supervisor
Yuanrui Li	Sagar Sen
Wagas Moazzam Butt	Sagar Sen



Publications

Articles in International Journals

- Cost-Effective Test Suite Minimization in Product Lines Using Search Techniques
 S. Wang, S. Ali and A. Gotlieb Journal of Systems and Software, vol. 103, pp. 370–391, 2015
- Combining Genetic Algorithms and Constraint Programming to Support Stress Testing of Task Deadlines
 S. Di Alesio, S. Nejati, L. Briand and A. Gotlieb ACM Transactions on Software Engineering and Methodology (TOSEM), vol. 25, pp. 1—37, 2015
- aToucan: an Automated Framework to Derive UML Analysis Models From Use Case Models
 T. Yue, L. Briand and Y. Labiche
 ACM Transactions on Software Engineering and Methodology, vol. 24, pp. 1—52, 2015
- Towards Evidence-Based Recommendations to Guide the Evolution of Component-Based Product Families L. Moonen Science of Computer Programming, vol. 97, pp. 105—112, 2015
- Testing Robot Controllers using Constraint Programming and Continuous Integration M. Mossige, A. Gotlieb and H. Meling Information and Software Technology, vol. 57, pp. 169–185, 2015
- 6. Infeasible Path Generalization in Dynamic Symbolic Execution
 M. Delahaye, B. Botella and A. Gotlieb Information and Software Technology, vol. 58, pp. 403–418, 2015
- Automated Product Line Test Case Selection: Industrial Case Study and Controlled Experiment
 S. Wang, S. Ali, A. Gotlieb and M. Liaaen Journal of Software and Systems Modeling, pp. 1—25, 2015

 Improving the Performance of OCL Constraint Solving with Novel Heuristics for Logical Operations: A Search-Based Approach
 S. Ali, M. Z. Iqbal, M. Khalid and A. Arcuri The Empirical Software Engineering Journal (EMSE), pp. 1—44, 2015

Certus: Glimpses of a Centre for Research-Based Innovation in Software Verification and Validation S. Sen, D. Marijan and A. Gotlieb International Journal of System Assurance Engineering and Management, pp. 1—25, 2015

 Focus section on quality software T. Tse, A. Gotlieb and Z. Chen Software, Practice and Experience, vol. 45, pp. 873—874, 2015

Chapters in Books

- FightHPV: Et spill som skal øke bevisstheten rundt HPV, og 'dulte' folk til å forebygge livmorhalskreft S. Sen, T. R. Lopez, E. Jakobsen and M. Nygaard in Special Issue: Catch-HPV, Edited by M. Nygård, Kreftregisteret, pp. 137–143, 2015
- Constraint-Based Testing: An Emerging Trend in Software Testing

 A. Gotlieb
 In Advances in Computers, Edited by A. Memon, Elsevier, pp. 67—101, 2015

Refereed Proceedings

- Efficient Architecture-Level Configuration of Large-Scale Embedded Software Systems
 R. Behjati and S. Nejati
 In 6th International Conference on Fundamentals of Software Engineering (FSEN). Tehran, Iran, April 22-24, 2015
- Applying A Restricted Natural Language Based Test Case Generation Approach in An Industrial Context T. Yue, S. Ali and M. Zhang In International Symposium on Software Testing and Analysis (ISSTA), Maryland, USA, July 14-17, 2015
- Cyber-Physical System Product Line Engineering: Comprehensive Domain Analysis and Experience Report T. Yue, S. Ali and B. Selic

In The 19th International Software Product Line Conference (SPLC). Nashville, USA, July 20-24, 2015

- UPMOA: An Improved Search Algorithm to Support User- Preference Multi-Objective Optimization
 S. Wang, S. Ali, T. Yue and M. Liaaen In The 26th IEEE International Symposium on Software Reliability Engineering (ISSRE). Gaithersburg, USA, November 2-5, 2015
- Evaluating Reconfiguration Impact in Self-Adaptive Systems – An Approach Based on Combinatorial Interaction Testing
 Sen, S. Di Alesio, D. Marijan and A. Sarkar In The 41st Euromicro Conference on Software Engineering and Advanced Applications (SEAA). Madeira, Portugal, August 26-28, 2015
- Towards More Relational Feature Models

 A. Gotlieb, D. Marijan and S. Sen
 In ICSOFT-EA 2015 Proceedings of the 10th
 International Conference on Software Engineering and
 Applications, Colmar, Alsace, France, 20-22 July, 2015

- 7. Synthesis of attributed feature models from product descriptions
 G. Bécan, R. Behjati, A. Gotlieb and M. Acher In Proceedings of the 19th International Conference on Software Product Line, SPLC'15, Nashville, USA, July 20-24, 2015
- Multi-perspective Regression Test Prioritization for Time-Constrained Environments
 D. Marijan
 In IEEE International Conference QRS. Vancouver, Canada, August 3-5, 2015
- Discovering Model Transformation Pre-conditions using Automatically Generated Test Models
 J.-m. Mottu, S. Sen, b. baudry and J. Cadavid In International Symposium of Software Reliability Engineering. Gaithersburg, USA, November 2-5, 2015

Technical Reports

- Generating Test-plans by Mining Version Histories T. Rolfsnes, R. Behjati and L. Moonen Simula, 2015
- A Practical Use Case Modeling Approach to Specify Crosscutting Concerns: Industrial Applications T. Yue, H. Zhang, S. Ali and C. Liu Simula, 2015

Theses

- Supporting Stress Testing in Real-Time Systems with Constraint Programming
 S. Di Alesio Ph.D. Thesis, University of Luxembourg, 2015
- Systematic Product Line Testing: Methodologies, Automation, and Industrial Application
 S. Wang
 Ph.D. Thesis, University of Oslo (UiO), 2015

Publications

Talks

- 1. Generating Worst-case Schedules with Constraint *Optimization – An Approach to Support Software* Performance Testing S. Di Alesio The 14th INFORMS Computing Society Conference (ICS'15), 2015 2. Combining Genetic Algorithms and Constraint Programming to Support Stress Testing of Task Deadlines S. Di Alesio The 10th Joint Meeting of the European Software Engineering Conference and the ACM SIGSOFT Symposium on the Foundations of Software Engineering (ESEC/FSE'15), 2015 3. Discovering Model Transformation Pre-conditions using Automatically Generated Test Models S. Sen International Symposium of Software Reliability Engineering, Gaithersburg, USA, 2015 4. Evaluating reconfiguration impact in self-adaptive systems: An approach based on combinatorial Interaction Testing S. Sen EUROMICRO, SEAA, Madeira, Portugal, 2015 5. Testing Data-Centric Systems Using Collective Intelligence S. Sen User Partner Workshop, Oslo, Norway, 2015 6. An Overview of Constraint-Based Testing A. Gotlieb Centre de Recherche en Informatique de Montreal (CRIM), 2015 7. A CP approach of the variability testing of software product lines A. Gotlieb Université Paris 1 Panthéon - La Sorbonne, 2015
- 8. Global Constraints in Software Testing Applications A. Gotlieb Université de Montpellier, France - LIRMM, 2015

Posters

1. Scientfic Hangman: Gamifying the Understanding of Cervical Cancer Screening Reminder Letters S. Sen, W. M. Butt, T. Andreassen and M. Nygaard IPVS, 2015



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