



2017

Certus

Annual Report

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## Intelligent Testing:

### Paving the Way for a Successful Exit Strategy

Since 2015, Certus has engaged in collaborative projects where Artificial Intelligence techniques are exploited to improve testing processes.

The scientists and engineers from Certus have focused on developing innovative intelligent methods for better selection, better prioritisation and better scheduling of test campaigns in continuous integration processes. This resulted in 2017 not only publications in top-venue AI Conferences such as IJCAI, IAAI and CP and Software Engineering Conferences such as ISSTA, ICST and others, but also in AI components deployed in real-world industrial processes. For example, the deployment of the SWMOD component allowed ABB Robotics to perform automated scheduling of test case execution by exploiting history-based test results. Other innovative applications of AI in Software Validation and Verification are on-going in the Centre, such as the preventive anomaly detection activity run together with Cisco Systems and Kongsberg Maritime. New methods for performing data analytics on test results are also in the spotlight for data-intensive systems in collaboration with the Cancer Registry. Finally, Esito is strongly engaged into the modernisation of a tool that was initially created by Certus researchers to assess the quality of test campaigns. These results and on-going innovation projects witness a strong activity in the Centre in Intelligent Testing to pave the way for a successful exit strategy.

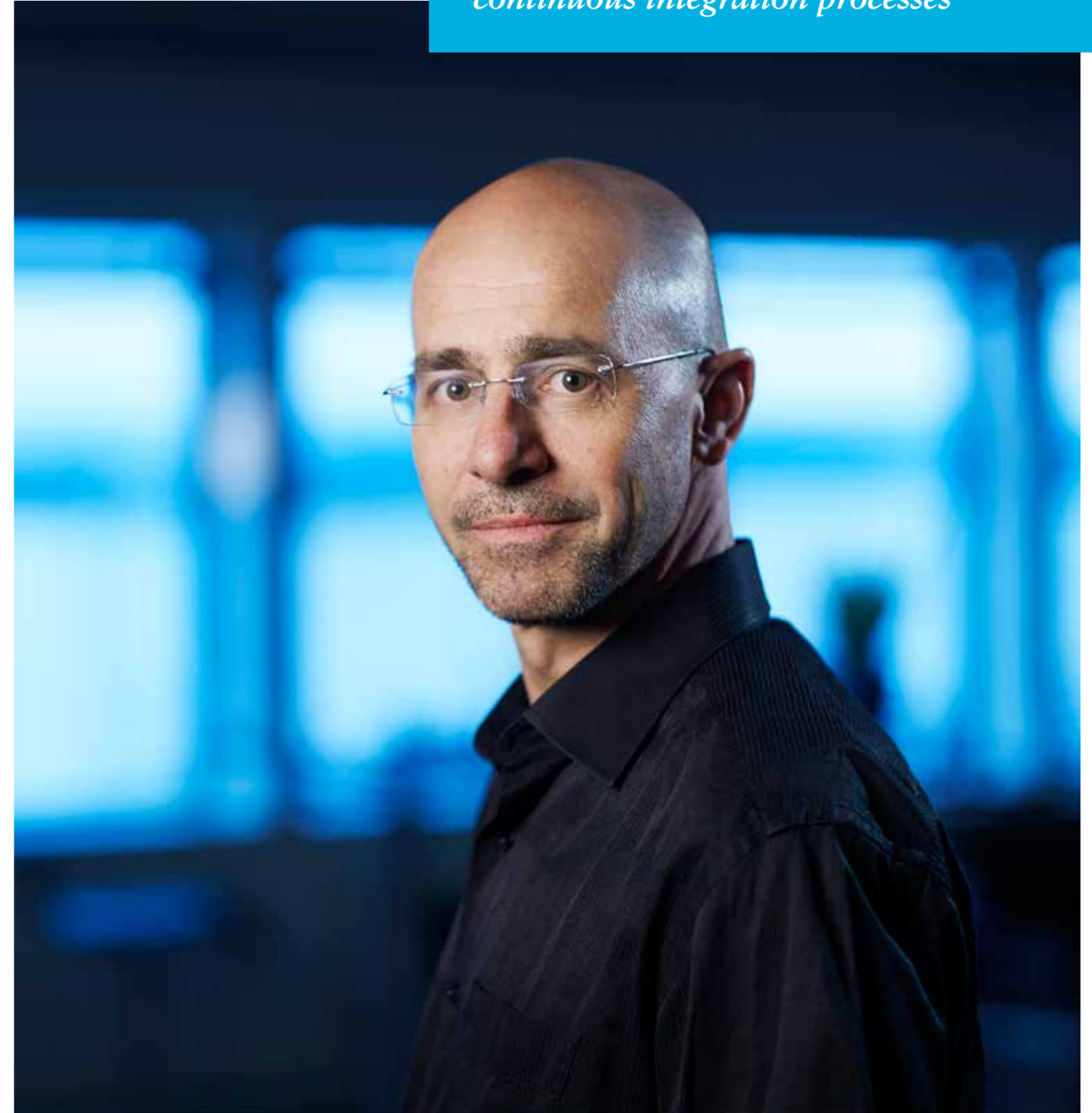
In 2017, Certus participated in the Norwegian Research Council's FRINATEK call for proposals and saw one of its proposals being selected for funding in a very demanding process. In fact, the initial selection round retained 29 proposals out of 410 applications. In the second round, seven projects out of those granted a grade of 6 or 7 were additionally selected for funding under the IKTPLUSS umbrella. The T-Largo proposal (Testing Learning Robots, Sep. 2018-Feb. 2022, 9.8 MNOK), was one of these seven projects. Being successful in such a competitive call is recognition of our expertise in research and innovation activities in the field of software validation and verification. The T-Largo project will be adjacent to Certus and will contribute to securing the funding of the Centre exit strategy.

Intelligent Testing is the core of Certus' future. Scientists and engineers are strongly engaged in responding to ambitious calls at the European level in this domain, and also committed to technology transfer activities with start-ups. By coordinating proposals and sub-projects in large European consortia, and by pushing its results toward industrial exploitation, Certus is clearly facing its destiny with strength and commitment.

In brief, I am strongly confident in our ability to continue Certus operations after the end of our public funding period, and to be successful in our exit strategy.

Arnaud Gotlieb  
Leader of Certus SFI  
Chief Research Scientist  
Simula Research Laboratory

*Certus have focused on developing innovative intelligent methods for better selection, better prioritisation and better scheduling of test campaigns in continuous integration processes*





## Harvesting

We are now in the seventh year of the funding period for Certus. The Centre is going well, and we continue to deliver strong contributions within both scientific and industrial domains. As I have an industrial viewpoint, I am very happy to see that we manage to transform scientific research into value for the industry. This is not easy, even when world-class research meets world-class industry, and even when both have the best intentions.

Among other aspects, there is a difference in planning horizons. Industrial R&D normally works on annual budgets, and road maps and organisations are subject to change on short notice. This may be a natural explanation of the variations we see in the user partners' contributions over time. The scientific community works on a longer horizon. A key factor in the success of Certus is the strong leadership of the Centre's management, headed by Arnaud Gotlieb. With a relentless pursuit of scientific results, and a personal engagement in deploying the results, we have managed to bridge the gap between research and industry.

ABB Robotics, the company I represent within the Certus Board of Directors, is focused on harvesting value from investments made in R&D. We invest the hours of one full-time position in Certus every year, and we need to report on the return on investment. Our main activity has been to work on a system for automatic testing of robot software. The work started with an industrial PhD. The research is presently continued in one of the projects within Certus, and there are now two PhD students working on related topics. Based on the research work, we have deployed a system for continuous and automatic testing of robots, first in ABB's local unit in Norway, and later in the larger global R&D organisation. This system is now in operation, using artificial intelligence techniques to optimally utilise the fleet of robots in our laboratories around the globe to continuously test software under development. This system not only increases the quality of the products, but also significantly reduces the time to market, which is a very important KPI for product development.

We also see other research results from the Centre being applied both in the industry and spread to other research projects. It is good to see that the SFI is working and that we meet the expectations from the Norwegian Research Council. We are after all given a responsibility to transform public funding into innovation. This is a responsibility we take seriously.

In 2017, five out of six partners contributed more than budgeted. This is promising, as we begin to prepare for life after public funding.

Jan Christian Kerlefsen,  
Leader of the Certus Board of Directors

*We are after all given a responsibility to transform public funding into innovation. This is a responsibility we take seriously.*



## Vision

## & Goals

Cost-effective software validation and verification is highly challenging. Manual testing of large software systems will soon no longer be fully feasible due to the increasing demands of larger systems and vast amounts of data. At Certus, we believe that this challenge can be addressed by using and reusing intelligent testing techniques inspired by artificial intelligence. By leveraging constraint optimisation, artificial intelligence and data mining research, we are able to design the tools of tomorrow for facilitating the validation and verification of complex software systems.

Certus works with a group of public and industry partners representing a cross-section of industry and public sector applications in software: ABB Robotics (since 2014), Cisco Systems, Esito, FMC Technologies (2011 - 2014), Kongsberg Maritime, Norwegian Customs and The Cancer Registry of Norway (since 2016). Our goal, in collaboration with these partners, is to determine the future needs within software validation and verification, and to produce research that results in exploitable methodologies and tools for all the partners to test and utilize.

Certus is now engaged in the preparation of a strong exit strategy together with its partners. The goal is to create a virtual testing laboratory that will serve as a technological platform to validate new releases of complex software systems.

### Key Figures

The Certus Centre annual accounts for 2017 shown below are presented in the standard setup used by the Research Council of Norway. Regarding funding, "Own financing" refers to funding provided by the host institution, other "public funding" refers to funding provided by the Norwegian Customs and Cancer Registry of Norway, while "other private funding" refers to funding provided by the remaining four user partners.

#### Cost in NOK 2017

Payroll / indirect expenses	21 940 362
Equipment	156 890
Other operating expenses	1 482 242
<b>Totals</b>	<b>23 579 494</b>

#### Funding in NOK 2017

Own financing	5 094 139
Other public funding	1 656 190
Other private funding	6 099 165
From the Research Council	10 730 000
<b>Totals</b>	<b>23 579 494</b>

### Certus Board

- Jan Christian Kerlefsen, Chair, ABB Robotics
- Are Magnus Bruaset, Simula
- Marius Chirstian Liaaen, Cisco
- Mette Wam, ESITO AS
- Bjørn Ove Olafsen, Kongsberg Maritime
- Jan F. Nygård, Cancer Registry of Norway

### Certus Administration

- Arnaud Gotlieb, Certus Centre Leader
- Tom D. Atkinson, Certus Administrative Manager
- Karoline F. Hagane, Certus Advisor

### Partners



### Gender & Equality

The Certus Centre has throughout its existence strived to achieve a high ratio of female researchers in order to ensure a gender balanced working environment, and to create good role models for students and researchers in recruitment positions. In 2017, 29% of key researchers in the Centre were women, 25% of project leaders were women, and the board consisted of 17% women. In 2017, more than 29% of the five positions completed (Masters' students and interns), were held by women, which we consider to be very positive for future scientific recruitment within the field of Software Engineering.

Gender is weighted in ongoing discussions on recruitment and promotions, and yet it is our experience that it is challenging to find and recruit female candidates in a field where only 15% of Master's students are female. All recruitment to Certus is done on an international basis, in order to have the largest possible selection of female candidates.

## Certus Centre Partners

### Scientific Projects

- Project 2: Industrial Exploitation

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- Project 5: Model-Based Engineering for Highly Configurable Systems

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- Project 7: Testing of Data-Intensive Systems

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- Project 8: Testing of Real-Time Embedded Systems (RTES)

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- Project 9: Smarter Testing of Evolving Software Systems

### User Partners



#### The Cancer Registry of Norway

Projects 5, 7

The Cancer Registry of Norway (CRN) has been a member of the Certus consortium since 2016. Software systems are an integral part of the effective functioning of any medium to large-sized organisation such as CRN, but CRN is in a unique position due to the amount of medical data that must be processed confidentially, and kept constantly up to date.

The number of cancer cases in Norway increases every year. This increase implies that more men and women will need cancer treatment, thus escalating the burden of cancer care in our hospitals. The Cancer Registry of Norway's vision is to combat cancer and the suffering this disease inflicts on individuals and their relatives, as well as to mitigate the challenges cancer causes in society. To improve the cancer care, high quality data on diagnostics and treatment given to cancer patients is needed. The Cancer Registry of Norway (CRN) collects, verifies and recodes these data by means of ICT-systems. It is vital that these processes are conducted correctly and without error.

As a partner of Certus, the CRN wants to improve the internal ICT-systems by using model-based testing and model-driven engineering, including the usage of models for documenting the software development process, automatic generation of code structure and tests from models, and risk-based testing on critical parts of the ICT-system.

#### simula 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 2017, Simula was deemed excellent in all three research areas in an evaluation by international experts organised by the Research Council of Norway (RCN). Simula has since expanded their activities to five research areas. 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: 2, 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. 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 centre leader Arnaud Gotlieb and University of Stavanger Professor Hein Meling. 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.



#### Cisco

Projects: 2, 8, 9

Cisco Systems Norway specialises in developing solutions for video collaboration and manufactures a broad portfolio of products designed for all types of meeting spaces. Cisco's collaboration solutions are business critical for a number of large customers across industries like public sector, oil and gas, and finance. As companies become more global with distributed teams, effective ways to support remote collaboration becomes essential to increase productivity and reduce travel.



#### Esito

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 utilise domain knowledge captured in models and offer its customers tools that give lower lifetime cost and better quality by utilising models and domain driven design in their application development.



KONGSBERG

#### Kongsberg Maritime

Projects: 5, 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.



## Project 5 completed:

### Model-based engineering for highly configurable systems

Project 5 came to an end in 2017 after a long and fruitful run since start-up in 2011. We asked project leader and Chief Research Scientist Tao Yue to outline the results and challenges from the project.

#### What was the main purpose of Project 5?

Nowadays, complex systems are rarely developed from scratch. For example, subsea oil and gas production systems and video conference systems are typical examples of complex Cyber Physical Systems (CPSs) that are integrated, via configuration, with a large number of components to facilitate the reuse of such components. Such systems associate SW/HW components, and may consist of a large numbers of sub-systems, typically geographically distributed and connected through a network. Model-Based Engineering (MBE) technologies offer a promising approach to reducing the complexity of developing cyber-physical systems. They improve the quality and productivity of the product development process by capturing information at a higher level of abstraction, providing a knowledge-sharing platform for communication among stakeholders, and enabling automated analysis such as checking the consistency of configuration and, recommending fixes for incorrect configurations.

#### Why was the project important?

Complex systems such as cyber-physical systems are everywhere in our daily life, from video conferencing systems and subsea oil and gas production systems, to smart buildings and smart healthcare products. These systems are mostly developed by reusing existing system designs, instead of from scratch, for the purpose of reducing development costs and improving product quality. Doing this systematically follows in the research stream of system product line engineering. However, configuring large-scale CPS product lines requires a systematic, interactive and maximally automated methodology with tool support.

#### What's next for you?

The affiliated RCN-funded FRIPRO project Zen-Configurator is still running and is highly related to Project 5. Zen-Configurator aims to increase the efficiency and effectiveness of configuring large-scale CPS product lines. I will continue to work on Zen-Configurator, at the same time as I step into my role as Head of Department of Engineering Complex Software Systems at Simula.

#### What are the future challenges for this scientific field?

Runtime and dynamic configurations of large-scale, highly-configurable systems are still an important scientific challenge. In the Zen-Configurator project, we are currently developing solutions focusing on addressing pre-deployment and post-deployment phase configurations of complex systems and covering the runtime and dynamic configuration of CPSs.



*Complex systems such as cyber-physical systems are everywhere in our daily life*

— Dr. Tao Yue, Chief Research Scientist and project leader of Project 5. Dr. Yue is presently Head of the Department of Engineering Complex Software Systems at Simula.

## Project 7:

### Testing of data-intensive systems

We spoke with Sagar Sen, Research Scientist with the Certus Centre, about the FightHPV project, which aims to increase awareness of the HPV virus and the importance of attending cervical screening.

#### FightHPV: Why choose the outreach strategy of developing a mobile app?

Mobile technologies have developed rapidly in the past decades. For example, in US, 95 per cent of residents have a cell phone and 77 per cent own a smartphone. Furthermore, more time is spent on smartphones than on desktop computers, up to five hours a day on average. Given the popularity of mobile games, FightHPV has been launched as a novel and promising tool to improve health communication for cervical cancer screening. Through game thinking and game mechanics in non-game contexts, users are engaged in the learning process as well as knowledge acquisition, positive health-related attitudes and positive behavioural changes. As participation in different forms of social media is common among the majority of the smartphone users, FightHPV is shared through social networks that can influence how others think and/or act. This is called social nudging via gamification, which helps others adhere to health promoting behaviour. Social nudging lies in the very nature of the human behaviour when we are actively involved in the lives of our friends and relatives discussing lifestyle choices.

#### How do you think gamification has worked in the process of encouraging women to attend screenings?

We have successfully designed and released the game-based learning tool FightHPV, which currently has more than 10,000 downloads from 45 different countries on Android and iOS platforms. Several women in Norway have signed up for a scientific survey through FightHPV to help us evaluate the impact of the game on women's screening behavior. Linking the screening database with the survey data from women, we are able to observe changes in behavior of women who did not attend screening earlier. The outcome of this study is expected to be summarized in 2018.

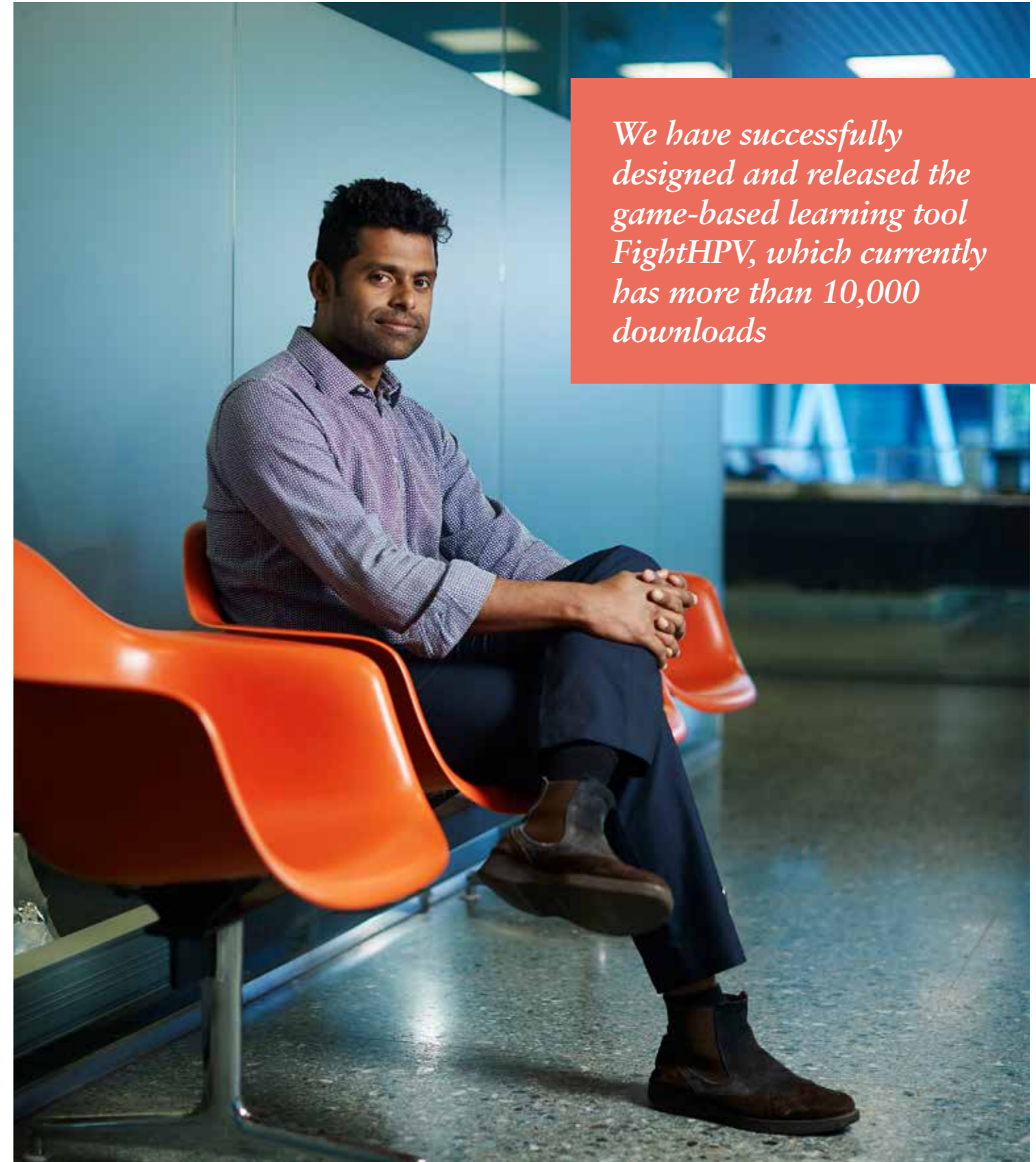
#### How does the app help you collect screening data?

The App allows a user to connect to an online site called Minside. Here the user has to log in using her BankID to participate in a survey. The personal number (PN) is collected through informed consent. Using the PN we are able to observe the future behaviour of a user on the screening database and determine whether she attended a screening. If a person is eligible for screening and hasn't screened in the last three years, we infer that playing the game played a major role in attendance.

#### What's next for FightHPV?

The goal is to study the impact of FightHPV over the next year and release the source code under a creative commons license, allowing for changes but publication with permission from the Cancer Registry. This should enable modification of the app for different languages and adaptations to screening programs in different nations. Also, the content can be adapted to cultural norms in other countries.

*We have successfully designed and released the game-based learning tool FightHPV, which currently has more than 10,000 downloads*





## Project 8:

# Testing of Real-Time Embedded Systems (RTES)

### Innovation results

The goal of project 8 is to devise practical, scalable, cost-effective, automated, and optimised testing techniques for Real-Time Embedded Systems that meet the requirements of industrial systems. In 2017, Helge Spieker has worked closely with ABB Robotics in order to implement testing tools developed in collaboration with our industrial partners. We spoke with Helge about the project:

#### What have you worked on with ABB?

Together with ABB, we are developing methods and tools for test suite optimization. Due to resource constraints, that is the available time for testing or the number of physical test agents, not all test cases can be executed at frequent intervals. With test suite optimization, we prioritize and select the most relevant test cases and schedule them onto the available agents. This process allows to put the focus on finding problems in the software early and reduce the feedback-time for the developers.

#### How have you worked with ABB robotics in order to meet their needs for testing robotics systems?

We start collaborating on a problem by discussing and understanding it. This includes viewing the industry needs behind the problem and relating it to existing research work. Once we have a common understanding of the problem, we try to formulate a research-based approach to solving the problem. This approach might go beyond the scope of the industry problem, but this is required to fully grasp influences and challenges of the proposed solution. Later, the results we found throughout our development are integrated into a solution that can solve the initial problem.

One important aspect of the collaboration is the close contact that we have with ABB, which allows us to quickly interact, receive feedback, and get necessary data to evaluate different solutions.

#### What are SWMOD and DynTest?

SWMOD and DynTest are related tools and processes at ABB that focus on the test automation of robotic systems. DynTest is the overarching framework and major test automation platform developed by ABB's engineers. SWMOD, developed at Simula/Certus, is one part of the system and is responsible for the prioritization, selection and scheduling of test cases. SWMOD implements results from our research collaboration with ABB in the area of optimised testing of real-time embedded systems.

#### What intrigues you the most about this research?

Working with an industrial partner like ABB is a great opportunity to solve problems with an actual, current requirement, and see actual applications of the solutions we find.

Furthermore, the different kinds of problems we are encountering allow us to apply and evaluate diverse solution approaches instead of having only one tool in our toolbox that gets applied to everything. Of course, we have established methods, but we also have the freedom to gain new experience.

#### Which tasks will the project handle in 2018?

For 2018, we expect to see increasing production usage and work load for the developed tools. This usage will provide additional data that we can use for analysis purposes, to quantify the actual improvements our research introduced. We need to regularly evaluate whether previous assumptions and conclusions still hold, or whether we need to adjust the way we are testing.

Also, extensions might be necessary as new constraints and requirements are identified through the extended automation of tests.



— Helge Spieker, PhD student with the Certus Centre.

*One important aspect of the collaboration is the close contact that we have with ABB, which allows us to quickly interact, receive feedback, and get necessary data to evaluate different solutions.*

## Project 9:

### Smarter testing of evolving systems

At the end of 2016, project leader Leon Moonen and Carl Martin Rosenberg started work on a new research track called Anomaly Detection and Diagnosis. Carl Martin Rosenberg is currently doing his PhD with Certus and Cisco, and this research track targets industry-specific issues.

#### What is the purpose of research in this field?

The interactions and dependencies in modern software-intensive systems have become so complex that developers and system administrators increasingly resort to operational data and logs for understanding, evolving and validating their systems. As a result, a vast array of heterogeneous data is collected throughout the software life cycle, ranging from version control data, test suite analytics and continuous deployment logs, to operational data from running systems.

The goal of this work is to investigate the use of machine learning algorithms to analyse collected historical data, learn the patterns or models of normal behaviour of the system, and use those models on run-time operational data to detect or predict deviations from the norm, also known as anomalies. The next step is to investigate how we can augment anomaly detection with deeper mining of development data to support diagnosis and root cause analysis, so that anomalies can be contained at run-time, and corrected in development.

#### What are the main challenges for industry within anomaly detection?

The main challenge identified by Cisco was how they could better exploit the wealth of data gathered during development and continuous deployment to further improve their QA processes. They realised that knowledge derived from this data may be useful to supplement existing software testing efforts and increase the cost-effectiveness of their quality assurance processes, as well as improve overall system robustness. Questions to be answered include: What data needs to be collected and analysed to give the highest predictive accuracy? What abstractions are needed to uncover general knowledge instead of overly specific facts? How should the data be analysed to discover concepts that are sensible to the users, and provide actionable findings? Can we create machine learning algorithms that, in addition to providing answers, can also provide a rationale or explanation to the user?

#### Where is the room for improvement in the present situation?

At the start of the project, Cisco had an existing solution for identifying recurring issues in continuous deployment logs that was based on matching logs against manually specified lexical patterns. However, this approach was only useful for a fraction of the collected data. The hypothesis is that an approach where these patterns are uncovered using machine learning algorithms will be more complete, and more effective. In addition, Cisco collects a lot more data than what was used by their existing solution, such as performance metrics and other operational data. This data can be exploited for learning behavioural trends, and used to predict deviations from those trends.

*One of our main breakthroughs in 2017 was the realization that clustering and anomaly detection are dual problems*

#### How far have you come in the past year, and what do you expect to be able to improve by the end of the project?

One of our main breakthroughs in 2017 was the realization that *clustering* and *anomaly detection* are dual problems, and that items which can not be clustered in a meaningful manner to historical data are anomalies. This insight allows killing two birds with one stone while addressing Cisco's challenge: by clustering the logs from faulty continuous deployment runs, we group all runs that share the same underlying issue. This enables more efficient use of QA resources since it needs to be addressed only once for every cluster. Moreover, future occurrences will be allocated to the same cluster, which at that point has a known solution. Both of these free up resources for handling logs that could not be clustered with other logs, i.e., the anomalies that need greater attention.

We are currently implementing this idea in an experimental prototype that allows us to investigate various algorithms and analyse the impact of their parameters. The next stage would be to investigate how this approach can be extended with further data mining technology to support *anomaly diagnosis*, i.e. help pinpoint what is the root cause of the deviation, to enable containment and correction.

#### What triggers your curiosity while working on this scientific field?

At its core, anomaly detection is an unsupervised machine learning problem, which aims to automatically uncover latent patterns in the data, instead of directly learning patterns from examples as is done in supervised learning. This process of uncovering knowledge that was not explicit before is very intriguing. That said, the lack of explicit examples, or a ground truth, for the problem also means that it is more difficult to ensure that the algorithm is behaving correctly. Consequently, designing an appropriate evaluation strategy is a crucial aspect of the research, and incorporating domain knowledge of the industrial partner is a key part of addressing that challenge.

Finally, it is interesting to investigate the various options available within machine learning to solve a problem; every method has its own strengths and weaknesses, provides you with a different perspective on the data you are working with, but also forces you to think about the problem in new ways.

— Dr. Leon Moonen,  
Chief Research Scientist at Certus.





## Adjacent activities

### in 2017

#### U-Test

The U-Test project was in its final year in 2017. In the last project phase we worked to make research results implemented in software tools more usable for our industrial partner. We also focused extensively on disseminating the results to a wide range of audiences including academic venues and industry conferences and events. Also, we successfully finalized our exploitation plans for our results beyond the project period. A new modelling standard called “Precise Semantics for Uncertainty Modeling” was also successfully initiated in the Object Management Group. The final European Commission review took place on February 15, and the project was successfully closed down.

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

Notable news from the MBT4CPS project during 2017 include 1) a keynote by Shaukat Ali on “Uncertainty-Wise Testing” at the Advances in Model-Based Testing workshop, coinciding with the 10th IEEE International Conference on Software Testing, Verification and Validation (ICST 2017) held in Tokyo, Japan from March 13 to March 17, 2017 2) Tao Ma published a paper titled “Fragility-Oriented Testing with Model Execution and Reinforcement Learning” at The 29th International Conference on Testing Software and Systems. The paper applies artificial intelligence techniques for testing software systems.

#### Zen-Configurator: interactive and optimal configuration of Cyber Physical System product lines

The paper titled “Product Line Engineering of Monitoring Functionality in Industrial Cyber-Physical Systems: A Domain Analysis” received the best paper award at The Software Product Line Conference (SPLC) conference. The authors are A. Iglesias, H. Lu, C. Arellano, T. Yue, and S. Ali.

#### Sweetzpot

Sweetzpot is a startup founded in 2015 to develop technology for real-time feedback in high-performance sports and health. It was co-founded by Sagar Sen, Arne Laugstøl and Håvard Bjor who met through Simula’s Grundergarasje. Today Sweetzpot has 16 employees, of which 7 are full time.

They launched their first product, a rowing sensor called Oarzpote in 2016 (<http://rowing.sweetzpot.com>) to measure the force curve of an oar’s blade in the water. A rower can see the force curve in real time on his/her smartphone to improve technique on the fly. The sensor has been sold all over the world by Sweetzpot to early adopters. They are now working on a second generation of the rowing sensor, Oarzpote Pro, to measure angles along with the force to build the world’s first consumer power meter for rowing.

Starting with a niche market like rowing, Sweetzpot is launching a mass market product for the measurement of breathing through its product, FLOW, to be launched via Kickstarter on 27 February 2018. FLOW measures breathing pattern, ventilatory flow in l/m, HR, and HRV, and can automatically detect the aerobic and anaerobic thresholds of an athlete.

The product is targeted for the endurance sports market but has applications in a wide range of activities such as yoga, singing, and voice training, to name a few. It can also be used in safety critical scenarios such as with firefighters and mine workers where remote monitoring of breathing is vital. The valuation of Sweetzpot in the last investment round was NOK 10 million, and we expect it to be NOK 50 million by August 2018, as a result of worldwide sales. Sweetzpot partners with several companies and academic institutions including the Certus V&V Center at Simula Research Laboratory. Certus brings state of the art testing and AI research into the development of Sweetzpot products. The future of Sweetzpot is about using AI to learn about human performance from experts and help transmit this actionable knowledge.



#### EvolveIT

Adjacent to project 9 is the EvolveIT project, funded through the FRINATEK program of the Norwegian Research Council. The overall goal of EvolveIT is to conceive novel recommendation technology that supports engineers with the evolution of families of complex, safety-critical, software-intensive systems. In 2017, we continued the evaluation of our recommendation technology on a selection of 17 large open source systems, in addition to the systems from Certus partners Kongsberg Maritime and Cisco Norway. We empirically investigated the impact of history length and age on recommendation quality to assess how much data needs to be collected and how often it needs to be updated. Finally, we developed a novel technique to predict recommendation relevance based on historical performance. This enables reducing developer interruptions by filtering recommendations with low relevance, and moreover allows for easy adjustment of the recommendation technology to adapt to an individual developer’s experience level.

#### MBE-CR: An innovative approach for longstanding development and maintenance of the Automated Cancer Registry System

There were three highlights in 2017 in the MBE-CR project based on the collaboration with Cancer Registry of Norway (CRN). First, we proposed an automated search-based constraint refactoring approach, SBORA, by defining four semantics-preserving refactoring operators and three quality metrics to increase the clarity and maintainability of cancer coding rules at CRN. Second, we proposed an automated rule-based change impact analysis approach to automatically analyze changes and provide consequent impacts to medical experts. The approach includes 1) a change classification to capture potential changes 2) a number of change impact analysis rules including dependency and impact rules; 3) an efficient algorithm to analyze changes and produce consequent impacts. Third, the rule engine, GURI, jointly developed between Simula and CRN, has been transferred to CRN on time and is in the production stage, and will eventually be used by medical experts.

#### Crystal

Dealing with large, evolving source code repositories is challenging, especially when performing searches. Does one reuse something previously developed in other context? And how does one conduct such a search? In 2018 we will add semantic search capabilities to Crystal.FEAT, enabling searches with high-level, abstract concepts closer to our understanding. For example, it will be possible to search using natural text expressions like “clipboard” or “open socket”, etc. These new capabilities stem from innovative concepts developed at Certus that enable the creation of smart indices (called program topoi) over source-code. Experiments in the prototype implementation showed that Crystal.FEAT can compact a software project into just 25 per cent of its original space. The process is fully automatic and, in the case of 50K lines of code, takes around 100 seconds. Software Heritage, the largest source-code repository on earth, currently housing more than 70 million projects, showed great interest in Crystal.FEAT and collaboration between the two is underway.

#### ecFeed

The ecFeed project is an innovation project that started and concluded in 2017. The project was carried out in collaboration with Testify, and aimed to explore approaches for test oracle generation in a model-based tool for test case generation. Test case generation in ecFeed is based on a model of the input domain of the system during testing. Given this model, ecFeed generates valid combinations of input data according to several strategies for combinatorial testing. The tool also supports specifying simple constraints that map combinations of input values to expected outputs. The project aimed to evaluate effective and practical approaches for test oracle generation in the context of combinatorial testing. Funding was provided by the Research Council of Norway. The project was led by research scientist Dusica Marijan from Simula and Anders Olsen from Testify.

## International collaboration

### in 2017

#### European collaboration

##### France

Following-up on a long-term collaboration with Inria, the ongoing work on the design of a constraint solving procedure for array constraints was published at IJCAI 2017 in Melbourne, Australia. In June 2017, Certus Leader Arnaud Gotlieb was invited as a keynote speaker at the French National Days of GDR-GPL 2017, Montpellier, France, where he presented Certus activities on testing robotic systems. The same month, he also gave a half-day lecture course at TAROT-2017 the European Summer School on Software Testing in Naples, Italy. Following-up on the co-supervision of Carlo Ieva's PhD thesis, Assistant Prof. Nadjib Lazaar and Prof. Souhila Kaci from University of Montpellier have also investigated various aspects of source code mining with clustering techniques together with Certus centre leader Arnaud Gotlieb. This resulted in two publications to appear in 2018.

##### Sweden

Certus continued the collaboration with Svenska Institutet för Datavetenskap (SICS) in 2017, and the focal point has been test execution scheduling. The results were published at the CP'2017 (Principle of Constraint Programming) in Melbourne, Australia. Certus participation to SweConsNet, the Swedish network on Constraint Programming, was also recognized as important which contributed to changing the name the network to NorConsNet for North Network on Constraint Programming.

#### International collaboration

##### Loyola University, Maryland (USA)

The many years of collaborating with Professor Dave Binkley at Loyola University Maryland (LUM) has resulted in an article that was published in Automated Software Engineering (ASE) and two additional journal articles in The Journal on Empirical Software Engineering (EMSE). Certus researchers are supervising a student at LUM in collaboration with Professor Binkley, whose project aims to continue techniques developed at Certus. The main concept of the project is to use dynamic techniques to recognise when to use the development history to provide a recommendation, in contrast to using a longer and pre-defined development history. An article based on this work has already been accepted to the SIGCSE Technical Symposium, and will be presented early in 2018. Professor Binkley's research stay and ongoing collaboration is funded by an NSF grant (IIA1360707) and J. William Fulbright Scholarship.

##### Osaka University (Japan)

In 2017, Chief Research Scientist Leon Moonen had a three month research stay in Japan, where he collaborated with Prof. Katsuro Inoue in Osaka University's Software Engineering Laboratory. During his stay he also gave invited talks and guest lectures at several other universities and research institutes. Dr. Moonen had the opportunity to present his work on History-Based Recommendations to Guide Software at the Tokyo Institute of Technology, The National Institute of Advanced Industrial Science and Technology (AIST), the Nara Institute of Science and Technology, the Kyoto Institute of Technology and the Graduate School of Information Science and Technology at Osaka University. Additionally, Dr. Moonen gave a keynote talk at the IEEE International Workshop on Empirical Software Engineering in Practice.

## Visitors

In 2017, Certus received visitors from several researchers from around the world:

Name	Organisation	Country
David W. Binkley	Loyola University	USA
Yan Li	Beihang University	China
Aitor Arrieta Marcos	University of Mondragon	Spain
Muhammad Zohaib	National University of Computer and Emerging Sciences	Pakistan
Bruno Lima	University of Porto	Portugal
Jaroslav Miszczak	Institute of Theoretical and Applied Informatics, Polish Academy of Sciences	Poland





## Certus Centre personnel

### in 2017

#### Centre director

- Gotlieb, Arnaud - Centre Leader – Chief Research Scientist

#### Key researchers

- Ali, Shaukat - Senior Research Scientist
- Ieva, Carlo - Senior Research Engineer
- Marijan, Dusica - Research Scientist
- Moonen, Leon - Senior Research Scientist
- Sen, Sagar - Research Scientist
- Yue, Tao - Chief Research Scientist

#### Visiting researchers

- Binkely, David of Loyola University, USA
- Postdoctoral researchers with financial support from the CERTUS Centre budget
- Wang, Shuai

#### Postdoctoral researchers working on projects in the CERTUS Centre with financial support from other sources

- Lu, Hong
- Nguyen, Phu-Hong

#### PhD students with financial support from the CERTUS Centre budget

- Collet, Mathieu
- Pradhan, Dipesh
- Rosenberg, Carl-Martin
- Spieker, Helge

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

- Ma, Tao
- Li, Yan
- Rolfsnes, Thomas Gramstad
- Safdar, Safdar Aqeel
- Zhang, Man

#### Administrative personnel with financial support from the Certus Centre budget

- Atkinson, Tom David
- Bruaset, Are Magnus
- Hagane, Karoline

#### Research engineers with financial support from other sources

- Hammad, Muhammad

#### Research Trainees working on Projects in the Certus Centre

- Ribiero, Manoel

## Supervision of Master's Students

### in 2017

An important part of the Certus concept is to support research in higher education. To that end Certus researchers supervise Master's studies in the field of software engineering. The following students were supervised by Certus researchers or partners and handed in their thesis in 2017.

#### Male Master's Students

Name	Thesis Title	Advisors	Institution granting the degree
Jens Førstund	Estimating position using QR-codes	Ståle Freyer (ABB) Karl Skretting (ABB)	University of Stavanger
Munir, Imad	A Large-Scale OCL Constraint Repository and Comprehensive Analysis for Supporting Automated Cancer Registry System	Shuai Wang Shaukat Ali Tao Yue	University of Oslo
Sletten, Kristian	Automated testing of industrial robots using HTC Vive for motion tracking	Ståle Freyer (ABB) Karl Skretting (ABB)	University of Stavanger
Schwitalla, Thomas	A rule-Based Framework for Supporting Automated Change Impact Analysis in the Cancer Registry of Norway	Shuai Wang Shaukat Ali Tao Yue	University of Oslo

#### Female Master's Students

Name	Thesis Title	Advisors	Institution granting the degree
Pourabedin Islami, Mozghan	Security Modeling of Cyber-Physical Systems: A Case Study of Smart Grid	Phu H. Nguyen Tao Yue Shaukat Ali	University of Oslo
More, Pooja	Crowd-driven Systematic Literature Review	Sagar Sen Magne Jørgensen	University of Oslo

## Chairs

Certus researchers have been selected to chair and participate in several 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

#### Steering Committee, Co-Organizer

- CSTVA'17 Workshop on Constraint Solvers in Testing, Verification and Analysis, Melbourne, 2017

#### Track co-chair:

- CP'17 23rd Int. Conf. on Principles and Practice of Constraint Programming, Melbourne, Australia Sep. 2017

#### Workshop chair, Program committee member:

- QRS'17 IEEE Int. Conf. on Software Quality, Reliability and Security, Prague, Czech, Jul. 2017

#### Program committee member:

- IJCAI'17 Int. Joint Conf. on Artificial Intelligence, Melbourne, Australia, Aug. 2017
- TAP'17 12th Int. Conf. on Tests and Proofs, Marburg, Germany, Jul. 2017
- ICTAP'17 29th Int. Conf. on Tools with Artificial Intelligence, Boston, MA, USA, Nov. 2017
- ICTSS'17 29th IFIP Int. Conf. on Testing Software and Systems, St Petersburg, Oct. 2017

### Tao Yue

#### Track co-chair:

- MODELSWARD'17: 4th Int. Conf. on Model-Driven Engineering and Software Development, Feb. 19-21, Rome, Italy

#### Program Committee member

- MODELS'17: ACM/IEEE 19th Int. Conf. on ModelDriven Engineering Languages and Systems, Saint Malo, France
- RE'17: 24th Int. Conf. on Requirements Engineering, Beijing, China
- SPLC'17: 21th Int. Systems and Software Product Line Conf., Beijing, China
- QRS'16: IEEE Int. Conf. on Software Quality, Reliability & Security. Vienna, Austria

### Dusica Marjan

#### Program Committee member

- QRS'17: IEEE International Conference on Software Security and Reliability, July, Czech Republic
- SEIP'17: Software Engineering in Practice Track at International Conference on Software Engineering, May, Argentina

#### Journal Review Boards

- IEEE Software
- Software: Practice and Experience
- International Journal of Control Theory and Computer Modeling
- International Journal of Systems Assurance Engineering and Management

The long-standing collaboration with Cisco Systems Norway on improving the efficiency of testing video conferencing systems has led to the development of a software testing tool TITAN. The tool performs test optimization of extensive test suites, in order to reduce costs of software testing at Cisco and improve the quality of the conferencing systems. Certus Researcher Dusica Marijan had the honor to present TITAN at IEEE International Conference on Software Testing, Verification, and Validation 2017 in Japan. The talk was received with great interest from both the academic and industrial software testing community.

### Shaukat Ali

#### Program Committee member

- ECMFA 2017: 13th European Conference on Modelling Foundations and Applications
- MEDI 2017: 7th International Conference on Model and Data Engineering
- SPLC 2017: 21th International Systems and Software Product Line Conference
- MDEbug 2017: 1st International Workshop on Debugging in Model-Driven Engineering
- SSBSE 2017 Challenge Track: Search-based Software Engineering 2017 Challenge Track
- TECPS 2017: 1st International Workshop on Testing Embedded and Cyber-Physical Systems
- MODELS2017: ACM/IEEE 20th International Conference on Model Driven Engineering Languages and Systems
- SDL Forum 2017, SDL Forum 2017
- T&D MODELS 2017: Tools and Demos at 20th MODELS Conference 2017
- A-MOST 2017: 13th Workshop on Advances in Model Based Testing
- ICST 2017: 10th IEEE International Conference on Software Testing, Verification and Validation

### Sagar Sen

#### Program Committee member:

- SER&IP'17: 4rd Int. Workshop on Soft. Eng. Research and Industrial Practice,
- ISSRE'17: 29th IEEE Int. Symp. on Software Reliability Engineering
- SANER'17: 24th IEEE Int. Conf. on Software Analysis, Evolution, and Reengineering,

### Shuai Wang

#### Co-organiser (general chair)

- 13th Workshop on Advanced in Model Based Testing (A-MOST 2017), collocated with ICST 2017

#### Program Committee member:

- MODELSWARD'17 International Conference on Model-Driven Engineering and Software Development
- SAC'17 ACM/SIGAPP Symposium on Applied Computing

### Leon Moonen

#### Steering Committee member:

- IEEE Int. Working Conf. on Source Code Analysis and Manipulation (SCAM, chair)
- Int. Workshop on Patterns Promotion and Anti-Patterns Prevention (PPAP)

#### Program Committee member:

- MMHS'16: 3rd Int. Workshop on (Meta)modelling for Healthcare Systems
- ICPC'16: 24th IEEE Int. Conf. on Program Comprehension
- SCAM'16: 16th IEEE Int. Working Conf. on Source Code Analysis and Manipulation
- ICSME'16: 32nd IEEE Int. Conf. on Software Maintenance and Evolution



# Certus Publications

## 2017

### Articles in International Journals

1. Reliability-Redundancy-Location Allocation with Maximum Reliability and Minimum Cost Using Search Technique Huihui Zhang, Shuai Wang, Tao Yue, Shaukat Ali, Chao Liu *Information and Software Technology*, vol. 82, pp. 36–54, Elsevier
2. Search and similarity based selection of use case scenarios: An empirical study Xiang Qiu, Shaukat Ali, Tao Yue, Li Zhang *Empirical Software Engineering*, pp. 1–78, Springer
3. Uncertainty-Wise Evolution of Test Ready Models Man Zhang, Shaukat Ali, Tao Yue, Roland Norgren *Information and Software Technology*, vol. 87, pp. 140–159, Elsevier
4. Deploying Constraint Programming for Testing ABB's Painting Robots Morten Mossige, Arnaud Gotlieb, Hein Meling *AI Magazine*, no. 2, vol. 39, issue Summer, AAAI
5. Using Global Constraints to Automate Regression Testing Arnaud Gotlieb, Dusica Marijan *AI Magazine*, no. 1, vol. 38, issue Spring, AAAI
6. Uncertainty-Wise Cyber-Physical System Test Modeling Man Zhang, Shaukat Ali, Tao Yue, Roland Norgren, Oscar Okariz *Software & Systems Modeling*, Springer
7. IOCL: An Interactive Tool for Specifying, Validating and Evaluating OCL Constraints Hammad Muhammad, Tao Yue, Shuai Wang, Shaukat Ali, Jan F. Nygård *Science of Computer Programming (SCP)*, vol. 149, pp. 3–8, Elsevier
8. Aggregating Association Rules to Improve Change Recommendation Thomas Rolfsnes, Leon Moonen, Stefano “Di Alesio”, Razieh Behjati, David Binkley *Journal of Empirical Software Engineering (EMSE)*, Springer
9. Automated Refactoring of OCL Constraints with Search Hong Lu, Shuai Wang, Tao Yue, Shaukat Ali, Jan F. Nygård *IEEE Transactions on Software Engineering (TSE)*, IEEE
10. Enabling Automated Requirements Reuse and Configuration Yan Li, Tao Yue, Shaukat Ali, Li Zhang *Software and Systems Modeling*, Berlin Heidelberg, Springer
11. Integrating Weight Assignment Strategies with NSGA-II for Supporting User Preference Multi-Objective Optimization Shuai Wang, Shaukat Ali, Tao Yue, Marius Liaaen *IEEE Transactions on Evolutionary Computation (TEVC)*, IEEE
12. Anticipating anonymity in screening program databases Rafael Caballero, Sagar Sen, Jan F. Nygård *International Journal of Medical Informatics*, vol. 103, pp. 20–31, Elsevier
13. Modeling and Verifying Combinatorial Interactions to Test Data Intensive Systems: Experience at the Norwegian Customs Directorate Sagar Sen, Dusica Marijan, Carlo Ieva, Astrid Grime, Atle Sander *IEEE Transactions on Reliability*, no. 1, vol. 66, pp. 3–16, IEEE Transactions on Reliability
14. Protecting Privacy in Large Datasets—First We Assess the Risk; Then We Fuzzy the Data Giske Ursin, Sagar Sen, Jean-Marie Mottu, Mari Nygård *Cancer Epidemiology Biomarkers & Prevention*, vol. 26, pp. 1219–1224, issue 8, AACR
15. Naming the pain in requirements engineering Mendez Fernandez, Stefan Wagner, Marcos Kalinowski, Michael Felderer, Priscilla Mafra, Antonio Vetrò, Tayana Conte, M-T Christiansson, Desmond Greer, Casper Lassenius *Empirical Software Engineering*, no. 5, vol. 22, pp. 2298–2338, Springer

### Book Chapters

1. Uncertainty-wise Testing of Cyber-Physical Systems Shaukat Ali, Hong Lu, Shuai Wang, Tao Yue, Man Zhang *Advances in Computers*, Elsevier
2. Software Product Line Test Suite Reduction with Constraint Optimization Mats Carlsson, Arnaud Gotlieb, Dusica Marijan *vol. 743*, pp. 68–87, *Software Technologies*, published and edited by Springer International Publishing

### Technical Reports

1. Uncertainty-based Test Case Generation and Minimization for Cyber-Physical Systems: A Multi-Objective Search-based Approach Man Zhang, Shaukat Ali, Tao Yue, “Malin Hedman” *Simula Research Laboratory*
2. A Pilot Experiment to Assess Interactive OCL Specification in a Real Setting Shaukat Ali, Hammad Muhammad, Hong Lu, Jan Nygård, Shuai Wang, Tao Yue *Simula Research Laboratory*
3. An Empirical Evaluation of Mutation and Crossover Operators for Multi-Objective Uncertainty-Wise Test Minimization Shaukat Ali, Yan Li, Tao Yue, Man Zhang *Simula Research Laboratory*
4. Uncertainty-Wise and Time-Aware Test Case Prioritization with Multi-Objective Search Man Zhang, Yan Li, Shaukat Ali, Tao Yue *Simula Research Laboratory*
5. Fragility-Oriented Testing with Model Execution and Reinforcement Learning Tao Ma, Shaukat Ali, Tao Yue *Simula Research Laboratory*

### Posters

1. SUNCPS: A Taxonomy of Security-related Uncertainty in Cyber-Physical Systems Phu Hong Nguyen, Shaukat Ali, Tao Yue *International Symposium on Engineering Secure Software and Systems (ESSoS'17)*
2. Uncertainty-wise and Model-based Testing of Industrial Cyber-Physical Systems Man Zhang, Shaukat Ali, Tao Yue, Phu Hong Nguyen *5th User Conference and Advanced Automated Testing (UCAAT)*
3. FightHPV : A Game to Raise Awareness and Nudge People to Take Action Against Cervical Cancer in Norway Tomas Ruiz Lopez, Sagar Sen, Elisabeth Jakobsen, Mari Nygård *Cape Town, South Africa, IPVS*
4. Using mobile games as an educational platform to promote human papillomavirus vaccination and improve sexual health in Zambian adolescents Adebola Adedimeji, Sharon Kapambwe, Sagar Sen, Mari Nygård *Cape Town, South Africa, IPVS*
5. Portinari: An Interactive Visualization Tool To Explore Alternative Patient Paths in Cervical Cancer Screening Manoel Ribeiro, Sagar Sen *Cape Town, South Africa, IPVS*

### Referred Proceedings

1. Constraint-Based Verification of a Mobile App Game Designed for Nudging People to Attend Cancer Screening Arnaud Gotlieb, Marine Louarn, Mari Nygård, Tomas Ruiz-Lopez, Sagar Sen, Roberta Gori *Proceedings of Innovative Applications of Artificial Intelligence (IAAI-17)*, Feb. 2017, San Francisco, USA, AAAI
2. CBGA-ES: A Cluster-Based Genetic Algorithm with Elitist Selection for Supporting Multi-objective Test Optimization Dipesh Pradhan, Shuai Wang, Shaukat Ali, Tao Yue, Marius Liaaen, edited by Atif Memon, Yasuharu Nishi *10th IEEE International Conference on Software Testing, Verification and Validation (ICST 2017)*, IEEE
3. Safety Evidence Change Impact Analysis in Practice Jose Luis “de la Vara”, Markus Borg, Krzysztof Wnuk, Leon Moonen, edited by Sebastián Uchitel, Alessandro Orso, Martin P. Robillard *International Conference on Software Engineering, ACM/IEEE*
4. Empowering Testing Activities with Modeling: Achievements and Insights from Nine Years of Collaboration with Cisco Shaukat Ali, Marius Liaaen, Shuai Wang, Tao Yue, edited by Luis Ferreira Pires, Slimane Hammoudi, Bran Selic *pp. 581–589 The International Conference on Model-Driven Engineering and Software Development (MODELSWARD) published by SCITEPRESS – Science and Technology Publications*
5. Test Prioritization with Optimally Balanced Configuration Coverage Dusica Marijan, Marius Liaaen *IEEE International Symposium on High Assurance Systems Engineering, ACM/IEEE*
6. Detecting and Reducing Redundancy in Software Testing for Highly Configurable Systems Dusica Marijan, Sagar Sen *IEEE International Symposium on High Assurance Systems Engineering, ACM/IEEE*
7. An Empirical Evaluation of Mutation and Crossover Operators for Multi-Objective Uncertainty-Wise Test Minimization Shaukat Ali, Yan Li, Tao Yue, Man Zhang, edited by Justyna Petke, Juan Galeotti *10th International Workshop on Search-based Software Testing, IEEE*
8. Mining Cross Product Line Rules with Multi-Objective Search and Machine Learning Safdar Aqeel Safdar, Hong Lu, Tao Yue, Shaukat Ali *Genetic and Evolutionary Computation Conference (GECCO)*, ACM
9. TITAN: Test Suite Optimization for Highly Configurable Software Dusica Marijan, Arnaud Gotlieb, Marius Liaaen, Sagar Sen, Carlo Ieva *International Conference on Software Testing, Verification and Validation (ICST 2017)*, IEEE
10. Search-Based Test Case Generation for Cyber-Physical Systems Aitor Arrieta, Shuai Wang, Urtzi Markiegi, Goiuria Sagardui, edited by Leire Exeberria *pp. 688–697, IEEE Congress on Evolutionary Computation (CEC)*, IEEE
11. A Multi-objective and Cost-Aware Optimization of Requirements Assignment Yan Li, Tao Yue, Shaukat Ali, Li Zhang *IEEE Congress on Evolutionary Computation 2017 (CEC)*, IEEE
12. Reinforcement Learning for Automatic Test Case Prioritization and Selection in Continuous Integration Helge Spieker, Arnaud Gotlieb, Dusica Marijan, Morten Mossige, edited by Tevfik Bultan, Koushik Sen *pp. 12–22, Proceedings of the 26th ACM SIGSOFT International Symposium on Software Testing and Analysis New York, NY, USA, ACM*
13. Efficient and Complete FD-Solving for Extended Array Constraints Quentin Plazar, Mathieu Acher, Sebastien Bardin, Arnaud Gotlieb *pp. 1231–123, Proceedings of the Twenty-Sixth International Joint Conference on Artificial Intelligence, IJCAI*
14. Product Line Engineering of Monitoring Functionality in Industrial Cyber-Physical Systems: A Domain Analysis Aitziber Iglesias, Hong Lu, Cristobal Arellano, Tao Yue, Shaukat Ali, edited by Goiuria Sagardui *The 21st International Systems and Software Product Line Conference, ACM*
15. Time-aware Test Case Execution Scheduling for Cyber-Physical Systems Morten Mossige, Arnaud Gotlieb, Helge Spieker, Hein Meling, Mats Carlsson *Proceedings of Principles of Constraint Programming (CP'17)*, Springer
16. Fragility-Oriented Testing with Model Execution and Reinforcement Learning Tao Ma, Shaukat Ali, Tao Yue, Maged Elaasar *The 29th International Conference on Testing Software and Systems, LNCS*
17. RCIA: Automated Change Impact Analysis to Facilitate a Practical Cancer Registry System Shuai Wang, Thomas Schwitalla, Tao Yue, Shaukat Ali, Jan F. Nygård, edited by IEEE *pp. 603–612, The International Conference on Software Maintenance and Evolution (ICSME)*, IEEE
18. Search-based Uncertainty-wise Requirements Prioritization Yan Li, Man Zhang, Tao Yue, Shaukat Ali, Li Zhang *The 22nd International Conference on Engineering of Complex Computer Systems, IEEE*
19. A Restricted Natural Language based Use Case Modeling Methodology for Real-time Systems Huihui Zhang, Tao Yue, Shaukat Ali, Ji Wu, Chao Liu *9th Workshop on Modelling in Software Engineering (MISE'2017)*, IEEE
20. Predicting Relevance of Change Recommendations Thomas Rolfsnes, Leon Moonen, David Binkley, edited by Gregore Ruso, Massimiliano “Di Penta”, Tien N. Nguyen *The IEEE/ACM International Conference on Automated Software Engineering (ASE)*, IEEE
21. Generating Test Sequences to Assess the Performance of Elastic Cloud-based Systems Michel Albonico, Stefano Alesio, Jean-Marie Mottu, Sagar Sen, Gerson Sunyé, edited by Geoffrey C. Fox *10th IEEE International Conference on Cloud Computing, IEEE*
22. 4th International Workshop on Software Engineering Research and Industrial Practise (SER&IP 2017) Sagar Sen, Judith Bishop, Karin K. Breitman, edited by Rakesh Shukla *pp. 1, 4th IEEE/ACM International Workshop on Software Engineering Research and Industrial Practice, SER&IP@ICSE 2017, Buenos Aires, Argentina, May 21, 2017, IEEE*
23. Portinari: A Data Exploration Tool to Personalize Cervical Cancer Screening Sagar Sen, Manoel Horta Ribeiro, Raquel Cardoso de Minardi, Wagner Meira, Mari Nygård, edited by Maria Angela Ferrario, Maria Angela Fer Pernici *pp. 37–46, 39th IEEE/ACM International Conference on Software Engineering: Software Engineering in Society Track, ICSE-SEIS, IEEE*

### Edited Books

1. The Proceeding of the 13th Workshop on Advances in Model Based Testing (A-MOST) Shuai Wang, Paolo Arcaini, Xavier Devroey *vol. 13, no of vols. 13, Tokyo, Japan, IEEE*

## Talks

1. Leveraging Machine Learning to Guide Software Evolution  
Leon Moonen  
8th IEEE International Workshop on Empirical Software Engineering in Practice (IWESEP), Tokyo, Japan, IEEE
2. Testing Cyber-Physical Systems under Uncertainty  
Shaukat Ali  
CPS Concertation Event, Brussels, Belgium
3. Uncertainty-Wise Testing  
Shaukat Ali  
Advances in Model-Based Testing (A-MOST)
4. Uncertainty modeling (UM) – Progress Summary  
Tao Yue, Shaukat Ali  
OMG Technical Meeting at Brussels
5. Reusable Use Case and Test Case Specification Modeling  
Tao Yue, Shaukat Ali  
The 16th International Conference on Software Reuse, Salvador, Brazil
6. Challenges and Experiences on the Adoption of Model-Based Methods and Model-Based Testing in Industry  
Tao Yue  
TAIC PART 2017, Located with ICST 2017, Tokyo, Japan
7. An Empirical Evaluation of Mutation and Crossover Operators for Multi-Objective Uncertainty-Wise Test Minimization  
Shaukat Ali  
Buenos Aires, Argentina, Proceedings of the IEEE/ACM 10th International Workshop on Search-Based Software Testing under the 2017 IEEE/ACM 39th International Conference on Software Engineering, ACM IEEE
8. Introduction to U-Test: Uncertain CPS behaviour and reliability  
Shaukat Ali  
Exploitation Event ULMA Handling Systems, Spain
9. Empowering Testing Activities with Modeling  
Shaukat Ali  
The International Conference on Model-Driven Engineering and Software Development (MODELSWARD)
10. Model-Based Engineering of A broad range of industrial applications and challenges  
Tao Yue  
Nanjing University of Aeronautics and Astronautics
11. Uncertainty-wise Test Case Generation and Minimization for Cyber-Physical Systems: A Multi-Objective Search-based Approach  
Shaukat Ali  
National Institute of Informatics, Tokyo, Japan
12. Uncertainty-wise Testing of Cyber-Physical Systems  
Shaukat Ali, Tao Yue, Man Zhang  
2017 IEEE International Symposium on Systems Engineering
13. Effective test scrubbing with machine learning and Python  
Carl Martin Rosenberg, Marius Liaaen, Thomas Hanssen Nordnes  
NDC TechTown, Kongsberg
14. Search-Based Test Case Generation for Cyber-Physical Systems  
Shuai Wang  
IEEE Congress on Evolutionary Computation (CEC)
15. RCIA: Automated Change Impact Analysis to Facilitate a Practical Cancer Registry System  
Shuai Wang  
The International Conference on Software Maintenance and Evolution (ICSME)
16. Search-Based Software Testing in Practice  
Shuai Wang  
Mondragon University, Spain
17. Opening Speech for the 13th edition of the Advances in Model-based testing (A-MOST 2017)  
Shuai Wang  
The 13th edition of the Advances in Model-based testing (A-MOST 2017), Japan
18. History-Based Recommendations to Guide Software Evolution  
Leon Moonen  
Graduate School of Information Science and Technology, Osaka University, Osaka, Japan
19. History-Based Recommendations to Guide Software Evolution  
Leon Moonen  
National Institute of Advanced Industrial Science and Technology (AIST), Japan
20. History-Based Recommendations to Guide Software Evolution  
Leon Moonen  
Nara Institute of Science and Technology, Nara, Japan
21. History-Based Recommendations to Guide Software Evolution  
Leon Moonen  
Kyoto Institute of Technology, Kyoto, Japan
22. History-Based Recommendations to Guide Software Evolution  
Leon Moonen  
Tokyo Institute of Technology, Tokyo, Japan
23. Learning How to Test Robotic Systems  
Arnaud Gotlieb  
Simula-HiOA Seminar April 5th, Fornebu, Lysaker
24. Intelligent Test Optimization  
Arnaud Gotlieb  
TAROT Summer School on Software Testing, Jun. 26th, Naples, Italy
25. Testing Robotic Systems: A New Battlefield!  
Arnaud Gotlieb  
French National Days of GDR-GPL 2017, Montpellier, France
26. Anomaly Detection and Data Clustering  
Carl Martin Rosenberg, Marius Liaaen  
12th Certus User Partner Workshop
27. Certus Project 9 – Smarter Testing of Evolving Software Systems  
Carl Martin Rosenberg, Leon Moonen  
12th Certus User Partner Workshop
28. Reflections on Unsupervised Learning Problems  
Carl Martin Rosenberg  
Simula COMMONS Seminar
29. Safety Evidence Change Impact Analysis in Practice  
Jose Luis “de la Vara”, Markus Borg, Krzysztof Wnuk, Leon Moonen  
International Conference on Software Engineering, Buenos Aires, Argentina, ACM/IEEE
30. Predicting Relevance of Change Recommendations  
Thomas Rolfsnes, Leon Moonen, David Binkley  
IEEE/ACM International Conference on Automated Software Engineering (ASE), Urbana-Champaign, Illinois, USA, IEEE
31. SER&IP: Introduction by Program Chairs  
Sagar Sen, Karin Breitman, Judith Bishop, Rakesh Shukla  
Buenos Aires, Argentina
32. Challenges in Testing IoT systems in the Wild : Some experiences in an IoT Startup: Sweetzpot  
Sagar Sen  
Oslo, Norway
33. Test Case Prioritization for Regression Testing  
Dipesh Pradhan  
12th Certus User Partner Workshop
34. Using Search Based Software Testing for Regression Test Optimization  
Dipesh Pradhan  
Simula COMMONS Seminar

## Statistics on Certus Publications

## Certus Publications

The Development Of Certus Publications								
	2011	2012	2013	2014	2015	2016	2017	TOTAL
Journal articles	3	12	13	10	10	13	15	76
Edited books			1	2		2	1	6
Proceedings, refereed	11	24	35	22	13	25	23	153
Book chapters	1	1	1	1	2		2	8
Talks, keynote		1		3		2	4	10
PhD Theses		3			2			5
Proceedings, non-refereed		1						1
Posters		1			1		5	7
Technical reports	4	8	3	3	3	9	5	35
Talks, invited		1	1	1	6	3	15	27
Talks, contributed		3	1	5	5	2	15	31
Miscellaneous		1	1					2
<b>TOTAL</b>								<b>361</b>





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