Certus
Annual Report
2013

Certus

Arnaud Gotlieb
leader of the Certus Centre

Head of the Software Engineering Department, Simula Research Laboratory

Since its creation in October 2011, the Certus Centre has attracted great attention from different players and has fostered innovation in software validation and verification (V&V). Certus was awarded status as a Centre for Research-based Innovation (SFI) by the Norwegian Research Council, based on the unique diversity and scope of its partners: Simula as the hosting research institution; FMC Technologies in oil and gas; Kongsberg Maritime in shipping and offshore; communication systems provider Cisco Systems; industrial automation leader ABB Robotics; Esito, a small enterprise delivering software modelling tools for large, data-intensive systems; and the Norwegian agency for Customs and Excise.

Software engineers and researchers have teamed up to create an innovative environment where specialised expertise and creative research combine to produce readily exploitable, take-away results. Even Certus partners with apparently little in common discover, once they begin to interact, that they share common technical interests and a hunger for information and communication technology (ICT) innovations. Emphasising the industrial exploitation of the results by its user partners, in 2013 Certus started to play a prevalent role within software V&V. Through the organisation of dedicated open courses and workshops, Certus has managed to reach a broader audience and communicate the importance of software quality in general. Gaining international visibility through new collaboration with academic and industrial partners has also been part of the centre's strategy in 2013.

Finally, by attracting additional funding and increased internal investment, Certus was able to initiate the industrialisation of software products (DEPICT and TITAN) that derived directly from research results, paving the way for future success stories.

Opening the door to multifaceted research and innovation concepts, where the creativity of researchers meets the expertise of software engineers, has been the primary goal of Certus. In that respect, 2013 has confirmed the academic and industrial outreach potential inherent in the Certus model.

The goal of the Certus Centre and the SFI programme is to promote innovation by supporting long-term research through close cooperation between R&D-intensive companies and a prominent research institution.

Contents

Certus beyond borders

Simula Research Laboratory nurtures close collaboration with a large number of academic institutions and commercial companies across several research topics, in Norway and abroad. Such collaboration with carefully selected partners possessing internationally leading competence has been a crucial component in achieving the laboratory's current standing.

This statement applies strongly to Certus. The centre currently has 17 researchers of 10 nationalities and, through personal networks, these researchers provide both informal and formal links to other internationally leading research groups in software V&V. For instance, the University of Luxembourg and the University of Parma are involved in the education of PhD students at Certus and will award the candidates' degrees after their work has been completed and defended. Another example is the joint supervision of an industrial PhD candidate that also involves Inria in France, one of the largest and most prestigious European research organisations within ICT. Within an even larger geographical perimeter, there is also substantial interaction with Beihang University in China, involving student and senior researcher mobility. Such elements are vital parts of the activities of Certus, even though the institutions mentioned are not formal members of the Certus consortium. In addition, several researchers at Certus contribute considerably to the international research community through active participation in programme committees and technical committees for leading conferences, review work for journals and proceedings, contributions to standardisation committees, and so on.

Several Certus' industrial partners have multinational characters that nicely complement the international flavour of the centre's academic collaboration. Cisco, FMC Technologies, Kongsberg Maritime, and ABB are all world-spanning organisations. Although the active staff members of Certus are located in Norway, they address technological problems and corresponding solutions that have shared ownership beyond borders. Moreover, collaboration with these companies and the people working there provides mechanisms for even wider international outreach. We recently entered into collaboration with the German software vendor Pure-Systems through an innovation project funded by the Research Council of Norway. This project aims to exploit a technology developed at Certus in close interaction with Cisco.

National statistics state that Norwegian researchers have so far been able to attract only 60% of the 10 billion Norwegian kroner that we – the Norwegian taxpayers – have sent to Brussels for research purposes.

From these perspectives, one can state that Certus has a strong international profile. This profile is well aligned with national strategies for research, in which close collaboration with the very best international partners is a priority. While such ambitions are set forth as goals for Norwegian research, the main obstacle is often that of accessing funding that truly supports, or even demands, international collaboration. National statistics state that Norwegian researchers have so far been able to attract only 60% of the 10 billion Norwegian kroner that we – the Norwegian taxpayers – have sent to Brussels for research purposes. It is then no surprise that the Norwegian government wants a better return on this investment. Recently, the Minister of Education and Research said, 'When we spend billions for this purpose, I consider Norwegian research institutions to take on a responsibility. Now, we need a change of pace'.[1] At Simula, we have taken this responsibility seriously. Acknowledging that only modest success in the European funding system has been our Achilles heel, we have spent the last 10 months mobilising a great effort towards the new European framework programme for research, Horizon 2020.

Information technology is one of the priority research areas in Horizon 2020. This prioritisation mirrors the increasing value that software systems have to society and society's exploding dependence upon such systems. To secure the impact of the research, the funding instruments of Horizon 2020 are focusing on innovation and collaboration with stakeholders in industry and the public sector. Given that we have excellent competence, innovative ideas, and a strong international network, Simula, and in particular Certus, should be well positioned to compete for this type of research funding.

A large number of Simula researchers were present at the 2013 ICT event in Vilnius last November, the official kickoff for the ICT-related parts of Horizon 2020. This contingent included a significant number of Certus people eagerly seeking information about the challenges and opportunities offered by the new framework programme. At the writing of this editorial, we are at the peak of activity in turning this initiative into a nice bouquet of competitive proposals. In particular, we are addressing a number of calls in Horizon 2020's Leadership in Enabling and Industrial Technologies pillar, which are due late April.

During the winter of 2014–2015, international experts will be conducting the mid-term evaluation of the second-generation Centres for Research-based Innovation, including Certus. One of the topics to be addressed in the forthcoming evaluation is the centre's exit strategy. In my mind, we should head for the European exit.

Professor Are Magnus Bruaset
Chair of the Board, Certus

Director of Computing and Software, Simula Research Laboratory

[1] In Norwegian, 'Når vi bruker milliarder på dette, mener jeg Forsknings-Norge også påtar seg en forpliktelse. Nå trengs et taktskifte'. Aftenposten, 27 March 2014.

Employing V&V as a strategic advantage

The Certus Centre has established a body of methods and tools for the validation and verification software-intensive systems. Working in close cooperation with the Certus partners, the centre's researchers have analysed and produced innovative methods to validate the following types of systems.

Real-time embedded software systems:

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 a set of real-time constraints.

Highly configurable software systems:

Families of software and hardware systems for which software reuse is a major concern, since many commonalities and variabilities exist between products of a product family. Facilitating such reuse will significantly improve the overall quality and productivity of product development.

Data-intensive software systems:

Software applications built on one or several database management systems and that deal with large amounts of data. These applications typically have to store, retrieve, and process millions of data entries.

2013 Annual Work Plan

In 2013, the centre undertook collaborative research to solve complex challenges proposed by the user partners.. Work activities covered eight projects that were governed through the Annual Work Plan. Four of the projects were research activities, one related to industrial exploitation, and the rest focused on management, communication, and dissemination. The combination of these projects is designed to enhance Certus' innovative environment. All in all, there were 20 active tasks in 2013, resulting in more than 60 deliverables, a substantial increase from 2012.

During 2013, another topic emerged from collaborative work between the user partners and the host partners,and a new activity relating to the "Smarter testing of evolving software systems" has been fully integrated into the 2014 Annual Work Plan as a separate project.

Why Certus?
The Certus Centre was established in 2011, in response to the continually increasing demand for dependable systems and ways to bring software V&V costs under control.

Arnab Sarkar, Research Assistant, Simula

Organisation

Arnaud Gotlieb, Leader of the Certus Centre, Simula

The Certus Centre

The Certus Centre is an official Centre for Research-based Innovation (SFI), appointed by the Research Council of Norway (RCN), with Simula Research Laboratory as the host institution. The Certus partners are independent legal entities and the Certus Centre is a collaboration project between these. This partnership is governed by the Certus consortium agreement. As the host institution, Simula has received an SFI grant from the RCN and accepts overall responsibility for the project, as outlined by the grant agreement between Simula and the RCN. Resources at the Certus Centre are divided according to a principle of proportionality, ensuring a fair distribution of effort between the host and the user partners.

Management of the Certus Centre

The Certus Centre is managed by the centre leader and the administrative manager, who report to the Certus board. The board, which consists of representatives from each of the Certus partners, approves the Annual Work Plan and governs the centre. The board plays an important role in maintaining oversight of the centre's ongoing activities and in the planning of the user partner workshops, organised twice yearly. The board's strong involvement allows clear focus on Certus' long-term goals and ambitions.

In 2013, the board consisted of:

Are Magnus Bruaset (chair, Simula), Mette Wam (Esito), Geir Magne Merkesvik (FMC Technologies), Marius Liaanen (Cisco), Merethe Gotaas (Kongsberg Maritime), and Katrine Langset (Customs and Excise). The management of the centre includes Arnaud Gotlieb (Certus leader, Simula) and Christian Hemmestad Bjerke (administrative manager, Simula). To contribute to partner cross-fertilisation, Certus' four board meetings in 2013 were held at Kongsberg Maritime, FMC Technologies, Cisco, and Simula.

Key Figures

The Certus Centre annual accounts for 2013 shown below are presented in the standard setup used by the Research Council of Norway. In particular regarding funding; "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 four user partners. Figures represent an increase in activity from 2012.

Cost in NOK 2013	
Payroll / indirect expenses	13 055 141
Equipment	49 729
Other operating expenses	8 016 002
Totals	21 120 872

Funding in NOK 2013	
Own financing	4 885 514
Other public funding	1 714 900
Other private funding	4 625 458
From the Research Council	9 895 000
Totals	21 120 872

Partners

Host Institution

[simula . research laboratory]
– by thinking constantly about it

Simula Research Laboratory is a non-profit public utility enterprise performing leading international research within selected ICT fields. In 2012, Simula was ranked first in the national RCN-conducted evaluation of research in ICT. In particular, the software engineering department received the top score, 'Excellent'.

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 V&V research. The Certus Centre is one of several research projects at Simula within software V&V.

KONGSBERG

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 to ensuring the reliability and correct functioning of offshore and shipyard systems.

TOLL CUSTOMS

Customs and Excise is an agency under the Ministry of Finance. Customs and Excise assesses and collects customs and excise duties, value-added tax on imported goods, and special taxes for the state treasury. The agency also 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 and excise in Norway. Their systems have high requirements regarding data integrity, availability, and security.

CISCO

Cisco Systems Norway specialises in video conferencing systems and manufactures a broad selection of products designed to realise 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 collaborations and minimise travelling become essential.

FMC Technologies

FMC Technologies is a leading global provider of technology solutions for the energy industry. One of its key technologies is Subsea Production Systems, large-scale, integrated, and highly configurable systems for managing the exploitation of oil and gas production fields. The subsea industry's need for high-quality and improved recovery rates has led FMC Technologies to utilise software to further improve its subsea technology.

= | esito

ESITO is an ICT company that develops and markets the model-based software development tool Genova. This tool is mainly used to develop administrative, mission-critical applications. Esito's vision is to provide its customers with lower costs and better quality in the development and maintenance of their applications.

ABB

ABB Robotics is a market leader in painting systems embedded into industrial robots. These systems are integrated control software systems that pilot the paint process applied to various industrial objects, such as car bodies and aircraft wings. The company produces systems in such a way that allows the operator to control both the motions and the painting process of the robot. To deliver market-leading products, ABB Robotics has made system V&V a high priority. The company will complement and strengthen Certus' position in software V&V by opening a new line of research collaboration in this area.

ABB was a collaborating company in 2013 and became a full partner in 2014.

Scientific Activities

Certus continues to develop techniques and tools for the modelling, certification, and testing of software-intensive systems.

Merethe Gotaas, Member of the Certus board, Kongsberg Maritime

In 2013, Certus concentrated on two main objectives:

- To focus our resources and activities on the areas in which we are most competent. In doing so, we were able to maximise our impact in the global software engineering community, as well as with our user partners.

- To maximise cross-fertilisation activities between the user partners. This was achieved by involving several partners in each project.

As an integrated part of our host partner Simula's strategy, in 2013 we made a strong impact in the global software engineering community in the areas of variability testing, modelling highly configurable systems, and testing data-intensive systems. We issued a number of high-quality publications and developed several software prototype tools, such as the TITAN tool and the Zen-RUCM editor. Another highlight was the experimental application of our techniques in industrial case studies.

Certus continued to build on the significant progress that was made in 2012, resulting in the development of strong expertise in variability testing and modelling and the software testing of database management systems. In 2013, we continued to encourage the Certus user partners to exploit the corresponding techniques, methodologies, and tools.

Model-based engineering for highly configurable systems

Involving the application of model-driven engineering techniques to the modelling and configuration of subsea integrated control systems, which can be regarded as highly variable software systems. In 2013, the project focused on requirement handling and analysis through the usage of families of structural and behavioural models.

Testing of data-intensive systems

Looking into the improvement of existing regression testing techniques to handle large database-centric applications. In 2013, research concentrated on test suite reduction and test case prioritisation when large database management systems are involved. Other research directions, including test oracle generation, were also explored.

## Testing of real-time embedded systems

Involving research into managing the testing activities of families of real-time embedded systems. The main focus during 2013 was variability management in the generation of test configurations and test cases, using techniques such as variability modelling and combinatorial interaction testing.

Sunil Nair wins the regional final of Researcher Grand Prix Oslo

PhD student Sunil Nair of the Software Engineering Department at Simula and Certus advanced to the national finals of Researcher Grand Prix with his victory in the Oslo regional competition in September 2013. Sunil's field of expertise is the certification of safety-critical systems and his winning presentation was titled 'Fasten your seatbelts! Safety is not guaranteed!' Sunil's project at Certus aims to define a common framework spanning vertical markets for railways, avionics, and automotive and establish an open-source safety certification infrastructure for these industries.

Researcher Grand Prix Oslo gives 10 elite researchers from regional institutions the opportunity to present their research in front of a wide audience, using only four minutes each. The presentations are then ranked by the audience and a panel of judges. Just being selected to present is in itself an honour, and winning the Oslo finals is indeed a feather in the cap of Sunil — and Certus.

Photo: Benjamin A. Ward / HiOA

Improving quality of product development
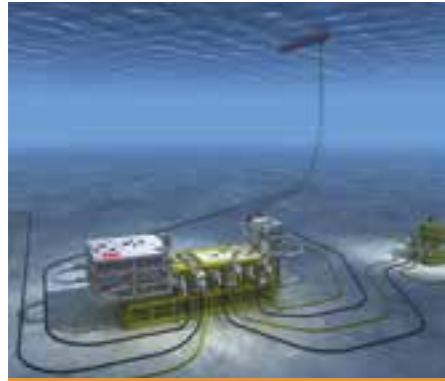
FMC Technologies

Background

Subsea oil and gas production systems are complex cyber-physical systems incorporating software and hardware components and consisting of a large numbers of sub-systems, typically geographically distributed and connected through a network.

Model-Based Engineering technologies offer a promising approach to reducing the complexity of developing cyber-physical systems. They improve the quality and productivity of a product development process by capturing information at a higher level of abstraction, providing a knowledge-sharing platform for communication between stakeholders, and enabling automated analysis.

Activities

In 2013, Certus applied MBE technologies to the subsea oil and gas production systems of FMC Technologies, with the aim of supporting requirements engineering, and the configuration and certification of large-scale and highly configurable cyber-physical systems, mainly including the following four activities:

1) Devising a model-based requirements management solution to handle the complexity of requirements engineering practice.

2) Deriving requirements-based, keywords-based, and model-based test generation solutions to enable systematic reuse and analyses at both the requirements and testing levels.

3) Evaluating the current product configuration process, with the aim of improvement through use of a model-based and semi-automated configuration solution.

4) Developing model-based solutions to facilitate safety evidence management during system development, evidence traceability, and evidence change impact analysis.

Impact

Certus has derived a solution for the systematic construction of a requirements repository that can be integrated with the current requirements management tool deployed by FMC Technologies. A requirements specification methodology together with a user-friendly editor (the Zen-RUCM software tool) were proposed and developed to enable the production of high-quality requirements specifications. The state of the art and state of the practice in safety evidence management were studied and the results were applied to propose model-based solutions for evidence traceability and evidence evolution management.

Highlights

Requirements are important artefacts that are typically used as inputs for later system development activities. Vague, inconsistent, and inadequate requirements can result in significant consequences, including system failure, excessive maintenance costs, and future loss of credibility and business. A radical solution for systematically and rigorously specifying, managing, and verifying a large number of requirements is critical to the success of the Norwegian subsea oil and gas industry. Developing such systems requires systematic and scalable solutions with tool support. Certus is committed to providing such a radical solution, currently lacking from the offering of commercial off-the-shelf tools dominating the market.

The Zen-RUCM tool

'Zen-RUCM: An Advanced Use Case Modelling Tool' was demonstrated at the ACM/IEEE 16th International Conference on Model Driven Engineering Languages and Systems (MODELS 2013) and positive feedback was received, indicating that such a tool is needed in the market. A teaser video for the demonstration was created and uploaded to YouTube.

Geir Magne Merkesvik,
Certus board member, FMC Technologies

Reducing effort in testing data-intensive systems

Background

Data-intensive systems are omnipresent in our information society. Large quantities of data are produced by online transactions that are processed and stored by systems used for scientific research, business, and e-governance.

Developed and maintained by the Directorate of Customs and Excise (Toll- og avgiftsdirektoratet), TVINN is a data-intensive system that processed about 30,000 customs declarations a day. The enormous amount of data flowing in and out of TVINN reflects numerous scenarios with individual/societal impact, such as the seasonal import of products, accurate tax computations, and the potential import of substances leading to criminal activities or hazards.

Testing TVINN to correctly handle these transactions is critical for test managers at Toll. Nearly 40% of test managers' time is spent maintaining TVINN at a high level of quality in the selective permeability of customs declarations.

Activities

In 2013, Certus researchers and test managers at Toll decided to focus on the specific problem of ensuring test coverage in the thousands of live declarations used for testing TVINN. According to test managers, live declarations are the most effective at detecting faults in TVINN. However, testing using live declarations induces considerable redundancy in the testing process due to duplicates. Moreover, simply testing with live declarations does not guarantee that all testing scenarios are covered. We developed an industry-strength tool called DEPICT to instantly verify the test coverage of millions of live declarations in a matter of seconds. DEPICT verifies the coverage of these declarations with respect to a classification tree model of test cases. It detects 'holes' in the live data and also finds which test cases are satisfied and how many times. Knowing what is covered and what is not greatly reduces the effort in testing these systems, since the process of creating a declaration is manual and requires human input through complex user interface. In addition, filling in a declaration requires expert knowledge in the Norwegian customs domain.

Impact

The tool DEPICT is currently installed on some servers at the Directorate of Customs and Excise. It has been evaluated for both test case coverage and test case documentation. DEPICT has become an industry-strength tool, with applications to test not only TVINN, but any large relational database system.

Highlights

Based on Certus research, it is possible to verify the coverage of live data that is used to test data-intensive systems. Millions of records are extracted from live transactions and apportioned in a complex relational database that acts as a blueprint for data flowing in and out of the system. Data interaction coverage ensures that these apportioned data satisfy cross-sectional system-wide functionality tests. Testers' knowledge of the coverage greatly reduces testing effort, since they no longer have to test blindly.

We developed an industry-strength tool called DEPICT to instantly verify the test coverage of millions of live declarations in a matter of seconds.

Improving the testing processes of cyber-physical systems

ABB Robotics

Background

Certus user partners such as Cisco Systems, Kongsberg Maritime and ABB Robotics develop and maintain complex cyber-physical systems. These systems must be reliable, safe, and efficient to avoid posing undue risks to their users or the environment. Constantly improving the validation processes of these systems is not only a moral obligation for these companies, but also a way to reduce the heavy costs related to V&V. Benefiting from Certus' expertise in the field, these partners team up with researchers in studying how to improve the testing processes of cyber-physical systems.

Activities

While testing new video conferencing systems developed by Cisco Systems or testing long lifecycle software products developed at Kongsberg Maritime, models can be used to support cost-effective test case selection, test suite minimisation with the aim of reducing the total number of test cases, and automatic executable test case generation for new functionalities. For test suite minimisation, a dedicated tool-supported methodology based on evolutionary algorithms has been proposed and strictly evaluated to preserve test suite fault detection capability and test coverage.

For complex industrial robotic systems, such as those developed and maintained by ABB Robotics, other types of models can be used for similar purposes. Constraint programming models originating from operational research and artificial intelligence have been used to provide original and cost-efficient solutions to software validation challenges.

Impact

Strong research and innovation results have been achieved in the area of model-based testing within this project, disseminated by many publications and active communication. New methodologies and models have been produced and released for the benefit of the user partners, including a constraint model that is employed on a daily basis at ABB Robotics within the continuous integration process.

Highlight

This project highlights a certain type of innovation in the domain of software V&V, the co-creation of results. Relying on a highly collaborative relationship, researchers and software engineers develop innovative solutions that are published in co-authored papers. This differs greatly from other types of industrial collaboration, where researchers usually propose something that is then evaluated by an industrial partner. The co-creation of scientific results has turned out to have a much better chance of success than other forms of collaboration.

Best Application Paper at MODELS 2013
Shuai Wang, Shaukat Ali, and Arnaud Gotlieb, together with Marius Liaaen of Cisco Systems Norway, authored the paper 'Automated Test Case Selection Using Feature Models: An Industrial Case Study'. For their work they received the Best Application Paper Award at one of the most prestigious and competitive arenas for research in the field, the ACM/IEEE 16th International Conference on Model Driven Engineering Languages and Systems (MODELS 2013).

Smarter testing of evolving systems

Courtesy Kongsberg Maritime

Background

Lehman's laws of software evolution state that it is inevitable that any successful piece of a software system performing a real-world task must be continually adapted or it will progressively become less satisfactory for its users.

Regression testing is the testing activity performed after such changes have been made, to give confidence that they do not negatively affect the behaviour of the unchanged parts of the software (the correctness of the newly introduced parts needs to be tested separately). Regression testing is generally performed by repeatedly executing test suites on the software system under the assumption that they should have similar outcomes before and after the changes were made, thereby ensuring that the changes did not have negative effects.

These test suites tend to grow in size as the software evolves. Moreover, certain parts of the test suite may become outdated or they may start to overlap with other parts of the suite. Over time, it becomes prohibitively expensive to execute the entire test suite available for a system, and regression testing no longer acts as a safeguard for evolution.

User partners Kongsberg Maritime and Cisco have observed this phenomenon in their own testing processes and asked Certus to investigate how to reduce the time needed for regression testing a set of changes, while ensuring the thoroughness of verifying that those modifications did not have any unintended effects. 'Smarter Testing of Evolving Systems' is a new Certus project, created at the end of 2013 to address these challenges.

Planned activities and impact

The goal of this project is to investigate smarter testing techniques to help to maximise the value of available test suites while reducing the costs of testing and maintaining high coverage and fault detection properties. This project's principal underlying idea is to drive these techniques based on the analysis of (trends in) historical data about the changes made and characteristics observed in successive releases of the system. One of the main research challenges is to devise techniques to 1) establish correct and detailed traceability links between software artefacts (e.g. requirements, designs, source code) and testing artefacts (procedures, suites, cases) and 2) to consistently maintain these traceability links during software evolution.

Currently envisioned research directions for smarter testing techniques include 1) test case selection, aimed at identifying exactly those test cases that are relevant for regression testing a given set of changes; 2) test suite minimisation, aimed at removing redundant test cases to reduce the number of tests; and 3) test case prioritisation, aimed at determining an order for running test cases so that faults are detected as early as possible (i.e. prioritise the testing of the code's most vulnerable parts).

The goal of this project is to investigate smarter testing techniques to help to maximise the value of available test suites while reducing the costs of testing and maintaining high coverage and fault detection properties.

Contribution to the scientific community

In 2013 Certus reaffirmed its position as one of the world's leading contributors to the international scientific community.

FMC Technologies

Researchers from Certus have been serving as programme committee member and chairperson for a number of prestigious and highly selective international in software engineering conferences, including the International *Conference on Software Engineering – Software Engineering in Practice track* (ICSE-SEIP), the *International Conference on Software Testing, Validation and Verification* (ICST), the *International Conference on Software Maintenance* (ICSM), the *International Conference on Program Comprehension* (ICPC), COMPSAC, MODELS, ECMFA, and QSIC. Most of the researchers were also involved in the review process of papers submitted to the field's most important journals, such as *ACM Transactions on Software Engineering and Methodology* (TOSEM), *IEEE Transactions on Software Engineering* (TSE), I*EEE Software, Information Software and Technology*, etc. Additionally, Certus researchers participated in Object Management Group standardisation committees for UML dedicated profiles.

Most important has been the steady stream of high-quality publications accepted for journals and conferences. In 2013, Certus maintained a very strong presence in ICSE, ICST, and MODELS. The MODELS Best Application Paper Award went to PhD student Shuai Wang for his paper 'Automated Test Case Selection Using Feature Models: An Industrial Case Study', co-authored with Arnaud Gotlieb and Shaukat Ali of Simula and Marius Liaaen of Cisco.

Conducting high-impact research and innovation projects for the Norwegian public and private sectors implies developing research results into deliverables more readily available for industrial application and exploitation. In close interaction with Norwegian public administrations and industrial partners, Certus researchers have developed the software prototype tools DART, DEPICT, and TITAN to improve the validation processes of data-intensive software systems.

High-impact software validation tools for Norwegian public administrations

DART and DEPICT are software tools intended to improve the validation processes used by some public administrations. DART is an automated regression testing tool developed in close collaboration with the Norwegian tax authorities. DEPICT is a test analysis and coverage tool for database management systems, which is now in effective use at the Directorate of Norwegian Customs and Excise.

Based on combinatorial testing techniques, DEPICT uses a high-level model of data interactions to analyse thousands of test declarations and quickly filter those that contain error-prone interactions. A strong impact on test quality assessment is expected for Norwegian public administrations.

A new test suite optimisation tool for industrial software product lines

TITAN is a test suite optimisation technology leveraging strong research results based on constraint programming, an artificial intelligence technique. The technology automates and optimises several stages in software testing processes, balancing expenditures and testing quality. TITAN has been pilot-tested in an industrial environment and has proven high potential for industrial exploitation. TITAN is currently being prepared for commercialisation through business development and further technological development, in constant interaction with its national and international partners. Certus foresees TITAN being developed into a marketable software testing product able to improve testing processes and enhance product quality, leading to stronger competitiveness and increased sales for industry.

A strong impact on test quality assessment is expected for Norwegian public administrations.

[1] IEEE International Conference on Software Engineering – Software Engineering In Practice track
[2] IEEE International Conference on Software Testing, Validation and Verification
[3] ACM Transactions On Software Engineering and Methodology

Industrial exploitation

Background

Scientific activities at Certus are grounded in our industry partners' practices. One of Certus' chief goals is to turn scientific output into viable objects for industrial application and exploitation. Through the 'Industrial Exploitation' project, Certus strives to build bridges from scientific knowledge to industry practice.

Activities

The focus area for the Industrial Exploitation project in 2013 was the development of Certus' exploitation strategy. The strategy aims to support the various stages of transfer and exploitation of research-based knowledge and technology developed within Certus. The goal is to maximise the value and impact of project results. To support implementation of the strategy, Certus developed its exploitation policy. The policy provides guidelines for Certus personnel involved in research and exploitation activities.

The initiative to develop the policy included collaborative work between Simula and Certus user partners. A dedicated working group was established in early 2013 and closely followed activities on policy development, ensuring progress towards the final document. In this process, multiple one-on-one and collective meetings were organised in the course of 2013 with the user partners, gathering their opinions, goals, and expectations on exploitation and establishing a shared vision for exploitation activities.

Bran Selic, external consultant

Through the Industrial Exploitation project, Certus strives to build bridges from scientific knowledge to industry practice.

In the course of the meetings, an open interview method and the communication tool Business Model Canvas (BMC) were used. BMC was used to describe scientific knowledge developed to meet user partners' needs and the infrastructure required to create, deliver, and capture the value inherent in such knowledge. The goal was to focus on identifying the business benefits for user partners of research investments in the Certus Centre. The information obtained through the meetings was thoroughly analysed and used by Simula in policy definition. The working group subsequently approved the policy.

Impact

The exploitation policy is intended to facilitate the technology transfer and exploitation process for all Certus members, provide instruments to measure the progress and evaluate the results of the process, and ensure that the exploitation strategy is consistently applied. Applying the exploitation strategy will ensure that the research output created by Certus is transformed into results with practical relevance and benefits for the user partners and that they are able to exploit effectively such results.

TITAN

Certus is merging scientific knowledge and industry practice through TITAN, a new technology to automate and optimise test management tasks.

Background

One of main Certus objectives is to generate high industrial impact for its research activities. To that end, the Industrial Exploitation project cooperates with Certus' industrial and public administration partners in innovation, technology, and knowledge transfer and exploitation. As part of this project, 2013 was marked by a strong initiative to develop and initiate the commercialisation of TITAN, a new technology to automate and optimise test management tasks, developed in close interaction with Cisco Systems.

Activities

Working through the Industrial Exploitation project, Certus used 2013 to lay the groundwork for a new innovation project, awarded by the Research Council of Norway under the FORNY2020 programme. The programme facilitates the commercialisation of results from projects conducted at publicly funded research institutions in Norway. The main goal of this programme is to increase economic growth based on research-based knowledge with promising market potential. In close interaction with Cisco Systems, researchers from Simula have developed TITAN, a novel testing technology aimed at improving software quality while reducing the costs of software development. TITAN is a test optimisation technology leveraging strong research results based on constraint programming. The technology automates and optimises several stages in software testing processes, balancing expenditures and testing quality.

TITAN has been pilot tested in an industrial environment and has proved its potential for industrial exploitation.

The FORNY–TITAN project is preparing TITAN technology for commercialisation. In constant interaction with national and international partners, the project team is working to elevate the technology to a point at which it will be successfully released to the market.

Highlights

This project demonstrates Certus' commitment to innovation and research-based commercialisation, converting advanced research into industry practice, and bringing economic benefits to industry. If successful, this project will release a marketable software testing product able to improve software testing processes and enhance software product quality, thus leading to improved competitiveness for industry.

The FORNY–TITAN project is led by Dusica Marijan, research scientist at Simula.

The main goal of this programme is to increase economic growth based on research-based knowledge with promising market potential.

Open courses held by Certus

Certus organised open courses for software industry professionals on 20–21 November 2013 at the Simula Research Laboratory. More than 40 industry professionals from various companies – such as Kongsberg Maritime, Norwegian Customs and Excise, ABB Robotics, the Cancer Registry of Norway, Cisco, Esito, and FMC Technologies – attended the courses.

Open courses are used to establish collaboration between different industry practitioners and showcase state-of-the-art research in software engineering. Topics for the courses were selected based on a preliminary survey, resulting in the following offerings.

1. From Myths and Fashion to Evidence-Based Software Engineering
Presenter: Magne Jørgensen

In this workshop, examples were provided of software engineering myths and oversimplifications, their origins and spread were discussed, and lessons focused on how to base important software engineering decisions and practice on evidence available from research, practice, and reliable empirical studies.

2. Software Architecture Design and Specification Using Model-Based Approaches
Presenter: Bran Selic

A well-designed and clearly documented architecture is a crucial prerequisite for the successful implementation of a software system, as well as for its subsequent evolution. This course examined how the new generation of model-based software engineering methods and technologies can be exploited to facilitate the specification and enforcement of software architectures.

3. Software Analytics
Presenter: Leon Moonen

This workshop presented an overview of the techniques used in software analytics and participants brainstormed with Certus researchers on what information could be collected and analysed to support certain tasks or decisions in their day-to-day environment, thereby taking the first steps towards defining a software analytics process.

4. Advanced Techniques in Software Testing
Presenters: Shaukat Ali, Sagar Sen

This workshop discussed automated software testing techniques used to select and optimise a set of test cases for both effective and adequate testing. Two approaches were discussed: a) automated search-based approaches (e.g., genetic algorithms) for test and requirements optimisation and b) combinatorial interaction testing of data-intensive and highly configurable software systems.

Feedback
An online survey was organised for feedback from attendees. Overall, the courses were well evaluated by the attendees. The topics covered were considered relevant. There was also feedback on improvements that we will consider for next year's open courses. Certus would like to thank Arnab Sarkar, Shuai Wang, and Teodora Tufa for their support in organising the event.

Odd Nordeide, Test leader, Norwegian Directorate of Customs and Excise

Certus user partner workshop

The twice-yearly Certus Centre partner workshops demonstrate what is possible when you gather a highly skilled and diverse group of people, give them a common goal, and empower them to make decisions.

Jan Christian Kerlefsen,
head of ABB Robotics.

The two-day Certus user partner workshops are attended by Simula's researchers, as well as user partners' managers and engineers. The participants work in different industries, are of different ages and genders, and have varied cultural backgrounds and skill sets. This diversity enables a more creative approach to problem solving.

Despite operating in different industries, the partner organisations have a common challenge: They operate complex software systems that need to work non-stop, year after year.

Format

Typically, the schedule includes talks from each of the partners, who provide their project status, and from the PhD candidates and researchers, who present their latest findings.

The workshops were developed with four purposes in mind: to provide a forum for sharing research results among partners of the centre, to ease the transfer of knowledge on advanced technologies developed by the researchers, to enable the researchers to identify the relevant issues the partners face, and to build a cooperative spirit within the group, which the centre believes is critical to producing ground-breaking research.

The workshops also play a role in framing the centre's future research priorities. Certus Centre leader Arnaud Gotlieb says this makes the user partner workshops a central function at Certus. "The workshops are not just about learning, they also empower the partners to drive the direction of our research," he states, adding that partner engagement is a key factor in the success of the centre. "Great ideas start with focusing on real-life problems. Our partners understand their daily challenges better than we do, so it is about listening very carefully and adapting our research to their needs."

Better together

The Certus Centre is based on cooperation between researchers and partners at the project level. However, the workshops go further, providing a forum for information sharing between all participants at the centre. Discussing a recent workshop, Jan Christian Kerlefsen, head of ABB Robotics, said exchanging experiences with the Certus partners was invaluable. "It was very interesting to find out that they are struggling with the same testing issues and working with some of the world's best researchers at Simula to find better solutions," he says. He adds that, as well as the formal presentations, he learned a lot through informal discussions with partner representatives and researchers: "The learning didn't stop when the sessions did. I got a lot out of chatting to the other participants during the breaks and made several new contacts."

Evaluation

To improve the workshops, participants are encouraged to provide feedback. The high response rate (close to 100%) is testament to the level of partner engagement at the centre.
In 2013, the March workshop received an average 4.2 out of 5.0 for quality and 4.2 for relevance. The November workshop showed a marked improvement, with 4.3 for quality and 4.7 for relevance. The evaluations also show wide-ranging appreciation for the informal parts of the workshops, which includes discussions between the formal sessions, a group activity, and dinner.

'It was very interesting to find out that they are struggling with the same testing issues and working with some of the world's best researchers at Simula to find better solutions.' – Jan Christian Kerlefsen, business unit manager of ABB Robotics.

Bran Selic and Razieh Behjati,
Simula, in discussion during one of the breaks at the user partner workshops.

The brightest minds for the toughest tasks

Astrid Grime, Customs and Excise

The Certus Centre is composed of a team of highly skilled and talented researchers who work closely with engineers employed by the centre's partners.

In 2013, the Certus staff grew to accommodate an expanded research program. In addition to the key researchers, a team of visiting researchers has made many valuable contributions. By combining international research experience and specialist knowledge with the enthusiasm of PhD students, the centre has created a strong team dedicated to excellence in research and innovation.

Gender distribution
As the Certus' host institution, Simula is committed to recruiting women into software engineering. Considering that only 15% of MSc-level software engineering graduates (a prerequisite for PhD study) are women, gender-balanced recruitment is a challenge, and Certus has met this challenge through systematic effort. There are currently nine full-time scientists working at Certus, of whom three are female and six are male. In 2013, the Certus board had a 50–50 gender distribution.

Simula wins the Gender Equality Award
Presented by the Norwegian Ministry of Education and Research, the Gender Equality Award (Likestillingsprisen) promotes gender equality in research institutes, universities, and university colleges. In 2013, the award went to Simula for its systematic efforts to improve gender balance at the institute.

The award includes a grant of 2 million NOK, intended as a supplement for ongoing work to improve gender balance. Norwegian Minister of Education Torbjørn Røe Isaksen handed out the award and praised Simula for "providing evidence that diversity can contribute to international success and outstanding research results," adding that society cannot afford to neglect scientific talent.

Aslak Tveito, managing director at Simula, commented, "We are very happy to have received the Gender Equality Award. This award will strengthen our work towards an even better gender balance, and even better scientific analysis."

As a project at Simula, Certus' contribution was key in earning the Gender Equality Award. Software engineering is heavily male dominated and Certus works systematically to promote gender equality in the field.

International cooperation

The field of international research into software V&V is moving at breathtaking speed. Just being in the international arena is not enough.

To be at the forefront of international research, Certus needs to be internationally recognised as one of the premier centres for research into software V&V. Certus' strategy rests on two pillars:

1) Long-term and focused collaboration with other world-class institutions and research groups.

As a leading research group itself, Certus also attracts distinguished researchers for stimulating and productive collaboration.

1) Certus' researchers are very active in the international arena and serve on a number of highly selective committees. This of course comes in addition to a strong track record for publishing in highly competitive journals and presenting at prestigious conferences.

In 2013, Certus attracted a number of prominent international speakers from the all over the world, and several researchers chose to come to Certus to perform their work. A full overview is provided in the following table.

Visiting Researchers			
Name	Topic	Gender	Affiliation
Maged Elaasar	Open Services for Lifecycle Collaboration and IBM Rational Tools	M	IBM Rational Research Canada
Emilia Mendes		F	Blekinge Institute of Technology Sweden
Roberto Bagnara	Automatic test input generation	M	University of Parma, Italy and BUGSENG
René Just	Mutation analysis and mutation-based test data generation	M	University of Seattle, WA, USA
Kostis Sagonas	Concurrency analysis in distributed systems	M	University of Uppsala, Sweden
Catherine Dubois	Formal certification of tax computations	F	ENSIEE-CNAM, France, Paris
Roberto E. Lopez-Herrejon	Software Product Lines Analysis	M	Johannes Kepler University of Linz, Austria
Olga Grinchtein	Test generation using constraint models	F	Ericsson and University of Uppsala, Sweden
Andrew Begel	Stopping Programming Mistakes Before They're Made	M	Microsoft Research in Redmond, WA, USA

Personnel in 2013

Certus leader
Arnaud Gotlieb

Administrative manager
Christian Hemmestad Bjerke

Key researchers
Arnaud Gotlieb
Sagar Sen
Tao Yue
Leon Moonen
Andrea Arcuri

Engineers
Carlo Ieva

Research assistant
Arnab Sarkar

Postdoctoral researchers with financial support from the SFI budget
Dusica Marijan
Shaukat Ali

Postdoctoral researchers working on projects at the SFI with financial support from other sources
Jose Luis de la Vara
Razieh Behjati

PhD students with financial support from the SFI budget
Shokoofeh Hesari
Shuai Wang

PhD students working on projects at the SFI with financial support from other sources
Morten Mossige, ABB Robotics, partially supported by the Research Council of Norway Industrial PhD programme
Erik Rogstad
Stefano Di Alesio
Sunil Nair Mohan

Arnaud Gotlieb
Certus leader, Simula

Christian Hemmestad Bjerke
Administrative manager, Simula

Supervision of master's students

An important part of the Certus concept is to support research in higher education. To that end, Certus researchers provide supervision for master's students in the field of software engineering.

Student	(Co-)Supervisors	Start Date	Status
Thomas Gramstad Rolfsnes	Tao Yue, Razieh Behjati	Jan-12	Defended (August 2013)
Soheil Mashayekhi	Sagar Sen	Jan-13	Working on the thesis
Man Zhang	Tao Yue	Sep-12	Working on the thesis
Gong Zhang	Tao Yue	Sep-11	Working on the thesis
Dipesh Pradhan	Shaukat Ali, Tao Yue	Dec-13	Aug-15
Waqas Moazzam Butt	Sagar Sen	Jan-14	May-15
Mari Hugaas	Sagar Sen	Jan-14	May-15
Marek Machnik	Sagar Sen	Jan-14	May-15
Pooja More	Sagar Sen	Jan-14	May-15
Paria Tahaee	Sagar Sen	Jan-14	Jun-14

Summer Interns 2013	Supervisor		
Arnab Sarkar	Sagar Sen		
Xiang Qiu	Tao Yue		
Fabio Biselli	Arnaud Gotlieb		

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