

Self-Healing and Self-Adaptive Systems

Dagstuhl Seminar 09201, May 10-15, 2009

– Executive Summary –

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1 Motivation

During the last few years, the functionality and complexity of software and systems in enterprise and non-commercial IT environments have increased a great deal. The result is soaring system management costs and increased likelihood of failures. There is a common understanding across researchers and engineers alike that enhancing systems with self-management capabilities is a promising way to tackle these challenges. These self-managing capabilities – frequently summarized under the term autonomic computing – include self-configuration, self-healing, self-optimization and self-protection. Recent years have brought a notable increase in related research activities, the driving forces being major IT players including IBM, HP, SUN, and Microsoft.

The Dagstuhl seminar “Self-Healing and Self-Adaptive Systems” focused on self-healing IT systems in the broader context of self-adaptive systems. Self-healing refers to the automatic detection of failures and anomalies and their subsequent correction in a temporary or a permanent manner. Self-healing systems are of particular interest as they directly impact improvements in dependability. Self-adaptive systems are ones that monitor their execution environment and react to changes by modifying their behavior in order to maintain an appropriate quality of service. Obviously, there is a substantial intersection between self-healing and self-adaptiveness: self-healing systems may be viewed as a special kind of self-adaptive systems.

2 Goals and Content of the Seminar

The overall goals of the seminar were

- to bring together experts from various disciplines and organisations for exchanging different viewpoints on the state of the art of methods and technologies for designing, implementing and evaluating of self-healing and self-adaptive systems,

- to foster open discussions on selected topics of the design space of such systems, and
- to facilitate community building in this increasingly important subject area.

In the invitations to the seminar participants three research fields were suggested in order to provide some structure for the presentations and discussions: fault detection and diagnosis, recovery and repair techniques, and frameworks and architectures for self-adapting systems. In order to establish a link between industrial practice and academic research, two focused application-oriented topics were intended to complement the seminar.

The following topics were suggested:

Fault detection and diagnosis

- Efficient system monitoring and application instrumentation
- Event correlation, anomaly detection and fault diagnosis
- Fault prediction techniques
- Root-Cause-Analysis and automated debugging
- Detection and diagnosing user-visible failures

Recovery and repair techniques

- Adaptive software rejuvenation
- Virtualization and other techniques for service availability enhancement
- Staging, micro-rebooting, and Recovery-Oriented-Computing
- Programming language support for healing
- Reactive versus proactive recovery techniques; when – and whether – to repair

Frameworks and architectures for self-adaptive systems

- Self-adaptation and self-healing as extensions of the operating system
- Lessons from mission-critical (high availability) software and systems
- Dependability and self-adaptiveness
- Methodologies for self-healing

The two application-oriented parts mentioned the following topics:

Self-healing solutions in IT infrastructures

- Approaches for error detection in rapidly-changing, heterogeneous environments
- System surveillance in face of geographic distribution and large scales
- Root-cause analysis in presence of security / confidentiality issues
- Fixing system errors with limited administrative privileges
- Software update distribution and management problems
- Current management tools and their shortcomings
- Specific telecom industry problems
- Case studies (e.g., IBM's "Shadows" and "Panacea" projects)

Fault management for application-software systems

- Black-box and gray-box approaches to error fixing
- Post-release detection and fixing of application errors
- Statistical bug isolation
- Studies in modeling of application performance and faults
- Handling faults in SOA systems
- Best practices and guidelines

While this item list was helpful as an orientation, not all of the items were actually covered during the seminar. Moreover, other concerns, such as modelling of and trust in self-healing systems, were emphasized in the presentations and discussions.

3 The participants

The seminar gathered 42 researchers from the following 14 countries:

Country	Number of participants
Canada	1
Czech Republic	2
France	1
Germany	21
India	1
Ireland	1
Israel	1
Italy	4
Luxemburg	1
Norway	1
Singapore	1
Sweden	1
Switzerland	1
USA	5

Most participants come from universities or state-owned research centers (37) while 5 participants were employed by industry or industrial research centers.

4 The program

The seminar talks were grouped by themes, resulting in the following agenda:

Monday, May 11th 2009

Introductory Presentation

Onn Shehory Software Self-Healing - Towards Generic,
IBM Research, Haifa Industry-Grade Solutions?

S1: Challenges in fault detection and diagnosis

Wilhelm Hasselbring Universität Kiel	Automatic Failure Diagnosis Support in Distributed Large-Scale Software Systems Based on Timing Behavior Anomaly Correlation
Mirosław Malek HU Berlin	Runtime Monitoring for Proactive Fault Management
Henry Muccini Univ. degli Studi di L'Aquila	Verification and Validation of Continuously Evolving Systems
Gabi Dreo Rodosek Univ. der Bundeswehr, München	Why is event correlation, anomaly detection and fault diagnosis so hard?
Andreas Zeller Univ. des Saarlandes	Programs that fix themselves

S2: Architectures and paradigms for self-* systems

Hartmut Schmeck KIT - Karlsruhe Institute of Technology	Organic Computing - a Generic Approach to Controlled Self-organization in Adaptive Systems
Wilhelm Hasselbring Universität Kiel	Adaptive Capacity Management for Resource-efficient, Continuously Operating Software Systems
Frank Eliassen University of Oslo	Self-adaptative Systems-of-Systems
Burkhard Stiller Universität Zürich	Methodologies for self-healing systems applied in terms of economic traffic management mechanisms
Grégoire Danoy Univ. of Luxembourg	Self-Adaptive Coevolutionary Optimization Using Reorganizational Multi-Agent Systems

Tuesday, May 12th 2009

S3: System support for self-healing

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| Theo Ungerer
Universität Augsburg | A Virtualization Architecture for Many-cores
with Real-time Constraints and Self-X Support |
| Artur Andrzejak
Zuse Institute Berlin (ZIB) | A case for transparent software rejuvenation |
| Andrea Polini
Università di Camerino | Monitoring Architectural Properties in Dynamic
Component-Based Systems |

S4: Managing problems in IT infrastructures

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| Tudor Dumitras
Carnegie Mellon
University, Pittsburgh | Why do upgrades fail and what can be done
about it? |
| Moises Goldszmidt
Microsoft Research,
Mountain View | On the road toward self-healing datacenters |
| Leonardo Mariani
University of
Milano-Bicocca | In-the-field Self-Healing |
| John Wilkes
Google Inc.,
Mountain View | How much is self healing worth? |
| Elaine Wong
EADS, Singapore | The day when decision support systems adapt
to the failings of humans and start making de-
cisions |

S5: Software engineering approaches for self-adaptation and self-healing

Kurt Geihs Universität Kassel	Challenges for the Model-Driven Development of Self-Adaptive Applications
Josu Martinez University College, Dublin	Functionality Recomposition for Self-Healing
Holger Giese Hasso-Plattner-Institut, Potsdam	On the Role of Models for Self-Healing and Self-Adaptive Systems
Roland Reichle Universität Kassel	Context modeling and reasoning for adaptive applications in ubiquitous computing environments
Tiziana Steffen Universität Potsdam	Margarita- Component-Oriented Behavior Extraction for Autonomic System Design
Ansley Post MPI für Software Systeme, Saarbrücken	Autonomous storage management for personal devices with PodBase (talk with Rodrigo Rodrigues)

Thursday, May 14th 2009

S6: Exploiting learning and modeling techniques

Christian Schloer Leibniz-Universität Hannover	Müller- Sandbox Learning: Try without error?
Felix Salfner HU Berlin	Failure Prediction for Proactive Fault Management
Jens Happe FZI Karlsruhe	Towards Performance and Reliability Prediction for Self-adaptive Systems
Paul A. S. Ward University of Waterloo	Cost-Aware and Adaptive Modeling and Monitoring for Problem Determination

S7: Self-* methods in applications and services

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| Volker Markl
TU Berlin | Robustness in Query Optimization |
| Umesh Bellur
Indian Institute
of Technology Bombay | A Programming Model and Run-Time Architecture for Adaptive Service Orientation |

S8: Diagnosis and healing in parallel and distributed systems

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| Derrick Kondo
INRIA Rhône-Alpes | Towards CloudComputing@home |
| Benjamin Satzger
Universität Augsburg | Generic techniques for self-healing distributed systems |
| Priya Narasimhan
Carnegie Mellon
University, Pittsburgh | Automated Online Fingerprinting in Large Distributed Systems |
| Bohuslav Krena
Brno University of
Technology | Self-Healing for Concurrent Software |
| Simin Nadjm-Tehrani
Linköping University | Recovery, built-in adaptation, and the update problem: The good, the bad, and the ugly |

Friday, May 15th 2009

S9: Use cases and applications of self-adaptation

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| Ralf König
LMU München | Engineering of IT management automation along tasks, loops, function allocation, implementation method catalog |
| Markus Schmid
FH Wiesbaden | Self-organizing QoS-Management in Service Oriented Architectures |
| Hartmut Schmeck
KIT - Karlsruhe Institute
of Technology | Organic Energy Management – controlled and self-organized adaptive demand side management in the energy system |

The major part of the seminar time was devoted to formal talks, which were attended by all the participants. This was complemented by sessions in six working groups, which were nominated and selected by the participants themselves.

The working groups allowed intense discussions on specific topics within the wide spectrum of subjects in the realm of self-healing and self-adaptive systems. The working groups were devoted to the following topics:

Group number	Topic
1	Healing and recovery
2	Learning & models
3	Terminology
4	Testing
5	Trust
7	Cost-effective fault management

The results of these groups are presented in separate documents.

An excursion to the Mosel valley on Wednesday afternoon was also part of the program.

5 Conclusions

The Self-Healing and Self-Adaptive Systems seminar was a fertile meeting in which a diverse population of researchers have met. It included industry and academia, senior and junior researchers, multi-national representation, and people coming from several disciplines. This diversity resulted in interesting and useful discussions, new understandings of the fundamental concepts and problems in the field, and in new collaborations on an array of problems which were not well defined or identified prior to this seminar.

Several work groups during the seminar not only generated new insights into specific topics in the field of self-healing and self-adaptive systems, but also initiated ongoing joint work, with group members continuing the work they started at the seminar.

The seminar included multiple presentations and discussions. Technical issues included all elements of the self-healing cycle, including monitoring, detection and diagnosis; recovery and repair techniques; testing, quality trust issue; and, architectures, infrastructure and use cases. The participants identified the need for better terminology and taxonomy for the field. They further indicated the need for case studies and benchmarks. Several participants stressed the need for trustworthy solutions. It was widely agreed that the potential of self-healing and self-adaptive systems is high, even though much of the existing work in this field is rather academic in nature, and industrial take-up has been relatively slow, with a few notable exceptions.

This seminar clearly illustrated the diversity, relevance, and fertility of the topics we presented and discussed. The intensity of the participants' involvement leads us to believe that the interactions fostered by the seminar will generate a lot of follow-up research, and eventually lead to practical use as well.