Scientific Report

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Nationality	Australian
Name of the *Host Organisation*	VTT Technical Research Centre of Finland
First Name / family name of the *Scientific Coordinator*	Eila Ovaska
Period of the fellowship	01/02/2015 to 31/01/2017

I – SCIENTIFIC ACTIVITY DURING YOUR FELLOWSHIP

The main research activities followed during my Alain Bensoussan Fellowship Programme are summarized here:

- Surveyed existing scientific literature on autonomic computing methods in digital service ecosystems (DSEs). Survey had three stages: planning, conducting and reporting. Planning stage defined research questions, and a search strategy using scientific databases. Conducting stage selected primary methods for comparison applying selection criteria, and performed data extraction and data analysis. In reporting stage, results were disseminated using a detailed Journal article.

- Proposed a model-based methodology and a domain independent, unified adaptation framework called *ADSEng* for evolutional, reflexive and autonomous digital service ecosystems. *ADSEng* consists of three stages to handle uncertainties in DSEs, i.e., requirements engineering, architecture and running system of cloud services.

- Designed and developed the prototype solution for reflexive and evolutional digital services using models at runtime technique. To this end, designed a catalogue of quality-driven, self-aware and self-adaptive architecture patterns to support *reflexivity*. Also, complex state machines of models at runtime that serve as a dynamic knowledgebase were modeled using executable state machines in Enterprise

Architect. Supported *evolution* between architecture and running system of cloud services using generation of software artifacts at execution time. Runtime models and the running system are casually (loosely) connected, so that both abstractions synchronize and evolve at the same time.

- Validated and assessed the approach and models using a concrete scenario of a DSE in digital health revolution, which describes an ambient-assisted living environment for elderly people.
- Reported the findings of the research in two Journal articles and two conference papers (see Section II).

I discussed my research work and progress with my scientific coordinator at VTT, Prof. Eila Ovaska, on a continuous basis. I am very thankful for her advice during the project. My colleagues and the working environment at the research centre were helpful in conducting the project work. I am also thankful to Mr. Daniel Pakkala and Dr. Tuomo Tuikka for supporting my candidature.

II – PUBLICATION(S) DURING YOUR FELLOWSHIP

1) Journal article to be submitted:
   - D. B. Abeywickrama and E. Ovaska. "Models at runtime for reflexive, evolutional and autonomous digital service ecosystems". *International Journal on Software and Systems Modeling (SoSyM)*. Springer.
2) Conference paper under review:
   - D. B. Abeywickrama and E. Ovaska. "Dynamic knowledge models for reflexive and evolutional digital service ecosystems". Submitted to the *12th International Symposium on Software Engineering for Adaptive and Self-Managing Systems (SEAMS'17) co-located with ICSE'17 Conference*, 11 pages.
   - **Abstract.** Uncertainty in digital service ecosystems (DSEs) can be attributed to several factors like the dynamic nature of the ecosystem and unknown deployment environment, change and evolution of requirements, and co-evolution among ecosystem members. Managing uncertainties in DSEs is very challenging, and therefore, novel and solid software architecting methods, techniques and tools are needed. Our research explores the means to handle uncertainties at the software architecture level of DSEs. In this regard, we apply valuable lessons learnt from the models at runtime (M@RT) technique. This paper proposes a novel, dynamic knowledge engineering approach to handle uncertainties in DSEs at runtime using M@RT. The approach aims to identify and solve two interrelated research problems: reflexivity and evolution of the ecosystem between the architecture and running system of services (e.g., cloud services). Reflexivity means that the system must have knowledge of its components to make intelligent decisions based on self-awareness. In addition, we provide tool support for automating reflexivity and evolution. For this, complex state machines of M@RT that serve as a dynamic knowledgebase are modeled using Enterprise Architect's executable state machines, and generation of software artifacts is performed at execution time. Casual connection is maintained between the runtime models and the running system. We validate and illustrate our approach using a DSE in an ambient-assisted living environment for elderly people.

3) Survey Journal article <u>published</u>:

- D. B. Abeywickrama and E. Ovaska. "A survey of autonomic computing methods in digital service ecosystems". *Service Oriented Computing and Applications (SOCA) Journal*, 31 pages, November 2016. Springer. DOI=10.1007/s11761-016-0203-8.
- **Abstract.** Service engineering of digital service ecosystems can be associated with several challenges, such as change and evolution of requirements; gathering of quality requirements and assessment; and uncertainty caused by dynamic nature and unknown deployment environment, composition and users. Therefore, the complexity and dynamics in which these digital services are deployed call for solutions to make them autonomic. Until now there has been no up-to-date review of the scientific literature on the application of the autonomic computing initiative in the digital service ecosystems domain. This article presents a review and comparison of autonomic computing methods in digital service ecosystems from the perspective of service engineering, i.e., requirements engineering and architecting of services. The review is based on systematic queries in four leading scientific databases and Google Scholar, and it is organized in four thematic research areas. A comparison framework has been defined which can be used as a guide for comparing the different methods selected. The goal is to discover which methods are suitable for the service engineering of digital service ecosystems with autonomic computing capabilities, highlight what the shortcomings of the methods are, and identify which research activities need to be conducted in order to overcome these shortcomings. The comparison reveals that none of the existing methods entirely fulfills the requirements that are defined in the comparison framework.

4) Conference paper <u>published</u>:

- D. B. Abeywickrama and E. Ovaska. "ADSEng: A model-based methodology for autonomous digital service engineering". *In Proceedings of the 8th International ACM Conference on Management of Digital EcoSystems (MEDES'16)*, pp. 34-42, November 2016. ACM. DOI=10.1145/3012071.3012072.
- **Abstract.** In digital service ecosystems (DSEs), business stakeholders provide the most important driving factors and managing them is a challenge. It requires systems and services to handle uncertainty. Uncertainty in DSEs can be attributed to several factors; for example, dynamic nature and the unknown deployment environment, and change and evolution of requirements. Therefore, there is a need for novel software engineering methods and tools to handle these uncertainties in DSEs. In this regard, valuable lessons can be learnt from the autonomic computing (AC) paradigm and systems that are characterized by self-* properties. This paper proposes a novel, systematic service engineering methodology called *ADSEng* for ecosystem-based engineering of autonomous digital services. In the current research, the means of handling uncertainty from requirements to architecture and running systems are investigated. To do this, two interrelated research problems are studied: reflexivity that is realized using AC techniques, and evolvability of the ecosystem, supported by automated transformations. Our main contributions are: (i) a modeling methodology from uncertainty specification to runtime models and (ii) quality-driven adaptation patterns embodied by digital services. The paper also presents key lessons learnt from the research experience thus far.

In addition, the following two book chapters and short conference paper were <u>published</u> during the Fellowship period (note: not related to the current ERCIM project):

5) D. B. Abeywickrama, J. Combaz, V. Horký, J. Keznikl, J. Kofroň, A. Lafuente, ... , E. Vassev. "Tools for ensemble design and runtime". Book Title: *Software Engineering for Collective Autonomic Systems: The ASCENS Approach*. In M. Wirsing, M. Hölzl, N. Koch & P. Mayer (Eds.), pp. 429–448, 2015. Springer.

6) N. Hoch, H. Bensler, D. B. Abeywickrama, T. Bureš and U. Montanari. "The e-mobility case study". Book Title: *Software Engineering for Collective Autonomic Systems: The ASCENS Approach*. In M. Wirsing, M. Hölzl, N. Koch & P. Mayer (Eds.), pp. 513–533, 2015. Springer.

7) D. B. Abeywickrama, N. Serbedzija and M. Loreti. "Monitoring and visualizing adaptation of autonomic systems at runtime". *In Proceedings of the Special Track on Coordination Models, Languages and Applications held at 30th ACM Symposium on Applied Computing (SAC'15)*, 1857-1860, April 2015. ACM.

III – ATTENDED SEMINARS, WORKHOPS, CONFERENCES

- Participated and presented a full conference paper at the 8th International Conference on Management of Digital EcoSystems conference (MEDES'16) from November 1-4, 2016 in Hendaye, France.
- Participated and presented a short conference paper at the 30th Annual ACM Symposium on Applied Computing conference (SAC'15) from April 13-17, 2015 in Salamanca, Spain.
- Presentations to the VTT research group in Oulu:
  - o Research interests on May 13, 2015
  - o Initial results of the *ADSEng* methodology on September 28, 2015
  - o *ADSEng* methodology and final results on January 27, 2017

IV – RESEARCH EXCHANGE PROGRAMME (REP)

- Group: Information Systems and Software Engineering group, Norwegian University of Science and Technology (NTNU), Trondheim, Norway
- Dates: November 2-6, 2015
- Local scientific coordinator (host): Prof. John Krogstie
- Outcome:
  - o I presented my current ERCIM project to the research group at NTNU on November 5, 2015. Also, I attended their internal group meeting on November 5.
  - o During my visit, I discussed my project with Prof. John Krogstie, and he explained NTNU's open and autonomous digital ecosystems (OADE) project which is related to my current project. I individually met several researchers (e.g., Assoc. Prof. Hallvard Trætteberg, Prof. Guttorm Sindre and Prof. Pekka Abrahamsson), postdocs and PhD students in the group to understand their individual research at the University.