Université de Lille 1 SCIENCES ET TECHNOLOGIES

Report on the document presented by Mr. Ilias Gerostathopoulos

Title of the document: Model-Driven Development of Software Intensive Cyber-Physical Systems

In the domain of Computer Science, the overall scientific context of the work presented by Mr. Ilias Gerostathopoulos is that of the design of so-called software intensive cyber-physical systems (siCPS). Cyber-physical systems are a new category of systems that are built on the seamless integration of computational algorithms and physical components. As recognized by the European H2020 research agenda, they are key components for the next generation of embedded information and communication technology (ICT) systems. The goal of the research activities undertaken by the candidate is to propose innovative solutions to increase the software quality of siCPS and to provide enablers for the next generation of siCPS. The work is organized around the definition of solutions for improving the dependability and the self-adaptivity of siCPS, i.e. their ability to react and to adapt to changing conditions in an open execution environment. The contribution consists in the definition of the Invariant Refinement Method (IRM), which is a model-based design process for siCPS, and the mapping of the IRM concepts to the existing Ensemble/DEECo software component framework.

The document is organized around a collection of papers that have been accepted for publications in international conferences. Seven publications are included. One of them won the ACM Distinguished Paper Award at the 16th International ACM SIGSOFT Symposium on Component-Based Software Engineering (CBSE) in 2013. CBSE is the premium international conference for research on software components. Each paper in the collection comes with an additional summary to link it to the context of the thesis, and with some comments on the contribution of the candidate to the authorship of the paper. This collection of papers is preceded and followed by chapters that introduce the work, present the state-of-the-art of the domain, present an overview of the contribution, evaluate the results, and conclude the documents.

Chapter 1 introduces the research domain and enumerates the research questions that will be addressed in the document. The case study that will be used throughout the work to illustrate the proposed solutions is introduced. This is an electric vehicle mobility case study defined in the context of the EU FP7 ASCENS project to which the candidate and his hosting team participated.

Chapter 2 presents the state-of-the-art of the domain in terms of requirement modeling and of software development methodologies for siCPS. In terms of requirement modeling and analysis, four approaches are reviewed: KAOS, NFR, i*, FLAGS. In terms of development methodologies and implementation abstractions, agent-oriented software development with the Tropos approach, and component-based software development approaches (Kevoree, Helena, DEECo) are reviewed. A third section concludes the chapter by revisiting the goals that have been defined in the introduction in the light of this state-of-the-art.

Chapter 3 presents an overview of the contribution and positions the papers of Chapter 4 with respect to the research objectives defined in the introduction.

Chapter 4 contains the collection of seven papers co-authored by the candidate in relation with his research activities. The first paper argues for novel solutions in terms of software engineering models and methods for the design and development of siCPS. The second paper goes from the requirements elaboration phase to the design phase, and proposes some founding ideas that later on will be integrat-

ed in the contributed IRM design method. The collection moves on to the third paper that deals the IRM design method. This is the core of the contribution by the candidate. The idea is to guide the refinement of high-level goals to low-level architecture concepts. IRM defines the notion of an invariant pattern as a mean to describe properties that must be enforced while refining the design of the system. Five such patterns are defined. The fourth paper is the direct continuation of the third one. The fifth paper provides an overview of the model-driven design and development process. The sixth paper is a technical report that presents the IRM-SA extension of the IRM method for self-adaptive systems. A new operator, the so-called OR-decomposition, is introduced in the IRM design method in addition to the AND-decomposition operator. This enables to take into account alternate behaviors in self-adaptation scenarios. The selection of an applicable configuration is modeled as a constraint logic program and solved with a SAT solver. The seventh paper focuses on the so-called e-mobility use case from the EU FP7 ASCENS project. This demonstrates the applicability of the IRM-SA method.

Chapter 5 briefly reports on the evaluation strategy that has been put into practice. The IRM-SA method has been applied to two case studies, one from the EU FP7 ASCENS project, and one that defines an emergency coordination system. A graphical editor and a plugin for jDEECo, the Java version of the DEECo framework, have been developed to support both the design and the runtime aspects of the IRM-SA method.

Chapter 6 concludes the document and reports on open challenges in relation with human in the loop for self-adaptive systems, uncertainty management, and the alignment of siCPS with other engineering science disciplines such as control engineering.

Opinion on the dissertation and the work presented

Overall, the document demonstrates the good level of research activities that have been conducted by the candidate. The notions of invariant pattern and the refinement-based method that are proposed are clever solutions for enabling the design of next-generation siCPS. In addition, the use of constraint logic programming for the selection of an applicable solution in self-adaption situations is definitively interesting.

In relation with this activity, the candidate has achieved a good level of publication in internationally renowned scientific conferences. One of the papers has been awarded an ACM Distinguished Paper Award, which is a very good achievement for a PhD candidate. Furthermore, the work has been conducted in the context of the EU FP7 ASCENS project and demonstrates some potential for industrial transfer.

The state-of-the-art does a good job of introducing the research activities. The analysis that is provided on the reviewed approaches demonstrates that the candidate has a clear understanding of the advantages and the limits of these approaches. I nevertheless may have wished that the relations between the lessons that have been learned following this state-of-the-art, and the contributions of the work be better elicited. This is especially true for example for the first part on requirement engineering (RE). As the candidate mentions it on p10 "this thesis does not focus on RE". But then, the reader is left with the job of understanding which elements from this part are picked and reused later on in the contribution.

The candidate argues for a novel synergy between the concepts of agents and components. This synergy is one of the key constituents of the contributed IRM design method for siCPS. Although not brand new, this is an interesting new attempt for the blending of these two approaches for which no

systems. The contributions are sound and interesting. They have been validated. They have been the subjects of international publications, and an award. They raise interesting new challenges and open questions, some of which are mentioned by the candidate, some others than can be the subject of debate among peers.

Conclusion

For all the above-mentioned reasons, Mr. Ilias Gerostathopoulos doctoral thesis "Model-Driven Development of Software Intensive Cyber-Physical Systems" meets, in my opinion, the requirements for a PhD in the domain of Computer Science.

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