University of Victoria | Graduate Studies

Notice of the Final Oral Examination for the Degree of Doctor of Philosophy

of

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"Runtime Modelling for User-Centric Smart Cyber-Physical-Human Applications"

Department of Computer Science

Wednesday, November 29, 2017
2:00 P.M.
Engineering and Computer Science Building
Room 660

Supervisory Committee:
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Dr. David Goluskin, Department of Mathematics and Statistics, UVic

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Abstract

Cyber-Physical-Human Systems (CPHSs) are the integration, mostly focused on the interactions, of cyber, physical and humans elements that work together towards the achievement of the objectives of the system. Users continuously rely on CPHSs to fulfil personal goals, thus becoming active, relevant, and necessary components of the designed system. The gap between humans and technology is getting smaller. Users are increasingly demanding smarter and personalized applications, capable of understanding and acting upon changing situations. However, humans are highly dynamic, their decisions might not always be predictable, and they expose themselves to unforeseeable situations that might impact their interactions with their physical and cyber elements.

The problem addressed in this dissertation is the support of CPHSs' user-centric requirements at runtime. Therefore, this dissertation focuses on the investigation of runtime models and infrastructures for: (1) understanding users, their personal goals and changing situations, (2) causally connecting the cyber, physical and human components involved in the achievement of users' personal goals, and (3) supporting runtime adaptation to respond to relevant changes in the users' situations.

Situation-awareness and runtime adaptation pose significant challenges for the engineering of user-centric CPHSs. There are three challenges associated with situation-awareness: first, the complexity and dynamism of users' changing situations require specifications that explicitly connect users with personal goals and relevant context. Second, the achievement of personal goals entails comprehensive representations of user's tasks and sequences and measurable outcomes. Third, situation-awareness implies the analysis of context towards an understanding of users' changing conditions. Therefore, there is a need for representations and reasoning techniques to infer emerging situations. There are three challenges associated with runtime adaptation: first, the dynamic nature of CPHSs and users require runtime models to make explicit the components of CPHSs and their interactions. Second, the definition of architectural and functional requirements of CPHSs to support runtime user-centric awareness and adaptation. Finally, the design and implementation of runtime adaptation techniques to support dynamic changes in the specification of the CPHSs' runtime models.

There four contributions of this dissertation add to the body of knowledge for the development of smart applications centred in the achievement of users' personal goals. First, we propose a definition and architectural design for the implementation of user-centric smart cyber-physical-human applications (UCSAs). Our design proposes a context-aware self-adaptive system supported by a runtime infrastructure to manage CRUD operations. Second, we propose two models at runtime (MARTs): (1) our UCSA Tasking Metamodel, which defines de concepts of a UCSA; and (2) our Galapagos Model, which supports the specification of evolving tasking goals, personal interactions, and the relevant contexts. Third, we propose our operational framework, which defines model equivalences between human-readable and machine-readable, available runtime operations and semantics, to manage runtime operations on MARTs. Finally, we propose our processing infrastructure for models at runtime (Primor), which is a component-based system responsible for providing reading access from software components to the MARTs, executing model-related runtime operations, and managing the propagation of changes among interconnected MARTs and their realities.

To evaluate our contributions, we conducted a literature review of models and performed a qualitative analysis to demonstrate the novelty of our approach by comparing it with related approaches. We demonstrated that our models satisfy MARTs characteristics, therefore making them proper models at runtime. Furthermore, we performed an experimental analysis based on our case study on online grocery shopping for the elderly. We focused our analysis on the runtime operations specified in the framework as supported by the corresponding MART (accuracy and scalability), and our infrastructure to manage runtime operation and growing MARTs (performance).