EASCI: Emergent and Adaptive Semantic Composition in IoT Ecosystems

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***Abstract*—IoT ecosystems are complex system networks of autonomous and interacting individual systems, which are adaptive as they show a special ability to adapt. Through the (emergent) combination of several services of this IoT ecosystem, higher-value goals can be achieved by the overall system. The design and realization of such an ecosystem is therefore very challenging. This special session will focus on topics related to IoT ecosystems and emergent service composition. Influencing and controlling such dynamical and autonomous changing system landscapes require innovative concepts and research approaches to address these challenges.**

***Index Terms*—IoT Ecosystems; Software Services; Service Composition; Self-adaptive Platform; Emergent Systems.**

I. Introduction

Similar to their natural counterparts, IoT ecosystems [1] can only be vital in the long term if a balance of needs and interests is achieved regarding data, services, and processes. The different life cycles of the individual systems, whose behavior and interactions change over time, are also decisive for the balance. These changes (e.g., in data models/domain ontologies) cannot usually be centrally pre-planned but result from independent processes and decisions within and outside the IoT ecosystem [2]. In addition, it is becoming increasingly apparent that industry-wide standardization efforts are too slow and inflexible when it comes to the speed of innovation in IoT components. This poses significant challenges to traditional approaches and technologies for self-adaptive systems, as these systems rely on automated (semantic) interpretation of data and functions in system composition. Many of the currently realized mechanisms for self-adaptation are based on maximizing the interface couplings of the participating components of an IoT ecosystem or similar demand-independent criteria (see, e.g., [3], [4]). This results in self-functioning systems at runtime, but in many cases these systems are not able to address the changing functional and non-functional needs of the users.

Influencing and controlling such dynamical and autonomous changing system landscapes require innovative concepts and research approaches to address these challenges. These innovative concepts and research approaches are the topic of the Special Track EASCI at ADAPTIVE 2023, focusing not only on the integration and composition of new sustainable and resilient services into existing IoT ecosystems, but also on new customer-centric business models and services to increase profitability.

For this special session we focus on the following topics related to IoT ecosystems and emergent service composition: Semantic integration of services in IoT ecosystems, emergent web service composition, automated service composition, resilience in IoT ecosystems, emergence in IoT ecosystems, concepts for interaction in an IoT ecosystem, runtime behavior and runtime optimization of IoT ecosystems, operator models and business models for IoT ecosystems, security of IoT ecosystems, service interoperability in emergent systems, and self-organization in decentralized IoT ecosystems.

II. Submissions

The first paper is entitled "Tailored Digital Twins for LCA & LCM - Stakeholder centered Digital Twin Framework Design for Product Lifecycle Managements and Assessment" (Briechle et al.) [5]. Emerging technologies like Digital Twins could help meet circular economy objectives such as the UN Sustainable Development Goals. Although using a framework to develop Digital Twins is widespread, it is often not directly suited to answer the information requirement that the stakeholders desire. As such, this paper aims to provide a requirement-based framework for designing a sustainable Digital Twin that satisfies all parties involved in its conception and use. The governing factor of the information requirement proved to be essential for designing fitting and energy optimized Digital Twins. The integration of the design of the Digital Twin as central part of the framework design allows the initial collection of information requests and allows simultaneously the retrofitting of already in use architectures for the own purpose by reconsidering the previously made selections in the design phase. An e-bike, a particular use case, is used as an example to demonstrate the application of the framework. Therefore, the use case includes three different stakeholder groups with their own information request to show how these influence the final setup of such a twin. Moreover, science direct and google scholar were explored for

bibliometric purposes. The proposed framework lays the path for improving the current lifecycle assessment while ensuring the optimization of Digital Twin design flexibility.

The second paper, "Emergent Software Service Platform and its Application in a Smart Mobility Setting" (Knieke et al.) [6] proposes the concept of an *Emergent Software Service Platform*, which is able to design software services from the set of available software services completely automatically at runtime. A major challenge in the context of such Platform Ecosystems is the composition of the available software services so that they function together as a more complex, higher-value software component. The following capabilities are addressed by the Emergent Software Service Platform:

1) It has to be able to elicit the current user requirements automatically at runtime.
2) It has to be able to automatically compose a software service, which meets the elicited user requirements, from the set of available software services at runtime.
3) It has to be able to execute an automatically composed software service at runtime and provide the result to the user of the Emergent Software Service Platform.

First experiments with the existing prototype show that it is able to automatically elicit the user requirements from an explicit request and is able to automatically compose and execute a software service that meets the recognized user requirements. Hence, these results show that it is viable to interpret the problem of autonomous self-adaptive software-service composition as a classical planning problem.

The final paper in this session, "Towards Transforming OpenAPI Specified Web Services into Planning Domain Definition Language Actions for Automatic Web Service Composition" (Schindler et al.) [7] regards web service composition. A common way to describe web services is using OpenAPI [8]. The OpenAPI specification defines an open and vendor-neutral description format for Application Programming Interface (API) services. In particular, OpenAPI can be used to describe, develop, test, and document REST-compliant APIs. The paper presents an approach to transform web services specified in OpenAPI into PDDL [9] actions. The advantage of this approach is that web service compositions can be performed with common PDDL solvers (e.g., ENHSP [10]). An example is given on how such a request for a given domain and given actions can look like. The paper also describes the differences in an OpenAPI specified web service and an action specified in PDDL. A set of transformation rules are defined and the pseudo code is described.

III. Conclusion

The EASCI special track includes a broad range of topics related to IoT ecosystems and emergent service composition. It contains both academic research papers as well as papers written in collaboration with industry partners. Interesting ideas for future work in this growing research domain are introduced.

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