Article

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Self-aware Pervasive Service Ecosystems

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Abstract

Here we present the overall objectives and approach of the SAPERE ("Self-aware Pervasive Service Ecosystems") project, focussed on the development of a highly-innovative nature-inspired framework, suited for the decentralized deployment, execution, and management, of self-aware and adaptive pervasive services in future network scenarios.

Keywords: Self-awareness in Autonomic Systems; Pervasive Computing Service; Nature-inspired Computing

1. Motivations

Pervasive computing technologies promise to notably change the future ICT landscape, letting us envision the emergence of an integrated and very dense socio-technical infrastructure for the provisioning of innovative general-purpose digital services. The infrastructure will be used to ubiquitously access services for better interacting with the surrounding physical world and with the social activities occurring in it. It is also expected that users will be able to deploy customized services, making the overall infrastructure as open as the Web currently is.

To support the vision, a great deal of research activity in pervasive computing and service systems has been devoted to solve problems such as: increasing dependability; supporting self-* features; enforcing context-awareness and adaptability; tolerating evolution over time and eventually ensuring that service frameworks can be highly-adaptive and very long-lasting [1]. Unfortunately, most of the solutions so far are proposed in terms of "add-ons" to be integrated in existing frameworks. The result is often an increased complexity of current frameworks and the emergence of contrasting trade-off between different solutions.

In our opinion, there is need for tackling the problem at the foundation, answering the following ambitious question: is it possible to conceive a radically new way of modeling integrated pervasive services and their execution environments, such that the apparently diverse issues of context-awareness, dependability, openness, flexible and robust evolution, can all be uniformly addressed once and for all?

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2. The SAPERE Approach

The overall goal of the SAPERE project is to show that a positive answer to the above question exists, by defining an innovative framework in which all the identified issues can be solved due to the inherent properties of the framework itself. To this end, SAPERE takes its primary inspiration from natural ecosystems, and starts from the consideration that the dynamics and decentralization of future pervasive networks will make it suitable to model the overall world of services, data, and devices as a sort of distributed computational. In particular, SAPERE brings the adoption of natural metaphors down to the core of its approach, by exploiting nature-inspired mechanisms (and in particular bio-chemical ones [2,3]) for actually ruling the overall system dynamics.

Specifically, SAPERE considers modeling and architecting a pervasive service environment as a non-layered *spatial substrate*, laid above the actual pervasive network infrastructure. The substrate embeds the basic laws of nature (or *eco-laws*) that rule the activities of the system. There, individuals of different species (i.e., the components of the pervasive service ecosystem) interact and combine with each other (in respect of the eco-laws and typically based on their spatial relationships), so as to serve their own individual needs as well as the sustainability of the overall ecology. Users can access the ecology in a decentralized way to use and consume data and services, and they can also act as "prosumers".

For the *components* living in the ecosystem, SAPERE plans to adopt a common modeling and a common treatment of services, data, and devices. All "entities" living in the SAPERE ecosystem will have an associated semantic representation, enabling dynamic unsupervised interactions between components. For the sake of simplicity, SAPERE will assume such semantic representations as associated by design to components. However, to account for the high dynamics of the scenario and for its need of continuous adaptation, SAPERE will define such annotations as living, active entities, tightly associated to the component they describe, and capable of reflecting its current situation and context. Such *Live Semantic Annotations* (LSAs) will thus act as observable interfaces of resources, as well as the basis for enforcing semantic and self-aware forms of dynamic interactions (both for service aggregation/composition and for data/knowledge management).

For the *eco-laws* driving the dynamics of the ecosystem, SAPERE envisions them to define the basic policies to drive virtual *chemical reactions* among the LSAs of the various individuals of the ecology. In particular, the idea is to enforce, on a spatial basis and possibly relying on diffusive mechanisms, dynamic networking and composition of data and services. In particular, data and services will be sorts of chemical reagents, and interactions and compositions will occur via chemical reactions, i.e., semantic pattern-matching, between LSAs. Such reactions will contribute establishing virtual chemical bonds between entities as well as producing new components.

Adaptivity in the proposed SAPERE approach will not be in the capability of individual components, but rather in the overall dynamics of the ecosystem. In particular, adaptivity will be ensured by the fact that any change in the system or in its components will reflect in the firing of new chemical reactions, thus possibly leading to the establishment of new bonds and/or in the breaking of some existing bonds between components. In other words, SAPERE will not promote adaptivity by creating self-awareness at the level of components, but rather promoting a sort of *systemic self-awareness*.

Such way of enforcing adaptation will also tolerate long-term evolutions of the system. In fact, even if SAPERE will not assume the capability of individual components to evolve, the injection of new updated components in the system, and their being automatically involved in the ecosystem dynamics, will provide for a sort of seamless evolution, as in natural selection.

3. Conclusions

SAPERE proposes a radical deconstruction of traditional perspectives on self-adaptive and self-aware pervasive service systems and, as the activities within the SAPERE Consortium will proceed, we will challenge the SAPERE finding and tools against innovative services in the area of crowd management [4], by exploiting an ecosystem of pervasive displays as a technical testbed [5]. Stay tuned on SAPERE!

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