Semantic Sensor Network Architecture for Pro-active Risk Management in the Factories of the Future

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Abstract. In recent years we have observe the increasing interest and a prevailing role of ICT in the context of factory environment. In parallel with increased sensing and actuating capabilities, the improvement in backhaul communications present a new factory scenario where more autonomous intelligent reasoning mechanisms could be envisaged. The Internet of Things (IoT) scenario that needs to be handle is characterized by highly variable spatial and temporal contexts that should be effectively managed. This paper presents and discusses the semantic management approach to complex system operation proposed by the FASyS project (Absolutely safe and Healthy Factory). Moreover, a distributed reasoning concept regarded as reasoning contexts proposed by the project is also proposed and the benefits discussed.

1 Introduction

Pervasive applications aim at providing the right information to the right users, at the right time, in the right place, and on the right device. In order to achieve this, a system must have a thorough knowledge and, as one may say, "understanding" of its environment, the people and devices that exist in it, their interests and capabilities, and the tasks and activities that are being undertaken. All this information falls under the notions of context. The need for reasoning in context aware systems derives from the basic characteristics of context data. Two of these are imperfection and uncertainty. Henricksen and Indulska [1] characterize four types of imperfect context information: unknown, ambiguous, imprecise, and erroneous. Sensor or connectivity failures result in situations, that not all context data is available at any time. When the data about a context property comes from multiple sources, the context information may become ambiguous. Imprecision is common in sensor-derived information, while erroneous context information arises as a result of human or hardware errors. The role of reasoning in these cases is to detect possible errors, make predictions about missing values, and decide about the quality and the validity of the sensed data. The raw context data needs, then, to be transformed into meaningful information so that it can

Moyano A., Lazaro O. and Fernandez-Llatas C..
Semantic Sensor Network Architecture for Pro-active Risk Management in the Factories of the Future.
DOI: 10.5220/0003142901030108
In *Proceedings of the International Workshop on Semantic Sensor Web* (SSW-2010), pages 103-108
ISBN: 978-989-8425-33-1

later be used in the application layer. In this direction, some suitable sets of rules can exploit the real meaning of some raw values of context properties. Finally, context reasoning may play the role of a decision making mechanism. Based on the collected context information, and on a set of decision rules provided by the user, the system can be configured to change its behavior, whenever certain changes are detected in its context.

If we also consider the high rates in which context changes and the potentially vast amount of available context information, the reasoning tasks become even more challenging. Overall, Knowledge Management in Ambient Intelligence should enable: (a) Reasoning with the highly dynamic and ambiguous context data; (b) Managing the potentially huge piece of context data, in a real-time fashion, considering the restricted computational capabilities of some mobile de- vices; and (c) Collective intelligence, by supporting information sharing, and distributed reasoning between the entities of the ambient environment.

In this paper, we present a brief review of different semantic reasoning techniques and we explain how existing technologies fail to fully address the issues of heterogeneous data sources, information uncertainty, operation in resource constraint environments and adaptation to dynamic reasoning spaces. The paper briefly introduces the approach that has been selected by the FASyS project to deal with such environment and explains the benefits that such approach would bring to the real system implementation of advance real-time reasoning over dynamic environments.

1.1 Semantic Reasoning in Smart Spaces

The SW Languages of RDF(S) and OWL are common formalisms for context representation. Along with their evolution, a number of SW Query languages (e.g. RDQL, RQL, TRIPLE) and reasoning tools (e.g. FaCT, RACER, Pellet) have been developed. Their aim is to retrieve relevant information, check the consistency of the available data, and derive implicit ontological knowledge.

The ontological reasoning approaches have two significant advantages. They integrate well with the ontology model, which is widely used for the representation of context; and most of them have relatively low computational complexity, allowing them to deal well with situations of rapidly changing context. However, their limited reasoning capabilities are a trade-of that we cannot neglect. They cannot deal with missing or ambiguous information, which is a common case in ambient environments, and are not able to provide support for decision making. Thus, we argue, that although we can use them in cases where we just want to retrieve information from the context knowledge base, check if the available context data is consistent or derive implicit ontological knowledge, they cannot serve as a standalone solution for the needs of ambient context-aware applications.

Rule languages provide a formal model for context reasoning. Furthermore, they are easy to understand and widespread used, and there are many systems that integrate them with the ontology model. However, all these approaches share a common deficiency; they cannot handle the highly changeable, ambiguous and imperfect context information. In many of the cases that we described, they had to build additional reasoning mechanisms to deal with conflicts, uncertainty and ambiguities. The proposed logic models suit better in cases, where we are certain about the quality of the collected data. Consequently, neither of these models can serve as the solution to the required reasoning tasks.

In an Ambient Intelligence environment, there coexist many different entities that collect, process, and change the context information. Although they all share the same context, they face it from different viewpoints based on their perceptive capabilities, their experiences and their goals. Moreover, they may have different reasoning, storage and computing capabilities; they may "speak" different languages; they may even have different levels of sociality. This diversity raises additional research challenges in the study of smart spaces, which only few recent studies have addressed.

Collecting the reasoning tasks in a central entity certainly has many advantages; we can achieve better control, and better coordination between the various entities that have access to the central entity. Blackboard-based and shared-memory models have been thoroughly studied and used in many di®erent types of distributed systems and have proved to work well in practice. The requirements are, though, much different in this setting. Context may not be restricted to a small room, we must also study cases of broader areas. The communication with a central entity is not guaranteed; we must assume unreliable and restricted wireless communications. Thus, an autonomous distributed scheme is a necessity. The OWL-SF framework is a step towards the right direction, but certainly not the last one. In order to deal with more realistic ambient environments, we need to eliminate some of the assumptions that they make. For example, different entities are not required to use the same representation and reasoning models, and we cannot always assume the existence of dedicated reasoning machines.

1.2 The FoF Knowledge Management Challenge & FASyS Approach

The special requirements of FoF ambient environments impose the need of logic models that inherently deal with the imperfect nature of context data. Models that embody the notions of uncertainty, temporal and spatial change, and incompleteness would provide more robust and efficient solutions.

Other issue that cannot be neglected is the computational complexity, which becomes even worse, if we consider the potentially vast amount of available context data. A possible solution is to partition the large knowledge bases into smaller pieces, share these pieces with other computing devices, and deploy some form of partition-based reasoning.

Finally, to achieve collective intelligence, we must study methods for integrating and reasoning with data coming from heterogeneous sources and possibly described in different vocabularies.

These main challenges related with pro-active risk management in a manufacturing environment cannot be solely addressed by a single solution, since practical implementation will not be able to handle the required expressiveness, reasoning demand in a scenario characterized by constraint computational devices and limited communication infrastructures.

For this reasons the FASyS system exploits a hierarchical architecture that relies on a System of Systems approach leveraging local reasoning capabilities combined with centralized workflow management. This approach permits that local reasoning behavior is adapted to local stable context information; e.g. layout information, with dynamic variant information; i.e. human-factor intervention. Thus, the proposed architecture is a suitable compromise between management of a large reasoning space – all possible events related to risks in a factory – with reduced space actuation based on relevant reasoning context. The FASyS approach is aimed at creating reasoning contexts that combined local static context information with dynamic contextual data that is adapted through centralized reasoning engines that manage large data volumes and events. The objective is therefore to permit fast local reasoning over small highly flexible spaces while overall logic and workflow is adapted based on high.level reasoning engines that operate over non-constrained computing infrastructures. The SoS approach ensures that autonomy is facilitated to the local entities in decision making process while decision is enhanced as uncertainty, consistency and relevance of data available for decision making is enhanced through centralized reasoned collaboration.

The scenario proposed by FASyS project demands that complex event reasoning is split into atomic decisions that conform a reasoning context. Thus, reasoning maps can be created based on the particular situations to be addressed by the area in the factory. This low level of the architecture is intended for improved performance and real-time system support. In this way, it is possible that the system intelligence is capable to react to most immediate risks.

Fig. 1. FASyS 3-level reasoning architecture.

The second layer of the architecture is intended for coordination and experience sharing among reasoning contexts. This second layer is in charge of reasoning map exchange. The aspect to be exploited by this second layer is related to the fact that clear similarities exist among reasoning areas. Moreover, humans, goods and machines move in the factory and make reasoning contexts individually dynamic and unique but with similarities in the larger scale. The operation of this knowledge plane is medium term and intends to build on best practices. This second layer should leverage personalized treatment of risks across reasoning contexts and should follow individuals, goods and objects through the factory shopfloor.

Finally the third layer is intended for long term operation and it is related to extensive event and strategic decision making. This high level layer is in charge of scrutinize the factory risk situation and consequently activate and deactivate strategies and services for effective risk management. Therefore, this reasoning layer is in charge of the risks management workflow configuration that is then actioned and adapted by the local risk reasoning contexts.

One critical aspect for smart spaces in the context of the Factories of the Future (FoF) is pro-active risk management. Zero accident can be timely and properly met only if human factors are successfully incorporated into the existing risk management IT workflows. Hence, the challenge is how to harmonise services that are provided both by human and software artifacts and therefore exhibit a great deal of interaction.

The Web's user-centric nature has led to an unusual role for people in information systems—more often than not, certain problems that are hard for software services to solve are outsourced to humans. Consequently, researchers have introduced the notion of distributed human computation in the context of AI-complete problems such as analyzing and tagging images [2].

In 2007, the WS-HumanTask (WS-HT) and BPEL4People (B4P) standards introduced models for weaving human interactions into SOA-based compositions. WS-HT and B4P target workflow-based coordination in SOA/Web services environments in enterprise settings. However, they lack the ability to create flexible compositions of human and software-based services. Related B4P standards specify languages for modeling human interactions, the life cycle of human tasks, and generic role models[3]

Compositions and processes are modelled using a language such as the Business Process Execution Language (BPEL)—a widely used and well-accepted composition language in the Web services domain—and executed in the actual environment where the composition model is deployed. These top-down composition models are limited in their use of context and adaptive control and thus fail to deliver the most effective runtime behavior. Not every interaction or task may be known at design time [4]); thus not all interaction links between services and people can be established a priori. As such, an adaptive composition of human and software services is a strong requirement.

To address this issue the FASyS project will base its research in the framework proposed in [4] by Dustdar et.al. The framework proposed is also consistent with a 3 layer architecture where data collection, human provided (knowledge)services and middleware services for collective design, monitoring and interaction/preference discovery are the main supporting blocks. FASyS proposes a more distributed architecture, where scale and human data interactions are managed locally while coordinated globally as presented in the Figure above. This should improve the performance under real-time and or time-contrained conditions for decision making and the interaction between human provided and web services will become more flexible.

2 Conclusions

The paper has presented the main challenges that need to be addressed by complex knowledge management architecture in the context of the FoF. The paper has presented the 3 layer architecture proposed by the FASyS project (www.fasys.es/en) to manage the inherent complexity of proactive risk management. Moreover, the interaction and coupling between such architecture and human provided- web service based dynamic workflow management solutions has also been discussed. The importance of knowledge sharing across reasoning domain to handle personalized and incomplete information for decision making has also been presented as a potential solution.

References

1. Henricksen, K. and Indulska, J. (2004), Modelling and Using Imperfect Context Information, Proceedings of PERCOMW '04', IEEE Computer Society, Washington, DC, USA, pp. 33-37.
2. C. Gentry, Z. Ramzan, and S. Stubblebine, "Secure Distributed Human Computation," *Proc. 6th ACM Conf. Electronic Commerce,* ACM Press, 2005, pp. 155-164.
3. F. Leymann, "Workflow-Based Coordination and Cooperation in a Service World," *On the Move to Meaningful Internet Systems 2006,* LNCS 4275, Springer, 2006, pp. 2-16
4. F. S. Dustdar, "Caramba—A Process-Aware Collaboration System Supporting Ad Hoc and Collaborative Processes in Virtual Teams," Distributed and Parallel Databases, Jan. 2004, pp. 45-66