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User Experience, Ambient intelligence and Virtual Reality in an Industrial Maintenance domain using Protégé

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Abstract

We present a novel approach for the exploitation of embedded knowledge in the domain of industrial maintenance. Our approach extends the SOUPA set of ontologies (Standard Ontology for Ubiquitous and Pervasive Applications) with two new ontologies (i) the Set of Experience Knowledge Structure, used to model the user's experience and (ii) the AR ontology which models an Augmented Reality environment that is used to enhance the maintenance experience through virtual elements. As test case, we present an application that implements our architecture in different portable devices with video input capabilities such as UMPCs, PDAs and Tablet PCs.

Keywords: ontology-driven software development, Ambient Intelligence, Set of Experience Knowledge

1. Introduction.

Industrial Maintenance (IM) can be defined as the combination of all technical and administrative actions, including supervision actions, intended to retain an entity in, or restore it to, a state in which it can perform a required function [IEV00]. From an application point of view, different research projects have been presented by the scientific community involving the implementation of Virtual and Augmented Reality (VR/AR) to extend the user's understanding and, in general, his experience during the maintenance work ([FRI02],[MAK05]). To our acquaintance, most of these approaches however, miss the potential of using knowledge-based theories in the domain that might enhance the user's experience. We show in this paper that the use of Semantics and AR techniques provide additional support to the maintenance tasks, by improving the user understanding of the elements being maintained. We base our approach in the SOUPA group of ontologies (Standard Ontology for Ubiquitous and Pervasive Applications) [CHE05]. Our approach extends SOUPA with two new ontologies (*i*) the Set of Experience Knowledge Structure, used to model the user's experience and (*ii*) the AR ontology which models an Augmented Reality environment that is used to enhance the maintenance experience through virtual elements. In our work we made an extensive use of Protégé both at an API level and as a user level in order to model our ontologies and handle them programmatically.

2. SOUPA (Standard Ontology for Ubiquitous and Pervasive Applications)

SOUPA is a shared ontology expressed using OWL [CHE05], designed to model and support pervasive computing applications (ambient intelligence). It consists of two distinctive but related set of ontologies, called SOUPA Core and SOUPA Extension as can be seen on Fig 1.

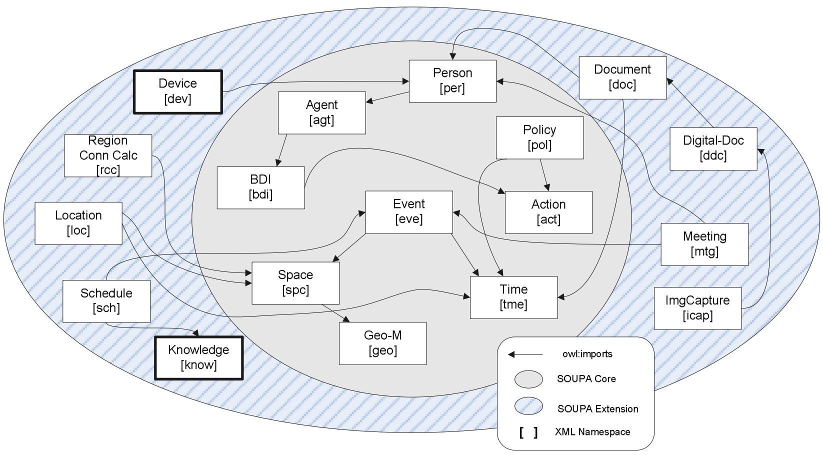

Fig. 1. The SOUPA group of ontologies (Core + Extension) [CHE05]

3. The Set of Experience Knowledge Structure

Set of Experience Knowledge Structure (SOEKS) is an experience tool able to collect and manage explicit knowledge of different forms of formal decision events [SAN07]. The SOE has been developed as part of a platform for transforming information into knowledge named Knowledge Supply Chain System. In the SOE, there are four basic components (see Fig 2): variables, functions, constraints and rules associated and stored in a combined dynamic structure.

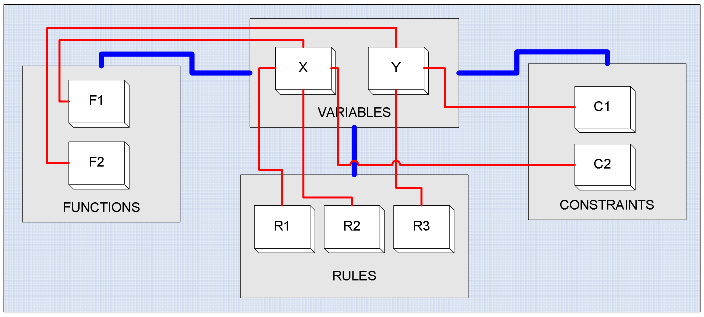

Fig. 2. The Set of Experience Knowledge Structure

4. The UDKE System

In this part, we introduce our Knowledge based Industrial Maintenance system using portable devices and Augmented Reality. We call our architecture UDKE (User, Device, Knowledge and Experience). UDKE provides a possible conceptual model of a maintenance system that combines knowledge, user experience and AR techniques. The schema is divided in layers which are depicted in Fig 3.

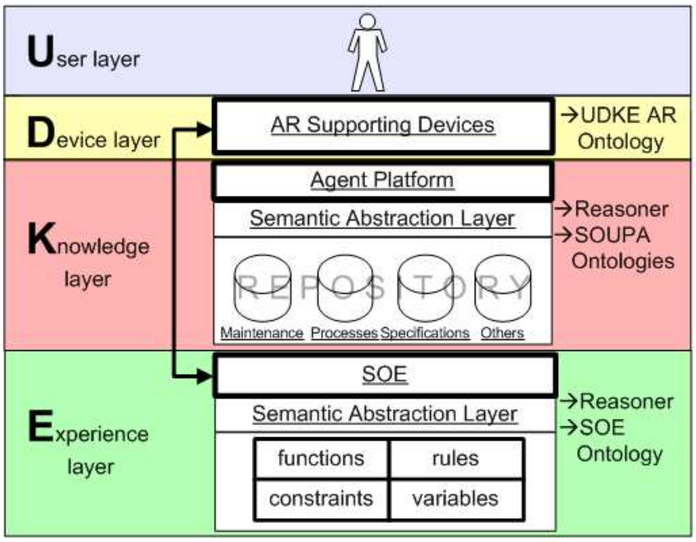

Fig. 3. The UDKE System

The User layer contains only the user, handling the particular profile, session, etc. The Device layer contains the modeling of the different devices used to capture the environment (a camera, a PDA, a pocket PC or a Tablet PC, etc) introduced as an extension to SOUPA that we call the UDKE AR ontology. In Fig 4, such extension is depicted (extending from the SOUPA **class dev:device)**.

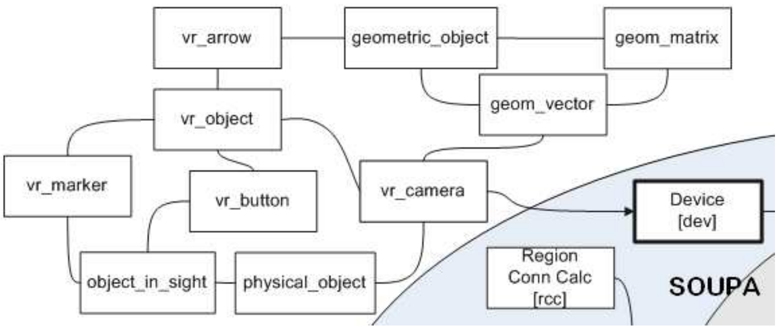

Fig. 4. The Augmented Reality extension of the SOUPA core

The Knowledge layer contains the agent platform whose main objective is to interact via majordomo messages with the Semantic abstraction engine. It contains the SOUPA Core and the SOUPA Extension ontologies as well as a reasoner system that is in charge of performing the semantic queries. The Ontologies feed their instances from different repositories relevant to the maintenance domain (historical data, programmed stops, cycles, etc). In the Experience Layer, the SOEKS is enclosed as an OWL ontology with different data bases that feed the reasoning system with functions, rules, constrains and variables used to specify new decisional events or even to contain past decisional events taken over similar elements (where similar refers to the object in sight element or in other words the element in which the maintenance engineer is considering at a given moment). In Fig 5 we show the extension place of the SOUPA set of Ontologies in which we derived the Set of Experience Knowledge Structure ontology that was presented by Sanin et al. [SAN07], the extension **class is know:Knowledge**.

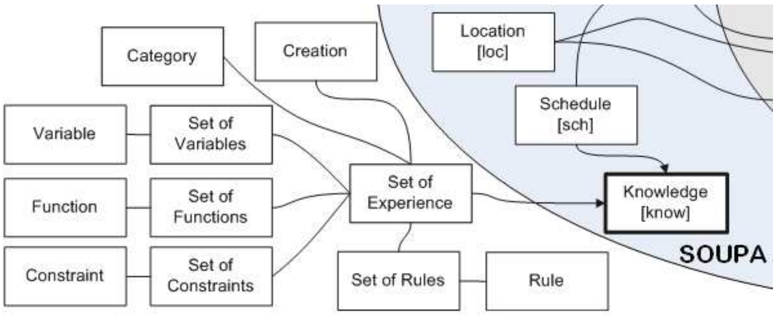

Fig. 5. The SOEKS extension of the SOUPA core

5. Application scenario

At present time, the system is being tested in a real maintenance environment. Rather than describing the actual experiments being held, we would like to present in this article a possible application scenario leaving the experiment results to be exposed in a future publication. In our scenario, the user during his maintenance patrol uses a portable device (PDA, UMPC or Tablet PC) with a camera connected. For every object to be maintained there exist a VR marker (following the sensor concept in ambient intelligence).

Every marker is an unequivocal grayscale pattern that can be easily printed in white paper by a regular PC printer. When the camera recognizes a marker, a matching element to be maintained is identified according to the context (user, task, priority) and a set of information is extracted from the repositories. The output video stream of the camera is mixed with 3D objects and other relevant information and is displayed to the user in his portable device screen. As can be seen in figure 6, the user is in front of an element (in this case a fire extinguisher) and when the system recognizes the matching marker, the user receives in the screen information such as the name of the element, the next programmed change, the maintenance procedure etc. All information is obtained from the repositories in the Knowledge layer and is maintained by the Experience layer.

Fig. 6. AR Enhanced user view using the UDKE Platform

6. Implementation issues

The system was tested using different portable devices, our implementation uses JAVA as the core language for the prototype implementation. The graphic library and the AR engine used were GL4Java and JARToolkit library respectively. All the ontology modeling was done in **Protégé** and the API used was the **Protégé OWL API**.

The agent platform used in our implementation was JADE, and for reasoning purposes over the ontologies we chose RACER. When a marker is detected, the system calculates the matrices necessary to place the augmented information via JARToolkit calls. Following the application flow, the Agent platform begin its work starting a majordomo service whose main function is to serve as an intermediary between the user and the rest of the architecture. The majordomo handles the events in the knowledge layer databases through reasoning over the SOUPA ontologies.

The majordomo also handles the Experience layer through reasoning over the SOEKS ontology (see figure 7) in order to obtain knowledge from past experiences or similar devices being maintained. Once that all that information is obtained/inferred and possible experience are acquired from the SOEKS using the reasoning system, a last step is performed by returning such information to the device (UMPC, Pocket PC, etc) and displayed (streamed) thought the devices graphical output.

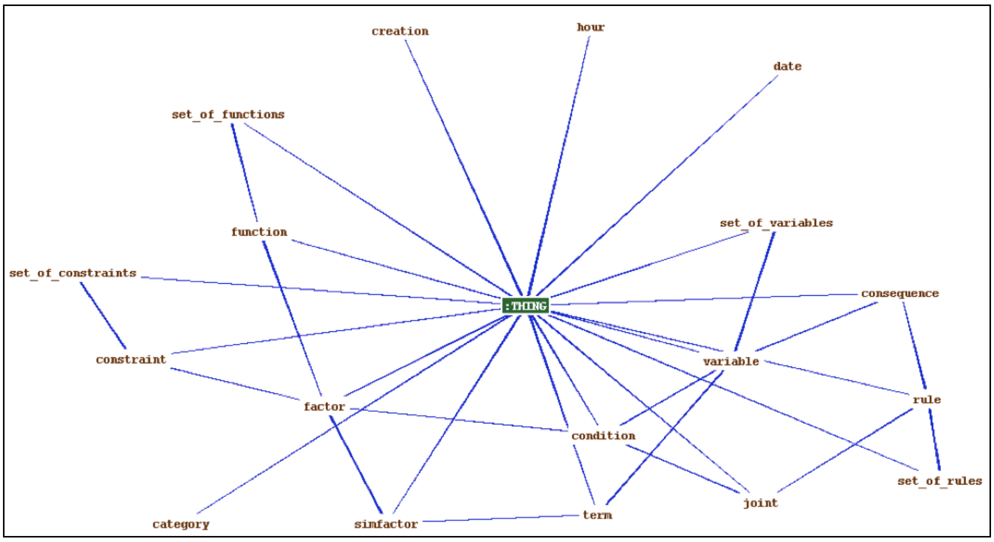

Fig. 7. Detail of the SOEKS ontology using the Protégé OWL-Viz plugin

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