S-Cube: A Semantic-based Middleware System for Context-Aware Services

Yong-il Jeong, Ivan Berlocher, Tae-sung Ahn and Kyung-il Lee
Mobico&Sysmeta, Inc.
#6F, Deok-Il Bldg., 967 Daechi-dong, Gangnam-gu Seoul, Korea
{ yijeong, ivan, albert, tony}@mobico.com

Abstract for Evaluation

Context-awareness is a core technology for ubiquitous computing that provides customized services for each user's interest and environment regardless of the time, location or devices. In order to implement such context-aware services, development of context representation, storage, sharing and management without any semantic ambiguity is of outmost importance. The semantic web[1] technology assists in effective implementation of context-aware services and assures interoperability between service agents.

This paper introduces S-Cube[2], an OWL and RDF-based middleware system, which provides such semantic based context-aware services, and describes the applications of S-Cube.

The development objectives of S-Cube are to represent and manage the information context, which has been acquired and processed according to the user's interest, and the physical and environmental contexts, which have been obtained through various types of physical sensors, and to perform reasoning based on the ontological representation of the accumulated context information.

The newly developed S-Cube incorporates the focused web crawling based on the user's profile, the text mining technology including information extraction and summarization, and the semantic web technology for representing and managing extracted informational contexts in OWL and RDF. By representing the context information acquired from various physical sensors and devices in OWL/RDF, and by performing reasoning thereof, it provides the semantic based services that enable a truly intelligent operation of the actuator. In order to evaluate the S-Cube system, an actual home network test bed was built and tested, and several service scenarios for multi-user environment were conducted through system emulation on the virtual space.

Through this study, we have developed a semantic based middleware system for context-awareness, and we have verified the system performance and availability by applying it to an actual user environment and to an emulated environment. We plan to expand the S-Cube system into a huge-scale service system and turn it into a telematics environment beyond the home networks.

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[1] http://www.w3.org/2001/sw/

[2] Semantic based middleware System for context-aware Services

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Abstract

This paper introduces S-Cube[1], an OWL and RDF-based middleware system which provides semantic based context-aware services, and describes the applications of S-Cube. It incorporates the focused web crawling, the text mining technology and the semantic web technology. By representing the context information in OWL/RDF, and by performing reasoning thereof, S-Cube provides the semantic based services that enable a truly intelligent operation of the actuator. In order to evaluate the S-Cube system, an actual home network test bed was built and tested, and several service scenarios for multi-user environment were conducted through system emulation on the virtual space.

1 Introduction

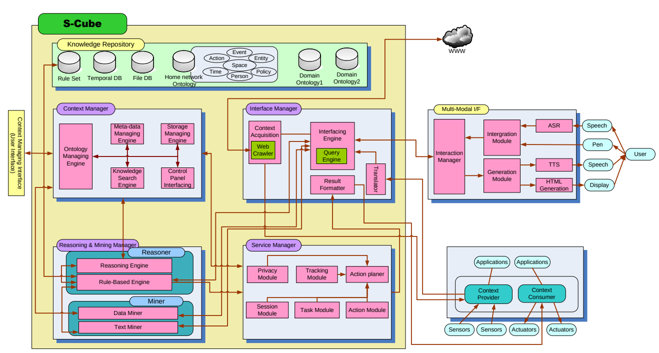
Context-awareness is a core technology for ubiquitous computing that provides customized services for each user's interest and environment regardless of the time, location or devices[Gandon and Sadeh, 2004]. In order to implement such context-aware services, development of context representation, storage, sharing and management without any semantic ambiguity is of outmost importance. In this paper, we introduce the S-Cube middleware system, which has been developed to provide semantic based context-aware services by adapting the ontological representation of user's contexts with reasoning, and describe the various application systems of S-Cube.

2 Architecture

The development objectives of S-Cube are to represent and manage the information context, which has been actively acquired and processed according to the user's interest, and the physical and environmental contexts, which have been obtained through various types of physical sensors, and to perform reasoning based on the ontological representation of the accumulated context information.

For the purpose of implementing intelligent information providing services, the text mining technology, i.e., focused web crawling, information extraction and summarization based on user profiles, and the semantic web technologies that represent and manage the informational contexts in the forms of OWL and RDF[Berners et al., 2001; Hendler, 2001] were incorporated into S-Cube. S-Cube was also designed to represent context information which has been acquired through various physical sensors and devices. With its accumulated contexts and reasoning, it provides the semantic based services that enable a truly intelligent operation of the actuators. The S-Cube system consists of four main components as shown in Figure 1.

First, the Context Manager stores and manages the contexts represented in OWL/RDF, supports management of various meta-data in the Knowledge Repository, and searches text content, RDF documents and meta-data within the DBMS.



[Figure 1] S-Cube Architecture

Second, the Interface Manager actively acquires the contexts outside of the middleware and provides interfacing with the application system. The Focused Web Crawler within the Interface Manager collects and selects informational contexts from the web according to the user's interest. The Context Translator included has also the capability to translate the format of context information transmitted internally and externally.

Third, the Reasoning & Mining Manager includes the inference engine with the capability to apply appropriate

[1] Semantic- based middleware System for context-aware Services

reasoning rules to the acquired and accumulated contexts and deduce new contexts and task policies; also, the mining engine that extract, analyze and regenerate the contexts according to the user's interest and preference.

Fourth, the Service Manager manages each user's privacy policy and generates and manages the service sessions, tasks and sub-tasks for each user or user group. The Service Manager ensures seamless service by performing integrated session management between the distributed S-Cubes.

3 Implementation and Experiment

This chapter introduces the Home Network Ontology which has been designed for implementing user-customized service in intelligent spaces and for representation and management of semantic based context, and describes the organization of the framework and interfacing protocol that were used for actual implementation of the middleware software. This chapter also includes details on examination and verification of various service scenarios on a physical home network test bed and an emulated space.

3.1 Home Network Ontology

We designed and applied "Home Network Ontology (HNO)" for representing context information semantically, making inferences from the context information, and for ensuring interoperability between various devices and multiple agents in intelligent spaces.

HNO, an ontology-based context model, is described by OWL-Lite and consists of several high-level classes such as Person, Time, Session, Event, User activity, Policy, Devices and so on.

3.2 Implementation and Interfacing Protocol

S-Cube was developed based on the Java framework. As mentioned above, each of the four managers constituting S-Cube has its own process, and multiple threads are executed depending on the number of sessions per user and number of unit service tasks. S-Cube's context manager is designed to allow interfacing with various external RDF/OWL parsers, triple converters and managers for OWL-based semantic representation, storage and management. At present, HP's JENA is used within S-Cube.

Reasoning is vital in providing intelligent services that are optimized to user contexts. S-Cube utilizes HP-JENA's reasoner and JESS, a rule-based reasoner. RMI and TCP/IP protocols are used for interfacing between the managers, and RDF/XML is used for data exchanges.

One of the unique characteristics of S-Cube is that it uses multi-modal interfacing (MMI) for user interface. An MMI is an interface that integrates various user modalities (text, voice, writing, etc.), and the MMI module utilized by S-Cube is in compliance to the EMMA recommendation proposed by the W3C.

3.3 Service Scenario and Experiment

In order to evaluate feasibility and extensibility of S-Cube, 20 different service scenarios were developed and applied to S-Cube. The scenarios included the family identification service using PDA, indoor environment control service using user priority levels, home appliance control service, information acquisition and provision service for weather, stock quotes, traffic information and so on. To examine the scenarios, an actual physical residential space was developed as a test bed, a physical home network environment was implemented on the test bed, and S-Cube was utilized to verify its successful operation in each scenario.

The Emulated Gateway with the multiple user avatar technology was developed to design and emulate various types of all imaginable smart spaces and to validate feasibility and extensibility of S-Cube in ways that cannot be done with conventional sensors and actuators. We have verified that the various actuators and devices worked effectively, and the semantic based information providing service was performed well in both physical and virtual spaces. We also verified that our HNO, OWL/RDF-based reasoning, and the text mining system could be applied effectively in smart spaces.

4 Conclusion and Future Work

We presented S-Cube, a middleware system for semantic based intelligent services in ubiquitous environments, and we discussed various application systems utilizing S-Cube. Major issues discovered during the implementation of S-Cube included the problem with the speed of the reasoner, connection problems and arbitrary changes of contents when using focused crawling, as well as improvement of the overall speed for S-Cube. In the future, we plan to resolve S-Cube problems, expand the system into a huge-scale context-aware service system, and utilize it not only for home networks but for telematics environments.

5 Acknowledgments

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DEMO Introduction

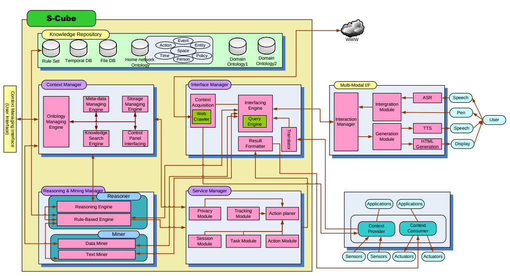
S-Cube is a semantic-based middleware using an ontological representation of diverse contexts in OWL/RDF language, offering context-aware services in the ubiquitous computing environment. S-Cube represents and manages the informational, physical, and environmental contexts according to the ‘Home Network Ontology’(HNO) model and makes reasoning to provide the customized service adapted to the user’s context. Using focused web crawling and text mining, such as information extraction, and summarization, S-Cube provides customized information services to its users based on their profile and preferences. The semantic web technology employed in S-Cube is an essential element ensuring communication between different agents without semantic ambiguities.

- **Features**

  - Context managing: Represents and manages informational, physical and environmental contexts in OWL and RDF.
  - Text mining: Performs Information Extraction and Summarization based on the user profile.
  - Focused web crawling: Performs crawling for information within the scope of interest.
  - Reasoning: Make inferences based on the ontology and the contexts (instances) accumulated.
  - Service managing: Generates and manages service sessions, tasks, and sub-tasks.
  - Multi-modal interfacing (MMI): User interface.

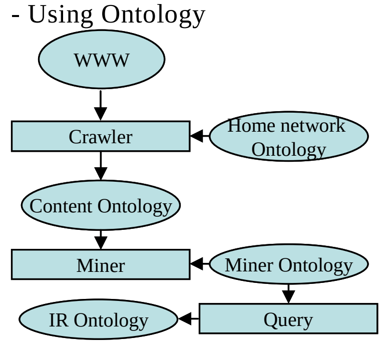
Architecture, Snapshot and Ontology

- S-Cube Architecture



- Snapshot

- Using Ontology



- **Components of S-Cube**

  - Context Manager, Reasoning & Mining Manager, Interface Manager, and Service Manager
  - Also includes Multi-modal Interfacing (MMI) Server, and Emulator Server

- **Communication and Protocol**

  - Transport: TCP/IP, RMI
  - Data format: RDF/XML

Running Demo

Please follow the steps below to run the demo:

1. Start the S-Cube Server, the MMI Server, DSR and ASR for speech recognition, the Emulator Server, and the client (web-browser) to execute the virtual environment.
2. Go through the user authentication process using the PDA.
3. At the screen after the authentication process, select voice or text to browse for information or control the home environment.
4. Verify through the client that the home environment changes according to the user’s location.

Authors

Yong-il Jeong, Ivan Berlocher, Tae-sung Ahn and Kyung-il Lee
{ yijeong, ivan, albert, tony }@mobico.com
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