SMARTRESOURCE TEKES PROJECT – ANNUAL REPORT "ADAPTATION STAGE" (2004)

TEKES

SmartResource Project

Year 2004

Annual Report

"Adaptation Stage"

Industrial Ontologies Group

Agora Center, University of Jyväskylä

JSP Jyväskylä Science Park · metso automation · University of Jyväskylä · TeliaSonera · TietoEnator Building the Information Society

February, 2005
Jyväskylä, Finland

Table of Contents

Project's webpage: *http://www.cs.jyu.fi/ai/OntoGroup/SmartResource_details.htm*

Group's website: *http://www.cs.jyu.fi/ai/OntoGroup/*

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1 Introduction

Project Motivation

With the development of technologies, very fast creation and communication of information/knowledge has become possible. Automated knowledge accumulation and sharing is becoming the most profitable kind of business for modern, *knowledge-based*, companies. Such industries are looking for fast and global solutions related to Knowledge Management, Enterprise Application Integration, Electronic Commerce, Asset Management, etc. Various industrial standards, which have been created and implemented by different industrial consortiums, appear to be insufficient for growing interoperability demands.

One of the domains, where knowledge accumulation and its timely delivery are crucial, is industrial maintenance[1]. Development of a global environment, which would support automation of knowledge management for industrial maintenance, is a very profit-promising and challenging task. The latter is what the Smart Resource project aims at.

Our intention is to provide tools and solutions to make heterogeneous industrial resources (files, documents, services, devices, processes, systems, human experts, etc.) web-accessible, proactive and cooperative in a sense that they will be able to analyze their state independently from other systems or to order such analysis from remote experts or Web-services to be aware of own condition and to plan behavior towards effective and predictive maintenance.

Project Approach and Goal

The contribution of this ongoing SmartResource project (2004-2006) together with strong research effort includes prototype implementation of *distributed Semantic Web enabled maintenance management environment* with complex interactions of components, which are devices, humans (experts, operators) and remote diagnostic web-services. The environment will provide automatic discovery, integration, condition monitoring, remote diagnostics, cooperative and learning capabilities of the heterogeneous resources to deal with maintenance problems. Maintenance (software) agents will be added to industrial devices, which are assumed to be interconnected in a decentralized Peer-to-Peer network and which can integrate diagnostic services in order to increase the maintenance performance for each individual device. In the project, the maintenance case is expected to demonstrate the benefits and possibilities of new resource management framework and Semantic Web technology in general for Finnish industry.

Thus, project approach harnesses the potential of emerging progressive technologies – Semantic Web, Agent Technology, Machine Learning, Web Services and Peer-to-Peer – in addressing its very challenging goals.

Project Stages

Project research and development activities are divided into three yearly stages: Adaptation Stage (2004), Proactivity Stage (2005) and Networking Stage (2006). Each year of the project delivers more enhanced version of architectural design and prototype implementation for the maintenance environment.

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[1] Metso Automation's customer magazine, (2003) *Automation*, *1*, 7-9.

Adaptation Stage defines Semantic Web-based framework for unification of maintenance data and interoperability in maintenance system. Its research and development tasks include development of generic semantic adapter mechanism (General Adaptation Framework) and supporting ontology (Resource State/Condition Description Framework) for different types of industrial resources: devices, software components (services) and humans (operators or experts). The key technology, which is utilized during the Adaptation Stage is *Semantic Web*. The latter is a relatively new initiative within W3C standardization effort to enable machine interpretable metadata in the Web. It provides standards and tools to enable explicit semantics of various Web resources based on semantic annotations and ontologies. Integration in general is considered nowadays as a “killer application” of Semantic Web technology, which particularly can be interpreted as heterogeneous data integration, Enterprise Application Integration and Web-service integration among other interpretations.

Proactivity Stage focuses on an architectural design of agent-based resource management framework and on enabling a meaningful resource interaction. Its research and development tasks include adding software agents (Maintenance Agents) to the industrial resources, enabling their proactive behavior. For this purpose, Resource Goal/Behavior Description Framework has to be designed, which will be the basis for making resource's individual behavioral model. The model is assumed to be processed and executed by the RGBDF engine used by the Maintenance Agents. Agent-based approach for management of various complex processes in the decentralized environments is being adopted and popularized currently in many industrial applications. Presentation of the resources as agents in the multi-agent system and use of technologies and standards developed by the Agent research community is a prospective way of industrial systems development. Creation of framework for enabling resources’ proactive behavior and such agent features as self-interestedness, goal-oriented behavior, ability to reason about itself and its environment and to communicate with other agents, can bring a value to the next-generation industrial systems.

The objective of the **Networking Stage** comprises complex behavior/interaction scenarios of Smart Resources (agent-augmented Device, Expert and Service) in the global decentralized networked environment. The scenarios assume agent-based interoperation of multiple devices, multiple services and multiple experts, which allows discovery of necessary experts in Peer-to-Peer network, using their experiences to learn remote diagnostics Web-services, making online diagnostics of devices by integrating diagnoses from several services, learning models for a device diagnostics based on online data from several distributed samples of similar device, etc. Emerging Peer-to-Peer technology and similar network architectures suite well the increasingly decentralized nature of modern companies and their industrial and business processes, whether it is a single enterprise or a group of companies [25]. The set of advantageous features of the Peer-to-Peer model includes decentralization, scalability and fault-tolerance along with low administration expenses. Client/server architectures with centralized management policy increasingly fail with big amounts of nodes, because of their complexity and extremely high demands on computing resources. Distributed content management systems address the need to access content wherever it resides, produce content while maintaining control over it, and collaborate efficiently by sharing data real-time within a distributed network of stakeholders.

2 Project Background Concept: a Global Understanding Environment

Global Understanding Environment (GUN)[2] is a concept used to name a Web-based resource "welfare" environment, which provides a global system for automated "care" over (industrial) Web-resources with the help of heterogeneous, proactive, intelligent and interoperable Web-services. The main players in GUN are the following resources: service consumers (or components of service consumers), service providers (or components of service providers), decision-makers (or components of decision makers). All these resources can be artificial (tangible or intangible) or natural (human or other). It is supposed that the "service consumers" will be able: (a) to proactively monitor own state over time and changing context; (b) to discover appropriate "decision makers" and order from them remote diagnostics of the own condition, and then the "decision makers" will automatically decide, which maintenance ("treatment") services are applied to that condition; (c) to discover appropriate "service providers" and order from them the required maintenance. Main layers of the GUN architecture are shown in Figure1.

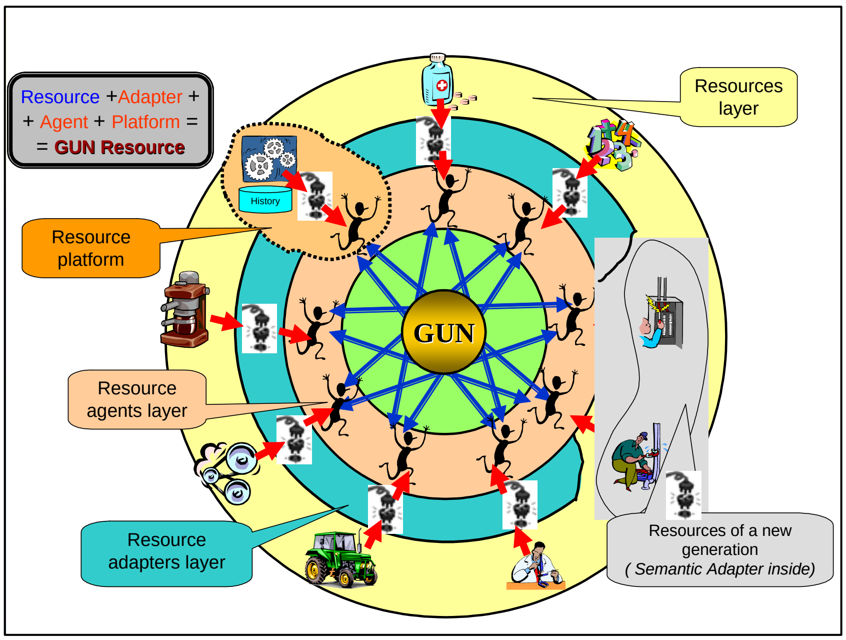

Figure 1 - Layers of the GUN architecture

Industrial resources (e.g. devices, experts, software components, etc.) can be linked to the Semantic Web-based environment via adapters (or interfaces), which include (if necessary) sensors with digital output, data structuring (e.g. XML) and semantic adapter components (XML to Semantic Web). Agents are assumed to be assigned to each resource and are able to monitor semantically reach data coming from the adapter about states of the resource, decide if more deep diagnostics of the state is needed, discover other agents in the environment, which represent "decision makers" and exchange information (agent-to-agent communication with semantically

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[2] Terziyan V., Semantic Web Services for Smart Devices in a "Global Understanding Environment", In: R. Meersman and Z. Tari (eds.), *On the Move to Meaningful Internet Systems 2003*, LNCS, Vol. 2889, Springer-Verlag, 2003, pp.279-291.

enriched content language) to get diagnoses and decide if a maintenance is needed. It is assumed that “decision making” Web-services will be implemented based on various machine learning algorithms and will be able to learn based on samples of data taken from various “service consumers” and labeled by experts. Use of agent technologies within GUN framework allows mobility of service components between various platforms, decentralized service discovery, FIPA communication protocols utilization, and MAS-like integration/composition of services.

3 Project Results (Year 2004, Adaptation Stage)

Semantic Data Model – Deliverable 1.1

We cannot say yet that Semantic Web technology as such is mature enough to be accepted by industry in a large scale. The reasons for that we have analyzed in [2, 13, 20, 25, [3]]. Some of standards still need modifications as well as appropriate tool support. For example, Semantic Web technology offers a Resource Description Framework (RDF) as a standard for semantic annotation of Web resources. It is expected that Web content with RDF-based metadata layer and ontological basis for it will be enough to enable interoperable and automated processing of Web data by various applications. However emerging industrial applications consider e.g. machines, processes, personnel, services for condition monitoring, remote diagnostics and maintenance, etc. to be specific classes of Web resources and thus a subject for semantic annotation. Such resources are naturally dynamic, not only from the point of view of changing values for some attributes (state of resource) but also from the point of view of changing “status-labels” (condition of the resource). Current RDF still needs temporal and contextual extensions.

This motivates one of the objectives of SmartResource project activities during the Adaptation Stage (year 2004), which is Resource State/Condition Description Framework (RSCDF), as an extension to RDF, which introduces upper-ontology (semantic standardized data model) for describing such characteristics of resources as states and corresponding conditions, dynamics of state changes, target conditions and historical data about previous states. These descriptions are supposed to be used by external Web-services (e.g. condition monitoring, remote diagnostics and predictive maintenance of the resources). Pilot version of RSCDF and appropriate schema developed using the freeware open source Protégé[4] tool, are presented in [4, 5]. Figure 2 depicts the conceptual meaning of RSCDF: it is an RDF-compliant semantic representation format for resource’s historical (life-cycle) data.

RSCDF inherits from RDF an approach of modeling a problem domain using triplet entities and building inter-related hierarchies of classes and properties. This approach endows the resulting data models with high extensibility and originally aims at providing a semantically rich descriptive data (metadata) about a corresponding resource to new-generation (intelligent) software processing tools.

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[3] Terziyan V., Kononenko O., Semantic Web Enabled Web Services: State-of-Art and Industrial Challenges, In: M. Jeckle and L.-J. Zhang (eds.), Web Services - ICWS-Europe 2003, Lecture Notes in Computer Science, Vol. 2853, Springer-Verlag, 2003, pp. 183-197.

[4] http://protege.stanford.edu/, official website of the Protégé tool

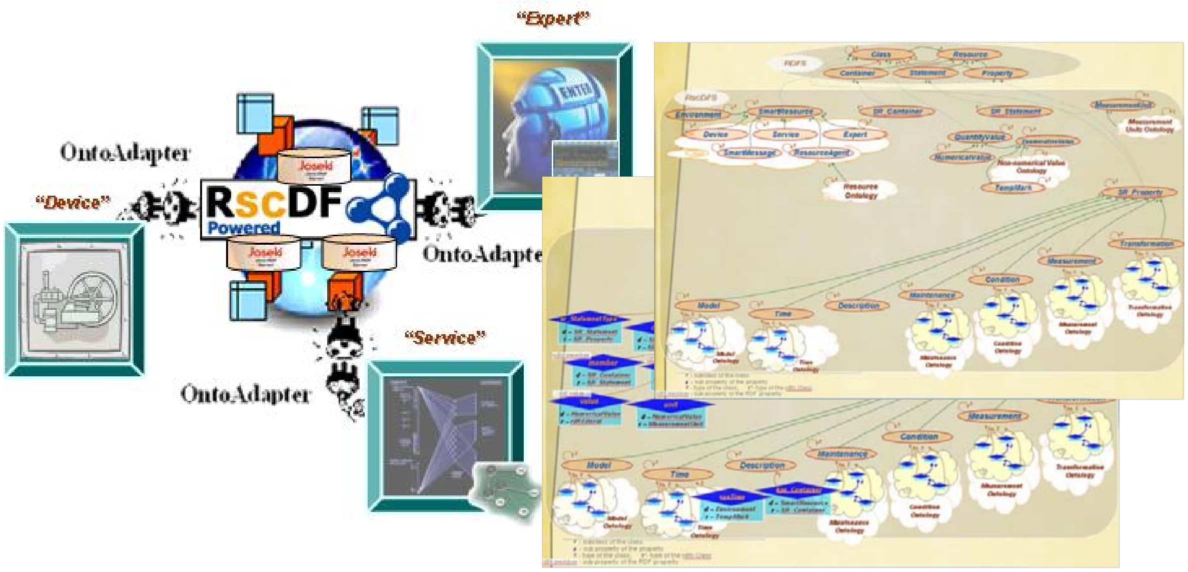

Figure 2 - Conceptual meaning of Resource State/Condition Description Framework

General Adaptation Framework – Deliverable 1.2

Another obstacle for the Semantic Web standardization effort relates to the fact that despite many industrial companies and consortiums have realized that explicit description of semantics of data and domain modeling is necessary for application integration, they have still used for that purpose their company/consortia specific standards or XML language that is inappropriate for global integration. Even realizing that Semantic Web is providing really global standards, it is already too late, labor and resource consuming to transform manually huge amount of already modeled metadata from a local to the global standard. One possible solution could be designing semantic adapters, which enable semiautomatic transformation from company specific standards to Semantic Web standards. This motivates the second objective of the SmartResource project (Adaptation Stage, year 2004) – a design of General Adaptation Framework, which provides a methodology for designing adapters from various data formats to RSCDF and back. The pilot version of the task is presented in [6] and additionally the approach of General Adaptation was tested on concrete implementations - adapters for three different samples of heterogeneous resources (device data, expert interface, Web-Service) [7]. The conceptual picture of General Adaptation Framework is shown in Figure 3.

In the approach of General Adaptation we distinguish two aspects of adaptation: data model transformation and Application Programming Interface (API) adaptation. The first aspect focuses on a transformation of resource data stored in a specific data model (relational database, family of XML-based standards, UML, etc.) to a unified semantic-rich format, in our case to RSCDF, and vice versa. For this purpose, we utilize a method of two-stage transformation, which assumes mapping of a specific data model to a corresponding canonical form from the same family of data representation standards. If, for instance, we need to transform an XML schema to RSCDF, first of all we have to define the XML canonical schema and make a mapping with it. The strength of the two-stage transformation is in reuse of a variety of existing powerful tools for data model

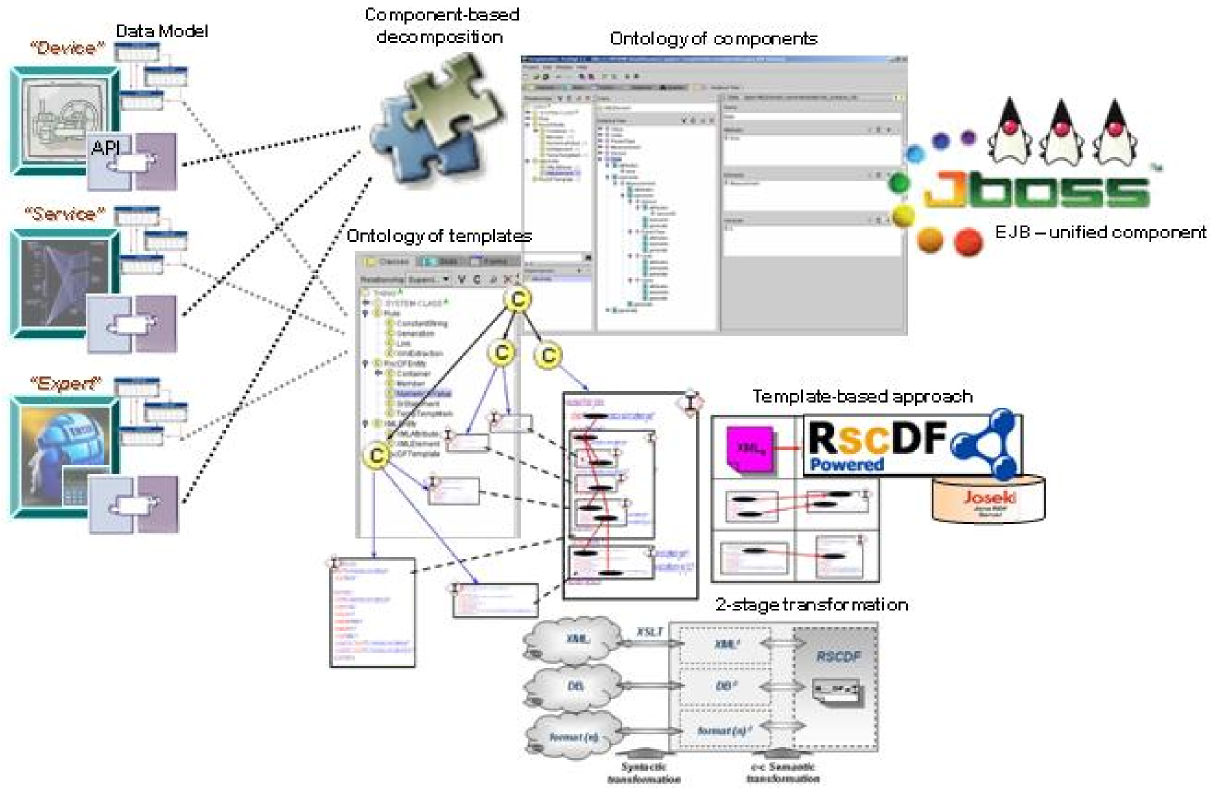

Figure 3 - General Adaptation Framework illustrated

mapping[5] and also in simplification of the data model mapping process for potential customers – owners of resources that are intended to be integrated into the target maintenance environment. The owners do not have to think about complicated ways of transformation of their data models to RDF-based standards – they just have to map their data model to the canonical one within the same standard (e.g., XML). After native-to-canonical data model mapping, the template-based approach of a transformation from a canonical form to RSCDF is applied according to GAF. This approach is based on automated generation of XML serialized RSCDF instances, which are determined from the ontology of templates. The ontology stores classified pairs of correspondence between canonical and RSCDF patterns – chunks of terminal strings of text. Thus, in fact, thanks to GAF, the process of data model transformation requires two efforts: mapping between the initial and canonical data schemata, and engineering of the ontology of templates. Having these two activities done, the data transformation between a native and RSCDF formats is carried out automatically.

The second aspect of adaptation – API adaptation - relates to a possibility of automated access to data entities in native storages through native application interfaces. For instance, a database entity can be accesses via ODBC (Open Database Connectivity) connectors using functional calls in different programming languages. To access a certain database records for further data transformation an appropriate programming component must exist. The component can either execute native functional calls or perform a direct access to the native data storage.

[5] MapForce homepage. http://www.altova.com/products_mapforce.html

Hence, to automate the retrieval of native data entities the existing types of API's must be decomposed using component-based analysis [6], classified and arranged into a centralized/decentralized library[5]. Such components, in a vision of GAF, are building blocks for automated assembly of a concrete adapter on the fly. The automated component integration is performed using ontology of components and the resulting adapter is run as an EJB[7] (Enterprise Java Bean) component on a JBoss Application server[8] in our implementation.

To a have a comprehensive framework for adaptation of resources, ontology of templates and ontology of components must be closely interrelated due to high dependency between data models and methods of accessing the corresponding data.

SmartResource Prototype Environment – Deliverable 1.3

For a practical testing of the developed approach of General Adaptation, the first version of the target prototype environment has been implemented. Technical report [7] contains the details of this implementation and in addition corresponding UML diagrams and source code description are available in [15] (Omondo[9]-generated). The implementation of the environment is supplied on a project's CD and can be launched on a workstation, which meets the specified requirements. Figure 4 illustrates architecture of the implemented prototype environment.

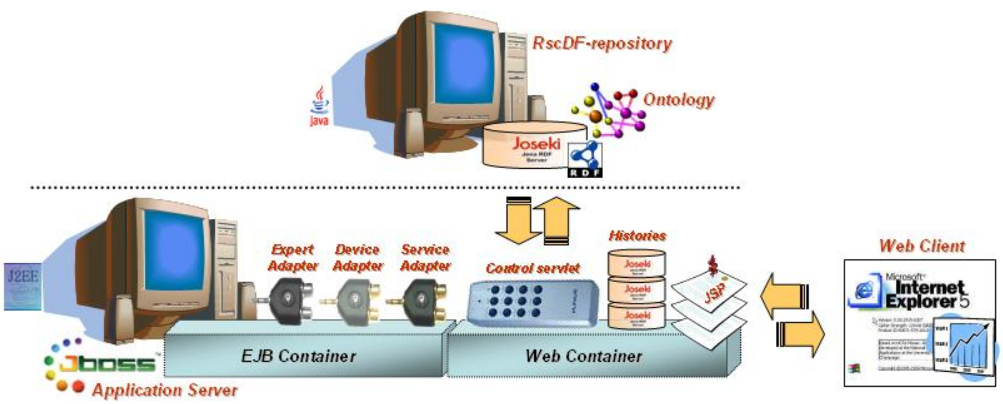

Figure 4 - Architecture of the SmartResource prototype environment, v. 1.0

For the process of software engineering the latest and the most powerful freeware and open source tools and technologies were used. The whole environment is based on Java 2 Platform,

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[6] Teschke T., Ritter J., Towards a Foundation of Component-Oriented Software Reference Models, In: Greg Butler, Stan Jarzabek (Hrsg.): Generative and Component-Based Software Engineering, Lecture Notes in Computer Science (LNCS), 2177, Springer Verlag, S.70-84, 2001.

Nierstrasz O., Gibbs S., Tsichritzis D., Component-Oriented Software Development, Communications of the ACM, Vol. 35, No. 9, Sept. 1992.

Nierstrasz O., Dami L., Component-Oriented Software Technology, Object-Oriented Software Composition, Nierstrasz O. and Tsichritzis D. (Eds.), pp. 3-28, Prentice Hall, 1995.

Lucena V., Facet-Based Classification Scheme for Industrial Automation Software Components, Proc. of Sixth International Workshop on Component-Oriented Programming (WCOP 2001), Budapest, Hungary, 2001.

[7] http://java.sun.com/products/ejb/, Enterprise JavaBeans Technology

[8] http://www.jboss.org/products/jbossas, description of the JBoss Application Server

[9] http://www.omondo.com/, official website of the Omondo modeling tool

Enterprise Edition[10] (J2EE) and was developed using Eclipse[11] Integrated Development Environment together with the Poseidon[12] UML-based modeling tool. Versioning control was carried out with help of the CVS[13] tool. As it was mentioned, during the concerned year, for testing the approach of General Adaptation Framework and the RSCDF format, three sample adapters were implemented (project tasks T4, T5 and T6). Their logic was encapsulated in three Enterprise Java Beans (EJB) and executed on the JBoss application server. Specification of the KF-330 blow molding machine was used for simulation of the device data (7 device parameters). Device states were generated in a form of XML entities according to the corresponding XML schemata (three different schema variations, plus a canonical one). State and Condition resource data encoded in RSCDF after the transformation were stored in a remote Joseki[14] RDF server. For creation of a local history cache, Jena[15] classes were used. Code that coordinated coherent work of the adapters and provided a control/monitoring over them, was executed in the control Java Servlet[16]. Visualization of the internal processes of the prototype environment was organized using a set of Java Server Pages[17] (JSP). Demonstrations were carried out using Internet Explorer web browser.

Web Service adapter incorporated learning algorithm (KNN-method) wrapped by a web service container using Axis[18] and Lomboz[19] (see Figure 5). The adapter using generated SOAP-client simulated software agent's requests for learning and diagnostics. For RSCDF-XML transformations, the adapter uses approach of 2-stage transformation with RDQL-templates.

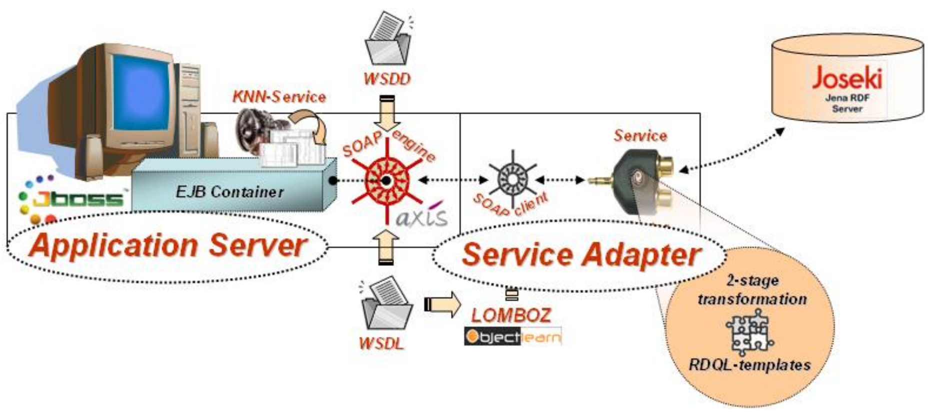

Figure 5 - Implementation architecture of the Web Service adapter

In the implementation of the human expert adapter, 2-stage transformation and User Interface Templates were used for flexible building of a specific human interface (Figure 6). Involvement of the JFreeChart[20] open Java library allowed generating images for representation of the device states. Human Expert is requested for a diagnostics via e-mail.

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[10] http://java.sun.com/j2ee/, Java 2 Platform Enterprise Edition
[11] http://www.eclipse.org/, Eclipse Integrated Development Environment
[12] http://www.gentleware.com/, Poseidon UML modeling tool
[13] https://www.cvshome.org/, CVS – Concurrent Versions System
[14] http://www.joseki.org/, Joseki RDF server
[15] http://jena.sourceforge.net/, Jena – A Semantic Web Framework for Java
[16] http://java.sun.com/products/servlet/, Java Servlet Technology
[17] http://java.sun.com/products/jsp/, JavaServer Pages Technology
[18] http://ws.apache.org/axis/, official webpage of Axis Apache
[19] http://www.objectlearn.com/index.jsp, Lomboz ObjectLearn Eclipse plugin
[20] http://www.jfree.org/jfreechart/, JFreeChart – free Java class library for generating charts

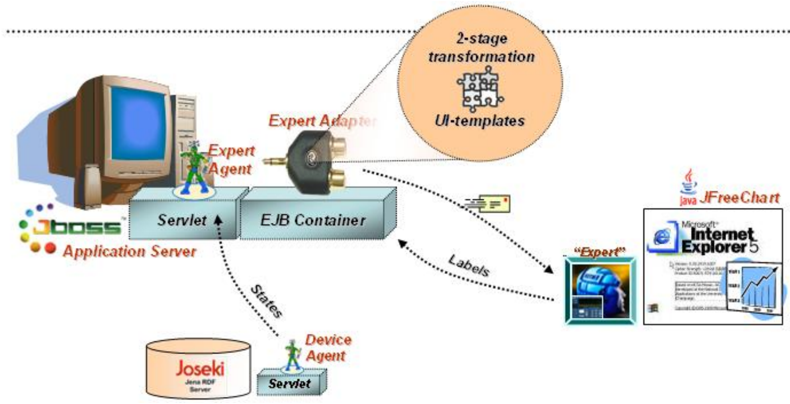

Figure 6 - Implementation architecture of the human expert adapter

4 Evaluation of the Project Results (Year 2004)

Scientific Value

First of all, the project results gained during its first year (year 2004, Adaptation Stage) have quite a significant scientific value. The research efforts undertaken by a group of young perspective researchers led by experienced supervisors have been addressed to a pioneer way of exploring the potential of the emerging promising Semantic Web technology. In contrast to ICT, the semantic technologies represent meanings separately from data, content, or program code, using the open standards for the Semantic Web. They are language neutral, machine interpretable, sharable, and adaptive, allow ontology based integration of heterogeneous resources.

During the Adaptation Stage the project team succeeded in development and prototype testing of the semantic modeling approach. The ultimate goal is to develop a solid semantic modeling methodology in order to simplify the relevant problem of Enterprise Application Integration. Currently, this problem has been attacked in its two major points: data model transformation and integration of Application Programming Interfaces. The introduction of the semantic modeling element (ontology of data model templates – structural patterns and interrelations between them) into the process of data model transformation has allowed its automation. Also, the competent decomposition of the data model transformation process into two stages (mapping of a native format to a canonical one and mapping of the canonical model to a semantic one) will relief resource providers of the complexities with semantics (facilitating the adoption of the Semantic Web technology) and will harness existing model mapping tools.

On the other hand, a novel combination of the semantic modeling (ontology of components) with the component-based decomposition (the latter has developed for over ten years) is going to increase significantly the efficiency of the Component-Oriented Analysis towards automation of the Enterprise Application Integration.

As for the semantic format based on the developed Resource State/Condition Description Framework, its presentation to a scientific community is intended to initiate a revision of the RDF standard in regard to its applicability to a highly dynamic resource maintenance environments (in a general sense of the "resource" notion). Current version of the RSCDF schema, which contains contextual and temporal extensions, is assumed be a first proposal that meets the above requirements.

The project research and development results have been written/published in about 20 papers. We have noticed from the Web that some of the early project publications are already used in teaching in some European institutions.

During the first project year, the following travels related to the dissemination of the project research results have been carried out:

1. Zharko A., IASTED International Conference on Software Engineering / IASTED International Conference on Databases and Applications / IASTED International Conference on Parallel and Distributed Computing and Networks, Travel to: Innsbruck, Austria, February 17-19, 2004. Reports: Visual Interface for Adaptation of Data Sources to Semantic Web, Community Formation Scenarios in Peer-to-Peer Web Service Environments, OntoEnvironment: An Integration Infrastructure for Distributed Heterogeneous Resources.
2. Terziyan V., Forth International ICSC Symposium on Engineering of Intelligent Systems, Travel to: Funchal, Portugal, February 28 – March 2, 2004. Reports: Semantic Web Services for Smart Devices Based on Mobile Agents.
3. Khriyenko O., 2nd IEEE International Conference on Industrial Informatics, Travel to: Berlin, Germany, June 24–26, 2004. Report: OntoSmartResource: An Industrial Resource Generation in Semantic Web.
4. Zharko A., International Workshop on Knowledge Intensive Business Infrastructure for Semantic Web, Travel to: Helsinki, Finland, June 24, 2004. Report: Intelligent Agents and Semantic Web.
5. Terziyan V., First IFIP International Conference on Artificial Intelligence Applications and Innovations, Travel to: Toulouse, France, August 21-28, 2004. Report: Learning Bayesian Metanetworks from Data with Multilevel Uncertainty.
6. Terziyan V., Forth IEEE International Conference on Advanced Learning Technologies, Travel to: Joensuu, Finland, August 30 – September 1, 2004. Report: Personalized Distance Learning Based on Multiagent Ontological System.

Strategic Contribution

Another significant contribution of the project period is the open source based tactics devised by the project team. During the first project year the team has mastered about 15 freeware open source tools that have enabled to develop a relatively advanced prototype with limited resources. As recent news reveal, the team has made a right choice with a Java-based RDF parsing libraries (Jena) and ontology engineering tool (Protégé). The software engineering approach, which assumes integration of the open source tools and technologies, will be applied for development of further versions of the prototype environment and will be transferred as an important experience to the coming team members.

Academic and Professional Growth

The active project research and related public activities has contributed much in the academic and professional growth of the project team members, especially of the young ones. Hardly any young project member has participated in such big research projects before and this possibility has given to them an experience of coherent joint work and an insight into efficient management of the project activities, rational labor division between all team members.

Thanks to the wide research field of the project, two doctoral students participating in the project, have been able to gain a half of the required doctoral credits in a comparatively short term (1 year). They have published few papers that contain material appropriate for their dissertations. Also, practical orientation of the project results will make the doctoral research more remarkable and significant for the world's scientific community. Participation in the project's seminars and conferences will influence positively on the oral abilities of the future Ph.D.s.

The project research idea has motivated a research paper [10], which was written and published by one of the project's doctoral students. The idea behind that paper has got a grant support from TeliaSonera.

During the first year of the project three team members have gained Master's degree and three of them have completed a practical training. Partly project results were included to the updated lecture material of the couple of courses taught by the team leader at the Department of Mathematical Information Technology.

Partner Network Widening

In addition to the existing partner contacts of the project team, which comprise Kharkov National University of Radioelectronics (Ukraine), Free University of Amsterdam (Netherlands), "OntoWeb" European Network of Excellence, Berkeley University (USA), Metso, TeliaSonera, TietoEnator, Jyväskylä Science Park, new contacts have been established that broadens teams' horizons and channels of the experience transfer and opens new commercial opportunities.

The local cooperation with TITU-group led by Prof. Jari Veijalainen gives a possibility to get experience from a huge European Adaptive Services Grid Project, which aims to develop a proof-of-concept prototype of an open development platform for adaptive services discovery, creation, composition, and enactment in web environment based on their semantic specifications. Mutual experience exchange in the area of Semantic Web Services will significantly increase the research results of the local part of ASG and SmartResource projects. Particularly, Ville Törmälä and Jarno Heikkilä from the ASG Project will write their Ms. Thesis with guiding support from the SmartResource project and vice versa, Anton Naumenko and Sergiy Nikitin from SmartResource project group will contribute to the development of ASG prototype.

A liaison has been created between SmartResource Project and FP6/STREP project CASCOM: "Context-Aware Business Application Service Coordination in Mobile Computing Environments" (2004-2007) via our SmartResource project's contact person Heikki Helin from TeliaSonera, who is technical coordinator of the CASCOM activities. The main objective of the CASCOM (http://www.ist-cascom.org/) is to implement, validate, and trial value-added supportive infrastructure for business application services for mobile workers and users across mobile and fixed networks. The essential approach of CASCOM is the innovative combination of intelligent agent technology, semantic Web services, peer-to-peer, and mobile computing for intelligent peer-to-peer mobile service environments.

In numerous meetings and seminars held during Autumn 2004, our partners have shown great appreciation to the first results of the SmartResource project and willingness for further co-operation. On the other hand, the team has understood deeper the needs of the funding companies and their strategies. Also, practical-oriented discussions and seminars with Nokia during that time have opened a real opportunity of future potential commercial cooperation. Cooperation with the IdeaMentoring project, which is focused on applications of Semantic Web technology in mobile industry, has brought a valuable experience in analysis of the SmartResource platform in a context of mobile resources.

Familiarization seminar with Minutor Oy has strengthened the belief in a strong demand on a Semantic Web technology in a close future. The research experience exchange with the group lead by Prof. Moncef Gabbouj and Prof. Karen Eguiazarian from Institute of Signal Processing (Tampere) has brought a clearer understanding of the SmartResource project challenge. For this purpose, the underlying SmartResource platform will be analyzed on use cases from multimedia analysis and semantic indexing.

Very important contact for further development and maturation of the SmartResource project results has become a large consortium of companies from paper industry related to the PaperIXI project[21]. It has become evident, that the SmartResource project has got several adjacent projects within Finland (MUKAUTUVA, ProServ, Mukautuva 2, SeMill, etc.) and it would be very advantageous for Finnish industry to coordinate these activities in a coherent manner.

Among the latest established promising contacts Wellness Dream Lab[22] can be remarked. Participation of the core project team members in a local Wellness seminar and meeting with the members of WDL will hopefully be a first step in deploying SmartResource activities in Wellness, which is very vital domain in Finland. Business expertise of the WDL members will bring new application areas to the scope of the SmartResource platform and, consequently, new business partners.

The following travels were intended for the widening and strengthening of the partner networks:

1 Kaykova O., Terziyan V., Cooperation with Kharkov’s Branch of the Industrial Ontologies Group, Travel to: Kharkov, Ukraine, June-July 2004. Reports: Machine Learning Web Service in Semantic Web, Modelling Peer-to-Peer Networks in Semantic web Environment, Web-Services for Management of Dynamic Web Resources, Ontology-Based Search in the Web.
2 Naumenko A., Kaykova O., Khriyenko O., Terziyan V., Visit to TeliaSonera, Travel to: Helsinki, Finland, September 2004.
3 Naumenko A., Kaykova O., Khriyenko O., Terziyan V., Visit to Metso Automation, Travel to: Tampere, Finland, September 2004.
4 Khriyenko O., Terziyan V., Visit to Minutor Oy and to Tampere University , Travel to: Tampere, Finland, October 2004.
5 Naumenko A., Khriyenko O., Terziyan V., Visit to Metso Automation, Travel to: Tampere, Finland, November 2004.
6 Kaykova O., Khriyenko O., Terziyan V., Visit to Tampere University, Travel to: Tampere, Finland, November 2004.
7 Khriyenko O., Terziyan V., Visit to TietoEnator, Travel to: Lahti, Finland, December 2004.

[21] PaperIXI Project Official Web Site, http://pim.vtt.fi/paperixi/.
[22] Official website of the Wellness Dream Lab (WDL): www.wdl.fi.

5 Utilization of the Project Results (Year 2004)

One of the general goals of the SmartResource project is a demonstration of the benefits and possibilities that the Semantic Web technology can potentially bring to Finnish industry. Trend within worldwide activities related to Semantic Web definitely shows that the technology has emerging growth of interest in both academia and business during quite small time interval. The stage of the technology (according to highly qualified expert evaluations[23]) is called now “From skepticism and curiosity to enthusiasm: People are now asking “How” questions as opposed to “Why” and “What””. Moreover prognoses[8] show that “semantic solutions, services and software markets will grow rapidly topping $60B by 2010”. Semantic technologies are building blocks of the next mega-wave of economic development, “distributed intelligence” and now is the time for semantic technology investments to strengthen portfolios[8].

Usability for Partners

The developed methodology of resource adaptation and its prototype implementation can be used by the funding partners in wide variety of tasks related to the problem of Enterprise Application Integration and to less global problems of legacy application adaptation. In addition, the proposed solution is compatible with the existing open W3C standard RDF, which provides rich semantic descriptions to resource data and hence enables resource maintenance by future specialized Intelligent Web Services or applications.

To apply the developed approach in the above mentioned tasks, the following steps of the technology maturation must be performed:

- Development of the library (centralized or decentralized storage) of reusable programming components according to the decomposition model recommended in GAF. In the development process both big and small software development companies can participate applying their unique expertise in specific component implementations and providing it over the world for a certain price. The great advantage for the component owners is that according to GAF, their components are meant to be discovered and linked to the specific adapter automatically thanks to the ontology of the components. TietoEnator is considered as a potential owner of such library, through which it could sell its huge experience in development of software components.
- Ontology of the software components must be engineered to automate the process of their search and acquisition. For this purpose, the existing types of the components must be systematized that requires involvement of a company or a consortium – a comprehensive player on a software market.
- Development of the ontology of templates, which contains a hierarchy of primitives from the canonical forms of different data models (XML, relational database, UML, etc.) and mappings between them. Decomposition of the existing data models into hierarchies of corresponding primitives requires expertise of many years in the domain of domain formalization using the concerned informational data models. For this reason, TietoEnator is considered as a potential owner of the realization of this approach. At least, a similar

[23] Davis M., The Business Value of Semantic Technology, In: *Proceedings of the Second Annual Semantic Technologies for E-Government Conference*, September 2004, McLean, Virginia, USA.

company using the described technology could provide tools of automated transformation between different data models, which are of current importance nowadays, too.

Communication providers can benefit from the available project results in the following way. GAF assumes adaptation and integration of the remote applications, too. This means that to assembly the necessary adapters, software components, which provide networked connectivity, must be available in the library/ontology of the components. Therefore, a software development companies would implement a specific components-connectors bound (configured) to a concrete communication provider (e.g. TeliaSonera), which will be placed in the library and will be further used by adapter purchasers. In the prototype implementation conventional information networked channels are used for connectivity between adapters, e-mail services are used to deliver diagnostics request to a human expert. The diagnostic request was also tested on a reach/availability from the mobile communicator and the diagnostic interface, too. In the implementation plans there is a sms-driven human expert notification that is also very beneficial functionally for communication providers.

Another opportunity of the results application is appropriate in the environment of heterogeneous communication operators, where interoperability is required for proper transaction transfer between operators and for integral representation of a state of communication system, or mobile user's state/condition. However, this needs additional analysis of the results in the mentioned context.

As an opportunity of direct application of the developed methodology and its prototype implementation in a full industrial scale pilot PaperIXI-Pro project is planned under supervision of Metso Automation. It concerns the transformation of PaperIXI models[24] made by large consortium of companies from paper industry to Semantic Web enabled metadata and ontology. One of the project goals consists in the adaptation of Paper Mill resources based on General Adaptation Framework that will result in a highly extensible architecture of the environment, compliant with Semantic Web standards and hence open for improvement towards automation.

Application Areas

The designed General Adaptation Framework and its implementation due to their original universality are supposed to find many applications in various domains, in which distributed heterogeneous resources exist and problems of interoperability and integration into dynamic open environments are emerging.

Besides its main application area – integration of industrial assets – more than once the project results were analyzed in a context of such application areas as Wellness (integration of human patients with embedded medical sensors, doctors-experts and medical web services), Ecology (natural environment with sensors, human experts in an environmental monitoring and Web Services for environmental diagnostics and prediction), Organizational management (staff/students with corresponding monitored organizational data, managers and automated systems for organizational diagnostics and management), Video Security Systems (objects under observation, monitoring experts and video/image automated processing tools).

Expert analysis of the project results and further brainstorming session have revealed their applicability in the Sports domain. Currently, many kinds of human wearable and implanted sensors exist and their integration could provide a comprehensive data set about a dynamics of a

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[24] PaperIXI Project Official Web Site, http://pim.vtt.fi/paperixi/ .

sportsman's state. The SmartResource General Adaptation Framework in this case could be applied for the adaptation of the heterogeneous sensors to a unified environment and their data – integrated to a comprehensive semantic data model. Data stored with these assumptions, can be available to sophisticated analytical software (even remote) or human experts, which are also supposed to be integrated to the same medium. As a concrete use case, we can consider a Bayesian classifier, which analyzing a track of ski-jumper state changes, gives a real-time instruction, e.g. about a right posture. The real-time instruction is very helpful for different sportsmen (swimmers, runners, water-jumpers, bodybuilders and so on) during their training; the corrections of the loading are made depending on the context (human condition, endured traumas, weather conditions, etc.). The output diagnosis of the decision making service can be not so response time demanding, like a generation of a monthly, yearly individual training schedules. The latter have been formalized, classified and specified rather well by now that makes them easy to represent in a form of ontology. Sportsmen training and instructing is a very relevant domain for automated learning services, which after the adaptation can learn on the unified sportsmen training data and act as an expert service in future.

Next application area covers various enterprise-wide knowledge management systems, research and development activities management systems, which integrate numerous heterogeneous companies' branches and coordinate their processes, providing an integral and unified representation interface. Enterprise Resources Planning (ERP) is a more concrete application area example: representation of the state of resources through the whole enterprise in the integral view is a current challenge of many large companies (e.g. Nokia) today (e.g. integration of reports in Excel, XML and different standard into one). Very often within one big company product or project data, which are distributed among many filial parts in heterogeneous formats/systems, must be transformed to a common format to enable determining the similarities and intersections between the products and projects.

Tender management (evaluation of subcontractors): such companies as Microsoft could utilize the project results for building a management system of the tender activities carried out among numerous heterogeneous 3rd party vendors. For this, the restrictions on specification of the required component/subsystem are formalized in a unified form (according to our solution it will be RDF/RSCDF) to enable automated semantic match with a corresponding descriptions of the 3rd party vendor solutions.

Statistical information gathering on the example of Automobile Industry. Manufacturers could accumulate statistical data integrating sensor/alarm data from embedded blocks inside car systems. Integration of heterogeneous data takes place here and its further analysis would help in planning production strategies.

6 Further Development

Semantic Web standards are not yet supporting semantic descriptions of resources with proactive behavior. However as our research shows [2], to enable effective and predictive maintenance of an industrial device in distributed and open environment, it will be necessary to have autonomous agent based monitoring over device state and condition and also support from remote diagnostics Web-Services. This means that the description of a device as a resource will require also the description of proactive behavior of autonomous condition monitoring applications (agents, services) towards effective and predictive maintenance of the device. For that we plan to develop in 2005 another extension of RDF, which is Resource Goal/Behavior Description Framework (RGBDF) to enable explicit specification of maintenance goals and possible actions towards faults monitoring, diagnostics and maintenance. Based on RSCDF and RGBDF and appropriate ontological support, we also plan to design RSCDF/RGBDF platforms for smart resources (devices, Web-services and human experts) equipped by adapters and agents for proactivity, and then to apply several scenarios of communication between the platforms towards learning Web-services based on device data and expert diagnostics to enable automated remote diagnostics of devices by Web-services.

Another challenge for Semantic Web is the contradiction between the concept of centralized and shared ontology to enable global interoperability and decentralized nature of today's global businesses. Actually the heterogeneity of ontologies is already the fact, which prevents inter-consortia interoperability. Discovering necessary resource or service in the network, which is heterogeneous on ontology level, requires specific solutions, among which semantic peer-to-peer resource discovery and context-sensitive ontologies can be an option. One of targets for our project will be implementation of such condition monitoring, remote diagnostics and predictive maintenance scenarios, which can be managed in decentralized P2P heterogeneous environment. The scenarios assume agent-based interoperation of multiple devices, multiple services and multiple experts, which allows discovery of necessary experts in P2P network, using their experiences to learn remote diagnostics Web-services, making online diagnostics of devices by integrating diagnoses from several services, learning models for a device diagnostics based on online data from several distributed samples of similar device, etc.

In general, the project's efforts strive to catalyze the evolution of RDF towards two directions: RSCDF (dynamics and context awareness) and RGBDF (proactivity and self-maintenance) and the ultimate result have to be a set of open standards that enable the GUN architecture (Figure 7).

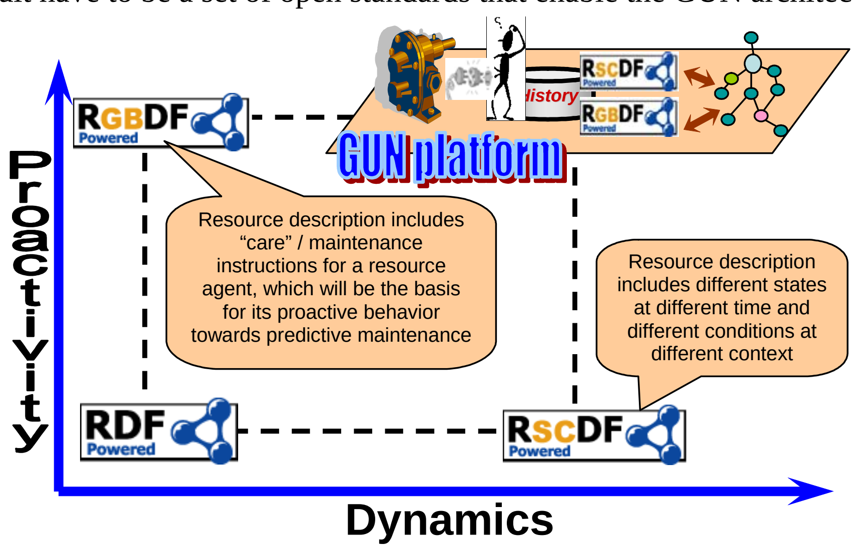

Figure 7 – Evolution of RDF towards GUN platforms through dynamics and proactivity

As it was mentioned above, the GUN environment is meant for online condition monitoring and predictive maintenance of various industrial resources. Utilization of RSCDF and RGBDF allows creation of agent-driven GUN platforms for each industrial resource, where all data related to monitoring, diagnostics and maintenance of the resource will be collected in the resource history ("lifeblog") and managed by the resource agent [22].

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