Ontology-Driven Knowledge Integration for Consumer-Focused Smart Companies

Track: Enterprise Resource Planning

Abstract

Modern trends of knowledge-dominated economy are from capital to intelligence intensive business environment and product push to a consumer pull management. This has resulted in designing consumer-focused companies. Knowledge integration (KI), based on synergistic use of knowledge from multiple sources must be relevant to company goals and processes. This is accomplished via design and development of knowledge at the system, facilitator, unit, and user levels. Ontology-driven KI approach is managed by translation and mapping between different ontologies. In this paper, models for KI based on ontology representations of information are presented.

Charu Chandra

Industrial and Manufacturing Systems
Engineering Department
University of Michigan-Dearborn
4901 Evergreen Road
Dearborn, MI 48128-1491
e-mail: charu@umich.edu

Alexander V. Smirnov

St. Petersburg Institute for Informatics
and Automation of
the Russian Academy of Sciences,
39, 14th Line, St.-Petersburg, 199178, Russia
e-mail: smir@mail.iias.spb.su

Introduction

As firms compete in global markets, they assume complex organizational forms, such as Supply Chain, Virtual Enterprise, Web-Based Enterprise, Production Network, e-Business, and e Manufacturing. Common traits of these organizations are (i) willingness to cooperate, (ii) global distributed product development and manufacturing, and (iii) high coordination and communication. These traits have led the trend of transformation from a *capital* to *intelligence* intensive business environment and from product-push to consumer-pull strategies. Figure 1 depicts this evolution from traditional forms of enterprise organization to the smart company (or "intelligent enterprise") (Olin et al., 1999).

Visions of the organization's future e-Business roles as a smart company (SmC) could be formulated as following (Cross, 2000):

- *Transparent* – SmCs will contain substantial amounts of information on capabilities, capacities, inventories, and plans that can be exchanged between tools, servers, and optimizing agents that will augment capabilities of their human masters.
- *Timely* – SmCs will be designed to meet a customer need exactly when the customer wants it.
- *Tuned* – Through collaboration and sharing of knowledge, the SmC will serve customer needs with a minimum of wasted effort or assets

Knowledge is a critical resource for any SmC's activity. System Information Integration deals with achieving common interface within and between various components at various levels of hierarchy in a system as well as different architectures and methodologies (Hirsch, 1995; Sousa et al, 1999) using distributed artificial intelligence and intelligent agents (Fisher et al., 1996;

Gasser, 1991; Jennings et al., 1996; Jennings, 1994; Lesser, 1999; Sandholm, 1998; Smirnov, 1999; Wooldridge and Jennings, 1995). Knowledge modeling and ontologies are defined to describe unique system descriptions that are relevant to specific application domains (Fikes and Farquhar, 1999; Gruber, 1995; Gruninger, 1997; Smirnov and Chandra, 2000).

As a result, there is a need to develop a new cost-effective approach to rapid knowledge integration for SmC business environment used for global awareness, dynamic planning and global information exchange that is based on the synergistic use of knowledge from multiple sources.

Consumer-Focused Smart Company Concept

Smart Company (SmC) is a temporal cooperation of independent knowledge-source units (enterprises, institutions or individuals) which provide a service on the basis of shared skills, information technologies and resources. Figure 2 depicts a SmC template. Its components are a set of technology and associated resources (A, B, C) available to a unit(s) I, belonging to a SmC at time intervals (T_j, T_m). Units of a SmC may share common technology and associated resources through coalition agreement(s). Sharing is facilitated through systems that are connected via common objectives and policies for their implementation.

SmC deploy B2C, B2B-S and B2B-G technologies that impact the market substantially by driving costs down through standardized, networking technology, and creation of entirely new enterprises and relationships by real-time interconnection with consumers. These technologies have a strategic objective of managing consumer’s needs by way of a proactive "consumer pull" as against the traditional "product push" strategy. To accomplish this objective, heavy emphasis is placed on customer relationship management, which involves identifying *goals*, and then to develop marketing programs aimed directly at fulfilling these goals. As a result, traditional enterprises mutate into more consumer-focused smart company.

Ontology-Driven Knowledge Integration as a Knowledge Management Technology

Data and Knowledge Management offers intelligent support for the e-management approach and are critical in realizing competitive advantage for networking organizations. Knowledge is the key to managing collaborative activities within and between SmCs. Therefore, knowledge must be relevant to overall business goals and processes and be accessible in the right form and at the right time. This is accomplished via design and development of Knowledge Management at following knowledge levels:

- System knowledge - describes rules for integration between units of SmC, and its management and maintenance.
- Facilitator knowledge - describes rules for distribution of knowledge and identification of access level in sharing data and knowledge base.
- Unit knowledge - describes reusable methods, techniques and solutions for problem solving at the unit level.

- User knowledge - describes knowledge related to individualized special skills of a user at the problem domain level.

An important requirement for collaborative system is the ability to capture knowledge from multiple domains and store it in a form that facilitates reuse and sharing (Sousa et al., 1999).

The methodology suggested in this paper is limited to designing SmC configurations for "product-process-resource" (PPR) systems and focused by utilizing *reusable knowledge* through ontological descriptions. It is based on GERAM, the Generalized Enterprise Reference Architecture and Methodology (ISO TC 184/SC 5/WG 1, 1997) at the domain level; and MES (MESA, 1998), MEIP (MEIP, 1999), NIIIP (NIIIP, 1994) and WFM (WFM, 1996) methodologies at the application level.

Applying above methodologies enable forming the conceptual model of the SmC system. This is accomplished by knowledge modeling its product, process, and resource components to satisfy manufacturing constraints in its environment. The implementation of e-management approach is based on the shared information environment that supports the PPR model used for integration and co-ordination of user's (unit's) activity. This model is studied from various viewpoints of user (unit) groups. Figure 3 depicts structure of external description for SmC's unit template.

Reusable knowledge management is a concept of knowledge management to organize "knowledge clusters" by their inherently common characteristics as observed in various problem domains and utilizing these as templates to describe unique conceptual models of an enterprise or its units / components.

Ontology is a form of knowledge representation applied in various domains. A FIPA definition of Ontology is as follows (FIPA, 1998):

- Ontology is an *explicit specification* of the structure of the certain *domain*.
- Ontology includes *a vocabulary* (i.e. a list of logical constants and predicate symbols) for referring to the subject area, and *a set of* logical statements expressing the *constraints* existing *in the domain* and restricting the interpretation of the vocabulary.
- Ontology provide a vocabulary for representing and communicating *knowledge* about some topic and *a set of relationships and properties* that hold for the *entities* denoted by that vocabulary.

Ontology is useful in creating unique models of a SmC by developing knowledge bases specific to various e-management problem domains. Ontologies are managed by translation and mapping between different types of entities and attributes. Ontological translation of a SmC, such as a virtual supply chain is necessary because networks are multi-ontology classes of entities. Various ontologies for an entity describe its unique characteristics in context with the relationship acquired for a specific purpose or problem. Each user works with its own ontology-based knowledge domain model. Major object hierarchy for SmC unit's template, are shown in Figure 4.

Ontology design is based on an ontology hierarchy. The top-level ontology is the "shared ontology" for domain independent representation of the problem set. This type of ontology is needed to describe an abstract model using common knowledge model representation. The lower-level ontology is an "application ontology", and is a combination of the "domain specific ontology" and the "problem-specific ontology". This type of ontology is needed to describe special knowledge about an application or a problem for unit and user. The top-level ontology is oriented for dynamic constraints network, while the lower-level ontology is for ontology-based constraints network (Smirnov and Chandra, 2000).

Knowledge management tools support the conversion of PPR-model, from ontology to ontology. An abstract PPR-model is based on the concept of ontology-based dynamic constraint networks.

The above Ontology Management approach is based on two mechanisms (Smirnov and Chandra, 2000): (1) Object class inheritance mechanism supported by inheritance of class ontologies (attributes inheritance) and by inheritance of constraints on class attribute values, and (2) Constraint inheritance mechanism for inter-ontology conversion supported by constraint inheritance for general model (constraints strengthening for “top-down” or “begin-end” processes).

Information Framework of Smart Company: Major Requirements and Technologies

Major functions of knowledge integration for a SmC could be determined as (i) communication; (ii) co-ordination, (iii) collaboration, and (iv) common or shared memory. This set of functions can be realized by using following technologies:

- direct knowledge entry by domain experts (based on GUI and object-oriented template library),
- knowledge repository parallel development by distributed teams (based on automatic change propagation and conflict negotiation),
- knowledge sharing by knowledge maps (based on reusable ontology theory and distributed constraint satisfaction technology), and
- distributed uncertain knowledge management (based on object-oriented fuzzy dynamic constraint networks as a shared ontology paradigm).

The implementation of the basic principle of cooperation in the SmC is based on distribution of procedures between different units / users (or different agents) concurrently in the common knowledge space. It is, therefore, natural to represent configuration management knowledge as a set of interacting autonomous agents in a multi agent environment. Agent is an entity that captures behavioral characteristics of the problem for a specific process or activity. Intelligent agent is an autonomous entity that can navigate heterogeneous computing environment and can, either alone or working with other agents, achieve some goals (Fischer et al., 1996).

Figure 5 illustrates the general structure of a multi-agent system for e-management of a SmC that would allow distributed application domain knowledge description on dynamic constraint networks and cooperative decision making by means of local, delegated and shared problem solving. Local problem is a domain specific problem that is applied for one agent (unit or user) and may have a unique solution. The delegated problem has two types of agents. One agent type is autonomous which may generate several solutions, while the other agent type acts as an arbiter that selects Pareto-optimal solution(s) from the solution set. The shared problem is common among agents (units or users) and may have a common solution.

An illustration of the information support architecture for a SmC is offered in Figure 6. The agent classification for this approach is described below.

- *Problem solving agent* (PSA) is oriented for a unique class of e-management problem that is applied for problem solving of different e-management processes described above. An example of a PSA, based on constraint satisfaction and propagation techniques is described in (Smirnov and Sheremetov, 1998).
- *System information agent* (SIA) is oriented for consistency checking, controls of constraints for integration between units of a SmC and its management and maintenance.
- *Facilitator agent* (FA) is oriented for distribution of knowledge and identification of access level in sharing data and knowledge base. It has three major components - (i) conventional reusable knowledge management techniques, (ii) common knowledge map that describes distribution of knowledge sources for a SmC, and (iii) ontology management.
- *Unit information agent* (UIA) is oriented towards application of reusable methods, techniques and solutions for problem solving at the unit level. It also includes the *user information agent*.
- *Object-relational adapter* that maps relational models to object-oriented data models and vice-versa.

In order to solve a problem, the PSA through the FA deploys reusable knowledge management to communicate with shared object-oriented data model (based on template libraries and repositories) in SIA and ontology-based / user-oriented knowledge domain models of UIA. Unit knowledge domain model describes the environment at the unit level, such as objectives, constraints and resources. FA utilizes the shared object-oriented data model for consistency checks of unit's data and knowledge for problem solving. FA communicates through object-relational adapter with Internet-based distributed relational databases that describe the dynamic environment of a SmC.

Conclusions

A *General Information Framework of Smart Company* utilizing above methodologies offers an integrated approach to knowledge integration by ontology-driven techniques for customer responsive systems. Implementation of the methodology would fundamentally change global business information environment by enabling constructive collaboration among its knowledge-source network units to achieve shared objectives. This approach satisfies the need for increasingly complex business relationships and underlying technology infrastructure that companies are implementing to support their global strategies.

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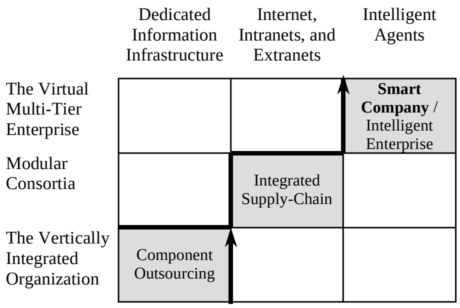

Figure 1. Enterprise Organization Form Evolution (Olin et al., 1999)

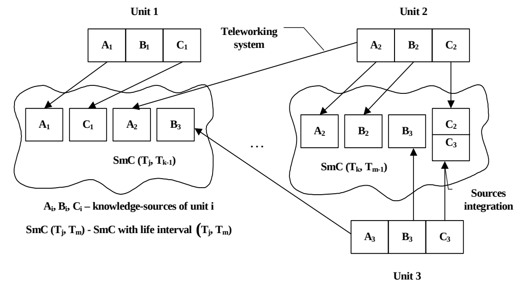

Figure 2. Smart Company Concept

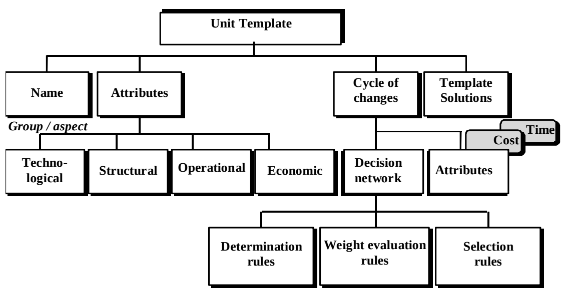

Figure 3. Structure of Smart Company Unit Template

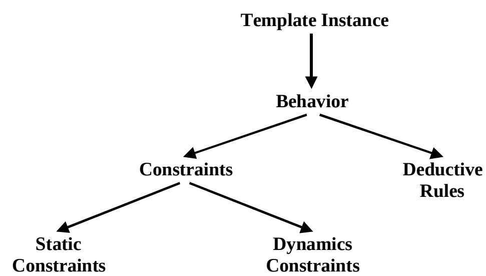

Figure 4. Hierarchy of Objects

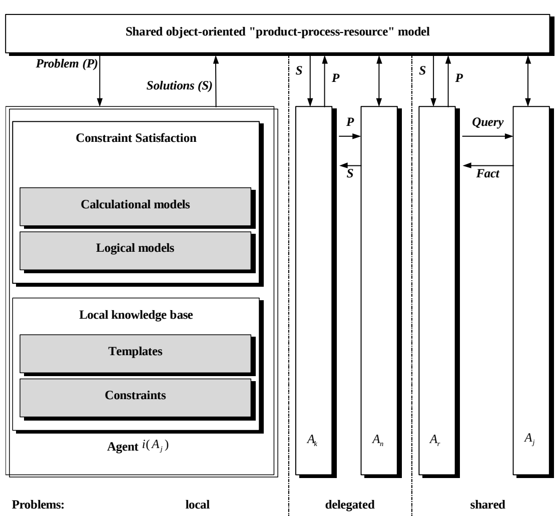

Figure 5. General structure of multi-agent system

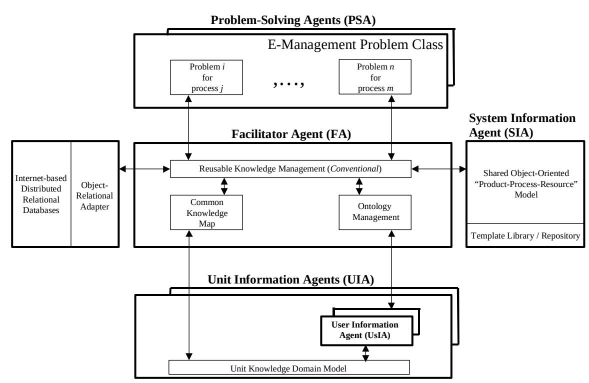

Figure 6. General framework for e-management information support of a smart company