Supporting Collaboration through Semantic-based Workflow and Constraint Solving

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Introduction

We describe a collaborative problem solving architecture driven by semantic based workflow orchestration and constraint solving. These technologies are based on shared ontologies that allow two systems of very different natures to communicate, perform specialised tasks and achieve common goals. We give an account of our approach for the workflow assisted collaboration with a specialised knowledge agent. In this case, a system with constraint solving capabilities. We found that systems built with Semantic Web based technologies are useful for collaboration and are easier to add additional specialised capabilities. However, much care must be exercised before correct semantics may be exchanged and collaborations occur smoothly.

Keywords: Virtual Organisation, Constraint Satisfaction, Business Process Modelling, Knowledge Modelling, IDEF3, Ontology, NIST PSL, Semantic Web, Product Synthesis.

Background Technologies

Formal Business Process Modelling Language (FBPML): FBPML is an extension of a merging of two recognised process modelling standards: IDEF3 and NIST PSL (the Process Specification Language). FBPML combines these two methods by adapting IDEF3's rich visual and modelling methods and mapping those modelling concepts to the formal semantics and theories of PSL. In addition, based on the design rationale from a business model, FBPML provides comprehensive process execution logic that was neither included in IDEF3 nor PSL. This business-decision directed execution logic was described and implemented using a First Order Logic representation. Process descriptions written using FBPML are immediately enactable using its workflow system. Data manipulated by the FBPML processes is described in the integrated data language (FBPML-DL) that may be used in its own right. The user may use FBPML-DL to describe their data models and instances. Descriptions of FBPML and FBPML-DL are automatically translated to semantic-rich OWL-S and OWL descriptions that facilitate interoperability with other systems that use those languages on the Semantic Web. [1] gives more details about this work.

As FBPML and FBPML-DL allow the modeller to express processes and constraints on data, they are also translated to an intermediate language, CIF, to facility the communication with the KRAFT system. Constraint Interchange Format (CIF) is RDF-based and its structure is defined in RDF Schema. One satisfying feature of this constraint interchange format is that the (name) tags used make a clean separation between information about logical formulae with the usual connectives, and information about Expressions denoting objects in the data model. Effectively CIF preserves a layer of rich semantic information while providing the processing convenience of RDF [2].

KRAFT (Knowledge Reuse And Fusion/Transformation) is a distributed agent-based information system that emphasizes the use of mobile constraint knowledge to dynamically compose problem instances and tailor them to suit problem solvers. It uses constraints as a uniform formalism to represent domain-specific knowledge, partially solved solutions and intermediate results. The KRAFT architecture contains "wrappers" that map constraints and data from heterogeneous resources onto a common shared ontology, named integration schema. When expressed against a KRAFT domain-wide integration schema, these mobile constraints become self-contained abstract knowledge objects that can move within a KRAFT-aware agent network [2].

I-X [3] includes a set of tools within a rich systems integration architecture. It visualises, takes decisions and tracks process executions at run-time. Several communication strategies have also been offered to talk with heterogeneous systems of different requirements. These communication methods are relatively flexible and may be modified at run time. Various work has been proposed and carried out in different application areas that will seek to create generic approaches (I-Tools) for the various types of tasks in which users may engage.

Architecture

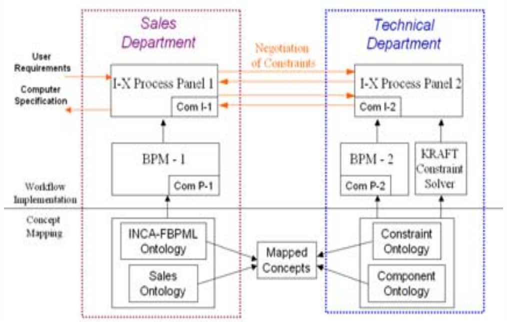

Figure 1. Conceptual Architecture of Workflow Collaboration

Our work is illustrated in a simple example. Consider solving a Personal Computer (PC) configuration problem in a virtual organisation that builds PCs based on customer's individual requirements. Different departments in the organisation are located dispersedly; each may have certain level of overlapping of domain knowledge and operations with another but may also has specific non-overlapping local expertise -- that may be data and/or work procedures related. They need to collaborate with each other to achieve common organisational goals - i.e. to build customer-tailored PCs. In this example, a sales and a technical departments are involved. Each of the sales and technical department has its own internal process models that govern its operations and may decide to change those operations at run-time, if so desired. Each process model also includes a set of communication processes that is responsible for the interaction with other internal departments or external organisations.

Figure 1 gives an overview of a conceptual architecture that enables collaborative problem solving using semantic-based workflow techniques. The horizontal line that goes through the two departments and divides them in two parts has been used to distinguish the two phases of implementation of workflow management and the underlying conceptual mapping that enables this implementation. Each of the three main technologies involved, FBPML, I-X and KRAFT, is supported by their own underlying methodologies and systems. In this example, two I-X process panels were used because their facilities suit our requirements, although other workflow systems offering similar functions may be used instead. I-X process panels manage and monitor workflow execution via process-aware (user) interfaces. The user may choose to alter processes at run-time, if so desired. I-X Process Panels also provide an open communication mechanism to accommodate potentially different interaction requirements. In this example we have chosen to use KRAFT system as our knowledge agent, due to its rich ability in semantics manipulation and extensive problem solving power. Other similar and/or specialised knowledge agents may be added to this framework if offering appropriate facilities.

As I-X is based on the conceptual framework of <I-N-C-A>, FBPML is firstly mapped to <I-N-C-A>. This result is indicated in the *INCA-FBPML* ontology in Figure 1. This enables FBPML business process models (BPM) to be translated and managed through I-X process panels. In addition, the *Constraint Ontology* that underpins the KRAFT system is mapped to the INCA-FBPML ontology that allows concept mapping between FBPML, I-X and KRAFT systems. During the process of concept mapping, patterns needed to produce correspondence between different systems during operations have also been identified and used to form the application context of the communication language. The communication processes within each department, indicated by *Com P-i*, are a recognised type of process in FBPML and are clearly labelled in its models. These communication processes are implemented in separate modules in this example to facilitate the communication.

Workflow Collaboration with Constraint Solving Capabilities

Figure 2. Workflow enactment through I-X process panels

Figure 2 shows the two I-X Process Panels used to instantiate FBPML processes. They assist FBPML dynamic task execution, decision making, communication and collaboration with the KRAFT System. The sales and technical units and their processes are each represented by the 'Edinburgh' and 'Aberdeen' panels. In this example, the sales department (Edinburgh) needs to resolve a technical task that is a part of its internal "Selling Customised PC" process. It therefore passes this task to its technical counter-part in Aberdeen. As this problem may be resolved using Constraint Satisfaction Problem (CSP) solving technologies, the relevant processes in Aberdeen decide to use a CSP solver, the KRAFT system. Provided with a problem description generated by the Edinburgh site, the KRAFT system returns found (partial) solutions back to the awaiting process in the Aberdeen I-X panel, which forwards them to Edinburgh. If a satisfactory solution was not found, the sales department may decide to negotiate through follow-up enquiries.

This experiment demonstrates process and workflow technologies that were implemented based on an open distributed agent architecture. This scenario mimics real-life situations where centres are often geographically dispersed and each operates at a certain degree of autonomy. This distributed structure also allows collaboration through semantic rich representations enabling an organisation to be agile in reaction to rapid changes. Specialised technologies and local autonomy, however, introduce disparity and a gap of knowledge that require bridging if collaboration is required. The mapping of the shared ontologies provides a rich and sound foundation towards correct exchange of semantics and facilitates smoother collaborative process execution.

Conclusion

Typically, the knowledge and operations within a virtual organisation are divided in different departments that are complementary with each other. Those units must collaborate to achieve common organisational goals. Distributed workflow systems that loose-couple with specialised knowledge agents provide a suitable framework towards this aim.

In this paper, we demonstrated such a collaboration based on different technologies: a workflow based (I-X and FBPML) and constraint solving systems (KRAFT). Our work has been successful in the defined task, but mapping effort was needed in the earlier stages of the project as not all modelling concepts can be easily mapped, so practical solutions must be found. This echoes the complexity of knowledge sharing and interoperability problems between any two or more potentially very different but partially overlapping systems that are known in the knowledge systems community. One of the ultimate goals of the Semantic Web is to provide ways of connecting any number of arbitrary systems to achieve collaborative tasks using semantically rich knowledge. This work is a step towards this goal.

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