Intelligent Support for Enterprise Modelling

Jussi Stader and Peter Jarvis

AIAI-TR-220
January 1998

Submitted to The 13th biennial European Conference on Artificial Intelligence (ECAI-98), Brighton Centre, Brighton, UK, 23-28 August 1998.

Artificial Intelligence Applications Institute
University of Edinburgh
80 South Bridge
Edinburgh EH1 1HN
United Kingdom

Abstract

Enterprise modelling - integrating models of all pertinent aspects of an enterprise - is essential to the management of change in organisations. An integrated view of an organisation provides insight into what aspects may be changed, how they may be changed, and what the overall effect of specific changes will be.

AIAI at the University of Edinburgh has an ongoing research programme which focuses on the use AI techniques to cover the requirements of enterprise modelling and the tools to support it. The AI techniques used in AIAI's programme range from knowledge representation, ontologies and process modelling techniques to visualisation techniques, intelligent workflow and coordination technology. The techniques are combined in an integrated toolset delivered on an agent-based architecture.

Part of AIAI's programme is the Enterprise project which has been instrumental in determining the requirements for enterprise modelling and in the development of an integrated toolset to support it. The results of the Enterprise project show that when combined with task management support, enterprise models may directly control the operation of an organisation. Based on the results of the Enterprise project, AIAI's TBPM project currently addresses coordination issues of enterprise modelling support.

In this paper, we first describe the requirements for enterprise modelling and enactment in general. We then discuss the Enterprise Toolset which was designed and was implemented to address these requirements. Finally, we evaluate the toolset and describe extensions that are currently being undertaken.

1 INTRODUCTION

Enterprise modelling - integrating models of all pertinent aspects of an enterprise - is essential to the management of change in organisations.In brief, the overall goal of enterprise modelling is to take an enterprise-wide view of an organisation, integrating all information that is available about the organisation. This enterprise-wide view can then be used as a basis for taking decisions [3]. Such an integrated view of an organisation provides insight into what aspects may be changed, how they may be changed, and what the overall effect of specific changes will be.

AIAI at the University of Edinburgh is aiming to provide an integrated set of computer-based tools to improve on the current level of support for enterprise modelling. This paper outlines the kind of support that is required and describes the approach that AIAI is taking in developing such support.

2 REQUIREMENTS OF ENTERPRISE MODELLING

In order to achieve, use, and maintain an enterprise-wide view of an organisation strong facilities for integration, communication, flexibility, and support are required. These can be detailed as follows.

- Integration must be achieved for three purposes: to relate information for obtaining different views of the enterprise; to relate tasks to the tools that support them; and to establish connections between the tools themselves.
- Communication must be achieved on different levels: between people in order to ensure that enterprise models are shared within an organisation; between people to ensure that they can contribute to common tasks; between tasks so that information can be used where it is relevant; and between the tools used to perform the tasks so that relevant data can be passed between them.
- Flexibility is important to allow an organisation to adapt to changes in its environment, its processes, and the availability of tools. It is also important to allow flexibility in the enactment of processes to ensure that people's time is used as effectively as possible, giving people the choice of what to do and when to do it.
- Support must be provided to take care of technical details and to ensure that the given flexibility does not result in confusion and that processes are carried out effectively.

Bearing these four issues in mind, AIAI has established an approach to provide effective support for enterprise modelling. The approach addresses the need for strong modelling facilities which are the basis for enterprise modelling support. In order to make full use of the models, task management support and the integration of tools are required. The requirements in these three areas (modelling, task management, and integration of tools) are described in detail below.

2.1 Requirements for modelling

The first and foremost requirement for enterprise modelling is a framework for the models themselves which determines what information is captured and how that information is expressed. There are two basic areas of concern: what do we want to say about an organisation (i.e. what kinds of models to we want to generate) and what terms do we use to say it (i.e. what is our common ontology which we use to express ourselves).

2.1.1 Ontology

One of the key problems in communication is to ensure that there is agreement about the meaning of terms. Different parts of an organisation often use different terminology which can lead to conflicts and ambiguity. To resolve such issues, a standard terminology is required. An ontology provides such a standard terminology. For an introduction to the field of ontologies and their development and use see [11]. Committing to this ontology has the advantage that terms are used consistently and unambiguously throughout the organisation. The ontology thus provides the basis for communication between agents, whether they are human agents or software tools.

For enterprise modelling purposes, an ontology should aim to cover all specific terms that are used within the organisation as well as more general terms about organisations (e.g. market, sales, revenue, etc.) and generic terms (e.g. process, resource, capability, etc.). To obtain full benefit from an ontology it is important that terms are defined in their context and that specific terms are grounded in the more generic terms defined. AI techniques for knowledge representation are well suited to define and formalise the terms and the relationships between them.

It is not always possible or desirable for everybody to share the same ontology. Differences in terminology usually develop for a reason and removing these differences may lead to difficulties in expressing information and thus hinder processes for the sake of standardisation. Ontologies provide an approach that allows for such differences. Defining several ontologies and explicitly specifying their differences makes it possible to translate between different sets of terminology and support communication.

2.1.2 Models

There are many different aspects of an organisation and its environment which should be covered in enterprise modelling. These include:

- the organisational structure
- the roles and responsibilities held by people within the organisation
- the processes that are carried out within an organisation
- the information that is used within an organisation
- the flow of information within an organisation
- the capabilities required or available within the organisation
- the artifacts that are produced by an organisation
- the market in which the organisation operates
- etc.

For many of these aspects, AI techniques have been developed that can be used to capture the information in the form of models and to visualise the captured information. These models and their visualisations can then be used for documentation and communication purposes. They can thus be used as a basis for standards or for describing best practice.

In enterprise modelling a variety of modelling techniques are required in order to provide effective support. Different problems may require different modelling approaches. For example, many problems can be described well using process modelling techniques. Other more information-oriented problems are difficult to describe in a process-oriented way and if process models of such problems are generated they are of limited use. This means that a variety of modelling techniques should be supported so that each can be used to describe the aspect of the enterprise for which it is best suited.

Each of the modelling techniques required should be based on a formalism grounded in the ontology which defines the models that are created so that the content and meaning of the resulting models is defined. Support for each of the modelling techniques should include software tools that are used to capture the models in the most suitable representation, and visualisation techniques that are used for viewing and sharing the information contained in the models. Furthermore, each type of model that is captured should be used to its full potential, including active support of organisation's operations.

AI techniques for capturing, representing, and visualising different types of models are well established, as is the use of such models as the basis for decision support and other knowledge-based systems. In addition, the approach of multi-perspective modelling provides techniques for using different types models and their representations and for establishing relationships between them so that they can be integrated.

2.2 Requirements for task management

Capturing information in models is not the only aim in enterprise modelling. The real objective is to obtain an enterprise-wide view of an organisation and to develop an understanding of how the organisation operates. For this purpose it is important to support the use of models in the actual operation of the company, rather than just using the models as documentation. The tasks that people perform in the organisation should be reflected in the models, and the models should be used directly to support the tasks as they are being carried out. In this task management process, alternatives should be available for inspection and suitable support in the form of software tools should be made available. In addition, information about the progress of tasks should be provided for monitoring purposes. Intelligent workflow techniques can address such issues.

Task management should also take into account how people work together to achieve an overall task. Many tasks are collaborative efforts between individuals whose interactions may be complex. Support for such collaborative work should include support for communication and coordination of tasks. Advances in the areas of intelligent workflow, computer supported cooperative working, coordination technology and agent-based systems can be taken advantage of to address these issues.

Task management should build on and pull together all the other efforts of enterprise modelling, putting the definitions, models, and techniques to use. The requirements for task management are to take advantage of integration and communication facilities in order to provide the support required, and to ensure that the flexibility achieved through integration does not result in confusion.

2.3 Requirements for the integration of tools

In most organisations there is a variety of software tools in use, supporting a variety of tasks. However, in most cases the tools are stand-alone solutions to problems and are at best integrated only with only a limited number of other tools. This means that information cannot be passed between tools and the benefit and support of the tools is not as readily available as it should be. The integration of available tools is an important aspect of enterprise modelling, in some cases because the tools can directly support modelling activities, and in other cases because the tools support some of the operations of the organisation.

In addition to integrating tools that are in use already, we want to be able to take advantage of future developments, integrating tools as they become available. The requirement is therefore for a flexible framework of integration that can handle current systems and new developments.

The field of AI has long been concerned with the integration of software tools and the area of agent-based systems in particular provides a suitable approach for the kind of integration required.

3 A TOOLSET FOR ENTERPRISE MODELLING

Many of the requirements in the previous section have been addressed during the Enterprise project. The Enterprise project was the UK government's major initiative to promote the use of knowledge- based systems in enterprise modelling, supported under the DTI's Intelligent Systems Integration Programme, Project Number 8032. AIAI lead the project and the partners were IBM, Lloyd's Register, Logica and Unilever.

In the Enterprise project we decided to concentrate on the use of process models as a basic support for enterprise modelling. Process models provide a process-oriented view which can be enacted in a running system. We developed a "Procedure Builder" to support the capture of process models.

We decided to support the integration of available tools with as little change to the tools as possible. The framework for this is an agent-based architecture together with a library to support the addition of tools to the system, the "Agent Toolkit". This allows for tools to be used in a plug-and-play style. New tools can be added as they become available and old tools can be phased out as they become obsolete. It is possible for human agents to be involved in the system in a similar way to software agents.

As well as providing support for integrating tools, we provide support for enactment of processes. The "Task Manager" integrates tools with process models and provides an agenda-style support for enactment. During the enactment progress is shown and alternative lines of action are managed. Where possible, the task manager provides support for recovering from failures when a task could not be performed properly.

In order to achieve this high level of integration and to allow all components to communicate effectively, there must be an agreement about the way in which terms are used. We have developed an Enterprise Ontology for this purpose. The "Enterprise Ontology" covers terms that are required for talking about processes, including information and capabilities. It also covers terms that are useful when talking about business environments.

The system we developed during the Enterprise project is the Enterprise Toolset. In summary, the components of the Enterprise Toolset are:

- the Procedure Builder for capturing process models,
- the Agent Toolkit for agent development,
- the Task Manager for integration, visualisation, and enactment support, and
- the Enterprise Ontology for communication,

These components combine with a flexible set of integrated, off-the-shelf tools in the working system. Figure 1 shows the general architecture of the Enterprise Toolset; the components are described below. In the figure, Toolset components are shown as rectangles, information like models and data is shown in diamonds and users (different roles) are shown as ovals. Arrows show information flow. For clarity, the Agent Toolkit has been omitted from the diagram.

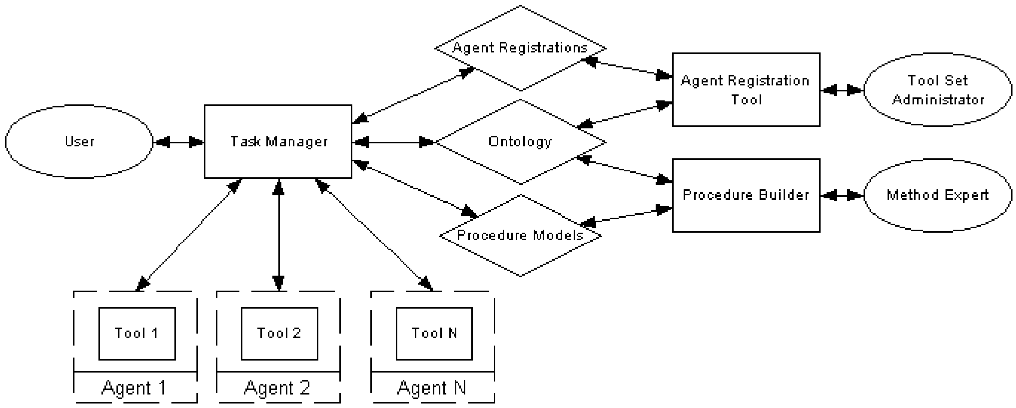

Figure 1: Enterprise Toolset Architecture

Enterprise Ontology We require an effective communication mechanism to achieve integration of a wide variety of tools, both new and old. Independently developed tools are likely to use different terminology which can lead to conflicts and ambiguity when the tools are integrated. To resolve such issues, we developed the Enterprise Ontology[10].

The Enterprise Ontology is a set of terms frequently used in enterprises, each carefully defined to conform as best as possible to common usage. We have concentrated on the areas of organisation, strategy, activities and processes, and marketing. We did not try to define all terms that are likely to be required; the terms we defined are ones that we expect to be generally useful. Every organisation will have their own set of terms that they use, so the ontology can be extended to suit the specific needs of the organisation.

The ontology is organised into a hierarchical set of terms, including relationships between terms. The terms and structure are formalised so that they can be used by software systems. The ontology thus provides the basis for communication between agents, whether they are human or software agents. A key part of the ontology is the hierarchy of capabilities which is used as a basis for task management (see below).

Procedure Builder The Procedure Builder is a graphical tool for describing and recording business process models. It allows the user to build process diagrams using the notation of Process Flow Networks (PFNs) as specified in the IDEF3 Process Description Capture Method [7]. The Procedure Builder also allows users to specify information which is specific to the needs of task management, in particular the capabilities required to perform a process and input and output specifications of the process. The Procedure Builder ensures that the Enterprise Ontology is used for all specifications, in particular those that are used for task management.

To represent the process information we developed a process modelling language which provides a well-defined framework. In developing the language we took account of emerging standards, such as PIF (Process Interchange Format [6]) and WAPI (the Workflow Application Programmer's Interface developed by the Workflow Management Coalition [12]). The output from the Procedure Builder can be exported for use directly by the Task Manager for process enactment.

Agent Toolkit For the agent-based architecture of the Enterprise Toolset we investigated a variety of externally available solutions and concluded, at that time (late 1994), that none of them was mature enough to use as-is or met all our requirements. We therefore developed our own agent-based solution which is supported by the Agent Toolkit.

The agent-based architecture of the Enterprise Toolset allows the Task Manager to use software tools (e.g. word processors, legacy bespoke systems, etc.) to support processes through intelligent agent technology. In effect, the Task Manager provides a layer of control above the agent-based architecture so that the user's tasks can guide the use of agents. Communication between the Task Manager and agents centres around the registering of tool capabilities, instruction for performing tasks, and the results of performing tasks.

The Agent Toolkit provides support for "agentification" of tools. It supports a "wrapper" approach to agentification of existing software tools because the technique does not require access to a tool's source code[5].

The Agent Toolkit provides a set of Tool Interface Modules (TIM), Controllers, and a Router to assist in the process. A TIM makes the "physical" connection between the existing software and the agentification wrapper. Connection mechanisms available are files, pipes, DDE etc. The Agent Toolkit provides a TIM with standard facilities required by each mechanism. The Router connects the wrapper to the agent network. It is responsible for both passing and accepting messages to and from the network respectively. The Controller module represents specific code to specifically make a tool an agent. In this module the agent programmer must define how outputs of the tool (via the TIM) are to be handled, processed and passed to the router for communication with the Task Manager. The same definitions must be provided for messages received from the Task Manager.

Keeping in line with emerging standards, the agent communication language we support is KQML (Knowledge Query Manipulation Language [2]) and messages are expressed using KIF (Knowledge Interchange Format [4]) and the Enterprise Ontology (see below).

There is also an Agent Registration Tool to make agents (software or human) available to the Enterprise Toolset, specifying details about the agent, such as its capabilities. The agent-based architecture allows agents to be added to and removed from the overall Toolset in a plug-and-play style.

Task Manager The Task Manager is the interface between the user and the Enterprise Toolset. It directly supports the user in performing their current tasks. The Task Manager uses techniques of intelligent workflow to plan user tasks and the use of agents. Information about tasks is available from the process models specified through the Procedure Builder, and information about agents becomes available when agents are registered. Appropriate agents are identified at run-time at the last possible moment, so that the most suitable agent can be identified, taking into account which agents are available at that time. Suitability of agent is assessed according to the capabilities required for the task and the capabilities of agents. Using the ontology of capabilities, the Task Manager can reason about how capabilities relate to each other and which available capabilities match the requirements most closely.

The Task Manager also handles outputs generated by tasks. It stores such output information and it can pass it on to other tasks that require the information. Since the information is expressed in terms of the Enterprise Ontology, the Task Manager has some knowledge about what the information means, how it can be used, and how it relates to other information. This knowledge can be used to provide more intelligent support for information management.

The Task Manager monitors the progress of a task's enactment, keeping track of which tasks are currently active, which have been completed, etc. This progress can be visualised in different ways, the visualisation being supported by the process diagrams captured with the Procedure Builder. The amount of support that the Task Manager gives to the user is flexible and can be adjusted by the user. Advice on what to do next is available on the basis of which tasks are ready to be executed and which have recently been completed. The Task Manager can also help the user to recover from failures, determining alternative routes of action.

The Task Manager effectively puts an extra layer of control on top of the agent services. It coordinates the use of agents at the level of the user's tasks and lets the user participate in this coordination, according to the tasks in which the user is engaged.

3.1 Evaluation of the Enterprise project

The approach taken during the Enterprise project is proving to be appropriate. The Enterprise Toolset has been implemented and a demonstrator has been built to illustrate the advances made. The results of the project show that an integrated toolset can provide suitable support for enterprise modelling and thus support for the management of change.

The advances in the three main areas of work are:

- The Procedure Builder is an advance on earlier software for capturing processes, in that it is able to capture and export models in a form that can be enacted.

- The Task Manager provides the overall integration between process models and tools, passing information between tasks. It is unlike other agent systems in that it puts an extra layer of control on top of the agent services. This lets the user participate in the coordination of agents, according to the tasks in which the user is engaged. It thus provides the user with a better chance to make effective use of the flexibility provided by agent-based technology. The Task Manager is different from most workflow support systems in that it provides flexible and intelligent support on the level of the user's tasks and intentions rather than passing through set sequences of events.

- Developing the Enterprise Ontology was not easy. However, we are pleased with the final result and during the project we developed a method for building ontologies [11, 9]. The Enterprise ontology is distinct from other ontologies for enterprise information in that it attempts broad coverage to include most terms important to enterprises rather than limited areas. It also exists in the form of a comprehensive, carefully prepared natural language glossary and in a formal language. Most other ontologies must be gleaned from various scattered papers, or exist mainly in formal languages and are thus inaccessible to non-technical readers.

The major strength of the overall Enterprise Toolset is that a process model can be built of any business activity which can then be used without modification to enact the process. The steps in the process are linked directly into the tools required to perform them. This enables the most suitable tools currently available to support the business process. In addition, the toolset provides a visualisation of the process illustrating progress as the process is enacted.

There are two major issues that have not been addressed by the Enterprise project. The first is the issue of cooperation. In a realistic business environment most tasks are carried out by more than one person, i.e. several individuals contribute to an overall task. Task Management in the Enterprise Toolset only takes into account a single user who is communicating with the Task Manager. During the enactment of tasks, other people may be brought in as human agents, but they are treated more as "human tools" for the user than as equal (or even superior) to the user.

The second issue that has not been addressed during the project is the issue of multi-perspective modelling for task management support. In Enterprise we use process models as a basis for all task management. As outlined in section 2.1.2 this is not always the best approach to a problem. There are cases in which, for example, an information model would provide more suitable support. A start has been made on this issue during the development of the Enterprise public demonstrator to use an information-based approach to task management for a specific problem [8]. However, it should be possible to provide this approach alongside the process-oriented one in an extended toolset.

In spite of these limitations, the work carried out during the Enterprise project provides a valuable step towards supporting enterprise modelling and the results of the Enterprise project are encouraging. The next section outlines what extensions are required to address the issue of coordination.

4 COORDINATING TASKS

The Enterprise Toolset can be extended with coordination technologies which can be used to provide support for multiple users. AIAI is currently involved in the Task Based Process Management project which investigates the use of coordination technologies in the support for enterprise modelling. The project is funded under the EPSRC programme Systems Engineering for Business Process Change (SEBPC) and is a collaboration between AIAI and the Chemical Engineering Department of Loughborough University. The project has industrial input from BG (British Gas), ICI, and Unilever.

Providing support for task coordination in enterprise modelling leads to requirements for modelling, tool integration and communication facilities, and task management facilities. The models required for single-user task support are simpler than those for cooperative work. Without coordination requirements there is no real need to model people beyond the capabilities they have or to model organisational structure. With coordination, organisational structure and the roles people take on within that structure become important. The types of interactions people engage in and the kinds of relationships that exist between people are now also relevant. Temporal aspects of tasks become important when different people work together, and the concept of authority has to be considered as well as that of capability. All these new concepts have to be modelled, leading to a richer model of the organisation, and their use within the task management environment has to be defined, leading to more powerful support for enterprise modelling. To give an example of the issues involved we discuss three issues in more detail:

1. The current capability specifications that may be attached to a process are functionality oriented. When a task is to be performed by a human agent, additional capability attributes may be desirable. Dellen *et al.* [1] use the categories of qualification, organisational unit, and role within an organisational unit to define the capability a person must have in order to perform a task. Qualifications are similar to the current capability specifications. An example of a current capability specification would be that to perform the task "review software module" the agent selected must be capable of "reading C++". Including organisational units and roles, it is possible to widen the specification to the person must additionally be a "member of quality assurance team" and "at least a senior software engineer".

2. Addressing issues of coordination the concept of delegation of tasks is important. Delegations can be of different "strength". The weakest form of delegation would be to offer a task to a set of individuals capable of performing it and allowing one of those individuals to voluntarily accept it. At its strongest, the delegation can specify that a task is to be assigned to an individual who is then obliged to perform it[13].

3. To support temporal aspects of how people work together constructs are required for specifying how reminders should be issued. These can be expressed in terms of the time between a person taking on a process and the first reminder being issued, the time interval between reminders, and the amount of time that may pass before the individual responsible for a task is informed that a person is not completing a delegated task.

Each new construct that is added to the modelling facilities must be grounded in the ontology if the construct is to be used effectively. This means that each new construct that is not already part of the ontology must added to the ontology, together with a specification of its meaning and how it relates to other terms in the ontology.

Adding coordination to task management requires more sophisticated criteria for selecting agents for tasks. Previously, aspects like capabilities and communication details were sufficient to determine which agents can perform a task, whereas now authority also has to be considered. Furthermore, where previously task management could work on the basis of strict delegation, there may now be negotiations, a need for reminders, and agents may even refuse to accept a delegated task. This means that communications about task management must be enhanced.

The effect of adding coordination facilities is most visible in the task management aspects of enterprise modelling. New types of interactions have to be supported, including delegations of different "strengths". New types of constraints like requirements on authority have to be managed, reminders have to be issued, different aspects of progress have to be monitored, visualised and problems dealt with, processes can be started by more than one user, different views of the current state of the task may be required by different people, etc.

Developing the support required for coordinating tasks, advances in several fields can be taken advantage of. Chief among these are the fields of agent-based systems, computer supported cooperative working, process modelling and workflow specification, and workflow management systems.

5 CONCLUSION

AI techniques are well suited to the requirements of enterprise modelling. The Enterprise project has shown that using AI to provide an integrated toolset with task management facilities is a valid approach. The approach is extensible so that facilities for the coordination of tasks and for a multi-perspective approach to task management can be added.

References

[1] B. Dellen, F. Maurer, and G. Pews. Knowledge based techniques to increase the flexibility of workflow management. *Data and Knowledge Engineering*, 1997. Also available from http://wwwagr.informatik.uni-kl.de/˜comokit.

[2] T. Finin, Don McKay, and Rich Fritzson (Editors). An overview of KQML: A Knowledge Query and Manipulation Language. Technical report, The KQML Advisory Group, March 1992.

[3] J. Fraser. Managing Change through Enterprise Models. In R. Milne and A. Montgomery, editors, *Applications and Innovations in Expert Systems II*. SGES Publications, December 1994.

[4] M. R. Genesereth and R. E. Fikes (Editors). Knowledge Interchange Format, Version 3.0 Reference Manual. Technical Report Logic-92-1, Computer Science Department, Stanford University, June 1992.

[5] M. R. Genesereth and S. P. Ketchpel. Software Agents, 1994.

[6] J. Lee, M. Gruninger, Y. Jin, T. Malone, A. Tate, G. Yost, and other members of the PIF Working Group. The PIF Process Interchange Format and Framework Version 1.1. Technical report, MIT Center for Coordination Science Working Paper 194, Cambridge, MA, 1996. Also available from AIAI as AIAI-TR-198.

[7] R. Mayer, Cullinane T., P. deWitte, W. Knappenberger, B. Perakath, and S. Wells. IICE IDEF3 process description capture method report (al/tr-1992-0057). Technical report, Air Force Systems Command, Wright-Patterson Air Force Base, Ohio, 1992.

[8] J. Stader. An intelligent system for bid management. *The International Journal of Project & Business Risk Management*, Autumn, 1997.

[9] M. Uschold and M. King. Towards a Methodology for Building Ontologies. Technical Report AIAI-TR-183, AI Applications Institute, 1995. Presented at the Workshop on Basic Ontological Issues in Knowledge Sharing Held in conjunction with IJCAI-95 in Montreal.

[10] M. Uschold, M. King, S. Moralee, and Y. Zorgios. The Enterprise Ontology. Available on World Wide Web from URL http://www-ksl-svc.stanford.edu/.

[11] M. Uschold and Gruninger M. Ontologies: Principles, methods and applications. *Knowledge Engineering Review*, 11(2), 1996. Also available from AIAI as AIAI-TR-191.

[12] World Wide Web site. at URL http://www.aiai.ed.ac.uk/project/wfmc/.

[13] The Workflow Reference Model. Technical Report TC00-1003, The Workflow Management Coalition, 1994.