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ABSTRACT

Competitiveness of an organization in the marketplace depends to a large extend on the adeptness of the business process in efficiently managing the workflow of an entity. Challenges that face business processes today is the inability reconfigure themselves based on knowledge from the workflow. The paper presents a framework that will allow information from the workflow to be stored as ontology documents that can be processed by a multi-agent system to provide dynamic capabilities to the business processes. The paper also looks at the benefits and limitations of integrating agent based semantic processing capabilities to workflow management systems.

Keywords

Business Process Engineering, Intelligent Agents, Multi-agent Systems, Ontology, State Ontology, Semantic Web, Workflow, Workflow Management Systems, Workflow Performance Measures.

INTRODUCTION

The productivity and profitability of a business depends on the efficacy of its business process in delivering its value proposition. The effective management of the business process, along with the adeptness of the business process contributes to the competitiveness of an organization in the marketplace. In many modern organizations, this places critical business responsibilities on the information systems to provide the smooth flow of information required to manage the business processes. Managing the information flow is crucial to ensure that accurate and adequate information is available to the business processes, as well as, to monitor and measure the workflow for strategic and predictive decision tasking purposes. Business processes are typically modeled as action-event sequences in workflow-based information systems and workflow automation systems.

While workflow systems are important to the efficient execution of a business process in terms of cost and speed, their effectiveness stems from the efficacy of the design of the business process. For most organizations, irrespective of whether they employ tactical workflow management systems (that uses sampling-based schemes for performance evaluations) or data-driven operational workflow management systems (first-hand observations used for process evaluations), optimization tasks of the business process usually requires human intervention for the analysis of process effectiveness measures which are determined a priori through management policy decisions. To be ahead of the game in today's highly competitive marketplace, it is pertinent that organizations start using dynamic decision tasking functions as part of the business process by which they become aware of problems as soon as they occur and be prepared to take corrective actions in a timely and proactive manner to avoid revenue loss and customer attrition. Such a capability will require continual monitoring of business process and continual evaluation of process metrics against established process measures to determine the nature of process errors. Not much research work has been done in this area of managing effectiveness of a business processes.

The objective of this paper is to develop a systems architecture found upon intelligent agents that are aware of the current state of each instance of a business process and the process goal. We propose an enhanced business process model that stores the ontology of the current system state at the node level in a dynamic fashion as an entity passes through the workflow. The ontology can be used to create a level of awareness that allows an intelligent agent to manage and monitor each business sub-function in a real-time and autonomous manner. This enhanced model will use agents to interpret and make decisions on the state ontology of the workflow and can be used to implement a true semantic internet based business process model. The paper is presented in three sections. The first section describes the background and terminology associated with business processes and semantic eBusiness components. The second section offers a detailed description of the details of the agent based framework for business process management. This section also uses a real world example to demonstrate the proposed model. The paper concludes by summarizing the strengths of the architecture and the limitations that can open new avenues of research in the future.

BACKGROUND AND TERMINOLOGY

Davenport & Short (1990) defines *Business Process* as "*a set of logically related tasks performed to achieve a defined business outcome*." Workflow Management Coalition (WfMC 1996) describes business process as a sequence of activities with distinct inputs and outputs and serves a meaningful purpose within an organization or between organizations. Davenport characterizes *processes* based on three possible dimensions (Davenport, et al., 1990) - a process can take place on an interorganizational or an interfunctional entity, can occur to manipulate objects (physical or informational) or can involve two types of activities (managerial or operational.) Business Processes can thus be generalized as having a 'begin' and an 'end' point and a series of intermediate tasks performed in sequence on some entity, object or activity.

Stohr and Zhao (2001) defines the term *workflow* as "*the automation of a business process in whole or in part, during which documents, information or tasks are passed from one participant to another according to a set of procedural rules.*" The role of Information Technology in establishing a high level of effectiveness and control in the automation of business process has been established beyond doubts. In this regard, Davenport correctly observes that Business Process Design and Information Technology are natural partners (Davenport, et.al, 1990.) One can easily argue that the biggest asset brought into workflow management systems designed to integrate any form of knowledge representations is the ability to respond to problems in highly effective and machine interpretable manner, thereby offering the organization competitive advantage in the marketplace.

Businesses certainly do not view knowledge management as a means to undergo organizational transformations (Davenport, Long, and Beers, 1998.) The problem facing businesses is not a lack of knowledge but how knowledge can be used effectively (Davenport, et al., 1998.) Monitoring activities associated with workflow management usually generates critical information that can be reviewed and reapplied to the workflow in an iterative manner to improve operational characteristics of the workflow. However in most cases this iterative treatment requires extensive human interaction. An improvement to this approach proposed in this paper is the possibility of integrating an ontological structure on top of the existing workflow model with the intention of storing state information about each phase (or node) of business process. Documenting the outcome of this monitoring activity can be easily formalized into independent *state ontology* to represent the node information at every step of the workflow process. Uschold (1998) states that ontology can take a variety of forms but it will include a vocabulary of terms and some specification of their meaning. Using state ontology to represent node information (referred as *state level ontology* henceforth) will allow knowledge of the workflow to be represented in a format that can be automatically or semi-automatically extracted and used. An *entity* in the business process will undergo a series of transformation as it makes its way from the begin node to the end node of the workflow. Vocabulary that describes the state changes of the entity as well as the expected state changes at each node and their relationships is recorded at the state level ontology. This state level ontology can be structured using common semantic languages such as RDF, BPEL, OWL and DAML+OIL.

Although the state level ontology, by themselves have no significant meaning, utility or processing capabilities, the real benefit of state level ontology becomes evident when we tie the state level ontology from the different nodes in the to create semantic information of the business process. The processing capabilities of a multi-agent system can then be used to identify potential problems as the entity moves through the workflow and proactively instruct the nodes on corrective actions. The presence of a state level ontology thus creates a semantically rich business process environment in which agents can interact with the nodes to provide adaptive functions of a higher level. Incorporating a multi-agent system architecture into the workflow model along with an intermediary state level ontology layer offers a new framework that addresses the knowledge usability shortcoming of a traditional workflow models. Although numerous definitions of agents can be found in literature, the properties of agents that allow usability of a multi-agent environment in this framework can be characterized (Jennings, Sycara and Wooldridge, 1998) as *situatedness* (agents receiving inputs from its environment and can perform actions which change the environment), *autonomy* (agents are capable of taking actions on their own without direct human intervention) and *flexibility* (agents are capable of responding in a timely fashion and are able to interact with humans or other artificial agents.) Using agents to take actions on the knowledge representations from the workflow management system offers an astounding new methodology to complement the semantic web schema (as proposed by Berners-Lee, Hendler and Lassila, 2001) with the business process engineering efforts.

Berners-Lee, et al. (2001) proposes that the "Semantic Web" comprises and requires the following components in order to function:

a. **Knowledge Representation**: structured collections of information and sets of inference rules that can be used to conduct automated reasoning.

b. **Ontologies**: systems must have a way to discover common meanings for entity representations. In philosophy, Ontology is a theory about the nature of existence; in systems, ontology is a document that formally describes classes of objects and defines the relationship among them. In addition, we need ways to interpret ontology.

c. **Agents**: Programs that collect content from diverse sources and exchange the result with other programs. Agents exchange "data enriched with semantics"

The semantic web as portrayed by Berners-Lee, et al. (2001) is reproduced in figure 1. Berners-Lee, et al. (2001) explains how the semantic web architecture depicts a model where ontology expression languages can be use by agents to create a "value chain" in which subassemblies of information can be passed from one agent to another during the creation of the entity by the end user. This paper aims to propose an improvement by which value can be added to this semantic web schema by suggesting how business processes can be (re)engineered to adjust to the dynamics of the workflow that an entity is subjected to.

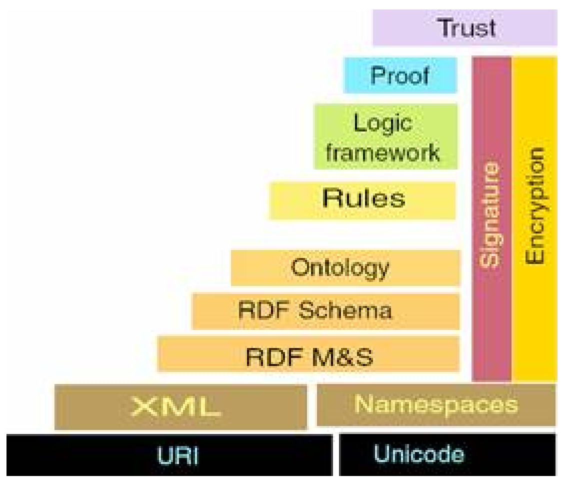

Figure 1. The semantic web architecture

(Source: http://www.w3.org/DesignIssues/diagrams/sw-stack-2002.png - (Berners-Lee, et al., 2001)

The following section attempts to provide an example on agent based semantic workflow model to demonstrate how the architecture can be implemented.

ARCHITECTURE AND EXAMPLE

In order to support the timely discovery and execution of corrective action in business processes, systems must become "aware" of the process and be able to manage its execution. Awareness of the state of the process and the entity is required for detection of problems as the entity moves through the workflow. This can be done by the evaluation of the run-time metrics of the activity performed at each node with established measures of process performance. The ability to draw inferences from the existing process state metrics is required to generate and evaluate alternatives and inform the nodes to execute corrective functions in an automated manner or with human intervention. In addition, the standard and ad-hoc reports should be flexible enough to capture the dynamic nature of the business environment so that analysis of the reports generate knowledge specific to the real time sate information of the nodes. In most current workflow systems, evaluation of reports is performed off-line due to lack of an effective method to determine the extent of correction to be introduced back into the workflow. Many large software organizations, including IBM, Oracle, SAP, have integrative workflow systems as part of their product offerings. Such workflow systems are "*designed to make work more efficient, integrate heterogeneous application systems and support inter-organizational processes*" (Stohr et al., 2001). The model proposed here is that the addition of a layer of abstraction that maintains state level ontology can be used by multi-agent systems to offer a simple yet effective problem solving methodology for workflow management.

Consider the example of an order fulfillment process comprising a series of steps that begin when information about the online order arrives leading to the delivery of the product to the customer and verification of delivery of the product. For example, when a customer orders a digital camera from an eCommerce site, the order fulfillment function (or department) in the organization receives the order including details of the product, customer information, due dates for delivery, shipping details and payment confirmation (figure 2.) In general, order fulfillment process executes a series of pre-determined, known steps which includes finding the product from inventory, verification of the product characteristics with the characteristics of the product ordered, packaging, labeling of the product package, applying an appropriate shipping method and actually shipping the product. The order fulfillment function culminates with verification of the delivery of the correct product to the correct customer at the correct address. The main step functions of this workflow are shown below (figure 2.)

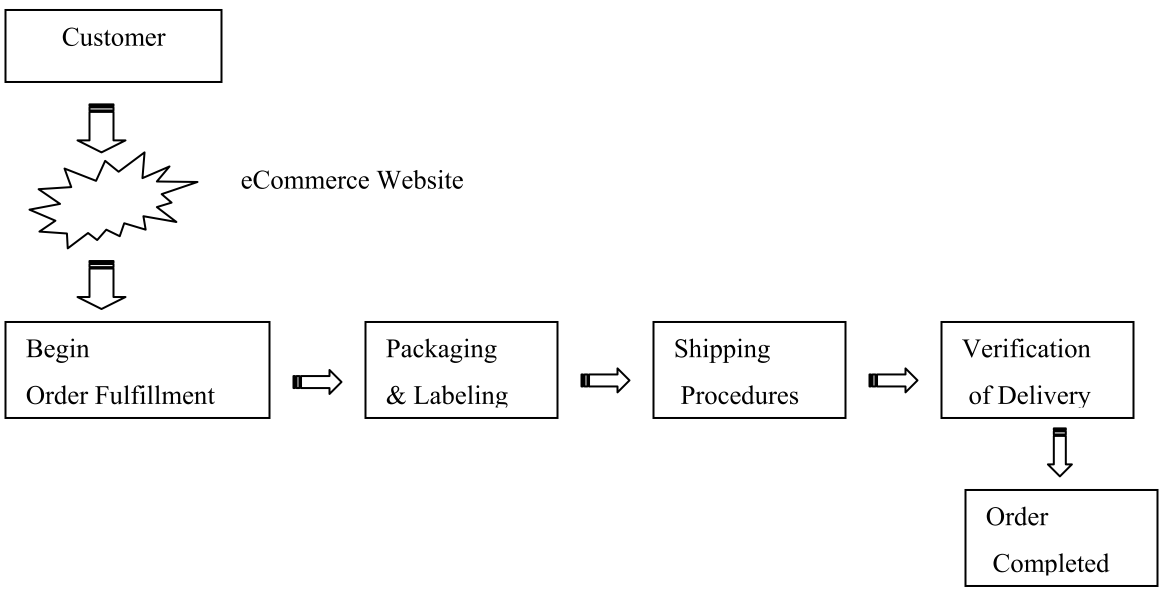

Figure 2. Order Fulfillment Process for an eCommerce order placed online.

Information systems view individual business process as known transformations applied to information inputs, sequentially or otherwise, to produce the desired information output. The underlying assumption for processes dealing with tangible goods is that the transformations applied to the tangible goods is the same as the transformations applied to the information; therefore the final information output occurs concurrently with the final tangible output. It is hence possible to separate the flow of information and the flow of tangible entities involved in a business process. It then becomes useful to transform the flow of information into corresponding state ontology at the node level and treat them as surrogates for the flow of physical and tangible entities in the problem domain.

Information technology and the information systems function are important considerations in the design of business processes. This is evident in the established role of information technology in business process automation, process improvement and in process redesign efforts that are all critical aspects of business process reengineering. In most cases, the flow of operations and individual tasks in a business process are usually treated as factors that are fixed and inflexible. Information systems implemented to automate business processes typically take the role of performing operational and supervisory control to ensure that the workflow is operating within the bounds in which it is designed to operate. Once the flow of the process and its measures of operational control are (re)designed, automated workflow models (for e.g. the order fulfillment process mentioned above) at its best, take on the role of a first order loop back control system (Simon, 1981.) In other words, the process work flow progresses in the predetermined sequence and according to known and previously established measures of process efficiency. The notion of control systems is introduced here to draw the analogy between control measures set by the managers overlooking a business processes and those prevalent in industrial control systems. First

Order Control Systems or conventional control systems can react to simple perturbations (routine or expected deviations from the predictable value) and can be programmed to take reactive steps to correct deviations in an attempt to stay within tolerance limits (Kavi and Deshpande, 1991.) For example, managers set rules on maximal fudge allowed on expected delays at any node within the business process. Any anomaly outside the limits set by the manager is treated as a condition that affects the efficiency of the workflow and warrants investigation to determine the cause of the problem. This is required to ensure that corrective steps can be taken to prevent similar occurrences in the future. However, the notion of tolerance in business process engineering is not as clinical as those in industrial control systems. But it is crucial to recognize the existence of tolerance levels within the workflow (explicitly documented or tacit knowledge of the manager) and its reliance as a means to flag a condition that requires immediate attention. Although we are using a concept prevalent in industrial control systems it is important to note that limits are set on performance measures (tacit or explicit) and they tend to be a lot more subjective.

A workflow of this form can be mapped as shown in figure 3. Upper and lower tolerance limits are determined by managers and monitored to ensure that workflow stays within these limits (the dotted curved line.) Anomalies due to unexpected events in the workflow (for e.g., missing product information or incomplete shipping address) affect the flow of entities through the business process (as can be seen by the dotted curve crossing the lower tolerance limits.)

Numerous research initiatives have suggested different methodologies to promote the workflow to a second order system (Simon, 1981) so that correction functions can be instituted in anticipation of, rather than in response to deviations from the normal (O'Brien and Wiegand, 1998; Palacz and Marinescu, 1999.) Continuous evaluation and monitoring of process efficiency measures are still required to provide vital input to tolerance decisions. In this research, we treat the flow of information among individual tasks in a business process as *a-priori* decision to the analysis of a business process.

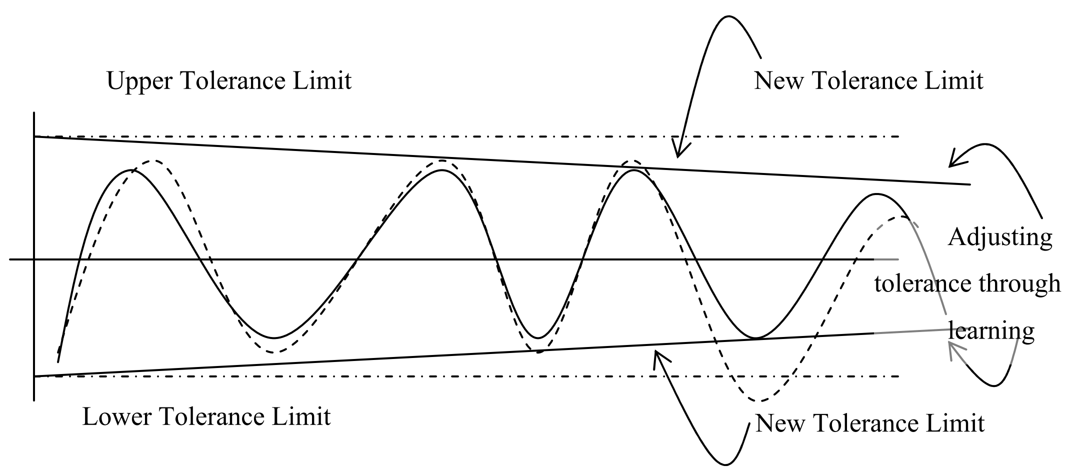

Figure 3. Adjusting tolerance limits through learning.

The focus of this research is to propose an integrative architecture to add structured knowledge representation and learning to the business process, and their constituent *a priori* tasks. The improvement suggested by this paper is made possible by adding two additional components to the existing workflow management system – a state ontology maintained at the nodes and a multi-agent system environment in which agents can communicate using agent communication language (ACL.) Together the integrative workflow management system can monitor and record knowledge pertaining to the changes that occur at the nodes (both on the entity as well as the node activity) at every point in time when an entity passes through the workflow model. Figure 4 represents the delivery fulfillment process for the digital camera that was ordered by the customer online. The figure shows two separate work flows (path denoted by A-B-D-F-H and path A-C-E-G-H) presuming that two orders where made by two different customers which are being processed through the order fulfillment business process. The node A (a customer order arrival) triggers the sequence of events that the entity (digital camera in this case) will undergo until verification of delivery to the customer at Node F where upon the order is completed at Node H.

The notion of ontology, once referred to the science of being, has evolved in the systems sciences to represent knowledge about entities and their relationships in a given domain. The knowledge representation view of ontology is analogous to the object-oriented (OO) paradigm where system entities and their relationships form the artifacts that comprise the system. The design of object-oriented systems leads to the definition of system entities that manifest themselves as objects in the system, as in the digital camera example above. The design process creates knowledge about the entities themselves and knowledge about the relationships between the entities and the business process. In addition, the systems design process creates rules for the interaction between these system entities to implement the business process and functional requirements of the overall system. This knowledge can be captured at each node and represented in the design documents to contain object details and their inter-relationships.

The proposed enhancements will capture and convey an understanding of the dynamics of the entity and their relationships with the work flow to the agent system in a real time fashion. As a practical matter, the work flow can be represented as a system of equations, where the equations in the set and their forms will be a reflection of the peculiarities and complexities of the process relationships being modeled. For illustrative purposes, consider the equation

$$O_i = F\,[X_1, X_2, X_3, \ldots X_m]$$

where O_i is the process of interest, X_1, X_2, etc., are determinants (state variables of significance associated with the entity and the nodes) and F is a high order functional operator that describes the connective characteristics of the model. The determinants can be further broken down into equations representing subsystems within the work flow. For example,

$$X_1 = R\,\{y_1, y_2, y_3, \ldots y_m\}$$

$$X_2 = E\,\{z_1, z_2, z_3, \ldots z_m\}$$

where X_1 describes the structuring (sequence, flow, scope), communication (receive, reply, invoke), exception (throw, terminate, compensate) and miscellaneous activities (assign, wait, empty) at the nodes (Xml coverpages, 2003) in the form of $y_1, y_2, y_3, \ldots y_m$ as a function R . X_2 represents entity specific instance properties (such as part number, product id, order number, shipping address, etc.) in the form of $z_1, z_2, z_3, \ldots z_m$ as a function E.

The linkage patterns of the work flow with the entities and the state information of the nodes can be represented in the ontology document. In an ebusiness arena, it is often the case that dissimilar entities move through the work flow. Correspondingly the behavior of the work flow (and allowable tolerance levels at the nodes) will also be different. For example, packaging time for a book order will be significantly different from the packaging time for a bicycle. The linkage patterns and tolerance levels at the nodes will therefore be specific to the product moving through the workflow. This raises an additional challenge for dynamic systems aimed at monitoring and maintaining performance efficiencies of the business process.

Ontology documents created to represent the system of equations can capture this dynamics. . Ontology documents can be created using FIPA compliant content languages like BPEL, RDF, OWL and DAML to generate standardized representations of the process knowledge. The structure of the ontology documents will be based on the system of equations. Description logic can assist in translating the system of equations into ontology documents to describe the algorithmic behavior of the work flow and the entity.

The other significant component of the model that will use the state level ontology to perform task assessments at the node is the multi-agent system (MAS.) An agent resides at every node to constantly monitor the predetermined performance matrices of the node. As the intelligent agent paradigm for systems design becomes more pervasive, description logics in the form of state level ontology will provide a viable solution for knowledge representation requirements of the workflow management systems. The DL model will provide the ontological requirements to represent actionable knowledge of a problem domain upon which agents can draw epistemological inferences to provide intelligent functional support for a system. While much work is currently underway in this area, the systems community lacks system designs that model the interactions between a task-specific goal-oriented agent community and domain-specific actionable knowledge documents. In addition, the systems literature lacks in the application of such a design to a pertinent business process to illustrate the benefits of the approach. The multi-agents system can analyze the ontology documents at each node level and provision the use of learning algorithms to center decisions that are based on an appreciation of the entire business process rather than individual node functions.

Revisiting the example of the order fulfillment process, agents attached to each node actively participate in communicating with other node agents to analyze knowledge representation (the state level ontology) that is dynamically refreshed as an entity passes through the workflow. Figure 4 illustrates the integrated order fulfillment workflow model that includes the state level ontology and the multi-agent community.

As seen in figure 4, the multi-agent system includes a Supervisory agent to ensure order and harmony within the agent community. The Supervisory agent performs two independent but related roles – that of ensuring synchrony between the agent communications at the nodes as well as maintain a *meta-workflow ontology*. To demonstrate the role of the supervisory agent, consider a case where the digital camera order gets delayed at the packaging and labeling node (this can happen because the packager noted that the camera was missing a strap, or because the item did not match the customer order.) The state level ontology is immediately updated to record this variance from normalcy. The node agents will recognize the state change by processing the state level ontology and inform the supervisor agent. The agent at packaging and labeling can also inform the shipping procedure node agent that a package scheduled to ship has been delayed at the preceding node. The supervisory agent will update the meta-workflow ontology to record this state of the entity (the digital camera). There could be the case that a node (or node agent) failure resulted in the node agents unable to communicate with other agents. The supervisor agent masterminds the multi-agent communication system and ensures that the anticipated node communication actually took place. Failure of timely and predicted agent communication or state level ontology updates causes the supervisor agent to take control and trigger appropriate events to provide functional support to the nodes within the workflow.

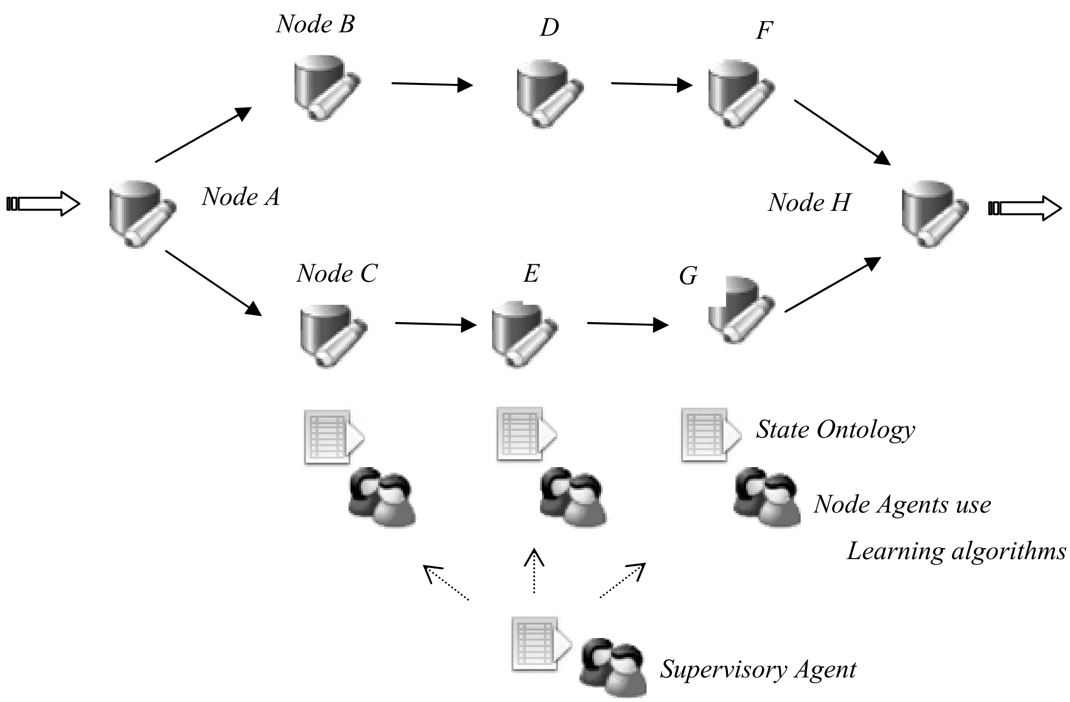

Figure 4. Multiple workflows for order fulfillment.

The inclusion of a state level ontology and the use of an FIPA compliant agent community (FIPA, 2003) that can communicate using ACL can offer significant improvements in the way workflows are monitored and controlled. The model can also act as antecedents to the goal of dynamic reconfiguration of processes based on real-time process efficiency measures. The proposed model will allow the workflow to stay within performance tolerance limits set by the managers by reducing the magnitude of deviations by taking advantage of the ability of agents to learn over time. Over time, the learning capabilities of the agents can be used to readjust the tolerance levels (as shown by the converging solid lines in figure 3) while maintaining the workflow efficiency within these levels.

CONCLUSION

The inclusion of an agent architecture that uses knowledge representation of the system state will offer improvements to the business processes by readjusting efficiently to match the changing dynamics within the workflow. An important contribution made by this architecture is the ability to enforce an *information lossless environment*, where no information about state-transitions of inputs is lost as the entities go through the series of transformations required by business process. For pragmatic reasons, here we make no distinction between directly observed and derived information determined from the past state of a processes. For the purpose of this research, we are primarily concerned with the ability to examine *all* pertinent data regarding the series of transformations that occur at any instance of a process or the entity. The architecture offers a method for monitoring and controlling a processes in real-time and with minimal off-line analytical activities required in the form of human interaction.

One of the strengths of the proposed architecture over traditional workflow management systems come from the use of knowledge representation languages used to create the node level ontology and the ability of agents to use the ontology document in an effective manner. For this reason a FIPA compliant content language like BPEL, RDF, OWL or DAML is chosen to create the ontology documents at the node. The expressive power of these content languages can be used by agents to offer reconfiguration information to the workflow management process (Zou, Finin, Ding and Pan.) Any change in characterization of the workflow from normalcy will be recorded in the state ontology and agents can take appropriate corrective actions on this change in a collaborative manner. The model allows the agent communication language to remain the same while the workflow improvements are effected on the system. Furthermore, the recent acceptance of OWL and RDF as W3C recommendations will see greater popularity in its use in the future (www.daml.org.) OWL and RDF being semantic web languages it will now be easy to incorporate the feature of the proposed business process improvements suggested in this paper to the semantic web schema described by Berners-Lee, et al. (2001.) The proposed model also allows adjustments to be recognized based on the individual requirements of the specific products moving through the work flow. The agents can dynamically address the variance allowable in the tolerance limits depending on the product specific requirements. Business Process Execution Language (BEPL) is being finalized as a w3c standard to handle data related to communication activities and exceptions between the nodes (Oasis, 2002.) Ontology documents based on these standards offers great potential to tie together the three aspects of an e-business enterprise, namely business process, human resources and information technology.

Although the paper makes a strong argument towards the combined synergies of ontology and multi-agent systems it clearly does not address all the issues pertinent to workflow management in an eCommerce environment. The paper only exposes wider research opportunities on how improvements can be enacted on business processes by using agents to link the commonalities and disagreements between the nodes expressed in the state level ontology. This research paper does not differentiate between explicit knowledge and tacit knowledge inherent in business processes. Future research could focus on how state level ontology can be modified to individually address the impact of tacit and explicit knowledge on the business process. Whether the model proposition presented in the paper is worthwhile or not is really a question of cost-benefit analysis. Clearly a model that follows this structure will have expectedly higher development and implementation costs including the need for powerful learning algorithms and agreed standards on ontology document structure to model the workflow. Weighing these against tighter and automated control on business process, it can be argued that the proposed improvement will offer advantages by reducing workflow delays which in turn is directly proportional to increased customer satisfaction and reduced latency between the begin and end points of the business process.

REFERENCES

1. Berners-Lee, T., Hendler, J. and Lassila, O. The Semantic Web, Scientific American, May 2001.
2. Baader, Franz. The Description Logic Handbook, Theory Implementation and applications, Cambridge University Press, 2002.
3. Davenport, T.H. and Short, J.E. The new Industrial Engineering: Information technology and business process redesign, Sloan Management Review, 31, 4 (1990), pp. 11-27.
4. Davenport, T.H., Long, D.W. and Beers, M.C. Successful Knowledge Management Projects, Sloan Management Review, Winter 1998, pp.43-57.
5. FIPA Specifications, http://www.fipa.org
6. http://www.daml.org
7. Jennings, N., Sycara, K. and Wooldridge, M. A Roadmap of Agent Research and Development, Int. Journal of Autonomous Agents and Multi-Agent Systems, 1(1), 1998, pp.7-38.
8. Kavi, K.M. and Deshpande, A.K. Specification of concurrent processes using a dataflow model of computation and partially ordered events. Journal of Systems and Software, Oct 1991, v16, n2, pp.107-121.

9. O'Brien, P.D. and Wiegand, W.E. Agent based process management: applying intelligent agents to workflow, The Knowledge Engineering Review, Vol. 13:2, 1998, pp.1-14.
10. Oasis, Global consortium for development, convergence and adoption of e-business standards, http://www.oasis-open.org/committees/tc_home.php?wg_abbrev=wsbpel, 2002.
11. Palacz, K. and Marinescu, D.C. An Agent-Based Workflow Management System, 1999, pp.1-11.
12. Simon, H. Science of the Artificial, Cambridge, MA: MIT Press, 1981.
13. Stohr, E.A. and Zhao, J.L. Workflow automation: Overview and Research Issues, Information Systems Frontiers, 3:3, Sept 2001, pp.281-296.
14. Uschold, M. Knowledge level modeling: Concepts and terminology. Knowledge Engineering Review, 13(1), 1998.
15. WfMC, Workflow Management Coalition, http://www.wfmc.org, 1996.
16. Xml coverpages, http://xml.coverpages.org/bpm.html , 2003
17. Zou, Y., Finin, T., Ding, L. and Pan, R. Using Semantic Web Technology in Multi-agent Systems: a case study In the TAGA trading agent environment, http://taga.umbc.edu/taga2