Ian David Lockhart Bogle and Michael Fairweather (Editors), Proceedings of the 22nd European Symposium on Computer Aided Process Engineering, 17 - 20 June 2012, London.

Operational, Tactical and Strategical Integration for Enterprise Decision-Making

Edrisi Muñoz[a], Elisabet Capón[a], Jose M. Laínez[b], Marta Moreno-Benito[a], Antonio Espuña[a] and Luis Puigjaner[a]

[a] *Department of Chemical Engineering, Universitat Politècnica de Catalunya, Barcelona, Spain.*
[b] *School of Chemical Engineering, Purdue University, West Lafayette, IN, USA*

Abstract

Enterprises are highly complex systems in which one or more organizations share a definite mission, goals and objectives to offer a product or service. As a result, decision-making in the enterprise becomes a highly challenging task, which is usually classified in several levels. In this work, an ontological framework is built as a mechanism for exchanging information and knowledge models for multiple applications and effective integration between the different hierarchical levels. The potential of the general semantic framework developed (model maintenance, usability and re-usability) is demonstrated using a case study concerning the enterprise supply chain network design-planning problem.

Keywords: Enterprise Model, Supply Chain, Decision Support Systems, Ontology Framework, Knowledge Management.

1. Introduction

Today, companies must strive to remain competitive by improving their operations to provide greater customer satisfaction while generating dividends to shareholders. In order to offer a better service to customers, quick time-to-market and operational flexibility have become crucial business drivers in many industries to respond rapidly to the continuously changing market conditions. Certainly, this pressure for greater flexibility has made enterprises evolve to more complex systems. Enterprises consist of multiple business and process units of different scales working together; the organization of the different scales and levels within such complex systems is crucial to understand, analyze, synchronize and improve their operations. We believe that one important step to accomplish such tasks is to represent the enterprise in an adequate ontological model, which captures the features relevant for supporting process managers in decision-making.

In order to deal with the problem complexity, it is necessary to decouple the system across a hierarchy of appropriately chosen levels without disregarding the interrelationship that exists among them. This is considered on the concept of supply chain (SC), which can be defined as the group of interlinked resources and activities required to create and deliver products and services to customers. Decisions are taken at different stages within the supply chain and at different levels in the management hierarchy, and differ in business scope, time horizon and resolution, data certainty and accuracy, process detail and optimization mechanism (Lasschuit and Thijssen, 2004). Traditionally, enterprise management has been divided in three decision levels:

strategic, tactical and operational. Long-term strategic level defines the business scope by determining the structure of the supply chain in a time period of years. Medium-term tactical planning is concerned with decisions such as the assignment of production targets to facilities and the distribution from facilities to markets. The operational level is related to short-term planning or scheduling which determines on a daily or weekly basis the assignment of tasks to units and the sequencing of tasks in each unit. Process control aims at achieving an efficient, safe, environmentally friendly and reliable operation to execute the production requests calculated at the scheduling level.

In this area, only some modest attempts at integrating a small subset of decision models exist, since the complex organizational structures underlying business processes challenge our understanding of cross-functional coordination and its business impact (Varma et al., 2007). A general classification distinguishes transactional systems, which are concerned with the acquisition, processing and communication of data over the enterprise (e.g., ERP systems); and, analytical systems, which introduce some reasoning to propose solutions for business problems (e.g., simulation and optimization). Despite the great advances in centralized transactional systems, the huge amount of data stored in such systems is usually not utilized to feed analytical systems that can provide smarter solutions which ultimately could represent a competitive advantage in the current business environment.

Therefore, effort must be devoted (i) to develop improved models and (ii) to the readily integration of information systems so as to provide decision support tools within a coherent framework which takes into account the available information on actual plant operations and market conditions. Holistic analytical systems which are instanced automatically from transactional systems data by means of an ontological framework are required to open new ways of making satisfactory overall decisions. This work proposes a semantic model approach, namely heavyweight ontology, for representing an integrated enterprise environment. A case study is presented to demonstrate how the ontology can be used as the link between transactional and analytical systems.

Several ontological approaches have been presented in the literature concerned with the enterprise domain as an important medium for attaining information systems interoperability. Basically, the existing ontologies only address the strategic level granularity and disregard the tactical and operational levels. In addition, the methodological approaches adopted are too far from the vast theoretical base related to the supply chain management, and only a very limited view on the scope of supply chain is tackled. No formal account of information flow supported activities such as replenishment, transport or reverse logistics is reported. This work aims at reducing some of the aforementioned research gaps.

On the one hand, and based on a previous work (Muñoz et al., 2011), which uses a semantic model for an effective production plant modeling of the scheduling and control levels, an improved ontology is developed to include the enterprise strategic level. As a result, these levels integration is achieved by means of a common model for re-usability, usability and a shared information structure based on the ANSI/ISA standards and supply chain management. Thus, the level of granularity of the model comprises the strategic and operational levels.

On the other hand, the model structure of the enterprise supply chain takes into consideration suppliers, producers, distributors and retailers, and includes the transport tasks. Consideration of a common model embracing this tactical level aligned with the aforementioned models has not yet been attempted.

2. Process industry ontology

The proposed ontology supports different activities by streamlining information and data integration, by means of an integrated model which captures the activities developed along the different levels of the enterprise structure in an enough general manner. As a result an integrated decision-making framework is provided. This section describes the domain, in this case the enterprise, of the ontology developed. Finally, the work done for the use of this ontological model as a connection between transactional and analytical models is presented.

The domain of the ontology comprises the enterprise entity, as defined at the introduction section. The enterprise activities related to the operational, tactical and strategic functions have been semantically modeled using robust process-operational and supply chain principles.

Information from different hierarchical levels is needed to improve the overall process performance. This requires important changes for integrating the decision-making system. However, the desired change cannot be made unless the information system is robust. In general, at the strategic level, the supply chain design and planning are optimized with information contained at the different hierarchical enterprise levels. For this reason the use of an ontology, which provides the shared and common domain structures that are required for the semantic integration of information sources may result in a competitive advantage. Although it is still difficult to find consensus among ontology developers and users, there is some agreement about protocols, languages and frameworks. Indeed, ontologies are hierarchical domain structures that provide a domain theory, have a syntactically and semantically rich language, and a shared and consensual terminology (Klein et al., 2002).

The ontology developed in this work, is built under the architecture of a nominal ontology and high ontology, taking into account the factors that influence the complexity, such as concepts, taxonomy, patterns, constraints and instances. The development and use of the ontological framework follows the methodology proposed by Muñoz et al. (2010) based on a Plan, Do, Check/Study and Act Cycle (PDSA), which results in an ordered sequence of steps, that are easy to understand and track. It is noteworthy to mention that the ontology is designed in Protègè and supported by high level informatics language (e.g. Java).

This ontological framework concerns the whole enterprise domain. The supply chain, planning and scheduling, and process control functions are modeled by the ontology. This domain is also encompassed by the ANSI/ISA standards, supply chain handbooks and expertise. The final model comprises 202 classes, 75 axioms, and 181 properties. The main parts of the ontology are:

- Concepts: They are the formalized definitions of those terms contained in the domain. In this work, concepts ranging from the more general strategic level, such as supply chain management, customers and markets, to the operational level, such as control modules and process parameters, are considered.

- Relations: They consist of the links that may be established among the concepts defined above. For example, the relation *hasFacility* links the Enterprise and Facility concepts.
- Basic fact types: They concern the main data describing the basic aspects of the concepts. For example, *BatchSize* has a *min_val* and *max_val* (minimum and a maximum size values).
- Restrictions: They describe the behavior of the concepts within the domain. For instance, a *MasterRecipe* must contain one *Header*.
- Rules: They consist of the guidelines that lead the instantiation process. For example, a *Formula* instance must exist in order to fulfill the instance of a *MasterRecipe*.
- Instances: The instances represent the particular reality of the domain and are associated to a specific problem.

The ontological model is managed by means of a high level informatics program; which allows the capabilities for mining data as a decision support system tool by providing information quality at every decision level.

3. Case Study

The case study is based on a supply chain network design-planning problem presented by Laínez et al. (2009). It consists of three suppliers, four potential locations for the processing sites and the distribution centers in a planning horizon of five annual periods. The production process fulfills the demand of six markets that entails two final products and one intermediate product.

Quantitatively speaking, the problem representation in the proposed ontological framework results in 612 instances. The reasoning time for the problem instances is 0.922 s CPU in a successful compilation.

It is important to mention that each possible site is fully represented in the ontology. Each production plant (site) may contain a set of four equipment technologies as presented by Kondili et al. (1993), a benchmark problem for the scheduling of batch process industries. Specifically, each site is described by 131 instances, which may be adequately used to make operational decisions. In addition, at the process control the principal components are instantiated in order to provide appropriated task and unit synchronization times, set points, controller algorithms and constants and monitoring targets to drive the actual operation.

The results of the optimization model (MILP) at the strategic level are identical to those reported in the original paper (Laínez et al., 2009). Furthermore, the previous results can be dated back to the ontological model for further exploitation by the other decision levels, such as the operational system of each site. Therefore, the scheduling function uses the previous results in order to perform the optimization task. In fact, several optimization approaches can be applied for the same semantic model. Thus, the results of the scheduling function can also be traced back to the ontological model and used by the process control system. This can be achieved by automatically updating the databases with the resulting optimization data.

4. Conclusions

This ontology enhances the way for achieving a successful enterprise decision-making supporting tool which adapts and recognizes the different elements found through the hierarchy models that are associated with the whole enterprise.

Moreover, a general semantic framework is proposed, which is able to model any enterprise particular case, proving its re-usability. Furthermore, it has been proved the ontology usability by its application to an optimization framework. As a whole, the main contributions of this environment and the model behind are re-usability, usability, higher efficiency in communication and coordination procedures.

This work represents a step forward to support not just communication but also the integration of different software tools applicable to the management and exploitation of plant database information, resulting into an enhancement of the entire process management structure. In addition, it has been proved the adequacy of an ontology as a means for sharing information about a general model for different problem representations. As a result, it solves the problem of integration, standardization and compatibility of heterogeneous modeling systems.

Finally, the different decision levels benefit from this tool because both design and operation can be supported by using the same modeling framework. Such feature increases the flexibility by adding new degrees of freedom at every decision level.

Acknowledgements

Dirección General de Educación Superior Tecnológica (DGEST), reference 072007004 - E.A. from México and financial support received through the research Project EHMAN (DPI2009-09386) funded by the European Union (European Regional Development Fund ERDF) and the Spanish "Ministerio de Ciencia e Innovación" is fully appreciated.

References

Klein, M., Fensel, D., Kiryakov, A., and Ognyanov, D. , 2002, Ontology versioning and change detection on the web. In 13th International Conference on Knowledge Engineering and Knowledge Management , 197–212.

Kondili, E., Pantelides, C., and Sargent, R., 1993, A general algorithm for short-term scheduling of batch operations–i. milp formulation. Computers & Chemical Engineering, 17, 211 –227.

Lainez, J. M., Kopanos, G., Espuña, A., and Puigjaner, L., 2009, Flexible design-planning of supply chain networks. AICHE JOURNAL, 55, 1736–1753.

Lasschuit, W. and Thijssen, N., 2004, Supporting supply chain planning and scheduling decisions in the oil and chemical industry. Computers & Chemical Engineering, 28, 863–870.

Muñoz, E., Capon-Garcia, E., Moreno-Benito, M., Espuña, A., and Puigjaner, L., 2011, Scheduling and control decision-making under an integrated information environment. Computers and Chemical Engineering, 35, 774 – 786.

Muñoz, E., Espuña, A., and Puigjaner, L., 2010, Towards an ontological infrastructure for chemical batch process management. Computers & Chemical Engineering, 34, 668–682.

Varma, V. A., Reklaitis, G. V., Blau, G. E., and Pekny, J. F., 2007, Enterprise-wide modeling & optimization – an overview of emerging research challenges and opportunities, Computers & Chemical Engineering, 31, 692–711.