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Integration of a multilevel control system in an ontological information environment

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Abstract

In the domain of chemical process engineering management, there are many specialists working together at different levels of decision-making. This work focuses on improving computational tools and models required in order to make robust decisions based on high quality information, with specific application to batch processes. The informatics system and the user interface developed to support robust and informed decision making is proposed. A basic ontological framework developed previously (the Batch Process Ontology (Muñoz, et al. 2009)) is extended to consider additional decision levels, as well as further solution strategies involving overall objective functions and control actions. Regarding to the Ontological framework developed, the emphasis is in simultaneously achieving high degrees of usability and re-usability. Preliminary results are presented and discussed.
Keywords: Ontology, Knowledge sharing, Knowledge management, Decision support systems.

1. Introduction

Decision Support Systems (DSS) are directly or indirectly related to manufacturing indicators, like economic efficiency, product quality, flexibility, reliability, etc. Global competition has made essential for the viability of the enterprise the use of such DSS, and the need for development of new tools to integrate the different time and scale levels involved have been highlighted.

The first requirement to achieve such integration is to define standardized information structures and more sophisticated information tools to exploit them, in order to improve the availability and communication of data between different decision levels and also the models behind the corresponding decision support tools. In this framework, the role of infrastructures that continuously and coherently support fast and reliable decision-making activities related to the production process is now of paramount importance (Venkatasubramanian et al., 2006). The use of an ontology is proposed, as a formal specification, that is a body of formally represented knowledge based on conceptualizations, which are abstract, simplified views of the physical or procedural elements.

The ontology elements should be part of the model intended to represent a system for some purpose, managing the relationships that hold among the elements of the model, allowing this model to be usable (Gruber, T. et al 2008). On the other hand, reusing ontologies is far from being an automated process. It requires not only consideration of the ontology, but also of the tasks for which it is intended. The key for the presented ontology reusability is that it lies on the basis of the standard ANSI/ISA 88 (International Society for measurement and control, 2001). In general, this standard should facilitate building larger, better and cheaper systems. It should also lead to a greater dissemination of these systems.

2. Ontological model

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). As it is well known, the design, construction and operation of chemical plants are considered the major engineering activities (Morbach et al., 2009) and, in this way, the ontological framework model should not only represent the terminology, but also the entire domain of chemical engineering processes, with a particular attention to the integration of control activities at different levels.

Therefore, on the one hand the ontology intends to resolve eventual terminological confusions, since one of its commitments is to guarantee the consistency with respect to queries and assertions using the vocabulary defined in the ontology. Also, it relates the different mathematical models within the system, showing the correspondence that there exist among them. The aim of this relation allows the enrichment of models and the flow of information for future decision making.

The proposed ontological model lies in the ANSI- ISA 88 standard that describes the entire scope of manufacturing activities. It provides a framework that an engineer may use to specify automation requirements in a modular fashion. In addition, the ontological model can be used for integrating batch-related information with Manufacturing Execution Systems and Enterprise Resource Planning Systems.

The description and models of the different functional decision levels that exist in companies helps to diminish in some way the hurdles that are present in the coordination and integration between these levels. The way of accomplishing this is by using the different models (i.e. those founded in the ANSI- ISA 88 standard). These models are: i) The physical model, which defines the hierarchy of equipment used in the batch process, providing the means to organize and define the equipment used in the process, and ii) The procedural model, which describes the strategy that enables the equipment in the physical model to perform a process task; it is defined as multi-tiered (hierarchical), and composed of different elements (Williams, T. J., 1989). Both the procedural and physical models are related each other by means of the recipes: a recipe consists for the set of information that uniquely defines the production requirements for a specific product. One of the most significant contributions that the standard offers to batch manufacturing is the separation of the recipe procedure and the equipment control logics.

3. Development of software architecture

The proposed informatics system allows the utilization of the ontology as a common model between actors, thus facilitating the communication and knowledge reuse among them. Even more, due to the current lack of integration between the different control levels (Purdue Reference Model) the ontology eases the decision support task by providing knowledge integration among decision layers.

The architecture of the proposed Ontological framework is based on BaPrOn (batch Process Ontology) described in Muñoz et al. 2009. One of the major requirements considered for this software architecture is that the system should be constructed in an open source, modular fashion (Horridge, M. et al 2007). In this way this ontology could be considered as nominal ontology and high ontology as well, taking into account the factors that influence the complexity, such as concepts, taxonomy, patterns, constraints and instances. The software Protégé was used for the generation of the ontological model using OWL (Ontology Web Language). The OWL language has the expressive power needed to represent the different domains of the solution we want to explore. This unifying aspect, for instance, may make it easier to establish, through collaboration and consensus, the utilitarian vocabularies (e.g. ontologies) needed for far-flung cooperative and integrative applications using the Word Wide Web and internal servers.

4. Background

The main objective established for development of this system was to promote the capacity to integrate different perspectives (i.e., different hierarchical decision levels) and the mappings between them. In this sense, the proposed Ontological framework contemplates the enterprise control system integration, where processes are categorized, the relationships between them are examined and imposed, and the properties that aim at specifying the aforementioned relationships are introduced.

4.1. Technological architecture

The application development is based on the MVC (model view controller pattern). The MVC proposes the identification and classification of the application functionalities in three different layers: model, control logic and user interface. These layers are clearly separated between them allowing the easy implementation of new features. Besides, this architecture facilitates the scaling of the infrastructure.

4.1.1. View layer

The view layer represents the page design code and manages the interaction with the final costumers, delivering the information in different formats. For the implementation of this layer, the Apache Struts framework (Holmes, J. et al 2004), which is an open source for creating Java web applications, has been used.

4.1.2. Control layer

The control layer includes the navigational code. A controller accepts input from the user and instructs the model and viewport to perform actions based on that input. So, the controller is responsible for mapping end-user actions to application responses.

4.1.3. Model layer

4.1.3.1. Business layer

In the business layer, also known as the domain layer, the programs are running. This layer communicates with the view layer, to receive requests and present the results, and with the data layer, to store or retrieve data from the database manager. Its logic usually corresponds to the software engineering practice of compartmentalizing, and is usually one of the tiers in a multitier architecture.

4.1.3.2. Data and Access layer

Data and access layer is where data resides and is responsible for accessing them. It consists of one or more database administrators to perform all data storage, receiving requests for storing or retrieving information from the business layer.

For this layer the Hibernate (Linwood et al., 2010) framework has been used. Hibernate facilitated the storage and retrieval of Java domain objects via Object/Relational Mapping. Today, Hibernate is a collection of related projects enabling developers to utilize POJO-style domain models in their applications, extending well beyond Object/Relational Mapping.

4.2. Software system

The Java platform has been used as a high-level programming language because it presents a good versatility, efficiency and security. In addition, Java code can run on most computers because Java interpreters and runtime environments, known as Java Virtual Machines (VMs), exist for most operating systems. Another key factor in the choice of Java is the fact that the ontological classes can be easily adapted (translated) into Java classes for the client's web use through the interface as it is shown in Figure 1. In this way, the easy development and future propagation of the software will be done as open source, meaning that it can be easily adapted to any process plant requirements. The application of the ontological model takes place inside the business layer.

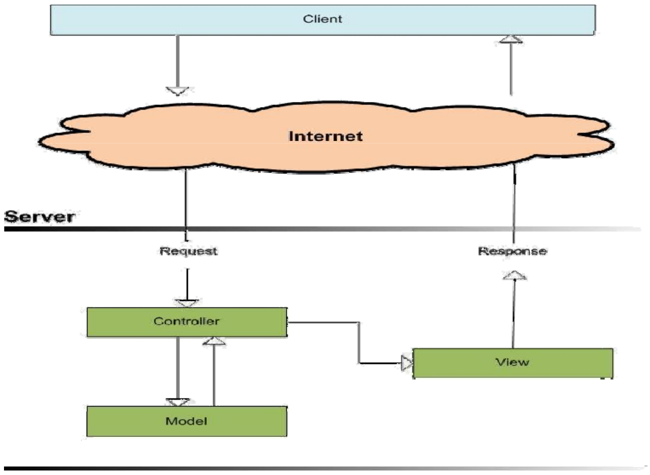

Figure1. Software system architecture

5. Results and Performance

Inside the domain of scope of manufacturing activities modeling, a business layer has been implemented to encompass the integration of the planning and the control tasks by means the standard ANSI/ISA 88. Each task process a XML recipe which contains the necessary information and data for the process performance. Once these recipes have been processed by an external application, they are sent to the next process stage acting as a path of the flow of information. Finally, the control and monitoring data can be saved in a database and, at the same time, sent to the planning level if this was required. The applications of planning and control include a Case Base Reasoning (CBR) method, to collaborate in the decision making task. At the same time this CBR helps in the information recovery, acting as a cache or reusing the data information.

The use of this software system improved communication and coordination procedures at the Planning-scheduling level and the control- monitoring level. Besides, there was an enhancement of reactivity in the system to incidences from different sources and levels.

6. Conclusions

A new supporting tool to coordinate and optimize the information flow among decision levels has been developed, in order to facilitate the decision making task. It makes use of a previously developed ontological framework through a friendly user interface.

Specifically, the ontological framework is adopted to represent the reality among different decision levels and establish a common model. As a result, several challenges prompted by integration are addressed: modularity, data availability, standardization, a more effective handling of disturbances and an efficient information flow. Jointly, they enhance the access to information, enriching its meaning by incorporating knowledge description. Furthermore, the benefits of the implementation of the framework (software system) include improvements in the way that data and information are managed at the different decision levels.

It is well known that it is difficult to simultaneously achieve high degrees of usability and reusability. Usability implies specialization to a particular task, whereas reusability requires genericity in order to be applicable in different contexts. However, the basis of this work lies down on the ANSI/ISA-88 standard as the base of the domain representation, moving the usable and reusable trade-off to new opportunities in its application. What is more the, easy adaptation to process plant requirements proved the framework usability.

The improvement on systems integration is achieved trough enhanced communication and coordination procedures. Reactivity to incidences was also achieved from different sources and levels of decision.

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