An Industrial Knowledge Reuse Oriented Enterprise Modeling Framework for Enterprise Management Information Systems

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Abstract. Existing enterprise modeling architectures can not provide effective support on expressing and reusing industrial knowledge. Industrial knowledge reuse oriented enterprise modeling for integrated management information systems (MIS) should be located between general purpose enterprise modeling and concrete enterprise application scheme, and an enterprise modeling framework for integrated MIS which is industrial knowledge reuse oriented is put forward in this paper. In this framework, a new lifecycle dimension was constructed by extending traditional lifecycle dimension and combing the multiple views mechanism of ARIS, knowledge reuse dimension was introduced to support the modeling and reusing industrial knowledge, and the language, methodology and tools dimension was introduced to express the sets of languages, methods and tools used in constructing, validating, maintaining and evolving enterprise models. Finally, the cement production industry was adopted as an example to illustrate how the framework can be employed to guide the reuse of industrial knowledge.

Keywords: *Knowledge management, Enterpriser model, Enterprise Resource Planning (ERP)*

1. INTRODUCTION

Enterprise model is a tool used to describe enterprise knowledge from multiple views, which provides a general problem-solving schema for enterprise repetitive problems under certain settings [1]. There are many famous enterprise model or enterprise reference architecture in the world, for example CIMOSA [2], PERA [3], GERAM[4], etc. Enterprise informatization practice shows that successful implementations of enterprise information systems can be expected and knowledge accumulation for specific industries can be realized [1]. Nowadays, successful enterprise informatization projects are still rare. We think one of main reasons is that the industry knowledge reuse enterprise modeling theory and implementation methodology has not given enough attention. Research on enterprise reference architectures which are industry knowledge reuse oriented is still deficient. In China, several national high-tech (863/CIMS) and national science projects aiming at building industry-specific enterprise reference models were launched. However, the research outcomes in this domain are still rare.

This paper studied on industry knowledge reuse oriented enterprise modeling framework. The main contribution is that an enterprise modeling framework for integrated MIS which is industrial knowledge reuse oriented was advanced and each components of this framework were analyzed.

2. LIMITATIONS OF EXISTING ENTERPRISE MODELING FRAMEWORKS

During the last decade, the information and telecommunication technology advanced dramatically. The external and internal environments enterprises faced have changed. The management theories and methodologies on which traditional enterprise reference architecture depended have evolved [1]. We should rethink about existing enterprise modeling frameworks. Several limitations of them are given below:

1. Generally, existing enterprise modeling architectures provide general frameworks and methodologies for enterprise engineering and enterprise integration, which can not provide sufficient support for industry-specific enterprise informatization engineering. For instance, in instantiation dimension, the division of generic and partial components was too generalized, which degraded the ability of modeling and reusing industry-specific knowledge.
2. Existing enterprise modeling architectures provide a group of static views aiming at single enterprise, which can not meet the needs of enterprise integration at different levels such as information integration, resource integration, business process integration and integration among enterprises.
3. The lifecycle dimension in existing enterprise modeling architectures generally was divided into three phase, namely, requirement definition, design and implementation, respectively. The lack of evolvement phase in most existing enterprise modeling architecture make it unable to be used to guide the continuous improvement and maintenance of enterprise information systems. Meanwhile, most existing enterprise modeling architectures have not provided modeling mechanisms for automatic modeling conversion and execution, thus can not meet the needs of managing models and systems during the maintenance phase.

3. POSITION OF INDUSTRY KNOWLEDGE REUSE ORIENTED ENTERPRISE MODELING FOR INTEGRATED MANAGEMENT INFORMATION SYSTEMS

The position of industry knowledge reuse oriented enterprise modeling should be located between generalized enterprise modeling and customized enterprise modeling (see Figure 1). It is not to put forward a brand-new enterprise reference architecture, but to revise existing general enterprise reference architecture to highlight the reuse of industrial knowledge at each stage in lifecycle dimension. Typical characteristics of industry knowledge reuse oriented enterprise modeling architecture are such as strong industry pertinence which means that the reference architecture for target industry (or family of industries sharing large quantities of similarities) can be reused in concrete enterprises belong to same industry readily, version based evolvement mechanism which means that sound industrial knowledge can be inherited, accumulated and reused for future versions. Obviously, this kind of industrial knowledge reused oriented enterprise modeling architecture is intend to offer a mechanism and methodology to realize knowledge reuse by means of abstracting managerial characteristics of target industry and reusing application solutions of all kind components (e.g. various generators, functions, subsystems, and related documents) which can be used in most different industries. Therefore, this architecture is very helpful to accelerate the popularity of mass customization of enterprise MIS systems. Here customization is industry oriented and version based.

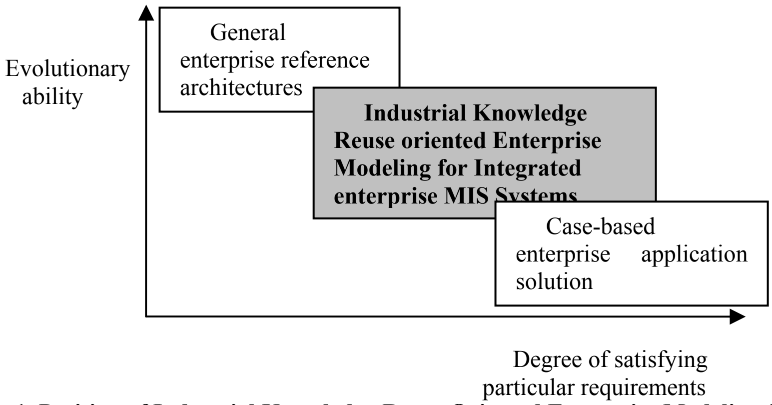

Figure 1. Position of Industrial Knowledge Reuse Oriented Enterprise Modeling for Integrated Enterprise Management Information Systems

4. AN INDUSTRIAL KNOWLEDGE REUSE ORIENTED ENTERPRISE MODELING FRAMEWORK FOR ENTERPRISE MANAGEMENT INFORMATION SYSTEMS

Based on above discussion, we present an industry knowledge reuse oriented enterprise modeling framework for integrated enterprise management information systems (MIS) (see Figure 2).

This framework emphasizes the roles in guidance of constructing and implementing industry specific enterprise information systems played by enterprise reference models, which is achieved by absorbing the advantages of multi-views and multi-dimensional enterprise modeling methodology, meanwhile considering the needs of knowledge reuse, especially software assets based systematic knowledge reuse. Compared with other traditional enterprise reference architectures, there are mainly three enhancements. First, this framework revised the dimension of stepwise particularization into knowledge reuse to accentuate the important roles of this dimension in realizing industrial knowledge reuse. Second, the lifecycle dimension in traditional enterprise reference architectures was extended by integrating multi-views modeling mechanism in which process view as the central view and worked in harmony with other views. Thirdly, the language, method and tool dimension was introduced to express the toolsets used to build, verify, maintain and evolve enterprise models.

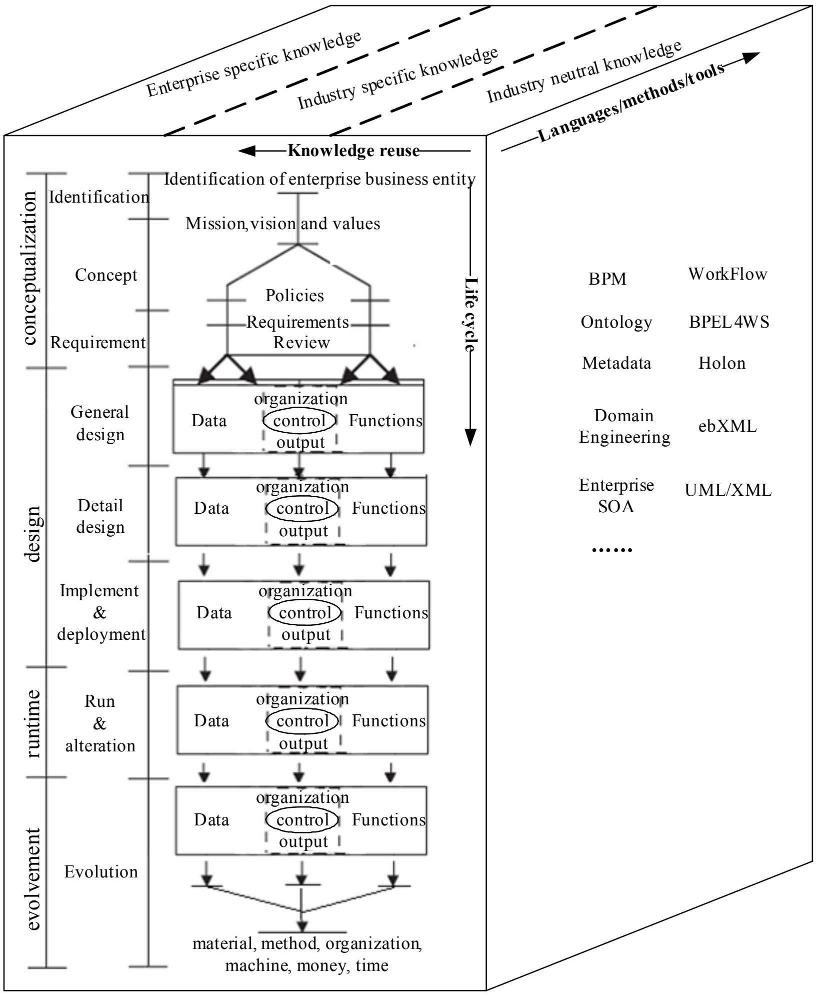

Figure 2. An Industrial Knowledge Reuse Oriented Enterprise Modeling Framework

4.1 Lifecycle Dimension

Life cycle is time dimension of the integrate enterprise modeling framework, which can be further divided into four sections: conceptualization, design, runtime and evolvement. There are several stages at each section. Generally, the outputs of one stage can be the input of the next stage, and continuous optimizing activities occur at each stage. When necessary, new tasks should be added at each stage in order to satisfy the reuse of industrial knowledge. Activities of each stage are discussed briefly blow.

1. Identification. Objects involved in knowledge engineering activities, such as entities, their boundary, external environments, etc, are identified, described and documented. Typical entities are enterprises, departments, teams, products and materials.
2. Concept. The entities obtained at identification stage are generalized to form concepts, which may involve the setup of domain of characteristic values. Typical characteristic value type is missions, visions, values, strategy, tacit, etc.
3. Requirement definition: At this stage, operating requirements for various entities are extracted and their feature sets are built. This task can be achieved along two threads. One is on the main outputs of target enterprises, usually involving products, services or both. The other is on management and control activities. Industrial feature sets involve many elements such as enterprise entities functions, behaviors, information, capabilities, strategy policies, etc. As to industries without industry reference models, the requirement definition documents may be built on the analysis of group of case enterprises belong to same industry or industries sharing large quantities of similarities.
4. General design. At this stage, a general schema for target industry is formed at a top level. The business components logically enabling enterprise systems belonging to target industry or industries are specified. Similar to general design stage of software engineering, the components' hierarchy, their interfaces and constraints are emphasized, while the internal logic of components are ignored at this stage.
5. Detail design. At this stage, the customizable, industry specific reference models are acquired by refining the general schema produced at previous stage. The industry specific models are the most important knowledge carriers which can be reused on many occasions. For instance, during the construction of industry specific enterprise management information systems, the analysis and design time can be reduced dramatically and the design quality can be guaranteed by reusing industry specific models of high quality. On the other hand, when applied in enterprise management information system implementation projects, industry specific reference models will be very helpful because enterprise specific models can be acquired easily by customizing relative industry reference models.
6. Implement & deployment. This is in fact a process of configuring and reengineering enterprise knowledge systems, which involves all kinds of knowledge engineering activities, such as combination of existing knowledge features and structures, knowledge finding, reference model configuration and customization, etc. According to the trend of software reuse and the ideas of model driven architecture, we think implementation and deployment is in fact a process of modeling because formal models are general be ready to execute.
7. Run & alteration. At this stage, IT system as an important enabler system is linked to enterprise entities tightly. IT system is used to accelerate information process and transmission in products and service processes provided by enterprises. When enterprise requirements change, if necessary, the enterprise model instance

embedded in IT system is altered and matched automatically to keep effective, which means the self-study and self-alteration mechanism should be provided in enterprise reference model library. The assimilation of new knowledge and evolvement of existing knowledge mechanism is indispensable at this stage.

8. Evolution. There is no evolution stage in most of existing enterprise architecture such as CIMOSA, Purdue, GERA, etc. The reason of introducing this stage is that generally enterprise information systems have long lifecycle and alterations and evolutions of information systems are indispensable. Enterprise models, enterprise management information systems, enterprise knowledge on enterprise modeling and enterprise models, have in essence is dynamic and evolutionary. Evolution stage concentrates on the management of industrial knowledge revision and maintenance. Evolution is made up of continuous and repetitive processes. Each process enriches existing enterprise modeling knowledge. Knowledge management at this stage is also version-based.

Another important enhancement in lifecycle dimension is that the multi-views are integrated, which greatly strengthen the modeling ability and operability of lifecycle dimension. Firstly, the traditional lifecycle dimension of ARIS was extended and the conceptualization section was refined. The refinement of conceptualization section makes it operable to acquire and share industrial knowledge. Secondly, modeling objects are extended to encompass manufacturing resources and production controls thus can meet the needs of information integration in enterprise job shop level. Thirdly, by integrating ARIS views into lifecycle dimension, the outputs at one stage can refining and evolve continuously at next stage, which means that the evolvement management on enterprise model has more operability.

To meet the needs of enterprise modeling for integrated information systems, modeling emphasis should be put on both the static enterprise entities (e.g. data, functions, organization, and outputs) and dynamic business process description. Enterprise information system logically incarnates material, information and finance flows of real enterprise. We think resources managed by MIS can be classified into five categories: organization related (e.g. employee, customer, supplier, team), material related (e.g. product, raw material, work in process product), machine related (e.g. workshop, device), method related (e.g. product process), money related (finance management), time related (e.g. factory calendar). During industrial knowledge reuse oriented enterprise modeling activities, the modeling on material information should be given enough attention. The organization and operation pattern of an enterprise usually relates with features of products and raw materials at great degree. Besides, the primary and secondary processes can be easily identified when attention was paid to products and materials related features and processes.

4.2 Knowledge Reuse Dimension

Knowledge reuse dimension serves the process of knowledge aggregation and reuse activities, which is the spatial dimension of enterprise modeling framework. There are three levels in this dimension.

1. Industry neutral knowledge level

There are many similarities exists in organize pattern, business domain, product organization among different industries. Naturally, industry neutral knowledge can be built by mining and generalizing knowledge commonly used in different industries. This level is made up of basic elements of enterprise modeling architecture, mainly the basic modeling components produced at different stages and model constraints, rules, glossary, services and protocols.

From semantic angle, the knowledge forms maybe industry neutral components, such as MRP (material requirement planning) computing component, BOM (bill of material) components, document component (e.g. invoice, contract, and order), calendar component, etc.

2. Industry specific knowledge level

On the basis of reusing and refining industry neutral knowledge, this level produces industry specific reference models. What this level concerns most is the expression and encapsulation of industry specific knowledge, and the outcome of encapsulation is usually the industrial components for different business domains. This level is aiming at different sub-industries belong to manufacturing industry, such as textile, mechanical manufacturing, medicine, food production, petrol and steel industry etc. Sometimes certain industry need to be further divided into smaller industries, thus industry tree occurs.

3. Enterprise specific knowledge level

What concerns most at this level is enterprise models for concrete enterprises, which are usually constructed by reusing and customizing relevant industry reference models. Knowledge about enterprise individualities at this level can be refined, generalized and transformed during knowledge evolvement cycle.

Industry neutral knowledge level and industry specific knowledge level sometimes are called industry reference model level, which is key points to implementing enterprise model knowledge reuse due to the fact that reference model level is built on aggregating and abstracting common enterprise requirement features from many enterprise informatized engineering projects. Industry reference model can be reused widely in business optimization, production plan, manufacturing control, etc., in enterprise engineering project. Shorter enterprise modeling time, higher modeling quality can be obtained by reusing industry reference models effectively.

4.3 Languages, Methods and Tools

In order to maximize the industrial knowledge reuse, we think three research fields should be paid close attention. The first is model driven architecture (MDA)[5], which offers a novel approach to solving the contradiction between the increasing complexity of enterprise applications and higher customer expectance. According to MDA theory, all kinds of models, especially those described formally, are in fact the most important reusable knowledge assets. The modeling process is also the application development process. Therefore, when combined with systematic software reuse methods, process and management practice knowledge, will be very helpful to guide the process of customization, reconfiguration and evolution of industry oriented management information systems. The second is domain engineering (DE)[6], which is the activity of collecting, organizing, and storing past experience in building systems or parts of systems in a particular domain in the form of reusable assets (i.e. reusable work products), as well as providing an adequate means for reusing these assets (i.e. retrieval, qualification, dissemination, adaptation, assembly, etc.) when building new systems. We think the industry reference models which incarnate industrial knowledge can be built by means of applying domain engineering in target industry (or similar industries). Actually, domain specific software architecture (DSSA) and other reusable components are important knowledge assets which usually have definite industry orientation. Furthermore, when considering the combination of domain engineering and enterprise service oriented architecture (ESOA), the more flexible, reusable industrial knowledge and the more agile IT solution for target industries can be achieved in theory. The third is about ontology. Ontology can be defined as an explicit formal specification of the terms in the domain and relations among them [7]. In the context of enterprise application, enterprise ontology refers to a set of glossary and definition related to enterprise businesses. From the angle of knowledge sharing, enterprise ontology can act as an ideal communication medium between different people and enterprise applications. We think well defined enterprise ontology can be a good start to build information view which is a part of enterprise modeling framework, which will promote the industrial knowledge reuse greatly.

5. CASE STUDY

The industrial knowledge reuse oriented enterprise modeling framework was used in the CIMS project of Pan-gu cement production enterprise group. By maximizing process industry knowledge reuse in cement enterprise informatization project, we finished project analysis and design, application system selection and system implementation with high quality.

The significance of the framework presented in this paper in prompting cement enterprise informatization was in three aspects. The knowledge reuse dimension was used to aggregate and reuse knowledge of cement industry, the lifecycle dimension was used to process management and control in the whole life of cement industry informatization engineering, and the languages, methods, and tools dimension provided expression methods and supporting tools for knowledge representation, reuse and management. Here, we put the emphasis on applying knowledge reuse dimension in overall solution for cement industry informatization.

According to industrial knowledge, we did not develop an overall solution from scratch, but from reusing and customizing existing industrial knowledge assets, such as general solutions for manufacturing industry, process industry reference framework, etc. The cement production industry can be regarded as a process industry, which has typical features of process industry. There are some typical features of process industry, for example, many kinds of sensors such as sensors for detecting temperature, pressure, location, velocity are widely used in production process; requirements of collecting, processing and visualizing data on line are very common; multiple systems coexists including automatic systems at device level, process control systems at job shop level, management information systems at business operating level; information integration requirements among different systems are urgent. Based on our industrial knowledge reuse framework, by means of maximizing reusing existing process industry knowledge, we advanced a reference framework for cement industry informatization, which are divided into five levels (See Figure 3).

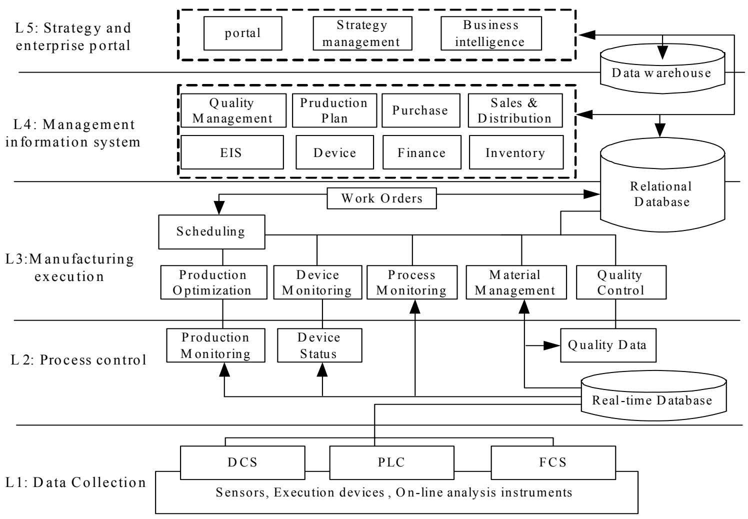

Figure 3. A Reference Framework for Cement Industry Informatization

1. L1: Data collection level. This level is composed of infrastructure systems such as distributed control system (DCS), programmatic logic control systems (PLC), etc, which collects control information from production fields. By installing relating sensors and on-line analyzing devices at target sites, real-time data about production process can be collected and then stored in real-time databases.
2. L2: Process control level. What this level concerns is the optimization of working operation and device control. This level accepts instructions from manufacturing execution level, dissolves them into concrete control instructions and passes them to control devices at data collection level. Device operating status and production data collected at data collection level is passed to manufacturing execution level via process control level.
3. L3: Manufacturing execution level. This level is the key to integrating enterprise management information systems and production control systems. Compared with management information system level, what this level concerns are production field resources, such as device utilization, production process, work in progress, etc. Some typical functions of this level are accepting work orders from management information systems level, scheduling and monitoring order execution activities, allocating device resources, and feeding information about resource utilization and inventory level back to management information system level.

4. L4: Management information system level. Most of modules (e.g. purchasing management, sales management, human resource management) in typical management information systems (e.g. enterprise resource planning, ERP) can be reused in cement industry. Some modules, e.g. quality management, device management, production plan, material management, need to be enhanced or reengineered when used in cement industry.
5. L5: Strategy and enterprise portal level. The aim of this level is to deepen the informatization of cement industry. Typical modules are business intelligence, e-commerce, etc.

6. CONCLUSIONS

This paper think that researches on industrial knowledge reuse oriented enterprise modeling provides a promising approach to solving problems such as low industry pertinence, high complexity of information system, too long implementation cycle, etc, which commonly exist in commercial general purpose enterprise management information systems. Based on the analysis on existing enterprise reference architecture, this paper advanced an industrial knowledge reuse oriented enterprise modeling framework for integrated information system, and gave a case study in cement industry. Our research indicates the industry specific information modeling and informatization can be improved greatly by maximizing the reuse of industrial knowledge.

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