REFERENCE MODELS FOR INTEGRATED DESIGN CHAIN NETWORK

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ABSTRACT *: New product "time-to-market" is the critical success factor today. The core competitiveness to survive severe and dynamic business environment comes from the capability of well-defined design-chain over enterprises that are related with the product, not the capabilities of individual enterprises. The collaboration in design-chains, however, is difficult due to the inherent complexity such as different design process patterns of each enterprises and the dynamic nature of design environment. To settle the collaboration problems in the design-chains, a frame-based approach, design-chain collaboration network(DCCN) is proposed in this paper. The DCCN is composed of three reference models capturing the different views of design-chain collaboration: design process reference model(DPRM), service component reference model(SCRM), and technology and standard reference model(TSRM). As the DCCN adapts the OMG's metadata architecture, the processes in design-chain can be extended according to the perspectives of collaboration with participants. Using the proposed network, managers of design group can integrate their internal and external design processes from conceptual phase to applications development phase with their participants. The DCCN can serve as a virtual basis to improve design processes immediately and continuously in order to enable collaboration and to breed innovation.*

KEY WORDS *: Design-Chain network, Frame-Based Approach, Reference Model*

1. Introduction

As products today have ever shorter lifecycles and they have also an unprecedented number of features and user preferences, the mass production is being replaced by the mass customization. As a result, "time-to-market" is the key success factor in new product development(O'Marah, 2002). Hence, enterprises must combine their core capabilities with other enterprises' core capabilities. Any enterprises no longer design complete products by themselves. This means that the competitive power in market has moved from individual enterprises to entire value-chains(Cadence Design Systems, 2003).

For the development and introduction of new products in market, the traditional design-chains consist of closed-chains of a few oligopolistic enterprises. This causes the higher entrance barrier to many unspecified enterprises which want to participate in the design-chains. This also causes the lack of agility to adapt themselves to the rapid changes of business environment. These problems can be solved by operating collaborative design-chains that consist of open-chains for many unspecified enterprises. To implement this collaboration, the integration of different processes of participants in the design-chain is indispensable.

The obstacles to the collaboration of design-chains stem from the characteristics of design-chain processes such as frequent and iterative feed-backs, content-dependent and resource-dependent processes, and many unspecified participants. The problems also stem from the limitations of the traditional process modeling methodologies(Harmon, 2003) that are too generic for a specific type of process, and lack of common terminology and performance metrics. They are designed by and for process specialists, not for process managers.

Designing and bringing products to market quickly and predictably are critical elements for success. To solve the above problems, some clues can be found in various information technologies which are needed to be integrated on a virtual basis - a network. Reference models describing the processes in a specific business domain can be a useful tool to this network(Harmon, 2003). In this paper, a net work is proposed describing how processes are represented and integrated for design-chain collaboration using reference models.

2. Related Works

There are a lot of efforts to realize the collaboration of product development such as CPC (Collaborative Product Commerce) and PLM(Product Lifecycle Management). These approaches consider the total lifecycle phases of a product from identification to decommission. They embrace the product-design, -development and -introduction processes as well as the associated management of product data, and require a coalition of internal and external constituencies. So they are complex process area and far-reaching initiatives yet.

The effect of the design phase during a new product development is very important because more than two-thirds of all product lifecycle cost is determined during the key conceptual design process. Although design accounts for only 5% of total costs under traditional cost accounting methods, it influences on 70% of total costs during lifecycle. In other words, the majority of total lifecycle costs are influenced during the crucial design phase (True & Izzi, 2002). To address the collaboration problems in product development, the proposed DCCN focused on the processes in design phase from the mission statement to the production lamp-up as described in section 3.

In the proposition of design process reference model, the common and key design processes across the enterprises are considered and abstracted to represent the high level of design processes. In this paper, the high level of processes means that the participants can understand the same semantics about the processes and interoperate with other participants. The low level of process means that the processes are different from participant to participant so that these processes are left to executable level. In fact, groups that have a time constraint but that still want to use consensus decision-making can adopt a 70/30 rule, that is, only the 70% can reach a consensus on a shared understanding for collaboration (Rebori, 2000). This rule makes sense when an enterprise adapts an approach to the collaboration with participants. In this perspective, the proposed DCCN is a so called frame-based approach (Harmon, 2003) such as SCOR(Supply-Chain Operations Reference model) (SCC, 2003).

SCOR, however, provides what processes should be accomplished and does not suggest how the processes can be implemented to interoperate with participants, though it guides best practices. The reference models in the DCCN provide templates for design processes as well as software components and enabling technologies for implementation and execution of the required design processes. In addition, SCOR has the limitations on the expansion to other value-chains and on the translation to different modeling languages.

3. Design-Chain Collaboration Network (DCCN)

The proposed DCCN takes the advantages of OMG's metadata architecture(OMG, 2002) for the model extension mechanism, the validation of well-formedness of models, and the mapping and transformation of model elements with other value-chains. DCCN also takes the advantages of frame-based approach(SCC, 2003) for the domain specific semantics and the performance metrics as well as the reference models(FEAPMO, 2003a, 2003b, 2003c) for the multiple-layered structure and the independency between reference models. The overview of DCCN is shown in Figure 1.

The interoperability of DCCN has different meanings in each layer according to the perspective of collaboration with participants using different modeling languages in a design-chain or other value-chains. In meta model layer(M2), the interoperation means *translation*, that is, the semantic mapping between the construction concepts of different modeling languages. This can serve as a basis for interpretation about process models written in different modeling languages. In model layer(M1), the interoperation means *transformation*, that is, the syntax mapping of the process models written in different modeling languages. In data layer(M0), the interoperation means *conversion*, that is, the data transition of process instances in run-time. The DCCN should be extended to connect to other value-chains for business development of an enterprise(Harmon, 2003).

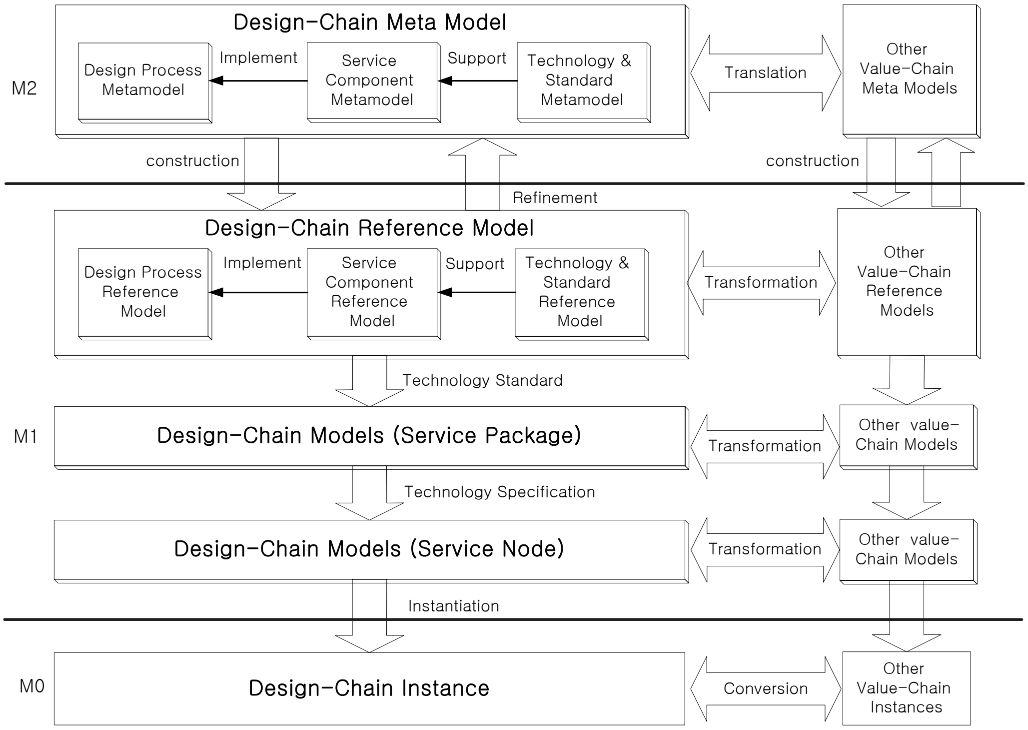

Figure 1. Overview of Design-Chain Collaboration Network

4. Design-Chain Meta Models

The meta model defines the essential elements, syntax, and structure of models that are used to construct object-oriented models of discrete systems(Poole, 2001). The meta model layer (M2) in DCCN contains the meta model (model of the model) describing the concepts and relationships of the constructors for the modeling of reference models as shown in Figure 2.

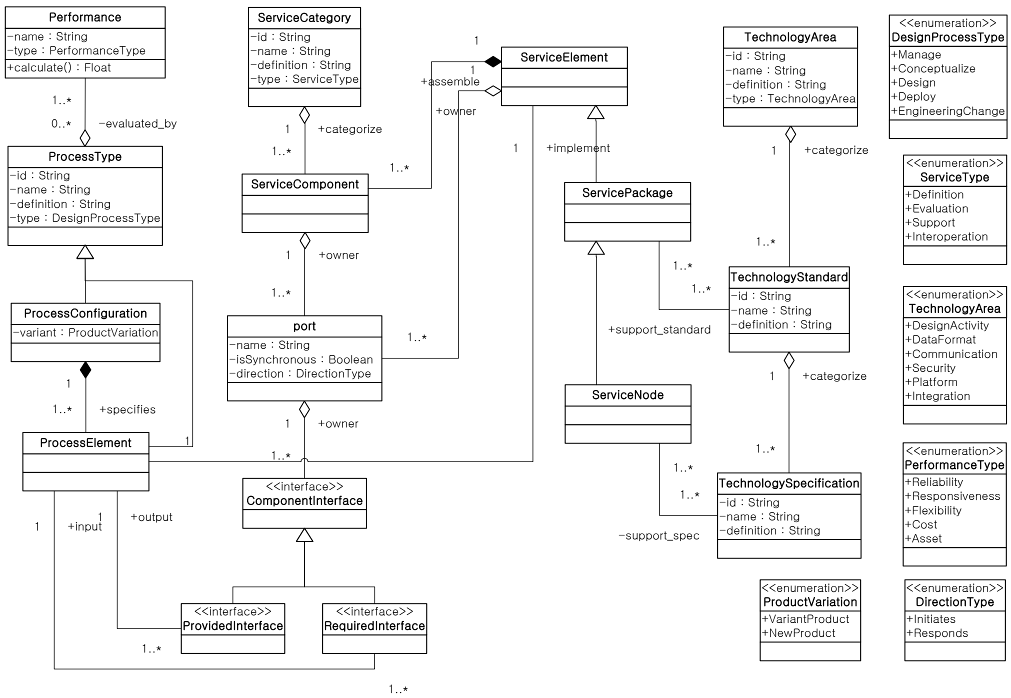

Figure 2. Design-chain meta model

The design-chain meta model allows interchange of metamodel and corresponding models in the design-chain or in the other value-chains, and enables automatic generation of model schemas such as DTDs, so it can breaks the wall between incompatible tools, repositories and applications.

5. Design-Chain Reference Models

The proposed network is composed of three reference models capturing the different views of design-chain collaboration : design process reference model(DPRM) captures design processes of enterprises for the collaboration of product development, service component reference model (SCRM) captures service components implementing the design processes, and technology and standard reference model(TSRM) captures technologies and standards supporting the service components. Each of the reference models has multiple layered structures, as shown in Table 1, and is independent to each other.

Table 1. Hierarchy of Design Chain reference models

Level	DPRM	SCRM	TSRM
1	Process Type	Service Category	Technology Area
2	Process Configuration	Service Component	Technology Standard
3	Process Element	-	Technology Specification

5.1 Design Process Reference Model (DPRM)

The DPRM captures the common design processes over enterprises for the collaboration of product development. The *process type* describes the scope of design-chain and the role of each participant. The DPRM has five process types: CP(conceptualize) for concept development, DS(design) for system-level design, detail design, test and refinement, DP(deploy) for production ramp-up, as compared to the traditional product development pahses(Ulrich & Eppinger, 1995), as well as EC(engineering change) for product modification and MG(manage) for management of processes. The *process configuration* is the specialization of the process type and describes the variants of design scenarios such as the development of variant product or new product. The *process element* is the decomposition of each process configuration into design tasks. The DPRM includes the performance metrics in each level for the evaluation of process execution. A fragment of DPRM is shown in Figure 3.

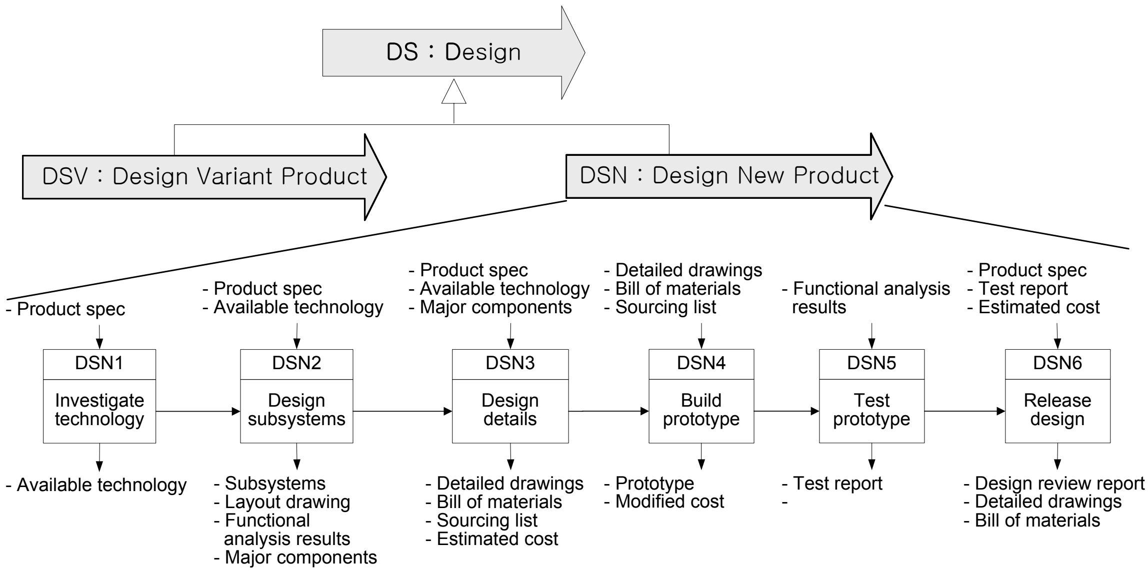

Figure 3. A fragment of DPRM

5.2 Service Component Reference Model (SCRM)

The SCRM describes service components implementing the design processes. The proposed SCRM extends the generic design activities(Sim & Duffy, 2003) to support the required activities for design-chain collaboration. The *service category* is the grouping of service components. The SCRM has four services categories: definition, evaluation, support and interoperation. The *service components* are the logical building blocks that assembled together to implement the process elements in DPRM level 3.

To bridge the DPRM and SCRM, the concepts of *service package* and *service node* are introduced in the proposed DCCN. Both concepts specify the assembly of service components to implement a specific process element. The participants can use their own application so long as the required interfaces and the provided interfaces are coincided. The difference between the two concepts is that the service package is specified by technology standards to represent the platform independent model(PIM), on the other hand, the service node is specified by technology specifications to represent the platform specific model(PSM) of model driven architecture(OMG, 2002). An example of service package implementing a process element is shown in Figure 4.

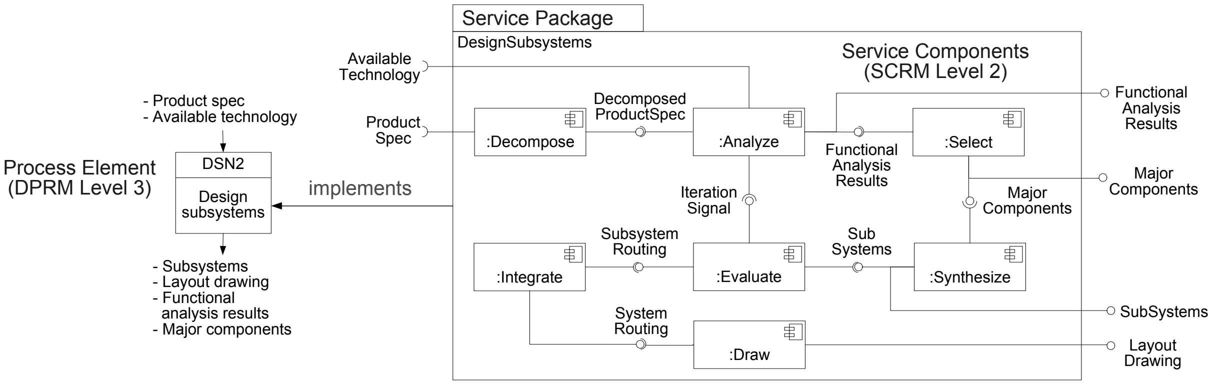

Figure 4. An example of a service package

5.3 Technology and Standard Reference Model (TSRM)

The TSRM specifies technologies and standards supporting the service components to interoperate efficiently. The *technology area* is the grouping of technologies and the proposed TSRM has six technology areas: design activity, data format, communication, security, platform and integration. The *technology standard* specifies the hardware, software and specifications that are widely used and accepted. The *technology specification* specifies the formal layouts for developing service components. The technology standard and technology specification support the service package and service node, respectively.

To bridge the SCRM and the TSRM, the concept of *technical basis* is introduced in the proposed DCCN. The technical basis represents the supporting relationship between the SCRM and the TSRM by specifying the technology that independently supports the component's functionality.

6. Design-Chain Models

Considering the design-chain reference models as reusable templates, the design process managers can describe the collaboration scenarios in a design-chain and communicate with their participants by simply matching their own design processes according to the predefined templates. The process elements and the software components as well as the supporting technologies are the major subjects of the coalition. Using the reference models, the design process managers can quickly characterize processes and analyze high level design processes. Moreover, if measures and historical data are available, then processes can be evaluated quickly and management systems can be established quickly to gather data to help identify where changes will be most useful. The DCCN guides the managers how the internal and external processes can be integrated from conceptual phase to applications development phase with their participants. This will be a step to the Poole(2001)'s long term vision of MDA such as knowledge-based orientation, dynamic architecture and adaptive systems.

Once the processes in a design-chain are modeled as the aggregation of service packages or service nodes and if there exist sufficient service component providers, then the process model can be transformed to executable models such as BPEL(Business Process Execution Language) (Andrews, Curbera, Dholakia, Goland, Klein et al., 2003) and WSDL(Web Services Description Language) (W3C, 2001). And then the process models can be instantiated and executed on the platform of web application server. Of cause, there are more requirements to realize the execution of design-chain models, for example, process cataloging, process monitoring, and transaction management of synchronous/asynchronous messages, etc. However, the execution of design-chain is beyond the scope of this paper.

7. Conclusions

Problems in integrated design-chain network which stems from different processes of each participants can be solved if the design-chain is modeled on a framework using reference models. In this paper, a new framework for design-chain collaboration is proposed. The framework takes advantages of the OMG's MDA for writing specifications and developing applications, SCC's SCOR for domain specific semantics and performance metrics, and FEAPMO's reference models for perspective of enterprise architecture.

The proposed network, DCCN , has three layers for meta model, reference model and instances. The meta model constraints the entities and the relationships of reference models. The reference models capture the different views of design-chain collaboration: DPRM, SCRM and TSRM. Each of the reference models has multiple layered structures and is independent to each other. The DCCN has the potentials to be a basis for value-chain integration to help the business development of an enterprise and can support the business managers to improve design processes immediately and continuously in order to enable collaboration and to breed design process innovation.

References:

Andrews, T., Curbera,F., Dholakia,H., Goland,Y. & Klein,J. et al.(2003), Business Process Execution Language for Web Services v1.1, http://www.ibm.com/developerworks /library/ws-bpel

Cadence Design Systems (2003), Design Chain Optimization: Competing in the disaggregated electronics industry, White Paper.

FEAPMO(The Federal Enterprise Architecture Program Management Office), (2003a), The Business Reference Model Version 2.0

FEAPMO(The Federal Enterprise Architecture Program Management Office), (2003b), The Service Component Reference Model Version 1.0

FEAPMO(The Federal Enterprise Architecture Program Management Office), (2003c), The Technical Reference Model Version 1.0

Harmon, P. (2003), Second generation business process methodologies, *Business Process Trends*.

O'Marah, K. (2002), PDM+ERP=PLM: TIBCO and PTC Join to Make This a Little Easier, AMR Research Alert, February 8, 2002.

OMG (2002), OMG model driven architecture, http://www.omg.org/mda

Poole, J. D. (2001), Model-Driven Architecture: Vision, Standards And Emerging Technologies, *ECOOP*, position paper.

Rebori, M. K. (2000), Two Techniques to Foster Collaboration Within a Group, *Journal of Extension*, 38(4), http://www.joe.org/joe/2000august/tt4.html.

SCC(Supply-Chain Council) (2003), Supply-Chain Operations Reference model (SCOR) version 6.0.

Sim, S.K & Duffy, A.H.B (2003), Towards an ontology of generic engineering design activities, *Research in Engineering Design*, 14, 200-223

True, M. & Izzi, C. (2002), Collaborative Product Commerce: Creating Value Across the Enterprise, *ASCET*, vol.4, Montgomery Research.

Ulrich, K.T. & Eppinger, S.D (1995), Product Design and Development, McGraw-Hill, Inc.

W3C(2001),Web Services Description Language,http://www.w3.org/TR/2001/NOTE-wsdl-20010315.