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학술논문

A Semantic Network Approach to PPO (Products, Processes, Organizations/Resources) Modeling for PDM Systems

Hyo-Won Suh*, Heejung Lee and Seungchul Ha**

ABSTRACT

The modeling method to support product development processes (PDP) must have certain characteristics including the ability to represent multiple viewpoints of the product development and integrate with currently available analysis and design methods based on CE concept. This paper describes the reference model to support multiple viewpoints (PPO: Products, Processes, and Organizations/Resources viewpoints) of the product development processes, from which each model (Products model, Processes model, and Organizations/Resources model) can be extracted, as well as produces PPO data schema. This reference model has associative relationships among the products, processes, and organizations/resources. To allow the extensibility to support design evolution, we propose structured data representation methods using semantic network, which can be constructed through first-order logic. The product development processes is so represented by specifying entities and semantic relationships among them that the appropriate information can be accessed and all of the relevant attributes about the entities can be retrieved simultaneously.

Key words : PPO information, Concurrent Engineering, Product Data Management, Product Development Process, Semantic Network, First-order Logic

1. Introduction

With the growth of the customers needs, com-petitive environment and complex technologies, Concurrent Engineering (CE) has been recognized as a strategy for the successful product development. The purpose of CE is to develop high quality products, and offer them at a lower price and in shorter time to the competitive market place. Product Data Management (PDM) system's implementation is the essential technology for the realization of CE concept[1,2].

Engineering departments are usually good at recording component and assembly drawings systematically, but often do not keep comprehensive records of related attributes such as where used and when used, etc. As a result, engineers often have problems of accessing the information they need at the right time, and there is a need for an appropriate information modeling methodology to manage the information about products, processes, and organization/resources (PPO), so that it might be easy to access and refer to[3-5].

This paper consists of two partsconstruction and application of PPO information model. We focussed PPO information modeling methodology and definition of class diagram using semantic network, and shortly discussed information relationship issue, that is, the immediate accessibility to those who need it.

2. Backgrounds

In the product development processes (PDP), products, processes, and organizations/resources (PPO) information have following characteristics.

–*complex relationship among the PPO information*

–*heterogeneous contents in the PPO information*

The product related data include kinds of BOM (Bill of Material), drawing, and documents. The responsible organizations and related processes are continually involved in defining and updating product information. In product development process, the decision of when to start to process, where the data to be used, what products to be produced by whom, etc are

*종신회원, 한국과학기술원 산업공학과
**한국과학기술원 산업공학과

sorts of process planning and management. The job assignment and resource allocation must be also arisen together with products and processes related information. Through the products life cycle all processes are taken part in the overall product development process, and various product types (e.g. components, parts, assemblies, text, images, 3D geometric data, and documents, etc) are created by different processes and involving organizations. Therefore, complex relationships among the PPO information and heterogeneous contents each information has, may well be obstacles to successful design of product development process.

Fig. 1 shows the complex and dynamic relationships among PPO information. Product information such as BOM and related documents are being changed or matured according as the processes are being progressed by appropriate organizations.

Generally, a model is an abstract representation of the real world, and the detailed parts which are not of interest to the designers or the ultimate users, should be excluded from the model. In developing information model to support PDP, there are special needs to understand the various data generated through the product life cycle. The easy and generic approach to gather PDP related information is to interview directly with engineers in the field. PPO related data, however, should be found manually, and that way is tedious and difficult.

Many methodologies have been developed for modeling the importance aspect of the products life cycle. In DICE system[6] the PPO model is a unified organization for the diverse products, processes, and organization information. This model contains all the information associated with the product, as well as ancillary information such as the history through which the design of the product evolved to reach the current version and processes which drove the evolution of the design. But the relationship among the PPO information is not mentioned. The information required throughout the products life cycle can also be described, structured, stored without redundancy and standardized if the relevant data concerning a company, its products and manufacturing facilities, is defined in Information Models[7]. These models can be developed using infor-mation modeling language such as EXPRESS (ISO CD 10303-11), Sriram *et al.*[8] suggested an objectoriented representation for product and design process to present an integrated approach to modeling the enterprise as a whole, which is based on the SHARED object model. Object-oriented representation in SHARED model is to describe a representation schema for design artifacts and a related scheme for representing design processed. Reddy *et al.*[9] also used a Product, Process, and Org-anization Model (PPO), and MOSES defines Product and Manufacturing Models[10]. The artificial intelligence techniques used for information modeling include knowledge representations[11], semantic networks and constraints rules[12], and constraint net[13,14].

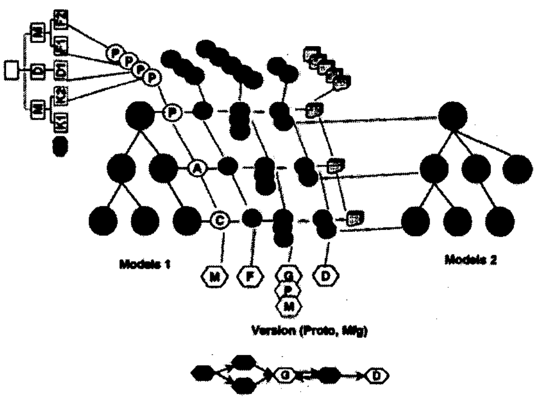


Fig. 1. Problem Statesment.

The widely used method to capture the PDP information is IDEF0. An IDEF0 model of the design process provides an enterprise viewpoint of information systems and describes the context within which data will be used and manipulated[15,16]. The IDEF0 method-ology also allows product development teams to agree upon and understand the engineering processes easily.

In manufacturing research area, it is very important to provide consistent data and its relationship for all the product life cycle activities, and engineering change order can be happened frequently in product development process. So modeling methodologies ideally should capture and represent product information, PDP and organization/resource information.

Conventional modeling methods such as IDEF0, objectoriented representation method, schema based representation, or other information models have focused on modeling the artifact and process in separate manner, or complex interactions between various facets of a products and related processes are manipulated, rarely including organization information. The ability to represent the many-to-many relationship among different facts of PPO information is the characteristics of semantic model suggested in this paper. A reference model which is based on natural language for PDP has the ability to share data during the engineering design process to support integrated product development and the next generation of information system supporting complex engineering design.

Engineering knowledge management (capture and use) fundamentally requires natural form of information, so sentence aided approach is needed to accompany with engineering evolution. Semantic network is so coninually updated as a reference model using natural form of information, that the appropriate information can be accessed and all of the relevant attributes about the entities can be retrieved simultaneously.

3. PPO Information Model

How to filter out irrelevant data and how to reduce the overhead required to access useful data are critical in the product development process. In addition, design process management is much more than simply co-work environment and database implementation. Intelligent design process must facilitate the processes needed to communicate quickly and easily in a dynamic and complex environment. Eventually, PPO information model proposed in this paper will support product development process efficiently and effectively.

3.1 PPO concept

The engineering processes are those carried out in a facility in order to produce products, and the organizations or resources are all the physical elements to enable the product realization.

In our research the engineering information of products, processes, and organizations/resources is defined as PPO information model. The PPO model should represent the necessary engineering and manufacturing information in time through the product life cycle, and capture the relevant relationship among the products, processes, and organizations/resources. Fig. 2 describes the concept that PPO viewpoint is extracted through the engineering method with acquired information.

If we can acquire information as well-defined form

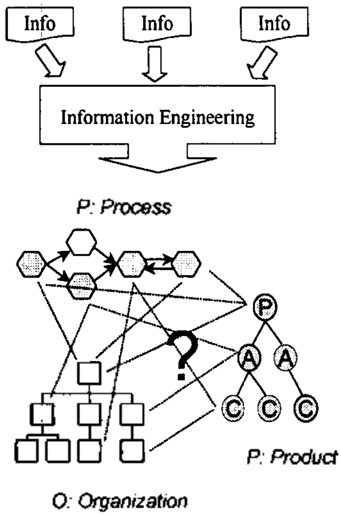


Fig. 2. PPO concept.

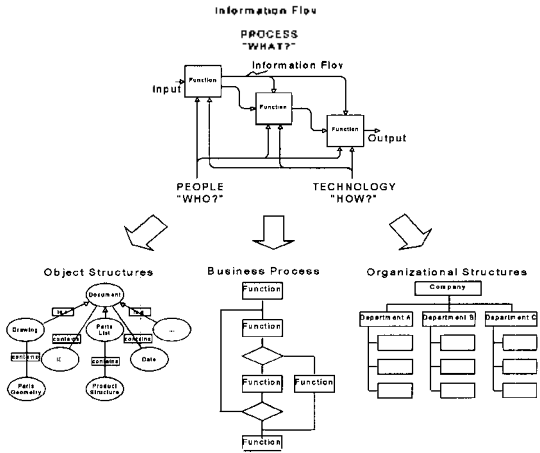


Fig. 3. PPO information extraction from well-defined Template (IDEF0).

like Fig. 3, information engineering phase is easier. Basically, IDEF0 model contains the PPO data itself-what the process to produce, how the process to be performed, and by whom the process to be supported -but it is hard to catch PPO interactions in IDEF0 model alone. Whether we acquire information as a natural language form or well-defined template (e.g. IDEF0, etc.), information engineering phase is critical for the construction of PPO model. We will continue with a natural language form for the generality in this research.

3.2 Requirements of PPO information model

PPO information model requires following three characteristics as a model, that is, *conceptuality*, *extensibility*, and *structured form*[4]. First, *conceptual model* eases the introduction of new information of product development process, and supports for implementation issue of platform independence. Second, PPO data are constantly evolved through the product life cycle, and *extensibility* allows support for new information requirements to be added to the PPO information model in a well-defined fashion and without corrupting existing relationship of PPO data. Third, *structured form* carries a more automatic way by mechanisms that depend on the structure of the representation.

We developed a framework for modeling PPO concept using not traditional modeling techniquesstructured analysis, data flow diagram, end entity relationship diagram[17] but artificial intelligence technology in order to capture the evolution of PPO related data. In addition, PPO class should be defined based on the requirements of the product development process. As a series of processes go on, related product information or itself must be changed, and the information of participant organization is revealed in detail. These data management concept is entirely the one of pursuit of PDM systems[18], so we should define the PPO class considering PDM implementation issue.

4. Framework of PPO Model

4.1 Overall framework

After acquiring the information of the product development in the natural language sentenced form, it is parsed into two parts, *-NP(Noun Phrase) and VP (Verb Phrase)*. Product and organization information are captured from *NP* part, and process information is extracted from *VP* part. These parsed data can be represented by the way of knowledge in the first-order logic. When the relationship in those PPO information set is needed, the appropriate one is accessed and all of relevant facts are retrieved at once.

First-order logic will be transformed into the semantic network, which has advantage of understanding, communication among designers, and representation of class hierarchy (set theory, inheritance, etc.). For the structure of PPO information space, product structure (bill of material: BOM) and organization chart is needed, and they should be also considered to the semantic network using the first-order logic. For the

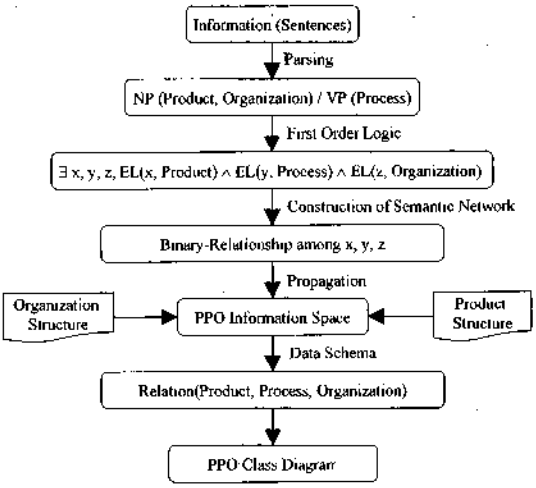


Fig. 4. Overall framework.

implementation issue, PPO information model is eventually transformed into class diagram. The overall procedure from the sentenced information model to class diagram is shown in Fig. 4.

PPO information model which is represented by semantic network is a kind of reference model. Using reference model, the semantic basis of shared PPO data can be established, and all of the attributes about the engineering process can be accessed and retrieved from the reference model simultaneously.

4.2 Information parsing

To capture the PPO data from the description of product development process, we need information parsing step. Fig. 5 shows that S(sentence) can be split into{NP(noun phrase), VP(verb phrase)} or{SS}, and then each phrase into sub-phrase, and so on[19,20]. For example, we have a sentence Designer makes a drawing, and then gives Engineer the drawing. The subsequence of the raw sentenceDesigner is *NP*, then we have a sentence *NP* makes a drawing, and then gives

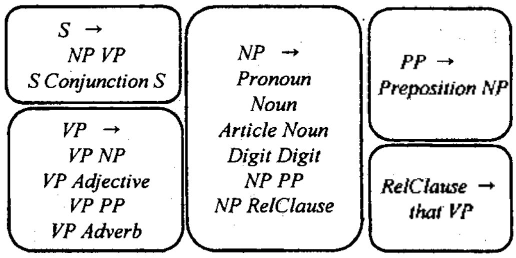


Fig. 5. Grammar for parsing.

Engineer the drawing. The subsequence of the second sentence is makes, which is *VP*. In this way, we get to obtain a parsed resultentity set {*NP1Designer, VP1-makes, NP2(a) Drawing, VP2gives, NP3-Engineer, NP2(the) Drawing*}. In the parsing phase, we get only the entity set itself, not a relationship, so we will find some binary relationships in the entity set using first-order logic. Considering PPO information model, product and organization related data are captured from *NP* entities, and process related data are extracted from *VP* entities.

4.3 First-order logic and semantic network

First order logic is a general language to represent entities and relationship among the objects[20]. First-order logic has sentences, but it also has terms, which represent objects which consists o, constant symbols (e.g., Designer, A, B), variables, and function symbols (e.g., Cosine, FatherOf). Entities are combined with connectives (e.g., ∧, ∨, →, ⇔, ¬) and quantifiers (e.g., ∀, ∃), which are used in logics for representing sentences, and predicate is used for representing characteristics of entities or relationships among them.

At first stage we represent the entity set {*NP1–Designer, VP1–makes, NP2–(a) Drawing, VP2–gives, NP3–Engineer, NP2–(the) Drawing*} as predicate calculus fact: Make (Designer, Drawing) Give (Designer, Engineer, Drawing). Most notations for structured objects involve the use of binary (two-argument) predicates for expressing facts about the objects as like the former predicate in this example. To convert the three-argument formula as like the latter predicate to one involving binary predicate[21], the existence of a particular giving event and a set of such giving events is postulated. The existence of a particular making event and a set of such making events is also postulated. For each argument of the original predicate, we invent a new binary predicate that relates the value of the argument to the postulated event. Using this schema, the formula Make (Designer, Drawing) would be converted to: ∃x, EL(x, Making-Events)∧Maker(x, Designer)∧Obj(x, Drawing), and the formula Give (Designer, Engineer, Drawing) would be converted to: ∃y, EL(y, Giving-Events)∧Giver(y, Designer)∧Receiver(y, Engineer)∧Obj(y, Drawing). The predicate EL is used to express set membership-Elementof. Skolemizing the existential variables x, y in the above

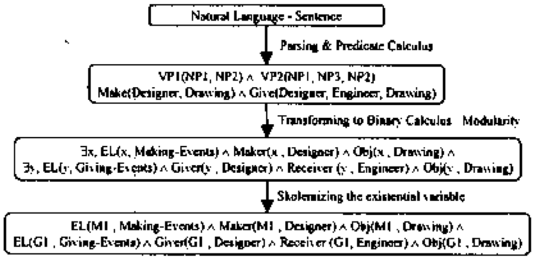


Fig. 6. First-order logic.

formula gives each name, say M1, G1, our postulated giving: EL(M1, Making-Events)∧Maker(M1, Designer)∧Obj(M1, Drawing)∧EL(G1, Giving-Events)∧Giver(G1, Designer)∧Receiver(G1, Engineer)∧Obj(G1, Drawing). Thus we have converted two predicate formulas to the conjunction of seven binary ones. Fig. 6 shows the overall procedure of first-order logic.

It is now accepted that every sentence in a logic could just as well have been defined as semantic network. Semantic network uses the metaphor that objects are nodes in a graph, these nodes are organized in a taxonomic structure, and that links between nodes represent binary relationship. Whether the language uses strings or nodes and links, or whether it is called a semantic network or a logic, has no effect on its meaning and implementation. We adopted semantic network as a reference model, since it is easy to visualize the steps that the inference procedure will go through and it is more easily combined with natural language parsing procedure. Critically, it is coincide with the requirements of PPO information model, and its construction is a kind of procedure defining the relationship among the binary relation set which is acquired from first-order logic. Binary relationship set acquired from "Designer makes a drawing, and then gives Engineer the drawing" example is described in Fig. 7. 'Makes' and 'Gives' are elements of each super set, but other entities are not, so we defined other three

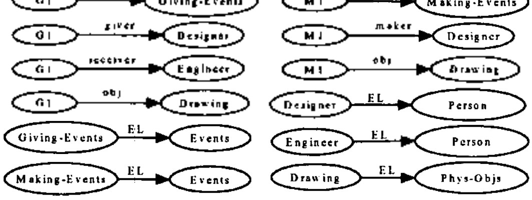


Fig. 7. Binary or pair relationship.

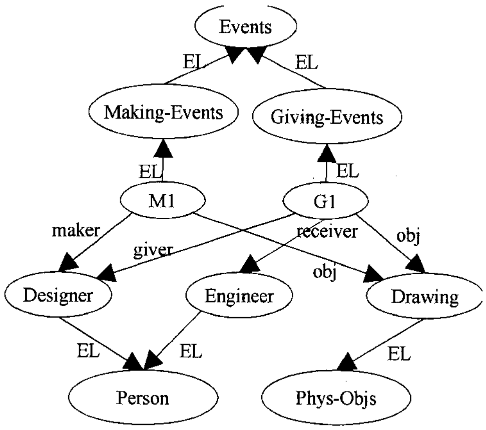


Fig. 8. Semantic network.

super set 'Person', 'Phys-Objs', and 'Events'. If we define binary or pair relations using following entity set {*NP1–Designer, VP1–makes, NP2–(a) Drawing, VP2–gives, NP3–Engineer, NP2–(the) Drawing*}, it is not needed to consider all combinations.

Basically *NP* cannot interact with other *NP* without *VP* concept. So we consider and define the relation, say, *NP* with respect to *VP*. In *EL* or *Refer(this is not appeared in this example)* relation case, however, we will have only to make a relation between entities of their own homogeneous set. Because product and organization related data can be captured from *NP* entities, and process related data can be extracted from *VP* entities, we define REL (Process, Product) or REL (Process, Organization), EL/Refer (Product1, Product2), EL/Refer(Process1, Process2), and EL/Refer (Organiza-tion1, Organization2). Fig. 8 shows complete semantic network of above example.

Table 1 describes data schema to store the binary links. REL can be named as every relation while the meaning is clear and unitary. REL is also key to the PPO information model. Using this REL, a matching operation in the semantic network is performed. EL is used to define the class hierarchy, and inheritance

Table 1. Data relationship schema

Relation	Product	Process	Organization
REL	V	V	
REL		V	V
EL	VV		
EL		VV	
EL			VV

v: associated relationship, vv: parent/child relationship.

property or aggregation concept is concerned with this EL relation. Refer is similar to REL except that there is not a cross-reference among the PPO data.

4.4 Application to PPO model

In product development process, assume that there exists "conceptual design process", that is,

"*CAD team does geometric modeling of the 3D CAD model and Drawings, and then these geometric data are transferred to CAE team who analyzes those model with FEM Analysis. Analysis results are sent off to CAD team, and CAD team modifies the conceptual model based on the ANSYS data and Inches from CAE team. All these conceptual design processes are performed by development teamCAD team and CAE team*".

Whether we get process description in a welldefined unit task template as like IDEF0, or in a natural language form above, we construct a semantic network using available information as possible at this first stage. This semantic network at first stage is shown in Fig. 9.

4.5 Evolution of PPO space

For the evolution of PPO space, we consider another PPO unit (another semantic network) should be added to the previously constructed semantic network. The new acquired information in a sentence form which is next design step like *CAD team reports the final conceptual design to PM* should be combined with existing semantic network. Fig. 10(a) shows the

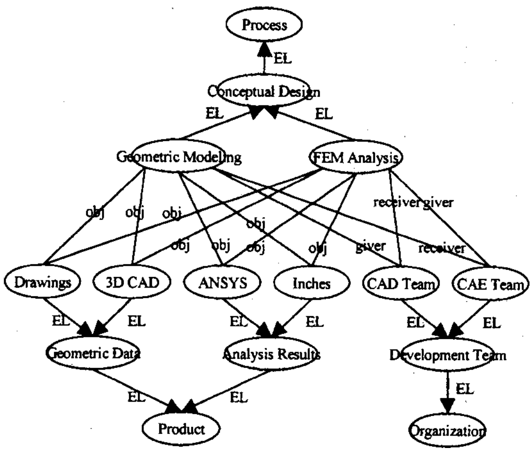
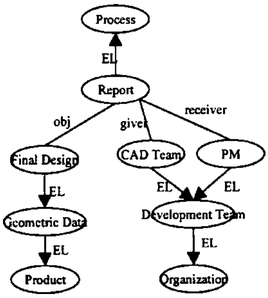
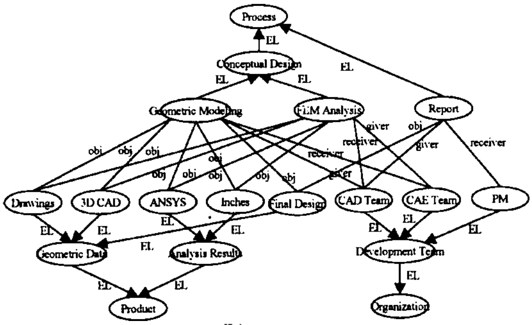


Fig. 9. Semantic network for conceptual design.



(a) another PPO unit



(b) merge

Fig. 10. Evolution of semantic network.

additional semantic network to be added into the old one in Fig. 9. Fig. 10(b) is the result of merging Fig. 9 and Fig. 10(a).

In summary, whether we got the data of processes, products, and organizations/resources separately or not, syntactic analysis of obtained data has been performed, and then we captured and described the binary relationship between products, processes, and organizations using first-order logic. According as new information is added to the existing PPO model, the binary relations are propagated based on relationship matching operations.

Table 2. General relationship

Relation	Product	Process	Organization
obj	Drawings	Geometric M	
obj	Drawings	FEM A	
obj	3D CAD	Geometric M	
obj	3D CAD	FEM A	
obj	ANSYS	Geometric M	
obj	ANSYS	FEM A	
obj	Inches	Geometric M	
obj	Inches	FEM A	
obj	Final Design	Report	
giver		Geometric M	CAD Team
giver		FEM A	CAE Team
receiver		Geometric M	CAE Team
receiver		FEM A	CAD Team
giver		Report	CAD Team
receiver		Report	PM

Table 3. ElementOf relationship

ElementOf	Sub Set	Super Set	Prod/Proc/Org
EL	Drawings	Geometric D	Prod
EL	3D CAD	Geometric D	Prod
EL	ANSYS	Analysis R	Prod
EL	Inches	Analysis R	Prod
EL	Geometric D	Product	Prod
EL	Analysis R	Product	Prod
EL	Geometric M	Conceptual D	Proc
EL	FEM A	Conceptual D	Proc
EL	Conceptual D	Process	Proc
EL	CAD Team	Development	Org
EL	CAE Team	Development	Org
EL	Development	Organization	Org
EL	Final Design	Geometric D	Prod
EL	Report	Process	Proc
EL	PM	Development	Org

4.6 PPO Data Schema

Table 2 and 3 show the data schema for the figure 10 (b). PPO data schema has two cases the PPO information themselves and the relationships among the PPO information. In this paper we do not represent the former case, which have been well defined in the current research such as STEP, ARISbusiness process engineering, information modeling, object-oriented, method, etc. Instead, we are only concerned with the PPO relationships at this time.

To model the hierarchical situation of information, we suggested the ElementOf relationships schema, and the General relationships is created to describe the general PPO relationships.

4.7 Implementation issue

PPO information systems configuration is depicted

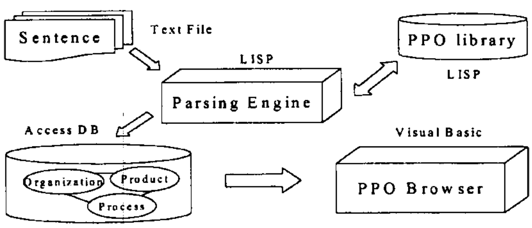


Fig. 11. PPO information systems configuration.

in Fig. 11. Based on PPO library, the parsing engine parsed natural language, that is, engineers description, into PDP related information pieces, which are transformed into semantic network. To support the independence of data from application, we use the one of the relation database system.

5. Conclusions

We suggested the construction procedure of PPO information model and some implementation issue. PPO information system in this paper contributes the sentence-based architecture system, and conveniently consists of the following two sub-systems, PPO information modeler and PPO information browser. In fact, the PPO browser Fig. 12 is a system which assists in the other project to support PDM systems combined PPO concept.

A number of tools and techniques have been proposed in the literature and application to address the modeling problems associated with the PDP. Due to the complex nature of design and the vast variety of PDP, directly applying the modeling methodologies to a new problem is very slim. Thus the usual classification schemes involved in PDP are not very useful. The key issue in this research is to provide an information aiding model and information reference model, which can be used as a basis for the product development process. A PPO information model must provide perspectives of the product development process if it is to adequately support an engineering design process. These PPO perspectives, or views, are required because of the different types of information available about the engineering design process and because of the integration needed for product development design process.

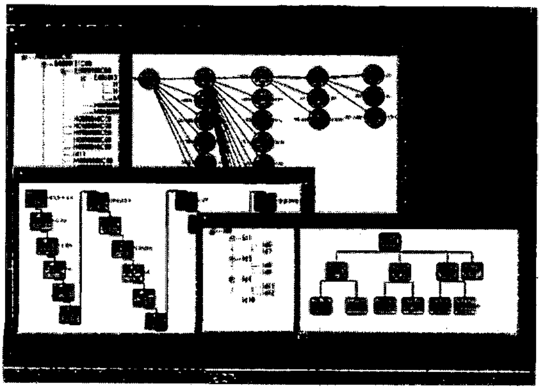


Fig. 12. PPO information browser.

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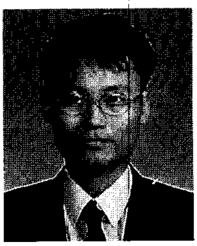
서 효 원

1981년 연세대학교 기계공학과 학사
1983년 KAIST 기계공학과 석사
1991년 West Virginai Univ. 산업공학과 박사
1991년~현재 KAIST 산업공학과 조교수
관심분야: 동시공학, 제품개발프로세스, PDM, DB응용, 정부공학



이 회 정

1996년 한양대학교 산업공학과 학사
1998년 KAIST 산업공학과 석사
1998년~현재 KAIST 산업공학과 박사과정
관심분야: 제품개발프로세스, 인공지능 응용, PDM

하 승 철

1997년 부산대학교 산업공학과 학사
1999년 KAIST 산업공학과 석사
1999년~현재 KAIST 산업공학과 박사과정
관심분야: 워크플로우, 제품개발프로세스, PDM