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Ontology Theroy Based Process Planning and Supporting System under E-manufacturing

***Abstract**. In order to satisfy new requirements for process planning and resources sharing in E-manufacturing, the structure and key technologies of the dynamic process planning and supporting system were discussed. The results show that the methods for building and storing manufacture model based on ontology could make the model have semantic nature. Theory studied in this paper laid a foundation for the process planning system, which not only to grasp the dynamic resource information, but also to realize the process resources and knowledge sharing, as well as to realize the process route optimization selection.*

***Streszczenie.** Zaprezentowano stadium teoretyczne tworzące podłoże dla system planowania procesu które nie tylko ma pod kontrolą dynamiczne zasoby informacji, ale także realizuje zasoby I przeprowadza optymalizację. (**System planowania i wspomagania procesu przy E-manufacturing**)*

Keywords: e-manufacturing; process planning and supporting system; manufacturing ontology; semantic retrieval.
Słowa kluczowe: E-manufacturing, optymalizacja, planowanie..

Introduction

E-manufacturing is an online network manufacturing which is not only driven by orders or the market forecasting but also based on collaborative manufacturing business. It is also an extension and expansion of network manufacturing system. E-manufacturing has many advantages, such as on-line, synergy, dynamic, agility and accuracy etc [2]. Process planning support system is the link that connects the design with production and also is the information centre of whole manufacturing system. The pattern of e-manufacturing requires not only the process planning to support transaction processing in different enterprises and within the enterprise but also optimization of multi-process routes based on the bottom-up and process data feedback, besides the mutual coordination and compromise in process planning of different parts' are also required. Therefore, dynamic and instantly share of process information are extremely important between enterprises. However, at present the process information is described in various forms and with different structures, which is not conducive to the information exchange for cross-platform collaboration. Furthermore, the traditional retrieval of process information is based on keyword with low efficiency and the precision is limited, so the process planning system cannot grasp dynamic resource information in different enterprise and area, which will affects the selection and optimization of process route. In order to solve the problems mentioned above, this paper puts forward a process planning support system supported by ontology theory. Based on semantic to realized the description of process resources and knowledge, retrieval of process information and decision of process route.

Overall Design of System

The process planning support system, based on the ontology theory, is realized by B/S mode under the e-manufacturing mode. Hierarchical structure is used to divide the system into network user layer, web server layer, semantic layer and data layer. The function structure is shown in Fig.1.

User layer is the entrance of the whole system. Users interacts with the system in the IE browser through network, including user login, browse manufacturing resource information, process decision-making and output optimization. Web business layer is responsible for handling information submitted by user, such as uploaded data, query process data, modify and delete data, as well as communication and data transmission between web server and database server. Semantic layer established a unified description and reasoning mechanism for various data resources. By building consistent semantic context in the ontology, process data description and reasoning can be achieved. The data layer responses to SQL request from the server, performs operations from database and completes the management of data through a series of stored procedures.

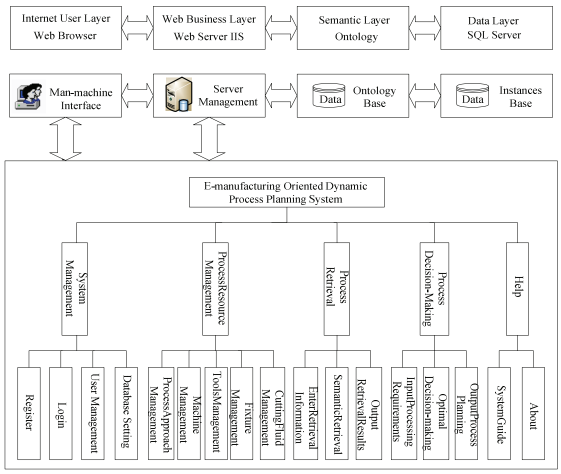

Fig.1. System function structure chart

Key Technology of the System

Manufacturing Ontology Modelling

Process design and manufacturing related to a wide range, constraints are existed from product features, materials, process size to the use of processing resource. The links between this information are all constrained by kinds of process knowledge. In order to construct an overall model, it is particularly important to express the process design and manufacturing knowledge. Ontology is a philosophical concept originally, mainly studies the nature of existence. In computer science or related fields, ontology refers to the basic method of use ontology. Abstract the entities in the real world as a set of concepts and the relationship between them by concepts analyzing and modelling [4]. Through apply ontology theory to the process design and manufacturing domain, express the manufacturing and process knowledge with manufacturing ontology model and construct the corresponding model base, the problems about intelligent express, sharing and dynamic search of process knowledge will be solved effectively.

After comparing the using scope and characteristics of ontology modelling methods, according to the characteristic of process design domain, the modelling steps of design and manufacture ontology are as follows:

1) Determine the important terms in the process design domain and depend on these to design manufacturing ontology classes.

2) Analyze the characteristics in process design domain; group concepts and determine classes and properties (table 1).

Table1. The design of manufacturing ontology

ontology	The relationship of class hierarchy	object/data attribute（part）	example
Material ontology	material：composite、metal、plastic… material properties: machine / physics / thermal properties…	Boiling point, density, elongation, melting point etc/description, file, value…	Cast iron, alloy steel, copper-lead alloy, aluminum etc
Organization ontology	Set: concept set, detail set, service group… Mechanism: enterprise, design section People: customer, employee, supplier	Contains the collection, hired, a subtask etc/ address, age, email, name, telephone…	An enterprise, worker, technician, manager etc
Process resource ontology	Technological equipment: tool, fixture, measure… Processing equipment: machine tool，non-machine tool, welding machine, injection molding machine… Miscellaneous assets: computer, software, algorithm	The type of, the accuracy of, scope of application etc. material manufacturing by, influence precision, the maximum or the minimum, number, target, value etc	CA6140, vehicle centering fixture, boring clamp, turning tool, twist drill etc
Objects of manufacturing ontology	Blank: casting, forging… Part: rotary type, non-rotary type… Characteristics: shaft, hole, cavity, end surface…	Density, melting point, yield strength/real valued, functional surface feature number, the value of string etc	Stepped shaft, headstock, inner cylinder processing piece etc
manufacturing method ontology	Non-machining: heat treatment, casting, forging… Machining: turning, milling, planning, grinding…	Processing type, real-valued function, whole type value, the value of string etc	Turning, milling, grinding, boring, drilling etc
Manufacturing task ontology	Resource selection: machine tool / tool / fixture selection… Parameter selection: machining/ forging parameter selection… Parameter calculation: geometry, welding, calculation of heat treatment parameter	Roughness requirement, flatness requirement, precision requirement, production lot size etc/ real-valued, feature number, the value of string etc	Surface Ra3.2, the selection of machine is CA6140

3) Determine the relationships between each ontology and class. By analyzing the relationships of five types of the ontology, their relationships are shown in Fig.2, determine, isDeterminedBy, has Acton, hasReform, isComposedOf etc. For example, process resource determines the selection of processing methods; in turn processing method is determined by the process resources, processing method acts on processing object, the accomplishment of processing task can transform processing objects etc.

4) Use Protégé to construct manufacturing ontology model and instantiated it (Fig.3 is the material ontology structure graph); the final model is saved as OWL file.

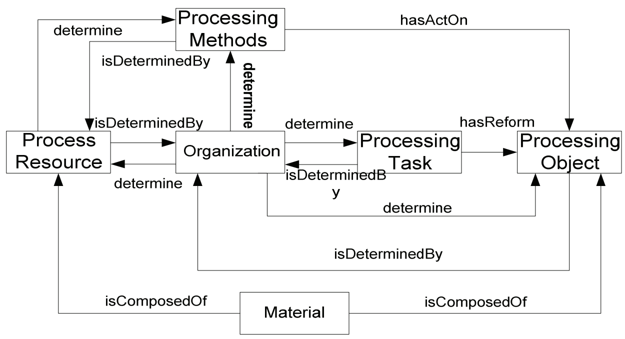

Fig.2 .Relationship of manufacturing ontology concept

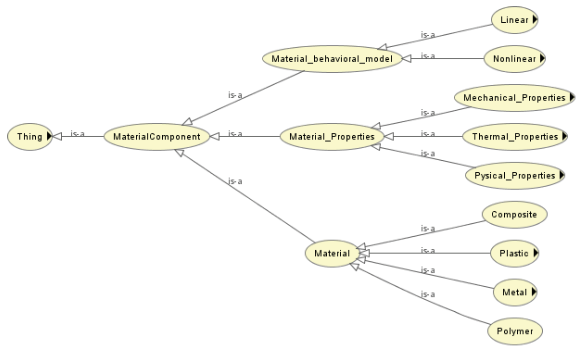

Fig.3. visual graphic of Material ontology

Storage of Manufacturing Ontology Model

Manufacturing ontology should be stored scientifically according to its own characteristics and application needs. At present, storage method of ontology can be summarized into three types: in plain text(such as OWL files), special management tools(such as OMM), relational database storage. Plain text is more intuitive and easy to understand, but when there are a large number of concepts and instances in ontology, the efficiency will be relatively lower, so it is not suitable for large-scale ontology management; secondly, special management tools are not mature enough; finally, the relational database suites for massive data storage, which is with high efficiency, easy to manage and search. Therefore, database is a better choice for the storage and management of ontology when the technology of the storage of semantic information is not yet mature.

At present, storage modes of ontology in the database mainly including horizontal mode, vertical mode, decomposition mode and mixed mode. These modes are simple in design, but their efficiency is quite low when store large ontology, besides, the cost are big when query and modify the data in database.

Manufacturing ontology model has a large amount of data, the semantics of ontology should be fully reserved when storing. Storage mode need not only standard but also easy to understand, moreover, manufacturing ontology itself is not static; it must be able to capture both the meaning of users queries and the change of relationships. So how to obtain a high query efficiency and excellent expansibility should be considered when storing manufacture ontology model into database. According to the requirements mentioned above and the structure of OWL file, after analyzing the advantages and disadvantages of various storage methods, this paper combined with the storage theory proposed by Li Man [6] and designed storage mode for storing manufacturing ontology into relational databases, and the storage mode is shown in Fig.4. Specific introduction is as follows:

1) Resource table(Resource): List all resources of ontology, including classes, properties and instances. Field NameSpace and LocalName are composing URI to mark ontology resources uniquely; field Type records the type of resources.

2) Property information table (Property, Propertyfield): Table Property describes the basic information of properties, such as property type and its characteristics Transitive Property, Symmetric Property, Functional Property and so on. Table Propertyfield is used to store domain and range of properties.

3) Relation table (Subclass, Equalclass, Subproperty, Equalproperty): These tables used to describe hierarchical relation and equivalence relation between classes and properties, which are corresponding to subClassOf, equivalentClass, subPropertyOf and equivalentProperty in OWL. These are the most basic relations and have high query frequency, so query efficiency of corresponding relation can be improved by storing these relations separately.

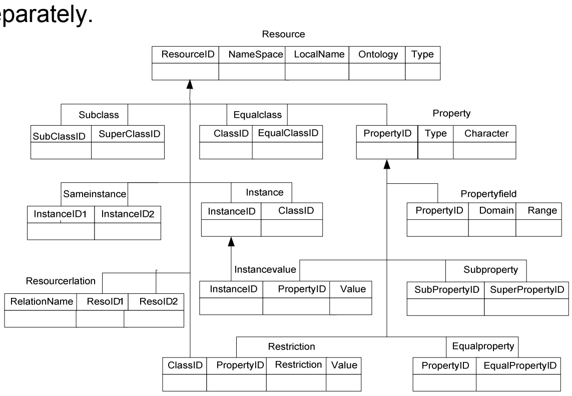

Fig. 4 storage mode for manufacture ontology

4) Relation table (Resourcerelation, SameInstance): Tables Resourcerelation is used to describe differentFrom, allDifferent, interesctionOf and other binary relations between two resources, as the usage frequency of these binary relations in ontology is not high, put information of these binary relations into one table. And sameAs relation is more commonly used, so use SameInstance table individually to store it.

5) Restriction table (Restriction): This table is used to store the description of the properties restrictions, such as allValuesFrom, someValuesFrom, minCardinality, maxCardinality, cardinality and so on. They are often applied to reasoning for the property values.

6) Instance information table (Instance, Instancevalue): Table Instance describes membership relations between instances and classes and determines which class an instance belongs to. Table Instancevalue describes property value of instance, and take the property value of an instance as a tuple of Instancevalue table by using triple-based vertical patterns. The query for instance and its property value often occurs is the cause of adopting this strategy and this type of storage can keep the stability of table structure.

Analyze these storage methods above, this mode is simple and intuitive, easy to understand, as well as preservation the semantics of ontology in maximum; it also has stable structure and easy to expand. When add or delete some information in database it only needs to modify the corresponding tuple in the table without modifying the mode of the table. Besides it is suitable for storing mass ontology and can greatly improve the efficiency of information query and retrieval.

Semantic-based Retrieval of Process Information

Concepts information related to manufacturing model is very large, so it is a universal issue to current enterprise that how to rapidly and effectively search needed process information. Traditional information retrieval is based on keywords, whose return and precision ratio are not high, therefore, this system introduces semantic retrieval technologies. Semantic retrieval analyzes and handles retrieval request from the semantic level that the words express, and provide foundation for information share and exchange in the semantic level by using ontology, and can improve return and precision ratio markedly.

Set of ontology concepts is often represented by undirected graph G=(V,E) when calculating concepts similarity by semantic distance, V represents the set of nodes, that is the ontology concepts set, E represents the edges of all nodes that form undirected graph and the links between the concepts. There may exists more than one path from one node to another node in the graph, and the number of edges of different paths may be different. Among all paths between two nodes, the path that has the minimum edges will be called minimum path, and the length of minimum path will be defined as semantic distance. The value range of semantic similarity is often limited between 0 and 1, the semantic similarity between one concept and itself is 1, that is complete similarity; conversely, if there is no path between two concepts, it shows that they are entirely irrelevant, so their semantic similarity value is 0; if the association lies between 0 and 1, we called it as indirect correlation, and its correlation degree and semantic distance that between two concepts are inversely proportional, that is, the further the distance is, the smaller the correlation or similarity will be [9].

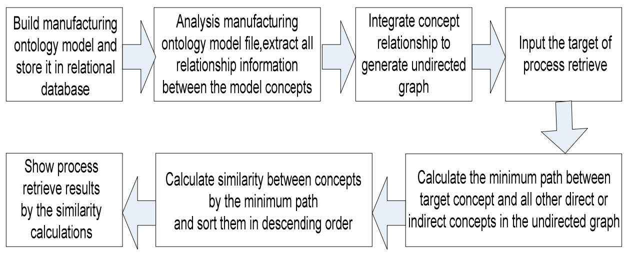

Fig. 5 the flow of semantic retrieval

Using semantic distance between concepts to calculate their similarity degree and obtain the quantified degree of similarity between them, the concepts are similar or same can be quickly and effectively obtained when introducing intelligent query. And through ontology reasoning, mining information related to user' requirements from existing resources, semantic query can be achieved. The algorithm theory above can be applied to process information retrieval, which technology flow is shown in Fig. 5.

System Implementation and Example

This system is based on Windows XP operating system and achieve Web server programming by using Myeclipse 5.5.1 GA, Tomcat 6.0 and other development tools, as well as JSP, HTML, xml and other languages, the database is built based on SQL Server 2000. The system based on ontology theory offers the basic guarantee for process planning and supporting system of E-manufacturing. The system is divided into five modules，including system management, process resource management, process information retrieval, process decision and system help etc.

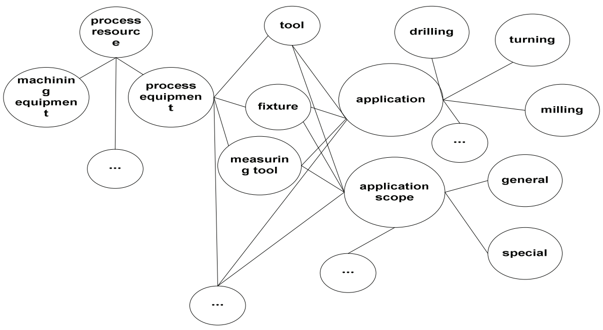

Fig.6. Concepts structure of part model

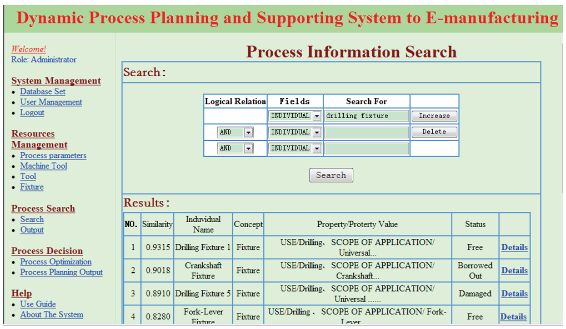

Fig.7. Results of information retrieval

Select part structure concept information of manufacturer ontology model in this system (shown in Figure 6), and instance query is carried out in the model with this relationships. The retrieval results are shown in Fig.7 when we input "drilling fixture" in the process information retrieval module. The retrieval results not only include "fixture" instance information with "drilling" function, but also some concepts and properties that has correlation with "drilling fixture", and display them orderly. However, traditional retrieval can only get concept or instance including characters of "drilling" or "fixture". This shows that recall and precision of semantic-based information retrieval is not only higher than keyword-based, but also more intelligent. This allows process planning system in e-manufacturing to grasp cross-enterprise and cross-regional dynamic resource information accurately, and provides strong safeguards for selection and optimization of process route.

Conclusion

From the analysis above, manufacturing resource and process knowledge have not only large information but also diversiform structures, as well as complex restriction relationships. Comb related concepts and relationships of process design based on ontology and build manufacturing information model will endow it with semantics, this is conducive to information exchange and sharing. Use relational database to store manufacturing ontology will meets the requirements that the process planning system needs large scale and high efficient query. Besides, the structure is stable, easy to understand, and also can ensure the ontology has clear relationships without losing semantics. Based on manufacturing ontology model, then use semantic distance to calculate their similarity degree between concepts and obtain the quantified degree of similarity between them, and finally realized processing information query that based on semantic, its recall and precision is improved significantly. Based on the research above, a dynamic process planning and supporting system was developed to satisfy the requirements of e-manufacturing model for process resource management, process information sharing, and process route decision and so on.

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