# Research on the Semantic Model of R&D and Design Resources of Group Enterprises

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**ABSTRACT**

In order to solve the problems of scattered and isolated R & D and design resources, low sharing degree and low collaboration efficiency among group manufacturing enterprises, affiliated enterprises and factories, based on the in-depth study of the connotation and characteristics of R & D and design resources, an R & D and design resource information model of group enterprises is established based on the concept of object-oriented and semantic knowledge, The software resources of a cloud manufacturing platform are described. Finally, the attribute extraction of an enterprise software resource list information text is carried out to realize the application and verification of the resource information model. The information model established in this paper classifies and defines the internal and external resources of the group enterprise uniformly and effectively, and realizes the dynamic scalability and automatic inheritance of resource dimensions, attributes and descriptions.

***Key words:*** *R & D and design resources；resource classification；semantics；information model；attribute extraction*

## 1. INTRODUCTION

In industry4.0Under the background, the global manufacturing industry is moving towards intelligent and service-oriented development, product upgrading is accelerating, and competition is more intense, which has higher requirements for the company's product innovation ability. As the core assets of the group enterprises, R&D and design resources such as hardware, software and information are an important support for product innovation. However, the R&D and design resources of group enterprises have the disadvantages of geographical dispersion, formal heterogeneity and storage distribution, which have certain obstacles to the speed of product innovation. At the same time, resources are shared within the Group and among partners to the greatest extent. Efficient sharing and safe sharing also have a great impact on product innovation, but the existing R&D resources are mainly based on their own dedicated expert information systems, and it is difficult to actually share R&D resources between different departments of the enterprise[1]. Therefore, it is particularly necessary to build a unified R&D and design resource organization system and a unified and integrated management of decentralized and heterogeneous resources.

In this paper, the connotation and characteristics of R&D and design resources of group enterprises are studied in depth, and the R&D and design resources of group enterprises are classified according to the relevant research results, and the information of R&D and design resources of group enterprises based on semantics is constructedThe model is described.


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## 2. GROUP ENTERPRISE R & D AND DESIGN RESOURCES

### *2.1.R&D and design resource connotations*

Traditional manufacturing resources have a broad sense of manufacturing resources and narrow sense of manufacturing resources [2], narrow manufacturing resources mainly refer to the processing of a part of the material elements required, is the manufacturing resources for the bottom of the manufacturing system, such as machine tools, tools, tooling, etc. Manufacturing resources in the broad sense are the software and hardware elements that complete all production activities throughout the life cycle of a product, including all elements involved in the process of design, manufacturing, maintenance and other related activities [3].

R&D and design resources are manufacturing resources. If there is no definite definition of R&D design resources, it can be considered that R&D design resources are a subset of generalized manufacturing resources, which is the sum of the resource elements used in the product design stage in the cloud manufacturing environment[4]. literature[5]It is believed that design resources are elements of product design activities, and provide help and support for product design activities. The definition of R&D design resources in this article is as follows: R&D design resources are the most basic elements of product design activities, generally referring to the sum of all resources that can provide support for product design activities.

### *2.2. Classification of R&D and design resources*

The classification of R&D and design resources is basically the same as the classification of manufacturing resources. From the perspective of the resource provider, according to the attributes of resources, user needs, use methods and the role played in manufacturing activities, manufacturing resources can be divided into human resources, manufacturing equipment resources, technical resources, material resources, application system resources, service resources, user information resources, computing resources and other related resources [6]. According to the existence of design resources and the formation relationship between them, the design resources are divided into two categories: design resources with entities and design capabilities without entities, of which the design resources of entities are further divided into intellectual resources, knowledge resources and tool resources, while the design capabilities of non-entities include the capabilities of demand analysis, program selection, conceptual design, structural design and entity design in the product design stage[4]. There is no fixed unified classification standard for R&D and design resources, and resources can be classified in multiple dimensions according to the different design activities of group enterprises and the connotation and characteristics of resources themselves. According to the connotation of R&D design resources and the requirements for unified management and sharing of resources, this article categorizes resources from the following five dimensions: the function of the resource in the group enterprise, the professional name of the resource, the business activity, the ownership of the resource, and the life cycle of the resource. Figure 1 shows the multi-dimensional classification model of the group enterprises developing and designing resources, of which the functional dimension is the main dimension of resource classification, and the professional field, business activity, ownership, life cycle, etc. are auxiliary dimensions.

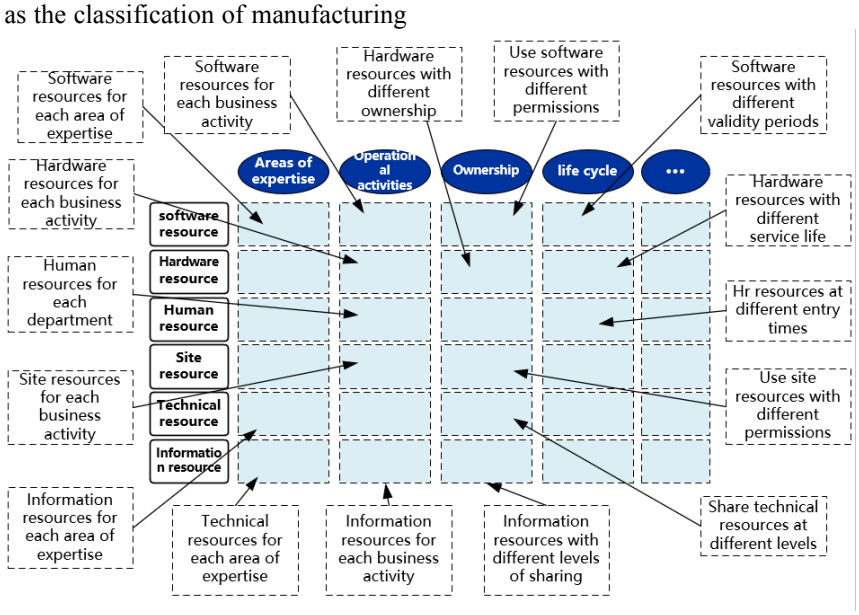


**Figure 1** R&D and design resource multi-dimensional spatial information model

(1) Resources have their own functions in group enterprises, both linked and differentiated. According to the different functions, R & D design resources can be divided into 6 categories: software resources, hardware resources, human resources, site resources, technical resources and information resources. Among them, software resources are the software and systems that support the management and collaboration of the design process of the Group enterprises and the main design activities of design, simulation, analysis and experiments, including management software, collaboration and communication software, design software, simulation software, analysis and calculation software; hardware resources refer to the management and coordination of the design process of the Group enterprises Design, simulation, analysis, experimental verification, trial production and other major design activities of the equipment, including production of prototype equipment, computers and servers, network equipment, experimental equipment, testing equipment, logistics and transportation equipment, office equipment, etc.; human resources are involved in the group's enterprise design activities of engineering and technical personnel, management personnel, service personnel and other personnel; site resources are to support the group enterprise design process management and collaboration, as well as design, simulation, analysis, experimental verification, trial production and other major design activities of the site, workshop, Laboratories, etc., including experimental sites, processing and manufacturing assembly sites, Test site, storage site, etc.; technical resources refer to the sum of resources that support the management, design, experiment, analysis and verification of the design process in the collaborative design process of the group, including standards, specifications, templates, rules, methods, models, experience, etc.; information resources are the information synthesis formed in a variety of media and media forms formed in the collaborative design process of the group, including market information, design and development information, manufacturing information, operation and maintenance information, quality information, etc. Figure 2 shows the information model framework under the resource function dimension.

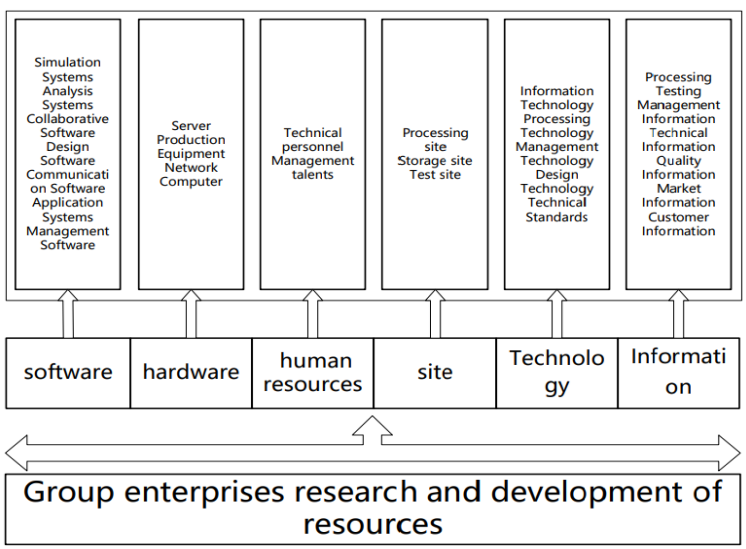


**Figure 2** Resource function dimension information model framework

(2) The group enterprise contains resources in various professional fields, and extracts a representative set of terms from each professional field according to the professional name of the resource, as a characteristic vocabulary of resource classification, and forms the classification standard of each professional resource. Resources under this dimension can be divided into categories such as control, hydraulics, manufacturing, power, inspection, calibration, structure, reliability, electrical, testing, management, and so on.

(3) Resources in group enterprises are applied to different business activities. All business activities are classified, and R&D and design resources are divided into six types of resources, such as demand analysis, R&D design, simulation and forecasting, test and testing, production and manufacturing, and administrative management according to the type and nature of business activities.

Demand analysis resources include resources related to activities such as index demonstration, technical analysis, program design, and stereotyped design of equipment and each subsystem; R&D and design resources include resources related to equipment component research and development, information system development, software development, etc.; simulation and prediction resources include resources related to activities such as equipment performance parameters and system performance; test and test resources include resources related to equipment testing, system testing, and other activities; production and manufacturing resources include resources related to equipment parts processing. Resources related to mass

production, equipment manufacturing and other activities; administrative management resources include resources related to management, collaboration, performance and other related activities in the collaborative design process.

(4) One of the purposes of building a R&D design resource information model is to facilitate resource sharing, thereby improving the efficiency of product R&D innovation. From the perspective of resource sharing, define the ownership dimension of the resource to describe the basic rules for the shareability and sharing of the resource. Resources under the resource ownership dimension include categories such as resource holder, sharing scope, sharing level, sharing object, sharing method, and sharing period.

(5) As a R&D design resource in the group of enterprises, bothWhether an entity resource or a non-entity resource has its own life cycle. Starting from the resource lifecycle dimension, you can divide resources into categories such as purchase date, useful life, and resource expiration date.

This paper takes the functional dimension of resources as the main dimension, and the professional area, business activity, ownership and life cycle as the auxiliary dimensions.

### *2.3.R&D design resource attributes*

There are many kinds of R&D and design resources, and each resource has several attributes. Combined with the object-oriented thinking, each resource is regarded as an independent object, and the properties of each object are both common and different, and there should be related attribute information of other dimensions. Based on the above factors, the attributes of R&D design resources can be divided into basic attributes, capability attributes, state attributes, inheritance attributes and dimension attributes. table1The attribute information of R&D design resources is classified and sorted out using the above attributes as the framework when constructing the R&D and design resource information model of the group enterprise.

**Table 1** Properties of R&D design resources

| Attribute category | The description of the property |
|---|---|
| Basic properties | Describe basic information about the resource, such as name, number, category, quantity, specification, source information, and so on. |
| Capability attributes | Embodies the ability of the resource, is the collection of multiple capabilities of the resource, describes the work and tasks that the resource can complete, and the relationship between the ability and the task is one-to-many. |
| Status properties | Describes the current state of the resource, such as usage status, task status, and so on. |
| Inherit attributes | Describes the inheritance relationship of a resource, treating the resource as a stand-alone object that inherits its parent class resources and properties. |
| Dimension attributes | Describes information about a resource in other dimensions. Resources are intersections under different dimensions, and dimension attributes reflect the relationship between different dimensions of resources. |

## 3. R&D AND DESIGN RESOURCE INFORMATION MODEL DEFINITION AND DESCRIPTION

The resource model describes the structure of resources and the logical relationships between them by defining the logical relationships between resources and the properties of resources [7]. Literature [8] proposes a manufacturing resource data model for cloud manufacturing systems. Literature [9] combining semantic knowledge and web technology, a processing equipment resource information model is established and described in XML. The literature [10] proposes a networked manufacturing resource model based on resource functions, and adopts Web services for encapsulation. Literature[11] proposes a semantic-based cloud manufacturing resource modeling and servitization encapsulation method, abstracts manufacturing resources into manufacturing capabilities, and constructs a semantic-based cloud service structure model using ontology modeling technology. Literature [12] based on XML research, describing the data elements of the manufacturing resource model, resource libraries, and other contents. The literature [13] proposes an optimal resource allocation model based on two-tier planning.

### *3.1.R&D design resource model definition*

Based on the object-oriented thinking, summarize the attributes of R&D and design resources, take the functional dimension of resources as the main dimension, abstract the common attributes of resources, and consider the differences of resources, add other attributes, and realize the dynamic expansion and automatic inheritance of resource dimensions, attributes and descriptions.

RDDR(Research & Development and Design Resources) = { Sw_R, Hw_R, HR_R, Fi_R, Te_R, In_R}, where Sw_R (Software_Resources) is a software resource, Hw_R (Hardware _Resources) is a hardware resource, and HR_R (HumanResource_ Resources) for human resources, Fi_R (Filed_Resources) for site resources, Te_R (Technology_Resources) for technical resources, In_R (Information_Resources) for information resources.

Software resources, hardware resources, human resources, site resources, technical resources and information resources are defined in the same way. This article takes software resources as an example, gives the definition and attributes of software resources, the definition of other resources is the same as that of software resources, and the attribute values vary according to the type of resources.

Defines 2 software resources

Sw_R(Software Resources) = {BasicProp, AbiliProp, StatuProp, InherProp, DimProp}, where BasicProp is the basic property; AbiliProp is the capability property; StatuProp is the state property; InherProp is the inheritance property; DimProp is the dimension property.

Defines 3 basic properties

BasicProp={name, brand, FBuyDate, FCost, FManagerUse, FVersion, FSoftType, FInstallModel, License, FLicNum, FKeyWord, FFromInfo, FCountry, FNecornot, other}, where name is the resource name; brand is the resource brand FBuyDate is the resource purchase date; FCost is the fee; FManagerUse is the resource owner FVersion is the software resource version number; FSoftType is the resource type; FFieldUrl is the location where the resource files are stored; FInstallModel is the installation method for the software resource; License is the resource license; FLicNum is the license quantity FKeyWord is the keyword of the resource; FFromInfo is the source information of the resource, including the source system, the source database, the source table and the source URL; FCountry is the country; FNecornot is required; other is the extensible attribute, which can be expanded according to the actual situation to adapt to the flexible changes of the resource.

Defines 4 capability attributes

AbiliProp={FAbility, FParameter, FRange, FPurpose, FObject, FFiletype, FTecIndex, FTech}, where FAbility is the professional technical ability of the resource; FParameter is the ability parameter of the resource; FRange is the ability range of the resource; FPurpose is the task that the resource can complete according to its ability, The capability attribute values with resources are one-to-many and vary with tasks and time; FObject is the resource capability object; FFiletype is the file type of the software resource; FTecIndex is the technical indicator; FTech is the technology involved in the resource.

Defines 5 status attributes

StatuProp={status, FValidityDate, FNote, FItem }, where status is the status information of the resource, including the use state, task status, maintenance state, etc.; FValidityDate is the validity period of the resource; FNote is the description of the resource, which is modified according to the real-time state of the enterprise; FItem is the project to which it belongs.

Defines 6 inheritance attributes

InherProp is an inherited property of a resource that treats a resource as a stand-alone object, and an inherited property describes the inheritance relationship of that resource to an upper-level resource. Take motion simulation software as an example: motion simulation inherits the simulation system and its properties, and the simulation system inherits the software resources and their properties.

Defines 7 dimension attributes

DimProp = {FFunction, FBusiness, FFiled, FOwnership, FCycle, other}, where FFunction is the functional property of the resource; FBusiness is the business activity property of the resource; FFiled is the professional property of the resource; FOwnership is the ownership attribute of the resource, including source information, resource holder, sharing scope, sharing level, shared object, The sharing method and sharing period are the life cycle attributes of the resource, including the purchase date, the service life and the resource validity period, etc.; other is the supplementary information of the resource dimension attributes, allowing the dynamic scalability of the dimension attributes.

### *3.2.R&D design resource information model description*

Group enterprise R & D and design resourcesInformationis a type of unstructured data, this article is based on a certain enterpriseCADSoftware, for example, is semi-structuredXMLThe language is described. Figure 3 shows an XML format description of the resource.

```xml
<? version="1.0" encoding="UTF-8" ?>
<Sw_R>
    <BasicProp>
        <name>CAD2000</name>
        <brand>Autodesk</brand>
        <FVersion>2000 Edition</FVersion>
        <FSoftType>Computer aided drawing software</FSoftType>
        <FInstallModel></FInstallModel>
    </BasicProp>
    <AbiliProp>
        <FAbility>Drawing engineering drawings</FAbility>
        <FPurpose>Machinery, electronics, clothing, construction</FPurpose>
    </AbiliProp>
    <StatuProp>
        <status>
            <usingsta>idle</usingsta>
        </status>
        <FValidityDate></FValidityDate>
        <FNote>deactivated</FNote>
    </StatuProp>
    <InherProp>
        <ParentProp>Structural design software</ParentProp>
    </InherProp>
    <DimProp>
        <FFunction>software resources</FFunction>
        <FBusiness>R & D and design</FBusiness>
        <FField>manufacture</FField>
        <FOwnership>
            <from>company A</from>
            <owner>department A</owner>
            <level>low</level>
            <object>company B</object>
        </FOwnership>
        <FCycle>
            <buydate></buydate>
            <servicelife>three years</servicelife>
        </FCycle>
    </DimProp>
</Sw_R>
```


**Figure 3** XML description of R&D design resource information model

## 4. RESOURCE ATTRIBUTE EXTRACTION BASED ON SEMANTIC ANALYSIS

With the design, production, maintenance and upgrading of products for many years, the group enterprises have accumulated a large number of R & D and design resource information, including product design documents, product models, various knowledge bases, etc., these various forms of resources include most of the information such as the classification and attributes of resources. Among the many forms of information, resourceText information accounts for the largest proportion, so it contains the most information about R&D and design resources. The traditional reliance on manual methods to read resource texts to obtain resource information is inefficient, which seriously restricts product innovation, so it is becoming more and more important to extract attribute information in resource texts efficiently and targetedly. Based on the analysis of the R&D design resource information model already defined above, this section takes the text of an enterprise software resource as the corpuspythonEnvironmental utilizationTF-IDFThe algorithm preprocesses the corpus of an enterprise software resource, analyzes the generated corpus, extracts the attribute values of the software resources, and realizes the application and verification of the information model of the resources.

### *4.1. Text message preprocessing based on TF-IDF*

Term Frequency Inverse Document Frequency (TF-IDF) is an improved feature word weighting method based on the terminology frequency statistical method to assess the importance of a term to one of the documents in a file set or corpus. TF is Term Frequency, which refers to the number of times a given word appears in the file, and IDF is the Inverse Document Frequency Index, which is a measure of the general importance of a word, representing the negative correlation between a term and the text. TF-IDF filters out some common insignificant words while preserving important words that affect the entire text. The new weight formula after the word frequency TF, the inverse text frequency index IDF and the two frequency statistical methods is as follows:

$$tf = \frac{n_i}{\sum_k n_k} \tag{1}$$

$$idf = log\frac{D}{D_x+1} \tag{2}$$

$$tf - idf = tf_{i,j} \times idf_{i,j} \tag{3}$$

where: *tf*—the frequency of words, the number of times the term appears in the document;

*idf*—Inverse text frequency;

*D*—The total number of corpus documents;

$D_x$—The number of documents containing the term, with $D_x + 1$ in logarithm to ensure that the denominator is not 0.

For a given enterprise software resource inventory text, the specific steps to extract the resource attributes are as follows:

A. The enterprise software resource inventory text is saved to the text database as the original data for subsequent processing.

b. Add the industry terminology in the mechanical industry field that the word segmentation tool cannot recognize to the word segmentation database to ensure the completeness and accuracy of the word segmentation results.

c. Use the word segmentation tool to perform word segmentation processing on the software resource list text, reduce the text from text granularity to word granularity, remove words with invalid semantic expression by deactivating the word list, and take these words as the basic features of the text.

d. Through the TF-IDF statistical method, the corpus after word segmentation is trained, and more weights are given to feature words with distinguishing ability, and the TF-IDF model is obtained.

e. Organize the data output of the TF-IDF model, and combine the manual assistance to remove the unrelated words, and extract the attribute values of the software resources.

Enter the text information of the enterprise's AutoCAD software resources "AutoCAD 2010 is

autodesk's CAD software, with autocad, you can safely, efficiently and accurately share design data with customers. You can experience the great advantages of the native DWG format. DWG is one of the most widely used design data formats in the industry, and you can keep everyone informed of your latest design decisions. With presentation-enabled graphics, rendering tools, and powerful drawing and 3D printing capabilities, your designs will be even better. ", after pre-treatment to get the result. Table 2 shows the TF-IDF preprocessing results of AutoCAD software resources in the list of enterprise software resources after collation, and the output result is in the form of a binary, in which the first digit is the entry and the second digit is the one The weight value of the entry.

**Table 2** Software resource text preprocessing results

| TF-IDF extraction results | TF-IDF extraction results | TF-IDF extraction results |
|---|---|---|
| ('Design Data', 0.2527466003346) | ('Sharing', 0.1529854169210263) | ('Render', 0.2527466003346574).) |
| ('Presentation Graphics', 0.2527466003346) | ('Graphics', 0.117582331853463) | ('Drawing', 0.2527466003346574). |
| ('Design Decision', 0.2527466003346) | ('Decision', 0.130151367005911) | ('3D Printing', 0.2527466003346) |
| ('AutoCAD', 0.1668169941308352) | ('Software', 0.0532242335073952).) | ('DWG', 0.5054932006693148) |
| ('Autodesk Corporation', 0.209781797232746) | ('Data', 0.0872982366228215) | ('CAD', 0.11655139679986319) |
| ('Data Format', 0.25274660033465) | ('Format', 0.2527466003346574).) | ('Design', 0.1542591283479169) |

According to the output data of autocad software resource text information preprocessing in Table 2, the extracted terms are sorted according to the weight of the terms, pressed The order of entry weights from highest to lowest is sorted as DWG, 3D printing, data format, format, rendering, presentation drawing, design data, design decision, drawing, Autodesk company, AutoCAD, design, sharing, decision, drawing, CAD, data, software. It can be seen that the software resource information preprocessing can well remove the irrelevant terms in the resource text information, and at the same time give higher weight to the resource attributes, which provides great convenience for the attribute extraction of the software resource inventory of the subsequent enterprise. However, this method cannot remove all irrelevant terms, and there are still a small number of irrelevant terms left, which is the shortcoming of the algorithm. Therefore, after pre-treatment, a small number of irrelevant terms need to be removed with human assistance.

### *4.2. Analysis of extraction results*

This article takes the enterprise software resource inventory text as the corpus for attribute extraction, which contains 59 software resources, and the extraction results of each software resource contain the attribute values of the resources and a small number of irrelevant words, and after manually assisted filtering, remove the irrelevant words, extract and sort out the attribute values of the resources. Due to space limitations, Table 3 lists only the attribute value extraction results for 10 of these software resources. According to the data in Table 3, the attribute values of the resources are sorted according to the various properties defined, and the attribute values of the software resources are obtained and stored in the attribute library for subsequent use.

**Table 3** Resource attribute extraction results

| Resource name | Attribute extraction results |
|---|---|
| ANSYSMechanical | Mechanical Analysis, Structural Mechanics Analysis, Thermal Analysis, Coupling Analysis, Metallic Materials (FObject), Rubber, Foam, Geotechnical, Nonmetallic Materials, Acoustic Analysis, Piezoelectric Analysis, Thermal/Structural Coupling Analysis, Thermal/Electrical Coupling Analysis |
| AutoCAD 2010 | Share design data, DWG, drawing, 3D printing, rendering, presentation drawings |

| | |
|---|---|
| AutoForm | Sheet metal, stamping, simulation analysis, CAE simulation software |
| Capp teaming technical editing system | Group technology, CAPP process compilation, PDM, data statistics |
| Pro/Engineer | CAD/CAM/CAE integration, 3D software, parametric technology, 3D modeling, product design |
| SAP | FI Financial Accounting, TR Financial Management, CO Management Accounting, EC Enterprise Management, IM Investment Management, PP Production Planning, MM Material Management |
| SINOVATION | CAD/CAM integration, hybrid modeling, parametric design, feature modeling, CAM machining, stamping dies, injection molds, automobiles, auto parts, machine tools, general machinery, molds and process equipment, design and processing |
| PDMLink | Parameter Technology Company (PTC), PDM solution, Web-based, product data management platform, Java-based, information sharing, centralized storage, centralized management, data security |
| Shanda Huatian WITT-CAPP | Process flow, process design, process management |
| Wuxi manufacturing service network | Enterprise supply and demand information, news updates, corporate recruitment, data download |

After analyzing the extraction results, the method used in this paper is relatively complete with the resource attributes extracted from the software resource text. According to the resource properties that have been defined, the extracted property values are as follows:

ANSYSMechanical: FAbility (mechanical, structural, thermal, coupled, acoustic, piezoelectric, thermal/structural coupling, thermal/electrical coupling), FObject (metallic, rubber, foam, geotechnical, non-metallic);

AutoCAD 2010: FPurpose (shared design data), FFiletype (DWG), FAbility (drawing, 3D printing, rendering, presentation drawings);

AutoForm: FObject (Sheet Metal), FAbility (Stamping, Simulation Analysis), FSoftType (CAE Simulation Software);

CAPP group technology editing system: FTech (group technology), FAbility (capp process preparation, PDM, data statistics);

Pro/Engineer: FTech (CAD/CAM/CAE integration, parametric technology), FSoftType (3D software), FAbility (3D modeling), FPurpose (product design);

SAP: FAbility (FI Financial Accounting, TR Financial Management, CO Management Accounting, EC Enterprise Management, IM Investment Management, PP Production Planning, MM Material Management);

SINOVATION: FTech (CAD/CAM integration), FAbility (hybrid modeling, parametric design, feature modeling, CAM machining, stamping dies, injection molds), FObject (automotive, auto parts, machine tools, general machinery, molds and process equipment, FPurpose (design and processing);

PDMLink: FFromInfo (Parameter Technology Company (PTC)), FAbility (PDM solution), FTech (Web-based, Java-based), FSoftType (product data management platform), FPurpose (information sharing, centralized storage, centralized management, data security);

Shanda Huatian WITT-CAPP: FRange (process flow, process design, process management);

Wuxi manufacturing service network: FRange (enterprise supply and demand information, news, enterprise recruitment, data download).

## 5. CONCLUSION

R&D and design resources are the core assets of the group enterprises and an important support for product innovation. Based on the connotation and characteristics of R&D and design resources, based on the R&D and design resource information model of group enterprises based on semantic knowledge, this paper classifies and defines the internal and external resources of group enterprises, and realizes the dynamic scalability and automatic inheritance of model dimensions, attributes and descriptions. In the next step, based on the semantic model of R&D design resources, the spatial model of group enterprise design resources will be studied.

## FUND PROJECTS

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