Coordination technology of design data based on data space

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ABSTRACT

Product design is most creative stage in product development process, and it can be regarded as a process that generating new data based on the accumulated data. Therefore, reusing existing design data is critical to the product design process. In order to support different design activities, a variety of design support systems need to be used in the design process. However, there is currently no design data interaction bus between different design support systems. Design data need to be accessed and operated in a point-to-point manner, management and reuse is very difficult. Aiming at this problem, this paper proposes a design data coordination technology based on the analysis of the relationship between design data and design support systems, which takes the data space as the design data interaction bus. This paper analyses the construction method and working principle of the data space, and uses the overall design process of the tank to verify. The example proves that coordination technology based on data space can realize the rapid interaction and reuse of design data.

Keywords: Data space, product design, design support systems, design data

1. INTRODUCTION

Product design is a highly involved, often ill-defined, complex and iterative process[1]. In the field of product design, about 75% of the product development projects are based on the "variant design" where minor changes are made to the existing designs of the previous projects[2,3]. The design data in the weapon system design process include design processes, design templates, intermediate data, design results, etc. These design data have three important characteristics, including: Design data are generated in different design processes and keep changing follow the development of the design process; Different design processes need to access design data; The design data management process will also operate the design data, resulting in changes to the design data. The above features result in the frequent interaction of design data between different design processes in a point-to-point manner, which makes the management and reuse very difficult[4]. Therefore, how to achieve the coordination of design data and design processes is a key problem that needs to be solved. The specific manifestations are:

- Different design processes use a unified interface to read design data to avoid point-to-point interaction;

- The changes of design data can be dynamically reflected to different design processes.

In response to this issue, Hui Huang proposed the concept of data templates, and designed a set of data management and integrated application models based on the data platform as the center bus[5]; Filieri and Alguezaui explore the barriers to knowledge sourcing and reuse from electronic repository and their implications within the virtual product prototyping stage of new products development[6]. Liu adopted XML data exchange technology to solve the problem of data exchange and sharing between different heterogeneous databases[7]. Wang et al. proposed a knowledge service method that supports intelligent design of the product, integrated and encapsulated design tools, and realized automated calculations[8]. However, these studies focus on the integration of the data itself, and pay less attention to the design support system. Based on the analysis of the relationship between the design data and the design support systems, this paper studies the design data coordination technology based on the data space, uses the data space as the design data interaction bus, analysis the construction method and working principle of the data space, and verified by taking the overall design process of the tank as an example.

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2. THE RELATIONSHIP OF DESIGN DATA AND DESIGN SUPPORT SYSTEMS

The design process is composed of a series of design activities, and different design activities require different design support systems[9]. During the design of the weapon system, a variety of design support systems will be applied, including product data management systems, experimental data management systems, design process management systems, and various CAD, CAE, CAI software tools, etc. These design support systems have a direct or indirect relationship with design data. The existing design support systems can be divided into four categories: design process system, data system, tool system and design data management system. The design process system is responsible for the decomposition and scheduling of design tasks; The engineering designers complete the tasks in the tool system and submit the results to the design process system after receiving the design tasks; All data received by the design process system will eventually be archived in the data system; The data management system extracts design data from different systems, and provides these design data to different systems in the form of services. In general, the following relationships exist between design data and design support systems.

2.1 Design data support the design support system in the form of services

Design data management system does not directly produce product design results, but produces better design results through the support of data systems, design process systems, and tool systems. Therefore, the core feature of the design data management system is service, which does not increase the workload of designers during the service process, but provides design data for designers in a silent manner.

2.2 Design data are widely derived from design support systems

Design support systems are the main tools and platforms for designers to complete design work. Process data and result data in the product design process are stored in these systems. In order to reuse these contents, the design data management system incorporates these contents into the design data management system by means of extraction and indexing. Therefore, the design support system is not only the service object of design data, but also the content source of design data.

3. DESIGN DATA INTERACTION MODEL BASED ON DATA SPACE

By analysing the relationship between design data and design support systems, this paper proposes a design data interaction model based on data space, as shown in Figure 1. The model mainly includes three components, namely data space construction engine, data space and data space publishing engine. The data space construction engine can map the data from different design support systems into a unified representation model (such as RDF); The data space is the core of the model, and a unified representation model is used to describe all data. The data space publishing engine publishes the data space to the outside world, and provides services such as data query and browsing.
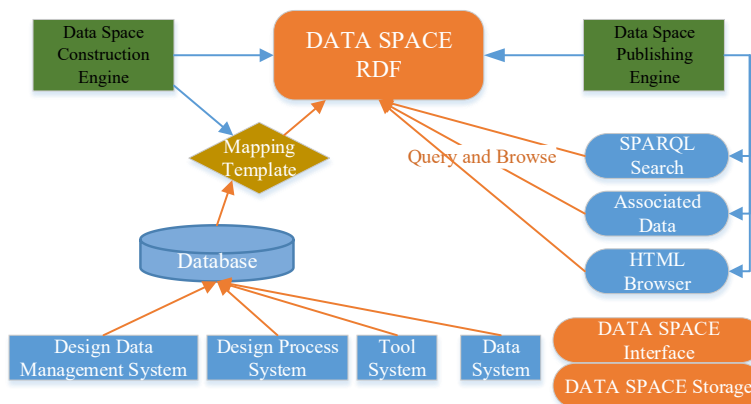

Figure 1. Design data interaction model based on data space.

Data space is a description method of heterogeneous data, which can describe the data from different design support systems in a unified way and publish and share it through the network. This method is based on three technical foundations, including:

- Uniform resource identifiers are used to describe data;

- Using RDF to describe data in different business systems, RDF uses triples to describe data Describe all data and the relationships between data. For example, a set of tactical technical indicators in tank design corresponds to a set of tank design schemes. The relationship between two objects is described in the database by means of primary keys and foreign keys, while in the data space, it is implemented by RDF triples.

- The data space can be published through the HTTP protocol, so that different design support systems can access the data space.

The mapping rules and access mechanisms of the data space will be described in detail in Sections 4 and 5 of this paper.

4. DESIGN DATA AND DATA SPACE MAPPING

Weapon systems are often very complex, including many components, parts, etc., and data of different structures are distributed in different design support systems. The data space construction engine can map data in different systems into a unified data space. The key issue is how to map the data stored in the structured database into RDF format and associate the data in RDF format with the data space. Relational databases and RDF are essentially the same, both describe the relationship between data through attributes and relationships, so relational data can be converted into RDF data. The mapping from relational database to RDF data is realized by mapping files, which mainly include three mapping rules, namely: database table mapping; database metadata (attribute) mapping; database relationship map. Combining the above three mapping methods can realize the mapping from relational data to RDF data, and finally form a data space.

In order to form a mapping file, the most important thing is to define the metalanguage in the template. The following explains the metalanguage used in the mapping relationship database.

4.1 Database definition

The database definition metalanguages are shown in Table 1.

Table 1. Database definition metalanguage.

Number	Metalanguage	Meaning
1	d2rq: jdbcDSN	URL
2	d2rq: jdbcDriver	Driver
3	d2rq: username	Login username
4	d2rq: password	Login password

4.2 Database table mapping

The tables in the database are mapped by "ClassMap", and its properties are shown in Table 2.

Table 2. Database table mapping metalanguage.

Number	Metalanguage	Meaning
1	d2rq: dataStorage	ClassMap data storage database
2	d2rq:class	Name of class in RDF
3	d2rq: urlPattern	URL Pattern of class
4	d2rq: NodeIdColumns	Field in database
5	d2rq: condition	SQL's where condition

4.3 Attribute mapping

The property information in the database is mapped through "PropertyBridge", and its properties are shown in Table 3.

Table 3. Database attribute mapping metalanguage.

Number	Metalanguage	Meaning
1	d2rq: belongsToClassMap	Which classMap belongs to
2	d2rq: property	Name of attribute in RDF
3	d2rq: column	Table fields containing attribute
4	d2rq: datatype	Data type of attribute
5	d2rq: constantValue	Defaults of attribute
6	d2rq: refersToClassMap	Related other classMap

4.4 Relationship mapping

In addition to different attribute information in relational data tables, what is more important is the relationship between different tables. Relationships are expressed in databases by foreign keys, which are essentially fields. Therefore, the relationship between different tables is also expressed by "PropertyBridge" like attribute. The "d2rq: refersToClass Map" in the table is used to point the value of a certain attribute to another "ClassMap", thereby realizing the reference relationship between ClassMaps.

```
# Define naming space
@prefix d2rq: <http://www.wiwiss.fu-berlin.de/suhl/bizer/D2RQ/0.1#>
# Define naming space
@prefix : <http://annotation.semanticWeb.org/iswc/iswc.daml#>
# Basic naming space of RDF and XML
@prefix rdfs: <http://www.w3.org/2000/01/rdf-schema#>
@prefix xsd: <http://www.w3.org/2001/XMLSchema#>
# Define database
map:Database1 a d2rq:Database;
     d2rq:jdbcDSN "jdbc:mysql://localhost/iswc"
     d2rq:jdbcDriver "jdbc:mysql.jdbc.Driver";
     d2rq:username "user";
     d2rq:password "password";
# Define table structure and attributes
map:Requiremanta d2rq:ClassMap;
     d2rq:dataStorage map:Database1;
     d2rq:class:Conference;
     d2rq:uriPattern "http://conferences.org/comp/confno@@Product.ConfID@@";
# Define attributes,Product requirements include functional requirements
map:Function a d2rq:PropertyBridge;
     d2rq:belongsToClassMap map:Requirment;
     d2rq:property:eventTitle;
     d2rq:column "Requirment.Function";
     d2rq:datatype xsd:string;
```

Figure 2. Mapping file example.

According to the above metalanguage, the content in the relational database can be mapped to RDF, and different RDFs can be integrated through mutual reference, so as to realize the integration between heterogeneous systems and heterogeneous data. Figure 2 shows an example of a mapping file. The mapping file includes three main parts. The first part is the namespace definition, which can ensure the uniqueness of all the defined design data in the data space; The second part is the database definition; The third part is the declaration part of the mapping. However, only publishing

relational data as RDF data cannot provide services. It is necessary to further publish RDF data and provide services such as query and browsing.

5. DATA SPACE RELEASE AND ACCESS MECHANISM

The purpose of the data space is to enable heterogeneous systems to query various data in all design support systems through a unified platform. Browsing data space is also data space query in essence, so it is necessary to build a query method independent of technology and system. Since the expression of data space adopts RDF, the corresponding query must also adopt SPARQL language. The data space release and access mechanism are shown in Figure 3.
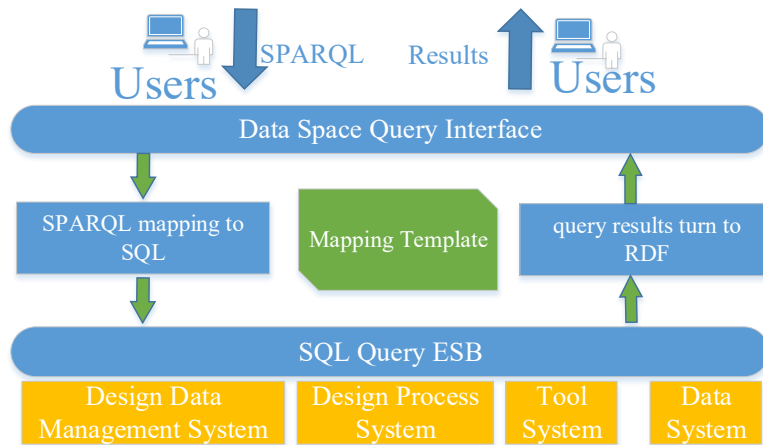

Figure 3. Data space release and access mechanism.

During the query process, other systems describe the query requirements through the SPARQL language, and the SPARQL query language queries the data space through the data space query interface. During the query process, the data space server parses the SPARQL language and converts the query requirements into the SQL language distributed in different systems, and executes the SQL language on different systems to obtain feedback results. After the SQL query result is obtained, the SQL query result is converted into RDF data through the mapping template, and the RDF data is fed back to the query subject. The mapping template plays a key role in the entire query process. Whether it is the process of converting from SPARQL language to SQL language or the process of converting SQL query results to RDF data, it depends on the definition of database metadata by the mapping template.

6. EXAMPLE OF DATA SPACE CONSTRUCTION

Based on the data space related technologies studied in this paper, the construction method and application process of the data space are illustrated by taking the overall design process of the tank as an example. The overall design process of the tank relies on the support of multiple information systems to complete. The project integrated management system completes the project definition, process definition, task distribution, progress control, etc.; The engineering design system completes the iteration of the design process; PDM can store the design process results; SDM can record the process data of the engineering design. There are inevitably a variety of interactions and reference relationships between these systems. For example, the project integrated management system will involve task data distributed to PDM, and the SDM system will also record the results stored in the PDM corresponding to the process data. Such multiple cross-references and data changes have brought about the inconsistency between the tank design process and design data. Therefore, the method of data space is used to coordinate heterogeneous data of different systems to achieve unified release and access of data.

6.1 Data space construction

According to the metalanguage shown in Tables 1-3, the mapping of design process data, PDM data, and design resource data is constructed. The fragment of the data space formed is shown in Figure 4.

Http://…..../Process/ProcessDefinition/TD Overall design

Pro:ProcessDefinition

Http://…..../Process/ProcessInstance/TD Overall design001

Pro:ProcessInstance

Http://…..../Km/KnowledgeItem/Method of combat technical indicators

Pro:ProcessTask

Km:KnowledgeItem

Km:Category

Http://…..../Process/ProcessTask/Combat technical indicator decomposition
Http://…..../Process/ProcessTask/power system
Http://…..../Process/ProcessTask/System Simulation

Km:SemanticTag

Km:Attach

Sdm:data

Http://…..../Sdm/Data/the middle of the power system
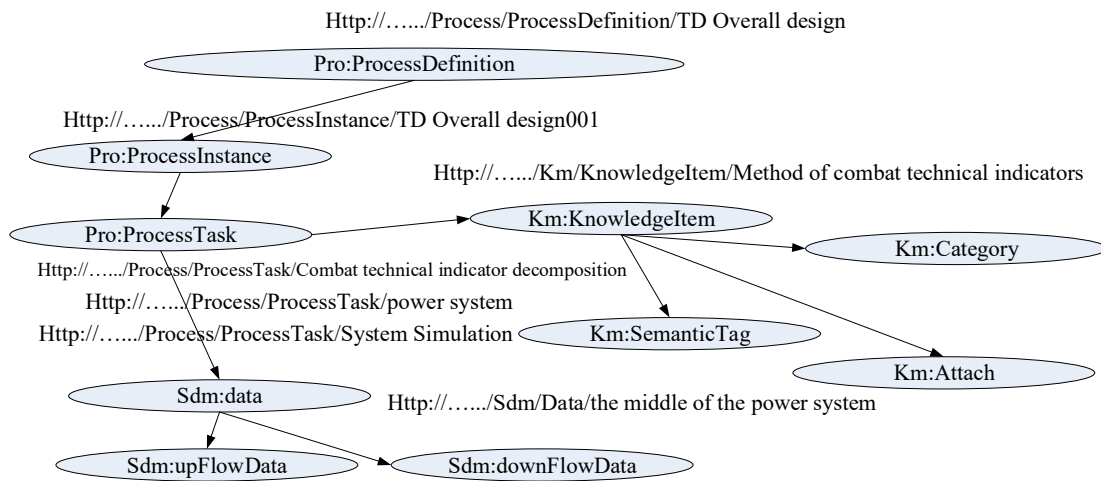
Sdm:upFlowData

Sdm:downFlowData

Figure 4. Data space example.

The data space shown in Figure 4 can be converted into the representation of RDF, and the basic content is shown in Figure 5.

```xml
<?xml version="1.0"?>
#Define different naming space
<rdf:RDF
    xmlns:rdf=http://www.w3.org/1999/02/22-rdf-syntax-ns#
    xmlns:pro="http://....../Process#"
    xmlns:know="http://....../km#">
    xmlns:sdm="http://....../sdm#"
>
<rdf:Description
    rdf:about="http://....../Process/ProcessDefinition/Tank001"
    pro:task="Task 1"
    pro:task="Task 2"
    ......
/>
    ......
</rdf:RDF>
```

Figure 5. Data space RDF representation.

6.2 Data space query

As shown in Figure 3, the design support system can query data in other systems through the data space, instead of directly obtaining data from the corresponding system. The query methods to obtain design data from the design process are shown below. SPARQL language is used in the query process, and its basic format is: sparql --data=<file> --query=<query>. "sparql" is the query command, "—data" refers to the data space file to be queried, and "—query" refers to the query statement. Existing design data will be reused in the overall tank design process. On the one hand, the design data management system will query and extract data from different systems, and on the other hand, the design process will also directly query design data in other systems. Taking the tactical index decomposition task as an example, the design data related to the tactical index decomposition task in the design data system are as figure 6. By joint query design task data and design resource data, all design data entries related to combat technical indicators are found.

```
PREFIX : <http://....../process#>
SELECT ? KnowledgeItem
WHERE {
: Combat technical index decomposition: relatedKnowledge ? KnowledgeItem
}
```

Figure 6. Query design data from data space.

7. CONCLUSION

Based on the analysis of the relationship between design data and design support systems, this paper proposes a data space-based design data coordination technology. The design data interaction model based on data space is designed, and the working principles and construction methods are expounded in detail. Finally, the construction and query method of the data space are verified by the example of the overall design process of the tank, and it is proved that using the data space as the design data interaction bus can change the way that different design activities operate the design data in an intersecting manner, so that the design data can be quickly managed and reused.

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