Integration of CAD & PDM on web distributed environment using XML-based web service

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Abstract: It is certain that the future manufacturing environment will be network-centric and spatially distributed based on Internet. Today, wide variety of distributed computing and communication technologies are available for implementing a system for product data exchange and sharing. One of the technologies that have been received most attentions for product data exchange and sharing is Product Data Management (PDM). PDM tries to integrate and manage process of data and technical documents that are connected to physical product components. In accordance to previous researches about PDM, it can be regarded as an integration tool of many different areas, which ensures that the right information is available to the right person at the right time and in the right form throughout the enterprise. PDM with Web-enabled CAD system is proposed in this paper in order to acknowledge the usefulness of the system mentioned. The system will use Web service on Visual Studio C#.Net to invoke the web application system.

Keywords: Web-enabled CAD, Product Data Management, XML, Web Service

1. INTRODUCTION

"The future winners are companies mastering information / data / document management." [3] In order to meet the market needs and get a better assessment from customer, the use of information technology (IT) should be maximized to obtain more accurate and reliable data and information. Many enterprises have used IT as the basis of the enterprise system to achieve ultimate goals that are to increase productivity, reduce lead times, shorten design cycles, improve quality, etc.

The idea of this research is from the experience of D&DE (Digitalized & Design Engineering) consulting company, which is located in Busan, Korea. This company provides engineering analysis service by using CAE systems. Customers provide their requirements not in the form of digital data. These requirements from many customers are too much to be arranged as product data. The existing system that D&DE uses currently is to design the requirements by using CAD system and to analyze it without considering any product data concept that could be well used in various analyses during product life cycle. One possible approach to address this problem is to introduce PDM system.

In order to provide better services to the customer, D&DE tries to expand the system such that the customer can access the system through web service. The objective of this research is to develop system that uses PDM concept and web technology. With the system, customers can access product data through web service provided by D&DE. The database designed in this research includes product data that can be used in various analyses during product life cycle. Based on the D&DE's requirements, Web-based PDM system is further investigated for possible implementation.

From the experience of D&DE, the document management system is required for any kind of service demand. In order to meet the future goal that is to design a product based on customer demand, a better document management system needs to be built. The PDM system satisfies this requirement.

Implementation of PDM based on web service is useful for PDM knowledge development. Many researches have focused on concept of PDM system. Few researches focused on issue of implementation are recently available. Especially researches on implementation of web-based PDM systems are rare.

In this research, web-based system and PDM are used in order to develop the system. The web-based system is designed to address a requirement of client-server model. PDM system is designed to address the requirement of managing product data for product life cycle.

In the proposed system in this research, PDM system accepts STEP (Standard for Exchange Product Model Data) file that is generate by CAD system and convert it into the database. This database is used for modeling (editing function) and displaying the part on the screen. The database is to store data structure and further information for PDM. The web-page design specifies a certain function relate with programming.

There are many kinds of commercial CAD software in the market. Most CAD software provides Standard for the Exchanged Product Data (STEP) converter. In this research, Mechanical Desktop 6.0 is chosen for the CAD drawing and as a converter from drawing file to the STEP file.

STEP (Standard for the Exchanged of Product Model Data) is based on the ISO 10303. There are many kinds of part that is available for the certain manufacturing company. The STEP file used in this research is based on STEP Part 21 (implementation part) about clear text encoding of the exchange structure.

The Web Technology plays an important role in implementation of the system designed in this research. Various mark-up languages like HTML, XML, SGML, etc. can be used to develop a web page. In order to fit with the PDM based on STEP file and Web Service that recently have been well-developed, XML technology which is already available in web service architecture is adopted. In the system, feature extraction is also included. The extracted features are stored in database and can be used in various following applications such as CAPP (Computer Aided Process Planning).

2. PRODUCT DATA MANAGEMENT SYSTEM

2.1. Concepts of PDM

PDM stands for Product Data Management. It means

managing information of product from several simultaneous points of view. The data for PDM include text document, CAD drawing file and other data objects that has its own description.

Product Data Management can be seen as an integration tool connection many different areas, which ensures that the right information is available to the right person at the right time and in the right form throughout the enterprise [6]. It can also be said that PDM is an information infrastructure to manage all product-related information and the complete product life cycle [4].

The PDM system is an integrated system to manage the product data, process data and all the documents that related with the product in a better repository. Information Technology / Software Package is just a tool to simplify and make rapid process of accessing the repository. IT or Software Package will reduce the accessing time to search, store, maintain, sort the documents, and can be accessed from any department, any place to support the enterprise activity. So, the PDM system includes all integration system and the system should be supported by a good IT or Software Packages. It's not only about the IT or Software Package, but also related with dealing people, changing system and redesigning process to apply the IT or Software Package.

2.2. PDM and STEP (Standard for the Exchange of Product Model Data)

STEP (Standard for the Exchange of Product Model Data) is based on information models. These models make the standardization efforts on information content, rather than implementation technology. This insures that the development of the model should not be discarded upon a change in computing technology.

In most of systems, PDM is built according to STEP standard to meet the requirement among various kind of technologies for distributed environment. Based on ISO 10303, STEP keeps developing the product exchange standard for global network-computing environment using XML.

2.3. PDM for Web-Enabled CAD system

The PDM term consists of the whole integration of enterprise business process, start from marketing, product design, process design, manufacturing process to distributing the finished good to customer. For the CAD system, PDM is limited on the product data, which is based on product management and data management, and also using the geometrical data to represent the product with STEP-based.

Product management discusses about the product structure and configurable of a product. And the data management is about making a well-established model of database management system. The geometrical data is used to address the feature modeling and feature recognition of a product.

3. WEB SERVICE

There are several term that can be mentioned for Web Service System. SOAP, WSDL, UDDI, XML are the embedded system on Web Service.[7] Visual C#.Net provides these tools to make a response-request service through the network for server-client tier technology. SOAP, WSDL and UDDI used the XML grammar for describing web services.

XML (eXtensible Markup Language) is a new generation of HTTP.[5] It is a data format for structured document interchange on the Web. The XML specification describes a class of data objects called XML documents, and partially describes the behavior of computer programs that process them. A key aspect of XML is its portability. It is self describing, easy to read and because it is ASCII; can be transferred using standard protocols such as HTTP.

SOAP (Simple Object Access Protocol), using XML syntax for exchanging messages to different type of application of client-side, is a distributed technology to invoke a connection to server without any barrier such as firewall. SOAP is a fundamental part of .NET, Microsoft's web programming platform. The previous technology such as DCOM (Distributed Component Object Model), CORBA (Common Object Request Broker Architecture) have some weakness in that SOAP can cover it.

The Web Service Description Language (WSDL) is an XML-based grammar for describing web services, their functions, parameters, and return values. Every web service must have a WSDL. The WSDL supplies the detailed information about the web service's functionality and how to access this functionality, to the clients. Rather than creating an actual WSDL file, ASP.NET generates the WSDL information dynamically. If a client requests the web service's WSDL file (either by appending *?WSDL* to the ASMX file's URL or by clicking the "Service Description" link in the web service help page), ASP.NET generates the WSDL description, which is then returned to the client and displayed in the web browser. Because the WSDL file is generated when it is requested, clients can be sure that the WSDL contains the most current information.

UDDI (Universal Description, Discovery, and Integration) is a web-based distributed directory that enables business to list them on the internet and discover each other, similar to a traditional phone book's yellow and white pages.

4. PROPOSED SYSTEM ARCHITECTURE

4.1. Database Management

The database management system only includes the CAD system, even PDM system can accommodate other data for data generated by CAM and CAPP as the integrated system. The database can be separated as 3 big section, product and part, versioning document, and geometrical and topological data.

The product and part database is about the product structure (tree structure) for BOM, assembly part and other things related with components. [9] The versioning document connects to the product and part data as an integration data for product design. Each product or part has their own document, which has its own version, in order to trace the historical design of a product and/or also make a configurable product. The geometrical and topological data that can be related with STEP file have a close relationship with feature modeling system and feature recognition module.

4.2. System Design

Using Microsoft Visual Studio.Net, C# developer system, it can be built the server-client system using the Web Service technology such kind of SOAP, WSDL and UDDI. This section describes the whole integrated system to be built.

The Web Server is located on the local host computer. The Internet Information Service, Windows Server component, provide connection through RPC (Remote Procedure Control) combined by ASP.NET language using Visual C#.NET.

Data for product can be provided through the database server; in this case we used SQL server, or using the STEP file converter to be an XML document. Thus, the data will be used

for feature modeling and recognition module for the product.

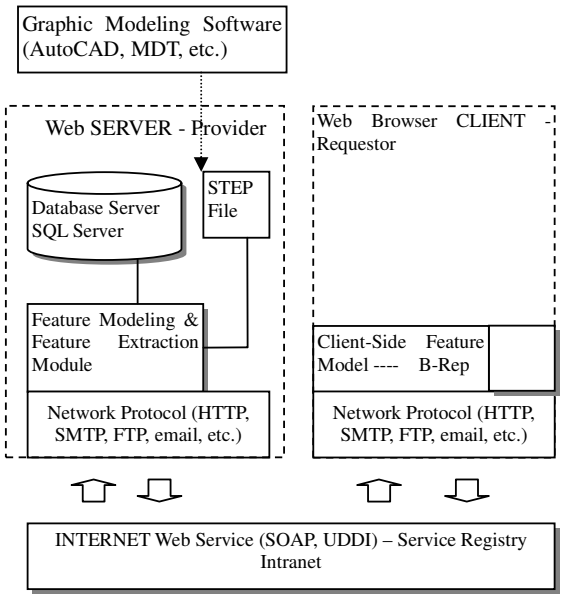

Fig. 1 System Design Architecture

The Feature Modeling and Feature Extraction module is connected to the network protocol (HTTP (Hyper Text Transfer Protocol), used WSDL based on XML grammar) and published through the internet via SOAP and UDDI – Service Registry. Once a request comes from the client, the network protocol flows the data using the Network Protocol to the server and the server updates the request and sends it back to the client through the same way.

4.2.1. Modules

4.2.1.1. Web-Server

The product data database included in this system is based on STEP standard. The system still need database system, which is used SQL Server, in order to easily-manipulate the graphical data in real time. The STEP file itself can be a directly converted data to the successor module.

The module for Feature Modeling System includes editing function as shown on the display on web browser and displaying the product data as a graphic file.

Feature Extraction module is about recognizing a specific feature as a slot, pocket, rib etc. This module is useful for making the process design, related with CAPP (Computer-Aided Process Planning) and accessing manufacturing cost. More complex a product design, using the complicated feature, means more difficult on the manufacturing process and it indicates more cost on producing the product.

4.2.1.2. Web-Client

The feature model on client side is a kind of display to show the product, included all of the components, which is connected to GUI (Graphical User Interface). B-Rep (boundary representation), one of the widely-used method for feature modeling system, can be used for the exchanging product data and display using request and response services.

The GUI, on client side, is built as easy as possible to be understood by the user. The design uses some term, like tree structure data, panel interface to see the part graphics.

4.2.1.3. Internet Web-Service Service Registry

In order to be recognized, a web service should be registered to a Provider and Service with UDDI Services. Microsoft provides a web site, http://uddi.microsoft.com, to have a free registration of a web-service and publish it through the internet. Each user has to register using Microsoft .Net Passport to manipulate the server-client web-service design with internet.

4.2.2. Feature Modeling

The feature modeling module includes parsing algorithm, transferring the geometrical and topological data from STEP file into database. The module provides tools to edit the part using the simple manually textbox column.

The feature modeling module makes data structure from the database management system. The data structure can be used for the extraction to obtain a specific feature. Table 1-4 shows simple data structure for cubic part, shown in Fig. 2.

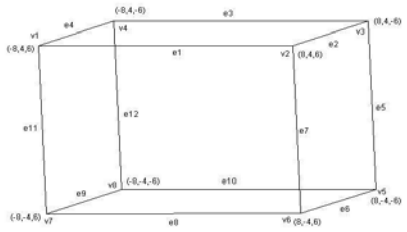

Fig. 2 Simple cubic

Table 1 Edge data structure

Edge	Vstart	Vend	dirX	dirY	dirZ	CurveType
e1	v1	v2	1	0	0	Line
e2	v2	v3	0	0	1	Line
e3	v3	v4	1	0	0	Line
e4	v4	v1	0	0	1	Line
e5	v3	v5	0	-1	0	Line
e6	v5	v6	0	0	1	Line
e7	v2	v6	0	-1	0	Line
e8	v6	v7	-1	0	0	Line
e9	v8	v7	0	0	1	Line
e10	v5	v8	-1	0	0	Line
e11	v7	v1	0	1	0	Line
e12	v8	v4	0	1	0	Line

Table 2 Loop data structure

Loop	e1	e2	e3	e4	e5
L1	e1	e2	e3	e4	null
L2	e2	e5	e6	e7	null
L3	e6	e8	e9	e10	null
L4	e9	e11	e4	e12	null
L5	e3	e7	e11	e8	null
L6	e5	e10	e12	e3	null

Table 3 Face data structure

Face	Loop	DirXx	DirXy	DirXz	DirZx	DirZy	DirZz
f1	L1	0	1	0	0	0	1
f2	L2	1	0	0	0	0	-1
f3	L3	0	-1	0	0	0	-1
f4	L4	-1	0	0	0	0	1
f5	L5	0	0	1	1	0	0
f6	L6	0	0	1	1	0	0

Table 4 Edge intersection of face data structure

EdgeName	FaceName1	FaceName2
e2	f1	f2
e6	f2	f3
e9	f3	f4
e4	f4	f1
e1	f1	f5
e7	f2	f5
e8	f3	f5
e11	f4	f5
e3	f1	f6
e5	f2	f6
e10	f3	f6
e12	f4	f6

The data structure that can be made from database is edge, loop, face, and edge intersection data structure. This data structure is numerical representative of the simple cubic shown in Fig. 2. The method to obtain the feature extraction is explained in the next section.

4.2.3. Feature Extraction

The feature extraction can be obtained from the data structure. The database design can be simply converted to data structure as explained above. To simplify the analysis of the data structure, graph pattern analysis is used. [1] The graph pattern analysis connects each intersection feature and analyzes them using the normal vector information provided by STEP file. Some of the analysis uses the looping information. The different direction of looping or edge can be useful information to obtain the extracted feature.

To obtain a complex feature, a simple feature should be understandable. Concave edge is the basic of knowing a perplex feature. Using the edge information, such as direction, curve type, length / radius, starting vertex and end vertex, combined with relative direction X & Z on the face information, concave edge can be analyzed easily.

The feature that extracted for this research is limited for the planar surface with three examples as shown in Fig. 3, Fig. 4, and Fig. 5. The slot, rib, pocket feature are used as the system prototype.

There is a specific pattern for recognizing the feature. The extracting function in this system is discussed using the relative direction of X, relative direction of Z on STEP file and the origin vertex value of a surface.

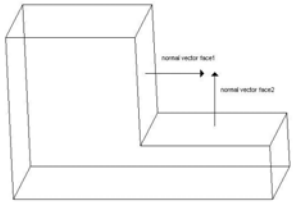

Fig. 3 Simple concave

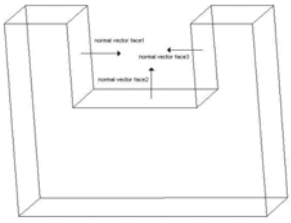

Fig. 4 Slot feature with 3 faces normal vector

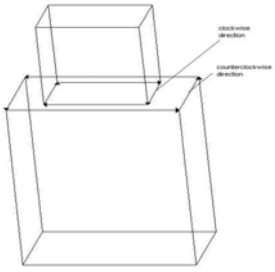

Fig. 5 Rib feature with clockwise and counterclockwise loop direction

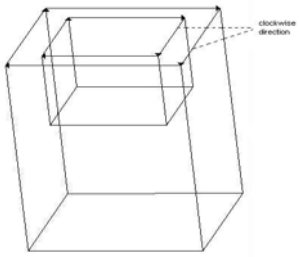

Fig. 6 Pocket feature with clockwise direction

A simple concave could be seen as the example on Fig. 2 The edge between face1 and face2 is considered as concave edge. It is because the face make a perpendicular angle, with the normal vector of face1 is x=1,y=0 and the normal vector of face2 is x=0, y=1.

The basic theorem for slot is based on the concave edge as explained above (Fig. 3) The complement feature for pocket is an additional feature at face3, which is making a loop with consideration of direction X on face1 is x=1,y=0 ; on face2 is x=0,y=1 ; on face3 is x=-1,y=0.

The rib feature has more complex surface rather than usual concave edge. This type of feature provides a face bound text file to identify the bounding feature between the below and the above stock. As we see on Fig. 4, the loop of the edge is different. The outer face has counterclockwise direction while the bound face (the inside rectangle) has clockwise direction. This information is provided on STEP text file.

The same as rib feature, pocket feature has the information with bounding face. The relative direction X and Z for the inner part has the same information with the rib feature (the above stock) as shown in Fig 5. The different between rib feature and pocket feature is the loop direction for the outer bound face and the bound face itself. Both of them have the same clockwise direction.

4.2.4. Algorithm

The algorithm to find patterns for slot, rib and pocket obtaining the data from database are listed in this section.

```
For (I = 2 to total_Face)
    If ((DirXx[i-1]==1 AND DirXy[i-1]==0 AND
DirXx[i]==0 AND DirXy[i]==1) || ( DirXx[i-1]==0 AND
DirXy[i-1]==1 AND DirXx[i]==-1 AND DirXy[i]==0 ))
    {
        Slot_Feature=true;
    }
```

For searching the clockwise (CW) and counterclockwise (CCW) direction, looping edge is used to find the direction toward a certain direction. For this example, x direction and y direction, from two connected edge, is used to find the pattern of clockwise and counterclockwise direction.

Throughout the STEP file, loop that makes a clockwise or counterclockwise direction is only about Face_Outer_Bound and Face_Bound. The feature extraction module is used for these two kinds of face on the STEP file.

…….

```
[Finding Direction]
    CounterClockWise[ ] = false;
    ClockWise[ ] = false;
    For (I=2 to Total_Loop)
    {
        If (Endvertex[i-1]==StartVertex[i])
        {
            {
                Case (the direction follow the following direction
                (x[i-1]=1, y[i-1]=0, x[i]=0, y[i]=1) ||
                (x[i-1]=0, y[i-1]=1, x[i]=-1, y[i]=0) ||
                (x[i-1]=-1, y[i-1]=0, x[i]=0, y[i]=-1) ||
                (x[i-1]=0, y[i-1]=-1, x[i]=1, y[i]=0) ||
                    {
                        CounterClockWise[i] = true;
                        ClockWise[i]=false;
                    }
            }
            {
                Case (the direction follow the following direction
                (x[i-1]=1, y[i-1]=0, x[i]=0, y[i]=-1) ||
                (x[i-1]=0, y[i-1]=-1, x[i]=-1, y[i]=0) ||
                (x[i-1]=-1, y[i-1]=0, x[i]=0, y[i]=1) ||
                (x[i-1]=0, y[i-1]=1, x[i]=1, y[i]=0) ||
                    {
                        ClockWise[i] = true;
                        CounterClockWise[i] = false;
                    }
            }
        }
    }
    For (I=2 to Total_Loop)
    {
        If All CounterClockWise[i]=true
            THEN the Loop is CounterClockWise
        If All ClockWise[i] = true
            THEN the Loop is ClockWise
    }

[Feature Extraction]
    For (FaceOuterBound[i] to FaceBound[i])
        {
    If ((FaceOuterBound[i]=CCW && FaceBound[i]=CCW)
        || (FaceOuterBound[i]=CW && FaceBound[i]=CW))
            {
                PocketFeature=True;
            }
        Else
            {
            RibFeature=True;
            }
    }
```

…….

The algorithm basically is acquired heuristically on obtained data structure above. By finding the certain pattern of the data structure, feature can be obtained and analyzed.

4.2.5. Implementation

Visual Studio C#.Net is a new .NET programming languages which almost similar with C++ or even Java languages. One advantage of using C#.NET is the ease of use that can make the same result as other web-programming languages such as C++ and/or Java.

5. CONCLUSION

In this paper, the PDM for CAD by using XML based Web service is proposed for manufacturing organizations which need to implement a concurrent engineering concept in their product development. The system is implemented for local engineering consulting company in order to demonstrate that the manufacturing organizations can actually have some benefits. The system has shown that the Web-enabled CAD system is very useful for engineering consulting companies which provide design service for new product needs.

The following advantages can be obtained with the implementation proposed in this research

- The documentation has a good structural mechanism to be shared among the business function of an enterprise
- Feature modeling and feature extraction module used in this system will be necessary for planning the manufacturing process design.
- Better control of the engineering data and historical design activity is well-established.

Microsoft Visual C#.Net, a new programming language which provides XML and web services, could establish a well-PDM distributed system using simple language for a new learner in web technology.

For the next step, it would be a better research to provide the process design until the manufacturing design using the PDM system.

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