Towards a Method of Data Management and Consistency Control Based on P2P for Collaborative Product Design

Pengfei Zeng[1,2,*], Yongping Hao[2], Weiping Shao[1] and Ze Tao[1]

[1]*School of Mechanical Engineering, Shenyang Ligong University, Shenyang, Liaoning, 110159, P.R. China*

[2]*R&D Center of CAD/CAM Technology, Shenyang Ligong University, Shenyang, Liaoning, 110159, P.R. China*

Abstract: In order to meet the requirements of collaboration product design (CPD) across multidisciplinary fields, a method on data management and update consistency control has been proposed based on the peer-to-peer (P2P) network, in the inter-enterprises design process. A kind of design mode of CPD and hierarchical structure of data management are both built. For the management needs of data exchange and information sharing across CPD process, group modeling and dynamic control method associated product design peers are achieved. The causes of data inconsistency are analyzed, and a detection model of data inconsistency is presented as well. Based on the product design constraints satisfaction problems, data update method and consistency control algorithm related to implementing the key update process are also put forward. Based on the open JXTA platform framework, the appropriate system architecture and its functional modules are established and realized for CPD data management. And further follow-up work is also discussed.

Keywords: Collaborative product design, Consistency control approach, Data management, P2P, System framework.

1. INTRODUCTION

Modern product development often involves many participants from different geographical enterprises, through collaboration and cooperation between each other to improve product quality, reduce investments and costs, and shorten lead time, in order to achieve a win-win situation. In the CPD process in which multiple parties and multiple fields collectively participate, design data exchange and information sharing is essential in time. Of course, each enterprise has its own data management system related to product design information [1], such as product data management (PDM) system and product lifecycle management (PLM) system. Thus, using design network environment, how to adopt a timely manner to transmit updated design data and information to appropriate design engineers is critical across enterprise data management.

Reference [2] presents two fuzzy-based systems for data replication and peer trustworthiness for JXTA-Overlay P2P platform. Many parameters have been taken into account to evaluate and decide about related system performance and reliability. Reference [3] proposes general analytical models for evaluating the performance of two approaches for recovering lost data in peer-to-peer storage and backup system. Yin *et al.* [4] makes a preliminary attempt at using a peer-to-peer multi-agent framework for decentralized grid workflow management in semantic grid enabled collaborative design. A decentralized, scalable semantic service registry is laid out in the P2P network for semantic discovery of distributed, heterogeneous grid with multi-agent support. Reference [5] concerns with product data transmission in networked design collaboration using P2P CAD streaming. A heuristics-based scheme is proposed to optimize the transmission efficiency among multiple users. The scheme allows a collaboration to quickly acquire a meshed CAD model of some level of detail by aggregating data fragments from the other collaborator.

Wang *et al.* [6] introduces a preliminary research work on P2P&VRML-based collaborative communication environment to support synchronous collaborative product design among geographically distributed design teams. A prototype system has been also developed on the basis of JXTA platform. In order to design an efficient collaborative multi-robot framework that ensures the autonomy and the individual requirements of the involved robots, Spaho *et al.* [7] present a P2P system based on JXTA overlay to act as a platform for robot collaboration and knowledge sharing. In the reference [8], a distributed system based on P2P network has been developed using CAD kernel and COM/DCOM. The proposed system can share functions among other systems, which can either serve as client or server needed. These increase its usability of functions applied for multiple operations simultaneously. A system hybrid client-server and P2P network enabled is proposed to implement Internet-based modeling collaboration among teams from multiple disciplines for the development of a Building Information Model (BIM) [9], which allows geographically separated design teams to work simultaneously on a single multidisciplinary BIM.

These scientists have done a lot of positive contributions and found some very encouraging results in the research fields of collaborative design data integration and document

*Address correspondence to this author at the School of Mechanical Engineering, Shenyang Ligong University, Shenyang, Liaoning, 110159, P.R. China; Tel: +86 24 24680968; Fax: +86 24 24682115;
E-mail: pfzeng@gmail.com

1874-4443/15 2015 Bentham Open

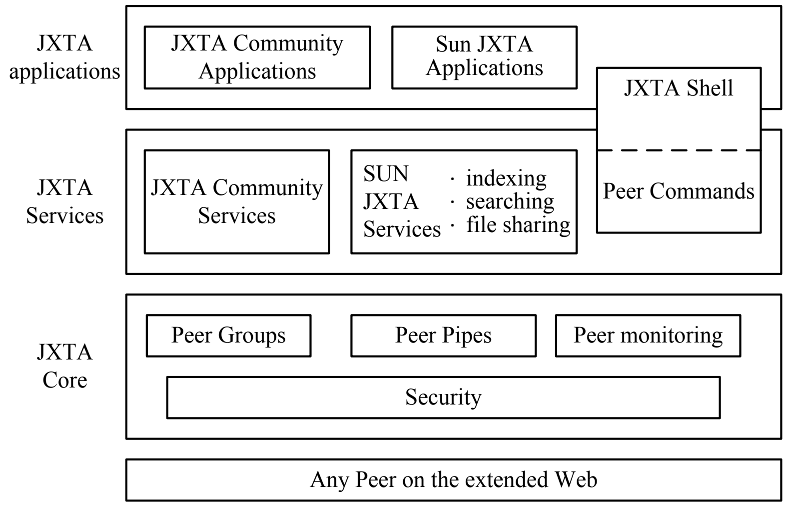

Fig. (1). JXTA triples layers.

management. However, related researches and other appropriate aspects that refer to design data management and consistency control about CPD based on the P2P network are quite rare in the above-mentioned results. In this paper, to meet the product design requirements by way of the P2P network collaboration environment, both the collaborative structural scheme and dynamic data consistency management method among design peers are discussed in CPD environments. Through achieving data management model and consistency control mechanism, a dynamic coordination consistency method of data exchange and information sharing is implemented in the CPD process. Finally, with the help of the open P2P platform-JXTA framework, a system application platform is established to design data exchange and information sharing in inter-enterprise collaborative process for CPD.

2. P2P AND JXTA

2.1. Definition and Application of P2P

The P2P network is the product combining distributed system and computer networks, and is a kind of network using peer-to-peer work mode [10]. In the P2P network, any network node can be seen as a Peer, their behavior is free, function is equal, connection is interconnected, and all Peers distributed self-organize to combine into a whole network. Therefore, it can greatly improve network efficiency, makes full use of network bandwidth, and develops potential for each network node.

The P2P technology enables network operation mode from centralized to distributed, that is to say the core of network applications from the server side move to each network node side. Accordingly, the level people exchange information on the network is improved to a higher degree, so that they are able to participate in the network communication in a more proactive way. Currently, some representative technology application areas of the P2P network are mainly consisted of real-time communication, data storage and sharing, search and inquiry, collaborative work, collaborative computing, search engines, online games, *etc*.

2.2. Open P2P Development Platform-JXTA

The JXTA project is an open source cooperative research project for P2P computing [11]. The JXTA is a common platform to build P2P application, defines a set of common protocols to achieve the P2P computing, and enables any device to connect, communicate and cooperate using P2P way, so as to establish a cross-platform virtual network on the top of the existing physical network. Its main concepts are listed as follows: peers, peer groups, messages, pipes, network services and peer group services, jxtasocket and jxtabidipipe, advertisements, security and IDs. The JXTA describes a typical three-tier structure of P2P application at present. The structure comprises a core layer, a service layer and an application layer, as well as the JXTA Shell, as shown in Fig. (**1**) [12].

Core Layer: provides some core functions such as communication, routing and P2P connection management for P2P services and applications, including some protocols and basic components to support P2P network connection, such as resource retrieval, message transmission, security, and peers and peer groups creation. All P2P solutions will share this layer element.

Service Layer: extends functions of the core layer to provide interfaces public services needed in order to support most P2P applications. But not all of the P2P applications use these interfaces. These interfaces mainly include: indexing, information retrieval, file sharing and peer authentication.

Application Layer: on the basis of the core layer and the service layer, application layer is included in some comprehensive application programs to run on P2P networks. These applications comprise file sharing, distributed storage, and real-time software packages, etc.

JXTA Shell: between the service layer and the application layer, helps developers and users to take advantage of the JXTA technology prototypes to use and control the P2P network environment. JXTA Shell executed in the internal network includes both built-in commands and external com-

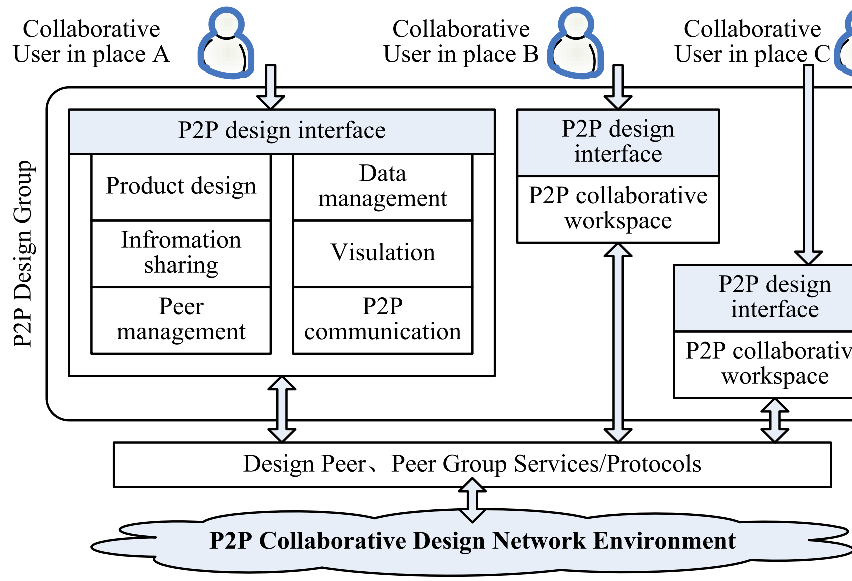

Fig. (2). Collaborative product design scheme based on P2P.

mands, which can also achieve more complex functions by combining peer pipelines together.

3. DATA MANAGEMENT REQUIREMENTS AND SCHEME FOR CPD BASED ON P2P

3.1. CPD Based on P2P Network Environment

In the distributed heterogeneous inter-enterprise practice of CPD, some weaknesses of traditional data management ways are gradually exposed out using particular enterprise server-centric, in terms of its openness, scalability, dynamic instantaneity, and adaptation and so on. Moreover, data security issues cannot be ignored in the enterprise. Therefore, we must establish loosely coupled data management methods and control mechanism of data release across collaborative enterprises, in order to exchange and share necessary design data and information for CPD processes. The other non-cooperative data is shielded in the enterprise.

In the inter-enterprise process of CPD, we can make full use of the P2P network to build overlay network related collaborative design data and information based on some enterprise application systems, to manage lightweight data control consistency. Employing P2P network technology to the CPD process, design team members can be considered as peers from the P2P network, the design data exchange and information sharing among team members can also be understood as data exchange and information sharing occur in peers, as shown in Fig. (**2**). In the collaborative design process, through on demand network communication, necessary design data exchange and information sharing are achieved. These ensure design data security from related enterprises. As a result, the CPD is implemented in distributed heterogeneous multi-disciplinary environment, and quality and efficiency of product design is highly improved.

Typically, enterprises internal product design data and related design information are managed and controlled using PDM system. By PDM system to implement task management of product design, and taking product configuration structure as basis, we can establish task hierarchy structure of collaborative design by way of the hierarchical product structure characteristics [13]. On this basis, if a design task will be delegated to a design peer in the P2P network, a tree relationship network similar to product structure will be formed among design peers, and the mapping of product structure and design peers hierarchy structure will be constituted. The association relationships product design tasks with design peers network structure based on the P2P collaborative environment are described in Fig. (**3**).

By establishing the P2P collaborative design network environments, data exchange and information sharing are realized among design peers in the CPD process. The two logic adjacent design peers may belong to different tree structure branch nodes or leaf nodes. Thus, a kind of new method of task allocation and management is established based on P2P technology for CPD, namely, taking hierarchical features to build task hierarchy related to design peers through product structure configuration tree, to express design peers task to tree network structure similar to product structure tree, and to map these design tasks to form P2P-based design tasks allocation and management system.

3.2. Data Management Scheme for P2P Collaboration

Cooperation enterprises that participated manage design data by PDM server-centric, and all related data of product design are stored in the server. An authorized user can log in the server system to complete design data submission and update operations. The server records related data operation logs, issues relevant update information and sends it to other users in the enterprise through computer network environment. In the P2P collaborative environment, a design peer can disperse on any location and depth in network, only when there is need to establish communication link with other design peers, to carry out necessary data update and information exchange. Security of sensitive design data in

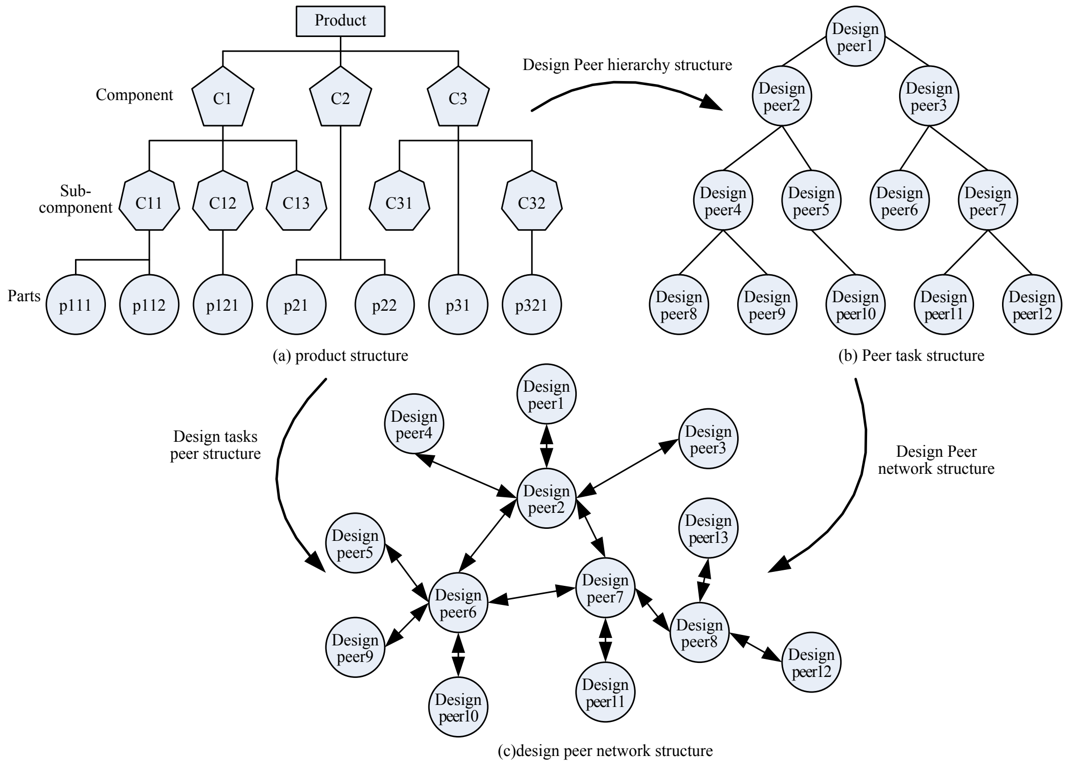

Fig. (3). Product design relationships association with P2P environment.

the server system is well protected. Meanwhile, they can greatly bring into play the design node initiative and have more time to engage in product design tasks. Even if the server is not required to participate in the whole update and exchange process, design peers can also implement plentiful and frequent data exchange and information distribution between each other, without affecting the design efficiency.

In the P2P-based CPD process, each design node can be seen as a design peer, and every design peer is assigned to different design tasks. Product design peer groups are constituted among design peers with the help of product configuration correlation relationships. When a design peer completes design tasks, he will update relevant design data and information. These changes may be reflected to the product configuration structure, and the corresponding product data version and design information will also be subsequently changed. Moreover, in the product configuration structure, some changes associated with part attributes, such as dimension, processing requirements, material performances, etc., will affect others features from related parts or components, such as assembly dimension and structure, machining precision, processing methods and so on. These modifications will also affect other design data and information from product structure tree through constraint network propagation. And thus a series of chain reaction is generated. Aiming at the influence product structure data associated, their subordinated design peers must also update or modify related responsible product design data and information to respond to the chain reaction. Only then data consistency of product design could be implemented in the whole collaborative process, to avoid design conflicts.

Because of design peers scattered in different geographical locations and different enterprises, we must ensure product data consistency to implement real-time associated data and information update, which is the only way to guarantee design data consistency in the whole product design process. To this end, a kind of data management model related to product design process is established for the P2P collaborative network environment, as shown in Fig. (**4**). When a design peer updates relevant design data and information, the consistency control management will be achieved through design constraint sets in product structure, and on the basis of the constraint sets to complete the design, data updates are transferred among other design peers, that is, data consistency among relevant design peers is enforced using the constraint satisfaction problems. So, when design peer groups will be defined, we must be establishing design constraints sets related to design peers.

4. DYNAMIC PEER GROUPS CONSTRUCTION FOR P2P DATA MANAGEMENT

4.1. P2P Group Modeling for Collaborative Design

In the P2P network collaboration environment, design peers joined in collaborative design processes are divided into two types: one *Peer*(*i*) and another group peer-*GPeer*(*j*). In the P2P network, design peers may form a peer group at adjacent location, the peer led by design peers is called the group peer. Thus, in the CPD process, a design peer can be expressed as:

Peer(i)=<User, IP, NodeID, PeerG(n), Token, State, {Task}, {ConSet}> (1)

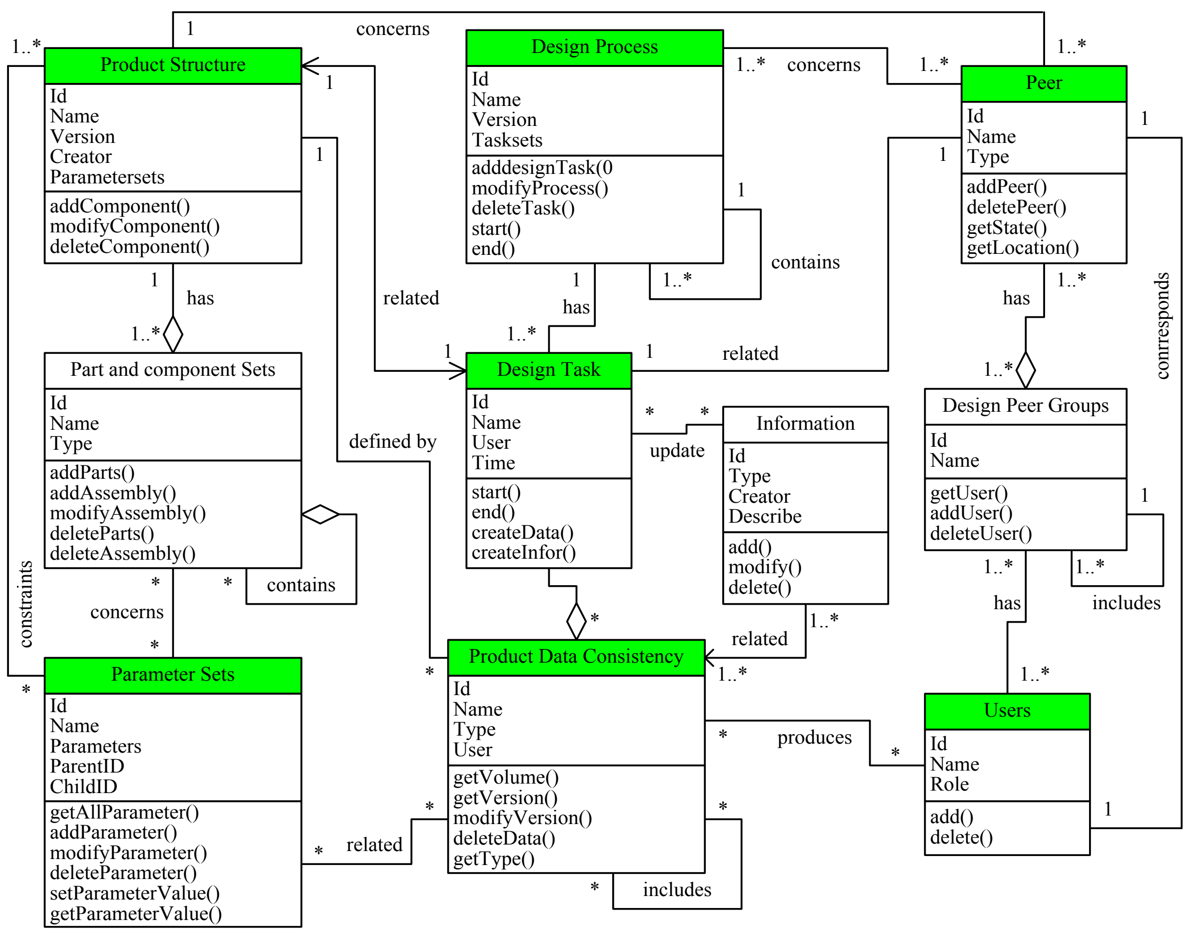

Fig. (4). Product data management scheme in P2P environment.

Where, *User* represents the design peer user name at the current location. *IP* expresses the design peer network address of host computer. *NodeID* shows the design peer identification in the design peer group, which is mainly used to verify the design peer effectiveness in the related peer group. It is also a validation function used to consider security reasons. *PeerG*(*n*) represents the peer group that the design peer belongs to. {*Task*} indicates the design task set of design peer in the collaborative process, as follows:

$$\{Task\}=\{Task_1, Task_2, Task_3, ..., Task_n\} \quad (2)$$

Where, *n*=*1*, *2*, *3*, ……, *N*, and *Task* represents design peer task.

{*ConSet*} represents the design constraint sets of product data that design task belongs to, as follows:

$$\{ConSet\}=\{ConSet_1, ConSet_2, ConSet_3, ……, ConSet_n\} \quad (3)$$

$$ConSet_i=\{C_1, C_2, C_3, ……, C_j\} \quad (4)$$

Where, *i*, *j*=*1*, *2*, *3*, ……, *N*, and C_j represents a single design constraint.

Token is a group node labeling the design peer located in P2P network. If *Token*=*0*, then the design peer is a peer, or else *Token*=*1*, on behalf of the design peer, is a group node (peer), and each design peer group allows only one group node (peer) at the same time. *State* expresses the network status design peer online or offline. If the *State*=*0*, it indicates that design peer is online. If *State*=*1*, indicates offline. Thereby the collaborative design peer groups can be expressed as follows:

$$PeerG(j)=<PeerGID, \{PeerG(m)\}, \{Peer(i)\}> \quad (5)$$

PeerGID represents the design peer group ID, which is mainly used to identify and verify the peer group effectiveness in collaborative design process. {*PeerG*(*m*)} represents the neighboring peer group that the *PeerG*(*j*) is connected to. The {*Peer*(*i*)} represents design peers collection within the design peer group:

$$\{Peer(j)\}=\{Peer(l), Peer(i), ……, Peer(m)\} \quad (6)$$

Where, *i*, *j*, *l*, *m*=*1*, *2*, *3*, ……, *N*. The group node is a special peer in design peer group. From product design perspective, in the collaborative process, it is assigned to design task sets {*Task*}, which participated in product design work. Meanwhile, the product data consistency management must also follow its design constraint sets {*ConSet*} when the group node implements data and information update and upgrade. And from P2P network perspective, the group node also follows necessary conditions to build up design peer network-*PeerGID*, and {*PeerG*(*m*)} directly adjacently connected to the group node, as well as {*Peer*(*i*)} is involved in the peer set and the like.

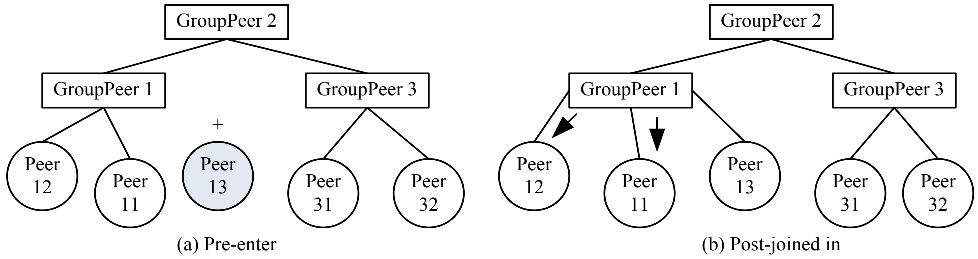

Fig. (5). A design peer joining in a peer group.

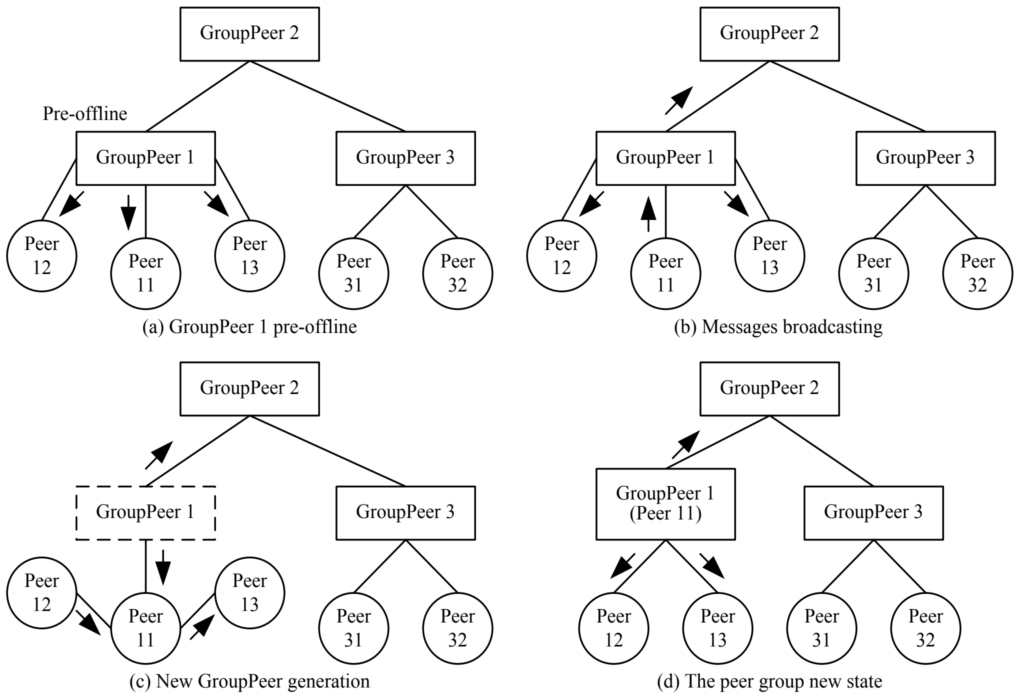

Fig. (6). Group peer conversion process.

4.2. Peer Group Dynamic Control Method

Due to design peers have dynamic characteristics in the P2P network, so we need to define the design peer group formation process and operation mode for CPD.

(1) Design peers joining or leaving a peer group

When a design peer joins in a certain design peer group, firstly, it must search the design peer group belonging to the PeerGroup via network, and send a joining request to the group peer. And the group peer verifies the design peer effectiveness based on the original collaborative design information. When the design peer is successfully identified, the group peer updates the design peer group management information, and sends an updated group lists to the design peer. At the same time the group peer will also broadcast a message the design peer joined in, so that other design peers are aware of the group state changes within the design peer group. The process in which a design peer joins in a certain design peer group, is shown in Fig. (**5**). After the design peer joined in the design peer group, it can carry out design task and complete design data exchange and information sharing. The process in which the design peer leaves from the design peer group is roughly analogous to the joining process. The difference is that the design peer sends offline request at the moment and the group peer broadcasts the design peer departure information.

(2) Group peer transferring process

In the P2P collaborative design process, we need to consider a special case that the original group peer wants to work offline and the peer group needs a dynamic recovery within the design peer group at the same time. That is to say, to ensure the design peer group effectiveness and the P2P design network connectivity, during the process, the group peer identity is converted. In the meanwhile, when the network connection is unblocked, a new effective P2P network topology can be established, which can restore or reproduce previous collaborative design network architecture by memory again. The process the group peer is transferred through is shown in Fig. (**6**).

When a group peer is offline, it must send broadcast message to each design peers within the design peer group, to determine and select successor group peer based on these information returned by each peers. After the successor is selected, the anterior group peer will send design group information to the successor, including the design peer group

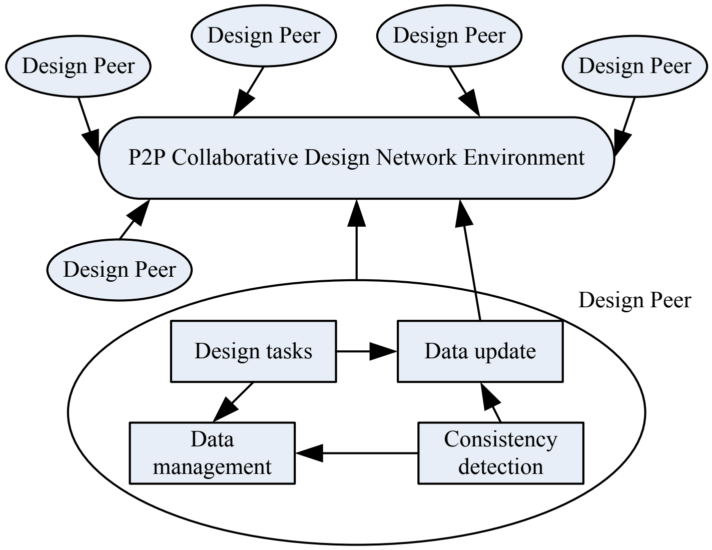

Fig. (7). Data inconsistency detection mode.

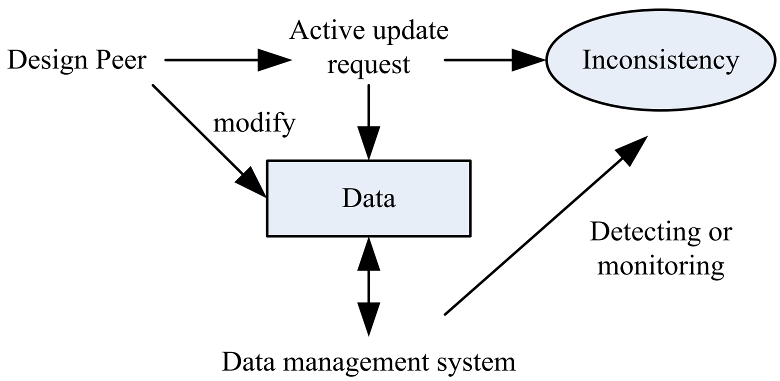

Fig. (8). Data inconsistency generation process.

ID, neighboring design group sets, design peer sets, etc., and notify other nearby design group peers about the group state change. At the same time, it sends its successor information to neighboring design peer groups as well. Finally, a new state about the changed design peer group is formed to safeguard the design peer group connectivity.

5. DATA UPDATE AND CONSISTENCY CONTROL ALGORITHM FOR COLLABORATIVE DESIGN

5.1. Inconsistency Detection Method for CPD Data

A design peer generates or creates design data according to its design tasks, and then transfers design data and information to other design peers through the P2P collaboration network. These data may be the original or initial data relevant to design peers starting or finishing their design tasks. Of course, the original design peer is also allowed to change and update these data or information. However, when the same design data or information is changed again by the original design peer, the message data or updated information must be immediately transferred to other relevant design peers. Otherwise, it will generate conflict among design data because other design peers lack the information about the latest version of the same design data or information, which ultimately results in design activities termination or failure because other subsequent design peers will not get accurate design data sources. So the first thing must be added from the data consistency detection module to the data management system functions. We can use the module to make system real-timely detection design data and information update or change from design peers, and timely achieve related data update information broadcast for relevant design peers by way of the P2P network environment. For all this, a detection model of data consistency of product design is established, as shown in Fig. (**7**). With the help of the P2P collaborative network environment, design peers carry out product design tasks, and each design peers has the design task data management module and the data storage module. The consistency detection module monitors the data management function module, to judge and distinguish new data submission and data update operation, and to take appropriate action.

Typically, the design data inconsistency or change mainly involves two aspects. On one hand, the design peer initiates requests to update design data or information and completes implementation. On the other hand, the data consistency detection module finds the change when the design peer passively modifies some design data. For example, the original data storage time and volume change, are also considered to produce inconsistency phenomenon. The generation mode of data inconsistency is described in the content as shown in Fig. (**8**). With the help of the method and model of data change detection, we can monitor the occurrence of data inconsistency, and we can also remove inconsistency barriers in the CPD process using some appropriate control methods and management mechanisms.

5.2. Design Data Update Method Based on Constraints Satisfaction in P2P

Constraint-based product design is an effective technique that can be applied to maintain consistency from different views in collaborative design [14, 15]. The root data inconsistency that is generated can be understood as design peer changes design constraints and its variable parameter value and constraint conditions are further optimized and reasonably reconfigured. In either case, it is likely to cause design data and information change, and it is also very necessary to monitor the constraints change and achieve updated data coverage reasonably and orderly in the P2P network. Meanwhile, the collaborative design constraint networks possess multi-domain, dynamic, distributed, multi-view and other characteristics. Because a certain part may be concerned with multiple discipline areas, in which constraint network detection is very complex, so that if one discipline's constraints information is updated or changed, the others constraints may be affected or propagated. In such a constraint associated update operation process, how to accurately identify global constraints and local constraints to transmit updated design data to the appropriate design peers is the key to achieve data update consistency control in the P2P collaborative design.

In the multidisciplinary CPD process, a design peer is affiliated with different product design disciplines. But because all design peers serve the same design goals and product, both interdependence and mutual restriction are inevitable relationships among design peers, and these relationships generally can be used to express constraint association forms in the constraint-based product design [16]. Interrelated constraint constructs a collaborative design constraint networks. Constraint satisfaction problems in the collaborative design can generally be defined as:

$$\text{CoDesignNet}(X, D, C, R) \tag{7}$$

Where, $X=\{x_1, x_2, \ldots\ldots, x_n\}$ represents the design variable set;

$D=\{d_1, d_2, \ldots\ldots, d_n\}$ is the domain of definition set, d_i is the possible values from the design variable x_i;

$C=\{c_1, c_2, \ldots\ldots, c_l\}$ is the variable constraint relationship set, l represents the constraint quantities, $c_i(p, q)$ shows constraint between the variable p and the variable q;

$R=\{r_1, r_2, \ldots\ldots, r_t\}$ is the relationship set constraint related variable valuations.

For any given i, $1\leq i\leq l$, if exists in function:

$$f : X \rightarrow \bigcup_{i=1}^{l} D_i \tag{8}$$

makes $(f(x_{i1}), f(x_{i2}), \ldots\ldots, f(x_{in}))\in r_i$

Then f is P solution space, and the constraint satisfaction problem is NP-complete. All solutions of constraint network can be expressed as:

$$R(z) = \{(X_1 = x_1, X_2 = x_2, \ldots\ldots, X_n = x_n) \mid \forall c_i, \prod V(c_i)R(z) \subseteq R(c_i)\} \tag{9}$$

Where, $\prod V(c_i)R(z)$ represents variable $V(c_i)(V(c_i) \subseteq X)$ projection in the relationship $R(z)$, $R(z)$ shows relationship among the constraint networks.

Through determining value of operation extension from interval arithmetic, a variable domain of definition can be controlled in a closed interval, i.e., $X=[a, b]=\{ x \mid a\leq x\leq b\}$. Any real number x can be used as an interval to represent [a-, a+]. The operation rules of interval arithmetic include:

For interval variable $A=[a, b]$, and $B=[c, d]$ have:

$$A+B=[a, b]+[c, d]=[a+c, b+d] \tag{10}$$

$$A-B=[a, b]-[c, d]=[a-c, b-d] \tag{11}$$

$$A\times B=[a, b]\times[c, d]=[\min(ac, ad, bc, db), \max(ac, ad, bc, db)] \tag{12}$$

$$A/B=[a, b]/[c, d]=[a, b]\times[\min(1/c, 1/d), \max(1/c, 1/d)] \tag{13}$$

The interval propagation algorithm calculates domains of defined changes, and the feasible solution spaces $D'(D' \subseteq D)$ that is each design variable X_i is caused by the constraint set C. For the constraint $R(C_i)=R(X_{i1}, X_{i2}, \ldots\ldots, X_{iq})$, set X_{i1} as the domain of definition to be D_{i1}, so the new domain of defining the constraint $R(C_i)$ is expressed as:

$$D_{i1}^{'} = \{f^{-1}([R(C_i)]) \mid X_{i1}\} \cap D_{i1} \tag{14}$$

Where, $f^{1}([R(C_i)])|X_{i1}$ represents that the design variable X_{i1} finds feasible solution space by reverse constraint $R(C_i)$. Therefore, for each variable of design constraints feasible solution space can be calculated.

In P2P collaborative design process, the constraint network is comprised of objects, variables and constraints. The object represents a design entity in the product design, and constraint indicates relationships among objects, while constrains are specifically reflected by appropriate variables. All variables are linked together through certain constraint relationships to be interwoven into a constraint network. For any product design, problems can be expressed as a constraint network composed of a number of interrelated objects, variables and constraints. The mapping relationship design variables, constraints, and domain of values with design peers can be described as follows:

$$M: X\cup C\vee R\rightarrow \text{Peer}(i) \tag{15}$$

Based on constraint relationship networks, collaborative design process is actually turned into constraint network solving process, and data update is bound to exist in the certain networks. Eventually, if a design peer updates related design data or information, it surely will be propagated to other design peers through the constraint networks, in order to achieve P2P data consistency based on design constraints.

5.3. Data Update Consistency Control Based on P2P Design Constraints

On the basis of constraint network relationships and data management model for CPD, this section presents a kind of consistency control method for P2P product data update. In P2P collaboration network environment, the design data update consistency of collaborative design process is divided into three levels: *key update*, *moderate change* and *tiny modification*:

1) *Key Update*: is that one design peer updates and upgrades its own data or information to trigger multidisciplinary constraints or global constraints in the design peer constraint set {*ConSet*}.

2) *Moderate Change*: refers to the design peer updates and upgrades its own data or information to effect single discipline constraints or local constraints within design peer constraint set {*ConSet*}.

3) *Tiny Modification*: represents design peer updates and upgrades its own data or information to satisfy a certain single constraint in constraint set {ConSet}.

The key to implementing *key update* is to find related design peers involved in the data update, judge their status in the whole P2P design group, and to transfer relevant data and information to corresponding design peers by approved state way. The *key update* algorithm can be described as follows:

check peer_data_update **do**
when $Peer \otimes \mapsto Data$
get $\langle C: X \prec D \rangle \subset \{ConSet\}$
if *C*□ *{GC}≠Φ*
return key_update
else if *C*□ *{LC}≠Φ*
return appropriate_change
else if *C*□ *{C}≠Φ*
return tiny_modification
else
return false
end
if(key_update)
$Constraintlist \Leftarrow \langle C: X \prec D \rangle$
$\{X\} \Leftarrow$ all variable in *Constraintlist*
$Peerlist \Leftarrow \{x_i$ in designPeer$|ConSet\} \cap \{X\} \neq \Phi$
send *msg* to all *peergroup*(*Peerlist*)
broadcast $\langle C: X \prec D \rangle$ through groupPeer to designPeers in *Peerlist*
$Peerstatelist \Leftarrow$ Peers' state in *Peerlist*
for j=1:<*Length*(*Peerlist*)
if $state_j = offline$
return false
discontinue
else
return true
end for
when *Peerstatelist* is ***true*** **do**
forward *key_update_msg* to all neighbor peers in whole peergroup
send *key_update_data* to all designPeers in *Peerlist*
end

In the implementation process, the variable assignment changes in design constraint parameter will not allow other design variables to find reasonable solution in a given domain or range. Within this situation, design constraint conflicts are generated, and it is very necessary to resolve and negotiate the design variable solutions. The general approach is to backtrack the design process and find the design change point that results in conflict, and to modify and negotiate incompatible design constraint solutions. At this point, the design peer's proposed key updates implementation might require certain concessions.

The *key update* process basically includes a series of consistency control process, such as update request, the state judge, design constraint modeling, conflicts detection, and target constraint relaxation. When design peer proposes the *moderate changes*, the original group peer makes appropriate response requests and sends updated data to related design peers through other group peer. Its detailed process is similar to the *key update* process. If a design peer wants to implement the *tiny modification*, it is done simply by group peers broadcasting messages involved in information updated among related design peers.

6. DATA CONSISTENCY MANAGEMENT SYSTEM DEVELOPMENT FOR CPD BASED ON JXTA

On the basis of the above series of basic analysis and key technology development, to meet the requirements of data update management and consistency control for CPD process in the P2P collaboration network environment, a management system framework of data update and consistency control of product design is constructed based on the open P2P network platform-JXTA, as shown in Fig. (**9**). The system framework is divided into four levels: user layer, application functions and services layer, data layer, and foundation layer.

User Layer: provides user interface of data management for design peers in the collaborative process. In the meanwhile, *User Layer* also can complete data exchange with some software tools or systems by application program interface, such as CAD, PDM *et al.*

Application Functions and Services Layer: includes basic JXTA services and advanced consistency management services. The basic JXTA services mainly use its several protocols to achieve design peers registration and connection, design data indexing, storage, replication and access, as well as message routing and design constraint sets query, in the collaborative design process. The advanced services are

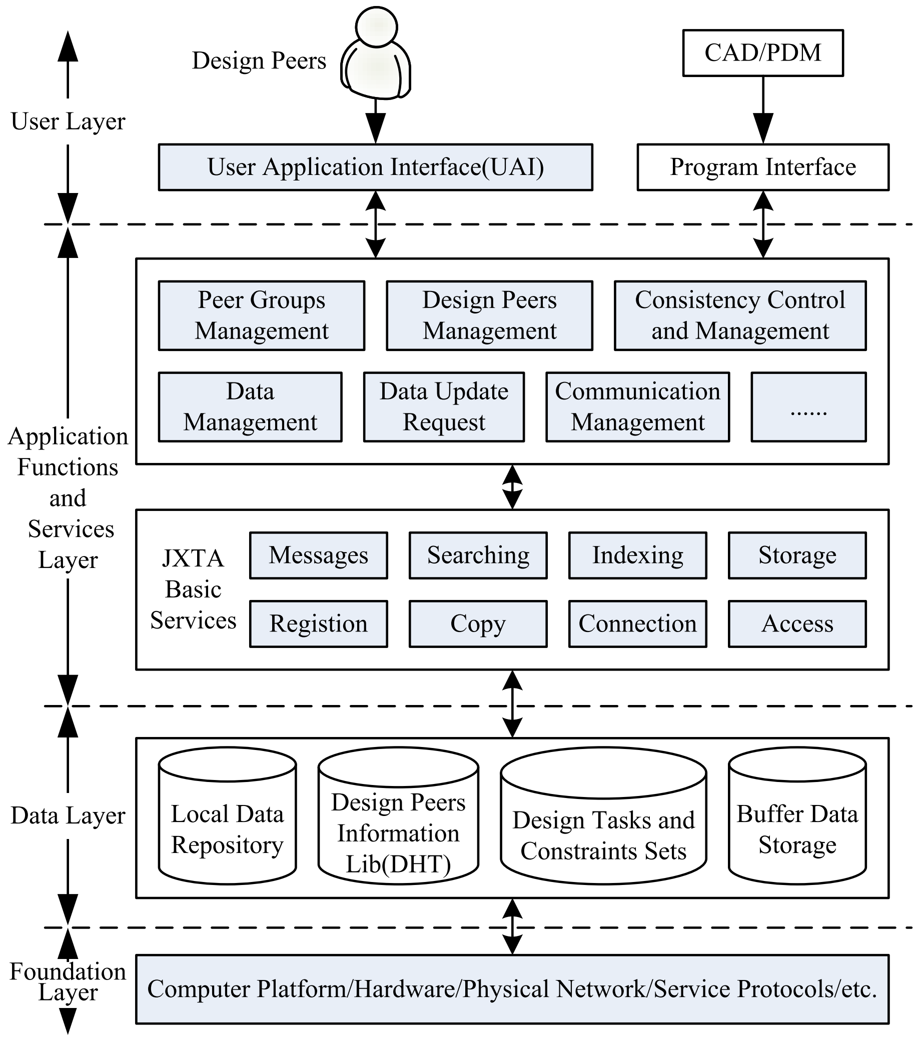

Fig. (9). Data consistency management platform based on JXTA.

mainly based on the provided JXTA basic services to achieve peer group management, design peer management, design data management, data update consistency management, and design peer communication management for collaborative design process.

Data Layer: provides local storage and data caches capacity for design peers in the collaborative design process, to build design information repository for P2P design group environment and design peers, design tasks sets and associated constraints sets and so on.

Foundation Layer: includes a series of hardware and software infrastructures, such as computing platform and physical network data created, stored and transmitted, in the collaborative design process.

It is worth noting that in both design data and messages sending or receiving process, the relevant P2P network protocols should be followed. In this section, the open JXTA framework is used to develop P2P network environment for collaborative product design process, so some protocols within JXTA framework must comply with the data and messages transmission and reception process as well.

CONCLUSION

To meet the requirements of dynamic data exchange and information sharing across enterprise domains CPD process, a methodology of design data management and consistency control is put forward based on the P2P network environment. On the basis of analyzing P2P definition, application and characteristics, the concept and structure framework of the open P2P development platform-JXTA is also discussed, so a P2P-based CPD scheme is established. Through product configuration structures, the associated relationships product design task structures with peer network structures are achieved, and a data management model is constructed for CPD across P2P network environment as well. All basic works such as P2P design group modeling, design peers dynamic management and design peer group interaction patterns are implemented in the CPD process. A design data detection model has been constructed, based on P2P data updates process of design constraints, realizing a data update consistency control algorithm. With the help of the open JXTA, a data management framework system for CPD is also developed. The subsequent work will cover applications testing, validation and implementation works.

CONFLICT OF INTEREST

The authors confirm that this article content has no conflict of interest.

ACKNOWLEDGEMENTS

This work is partly supported by the National High-Tech. R&D Program of China (2009AA04Z167), and the National Natural Science Foundation of China (50975183), Shenyang Science and Technology Plan Program (F12-258-1-00), Program for Liaoning Excellent Talents in University (LJQ2012019), and Program from Liaoning Province Department of Education (L2012067).

ABOUT THE AUTHORS

First Author: Pengfei Zeng, assistant professor and PhD of Shenyang Ligong University, The author's major is data management and collaborative product design.

Second Author: Yongping Hao, professor and PhD of Shenyang Ligong University.

Third Author: Weiping Shao, professor and PhD of Shenyang Ligong University.

Fourth Author: Ze Tao, assistant professor and PhD of Shenyang Ligong University.

REFERENCES

[1] G. Ducllier, P.-A. Yvars, and B. Eynard, "Managing design change order in a PLM platform using a CSP approach", *International Journal of Inactive Design and Manufacturing*, vol. 8, no. 3, pp. 151-158, 2014.

[2] E. Spaho, L. Barolli, F. Xhafa, A. Biberaj, and O. Shurdi, "P2P data replication and trust worthiness for a JXTA-Overlay P2P system using fuzzy logic", *Applied Soft Computing*, vol. 13, no. 1, pp. 321-328, 2013.

[3] A. Dandoush, S. Alouf, and P. Nain, "Lifetime and availability of data stored on a P2P system: evaluation of redundancy and recovery schemes", *Computer Networks*, vol. 64, pp. 243-260, 2014.

[4] J.W. Yin, W.Y. Zhang, Y. Li, and H.W. Chen, "A peer-to-peer-based multi-agent framework for decentralized grid workflow management in collaborative design", *International Journal of Advanced Manufacturing Technology*, vol. 41, no. 3-4, pp. 407-420, 2009.

[5] C.-H. Chu, and Y. H. Chan, "Optimized product data transmission in LOD-based collaborative design using P2P CAD Streaming", *Journal of Intelligent Manufacturing*, vol. 23, no. 5, pp. 1559-1571, 2012.

[6] L.R. Wang, J.C. Wang, L.X. Sun, and I. Hagiwara, "A peer-to-peer based communication environment for synchronous collaborative product design", In: *Proceedings of the 4th International Conference on Cooperative Design, Visualization, and Engineering,* Shanghai, China, pp. 9-20, 2007.

[7] E. Spaho, K. Umezaki, L. Barolli, F. Xhafa, and M. Younas, "A fuzzy-based reliability system for knowledge sharing between robots in P2P JXTA-overlay platform", *Cluster Computing*, vol. 16, no. 4, pp. 933-945, 2013.

[8] S.-L. Choi, S. Park, and M. Subramaniyam, "Development of a distributed geometric modeling system based on peer to peer", *Journal of Mechanical Science and Technology*, vol. 24, no. 1, pp. 289-292, 2010.

[9] H.-M. Chen, and C.-C. Hou, "Asynchronous online collaboration in BIM generation using hybrid client-server and P2P network", *Automation in Construction*, vol. 45, pp. 72-85, 2014.

[10] H. M. N. D. Bandara, and A. P. Jayasumana, "Collaborative applications over peer-to-peer systems-challenges and solutions", *Peer-to-Peer Network and Applications*, vol. 6, no. 3, pp. 257-276, 2013.

[11] L. Gong, "JXTA: a network programming environment", *IEEE Internet Computing*, vol. 5, no. 3, pp. 88-95, 2001.

[12] JXTA, http://www.jxta.org. [Accessed: Sept. 18, 2014].

[13] P.F. Zeng, Y.-P. Hao, W.-P. Shao, and Y.-X. Liu, "Research on task modeling and scheduling method for collaborative design process in product data management system", *Chinese Modern Manufacturing Engineering*, vol. 9, pp. 29-32, 2007.

[14] R.J.- Arinyo, A.S.-Riera, and S. V.- Marta, "Constraint-based techniques to support collaborative design", *Journal of Computing and Information Science in Engineering*, vol. 6, no. 2, pp. 139-148, 2006.

[15] Y.-L. Lai, "A constraint-based system for product design and manufacturing", *Robotics and Computer-Integrated Manufacturing*, vol. 25, no. 1, pp. 246-258, 2009.

[16] C. Lottaz, I.F.C. Smith, Y. R.- Nicoud, and B.V. Faltings, "Constraint-based support for negotiation in collaborative design", *Artificial Intelligence in Engineering*, vol. 14, no. 3, pp. 261-280, 2000.

Received: December 15, 2014 Revised: January 04, 2015 Accepted: February 25, 2015