Web–based decision system for effective process planning in network manufacturing environment

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Abstract — **Recent advancements in Information technology and pervasive applications of Web-enabled services wield a profound influence on manufacturing systems and in particular on distributed networked manufacturing environment. In this paper, a modelling schema is proposed for integrating a distributed feature-based design system to organize concurrent engineering activities effectively. Later, with developed Web based decision support tool the activities of manufacturing system are integrated. The managerial insights listed in this report, obtained from the analysis suggest that the developed methodologies and tool for networked manufacturing environment offers with a number of benefits such as high interoperability, openness, cost-efficiency, and production scalability.**

***Keywords** – networked manufacturing system; interoperability; web-based decision support system; process planning.*

I. INTRODUCTION

With the increased accessibility of Internet technology, manufacturing systems are advancing towards supporting distributed and collaborative activities in distributed manufacturing environment.

The World Wide Web (WWW) technology, offers tremendous opportunities for the sharing of information among enterprises that are globally distributed. A web application is defined as any software application that depends on the web for its correct execution (Gellersen and Gaedke, 1999). In this paper, a process planning and scheduling integration module has been wrapped as a web-enabled service and made available on the Internet through the use of web browsers to support the distributed design and manufacturing analysis.

One of the first and most important initiative in the development and execution of web based decision support systems in the product design and the manufacturing is the MADE (Manufacturing Automation and Design Engineering) an American research project,

Several researches (Cutskosky et al. 1996; Petrie, 1996; Whitney et al. 1995; Bryant et al. 1996; Will, 1996) involved in handling the above mentioned MADE program and their contributions are revealed in the form of several valuable publications. However, this program was extending through RaDEO (Rapid Design Exploration and Optimization) Program in the year 1997. Since then, the rapid developments of product design and manufacturing in web based systems have changed the distributed manufacturing environment.

From the wider perspective of design and manufacturing, the web technology enables a great potential to develop virtual decision support systems to support rapid development of mechanical products to meet global competition. Wagner et al. (1997) described a model for remote analysis of computer-aided design (CAD) models for the exchange of geometric data. Later, they tried to apply the proposed concept in industry environment; the results show its effectiveness. A group of researches and programmers, (Bailey, 1995; Wright and Burns 1997) developed a Tele-Manufacturing facility project to provide rapid prototyping services on the internet. Sung et al. (2001) proposed a web based system for the integration of product design and process planning using CyberCut experiment based on Java based programming. Roy et al. (2003) presented an open collaborative design environment approach that can integrate 3D geometry of a product on the WWW with conventional CAD packages. With single internet interface, the semantic and syntactic content of the product model from different operating systems can be accessed to demonstrate the open architecture and interoperability.

Significant progress has been achieved in developing and applying web support systems for process and production planning and control. The web based simulation and production scheduling for production planning and control problem is detailed in order to minimize the production costs, lead-times, inventories and maximize production and due date performance an IPPI (Integrated Production Processing Initiative) project has been initiated. IPPI aims to develop and validate a prototype process planning system by defining the product data into the STEP (Standard for the Exchange of Product Model Data) files which are capable to generate intermediate product models when necessary. Bailey and Verduin (2001) and Beiter and Ishii, (2003) developed a Federated Intelligent Product Environment (FIPER) system funded by National Institute of Standards Technology (NIST) to develop a new product design and analysis technology. For design analysis and product lifecycle support with design tools/methods such as Java Native Interface (JNI) and FIPER Standard Development Kit (SDK) tool kit a web based distributed framework has been developed. Xiao et al. (2001) developed the Web- Distributed Product Realization (DPR) system for collaborative design and manufacturing based on Java Remote Method Invocation (RMI) mechanism and event base mechanism to coordinate the functional modules effectively. Mervyn et al. (2003) proposed a Web-based fixture design system in which EXtensible Markup Language (XML) format was designed to transfer the information and knowledge between functional modules in a distributed environment.

Although, many contributions arose in the area of production scheduling problem from the above mentioned projects i.e. CyberCut and MADEFAST experiments, but they were not interoperable. Considerable efforts have been made with different and most popular distributed object paradigms such as Microsoft Distributed Component Object Model (DCOM), OMG's Common Object Request Broker Architecture (CORBA), JavaSoft's Java/Remote Method Invocation (Java/RMI) to undertake the development of interoperable application (Huang and Mak, 1999a). For enhancing the interoperable property in the distributed environment, the paradigms and applications extensively try to improve the formats and contents of the information. It is not necessary to deal with the technical content of the information (Huang and Mak, 2001). Thus, many knowledge integration methods have been developed (Bless et al. 2008; Bombardier et al. 2007; Gardner, 2005; Kwon et al. 2007; Ozman, 2006). Out of all these integration methods, Knowledge Interchange Format (KIF) for KQML (Knowledge Query and Manipulation Language) and STEP (STandard for the Exchange of Product model data) for product design, process, and manufacturing are effective ones. Even though, standard effective formats have been established, there is a huge concern on the volume of data that need to exchange between different distributed systems. These exchange messages need engineering ontologies (Daconta et al. 2003; Lin and Harding, 2007; Uschold and Grueninger, 1996) to develop.

Recent rapid developments in information technology have been pushing the manufacturing sector into another level. Digitalization and networking of enterprises bring the challenges of accessibility and interoperability in a distributed environment. Therefore, advance and pervasive applications are required to enhance the interoperability and also to support the distributed collaboration. These issues have not been yet dealt adequately to develop web technology for more flexible manner to share and interoperate the manufacturing processing data. As a part of this research work, we have developed a web based decision support system (WBDSS) which can act as an interactive medium for conducting effective manufacturing analysis, and to support for remote optimization. Subsequently, architecture is proposed that shows how the interactions between different modules right from 2D/3D model to remote optimization services can be achieved. Moreover, a flow chart has been created to describe the step by step procedure of different functionalities. Finally, we propose a new approach for the design and development of an interactive distributed manufacturing environment for internet users to organize concurrent engineering activities effectively.

This paper has been classified into six major sections. Section 2 explains about the important features of network manufacturing system and the architecture of its working procedure. Section 4 includes a detailed illustration of the five functional modules of the suggested WWW model including complete structure. Section 5 contains the complete framework of the proposed web enabled service system which helps in the effective collaboration of the enterprises of the network manufacturing. The paper ends with section 5 proposing future works related to the paper.

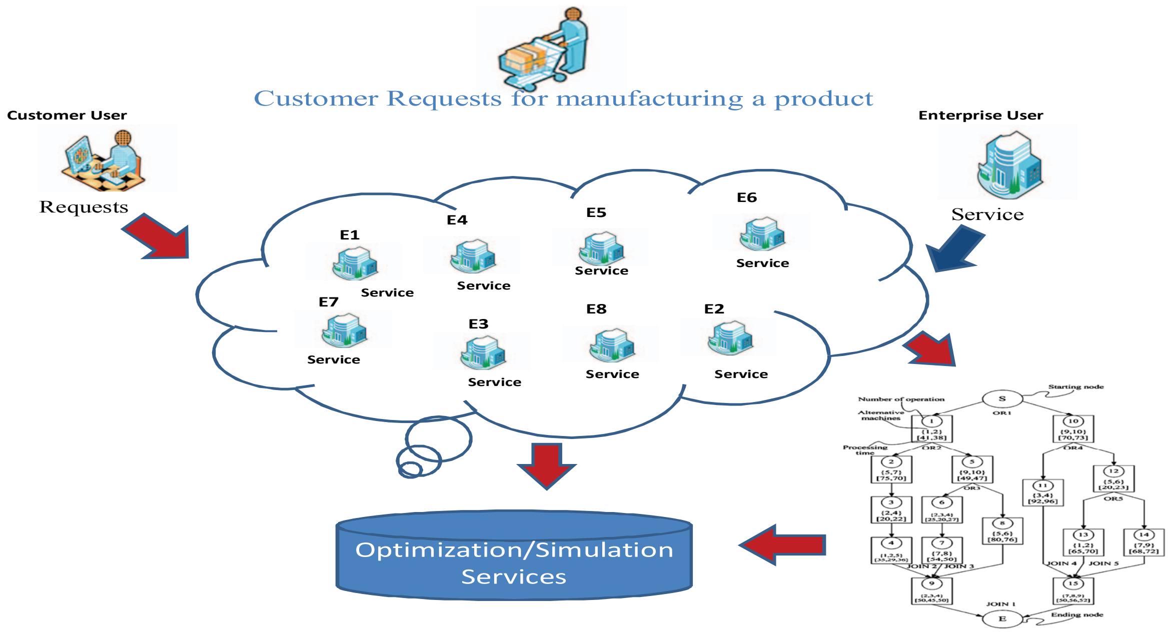

Figure 1 Networked manufacturing system architecture.

II. Network manufacturing system description

A networked manufacturing system (NMS) can be defined as a manufacturing-oriented network that employs Internet and other related technologies to cater the needs of distributed manufacturing environment. It has the capability to encapsulate the manufacturing enterprises' information and to provide the manufacturing services where interoperability between enterprises can be achieved. Figure.1 illustrates the architecture of NMS. The NMS starts with a request from the customer whose product task can be handled by the web based manufacturing service through two different modes viz. Customer User (CU) and Enterprise user (EU). CU is defined as a customer or organization that accepts the manufacturing requests from the customers to analyze and process the production tasks with the support of web based decision system in order to provide a feasible solution in effective manner. Through web based manufacturing service (WBMS), it is possible to analyze manufacturing product requests of multiple organizations. On the other side, the functionality of EU is same as CU mode at initial stage, but due to its self-service providing capability the requested product can be served entirely by EU itself. In most of the practical cases, serving of all the product requirements by single EU is almost impossible. Thus, similar to CU, the EU searches for qualified enterprises with the support of web based decision system to fill the requirements of the unfinished tasks such as finding of potential enterprises, communication with remote servers, interactions with the customers, and remote optimization services.

In this case, the EU can serve as a directive company in this virtual organization where it can take initiation to interact with the customer, and collaborating with other related enterprises as a coordinator. This way, User, and EU are able to accomplish varied and more demanding production tasks that are unattainable by a single enterprise. In this paper, we have considered the User mode to carry the process. However, after finding the necessary product data and the enterprises' information, an effective approach to describe the manufacturing functions requirements and their implementation on networked manufacturing environment is accomplished. Thereafter, with suitable meta-heuristics and simulation techniques, the complex problems in distributed manufacturing environment such as IPPS were solved to achieve the objectives of the User that can be solution to the final customer.

III. Proposed WWW collaborative model

In this section, five functional modules and their detailed structure and functionalities are displayed in Figure.2 and are elucidated as follows:

Module1 in Figure 2 represents, a 2D/3D model of a feature based part where the front-end-client embedded in a web browser provides users with various functionalities such as visualization of design models, invoking remote process optimization services, and an interface to data base and knowledge servers to store and retrieve information. for 2D/3D visualization environment where the optimization results, graphs and design models produced by the remote optimization services can be manipulated according to the user needs.

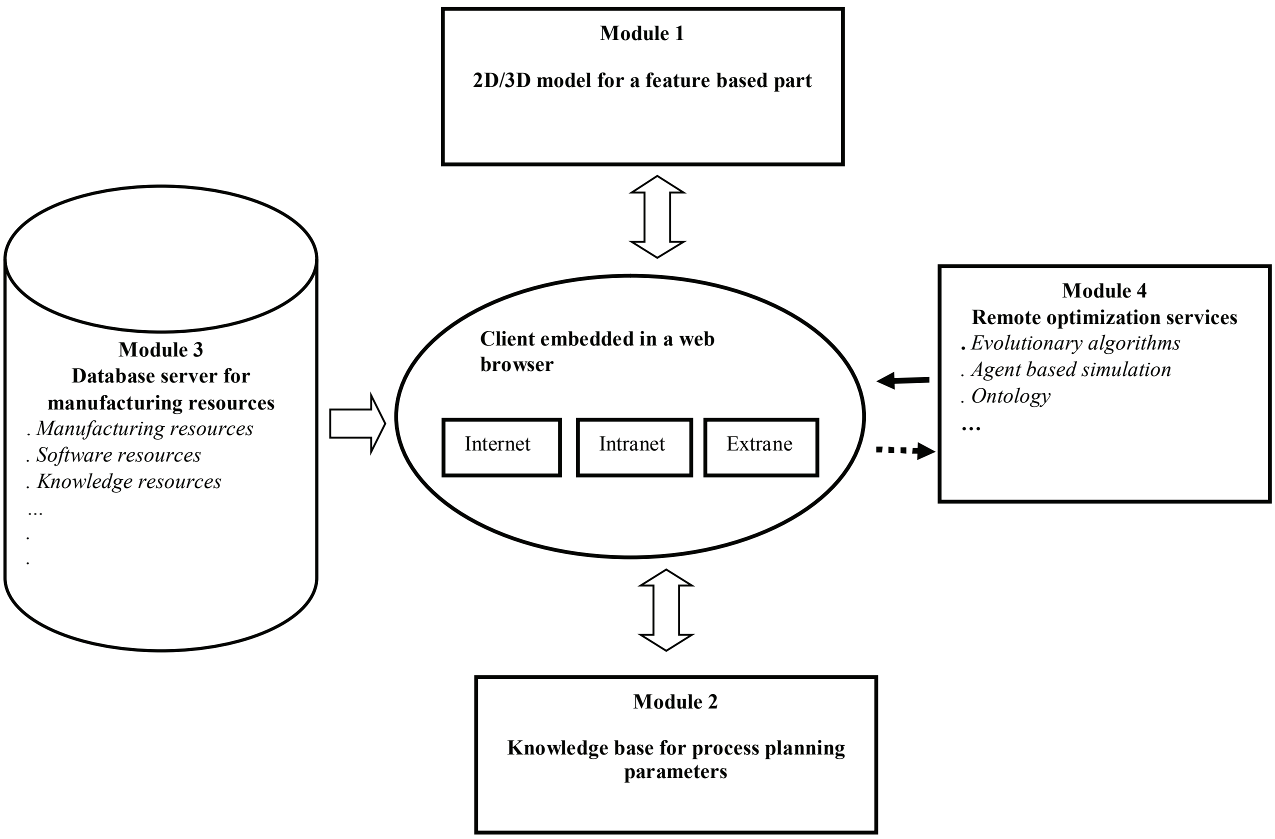

Figure 2. Modelling schema for the Functions of web-based system.

Module 2 involves, the detailed information of a product and its part type requirements such as operations, processing times. The knowledge base of the above requirements is useful to determine the best sequence of operations that involved for manufacturing a product in best effective manner. In this module some other requirements for obtaining best operation sequence were feature extraction and decision making in process plan generation. Module 3 resembles, a database server for manufacturing resources where the resources' information i.e., available machines, tools, TAD and their costs utilized for determining process plans of a design model. Module 4 includes remote optimization services for process planning which includes single and multi-objective optimization algorithms, simulations and Ontology as analysis Servlet that would respond through a web server in the online invocation and evaluation.

IV. ARCHITECTURE OF THE PROPOSED WEB ENABLED SERVICE SYSTEM

Architecture of the proposed web enabled service system is shown in Figure.3. The primary intention is effective integration of distributed process planning and scheduling and development of web enabled service system that assists the geographically distributed enterprises located in the networked manufacturing with effective coordination and collaboration. The proposed architecture can better serve distributed manufacturing requirements. The execution of the aforementioned modules takes place based on the database development of each module.

First, the information is gathered from the literature and it is employed for the database development. Here, we have used the feature based products' data from the literature and then created Ontology files to create knowledge with the help of decision manager and then stored it in the knowledge repository. The generated files can be easily converted into XML files with flexibility to transfer and exchange the information between distributed manufacturing resources. The manufacturing data base includes information of geographically distributed resources, transportation time of the resources, tools, TADs, respective machining times, and the list of candidates/candidature list for the operations of a plan. Later, according to users' requirements the available data has been pre-processed to find the status of the corresponding resources, and to filter the generated bids for efficient performance of the negotiation.

The decision making environment after pre-processing facilitates with database server that have required enterprise resources information and knowledge repository for alternative process plans information. After data pre-processing, decision making environment initiates selection of algorithms, approaches or methods that are suitable for solving the concerned problem. The execution of various modules takes place according to the selection with the user interface. The developed static web service system environment acts as an interface mechanism with the remote optimization/simulation services for the execution of the user requirements. In this research, we have incorporated numerous prominent single and multi-objective evolutionary algorithms such as genetic algorithm, hybrid genetic algorithm,

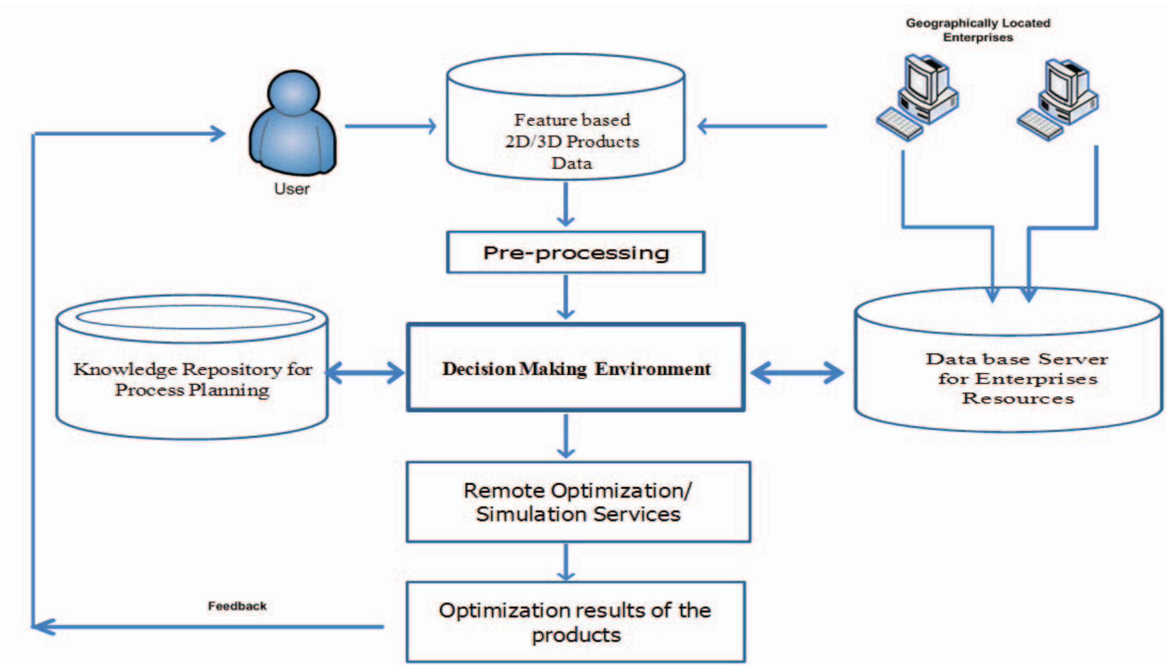

Figure 3 Web enabled system architecture.

DNA, hybrid DNA, NSGA-II, controlled elitist NSGA-II, and simulation with mobile agent based approach.

The obtained results from remote optimization services are presented in the form of Gantt charts, bar charts, figures, and tables and are transferred to the user. Here, due to the flexibility to convert the data into
XML based format, the possibility of transferring the information to varied operating systems with proposed web based DSS is possible. This leads to enhancement of interoperability. Another important functionality of this DSS is, it can provide a feedback message to the user in real time, if further improvement or manipulation of the results is required. The execution of various modules and their integration with the developed DSS is depicted in Figure 3.

V. WEB BASED DECISION SYSTEM TOOL

Figure.4 presents a snapshot of the web based decision system tool where different modules have been integrated to enhance the interoperability in a distributed manufacturing environment. The design and development of an interactive distributed manufacturing environment for the internet users can be successfully achieved.

Moreover, effective utilization of the web based technologies, developed services, and the relevant system enables geographically distributed design and manufacturing enterprises.

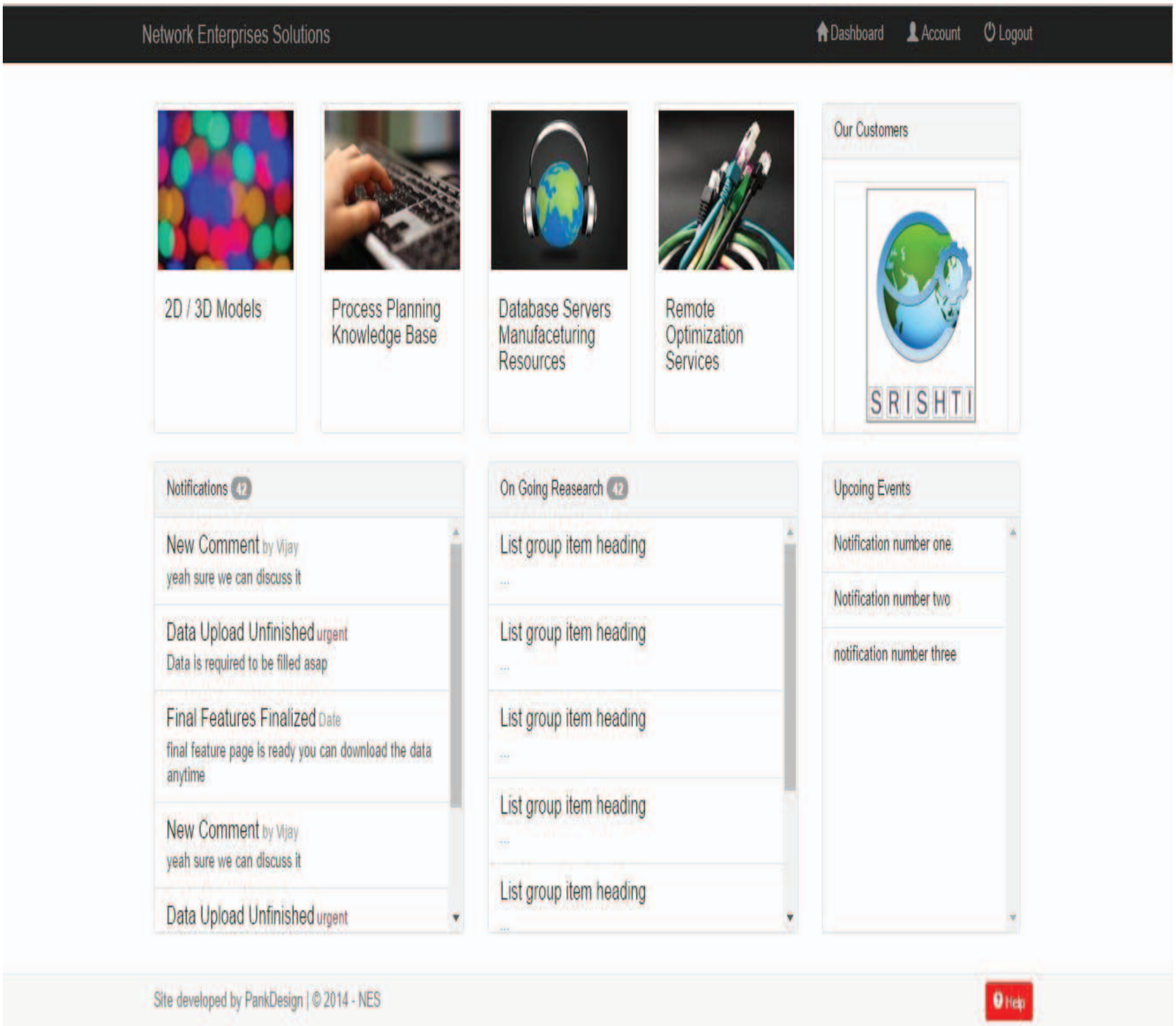

Figure 4 Snapshot of the developed Web based decision system tool

A. Implementation

The part feature and the high level information such as required data for process planning, and machine data are stored during the part feature creation. The feature and the model parameters shown in Figure 5 can be customized to avoid the complexity during feature reorganization. The green colour in the Figure 5 indicates the corrected parameter after interaction with manager. Otherwise, if the user requirements have involved any major corrections with large data then the decision making process could be possible by converting the large data into XML files from Protégé based Ontology software for easily sending of data. After mutual agreement the part feature chart is freeze with the Finalize option button.

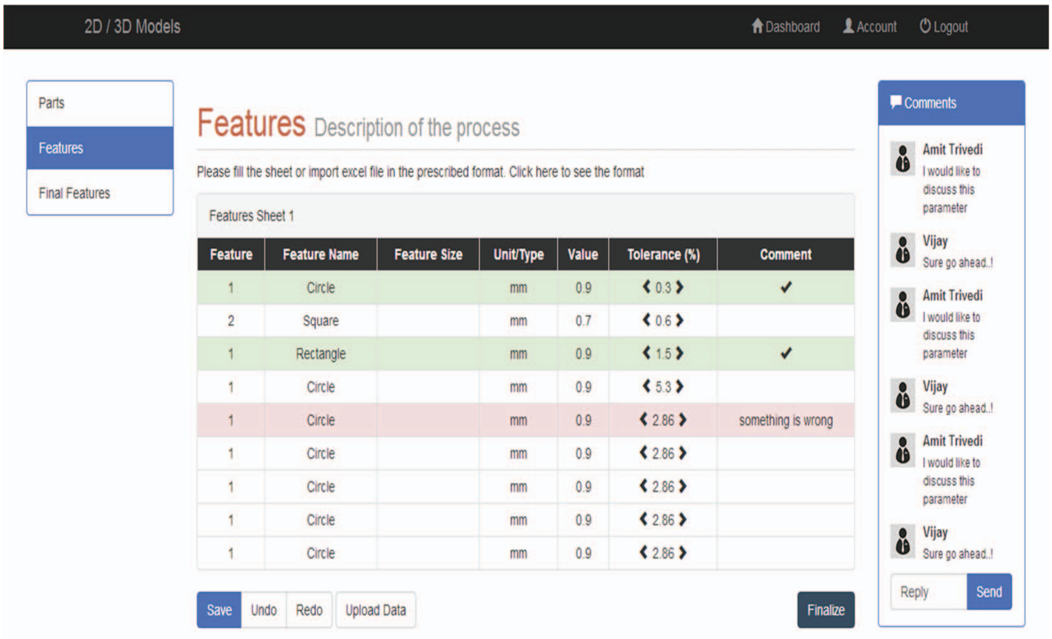

Figure 5 Snapshot of the Part feature implementation

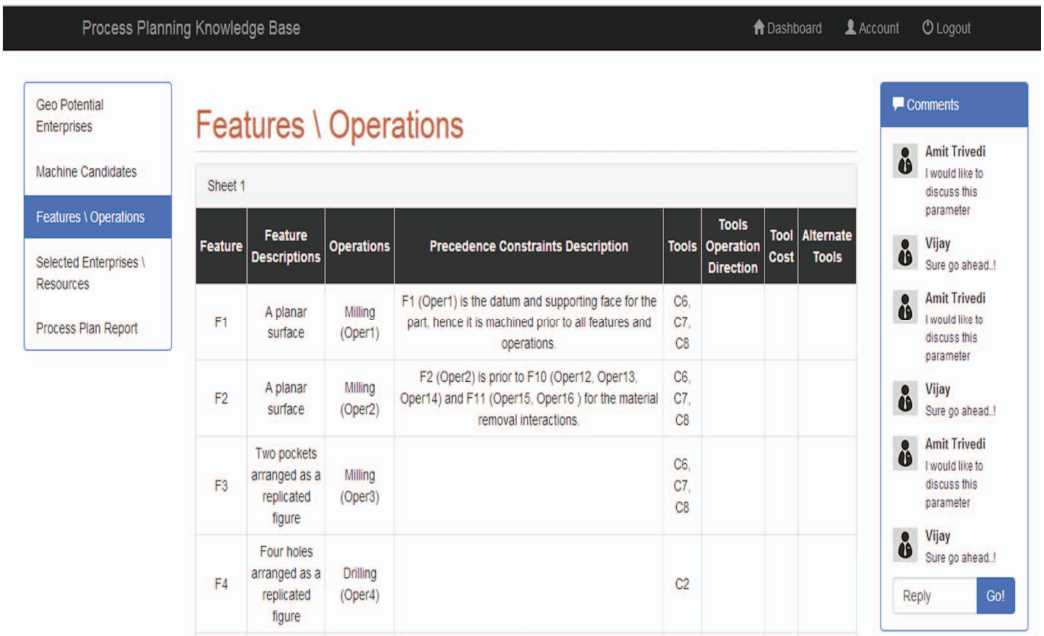

Figure 6 Snapshot of the Process Plan Knowledge base implementation

The execution of the part feature selection module will be carried out in accordance with the type of the process plan knowledge based implementation requirements. In this module, the feature description, type of operations, precedence constraint description in relation with part type is detailed. The details of the implementation part are illustrated in Figure.6. Moreover, enterprises selected for performing the detailed process plan knowledge, and the transportation time between the selected enterprises are stored in the knowledge base of the user. Finally, after obtaining information, IPPS has been carried out with developed methodologies to accomplish the desired objectives of the user.

VI. CONCLUSION

Networked manufacturing system is an advanced manufacturing pattern for enterprises to run their businesses by using networks, particularly with the aid of internet services. As a new manufacturing paradigm it has the capability to share the resources including information and technology for design, manufacturing, and management. In this work, an attempt has been made to develop flowchart, architecture and a web based decision support system to support distributed process planning and scheduling. The database and process plan knowledge based system approach has been implemented for the execution of operations to generate feasible process plans. Integration of all the aforementioned modules is carried out with a developed web based decision system. It acts as a convenient platform for users to view and evaluate a design model effectively through dynamically invoking remote process planning optimization services. The developed intelligent and interactive distributed process planning system is user friendly, flexible and expandable in nature. The proposed approach is a generalized one, therefore it is possible to generate flexible process plans for any type of complex parts once the process capability information is updated in the system. However, the present system is limited to prismatic parts in manufacturing. In near future, it can be extended to all kinds of manufacturing parts and distributed problems in supply chain management.

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REFERENCES

[1] Gellersen, H.W. and Gaedke, M., 1999. Object-oriented web application development. *IEEE Internet Computing*, *3*(1), p.60.

[2] Cutkosky, M.R., Tenenbaum, J.M. and Glicksman, J., 1996. Madefast: collaborative engineering over the Internet. *Communications of the ACM*,*39*(9), pp.78-87.

[3] Bailey, M.J., 1995. Tele-manufacturing: rapid prototyping on the Internet.*IEEE Computer Graphics and Applications*, (6), pp.20-26.

[4] Uschold, M., & Grueninger, M. (1996). Ontologies: Principles, methods and applications. The Knowledge Engineering Review, 11(2), 93–155.

[5] Lin, H.K. and Harding, J.A., 2007. A manufacturing system engineering ontology model on the semantic web for inter-enterprise collaboration.*Computers in Industry*, *58*(5), pp.428-437.

[6] Daconta, M.C., Obrst, L.J. and Smith, K.T., 2003. *The semantic web: a guide to the future of XML, web services, and knowledge management*. John Wiley & Sons.

[7] Ozman, M., 2006. Knowledge integration and network formation.*Technological Forecasting and Social Change*, *73*(9), pp.1121-1143.

[8] Sung, Y.T., Chang, K.E., Chiou, S.K. and Hou, H.T., 2005. The design and application of a web-based self-and peer-assessment system. *Computers & Education*, *45*(2), pp.187-202.

[9] Bailey, M.W. and VerDuin, W.H., 2001. FIPER: an intelligent system for the optimal design of highly engineered products. *NIST SPECIAL PUBLICATION SP*, pp.467-477.

[10] Beiter, K.A. and Ishii, K., 2003, January. Integrating producibility and product performance tools within a Web-service environment. In *ASME 2003 International Design Engineering Technical Conferences and Computers and Information in Engineering Conference* (pp. 1007-1014). American Society of Mechanical Engineers.

[11] Xiao, A., Choi, H.J., Kulkarni, R., Allen, J.K., Rosen, D., Mistree, F. and Feng, S.C., 2001, September. A Web-based distributed product realization environment. In *Proceedings of ASME 2001 Computer and Information in Engineering Conference, Pittsburgh, PA*.

[12] Mervyn, F., Bok, S.H. and Nee, A.Y.C., 2003. Development of an Internet-enabled interactive fixture design system. *Computer-Aided Design*, *35*(10), pp.945-957.

[13] Huang, G.Q. and Mak, K.L., 2001. Issues in the development and implementation of web applications for product design and manufacture.*International Journal of Computer Integrated Manufacturing*, *14*(1), pp.125-135.

[14] Huang, G.Q. and Mak, K.L., 1999. Design for manufacture and assembly on the Internet. *Computers in Industry*, *38*(1), pp.17-30.

[15] Bless, P. N., Klabjan, D., & Chang, S. Y. (2008). Heuristics for automated knowledge source integration and service composition. Computers and Operations Research, 35(4), 1292–1314.

[16] Bombardier, V., Mazaud, C., Lhoste, P., & Vogrig, R. (2007). Contribution of fuzzy reasoning method to knowledge integration in a defect recognition system. Computers in Industry, 58(4), 355–366.

[17] Gardner, S. P. (2005). Ontologies and semantic data integration. Drug Discovery Today, 10(14), 1001–1007.

[18] Kwon, O., Kim, K. Y., & Lee, K. C. (2007). MM-DSS: Integrating multimedia and decision-making knowledge in decision support systems. Expert Systems with Applications, 32(2), 441–457.

[19] Tay, F.E.H. and Roy, A., 2003. CyberCAD: a collaborative approach in 3D-CAD technology in a multimedia-supported environment. *Computers in Industry*, *52*(2), pp.127-145.

[20] Petrie, C.J., 1996. Agent-based engineering, the web, and intelligence. *IEEE expert*, *11*(6), pp.24-29.

[21] Wright, D.T. and Burns, N.D., 1997. Cellular Green-Teams in global network organisations. *International Journal of Production Economics*, *52*(3), pp.291-303.

[22] Wagner, R., Castanotto, G. and Goldberg, K., 1997. FixtureNet: interactive computer-aided design via the World Wide Web. *International Journal of Human-Computer Studies*, *46*(6), pp.773-788.

[23] R. V. E. Bryant et al., "Common product/process models for interfacing manufacturing simulation, process planning and CAD", in Proceedings of the 1996 ASME Conference, Irvine, http://www.deneb.com/MADE/papers/dfm/dfm96.html, 1996.

[24] D. Whitney, M. Anderson, C. Cadet et al., "Agile pathfinders in the aircraft and automobile industries – a progress report", Internal Working Report, MIT, 1995.

[25] P. Will, Active Catalogs Project Home Page, http://www.isi.edu/active-catalog/index.html, 1996.