Internet-enabled Integration of Co-design and Concurrent Engineering

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Abstract – In order to facilitate the product design and realization processes, an Internet-enabled prototype system has been developed to support collaborative and concurrent engineering design through seamlessly integrating three functional modules, i.e., co-design, Web-based visualization and manufacturing analysis, based on some Java and Web technologies. This prototype system can be used for a design team geographically distributed to organize a 3D collaborative and concurrent engineering design effectively, and the proposed distributed and integration architectures can enable the system to be generic, open and scalable.

Keywords: Co-design, Concurrent engineering, Manufacturing analysis

1 BACKGROUND

Manufacturing corporations have become more product-oriented, aiming at decreased lead times from design to manufacturing, minimal work-in-process, just-in-time flow of materials, and high efficiency and flexibility of manufacturing capacity utilisation. Recently, many philosophies have come into existence to facilitate the product design and realisation processes. Concurrent engineering (CE) is a systematic approach to integrate the design of products with related manufacturing processes using some software packages and computing techniques in a computer environment. Within CE, a designer can consider and evaluate the downstream manufacturing processes of the product lifecycle in the initial design phase. Co-design is another increasingly important philosophy used in modern manufacturing corporations to collocate a multidisciplinary design team to carry out a complex design task through effective communication and collaboration. CE and co-design are complementary in functions since the former emphases a vertically seamless linkage between the upstream design and the downstream manufacturing processes through the creation of intelligent strategies for effective information interchange, while the latter focuses more on the horizontally interpersonal aspects of group work in the upstream design phases. With the trend for global competition and the rapid advances of the Internet technologies, both of them are moving towards supporting distributed applications, in which geographically dispersed users, systems and resources can be integrated in an Internet/Intranet environment beyond the traditional boundaries of physical and time zones. The appeared systems and methodologies only focus on one of the above aspects and cannot meet the requirements of practical produce design and development effectively [1-4]. Therefore, it is imperative to develop an Internet-based integrated system to support CE and co-design simultaneously.

2 OBJECTIVE

An Internet-based integrated prototype system is needed to support interrelated activities and share domain knowledge between designers and systems through integrating CE and collaborative design functions. This prototype system should consist of three primary modules: (1) a co-design module to enable designers to fulfil product design collaboratively; (2) a Web-based visualization module to support product preview and evaluation of design parts; and (3) a manufacturing analysis module for designers to conduct CE methodology through invoking some distributed services. The prototype system needs to provide: (1) a convenient and flexible platform for users to carry out a co-design activity, with a scenario similar to the actual teamwork situation; and (2) a generic and scalable distributed mechanism to integrate different functional modules in the system effectively to support CE, Web portal-based visualization and co-design.

3 METHODOLOGY

In order to support a co-design activity with the CE methodology, an integrated and Internet-based system has been established to consist of three functional modules - a co-design module for organizing distributed and co-modelling design activities, a Web-based visualization module to facilitate product review, and a module for downstream manufacturing analysis to enable CE design [5]. The entire system structure and the functions are shown in Fig. 1. Some functional details of the modules are given in the following sub-sections.

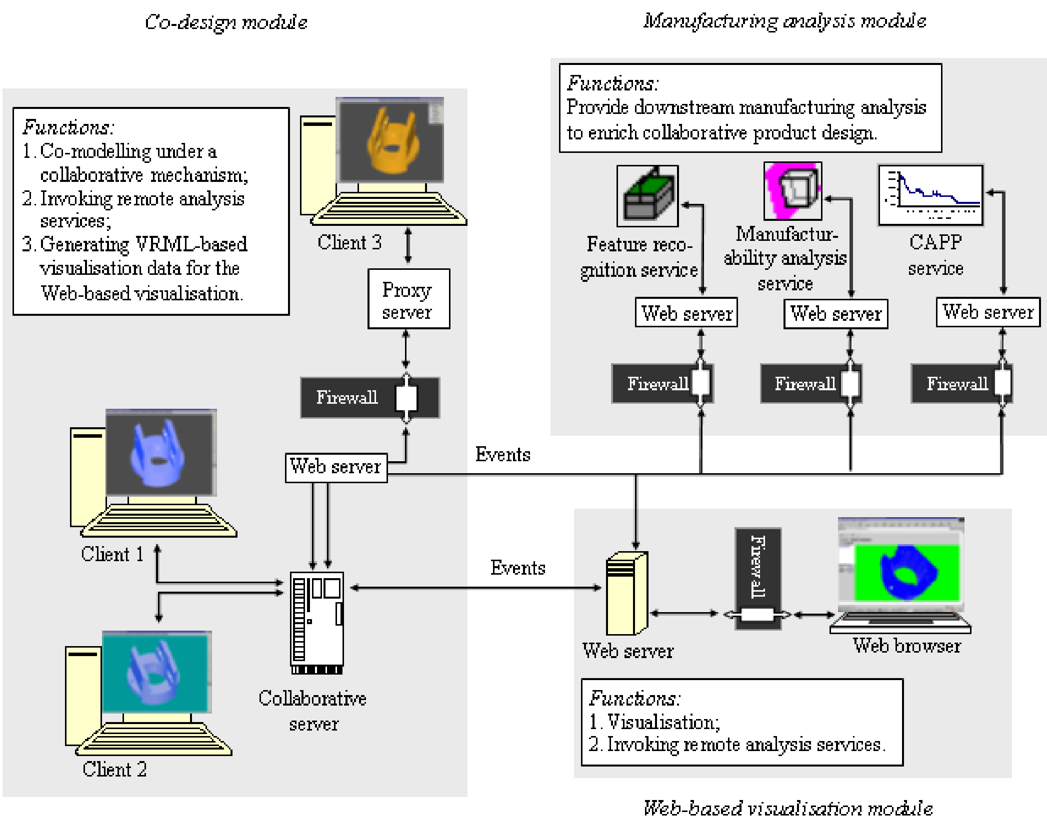


Fig. 1. Prototype structure and functions.

3.1 Co-design module

A co-design module has been established to support simultaneously co-modelling activities of designing parts. It is based on the Java RMI mechanism and consists of a collaborative server and clients [6]. In the collaborative server, a look-up service is designed to provide a naming mechanism to manage clients and manufacturing analysis services dispersed in the integrated system. The collaborative server can dynamically generate working sessions based on a Java RMI 'object factory' mechanism, and provides references to these sessions for clients to request and manipulate. A working session maintained by a session manager is to provide a common working space for designers to participate in a collaborative design community to share and manipulate co-design models. Each session is associated with a feature-based modelling system developed based on a solid modelling kernel, i.e., Open CASCADE™. Through a Java wrapping mechanism - Java Native Interface (JNI), the modelling kernel written using C++ can be linked with the Java-based communication facilities through a shared library, and the native API functions of the kernel can be invoked and manipulated by Java applications. Each client is a Java application-based user interface. It can support designers to input feature parameters for creating a part in the server side, visualize the part dispatched from the server, select entities in a feature for local operations, and manipulate the part such as queried of dimensions and distance between entities. The Open CASCADE provides a function to convert its proprietary design models to VRML models and can pass them to a Java3D-based VRML browser in a Web-based visualization module for display and manipulation.

3.2 Web-based visualization module

Visualization of design models in the Web is one of the effective means to assist co-design. Based on it, design models can be dynamically published in a Web environment and conveniently accessed by remote people from the management, marketing, maintenance and customers for efficient design collaboration, design process monitoring or product preview. A Web-based visualization module has been developed based on the Java Servlet, Applet and Java3D technologies to provide visualization-based operations and some collaborative functions such as chatting and messaging. This module consists of a Tomcat Web server, a Java3D-based Applet client, communication services based on the Java Servlet mechanism in the Web server side to exchange information between the this Web server and one of the Applet client, the collaborative server in the co-design module, and the analysis services in the manufacturing analysis module. In the Java3D-based Applet client, a VRML model generated in the above co-design module can be browsed and manipulated.

3.3 Manufacturing analysis module

A computer-aided process planning (CAPP) evaluation functional module has been develop and integrated in the system to support the CE design. With the CAPP, the activities of selecting machining resources, determining set-up plans, and sequencing machining operations can be considered simultaneously so as to achieve the globally lowest machining cost according to a combined evaluation criterion of minimising machining costs, cutting tool costs, machine changes, and tool and set-up changes. The manufacturability analyser can be used to evaluate the feasibility of machining a design part from the perspectives of the machining volumes and elements such as position faces for machining tools and Tool Approach Directions (TADs). The workflow of the algorithm is illustrated in Fig. 2. Due to the space limitation, the details of the algorithm and optimization processes are not shown here.

Presently, the CAPP service with four alternative methods - Genetic Algorithm, Simulated Annealing, Tabu Search and hybrid Genetic Algorithm and Simulated Annealing, has been integrated in the system [7]. The cost of a process plan can be computed in Table 1. In the co-design and visualisation modules, the CAPP service, which is managed in their individual look-up services, can be invoked for on-line evaluation of a designed or viewed part.

4 RESULTS & DISCUSSION

A case is illustrated here to show a co-design process with CE functions. The responsibilities of designers for the task are listed in Table 2.

Some results to show a working process are given as follows.

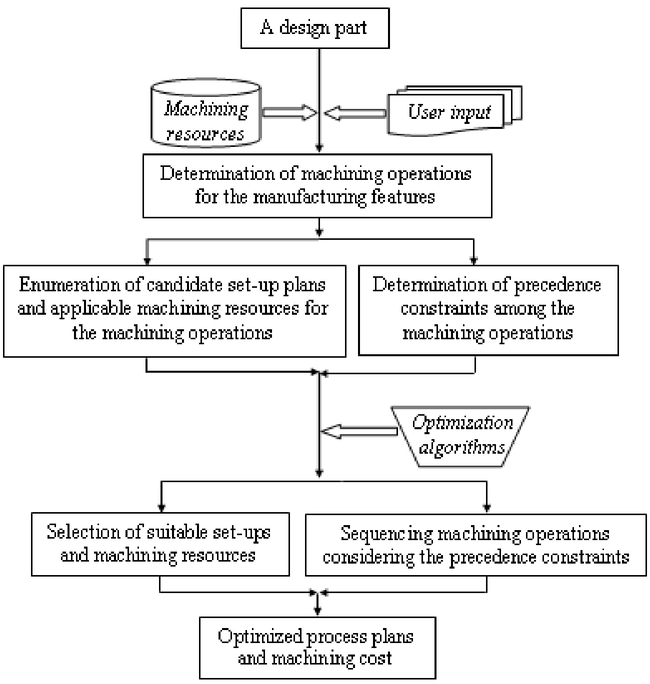


Fig. 2. Workflow of the CAPP process.

Table 1. Machining cost for a process plan in the CAPP.

Variables	Descriptions
TMC	Total Machine Cost of a process plan
TTC	Total Tool Cost of a process plan
TSC	Total Set-up Cost of a process plan
TMCC	Total Machine Change Cost of a process plan
TTCC	Total Tool Change Cost of a process plan
APC	Additional Penalty Cost of violating constraints in a process plan
TWC	Total Weighted Cost of a process plan

$$TWC = w_1 * TMC + w_2 * TTC + w_3 * TSC + w_4 * TMCC + w_5 * TTCC + w_6 * APC$$

where $w_1 - w_6$ are the weights

(1) Fig. 3(a) shows the display windows of Designers A and B in the co-design module. During the modelling process by a designer, the relevant intermediate information is packaged as events and shared with other designers automatically in a design session. In the client side, each designer has the freedom to adjust some viewing properties of the part such as the colour, viewing position and background for his/her visualisation convenience and preference, and a discuss pad and a session manager shown in Fig. 3(b) are equipped in the system. In a session manager, designers can log on/off a session and the ‘control token’ can be exchanged. During the working process of a designer, a discuss pad can be invoked by any other designer in the design session to make some comments or discussions based on a captured picture of the design part. Designers can chat through text or label the picture for sharing ideas.

(2) Designer C observes the design part in the Web-based visualisation module and the part is shown in Fig. 3(c). He/she can change the visualisation mode of the part, for example, hiding the meshes, highlighting a feature and retrieving its parameters, rotating and zooming the part (see Fig. 3(d)).

(3) Designer C can invoke the CAPP service from the Web environment dynamically, and the final optimization results are shown in Fig. 4(a). Fig. 4(b) is a convenient Java2D-based visualisation and manipulation tool installed in each client to observe, query, zoom and edit the intermediate results represented as 2D information.

5 CONCLUSION

An Internet-based system, which includes three modules for co-design, Web-based visualization and manufacturing analysis, has been developed to support collaborative and CE design. Some state-of-the-art Java and Web technologies have been used to establish a seamless integration infrastructure for these modules, and an effective collaborative mechanism to organize product design has been proposed. The main contributions of this work are summarized as follows:

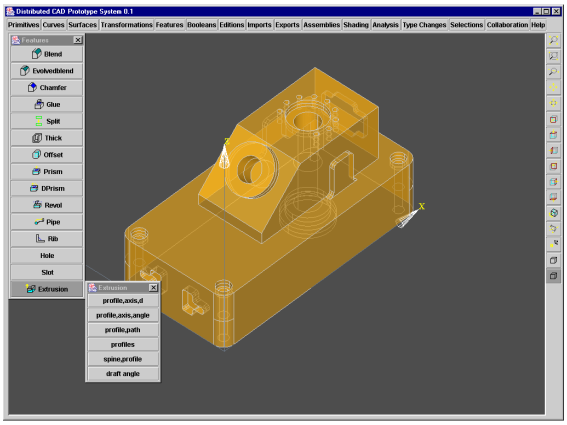
(1) The integrated system can effectively support a dispersed team for carrying out feature-based collaborative design activities, with organizations and working manners similar to actual teamwork situations. The system provides co-modelling and visualisation tools to meet the co-modelling or visualisation requirements arising during co-design activities within or across enterprises. Analysis services can be invoked to conduct the CE principle during design processes; and

(2) According to the different conditions, various Java and Web technologies have been used

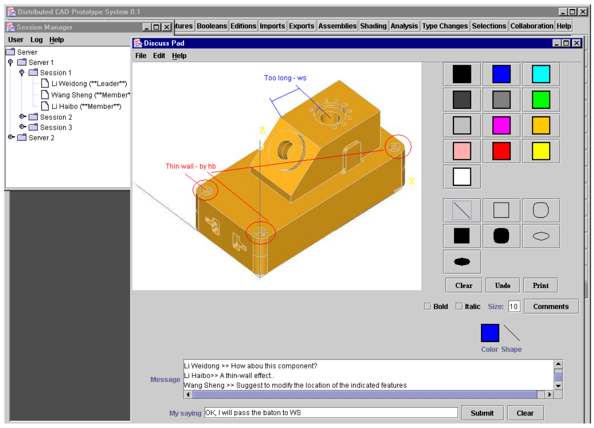
and deployed in different parts of the integrated system to meet the system requirements in terms of efficiency and functions. Through some designed Java-based services and event-based mechanisms, these distributed technologies have been seamlessly integrated.

6 INDUSTRIAL SIGNIFICANCE

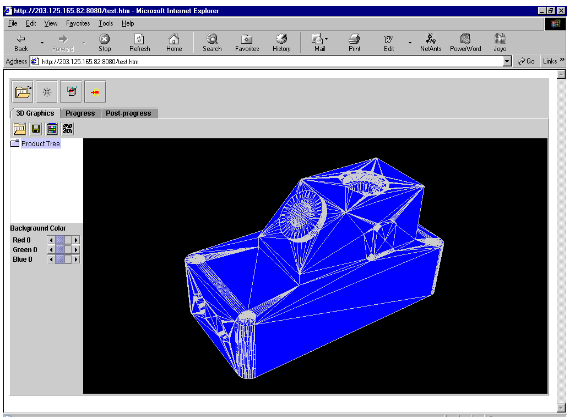
With the demands of faster new product introduction and more complex, and customized products, local companies need to participate in global design chains and collaborate with each other and overseas partners to pursue competitive advantages. Consequently, designers in Singapore are increasingly faced with the challenges of integrating distributed product design and development teams made up of increasingly diverse sets of skills, varying design processes and different business measures. The developed Internet-based integrated prototype system can address such issues for the collaborative product development in design chains in the Singaporean business environment.



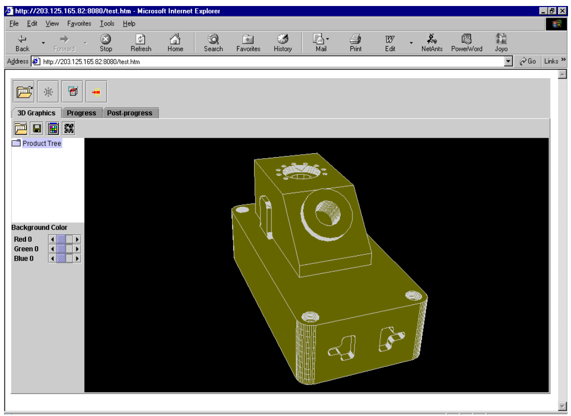
(a) A design part shown in a client



(b) The session manager and discuss pad provided for clients

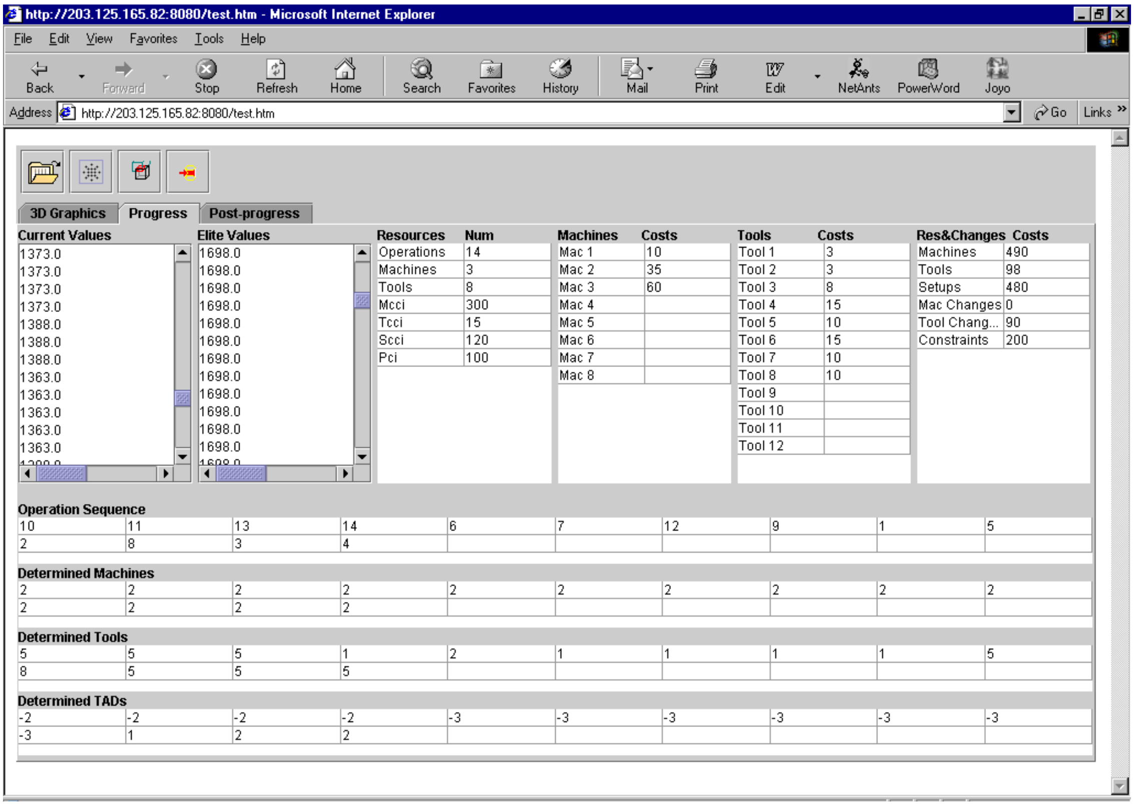


(c) The part with meshes is shown in a Web browser

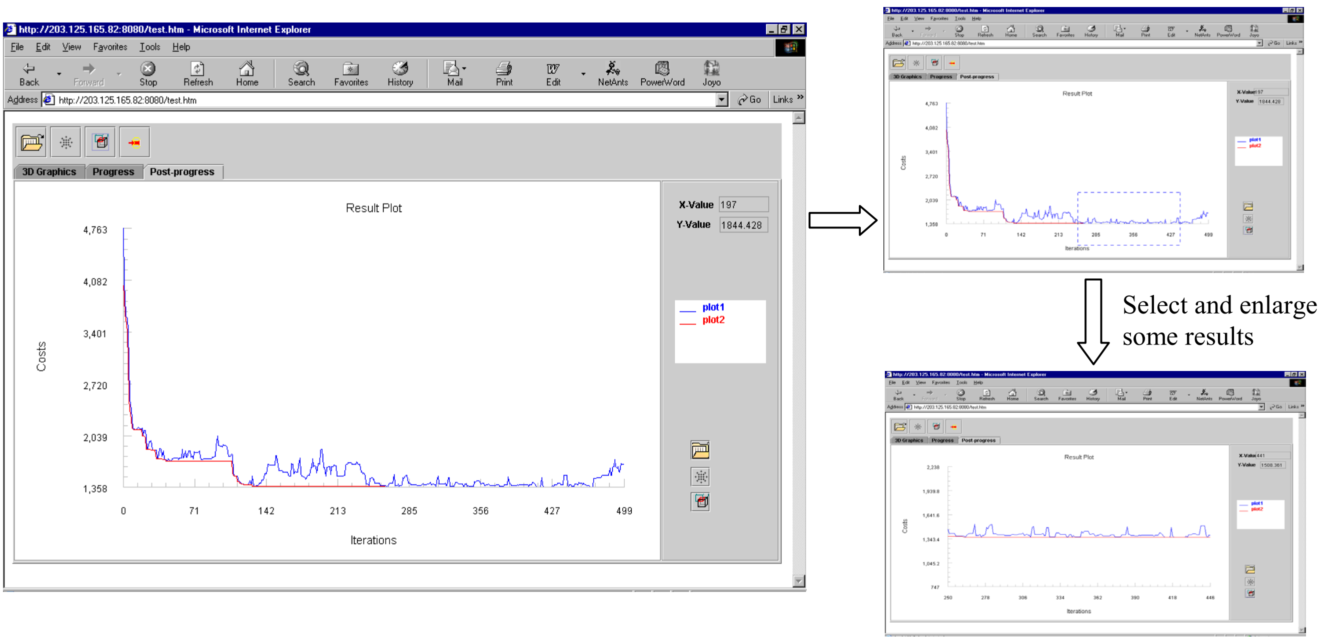


(d) The visualisation mode of the part is changed in the Web browser (without meshes)

Fig. 3. A case study for designing a part in the integrated system.



(a) The optimization results of the CAPP service for the design part.



(b) A visualization window for the optimization results of the design part.

Fig. 4. Windows supported by the CAPP service to visualize the optimization results of a design part.

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