WEB BASED MULTI AGENT PLATFORM FOR COLLABORATIVE MANUFACTURING

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*The incessant pressure of meeting customer demands at a decreasing cost across the globe is forcing the modern day manufacturers to adopt a paradigm shift from the traditional way of manufacturing. This includes the utilization of digitalized manufacturing information flow in the form of agents to facilitate the collaborative product development and manufacturing across different geographical locations. To meet these growing needs and fierce competition in the current manufacturing arena, the authors in this paper have presented an" **iManufacturing"**-an intelligent manufacturing based on internet, intranet, web and agents. The architecture utilizes the distributive and autonomous behavior of the functional agents, CORBA, XML, Java and web.*

1. INTRODUCTION

Modern day manufacturers have been challenged by global competition and growing customers expectations for quick product delivery at competitive prices. This has caused a paradigm shift in traditional methods of manufacturing and businesses, resulting in a shift from legacy information systems to internet-based environments. The pressure over these industries are greater than ever before, thus to achieve success in this situation organizations are relying on distributive technologies and cooperative partnerships with other organizations (Choo, Detor,and Turnbull, 2000). Digital manufacturing has emerged as a promising solution to support responsive manufacturing that aims to *"create, validate, monitor and control agile, distributed*

manufacturing production systems geared towards build to order and lean production"(Brown, 2000). In order to do away with ambiguities of tacit knowledge and fulfill aforementioned targets, digital manufacturing hinges on tangible knowledge convertible to digital values ((Seino et. al., 2001).
Recent research in this field has emphasized the need to have a collaborative product development (CPD) system which has been defined as: "an Internet based computational architecture that supports sharing and transferring of knowledge and information of the product life cycle amongst geographically distributed companies to aid taking right engineering decisions in a collaborative environment (Rodriguez and Al-Ashaab, 2002). The present paper utilises the communication and control aspects of machining units in a web based architecture which is the essence of digital manufacturing. An industrial survey carried out by Rodriguez and Al-Ashaab (Rodriguez and Al-Ashaab, 2005) clearly indicates the need for collaborative product development i.e. distributed manufacturing. This has been portrayed in figure 1.

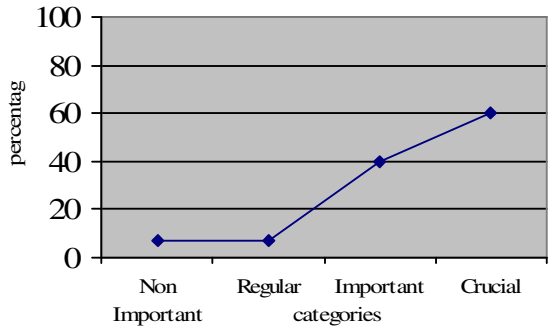

Figure 1: Comparative study supporting collaborative product development (adapted from (Rodriguez and Al-Ashaab, 2005))

The on-going research in this area has proved to be successful in developing technologies that support collaborative product development but has been mainly concentrated in sharing product data and providing collaborative tools in integrating multidisciplinary systems. There are still issues such as the sharing of know-how of the geographically distributed partners which need further investigation. The authors perceive the distributed manufacturing system to be spread all across the globe and the information such as design, manufacturing knowledge, process planning, and product models, which exist at different locations are to be shared and coordinated through the web to facilitate manufacturing at diverse locations as portrayed in figure 2.

Based on this distributive manufacturing concept, the ***iManufacturing***- an intelligent distributive manufacturing system based on the Internet, intranet, agents and web has been introduced in this paper. This architecture utilizes the communication, coordination and autonomous behavior of agents and aim to integrate collaborative product design and development. In order to achieve better global competitiveness and enhanced communication, communication and coordination among diverse geographical locations, the web based architecture is

governed by the attributes of digital information exchange that help in alleviating the prevailing ambiguity and impreciseness.

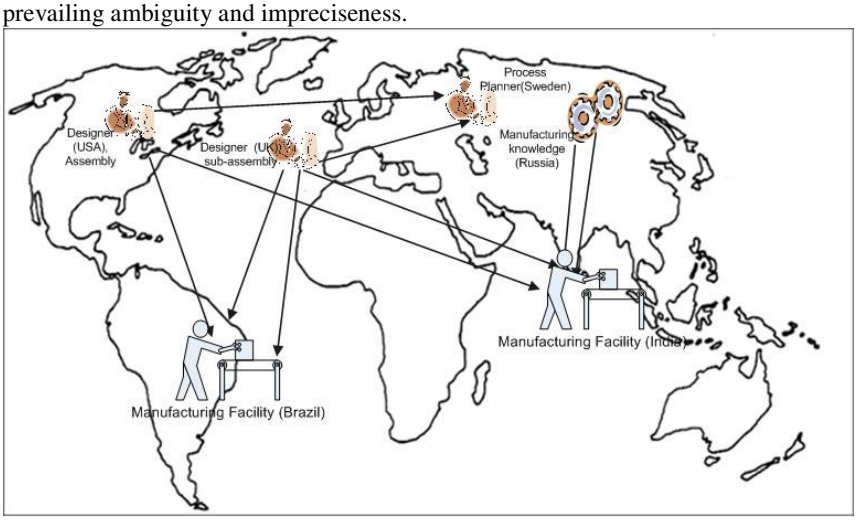

Figure 2: A distributed manufacturing scenario across the globe

This architecture works on the basis of coordination and information exchange among the process planning agents which work under centralized web based control and are guided on the principles of random search algorithms. The focus of the paper is to present the *iManufacturing* architecture that helps in avoiding the ambiguities of the information exchange with the utilization of the digitized information which helps in easing the information data flow among the different agents, to ensure seamless data and information transfer within the manufacturing system.

The rest of the paper is organized as follows: Section 2 discusses a number of web based architectures with the proposed *iManufacturing* architecture being described in section 3. The intelligent search engine is described in section 4 and a range of implementation issues are discussed in section 5. The final section of the paper provides a number of conclusions.

2. WEB BASED MANUFACTURING SYSTEMS

The Web has become one of the most important internet tools providing a platform independent way for sharing, disseminating and retrieving information. This environment has made it possible for the design models to be dynamically shared, updated, accessed and manipulated remotely. Chen and Liang(Chen and Liang, 2000) have presented a web-based system that integrates and shares engineering information for facilitating design and manufacturing activities in the form of a domain investigation, together system design and modeling. A platform-independent real-time monitoring system has been proposed by Ong and Sun (Ong and Sun, 2003) which utilizes mobile agents within a web-based distributed architecture. A web-based system based on the Java Applet programming named as CyberCut has

been developed (Smith and Wright, 1996) in the University of California at Berkeley. This system includes mainly three modules, a Web-based feature-based design tool, a new geometric representation for information exchange between design and process planning modules, and an automated process planning and machining systems. Xiao et. al. (Xiao et. al., 2001) effectively demonstrated an organized workflow for the design process which can be altered by users through assembling components with the help a Web-DPR system. A web based fixture design system has been presented (Mervyn et. al., 2003) which uses an XML format for transferring information and knowledge between functional modules in the distributive environment. Choi et al.(Choi et. al., 2003) have shown the utilities of web based architectures in establishing a new generation of distributed design and manufacturing platform. Amidst all these research developments in web based systems, some research issues (Li, 2005) still need further investigated which are summarized as follows:

(i) *There is a need for the adaptable wrapping mechanism for effective web based applications.*

(ii) *An intelligent manufacturing system based on the web still needs to be developed that integrates visualization based systems and remote application services to facilitate product design and manufacturing on the web.*

Keeping with the current research trends, an architecture based on the web and agents for intelligent manufacturing is presented in next section.

3. *iMANUFACTURING* FRAMEWORK

The framework entitled as *"iManufacturing"* has been proposed to support a range of manufacturing facilities in the distributed manufacturing environment. These facilities are considered as shop floor manufacturing workstations with CNC controllers such as Siemens, Faunc, and Mazak to carry out the manufacturing tasks. The present framework has been proposed to realize a plug-and-play operational environment to support these facilities which are distributed throughout the world. The major aim of the present framework is to provide distributed intelligence in the form of digitized information to perform manufacturing operations starting from the point of accepting product design information from a number of remote locations. The operability of the system depends on several vital factors such as data exchange ,data sharing, communication protocol and architecture. The framework is presented in figure 3,and makes use of the three agents type design agent's, process planning agent's, and manufacturing execution agent's, in addition with product and process databases. Design, process planning and execution of the manufacturing tasks are carried out by distributed cooperative agents. The autonomous behavior of the agents play a vital role in the decision making in the distributive environment which requires a high level of autonomy in utilizing the resources. The agents are proposed to be implemented using the Common Object request broacher architecture (CORBA) (Rosenberg, 1998)objects with Interface Definition Language(IDL) (CORBA, 2003), that provides the application-independent specifications to the client i.e. web servers in the various facilities at different locations. Since CORBA is platform independent and language independent, it is useful in distributed communications in manufacturing. The function of the agents is based on a

communication layer that depends knowledge Query Modeling Language(KQML)/XML message representation along with a user interface. The agents function according to the needs of the manufacturing execution environment that help in collaborative product development. The design activities are supported by the design agent that initiates queries to other agents regarding the manufacturability of the design. The process planning agents provide the process plan on the basis of process database to carryout the manufacturing operations. The manufacturing execution agent is responsible for performing manufacturing operations. These facilities contain different CNC machining workstations which are integrated via the Intranet and are controlled at a facility level by Java-based terminals (Cheng, Pan, and Harrison, 2001). At this facility level these terminals enable adaptablity of manufacture between each of the CNC workstations. The manufacturing execution agent which resides inside each of the CNC's are connected through these Java –based terminals to coordinate with other agents and carry out the manufacturing tasks. The different functional elements of the architecture are described as follows:

(i) Product database: class features model the generic product libraries and are distributed at different locations. Class features are mainly composed of element-features, attributes, and relation among features and attributes. These class features are distributed remotely and are gathered using web links. The product database is created using class features which are created at one location and accessed at different locations using web-browsers. A VRML browser is used for extracting modelling product geometry.

(ii) Design Agent: The product data base provides the part feature related information in the form of the Extendable Stylesheet Language transformation (XSLT), which is processed by a design agent. A message is generated by the design agent that includes the part information, and machining features which is sent to the manufacturing execution agent based in the different facilities to check the corresponding manufacturing feasibility. This is sent in the form of a XML file to the manufacturing execution agent which in turn sends back the information regarding the preferred processes and resources. This is further sent to the process planning agent to carry out the process planning operation. The web accessibility of the product database with different classes helps in the possible design improvements at an early stage of manufacturing that helps in maintaining the product quality and also in reducing the manufacturing cost.

(iii) Process database: This contains the different machining data, material data and tooling data which is accessed by the process planning agent.

(iv)Process Planning Agent: All the relevant features and process data is made available to this agent through XML parser (2004) which means processing of information carried out by the design agent. The process planning agent employs intelligent algorithms such as the Genetic Algorithm (GA), Simulated Annealing (SA), Tabu Search (TS), Artificial Immune System (AIS), based search engine that performs process planning for a feature-based part. These optimization tools help in reducing the machining time which reduces the cost. The message from this agent is communicated to the manufacturing execution agent at the CNC manufacturing workstation to carry out the necessary sequencing of the machining operations. This agent also works as the decision agent and allows the interpretation of the process

plan for the specific workstation using the process database to provide a specific manufacturing plan for an individual CNC workstation.

(v) Manufacturing Execution Agent: This agent is responsible for processing the manufacturing of parts and generates the manufacturing codes for the operations from the controllers to the different machines. In addition it provides feedback for communication with the design agent and process planning agent and reports the required process control information for the corresponding design and process planning.

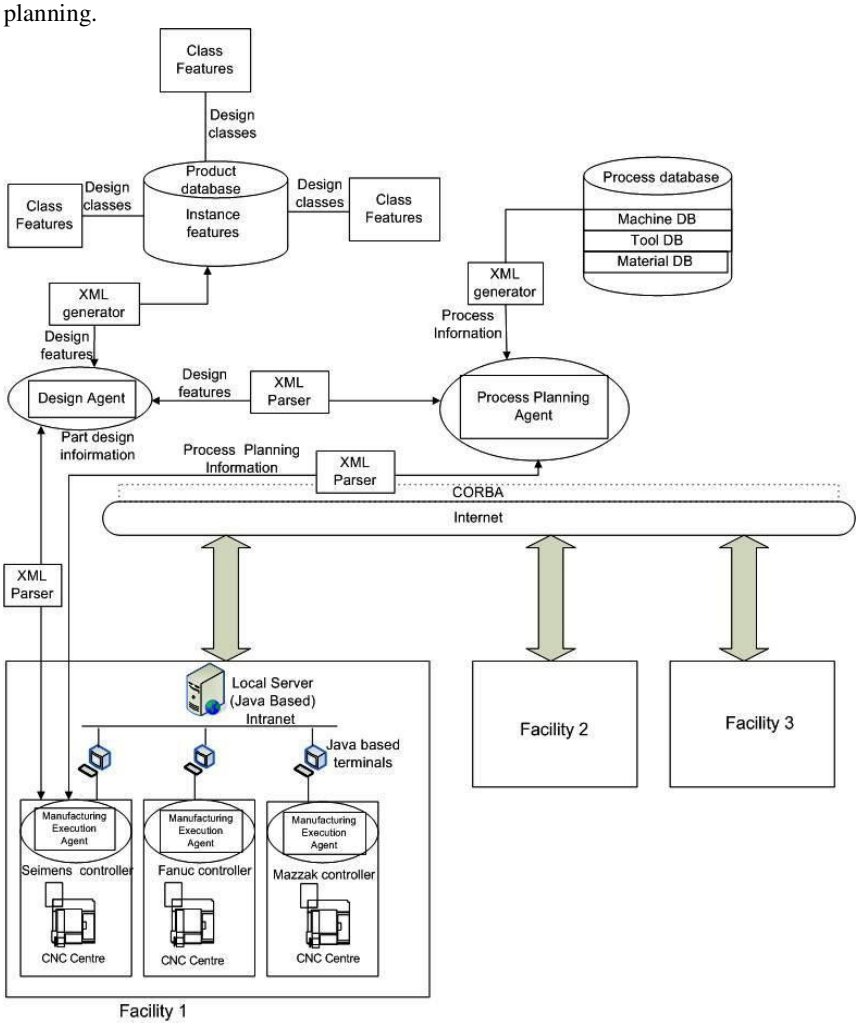

Figure 3: *iManufacturing* framework

4. INTELLIGENT SEARCH ENGINE

The process planning agent incorporates an intelligent search engine that carries out the process planning for the part features with the use of intelligent algorithms such as GA, SA, AIS, TS etc. The functionality of the process planning agent is shown in the following figure 4.

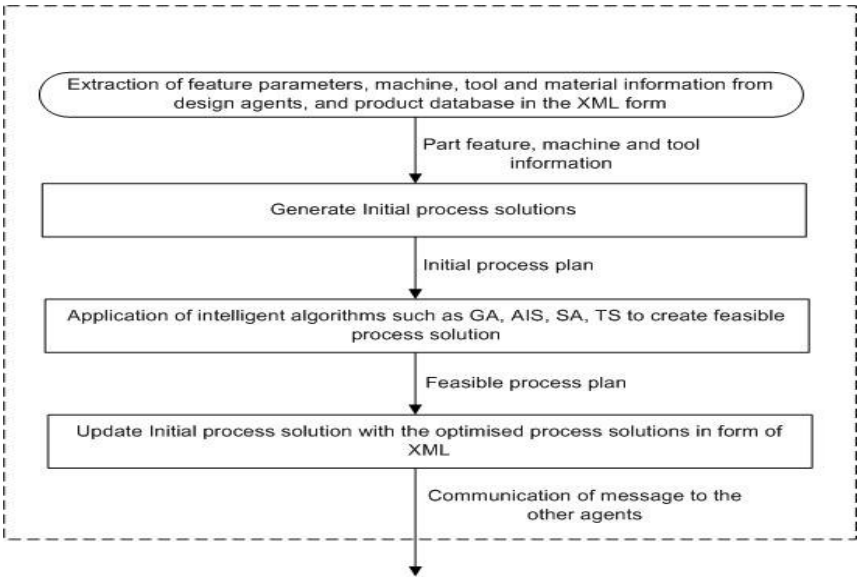

Figure 4: Process planning agent functionality

The intelligent engine utilizes the random search algorithms ability to search through all possible alternatives and generate the feasible and optimised solutions. This agent initially extracts the design features, tooling, material, machines in XML form which is later being optimised using the intelligent search algorithms to generate the optimised process solutions. The optimization is to be carried out based on certain optimization models that aim to minimize machining cost, tooling cost, machining time, set-up costs with relative various constraints such as machining, designing, feature interactions. A form of the XML file has been represented in the following figure 5.

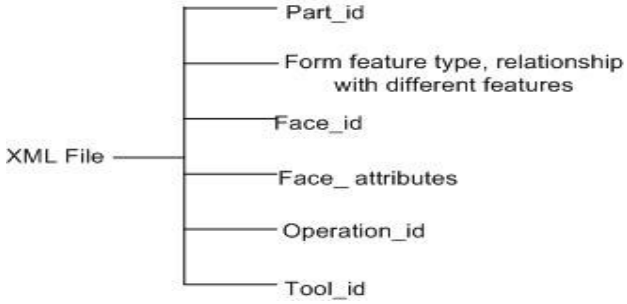

Figure 5: XML file representation for the part

5. IMPLEMENTATION ISSUES

There are certain important implementation issues such as security, privacy and system reliability that can affect the performance of these systems over different facilities throughout the world. One of the important issues in the collaborative manufacturing is related to the privacy of proprietary information in the form of

competitive manufacturing information related with order and cost details related to particular facility. Majority of systems are implemented on the intranet behind a firewall, there is still communication across different intranets and internet. However the agents are autonomous, the communication among the agents should be reliable to ensure the stability and reliability of the manufacturing systems.

6. CONCLUSIONS

A framework composed of agents such as design, process planning, and manufacturing execution agents shows significant potential for supporting collaborative manufacturing. The framework provides a seamless integration of different agents communicating messages regarding the part design, planning information with the different CNC controllers in the various facilities across the web. The proposed web based system consists of an intelligent search engine within process planning agent that aims to obtain optimised process plans which help in reducing machining, tooling and setup costs.

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