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AGENT BASED MANUFACTURING CAPABILITY ASSESSMENT IN THE EXTENDED ENTERPRISE USING STEP AP224 AND XML

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Abstract: Data exchange in the extended enterprise is one of the most critical tasks in supporting collaborative decision-making. Companies often rely on geographically distributed suppliers for efficient product design and manufacture. Early design assessment can substantially reduce the cost of product development and production. This research proposes a new STEP AP224 EXPRESS based data model to facilitate the exchange of part and process data between distributed key agents in the early design process. The approach is illustrated using a prototype XML/CORBA environment to support the information exchange between collaborating design and manufacturing agents.

Keywords: Early Design Assessment, Collaborative Design, STEP AP224 and XML

1 INTRODUCTION

In today's competitive manufacturing world, companies constantly seek to optimise their manufacturing processes and improve their overall performance. One of the key factors for success of new products is how efficient is the utilisation of the product development time and how well the early design decisions are coordinated between all major stakeholders. Early design assessment is an effective method for cutting costs throughout the product development phase. Performing the early design assessment in a collaborative environment is a technique used to concurrently review the design from different points of view, thus reducing the gap between the design and the production stages in product development.

One of the critical developments for improved communication of product and processing data in machining has been the development of the STEP AP224. Feature extraction routines utilising STEP AP224 were proposed by Bhandarkar and Nagi[1] The research focuses on the extraction of the feature information by converting low level geometry into higher level manufacturing information. Ming et al.[2] developed an information model for CAPP by using object-oriented model based on STEP AP224 and product data exchange. The model consisted of part information model, process plan information model and production resource information model. Zha and Du [3] proposed a prototype system for integrated design and assembly planning utilising an EXPRESS model representing STEP information for the part representation. Pena-Mora and Hussien[4] reported a PDM system with integrated early design system using AP 224 for feature representation. Moreover, the system supported parameters for manufacturability assessment and process planning generation. Due to the complexity of STEP AP224 representation, there is still a gap between the capabilities of the AP224 and its use and the great potential for data integration offered by AP224 has been mostly unutilised.

Another important drive for developing collaborative decision making applications in manufacturing has been the development of web enabling tools and data structures that can support distributed environments. `Other reported distributed design support systems include the distributed agent-based design negotiation and co-ordination environment CAIRO [5]; the web-based electronic design tool WELD[6]; and the internet-based computer-aided design evaluation tool WebCADET [7].

With the advent of internet-based communication XML (eXtensible Mark-up Language) has been used increasingly to transmit structured information in a universal way across different architectures [8][9] reported a new Product Data Markup Language (PDML) creating a unified use of XML for the purpose of product data exchange. The PDML used STEP as a Product Data Exchange (PDE) technology.

Despite the advances in developing distributed design systems there is still a lack of integration between the design and facility planning activities at early development stages [10][11]There is also insufficient understanding of companies own production capabilities, their distribution between different company sites and the production capabilities which major subcontractors and suppliers can offer which results in inefficient use of available resources and development of more expensive designs. There is a further need to develop generic methods and tools to capture the capabilities of manufacturing processes and map the parameters used for their representation to the machines and processing systems participating in the extended manufacturing environment.

The paper reports on a STEP AP224 compliant product data model and pilot environment for rapid product manufacturability assessment in extended enterprises using collaborative, autonomous design and manufacturing agents. The approach is based on applying the product data model using XML for exchange of requests and information between design, processing, and facility planning agents. The decision making process is supported by multilevel manufacturability domain and inference models.

2 DATA MODELS – AN OVERVIEW

The decision making at the early stages of design manufacturability assessment is based on matching product requirements to processing capabilities and available resources in the extended enterprise.

2.1 Component Data Model

The request for design manufacturability assessment is based on a component data model representing the target components constituting the new product. Components are described using form features and their relationships[12].

STEP AP224 is an ISO application protocol offering a framework for using machining features in process planning. It specifies the requirements for defining the machining features and the parameters needed to correctly and sufficiently represent them. It would therefore be beneficial if AP224 could be used for representing the product model in a way that would allow structured feature information to be directly used for downstream planning decisions. A major barrier for this is the fact that the standard STEP file even for a very simple part feature is long and difficult to process or understand by the planner. Traditionally a STEP files contains a variety of data about the part and its features that is not closely related to process planning. Here a supplementary part feature model is proposed to reduce the complexity of representation and provide a meaningful part feature definition closely related to AP224 which can be used in process planning activities.

2.2 Process and Facility Data Models

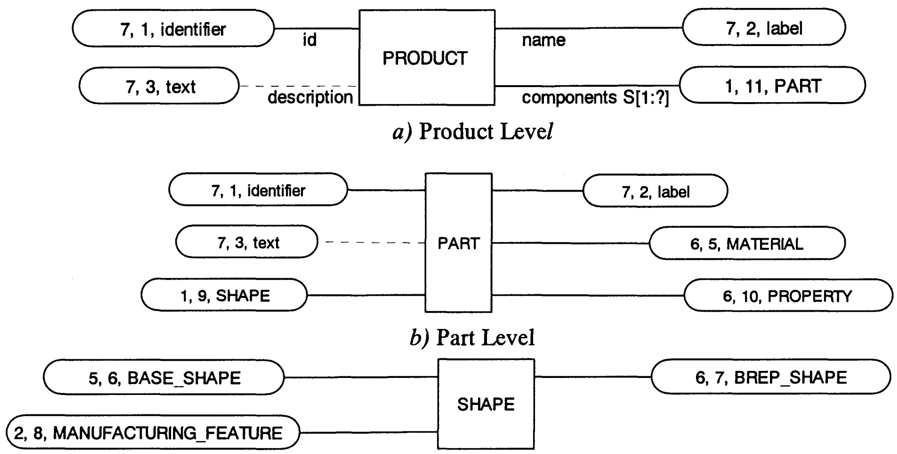
The approach adopted in this work is to relate process capability to three fundamental levels. The first is a "form generating schema" to be used for describing process knowledge at a level that is independent of the machine tool and machining facility used for process execution. Form generating schema (FGS) is defined as a technologically meaningful combination of tool of specific geometry, set of relative motions between a part and the tool and the typical levels of technological output that can be associated with using that combination of tool and relative motions FGS are machine independent but can be used to provide a generalised description of machine tool capabilities.

The second level of abstraction is the "facility" level that is used to describe the distribution of manufacturing capabilities in each facility belonging to the extended enterprise. The overall capabilities of a manufacturing facility are described by a set of resource elements (RE) [12]. Each RE represents a collection of form generating schemas which uniquely define the exclusive machine tool capability boundary and the shared boundaries between machine tools. At extended facility level, the distribution of manufacturing capabilities between different geographically distributed facilities is described by technological elements (TE). TEs are collections of form generating schemes which uniquely define the exclusive and shared machining capability boundaries between the machine tools of different business entities/facilities[13].

3 STEP AP224 COMPLIANT DATA MODEL

The product model is described using EXPRESS and EXPRESS-G representations. The STEP AP224 file was analysed and a technique for data extraction was introduced. The extracted information was represented using XML as the main data communication format for the proposed prototype manufacturing system. The model starts with the PRODUCT entity where basic information about the product such as name, ID, description and components are held (see Figure 1a). The four attributes are used to differentiate the part as all the part information is stored in a database and these can help in proper retrieval of information. The components attribute of the PRODUCT is defined in terms of a set of instants of PART entity. This way sets the coherency between the product and its components.

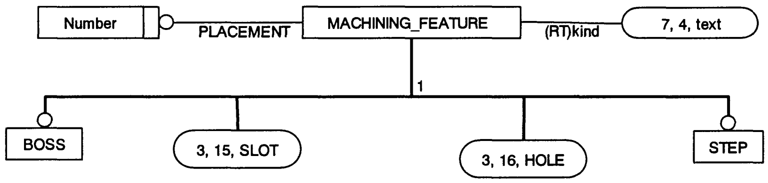
The PART entity holds the specific machining data. (See Figure 1b). The product could be made of one or several parts and this is not in the focus of this research. This research concentrates on how each part is defined in terms of machining features based on STEP AP224. The PART entity again contains attributes to differentiate it from other parts, and these are ID and Name. The description attribute holds text containing any extra data the user wants to state about the part. The remaining three attributes are the most related to the process planning. The first one is the material; this attribute is an instance of the MATERIAL entity. This entity holds information about the type and the properties of the proposed material.



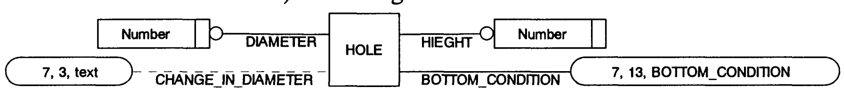
c) Shape Level

Figure 1. Product and Part level description

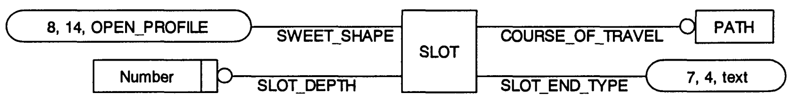
The shape entity holds all the information about the geometry of the part and as well as the part's features (see Figure 1c). The shape is represented by the *Base_shape* entity representing the shape of the block raw material; the *Brep_shape* entity representing the boundary representation definition of the part in terms of constituting faces and the M*anufacturing feature*, where the high-level shape information is held. A machining feature is a subtype of manufacturing feature and it is a supertype of one of a number of possible types (see Figure 2a). The figure shows just four of these subtype features. Each of these features has its own set of attributes needed to be conforming to the standard. The model is illustrated with two entities: a hole and a slot (see Figure 2b&c).



a) Machining Feature DataModel



b) Machining Feature - Hole



c) Machining Feature – Slot

Figure 2. Machining Feature Data Representation

4 AGENT BASED SYSTEM ARCHITECTURE

In an extended manufacturing environment the decision making is based on collaboration between different geographically distributed facilities with a high level of autonomy in the extended enterprise organisation. Such autonomy can be effectively described by using a multi-agent representation of the main decision making modules within the distributed design environment. In the context of the reported research an agent is considered to be autonomous collection of object oriented decision making algorithms, software tools, and data structures to support human-centred decision making process in a well defined domain and provide communication to other agents. The experimental product and facility prototyping system is developed as a distributed multi-agent CORBA environment (see Figure 3).

The decision-making agents are implemented using CORBA objects with IDL (Interface Definition Language) interfaces allowing application independent specification of available member functions to a client. To call member functions a client needs to know only the object's IDL definition without any details such as programming language used, object location, or operating system. The communication between different agents is supported by a CORBA interface database that stores information about the IDL interfaces implemented within the environment. Each agent is based on communication layer (ORB), parser using KQML/XML message representation and a user interface.

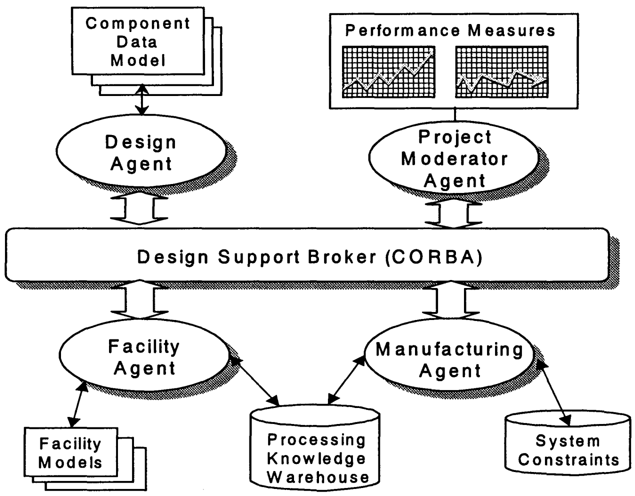


Figure 3. Integrated product and facility prototyping environment – an overview

The sequence of decision-making activities is summarised in Figure 4. The design agent passes the design model to the manufacturing agent with a request for process and facility prototyping. The manufacturing agent communicates with the corresponding facility agents for developing planning alternatives and establishing initial facility prototype. The project moderator is an agent that supports the decision making process by providing periodic evaluation and guidance based on a set of performance indicators. The prototype agent-based modules have been implemented within a distributed computer environment consisting of three workstations linked together within a local area network (LAN) and using TCP/IP protocol.

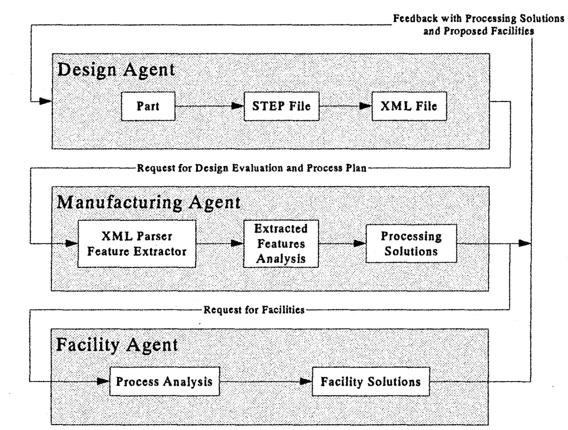


Figure 4. Manufacturability assessment - key decision making activities and actors

The design agent sends requests for manufacturability assessment based on a STEP AP224 product model and a query message. The STEP file is represented using XML based on AP224 application protocol (REF). Once the request is accepted by the process planning agent the critical part features are extracted from the XML file. The geometry of the part can be viewed using the STEP file and if any additional data is needed, it could be obtained from the STEP file. After analysing the part, process planning agent facilitates the selection of processing alternatives. As a result, a number of possible solutions are generated that are communicated to the facility agent.

The facility agent attaches technological elements to each processing alternatives and provides support for optimisation of the overall set of technological elements and final machining equipment selection. Each proposed processing and equipment solution is evaluated by the project moderator agent (not shown) and performance measure values attached. The preferred solution is then sent to the design agent and issued to the designer who initiated the request. An example of the results from the manufacturability assessment process is shown in Figure 5 illustrating the initial design model, the selected processing solutions and facility resources.

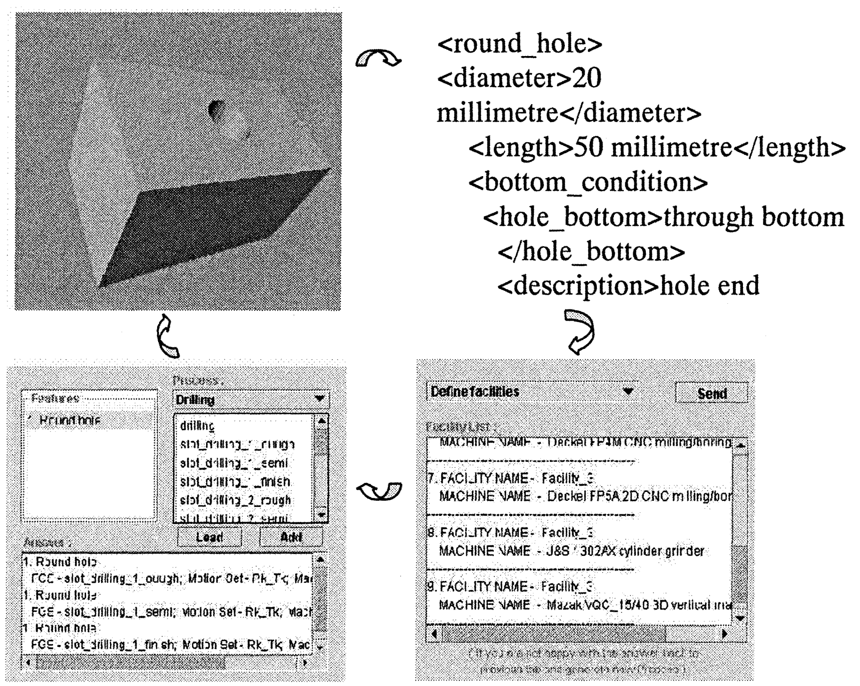


Figure 5. Manufacturability assessment process - an example

5 CONCLUSIONS

The reported research aims at providing the designers with a rapid manufacturing feasibility assessment tool to be used at different design and planning stages in extended manufacturing enterprises. The design evaluation framework provides an integrated platform to support the decision making in distributed design teams. It is based on matching the design requirements to the facility capabilities in an extended enterprise environment using generic models for representation of the processes and resource capabilities in an extended ('virtual') manufacturing environment.

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