Product Development Processes Supported by Integrated Telecooperation Systems for Small and Medium Manufacturing Enterprises

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ABSTRACT

A telecooperation system supports synchronous cooperation among all the product development partners and enables compensation of deficits concerning traditional information/communication technologies. By analyzing the product development processes and communication scenarios of a company manufacturing automobile parts, the specifications for the suitable telecooperation system were defined. An integrated telecooperation platform that combines the commercial softwares with the new developed modules for customer-oriented functionalities was created as a product development guideline. Future work is strongly required in order to define the best way to improve the integrated platform, based on the functionality of ERP and PDM systems.

Keywords : Telecooperation system, Collaboration, Communication scenario, Functionality, Integrated platform

1. Introduction

In order to keep and increase competitive potential, industrial enterprises have to reduce their costs for product development as well as shorten lead time in product development processes. Moreover, they have to respond to market factors and conditions such as increasing demands for functionality and individuality of products, short product life cycles, high pressure on prices and time to market(Eversheim[1]). Technical quantum jumps in connection with high time and cost pressure lead to high development risk. To cope with these challenges, many enterprises have to collaborate with each other globally.

Coordination, communication, and cooperation between manufacturers and suppliers are required to execute product development processes effectively and efficiently. In addition, the use of efficient information and communication systems is needed to increase the industrial competitiveness in product development processes. These can be attained by introducing a higher form of organizational networking in terms of telecooperation.

With innovative information and communication technologies, a telecooperation system supports synchronous cooperation among the product development team, the product distributor and the customer and enables compensation of deficits concerning business trips and traditional information and communication technologies, e.g. telephone and fax. One of the main problems is the selection of a suitable telecooperation strategy, which can be generated only by time-consuming information search.

The objective of this study is the development of a telecooperation system for supporting product development process. The system is implemented with customer-oriented functionalities.

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2. Telecooperation

Telecooperation is multimedia-supported performance service for spatially distributed partners. Audio and video signals of cooperation partners as well as processed data are transmitted. The transfer is made by telephone or ISDN(Integrated Services Digital Network) lines, internet, intranet or other network structures. The use of telecooperation is especially meaningful with frequent, short and simple coordinations. Telecooperation can be considered also in terms of communication, cooperation and coordination.(Fig.1)

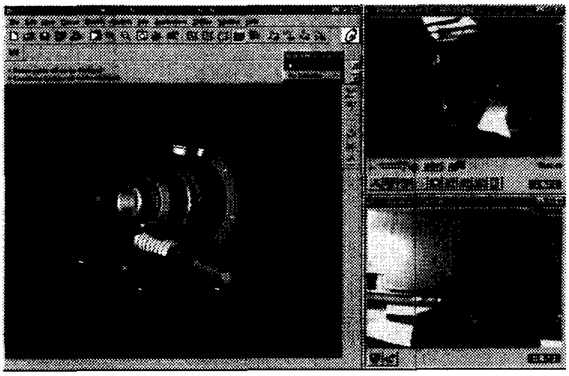

Fig. 1 Telecooperation system

Communication connects people with one another. This connection is realized by information exchange. Thus communication can be defined as a process of information exchange between communication partners for the purpose of understanding(Cagliano[2], Adelson[3], and Rodgers[4]).

Cooperation can be defined by following aspects: the spatial separation of communication partner, the use of information and communication technologies, the form of collaboration, and the type of cooperation partner. The spatial separation of communication partners is the fundamental constituent of all definitions of telecooperation. The use of information and communication technologies concerns the application of EDP(Electronic Data Processing) systems for bridging long distances.

Collaboration is characterized by participants, who work together for a cooperative result. Telecooperation defines a specific form of organization that would not be possible without the help of technical communication media. Another aspect of cooperation is the type of partners. Both enterprise-internal organization units, e.g. a location-overlapping cooperation and independent enterprises, e.g. cooperation between manufacturer and supplier must be taken into account here.

Coordination can be described as proceeding of cooperative work between cooperation partners, and consists of a number of actions and processes for attaining a particular result. Here it depends on the form of collaboration and the type of cooperation partners mostly. Coordination can be supported efficiently in the context of telecooperation by the use of modern information and communication technologies.

2.1 Potentials of telecooperation

Development time and cost can be reduced with the implementation of telecooperation in the following ways: saving of time and cost by avoiding business trips, reduction of expenditures for pre- and post-processing by meeting, faster problem solution by cooperative teleconferences, and continuous work process and information exchange between cooperation partners. It has already been proven that the implementation of telecooperation can reduce lead times by modified processes by 30% in the context of national cooperation and by 80% in the context of international cooperation(Eversheim[5]).

Beside temporal and economical potentials, strategic potentials can also be opened up by the use of telecooperation. Thus telecooperation systems enable distribution of core processes in a strategic network(from concept development to start of production) and stronger integration of distributed partners(manufacturers, suppliers as well as customers).

The highest potential is the improvement of development processes. Telecooperation enables fast, uncomplicated and also spontaneous communication over long distance. It is regarded by users as a media, which supports more frequent idea exchange and increases the quality of development results. Another high potential is the implementation of continuous working processes. Today communication via telephone and fax causes frequent misunderstandings among communication partners. The risk of misunderstandings can be reduced considerably by CAD conference instead of telephone conference or fax.

2.2 Current research works

Topics related to telecooperation have been treated by many different researchers from various fields. Rosenman[6] proposed CADOM(Component Agent-based Design-Oriented Model), a schema for a design-oriented model to capture an information infrastructure with regard to collaborative design. It classifies design data into functional, structural and management data and has emphasized a product modeling.

In the sociotechnical theory for understanding distributed engineering environment, sociotechnical researchers claim that the social and technical subsystems of an organization must be optimized jointly for the greatest overall performance results. They address how to build an effective framework for distributed work groups(Sarkis[7], Hacker[8], Lu[9], and Hammond[10]). Furthermore, Lu[9] provides methodology for managing design conflicts based on a sociotechnical framework.

With the development of the networking of information technology, computer-supported cooperative work is known quite widely as Groupware. It is a software designed to run over a network in support of the activities of a group or organization. Therefore, Groupware is allowing greater geographical and temporal Hexibility in carrying out a wide range of intellectual work. Olson[11] introduces how to design such systems and what effects they have on the individuals, groups, and organizations that use them. Their approach focuses on ordinary elements of infrastructure in future networked computing systems. The various activities in product realization are highly distributed. These require efficient communication amongst the various individuals and the various software tools that are used by them. So, there is a need for a computerized framework that can support distributed design. Recently, web-based software frameworks were presented for supporting collaborative product development in a distributed environment(Park[12], Xiao[13], and Park[14]). In these frameworks, the problems in the product development process, resources management and information communication are solved systematically.

Telecooperation has attracted attention from both commercial software developers and academia. Commercial tools in general focus on facilitating collaboration by providing information exchange and management tools. The Windchill system of PTC(**www.ptc.com**) describes a web-based workspace to collate all data generated during design, manufacturing and delivery. Distributed engineers access and update this knowledge resource from their web browsers. A similar suite of products, ENOVIA(**www.enovia.com**) manages a collaborative and distributed model of the virtual product to support concurrent engineering.

The above broad studies regarding collaboration and communication between engineers are not proper for executing product development process effectively and efficiently. They were not mapped onto a whole collaborative architecture specifying the distributed product development, but considered only their specific results such as product modeling, sociotechnique groupware and framework and so on. To compensate for this problem, the concept for collaborative system is developed in this paper, based on the communication strategy and customer-oriented functionalities derived from the analysis of product development process.

3. Requirements Model for Telecooperation System

3.1 Model of product development process

Information about possible strategies, communication and cooperation processes will be collected and structured to identify suitable application areas and to specify the requirements for telecooperation system. Prerequisite for these activities is sufficient transparency about the existing structure and procedure of product development(Eversheim[1]). For this purpose, a suitable tool, so called communication plan, is developed. In Fig. 2, a communication plan of a company is shown.

The development activities are connected themselves through information flow. Each activity is usually defined by task, needed resources and related processes. The communication relations including resource information carried by participated teams, apart from information flow, are also assigned to the activity.

For a requirement oriented assignment of telecooperation system to the support of determined communication relations, besides communication partner, distance, intensity and the type of respective communication process have to be characterized in the communication plan. According to the tasks and these information, the communication processes can be

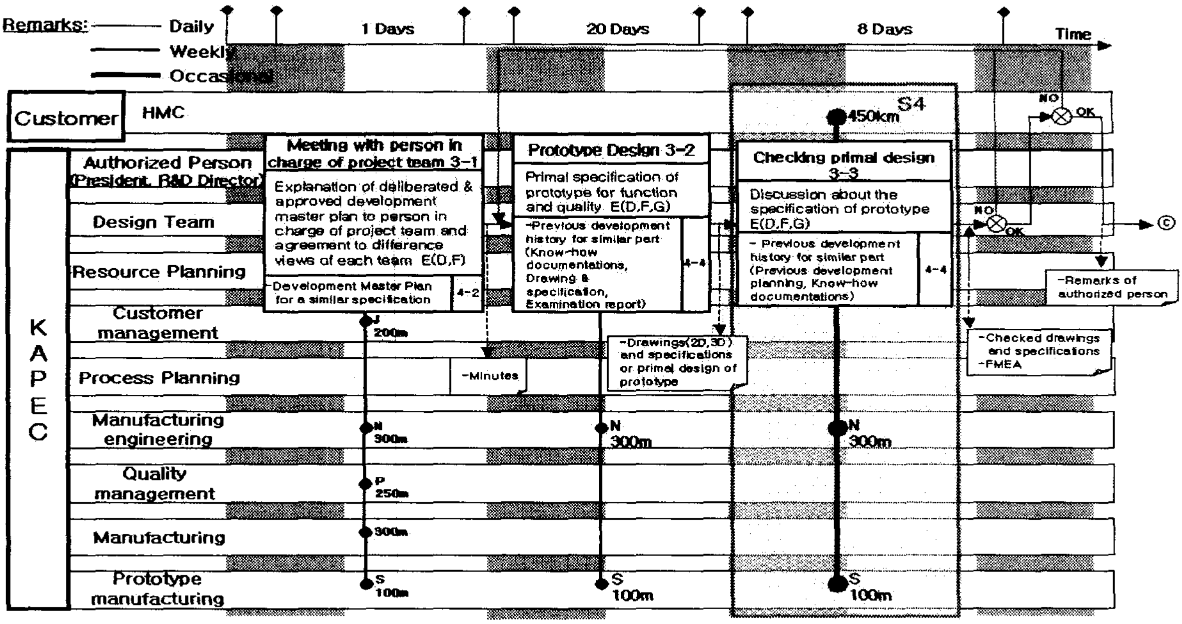

Fig. 2 Communication plan for product development

divided into five scenarios which describe all co-ordination processes in development projects(Table 1).

Communication scenario 1 describes directed distribution of information in the context of project transaction. Thus the information demand is defined. The sender assumes the information, which is needed by the receivers due to their activities or functions. A possible example is the passing of meta-information to other points in the development process. The problem is structured and the receiver knows how to use the information correctly. Therefore the solution method is regulated. In this case feedback to the information-sender does not take place.

Communication scenario 2 concerns a situation, which is characterized by a well structured task and low problem complexity. The initiator of further inquiry

Table 1 Definition of communication scenarios

feature	Scenario 1 anonymous data-transfer	Scenario 2 simple consultation	Scenario 3 complicated consultation	Scenario 4 common problem solution	Scenario 5 common problem definition
claimed interaction	none	auditory, visual	auditory, visual	auditory, visual, dataintegration	auditory, visual, dataintegration
problem	structured	structured	structured	semi-structured	unstructured
problem-complexity	low	low	middle	high	high
information demand	precise	precise	precise	dependent on the problem	indecisive
solution method	fixed	fixed	fixed	fixed or open	open

knows a form, in which the necessary information is indicated to the receiver. In this case, an auditory as well as visual interaction between involved parties is necessary. The receiver recognizes the information demand by means of inquiry and takes action subsequently.

Communication scenario 3 also describes a kind of consultation, but with higher problem complexity. This situation occurs, if the initiator of further inquiry does not know the form, in which the necessary information is presented to the receiver. In order to check the circumstances, at least auditory and visual interaction between the involved parties is necessary.

Communication scenario 4 concerns the solution of detailed problems. The task is only semi-structured and the problem complexity is high. This requires interaction between parties, which participate in the problem solution process. Apart from the auditory and visual interaction, common access to data is also necessary. As it concerns a detailed problem, the solution method is principally well known.

Communication scenario 5 describes the special case of common determination of problems. The cause of the problem is still unknown. Therefore, the task cannot be structured yet. The problem complexity is high. The information demand is indefinite, because it is not obvious, which information can be used as contribution to the solution of the problem. Therefore the solution method is still open.

With these five scenarios, it is possible to categorize any development processes in a standardized way. The existing development processes are reformed into the communication and coordination processes for suitable telecooperation system. During this step, some development processes are combined by specification of the communication and coordination relations. The result of this analysis is sufficient transparency about the exiting structure and procedure of product development and communication strategy for suitable telecooperation system.

3.2 Requirements of telecooperation

Following the determination of a communication strategy for the company, the specifications for the suitable telecooperation system have to be defined. The following list derived from the direct information of the company gives a review of the most important functionalities, which a suitable telecooperation system has to fulfill.

- Single- and multi-point connections (2-9 partners)
- Dynamic administration of communication partners
- Audio connection
- Video connection
- Shared whiteboard
- Dialogue-window/Chat-box
- Pointing-function
- File/Data transfer
- Common database
- Application sharing for CAD software Pro/Engineer and CATIA
- Application sharing for MS-Office
- Application sharing for PDM-data
- 2D / 3D-Visualisation
- Simultaneous use of different applications

First of all, it is necessary to find out a correlation between the coordination scenarios defined in the communication plan and the different communication means. The result of this process is the cognition of suitable communication means for the communication situation in the company. According to the analysis of the product development processes of the company in terms of communication and coordination, they mostly belong to the communication scenario 3 and 4 of the five communication scenarios expressed in table 1. From this result, a video-conference as well as a CAD conference is needed. If a video- or CAD conference takes place between partners at different locations, the number of participants defines the type of conference. In case of more than two partners at different locations, a multi-point conference and a central control server is required.

Other requirements result from the existing network at the company. The infrastructure of hardware and software in the company has to be taken into consideration. The interoperability of existing software must be warranted. The company requires a PC-based solution which is interoperable with the currently used PC-platform Windows-NT. The prevalent CAD software is Pro/Engineer from PTC. Only in a few cases CATIA is used. The interfaces to both CAD systems are desired. In order to share PDM data, an interface to the currently used PDM system should be possible. All the

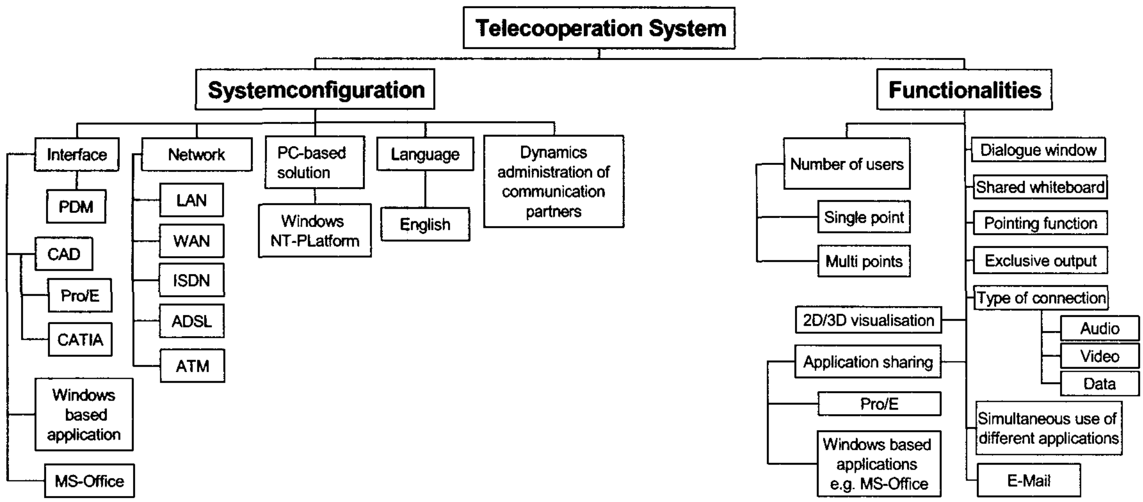

Fig. 3 Telecooperation model for the participated company

requirements for the company are illustrated in the Fig. 3.

4. Implementation of Telecooperation Systems

4.1 Concept of implementation of the systems

The claimed requirements for cooperative product development were derived from the communication plan. The information about possible strategies of communication and cooperation processes were also collected from that. Based on these requirements and information, three modules, i.e., product development guideline, TelEvIn and Portal, are developed to carry out product development processes effectively and efficiently.

The product development guideline is a web-based system to support the product development. It is designed to process the projects in the right way and to support the use of telecooperation systems within the product development processes. By creating company-specific standard processes and visualizing them within the product development guideline, the engineers have the possibility to use a well structured approach for their daily work. This leads to higher transparency within the company's processes as a precondition to develop products efficiently. In order to integrate telecooperation systems into the product development, different modules of the guideline support the work with telecooperation systems. For a standardized approach in product development processes, aspects of organization, information, process, methods and systems of the enterprise should be considered.

With internet technologies the guideline can integrate pure visualized process, supported methods and tools, process-specific classification of responsible and participating coworkers, standardization and administration of necessary information(documentation) into one comprehensive platform. The main structure of the guideline is given by the process-oriented visualization of the company-specific standard product development process. The product development guideline enables the user to choose different ways of visualization. The user has the possibility to work with a kind of listing of all the process-steps or with visualization in form of a process-chart.

The first level of a standard process is characterized by the main development phases such as development plan, design input, design output, examination of design verification, confirmation of validity and customer approval. Dependent on the complexity of the product development process, different sublevels can be defined to detail these phases(Fig. 4). The lowest level gives a detailed description of the activities to be performed within every single process. Here the engineer finds all the tasks he has to do in the correct sequence. Each task/activity is described in detail and further information is given.

In order to correctly process the activities for each task, supporting methods like FMEA(Failure Mode and Effect Analysis) and tools are deposited in the guideline. In order to ascertain the acceptance of methods and tools, examples for their appliance in individual steps can serve as guideline. The examples help the user to perform the tasks correctly. The documentation of results is supported by means of standardized project reports providing information and other forms of documentation. Thus the standardized form of documentation constitutes an initial step towards knowledge management in product development.

The product development guideline can be called up by means of a common internet browser. The modular structure allows successive adaptation and optimization of the system. The quasi-living tool thus constitutes a knowledge store which is easily accessible to any company staff member and cooperation partner, due to its platform independence. Besides the functionalities characterized as adjustable and interpretable according to company-specific requirements, the product development guideline also provides further individual functionalities.

The product development guideline is characterized by high flexibility and easy handling of changes of content. A special "content management function" supports the user of the software by modifying contents. Thus it is easy to change the standard process, the methods, examples, the organization chart etc.

The TelEvIn(Telecooperation system Evaluation and Integration) offers a support to select and integrate suitable collaborative method into development processes and to evaluate the economical efficiency of their implementation. The first module in the tool supports the selection of suitable communication medium after analyzing the present communications scenario. In an interactive process, the user defines the communication scenario based on the criteria such as data security, duration of communication, intensity of coordination etc. Additionally, the communication objects, including physical models, manual data, CAD data and digital data, have to be specified. For the selection, a correlation matrix between the defined

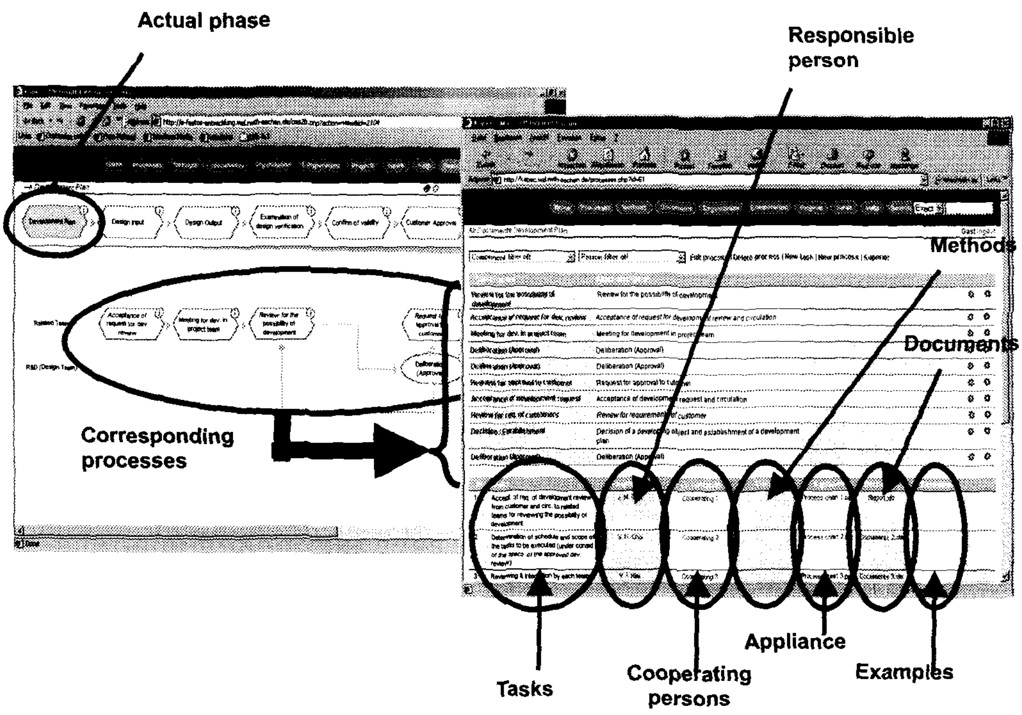

Fig. 4 Screenshot; product development guideline, sublevel of standard process

communication scenario and the communication media such as business trip, fax, video- and CAD- conference, e-mail and so on is developed. By help of this matrix, the suitable communication media are quantitatively and qualitatively evaluated and the user is able to decide which communication media should be taken into account for the present cooperative process. The second module supports the evaluation of the economy of the collaborative system. All necessary information for calculation should be specified by the user expenses. Cost parameters are personnel costs and infrastructure costs, software and hardware costs, ADSL costs etc. The independent variables are spatial distance of conference partners, conference duration and frequency and so on. The proper economic counting calculates possible savings of costs in consequence of substitution of business journeys by collaborative system.

The third additional tool is named Portal and supports the prioritization of development projects, which is applied in subsequent steps. In the first step the project concepts are registered and classified. Criteria suited to evaluate the projects, as e.g. market share and degree of innovation, are determined on the basis of company-specific features(Fig. 5). In any case the estimated development cost and capacity requirements are predetermined and calculated. Each project is characterized by means of this list of criteria. The different criteria are evaluated once again, now taking into account the relevance for the company. In the course of the following step towards standardization all the individual criteria are superimposed, i.e. a standardized final evaluation is calculated which accounts for every single project. Based on these numerical values an initial ranking of the projects can be determined. Often the development areas are not limited by lack of concepts or projects but rather by missing capacities and budgets.

For this reason, the further ranking of individual projects is performed in steps with a particular focus such as capacity and budget requirements or project type. The project list is "cut off" when the capacity required starts to exceed the capacity available and possibly enlarged by outside capacities.

Through the development of these modules most of the requirements shown in Fig. 2 were fulfilled. So the developed modules enable and support various kinds of product development activities. They were designed to capture and manage the elements of an optimal decision for carrying out product development process.

4.2 Integrated telecooperation platform

The result of this study is an integrated telecooperation platform that combines the commercial telecooperation software with the newly developed module which complies with customer-oriented functionalities. The developed product development guideline is the platform for the whole system. The teleconference platform includes functions for video as well as for CAD conferences. The authors decided to create an interface to Microsoft NetMeeting for video and audio conferences and PTC Pro/Collaborate for CAD conferences.

One important element of telecooperation is the video conferencing system. During a meeting, video as well as

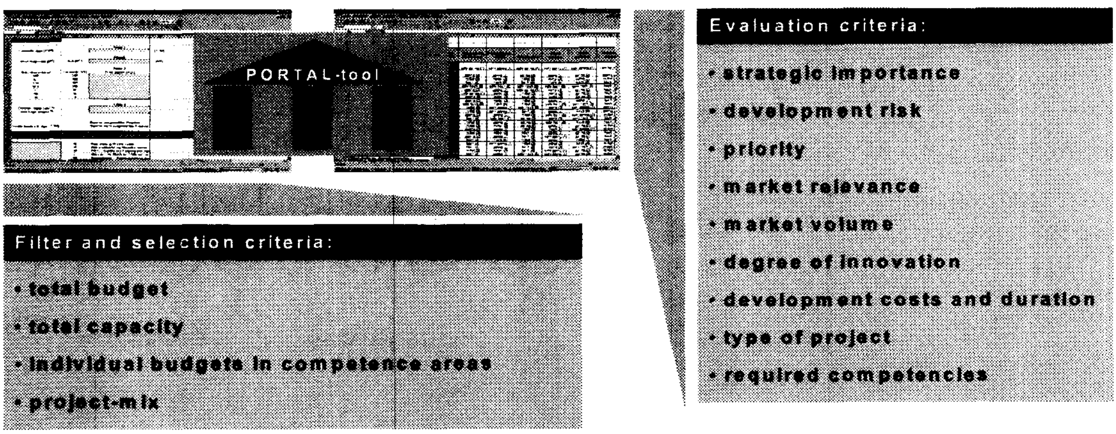

Fig. 5 Evaluation criteria for project prioritization

audio data are transferred so that the participants have the possibility to avail various communication forms such as speech, mimic and gesture. Microsoft NetMeeting was implemented as a typical video conferencing software in the telecooperation model. With this software it is also possible to realize application sharing with windows-based applications such as Microsoft Excel or Microsoft PowerPoint.

CAD conferences enable synchronous processing of joint data material. Main applications of data conferences are shared whiteboard and application sharing. Shared whiteboard is a kind of electronic notepad to which all conference participants have simultaneous access. Application sharing enables the interactive use of the same application for several persons, independent of their residence. Since CAD conferences with PTC Pro/Engineer, a CAD system of the participated company, are only possible with special PTC software, the authors decided to implement PTC Pro/Collaborate to realize the conferences and data transfer.

The various functions of Pro/Collaborate are shown in Fig. 6. The user can view and analyze information data in a variety of forms, ranking from office documents to 2D drawings and 3D CAD models via web-based visualization. Additionally, the user can exchange and modify different data formats(office documents, 2D/3D data etc.) with cooperation partners via web-based workspace and save the data in the Pro/Collaborate server, which is secured with a password(access authority) and a high encryption code.

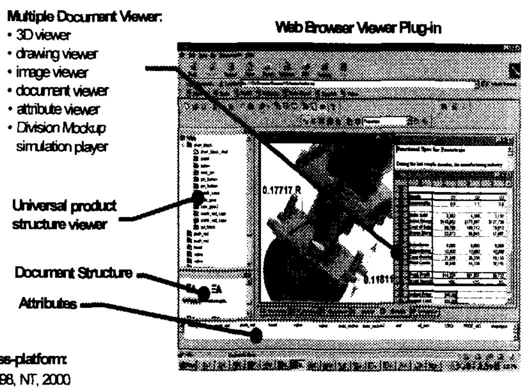

Fig. 6 Screenshot; Pro/Collaborate and its functions

To add, access and process data stored in a computer database, this platform may be implemented based on the functionality of ERP and PDM systems. For that, the platform for the collaborative system has to include functions for video as well as CAD conferences. With these functions, the user can make an application sharing in documents and 2D or 3D data with cooperation partners.

4.3 Implementation

Based on the framework described above, the proposed architecture was implemented on the development environment, which consists of Windows 2000, Apache and Dyna-PDM(Fig. 7). Windows 2000 was used as an operating system and Apache was selected for web service functionality under the consideration of security and access speed.

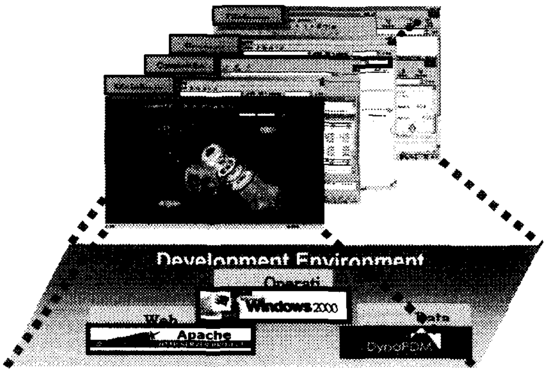

Fig. 7 Implementation of the collaborative engineering system

The PDM system, i.e., Dyna-PDM developed by a Korean company, is used for the collaboration processes in collaborative modules. Now, the modeling work for the integrity of product data and information is being proceeded to realize the interface between the PDM system and the modules.

The user interface is implemented by PHP which is a web-based API(Application Program Interface) language. By help of this, each development process is debugged and edited easily since it is formed with the independent template. Furthermore, the access authority to working scope is limited according to the account assigned to each user.

5. Conclusion

In order to optimize communication and coordination processes for collaborative design, a process-oriented specification of the corresponding interactions among the engineering partners was realized by product development processes with a communi- cation plan. The result was a communication strategy for the company with detailed information about communication medium required for an engineering process. From this result, the specifications for the suitable telecooperation system were defined. Based on the specifications, the modules were developed to carry out product development processes effectively and efficiently. In order to combine these modules and the additionally required customer-oriented functionalities, an integrated platform was developed to have a user-supporting environment for the application of telecooperation.

In order to verify the functionalities of the developed collaborative system as future research work, the system will be transferred for the test of its application in the automotive power train development process. A future joint work with experts in the development team and its cooperative teams is strongly needed to improve the system's capability.

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