MODELING GLOBAL PRODUCT DEVELOPMENT PROJECTS – THE IDEA OF THE PRODUCT COLLABORATION INFORMATION MODEL

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ABSTRACT

An empirical investigation in product development shows that re-engineering processes have influenced organizational structures and operational processes due to the rising number of international development cooperation. Companies are faced with new challenges which have arisen in so called global product development projects: They have no experience in organizing global teams, no instructions in ingeniously using information and communication technologies (ICTs) in virtual meetings and no idea which technology should be used to support global product development.
One key factor to cope partly with these challenges is to introduce standardized collaboration processes to get the information during the processes when it is needed. Another key factor is to analyze the organizational structures to manage global teams in a right way. However the core of product development is the three dimensional geometric model, which includes further information in form of metadata (following the idea of the integrated product model). This contribution aims to connect new organizational structures and collaboration communication processes in virtual work environments with a product collaboration information model. This three dimensional geometric model should integrate vital information for such global product development projects.
This contribution will take into account the changes in organizational structures and operational processes and find out the role of the product collaboration information model in global product development projects. Furthermore this document describes an approach for modeling these three components which on the one hand should be part of the development process and on the other hand should give an advice for managing global product development projects.

INTRODUCTION

In the globalized economy, organizational structures and methods used in product development have changed. Companies and organizations have responded by re-engineering involved processes, increasing the use of information and communication technologies. But why has product development gone global? Beside the three factors of the magic triangle to make more benefit, to reduce development time and to produce higher qualities, a lot of advantages for the global product development processes can be achieved. Customer's requirements can be integrated earlier in the product development process. An engineer located on the sales market can understand costumers' needs and feelings in a better way than located far away. Today it is essential for companies to be represented on global market to be competitive. Furthermore in global product development worldwide dispersed engineering expertise can be combined on one project. In global dispersed projects experts are able to work on several projects on the same time without leaving his location.
The partitioning and/or distribution of development and production in global working environment have been taken place since years. In contrast to the distribution of development partitioning is relatively new. Worldwide networked locations are the assumption for applying new information and communication technologies (ICTs). Web-based engineering software makes it possible to modularize the product development process in design, simulation, calculation etc. Companies as well as engineers are faced with the new working situation.

GLOBAL PRODUCT DEVELOPMENT PROJECTS

An empirical investigation is dedicated to show the different streams in global industrial product development projects. The results are needed to identify and specify the scenarios for modeling global product development projects and to figure out the information, which is vital for carrying out dispersed development processes. Interviews with experts in global industrial projects show tendencies in global product development and reasons for going global.

Streams in global product development projects

One of the reasons for re-engineering the product development processes is based on new organizational strategies. The fusion of companies forces organizations to restructure mostly redundant development departments to reduce development costs. Development departments across the globe compete one with another to survive. The lack of trust in this kind of global development projects leads to less transparency in knowledge, information and data sharing.
Original equipment manufacturers (OEMs) often mutually cooperate to become more competitive. The idea to share development expertise should lead to new innovations and should also reduce development expenses. In this case the cooperation partners are often at the same knowledge and authorization level.

To reduce costs and to compensate for the less number of German engineers, more and more product development projects are outsourced. The outsourced projects are mostly closed development projects of components or technical systems. The development results are adapted in intersections in firm defined assembly spaces. In this case the hierarchical structure is clearly defined: the employer makes the conditions for the development process including milestones and clarifies the expected development results. The customer is bounded to the employer's requirements. Managing teams across the globe is challenging, particularly working across different time zones.
One tendency is the vision to work 24 hours 7 days a week on one design project across different time zones. Realizing the so called "follow the sun"- project should reduce development costs [Gier-01]. In this case design and product development knowledge have to be formalized.

RE-ORGANIZATION OF PRODUCT DEVELOPMENT

The different streams in global product development need different organizational structures and operational processes, appropriate strategies in managing global teams and suitable technologies for communication. In addition to, the product development works with highly sensitive development data. The different kinds of global product development projects impact the authorization spaces of development data.

Organizational structures

Global product development is always organized in projects, which are arranged in team work. These global development projects are usually embedded in standard organization structures. Therefore the project organization can vary between staff project organization, pure project organization, or matrix project organization. [HeLe-05]
Global product development projects are organized analog to virtual organizations. The definition of virtual organizations as cooperation is the fusion of companies to combine worldwide distributed expertise in a definitive time span to make benefit and to be competitive in the global market. Characterizing for virtual organizations is that these kinds of projects are often arranged without investments [BuWW-03] [Hans-06] [Inno-08]. [GPFe-08] and deal with engineering collaboration in virtual organizations. In Figure 1 the virtual organizations are integrated in the classical organization models [PiRW-03] [Reic-98]. Realizing virtual organizations is driven by innovative developments of ICTs.

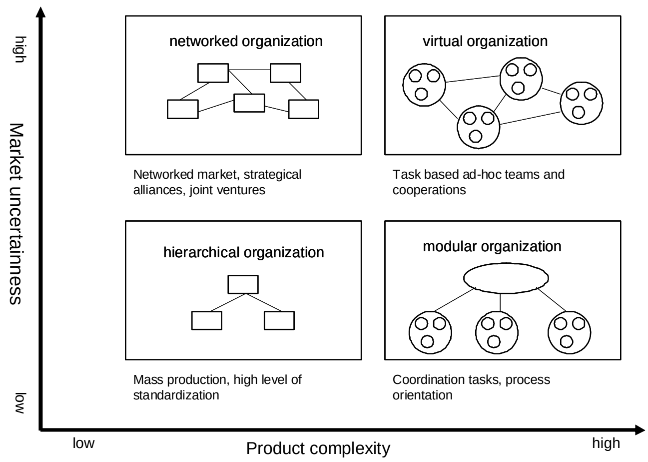

Figure 1**:** Organization Maturity

Fact is that cooperation becomes more complex in dispersed interdisciplinary team work. The effort to meet the requirements on cooperation arises [StLe-01]. Cooperation means the efficiently work-sharing to achieve better working results between dispersed employers, organization divisions or organizations [Schm97]. Cooperation in context of computer supported cooperative work technology is called tele-cooperation [Remö00].

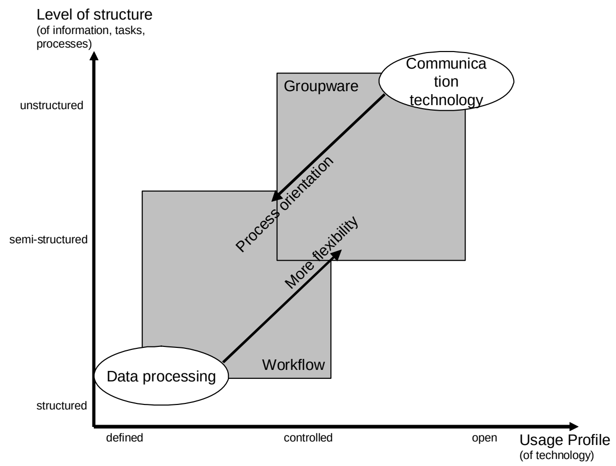

Figure 2: The Application of Technology in Global Product Development

CSCW-Technologies

"Computer Supported Cooperative Work (CSCW) is a generic term which combines the way people work in groups with the enabling technologies of computer networking and associated hardware, software, services, and techniques" as outlined by Wilson in [Ande-07]. CSCW-technologies resolve the limitation of time and space in collaboration, thus team meetings can take place anywhere and anytime.
A classification of CSCW-technologies regarding time and space in the CSCW-Matrix was developed by Johansen in 1988 [Joha-88]. Burger [Burg-97] integrated the classification of CSCW-technologies in the 3C-Model (communication, coordination and cooperation) of Teufel.
Tools providing the possibility to communicate can be subdivided into tools enabling asynchronous and synchronous communication. Communication tools can be used individually or can be connected with further Groupware systems. Coordination tools should enable an

unhindered and efficient flow of work in collaboration. Coordination can be processed by the project members themselves by using the aforementioned communication tools or by special workflow management systems. Workflows should advance the project's progress in coordinating activities and resources of team members. Systems for coordination also enable access to development data and allow for easier administration of the project information. Cooperation tools should fulfill different requirements depending on the project phase. Therefore a number of systems are needed with various applications, such as permitting synchronous as well as asynchronous working on common documents.
E-Collaboration Systems, Groupware Systems and web based Conference Systems integrate different aforementioned CSCW-applications for communication, cooperation and coordination to support various scenarios. Web based Conference Systems have been established for applying synchronous virtual meetings, whereas E-Collaboration Systems are information systems, which professionally support data and information exchange by included workflow management and life cycle functions.

Product development technologies

In product development special software tools are developed to support the requirements of this highly information sensitive working sector. To manage information product data management systems (PDM-Systems) are developed. The product data management functions are implemented in order to take on different data management tasks, like for example user management, product structure management, configuration management, version management, release and change management as well as project management. In summary PDM-Systems store and administrate different kinds of data as well as permit the access to data. To enable collaboration between widely distributed engineering centers special internet based collaboration platforms are integrated.
In current collaboration platforms more and more CSCW-applications are integrated. Collaboration platforms are entitled to act as a connection point for distributed developers where interactions for developing products should take place. Recently integrated social software functionalities should trigger developers to share their information and knowledge. These new functionalities enable a new kind of thinking and working structures in product development. A software investigation shows that development projects aren't sufficiently supported by cooperation functions in engineering tools [AVRo-08]. The implementation of social software functionalities is one step towards making it possible for dispersed developers to cooperate.
Assumption for choosing suitable ICT and engineering tools in distributed projects is to analyze cooperation connections in cooperation. Cooperation is based on communication. The right choice of ICTs is named as the critical success factor in [SSUn-01].

Global Teams

In the globalized economy more and more companies decide to develop products in global fields. Global teams are both geographically dispersed and culturally diverse. They work together in virtual working environment. Communication only takes place supported by technology. The team members working together networked seldom know each other personally. Furthermore, the multinational global teams are mostly embedded in different organizational structures.
The team mates live in different time zones. On the one hand product development in multicultural field can evoke synergy effects. "Such teams have the potential to provide companies with a more practiced and economical way to develop new products and services."[DKBa-01] It is said that products developed in intercultural teams are more innovative and perform better than conventionally developed products. But on the other hand research suggests, however, that these companies are struggling to deal with the myriad problems arising from the use of such global teams [BAHs-97]; [BGMR-98]; [DoKa-96]; [DKGr-99]. Much of this struggle seems to stem from the nature of global teams.
The challenges can be subdivided in challenges for personal interaction in global teams and for managing them. The team members have to cope with different languages and have a different set of cultural belief in their team. These often lead to misunderstandings and more room for interpretation in discussions and decision making. Different countries have a different focus on skills, mirrored by education and working attitude of the team mates. One key difference is the different approach to work in various companies. Cooperation companies have to combine different methods and processes which are often stem from different historical backgrounds.
Managing global teams is the most difficult issue as many investigations are dedicated. In these investigations success or failure are attributed by the management of global projects. In global distributed working environment it is difficult for an engineer to get the right information as soon as it is needed. The circulation of information and knowledge has an important role in product development process. In addition to cooperation between companies there is often non-uniform technical support. But last but not least these aspects make it complicated for project managers to build a common project goal and task strategy as well as cohesion between the team members.
The following table lists the management tasks investigated by a research group at a Northeastern University in Boston, Massachusetts [BMDo-06]. The investigation was an empirical study in 300 companies over ten years.

Challenge	Steps Required to Meet the Challenge
No. 1—Members who speak different native languages.	• Send critical documents and material to all team members. • Allow time for members to digest and respond to information. • Develop and distribute written records of all meetings. • Educate team members about challenges of communication in such a team. • Work with members to create common terminology with clear definitions.
No. 2—Members with different cultural backgrounds.	• Be aware of and sensitive to cultural diversity. • Possess strong interpersonal/communication skills. • Learn about cultures of individual team members. • Offer cultural diversity training. • Engage team members in discussions about their respective cultures. • Understand that face-to-face interaction is critical in some cultures.
No. 3—Members living/working in multiple countries.	• Hold a face-to-face meeting at beginning of project. • Hold project progress meetings throughout project. • Send information and materials prior to each meeting. • Keep track of team member participation during meetings. • Engage all members during team meetings. • Summarize each meeting and the decisions made and distribute to all team members for feedback. • Vary timing of meetings to accommodate different time zones.
No. 4—Members from different companies.	• Select team members with strong personal networks. • Provide time for team members to get to know one another. • Help team members identify mutual interests and needs. • Have team members work together and interact socially. • Facilitate continual interaction amongst team members.

Tabelle 3: Herausforderungen und Vorgehensweise für Managers

Figure 3: Challenges in Global Teams

CHANGING PROCESSES – OPERATIONAL STRUCTURE OF GLOBAL PRODUCT DEVELOPMENT

Processes generally describe sequences of activities within an enterprise. They are actually carried out within the framework of operational project management [ProS-07]. In cross-enterprise networks lots of processes have been changed. This paragraph will take into account the changes in personal interaction in global product development.

Basically all communication processes have changed in global product development projects. Groupware as well as special communication tools enables the synchronous and asynchronous communication in teams across the globe. The choice of communication tools depend on the richness of the communication that means how important the transferred information for the results of the task is. In distributed team work, communication is more focused on the project tasks because as aforementioned the team mates often do not know each other. The social component of communication is often missing. On the one hand this aspect advances the project process, but on the other hand trust plays an important role in the project's success.

The disadvantages of CSCW-technology use is that team members are confronted by a flow of redundant information. Due to working in different time zones decisions can not make ad hoc. asynchronous CSCW-technology compensate for this time span in distributed projects across the globe. [SHSS-97]

Challenging processes in global product development are the processes of decision making and problem solving in virtual working environment. Decision making is difficult at all but global teams are faced with the problem that they don't know each other and therefore cannot estimate the knowledge and information level of the team mates. [Auer-98] describes the key factors influencing decision making in groups, including the information level as well as sociological and socio-cultural issues. In product development decision making basically takes place based on facts, like costs, security and collisions between parts. Thus global meetings for decision making should be well prepared. First of all the actors need preparation in tele-cooperation systems, for example the way how to deal with videoconference systems. Subjects, respondents and actions should be well defined before starting a global virtual meeting.

In global product development an approach has to be found to make design reviews. Relatively easy communication ways can become very complex in virtual working environments.

PML – AN OBJECT ORIENTED PROCESS MODELING LANGUAGE

PML, the Process Modeling Language, has been introduced in [AnMR-08], [AnRR-08], and [AnRa-08]. This chapter gives a short overview about the basic concepts and introduces a new event model for PML, which enables integral modeling of organizations.

PML has been derived mathematically from UML in an abstract way to get a process object from an information object [AnMR-08]. This enables PML to use most of the UML notations and all of the object oriented modeling concepts [Oest-06]. The main idea behind this technique is that a process is a generic construct, which is modularizeable, exchangeable, extendable and very flexible. Thus a process is highly reusable and does not have to be (re-)modeled for every new product – or say project. This leads to the next concept: a process is a generic description of implementable workflows and can be instantiated. As soon as a process is instantiated it gets a project and the process parameters, which have been defined in a generic way, will now be specified with real world data.

process
methods (event list): event
resources

Figure 4**:** PML Process Class Diagram

Figure 4 shows the principal PML process class diagram. The first field holds the name of the modeled process, which should be meaningful for clearness of the process model. The second field lists all the methods ("synonyms": activity, operation) that are members of this process. Those methods can be other processes, modeled as aggregations, or atomic activities. The last field lists the resources needed for this process, like machines, algorithms, employees etc.

The above mentioned aggregation of methods leads to one of the main concepts of PML, or object oriented modeling in general. PML supports, as UML does, inheritance, which leads to generalization und specialization, and three types of aggregations: association, aggregation and composition. Those concepts support hierarchical modeling of processes, which is necessary for flexibility, extendibility and reusability. Inheritance means that processes can be grouped by using a common super class, which defines common methods or resources or at least a common kind of process. E.g. the processes drilling, milling, and turning can be grouped using the super class chipping. Associations, aggregations, and compositions have the same meaning as used in UML and support hierarchical structures particularly regarding to modularization and extension of the process model.

In Figure 4 the central field lists the methods. A method can get a list of events as parameters and may return an event as result. This basically is the new event model introduced in PML. The importance of this notation is quite obvious. A method starts running as soon as all events from the parameter list have appeared. E.g. a change process listens for a change request and starts as soon as a change request appears. If more than one condition has to be fulfilled the event list holds more than one event and all have to become true to trigger the start of the event. On the other side, a method may return an event, e.g. to express that its runtime has elapsed, certain information has been gathered etc.

event
information list

Figure 5: PML Event

To get fine grained event models a new element is introduced, which is shown in Figure 5. An event class is similar to a UML or PML class, except that it only contains 2 fields: a name field and a information list field. The name field again defines the name of the event and should have a unique identifier. The information list holds information or data, which results from the runtime of the process and may be needed for the following processes. Information can be calculation results, design data, a decision etc. Using unique identifiers for events and using events as parameters and return values of methods the process sequence is explicit and controllable. Hence activity diagrams or sequence diagrams are redundant and thus not needed, but optional.

Events, as they are classes, can be inherited to use object oriented concepts for event modeling. This may be helpful for example to group events and listen for certain types of events. Imagine a process where every activity has to be logged, so there would be a process that listens to every occurring event to log the success or failure of an activity.

3 VIEWS TO AN ORGANIZATION MODEL

Companies can be described to be built up on three planes: an organizational plane, a data plane, and a process plane.

The organizational plane is well structured and describes the company's resources. It can be built up as a hierarchical structure, a matrix structure, or a modular structure, see Figure 1. However, the organizational plane describes business units, divisions and departments, employees and their membership to departments, projects, or groups, and finally the physical resources of a company.

The data plane defines the product data and the product structure. The product data not only consists of geometric data, production information, simulation results, etc., but also includes meeting records, and thus minutes from the decisions. Product data is typically stored and administrated by product data management (PDM) systems.

The third plane is the process plane. Particularly for complex products the development will not start before the process definition has been completed. Hence the process plane is the dominating plane of a company's organization.

Figure 6 shows the 3 planes in a principal way. It is important to note, that the 3 planes are orthogonal, which basically means they are independent from each other, but are linked together – the dominating plane for the interdependence is the process plane. If a company restructures their organizational or process plane, they may introduce a certain amount of dependencies between the planes, but they also may outsource several processes or include external organizational units to fulfill the process requirements. This clarifies the orthogonality of the three planes.

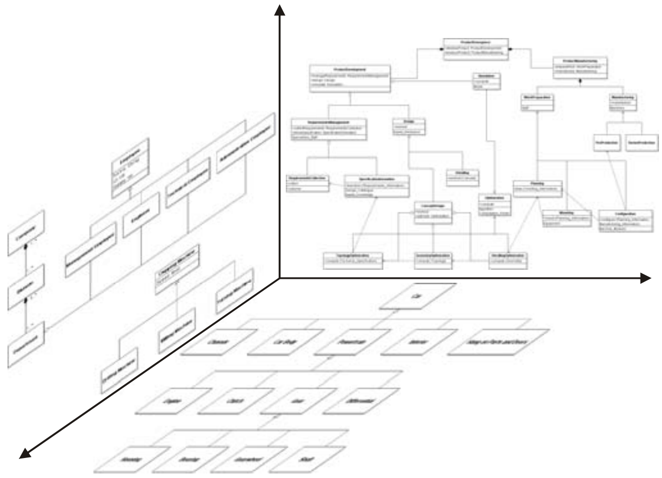

Figure 6: 3-Planes Organizational Structure

Using UML and PML the 3-plane organization model can be implemented in an easy, consistent, uniform, and object oriented way. Although the data model and the organization model do not necessarily have to be modeled with UML, PML is designed to integrate links to UML descriptions of the 2 orthogonal planes.

The PML resources work best if they are UML classes from the organization plane. This leads to high integrity of the process model. In the above chapter event classes have been introduced with information lists. They are designed to be UML classes from the data plane. Thus every process information is storable and accessible in the data plane, which shows the fundamental idea of the new event model.

Also supplier integration is easy and powerful using PML, or more precise the UML / PML 3 plane organization model. Supplier integration then is just specialization of the process data, and organization model.

PRODUCT COLLABORATION INFORMATION MODEL

In this chapter the idea of the product collaboration information model is described. The product collaboration information model (PCI-Model) is based on a three dimensional geometric model with further information for collaboration. The model is built on three information levels: organization and process information integrated in a current geometric state recording of the developed product.

The geometric state records are modeled in the data plane and hold links to the organizational plane. Thus the corresponding responsibilities can be addressed in the data plane. The update of the data is driven by the process model and generates events, which may start new processes, e.g. change requests. The PCI Model fits into the 3-plane organization model and is designed to support global cooperation processes.

In this paper the idea of the PCI-Model is shown by the example of a decision making process. Research has to be done for extending the PCI model on further processes, for example design reviews and change management.

The PCI-Model should represent the status of the product model including all states of changes and releases. Changes and releases are a result of a decision making process. Annotations in form of dialog maps represent the process which has lead to a decision. Who argued why? Furthermore

the decision making process includes different organizational structure information, for instance who was responsible for the change, which team worked at the model and when as well which organization locations where included.
Including an evaluation about the used technology for realizing the decision making process, the PCI-Model gives an advice for further virtual meetings.
In global product development it is important to include information about the process as well as the organization. The PCI-Model should be used for long-term archiving where all results should be included as lessons learned. This can be basis for further knowledge management in global working environments.

CONCLUSION

In this paper a new event model for PML, the Process Modeling Language, has been introduced and it has been shown, how this event model fits into the object oriented design of PML. To model all relevant data, structure and processes a 3-plane organization model has been introduced and the orthogonality of the three planes has been shown. Furthermore the dominant role of the process plane has been shown and the interdependency to the data plane and the organizational plane. With the introduction of the Product Collaboration Information model (PCI) the interdependency between data and resources has been shown and why they are needed to support a global distributed collaboration project.
In future works the details of the PCI model have to be addressed to get a fine grained description of needed data for certain levels of collaboration. The PCI model will be modeled with UML and be linked to a generic PML model to show why PCI is needed to support global distributed cooperation and which levels can be addressed.

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