# An Approach To Use Semantic Annotations In Global Product Development To Bridge The Gap In Interdisciplinary And Intercultural Communication

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**ABSTRACT**

In the globalized economy more and more companies practice worldwide distributed engineering. Local division and global distribution of production and development activities demand tools to support communication processes. In this paper an approach is introduced that enables everyone who is involved in the development of a product to create and modify semantic annotations in 3D-CAD systems and 3D-PDF-based communication processes. Thus current implemented annotation technology in 3D-CAD-Systems is enhanced. These annotations are linked to a semantic media wiki which contains additional information or personal data about the respective authors. This allows the creation of a social network in globally distributed product development. The approach dedicates a paradigm shift in product development by using low-structured methods in relation with traditional 3D-design spaces.

**Keywords:** Global Product Development, Communication, Semantic Annotation

## 1. INTRODUCTION

Global product development and off-site or globally dispersed production facilities, respectively, are strategies for companies to compete in global markets.

Global Product development is maximizing financial and operational productivity of the product development process by global dispersion of development activities. These development activities comprise marketing activities to identify customer needs, engineering activities like design and simulation, production planning and after sales processes such as maintenance and change management. Production in low-cost countries increases the profit of companies, even though protectionism forces them to produce a certain percentage of a product in the target country itself. Due to the consequent standardization of development processes, production lines and testing procedures, products can be developed and produced anywhere and anytime merely depending on the location's capacity.

Moreover organizations concentrate on their core competences and thus global competence centers are established. To extend their market position companies ally in joint-ventures and cross-company co-operations.

TROXLER et al. confirmed that the new organization of product development has increased the communication as well as the cooperation effort [1]. SCHLEIDT empirically investigated the changing working circumstances in engineering. SCHLEIDT [2] has shown that contemporary global engineering is increasing moving towards information and communication technology (ICT) supported communication orientated approaches (Figure 1).

The use of modern information and communication technology (ICT) and the modularization of product development [3] have enabled the global engineering concept. Yet the product development and generation process can only be successful by assuring information transfer across locations. Today, information is mostly transferred by communication within the (dispersed) teams. Unhindered knowledge and information sharing is the key to success in global teamwork.

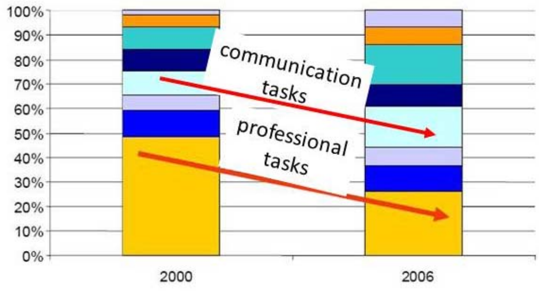


**Figure 1 – Management Activities**

Already in 1988, SOUNDER investigated the influence of communication quality on the success of the product development projects. As per figure 2, the success of product development highly depends on the communication quality.

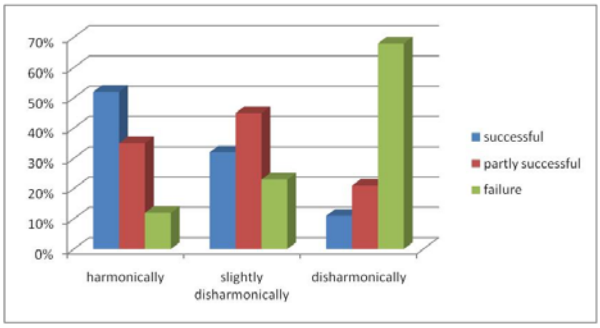


**Figure 2 – Communication Quality and Project Success**

To complicate matters, in global dispersed teamwork, team members hardly know each other and communication predominately takes place via media (ICT) [4]. Additionally teams are more and more intercultural and interdisciplinary. The challenge is to assure a common ground and to overturn the virtuality in dispersed teams. Technology for sharing important development data is sufficiently introduced in the product generation process but the challenges emerging from communicating via media have not been solved yet.

The big advantage in product development as well as in product generation the possibility of visualizing the communication's subject. This paper addresses to integrate product representation and presentation into the communication process to share information and to assure a common ground in globally distributed teamwork. The applied technique is supposed to cover platform independence and to include different viewpoints of expertise on products' presentation within the communication process.

## 2. COMMUNICATION VIA ICT

Communication is the process of transferring information from one entity to another. The receiver decodes the message and sends a feedback to the sender. All forms of communication require a sender, a message, and a receiver [5]. In global working environment communication generally takes place via communication technology. Research in computer assisted communication (CAC) showed that communication via media nearly score as high as conventional communication regarding efficiency and effectiveness. Especially written communication helps to bridge language barriers of dispersed teams by giving the team colleague time to decode the message [6]. WINTERMANTEL [7] describes essential factors of CAC:

- **Cues-filtered out - Theory:** Due to filtering social amenities, CAC is less personal and thus more task-orientated.

- **Social presence - Theory:** The interaction and intensity within communication depends on the number of transferring communication channels.

- **Social information processing - Theory**: The distance to the communication partner is counterbalanced by social revealing attitudes.

- **Messaging-threshold Theory**: The barrier to send negative messages is higher in CAC than in conventional face-to-face conversation.

Some of the highlighted negative aspects of CAC are the time-intensity and the difficulties within the decision-making process.

## 3. SEAMLESS PROCESS-CHAIN

Nowadays the technical drawing is the most important medium to communicate product development information in companies. The technical drawing transports information between the product development phases, for example manufacturing information and tolerances. In the near future the conventional process should be replaced by a seamless process-chain without drawings and media discontinuities. The vision is that, from the beginning of the concept phase up to the point of product manufacturing, the digital model will become the basis. The approach of the integrated product model allows the digital geometric model to meet the requirements resulting from the entire product life cycle. The advantage is that media discontinuity is avoided [8].

Consequently the most important product information has to be displayed in the 3D-CAD-model. To realize this seamless process chain, "Product Manufacturing Information" (PMI)-technology has been established. Current CAD-Systems integrate functions to create and administrate PMIs in the 3D-CAD-model (e.g. Pro/E CATIA, UGS NX, SolidWorks etc.). PMIs are strategically seen as a long term project to attach and store relevant product and manufacturing information in the 3D-CAD-model. The aim of this approach is to consolidate attributes of product definition, dimensioning and tolerances to organize them in the CAD environment. Standardizations (ISO/FDIS 16792 [9], DIN 32869-2 [10] und VDA 4953 [11]) focus on the structuring in CAD-models and on guaranteein PMI's consistency.

## 4. CONCEPT: 3D- COMMUNICATION PROCESS

### Introduction

Collaborative Engineering addresses all technical and organizational activities between globally distributed business units, regarding conjoint development processes [12]. The main emphasis is to assure the collaboration of all involved teams and all activities, regarding the development of the product. The application of Simultaneous Engineering [13] and Concurrent

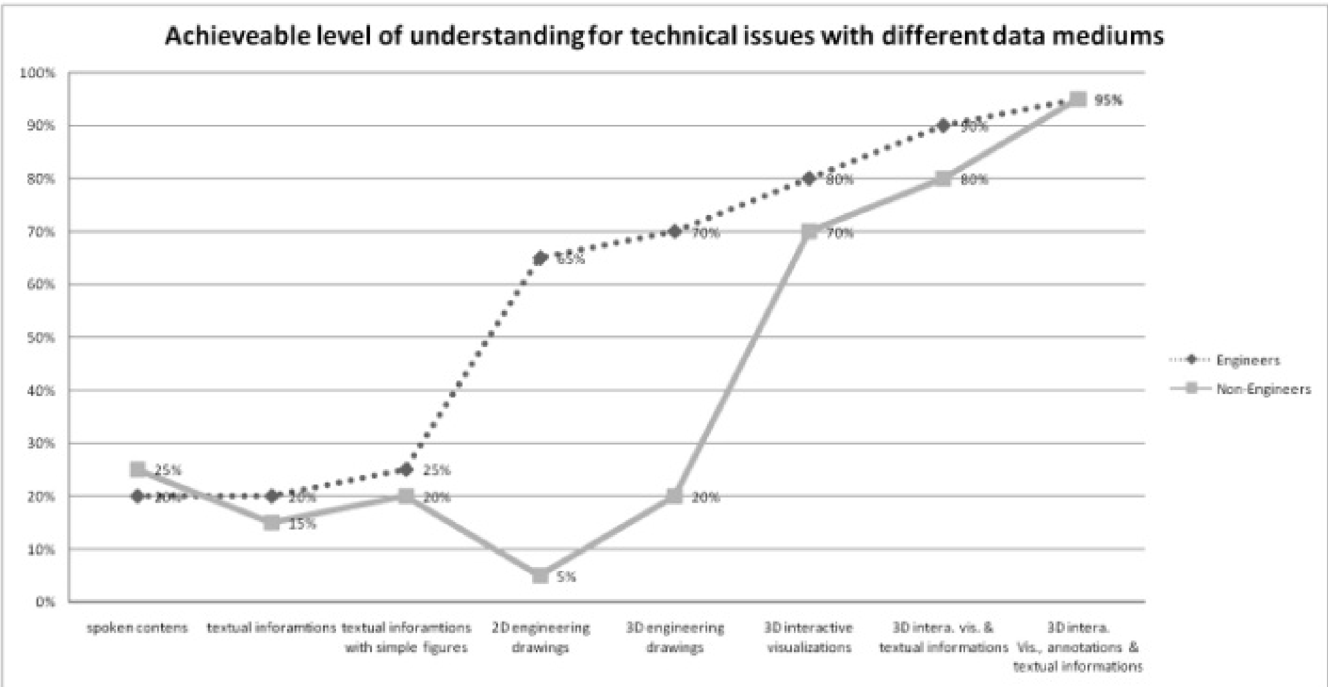


**Figure 3- Level of Understanding**

Design [14] concepts meet these challenges in a methodical way.

As Figure 3 illustrates, the level of understanding for technical matters significantly increases through the use of visual impressions of the product and is boosted by adding user interactivity and annotations [15]. A study by ANDERL et al. [16] revealed that enhanced 3D-representations are instantly understood by about 90% of the engineers compared to only 10-30% for plain texts or 2D mechanical drawings. 3D-representations also enable people with a non-technical background to gain the same level of understanding for a complex problem as engineers do (common ground).

The methodology to explain technical issues by interactive 3D-models helps globally distributed divisions to gain larger cohesion and to establish more efficient communication processes. Communication processes with the ability of transferring information also via 3D-representations enable collaborative engineering to work significantly more efficient, as technical issues and problems can be demonstrated much more vividly and are easy to understand without the need for special terminologies if 3D-models are used as interactive contents [16].

**Process integration and general approach**

Designers in product development annotate the 3D-model within their common 3D-CAD-environment. The annotation, e.g. a question or important information, should be transferred to the colleagues abroad. Working within the 3D-environment is important for not disturbing designer's working process.

The annotation takes a special role in this approach. It has to be completed by several user-defined attributes, like author`s name, date, content of the annotation and web-links, e.g. to product development data or other web-pages. Thus, the paper presents a concept to implement a semantic annotation in CAD environments.

For a distributed working environment and in interdisciplinary team work different points of view must become visible in communication. Because of heterogeneous software systems and different file formats, the use of compressed model data "the so called lightweight representation of the 3D-geometry" [17] makes sense. CAD files are too resource-heavy for the use in global distributed applications. Enhanced product representation is needed [17]. Thus, compressed CAD-data involve approximated or simplified geometric representations that can be processed in further CAx-applications.

Therefore the designer converts the native 3D-CAD-data into a platform independent format and sends it to his colleagues. The distribution of the data can be done either via email or via workflow systems. Another possibility is to use common server technology.

Problems in global distributed working environment arise in anonymity within teamwork. A social network database stores user profiles and context information about organizational and project structures. In this web-based data pool one can identify experts and competencies. Herein, the additional stored meta-data in annotations are useful. The semantic social network database uses the same annotated items (by tagging) to build a connection between the annotation in 3D-Geometry and the user profiles within the web-based database. Therefore annotations link both information pools.

The so called context information platform has three main tasks:

- Identification of experts to which questions or information can be distributed,
- support of the decision making process and
- help in recapitulation of decisions' context for the application in further projects as lessons learnt.

The second point means that in this platform naturally established communication paths between dispersed teammates become visible. The advantage is that "naturally" emergent communication networks can be recapitulated in this kind of social network functionality.

The colleague abroad opens the converted model in a platform independent document. Herein he has the possibility to comment on the annotation or to answer and discuss the posed question. Afterwards the data is sent back or published on the document exchange server.

The technical challenge is to transfer the commentaries back to the native 3D-CAD-model to the right position to avoid media discontinuity and the consistent use of the "same" semantic annotations in the 3D-CAD-model as well as on the web-based platform.

This concept includes the following important components: The Product Communication Model, the 3D-geometry of the product as the annotation "carrier" and the web-based social network platform representing user profiles and global organizational structures of the development projects.

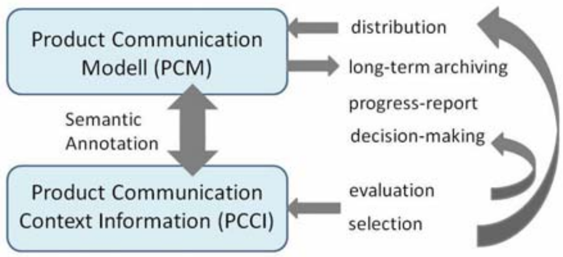


**Figure 4 - Concept**

The key factor is the semantic annotation. In this context a semantic annotation is understood as a formally structured annotation including meta-data (name of the author, date, link to external development data etc.). The meta-data are connected to an additional context information space where user profiles as well as project data are stored. Thus the annotation can be assigned to a definite project status afterwards. One problem of working in a virtual environment is that the team members hardly know each other. By the means of the semantic annotation one can get an idea of the dispersed teammate, his competences and project experience, his cultural background and his position in the organization.

The annotation should trigger a conversation about issues. Issues can emerge due to technical problems as well as economical, environmental or project management difficulties. On the basis of the social context information the commentary to the first annotation can be evaluated and after that a well-grounded decision made.

**Advantages**

The authors assume that the introduced concept holds the following advantages:

- The visualization of the object under discussion helps to bridge language and accommodation barriers in globally dispersed as well as in interdisciplinary teamwork. Communication by displaying the product between different cultures and disciplines helps to build a common ground in team work.
- The possibility to directly annotate the model in a CAD-environment does not disturb engineers` working process.

- The system independency allows a flexible application during the working process of engineers. The process can be adopted to planned/unplanned and synchronous (in connection with application sharing)/asynchronous discussions. The subject of the discussions is not topically limited.
- This concept includes Web 2.0 technology to build a worldwide distributed social network system. The web-technology offers permanent access for all participants. In a global working environment team members hardly know each other. Modern information and communication technology helps integrating more social factors into global distributed work. Especially the Web 2.0 philosophy encourages people to bring in their own ideas. The outcome shows social networks and is emerging an expert community.
- The compressed 3D-data can be performed easily. Data-exchange and visualization can be done rapidly. This assures an easy handling and performance of 3D-CAD-data.
- The reduction of the native 3D-data protects them from misuse in co-operations.
- According to the approach of the integrated product model all information is permanently documented and stored within the 3D-CAD-model. This can be used to reconstruct the discussions and decisions, which can be useful for further projects. The conversation about an issue is documented and associated with the geometry and can therefore be used in further projects and processes as lessons learned or to sum up the decisions made.
- Communication by displaying the product helps to build a common ground in team work between different cultures and disciplines.

## 5. IMPLEMENTATION

Figure 5 shows the implementation scheme of the introduced concept. The concept is realized by using the following systems: CATIA V5 (as 3D-CAD-System), Acrobat 3D (as format independent platform) and MediaWiki (as web2.0 technology). XML is used for data exchange.

### CATIA

CATIA (Computer Aided Three-Dimensional Interactive Application) has been developed by Dassault Systems and distributed by IBM & partners [18].

Currently, most CAD systems implement hybrid-modeling strategies to combine the advantages of the various approaches, as does CATIA. The primary structure consists of Constructive Solid Geometry (CSG)-structure (generative solid modeler) which describes the complete model in the part structure. The secondary structure includes the boundary representation (B-Rep) that represents the shapes by their external boundaries (a collection of faces, edges and vertices) and freeform surface modeling to represent parts with complex surfaces [17].

This implementation is done within the CATIA workbench „*Functional Tolerancing & Annotation*“ (*FT&A*).

### PDF

The Portable Document Format (PDF), which was developed in 1992 as a derivative of the Postscript-Format, was extended by numerous new functionalities regarding the visualization of 3D-geometries in early 2005. Users viewing the document can easily rotate, pan, tilt and zoom the 3D-object as well as trigger stored animations of the 3D-object. Aside from the functions, PDFs were enhanced for a combination of both, graphical and textual information in one document.

PDF offers the following basic features:

- Platform-independent/portable: Users are able to view PDF-files independently from the operating system or hardware they are using. There is for example no need for a CAD-System to view 3D contents based on PDF technology. This platform independency enables a high portability.
- High degree of awareness and diffusion rate: according to a study of Adobe Inc., applications for viewing PDF-files are installed on 90% of all personal computers worldwide.
- Protection of data privacy: PDF-documents can be signed with digital keys, or they can be cryptographically secured. This feature enables the owners of PDF-files to determine the addressees and their access rights individually.

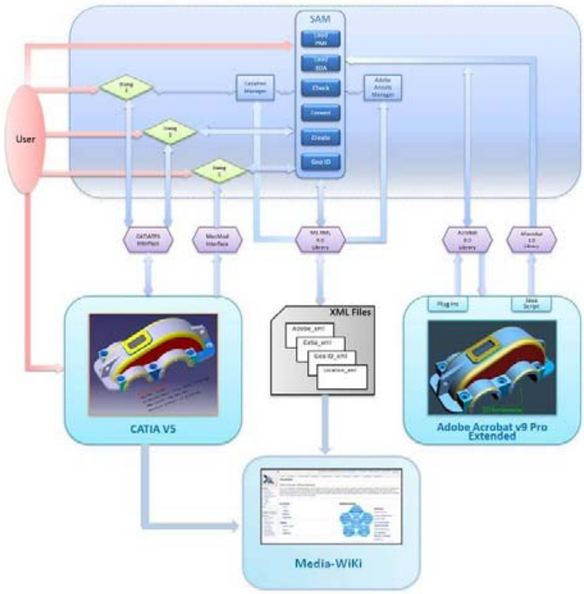


**Figure 5 - Implementation**

All these characteristics privilege the PDF-format as an optimal platform for the discipline-wide sharing of complex engineering data, especially in global co-operations. Additionally, since 2005 PDF is the ISO standard for technical product documentation.

3D-PDF supports common 3D-CAD-formats (CATIA V5, UGS NX, Pro/E Wildfire). During the creation process of a 3D-PDF-document, most engineering 3D-data associated with the original model are eliminated. The 3D-data usually is converted and compressed either in the PRC- or U3D-format. The reduced files can be downloaded quicker from the World Wide Web and rendered faster on screen.

U3D stands for Universal 3D. It has been developed by Intel, Adobe, Boeing and the Industry Forum (3DIF) in 2004 [19]. The specification for U3D, the third edition of ECMA International’s ECMA-363 Universal 3D File Format Standard (ECMA International 2006) and the corresponding implementation software has been released as open source [20]. In addition, U3D is supported from Version 7 of Adobe Acrobat (PDF Version 1.6) [21]. Since 2005 U3D is universal and standardized for the exchange of 3D drawing data and is supported by Adobe Acrobat since Version 7, CATIA V5, I-DEAS, Autodesk Inventor etc.)

PRC has been invented by TTF (Trade and Technology France). Its main selling point is the good performance due to the data compression factor up to 150 [20]. After being compressed the 3D-data contains the exact B-Rep-Geometry, which makes it usable in further CAx-Applications. The specification of PRC is published in Acrobat 9 SDK. Adobe allows three different stages for converted data.

**XML**

XML (eXtensible Markup language) is a free open standard and has been produced by W3C (World Wide Web Consortium) and several other related specifications in 1998. It presents a markup language for text documents. XML is platform independent [22]. It supplies a set of rules for encoding documents electronically. In comparison to other markup languages XML does not define firm tags. Tags can be defined by the users themselves, but have to follow general rules. XML describes a structure and the content of a document, but not the formatting. This markup language is easy to read and write and thus it is outstanding for data exchange between various applications [23].

There is a variety of programming interfaces which software developers may use to access XML data, and several schema systems were designed to aid the definition of XML-based languages.

**Semantic Media Wiki**

MediaWiki is a web-based wiki software application. The wiki-technology enables a common editing of internet pages. Therefore wikis are predestinated for cooperative work. Advantages of wikis are easy handling and hyperlinked pages. MediaWiki is written in the PHP programming language, and can use either MySQL or PostgreSQL relational database management system. Semantic MediaWiki (SMW) is an extension to MediaWiki, that allows annotating data within wiki pages and makes them computer interpretable. Annotations can be searched by using semantic search functions. The structures are build up and displayed in the ontology browser [24].

**Implementation concept**

The exchange of the annotated part model takes place between CATIA V5 and Acrobat 3D. Version 8 in Acrobat enables the import of original 3D-CAD-PMIs in 3D-PDF-documents. This implementation is done within the CATIA work bench „*Functional Tolerancing & Annotation*“ (*FT&A*).

A Toolbox is implemented for creating and managing "semantic" annotations with the following functions:

**Create** enables the creation of a new user-defined annotation in the CATIA environment. **Check** reviews the status (*new, unchecked, loaded, modified and invalid*) of the annotation. The user is free to decide which annotations should be transferred back from the lightweight representation (Acrobat 3D) to the native CATIA-file. **Convert** imports the annotations with the status *new*. During the conversion the association to geometry elements can be chosen. The identifying process can take place automatically or by manually picking the geometry element (**GeoID)**.

The annotations extracted from CATIA, Acrobat and MediaWiki are saved in XML-files with the functions **Load PMI** (for CATIA), **Load 3DA** (for Acrobat 3D) and **Load Media** (for semantic Media Wiki). All attributes characterizing the annotations are saved in these files. The developed application „Semantic-Annotation-Manager“ manages the XML-files of the "Acrobat-Annotation Manager", the "CATIA-Annotation Manager" and "Wiki-Annotation-Manager" and allocates further functions.

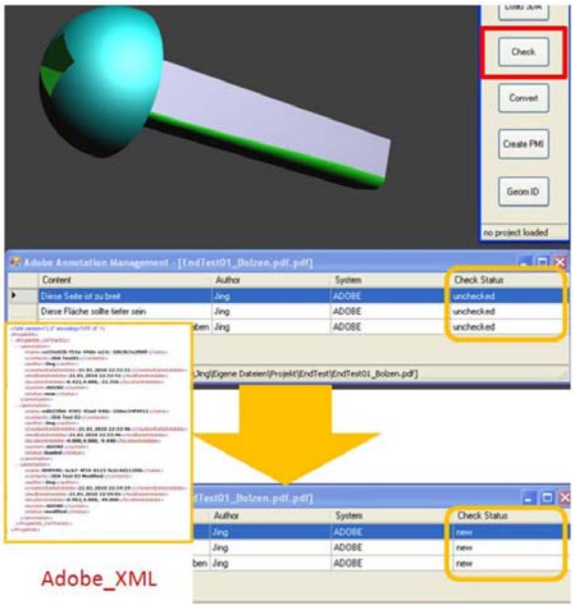


**Figure 6 – Annotation Editor**

The structure of the social context information space is partly given, but mostly patterned by the users themselves (Web 2.0 philosophy). A structure is needed to guarantee a set of stored meta data about the users, the organizations and the project structures. The structure is modeled in UML (Unified Modeling Language) and implemented within the MediaWiki as an ontology[1].

Thus, communication sequences, communication as well as the social network structures become visible in this space. A social network has been established.

**Example**

For a better understanding, an example of the implementation is given. The annotation added by a designer includes meta-data about the author and is attached to the 3D-geometry. It is then converted into the 3D-PDF-format. In the meantime the annotations are stored in external XML-files.

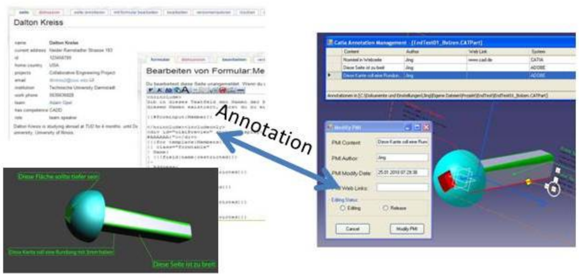


**Figure 7 - Example**

The designer picks out his expert team in the Semantic Media Wiki. The semantic structure (represented in the before mentioned ontology browser) enables user-defined searches for definite attributes.

By using the network or e-mail-based distribution function in Adobe Acrobat the compressed 3D-data is distributed to the

1 An ontology deals with the question how entities can be grouped, related within a hierarchy, and subdivided according to similarities and differences [25].

experts. After having commented the annotation, the 3D-PDF-file is sent back. All commentaries are collected in one 3D-PDF-document. Now the designer has the possibility to evaluate the commentaries regarding the items: user profile of the commentator, the review of the commentator and the used key-words (which can be automatically extracted). He then loads the important commentaries back in CATIA by using the annotation manager function.

## 6. CONCLUSIONS

Global product development and global manufacturing require information technology and modern communication technology. In globally dispersed teams cultural and hierarchical differences as well as different specializations lead to communication problems. It is shown that communication based on 3D-models can help to reduce these issues. A toolbox was introduced that allows to create, modify and exchange annotations in CAD systems and collaborative discussions or workflow-based decision processes. Coupled with semantic annotations and a semantic media wiki a powerful system for global teamwork was created.

The use of XML as a data exchange and storage format allows the further use of annotations in various applications, e.g. for visualization in argument maps or for the application of analytical hierarchy processes to support the decision making process.

The distribution process of the annotations can be integrated in common web-based product data management (PDM) – systems. Within these PDM-systems an automatic, workflow-based notification service for distribution can be realized.

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