INTERNATIONAL CONFERENCE ON ENGINEERING DESIGN
ICED 05 MELBOURNE, AUGUST 15 – 18, 2005

PROVIDING COMMUNICATION MEDIA FOR DISTRIBUTED DESIGN

Jöran Grieb and Udo Lindemann

Keywords: distributed development, communication model, communication media

1 Introduction

Increasing market pressure and continuously progressing globalization influence design processes. Nowadays design teams in global companies are not necessarily working in one location, but are characterized by a large number of participants, working in a locally distributed group [1]. Since face to face meetings imply time and cost consuming travel, distributed working design teams are forced to communicate using different kinds of media. However, exclusive use of electronic communication media is not sufficient for an effective collaboration [2]. Actually, communication media in distributed working teams have the effect of slowing down cognitive synchronization and shared understanding during the design process [3].

Törlind[4] shows, that high performance communication media improve the communication and make it easier to work together in a locally distributed environment. On the one hand, the use of these tools is limited due to certain preconditions that cannot always be fulfilled. Beside the bandwidth, which can lead to significant performance reduction, firewalls and other safety precautions hinder the use of these media [5]. For example most products supporting synchronous real time collaboration over the internet require open ports through the firewalls [6]. On the other hand, companies succeeding in improving productivity through enhancing collaborative performance can create sustainable competitive advantages [7]. Therefore, even if it is often not possible to use the best communication media on the market, there should always be the ambition to apply the best communication media available under the given circumstances.

2 Objectives

In this paper we present a model that suggests a combination of communication media in distributed design situations. Generic information concerning communication media and situations enables the designer to find suitable media according to different boundary conditions.

The general goal is to identify suitable media for certain situations and to determine what kind of media should be proposed under the inherent circumstances. The required information is gathered on basis of the analysis of communication media in design processes in literature, as well as accomplished surveys and conducted design experiments. This knowledge needs to be stored and arranged in a way that it can be used by designers in distributed situations.

There are several possible proceedings to support the media selection in distributed development. In addition to Salhieh and Monplaisir [8], Gaul [9] describes a technique to classify communication media according to media properties. Furthermore, the importance of these properties for the transmission of certain information types is defined. By comparing the properties of the media with the properties of the information it is possible to determine suitable communication media. In the procedure described by Gaul [9], the media and information types are not classified generally, because they are dependent on the company. As the information is very specific and needs to be redefined according to changing boundary conditions it is not possible to store general insights into the interrelation of media and design situations in a model.

The models referred to above require classification of situations in distributed development, allocation of properties to certain media and definition of interdependencies between situations and media properties. This is not only time consuming, but difficult and requires special knowledge of communication situations.

This paper proposes the expansion of these models by abstracting the information, concerning interrelations of media and design situations, based on generic information. This contributes to the storage of information about the interrelations and the usage of this knowledge in different environments, without the need to redefine the interrelations for each case.

The proposed model facilitates the classification of the situation by means of a checklist of general situation characteristics. Media will be allocated on the basis of the selected situation characteristics. The situation characteristics include boundary conditions which might constrict the use of certain media. The correlation between situations and media will be defined on a highly abstract level, in order to enable storing this information and using the model independently of specific situations. It might still be necessary to update the complex interrelations between situation and media according to new insights regarding distributed development. However it will not be necessary to redefine them completely when using the model in different environments. This provides the opportunity to carry out the analysis of interrelations very thoroughly, since the collected information can be used more generally. Our analysis is based on literature review, a survey and design experiments.

3 Method

The general proceeding is as follows: The first step contains the association of situations and suitable communication media. This creates the initial set up of the model. The second step is the use of the model. The model will propose a combination of suitable media for a specified situation according to the classification of this situation by means of situation characteristics. Even though the main focus of this paper is the set up of the model, the use of the model will be explained briefly.

The model is based on the analysis of distributed design processes. Different means of information acquisition have been used to obtain the necessary knowledge about communication media, characteristics of distributed design situations and their correlations. In literature case studies of distributed design experiments are available. In most cases these reports include documentation about communication media and design situations (e.g. [3],[2],[10] etc]). Apart from literature review, results of a survey in industry have been used. Designers were asked about available communication media and what groups of different communication media they use in certain situations in distributed development. The third

source of information is the analysis of distributed design experiments. The intensity of media use is detected by video analysis and questionnaires. These design experiments are not yet completed, but first insights support the arrangement of the model. After the completion of the experiments, the results will be included in the model.

Initially a framework to classify and characterize media and situations in distributed development needs to be developed. Within this framework situations and media need to be abstracted to a high degree. This is necessary to ensure that the model will fit in a broad field of different situations and be capable of containing general statements concerning interrelations of media and situations.

3.1 Characterization of situations and communication media

The following passage discusses situations in distributed development processes. To enable statements on an abstract level, which is necessary to cover different environments and assign the statements to different situations, the situations are specified by situation characteristics. Only characteristics that are assumed to influence the suitability of communication media in distributed development are represented by the listed situation characteristics. The characteristics are arranged hierarchically. The category levels are: Environment/Tools, Design Process/Task and Designers/Participants. Environment/Tools comprises characteristics that deal with external boundary conditions and that are not related to the design task or the designers. Design Process/Task includes characteristics related to the Design Process, or the Task. This category deals with "what should be done" and "how it should be done". It covers both the Process, e.g. the structure of the process and the Task, e.g. the complexity of the problem. Designers/Participants contains characteristics that are only related to the people participating in the distributed development process, e.g. how well these people know each other and if they speak different languages. Figure 1 depicts the general structure of the situation characteristics.

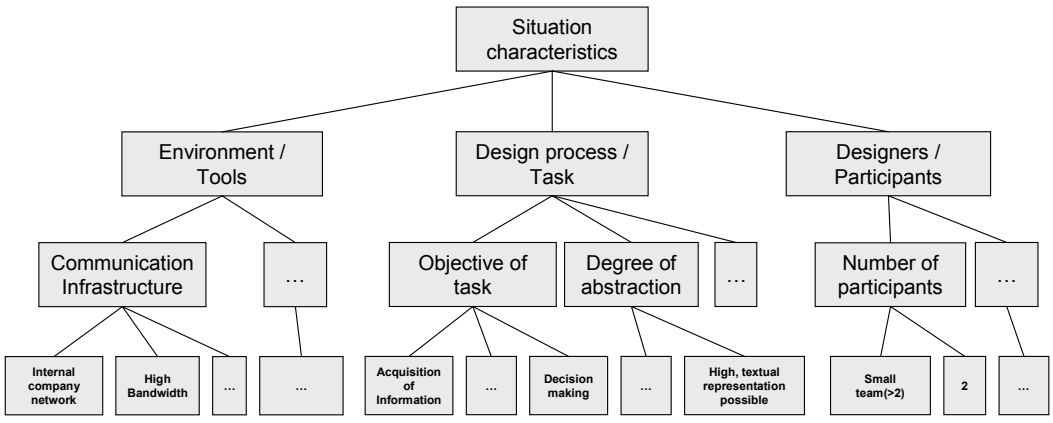

Figure 1. General structure of the situation characteristics

On the bottom level these characteristics generate an accumulation of situation specific attributes. This accumulation of attributes will be used as a checklist. This makes it possible to characterize a situation in distributed development without much effort. It needs to be kept in mind that only attributes are included which might influence the suitability of communication media. However, taking this fact into account, the characteristics should represent the situation as completely as possible.

In order to obtain a representative collection of relevant characteristics, several publications dealing with the classification of distributed development were analyzed. Gierhardt et al. [11] developed a list of criteria of distributed development processes to identify typical problems in these processes. Ostergaard and Summers [12] describe a taxonomic classification of collaborative design, while Eckert and Stacey [13] set up dimensions of communication in design for classifying design scenarios. These classifications were searched for criteria that influence the suitability of communication media. The criteria were supplemented by attributes that were extracted from a survey and several design experiments. The preliminary classification is depicted in table 1.

Table 1. Classification of situation characteristics

Designers/Participants	
Context information	Participants have the same knowledge of the context.
	Participants have different or no knowledge of the context
Equality/balance of expertise, knowledge	Equal levels and shared fields of expertise
	Different levels and/or complementary fields of expertise
Familiarity	Participants know each other well
	Participants are not familiar with each other
Competence with media/groupware	Experienced, frequent user (skilled and comfortable with the medium)
	Novice, infrequent participant
Number of participants	2
	Small team (2-10)
	Big team/ several small teams (>10)
Language	Participants speak the same language (mother tongue)
	Participants speak different languages
Composition of team	Multiple disciplines
	Single discipline

Environment/Tools	
Communication infrastructure	Internal company network (Intranet like connection)
	Internet (Connections through firewalls)
	High bandwidth (>1MB/s)
	Low bandwidth (<1MB/s)
	Videoconference hardware available
	Stereographic hardware available
Compatibility of design tools? (e.g. CAD)	Yes (e.g. same CAD,CAE tool)
	No (e.g. different CAD,CAE tool, usage of standard interfaces)
Locations	Participants are located at different rooms on the same location
	Participants are located at different sites/locations of the same company within the same company
	Participants are located at different companies or in different countries
Time restrictions	Same time (synchronous communication possible)
	Different time (synchronous communication not possible)
Organization	Participants work for the same company
	Participants work for a company and its supplier
	Participants work for different companies

Design Process/Task	
Perceived criticality	Highly critical design process information (transfer of information has great impact on the design process)
	Medium critical design process information (transfer of information has low impact on the design process)
	Not critical design process information (transfer of information has no impact on the design process)
Level of confidentiality	Highly confidential information (some can be shared)
	Medium confidential information (all can be shared)
	Not confidential information, information needs no protection
Division of work	Joint working on tasks (Joint Designing)
	Separated concurrent working, joint meetings (Interface Negotiation)
	Negotiated handover, sequential working (Handover)
Degree of abstraction	High (textual representation possible)
	Medium (representation by sketches, function structures)
	Low (Complex structures, e.g. CAD Models)
Number of interfaces between partners	High (highly coupled tasks regarding product/process)
	Low (loosely coupled tasks regarding product/process)
Structure of process	Well defined/structured process (routine design)
	Ill defined/structured process (novel design)
Complexity of problem	High (e.g. car, plane, other complex systems)
	Low (e.g. nutcracker, stapler, other low complex problems)
Objective of task	Generation of ideas/alternative solutions
	Problem solving
	Decision making
	Acquisition of information
Duration of communication	Brief communicative activity (seconds to few minutes)
	Extended communicative activity (several minutes to hours)
Information type	Objective information (facts, specifications etc.)
	Subjective Information (opinions, judgments etc.)
Time pressure	Task is time critical
	Task is not urgent
Conflict potential	Low (most likely no conflicts will occur)
	High (most likely (heavy) conflicts will occur)
Documentation	No documentation of information exchange needed
	Documentation of information exchange helpful
	Documentation of information exchange needed for legal matters

In addition to the classification of the situations, the classification of the communication media themselves is necessary. Besides standard media like letter post and telephone that have not changed for decades, more and more computer aided communication media support distributed design processes. These media evolve rapidly and many new products appear on the market within short periods. The need to handle various different media and to be able to

include new, not yet existent, media in the model leads to the necessity to classify the media on an abstract level. Like the situation characteristics, the media characteristics are arranged hierarchically. Only attributes which might have an effect on the suitability of media in distributed development are considered. The super ordinate levels are: Infrastructure, Functionality and Nature. Infrastructure contains characteristics related to the question "What requirements have to be fulfilled to make the medium work?". For example some media need special hardware which is not included in standard PCs and some computer aided communication media demand for special properties of the available network connection. Functionality comprises characteristics concerning the question "What kind of features do the media provide and how do they work?". The related characteristics give hints to the kind of information that is transferred and note if it is possible to edit the data during communication and so on. Nature includes characteristics related to the "soft skills" of the media, e.g. if a medium is available ad hoc, or if it requires preparation. Figure 2 depicts the general structure of the media characteristics.

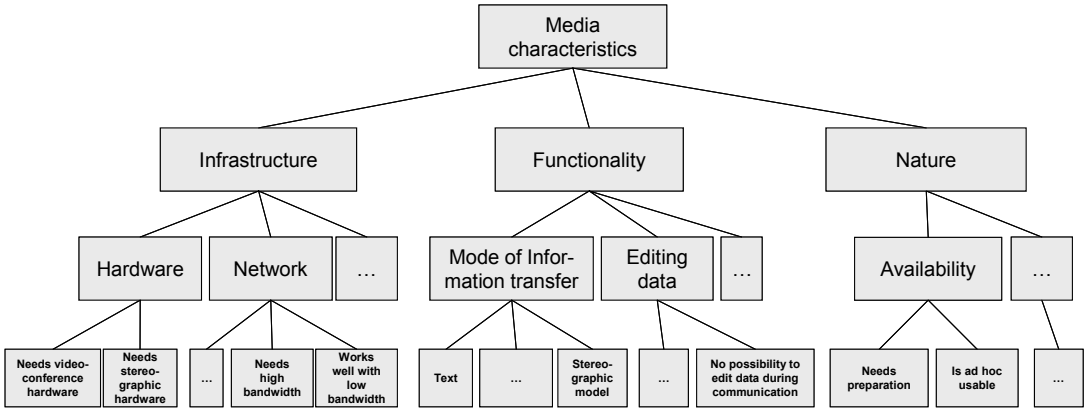

Figure 2. General structure of media characteristics

On the bottom level, these characteristics allow an abstract allocation of general media characteristics to general situation characteristics. The characteristics should cover relevant attributes of media, which might have an effect on the suitability of communication media, as completely as possible.

In order to obtain a collection of relevant characteristics some literature review was done. Lindemann et al. [14] suggest some media characteristics for a similar model. The dimensions of communication of Eckert and Stacey [13] provide attributes that are important for communication media. In addition, the taxonomic classification by Ostergaard and Summers [12], as well as the above stated situation characteristics, gave ideas which media characteristics might be important to consider. Finally, the accumulation was complemented by aspects which emanated from a survey and design experiments. The preliminary classification is depicted in table 2.

Table 2. Classification of media characteristics

Infrastructure	
Network	Intranet connection (No firewalls)
	Internet connection (Through firewalls)
	High bandwidth (>1MB/s)
	Low bandwidth (<1MB/s)
Hardware	Special videoconference hardware
	Special stereographic hardware
Software	Special communication software on all sites
	Special communication software on one site and standard communication software on other sites (e.g. web browser)
	No special communication software
Competence of User	Well trained/experienced users
	Not well trained/experienced users

Nature	
Form of Information	Good support of formal information exchange
	Good support of informal information exchange
Duration of communication	Suitable/comfortable for brief communicative activity
	Suitable/comfortable for extended communicative activity
Availability	Preparation in order to use
	Ad hoc useable
Reliability	Absolutely reliable
	Not in all situations reliable
Human closeness	Supports the feeling of human closeness
	Does not support the feeling of human closeness
Trust	Trust and familiarity needed (suitable if participants know each other well)
	Trust and familiarity not needed (suitable if participants do not know each other well)

Functionality	
Level of security	Information transfer is not encrypted
	Information transfer is encrypted
Editing data	Participants can edit data simultaneously
	Participants can edit data sequentially
	Only one participant can edit data
	No possibility to edit data during communication
Synchrony	Supports synchronic communication
	Supports non synchronic communication
Mode of information transfer	Gestures
	Mimics
	Verbal (Audio)
	Written (Text)
	Abstract graphics (Sketches, Graphs)
	Concrete graphics (CAD Models, Technical Drawings)
	Stereographic (VR-DMU)
	Files (Programs)
	Physical Objects (Prototypes)
Number of participants	Supports 2 participants
	Supports small teams (2-10)
	Supports big team or several small teams (>10 participants)
Documentation	No direct documentation of information exchange possible
	Direct documentation of information exchange possible
	Documentation of information exchange is directly suitable for legal matters

On the one hand, these classifications establish the foundation for the proposed model and should not be constantly redefined. On the other hand, these characteristics can and should be modified and complemented according to new or yet unaccounted insights. Therefore, they are not quoted to be completed and final.

3.2 Allocation of media and design situations

An essential part during the further process is to allocate media to the media characteristics they provide or need in order to function (provided media characteristics). So, for example a Shared VR Viewer can be assigned to specific characteristics (Figure3). In this example the Shared VR Viewer needs special stereographic hardware and a high bandwidth network to work. It uses stereographic models as mode of information transfer and it is not possible to edit this data (the models) during communication. The Viewer requires lead time before it can be used. Additionally, it is allocated to several more attributes that are not mentioned in this example.

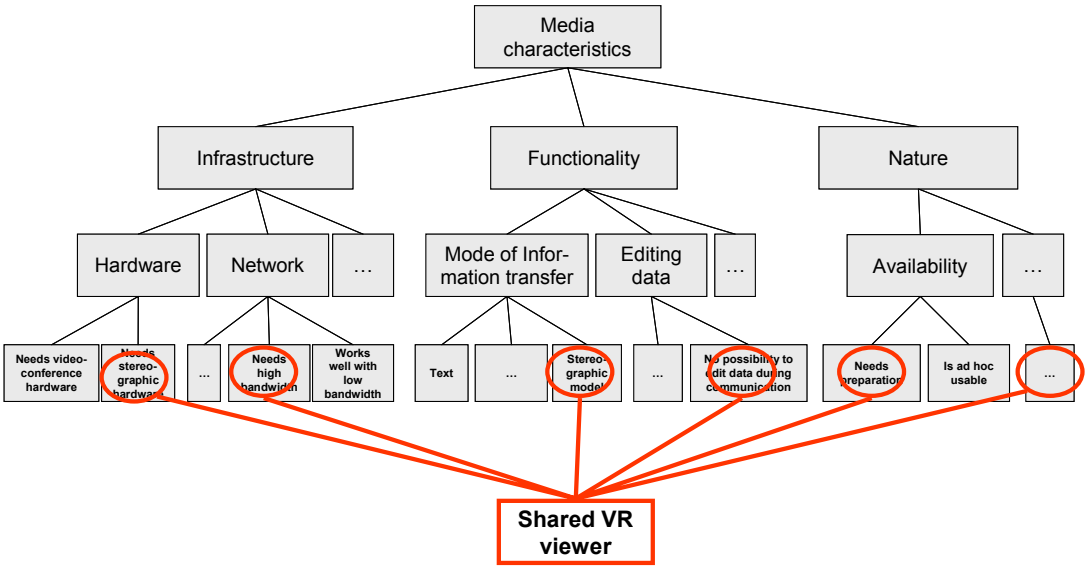

Figure 3. Allocation of media to specific media characteristics

This presented step classifies actual media by associating them with abstract media characteristics. Alternatively, it is possible to allocate certain groups of media instead of individual media. It is possible to consider the media group "Voice Over IP" or for example Skype™ as an individual media. It is proposed to use these media groups only if the different products can barely be distinguished according to the attributes. For example it could make sense to classify email as a communication medium instead of the different email clients (Thunderbird, Outlook, Netscape) if the considered attributes are alike.

Information on how to carry out these allocations can be extracted from literature reviews, distributed design experiments, surveys etc. Even product descriptions can be taken into account. This allocation of media to abstract attributes makes it possible to document the communication media and their properties in a consistent framework. The assignment of the media to the media characteristics will be documented in a matrix in the final model.

The next step is the allocation of the situation characteristics to the media characteristics that are needed according to the specific situation. It is assumed that certain situation characteristics require certain media characteristics. For example the situation characteristic "Competence with media/groupware: Novice, infrequent participant" requires the media characteristic "Competence of user: Doesn't need well trained/experienced user" (figure4).

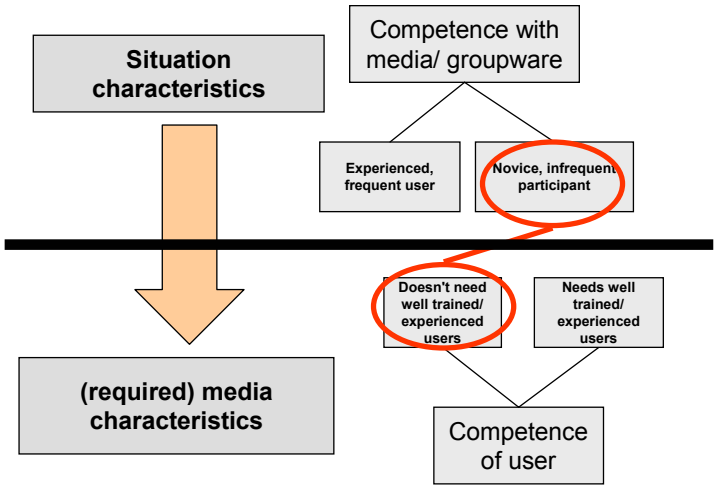

Figure 4. Allocation of Situation characteristics to (required) media characteristics

In order to assign all situation characteristics to all (required) media characteristics the situation characteristics and the media characteristics are arranged in a matrix. Figure 5 depicts a simplified situation-media matrix.

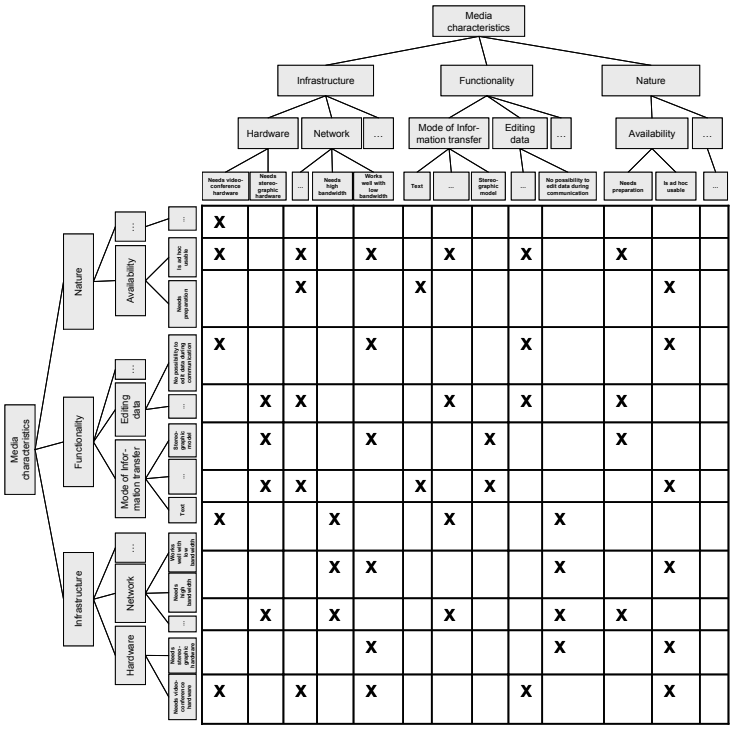

Figure 5. General structure of the allocation of Situation characteristics to media characteristics

The allocation of these characteristics will be based on literature review, a survey and distributed design experiments. This step is very extensive and therefore not finished yet.

4 Model

The model described below is composed of the classifications and allocations of media and situation attributes that are mentioned previously in this paper. By comparing the media characteristics that are required by the situation characteristics to the media characteristics

that are provided by the different media, the model proposes a combination of suitable communication media according to the situation. Figure 6 depicts the general structure of the model.

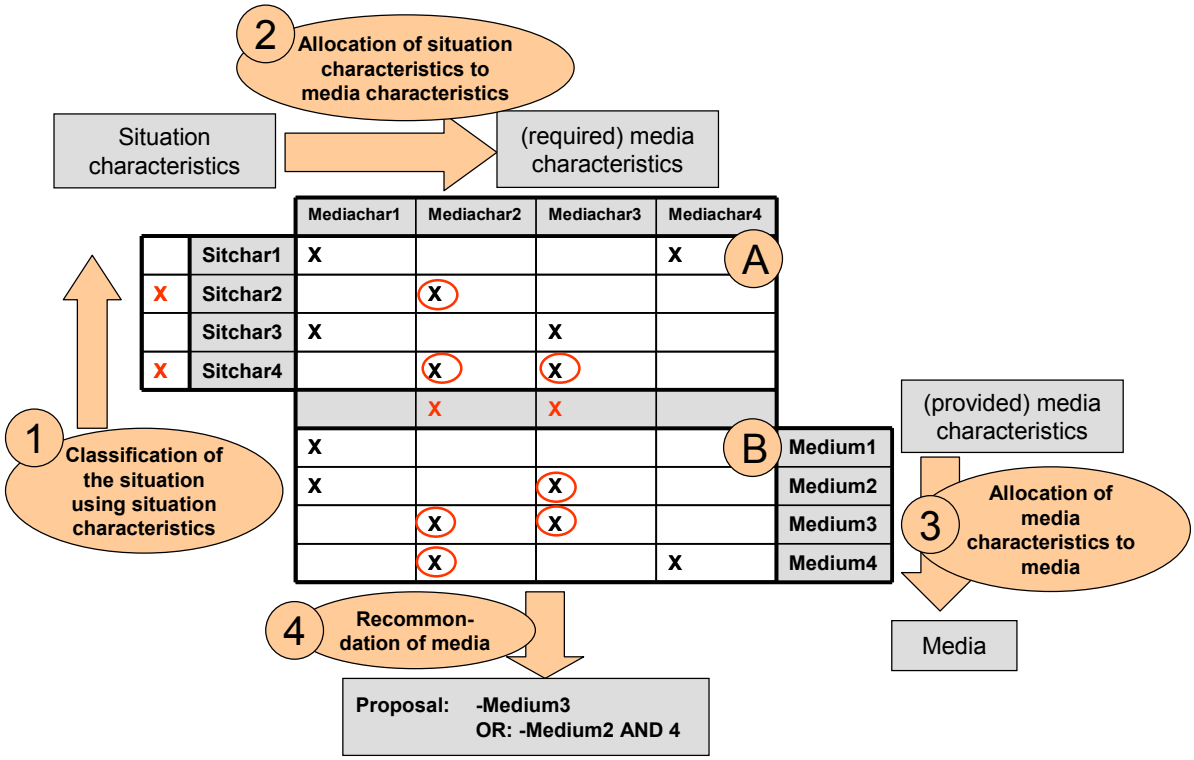

Figure 6. Structure of the model to propose communication media

The actual application of the model is as follows: The Situationchar/Mediachar matrix (A) and the Mediachar/Media matrix (B) are arranged as described in the previous chapter (black Xs). The allocations on an abstract level should allow the usage of the model in a wide field without redefining these mappings. The first step (1) of the application of the model consists of the classification of the situation in distributed development by means of the defined situation characteristics (red Xs). This step is like filling in a simple checklist and is not expected to require special knowledge about communication and media in distributed development. The next step (2) is the allocation of the specified situation characteristics to the media characteristics. Since the general allocations are displayed in the matrix, this is just a process of looking up what media characteristics are related to the specified situation characteristics (red circles in matrix A). Now it is possible to compare the media characteristics which are required by the situation to the media characteristics which are allocated to actual media (3), (red circles). This information allows a proposition of suitable media (4). In the example presented in Figure 6, the proposition would be that medium 3 or a combination of media 2 and 4 provide the media characteristics required.

5 Discussion

The crucial point of the proposed model as well as of the models proposed from Gaul [9] and Salhieh and Monplaisir [8] is the correct representation of the relations between situations and media. On the one hand, the very detailed attributes of situations and media and their interrelations represented in matrices make the initial building of the model very time

consuming and require intensive engagement in distributed development. On the other hand, the representation on an abstract and general level makes it possible to use the model with the same matrices in distributed development processes which do not have to be similar to the ones analyzed in the first place. The authors are aware of the fact that it will probably not be possible to fill in the proposed matrices completely and correctly during the research project. Even though various experiments and reviews are carried out, not all situations that can occur in distributed development will be known by the end of the project. However, due to the abstract classification it is possible to develop the model further according to additional findings. Furthermore, it is assumed that the model can give reasonable suggestions for communication media according to specific situations, even if the underlying matrices are not completely and ultimately filled in.

Within the course of a research project at our institute, the matrices will be filled in on the basis of student experiments, literature review and a long term distributed development case study. These studies are still ongoing and so the building of the matrices is not finished yet. Nevertheless, the model was developed further (Figure7). One point is the weighting of the required and provided media characteristics. It is assumed that weighted criteria will be more appropriate to represent the actual interrelations between the attributes. Whether or not a better quality of the model justifies the additional effort which is caused by this weighting remains unanswered. Furthermore, it might be interesting to consider the compatibility of communication media as proposed by Lindemann et al. [14].

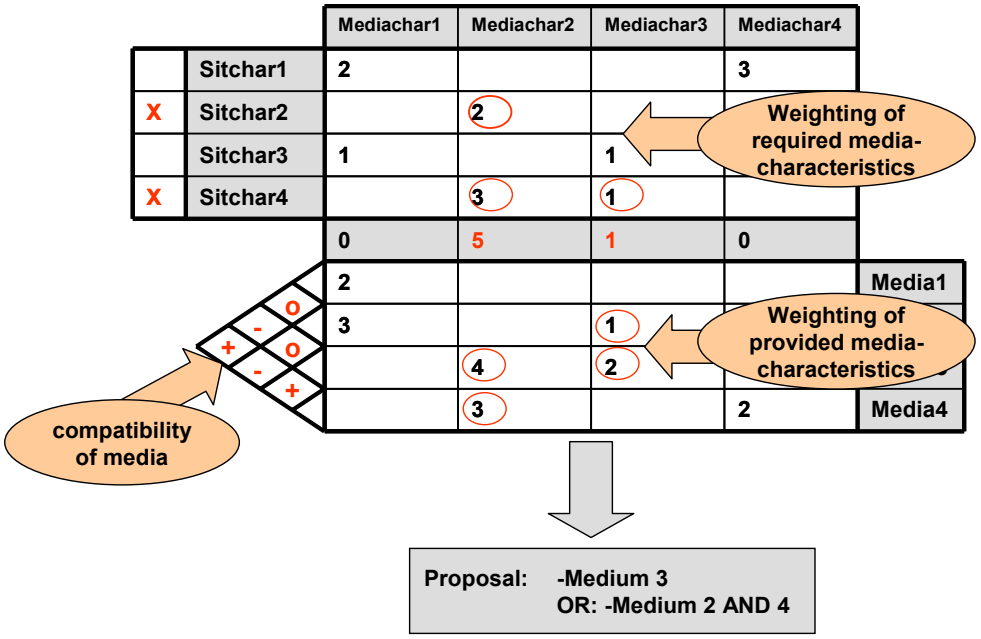

Figure 7. Further development of the proposed model

6 Conclusions and Future work

On the one hand, the quality of communication media can influence the quality of the design process; on the other hand, the usage of communication media in distributed development is restricted to several boundary conditions such as network infrastructure. The presented approach to use the communication media, which are most suitable under given boundary conditions, is based on a model that proposes communication media depending on boundary

conditions. The designers only need to characterize the situation according to a checklist of attributes and obtain a proposition of what communication media are suitable.

An important part of the model is the abstract classification of situations and communication media in distributed design. This makes it possible to store the general interrelations between situations and media in matrices. Furthermore, this kind of structured representation of media and situations and their interrelations helps to gain a deeper understanding of communication media in distributed development processes.

Further work comprises the final building of the model including the actual matrices as well as the validation of the model. A software implementation is considered, to simplify and automate the use of the model.

7 Acknowledgments

We thank the DFG (Deutsche Forschungsgemeinschaft) for funding this project (Li699/11-1).

References

[1] Stetter, R. ; Lindemann, U. ; Pulm, U., "Effective Strategies for Distributed Product Development", In: Ehrig, H.; Krämer, B. J.; Ertas, A. (Eds.): Proceedings of the Sixth Biennial World Conference on Integrated Design and Process Technology (IDPT-2002) Pasadena, 23.-28.06.2002. Pasadena: Society for Design and Process Science, 2002.

[2] Vajna, S.; Marosvary, Z., "Communication and Knowledge Sharing in Distributed Engineering Design", In: Marjanovic, D. (Ed.): International Design Conference - Design 2004. Dubrovnik (Croatia), 18.-21. May 2004. Zagreb: Sveucilisna tiskara 2004.

[3] Ruiz-Dominguez, G.A., Boujut, J.-F., Diallo, T., "On the sequential effect induced by the use of communication tools in distant collaboration", In: HORVATH & XIROUCHAKIS (Ed.), Proceedings of the TMCE 2004, Rotterdam, Millpress, 2004.

[4] Törlind, P., "Distributed Engineering Via Broadband – A Case Study", In: Proceedings of International Conference on Engineering Design - ICED 03. Stockholm. The Design Society, 2003.

[5] Kufer, S., "Collaborative Engineering: Desire and Reality", In: Proceedings of the 20th CAD-FEM User´s Meeting, International Congress an FEM Technology, 9.-11.Oktober, Friedrichshafen, 2002.

[6] Kristensen, K., Hildre, H.P., Slettebakk, J.K., Sondov, M., Hogberg, A., "Establishing an Infrastructure for Value Chain Collaboration in the Norwegian Oil Industry – A Case Study", In: Proceedings of International Conference on Engineering Design - ICED 03. Stockholm. The Design Society, 2003.

[7] Kristensen, K., "Physual Designing, A Supportive Framework for Dispersed Engineering Design", PhD Thesis, ISBN 82-471-5607-5, Department of Engineering Design and Materials, Faculty of Engineering Science and Technology, Trondheim, 2004.

[8] Salhieh, S., Monplaisir, L., "Collaboration planning framework (CPF) to support distributed product development", Journal of Intelligent Manufacturing, 14, pp581-597, 2003.

[9] Gaul, H.-D., „Verteilte Produktentwicklung – Perspektiven und Modell zur Optimierung“ ,(Produktentwicklung München, Band 45), Munich, Dr. Hut, 2001.

[10] Suchan, J., Hayzak, G., “The Communication Characteristics of Virtual Teams: A Case Study”, IEEE Transactions on Professional Communication, Vol.44, No.3, pp174-186, September 2001.

[11] Gierhardt, H., Gaul, H.-D., Ott, T., “Distribution in Product Design and Development Processes”, In: ASME (Ed.), Proceedings of the 1999 ASME Design Engineering Technical Conferences and Computers in Engineering Conference, New York: ASME 1999, DETC99/DTM-8777.

[12] Ostergaard, K.J.; Summers, J.D., “A Taxonomic Classification of Collaborative Design”, In: Proceedings of International Conference on Engineering Design - ICED 03. Stockholm. The Design Society, 2003.

[13] Eckert, C., Stacey, M., “Dimensions of Communication in Design”, in Proceedings of the ICED 01 in Glasgow, 2001.

[14] Lindemann, U., Fuchs, D.K., Gaul, H.D., “House of Communication – Ein Kommunikationsmodell im globalen Umfeld”, ZWF, 95 (2000) 7-8, pp366-368

Jöran Grieb
Institute of Product Development
Technische Universitaet Muenchen
Boltzmannstr. 15
D-85748 Garching
Germany
Phone: +49 (0)89 289 15129
Fax: +49 (0)89 289 15144
E-Mail: grieb@pe.mw.tum.de