INTERNATIONAL DESIGN CONFERENCE - DESIGN 2008
Dubrovnik - Croatia, May 19 - 22, 2008.

DESIGN 2008

MODULARISATION OF PRODUCT DEVELOPMENT CONTENT – PROVIDING USER-SUITABLE DOCUMENTS

M. Lenhart, H. Weber and H. Birkhofer

Keywords: modularisation of knowledge, expertise, learning

1. Introduction

Product development is an integrating function which requires a broad spectrum of knowledge. However, the related knowledge covers very different knowledge domains and has a complex and ill-structured nature. Thus, the requirements for designers are fairly challenging. He/she should be able to access domain-specific knowledge as well as multidisciplinary knowledge and should be familiar with the flexible application of design methods [Pahl 2006]. Hence the questions: how can these requirements be archived by the designers and how can this achievement be adequately supported.
One important way to archive knowledge is to have documents for learning and applying. In order to provide a good transfer of knowledge from the documents to students and designers, they should be suitable to the user's cognition or the user's level of expertise respectively [Cross 2004]. The better the content of the documents fits the level of expertise of the user, the more efficient the transfer of knowledge will be. Therefore it is necessary to have documents suitable to the level of expertise and the situation of their usage.
In this context user-specific as well as situation-specific requirements have to be considered. To cover a broad range of scenarios, a large number of different documents must be created. These documents should have similar or even identical content – at least to a certain extent. A systematic modularisation of this content could help to reduce unnecessary work within the document creation process. The ideal user specific document could be the output of a 'modular construction system'.

2. Related Research and Deficits

In the past modularisation concepts were developed from a mainly system-centred perspective. Conceptual and technical feasibility took centre stage. Within the learning context the most popular models are the Learnativity content model [Wagner 2002], the SCORM content aggregation model [ADL 2004], the Cisco RLO/RIO model [Cisco 2003], and the NETg learning object model [L'Allier 1997]. Taking a closer look at these models, it is striking to note that the target group of these learning objects, i.e. the user of the generated documents and their requirements, are not considered sufficiently. Only general aspects of basic didactic concepts are considered in some of the concepts (e.g. NETg), but feasible, domain specific instructions on the definition and design of learning objects are missing. In regard to the requirements of a scenario-specific modularisation concept, which considers both the user as well as the situation of document usage, the following deficits can be identified in named concepts:

- Inadequate consideration of domain specific characteristics (e.g. complexity, structure)
- Insufficient consideration of user, situation specific and especially cognitive requirements
- Deficient consideration of didactical aspects

- Impractible classification of content modules
- Insufficient support of the configuration process
- Lacking information on the reusability of different contents

The practical implementation of those modularisation approaches is the author's responsibility. Explicit recommendations for the modularisation and the configuration processes are missing. User-centred cognitive aspects are considered insufficiently if at all. As a lacking consideration of user specific aspects can have a negative impact on the usefulness and acceptance of the generated documents, the following modularisation approach will have a special focus on the reader and reading situation characteristics [Lenhart/Birkhofer 2006]. Related research on cognitive requirements of scenario specific documents will be introduced in the following section.

3. The User-Centred Modularisation Approach

To realize an effective and efficient, document-based transfer of product development knowledge, different user scenarios have to be considered. A user scenario is defined as a combination of a person on a specific level of expertise (e.g. novice, intermediate, expert) and a specific user situation (e.g. learning/teaching, application of methods, research and information) [Berger 2004]. Every scenario has to be supported with specific product development content. This content can be provided by scenario-specific documents, which differ in size, structure and layout. Within this context the design, management and the whole creation process of the documents play a decisive role.

3.1 Basic parameters of the configuration model

The primary object of the following modularisation approach is the definition of a

- *modularisation process* to create a modular content base and a
- *configuration process* to generate scenario specific documents.

In the following image the focus is on the support of the configuration process. Within this context the various aspects and interdependencies of scenario-specific document characteristics are challenging. According to former research on user-suitable documents, the three main aspects of configuration, i.e. content, content structure and layout have to be implemented in a procedural model (cf. Fig. 1).

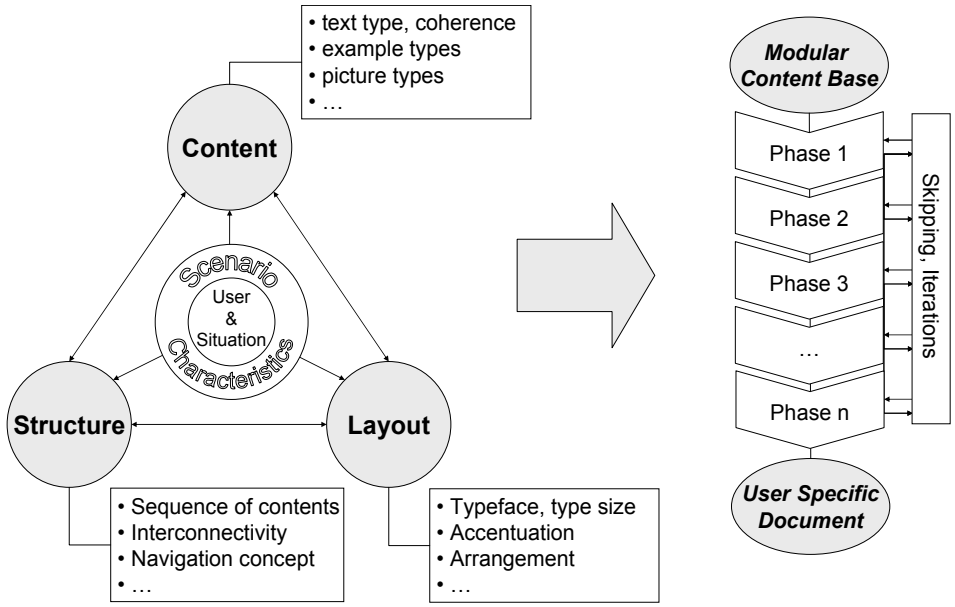


Figure 1. Main aspects of configuration

Starting from a modular content base the configuration process has to pass a certain number of different specific configuration phases. Due to potential interdependencies between those phases several iterations could be necessary.

3.2 Scenario-specific document requirements

In addition to the text structure, the text type and text coherence are fundamental parameters for the design of scenario-specific documents. Within this context coherence is defined as what makes a text semantically meaningful and results from the interaction of the text basis and the reader's prior knowledge. Therefore, text coherence or the document's level of detail, respectively, has to be reduced with increasing expertise. Three text types must be differentiated regarding scenario-specific documents [Ballstaedt 1997, Lenhart/Birkhofer 2007]:

- Expository texts describe facts, i.e. they verbalise complex concepts and relationships and help the reader to expand his declarative knowledge. That means display of especially definitions, explications and argumentations. e.g., Within the description of a development method they can describe prerequisites and contexts of method application.
- *Instructional texts* verbalize procedural knowledge. They present detailed information about method application (e.g. why, when, how to apply). This content type is indispensable for documents dealing with product development, as the acquisition of procedural knowledge structures is a major learning goal.
- *Additional Didactic texts* supplement the text with didactic elements to stimulate and support specific learning processes. These include the description of learning goals, control questions, summarisations, and advanced organizers. In this way exemplary descriptions of products and method applications can be integrated.

To provide optimal support for a specific scenario, the modularisation approach must allow the determination of a specific proportion of expository, instructional and additional didactic texts. As a result, the text type is an important criterion for the classification and selection of single content modules. In product development prescriptive procedures take centre stage, but in general instructional texts can not support a situation of knowledge application sufficiently. According to the reader's level of prior knowledge, specific expository contents must be integrated to provide the required background knowledge. To summarize, it can be stated that the proportion of different text types is dependent on the specific situation, its instructional goals and the user's characteristics, including his prior knowledge and cognitive processing.

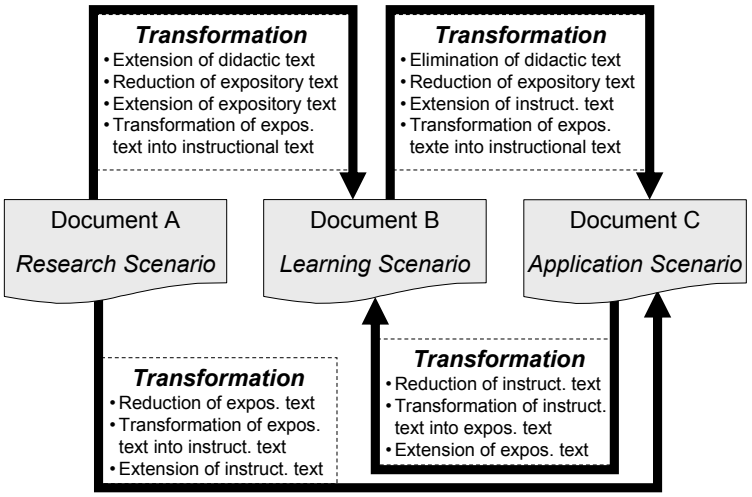
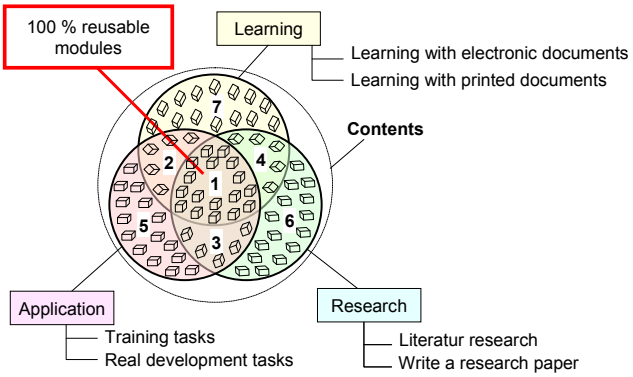


Figure 2. Transformation of situation-specific documents

In practise documents can be adapted to a specific situation by an extensive and time-consuming revision. Within this process, sentences or even whole sections must be modified, added or eliminated. Fig. 2 illustrates this conventional procedure for a transformation of a research document into documents for learning and application scenarios. Additionally, the text coherence has to be adapted to the user's requirements. Within this context a modular document design would be helpful to reduce unnecessary work.
In addition to these further requirements, the design of orientation and navigation instruments and the relation of pictures and descriptive comments have to be considered, and the level of abstraction of integrated pictures decided.

3.3 Classification of scenario-specific content modules

As the modularisation of existing content requires remarkable efforts, it should be done especially in areas where a high level of reusability can be assumed. Within this context reusability can refer to one single situation, e.g. when user-specific documents have to be generated for different learning scenarios. Content modules can also be reused in different situations. An ideal classification of content modules should enable the author to use them irrespective of the regarded situation and user type. In practise the three defined situations form several intersections with different degrees of reusability. Fig. 3 shows the general classification of content modules that are used in the regarded modularisation approach. The classification relates the user scenario to the level of potential reusability.



Nr.	Symb	Module types	Examples	Module characteristics	Reusability
1		General facts	• Definitions • Product description	• Expository • Abstract, concrete	High
2		Procedural descriptions	• Instructions • Rules	• Instructional • Abstract, concrete	Medium
3		Theoretical background (procedure)	• Explanatory notes for procedures	• Instructional, expository • Abstract	Medium
4		Theoretical background (facts)	• Explanatory notes for facts	• Expository • Abstract	Medium
5		Application specific content	• Checklists • Forms (instructions)	• Instructional, expository • Concrete	Low
6		Scientific content	• Theories • Models	• Expository • Abstract	Low
7		Didactic contents	• Learning goals • Tasks	• Didactic additions • Abstract, concrete	Low

Figure 3. Content modules and their potential reusability

Contents of section 1 (cf. Fig. 1) show the highest level of potential reusability as they can be used in all three situations. These contents contain expository text on an abstract level (general description) or on a concrete (examples) level. The contents of sections 5 to 7 are situation-specific. Modularisation and storage of those contents should only be considered, when the reusability within the regarded

situation is supposed to be extraordinary high. Within sections 2 to 4 the potential reusability has to be assessed from case to case.
The content modules described above represent the textual information. The classification also contains so called structure modules, which represent the structure of the modularized document. Structure modules contain a list of specific terms, which enables the author to create a complete document covering all relevant aspects of a theme. In the context of generating new documents, they can provide a suggestion for an appropriate content structure. As the definition of an appropriate content structure can be very challenging, predefined structure modules should provide considerable support in reducing unnecessary work. Of course, the author should be able to modify structure modules according to his specific needs.

3.4 Procedure model for a scenario-specific modularisation

An effective and efficient configuration process requires a comprehensive content base. The extension of such a content base can be realised by modularising already existing documents or by generating new content in a modular shape. As most authors are not familiar with modular writing the following procedure will concentrate on documents modularised within a separate procedure. At this point it is important to point out that the effort of modularising a document can only be justified when the potential reusability is considered to be high.
Fig. 4 shows the procedure of content modularisation that is realised in the approach described below.

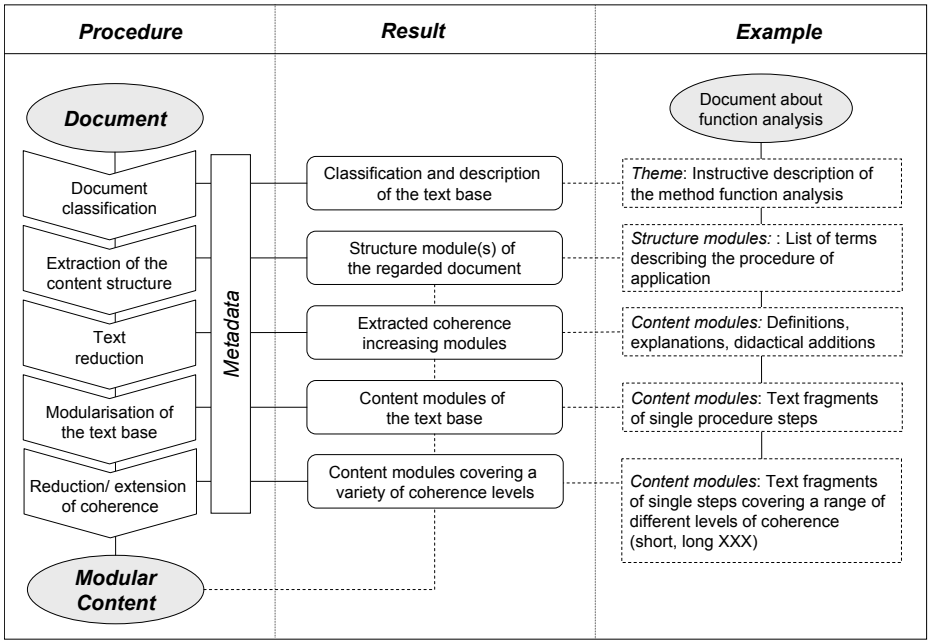


Figure 4. Procedure model of modularisation

The modularisation process starts with a classification of the regarded document. The classification covers the content's topic as well as its original intention. A short description provides help for classification, recovery and access to the later content modules.
Thereafter structure modules and content modules are extracted, provided with metadata and archived. In the majority of cases, structure modules contain the captions of chapters and subchapters in the original order. Depending on the quality of the document, the term structure may have to be adapted afterwards. Content modules must to be marked with metadata, especially regarding their level of coherence. To create individual user-specific documents the content base must contain a certain

variety of content modules dealing with the same topic, but representing different levels of coherence. Thus, a systematic extension or reduction of the extracted content module could be necessary.
The optimal size of a content module depends on the number and complexity of the embodied ideas and the realized coherence. It is therefore difficult to give general recommendations about the size. However the content of a single module should be self-contained to ensure an integration in various contexts.

3.5 Procedure model of a scenario-specific configuration

Based on the modular content base, the configuration process starts with an analysis of the user scenario in question, i.e. the user and situation characteristics (cf. Fig. 5). Thus the specific user type and situation are identified. In the following image, corresponding requirements for the document design have to be defined. The user classification is mainly based on the user's prior knowledge, while the reading situation is classified by the individual goal of document usage.

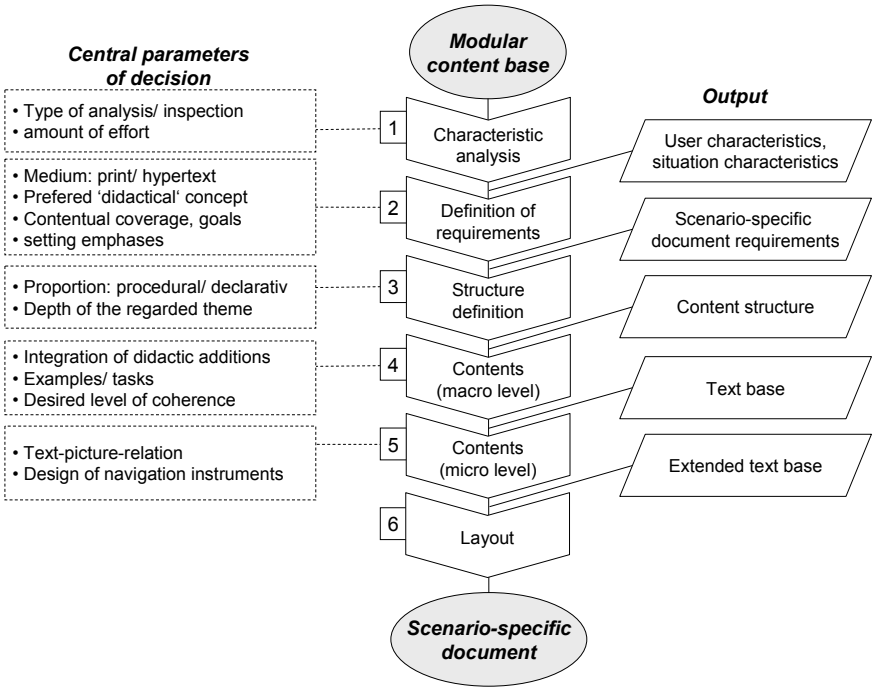


Figure 5. Procedure model of configuration

The document requirements are derived from the specific scenario characteristics. The following main configuration process starts with the definition of the document structure. According to the requirements profile the author has to define a systematic declarative or procedural content structure. Additionally, the characteristics of the chosen medium (print, hypertext) have to be considered.
After defining the content structure, corresponding content modules have to be integrated. In doing so a fundamental text base, which only contains a description of the essential facts and relations, is generated. Depending on the defined user type and situation, this text base has to be extended step by step. In this context other content modules have to be integrated, which increase coherence or provide didactic support as well as pictures.
In the last phase the document layout must be revised and adapted. Finally, supporting orientation and navigation guides (e.g. indices, navigation bars, tables of contents) must be integrated and adapted to the document structure, before the document undergoes a last check and revision.

4. Exemplary application of the configuration model for a hypertext system

In addition to several printed documents about the methods *function analysis* and *function synthesis*, the above configuration model was used to develop the content for a hypertext system presenting several examples of method application. The content base was extracted from the lecture notes of the product development lecture of the institute pmd at the Technische Universität Darmstadt.

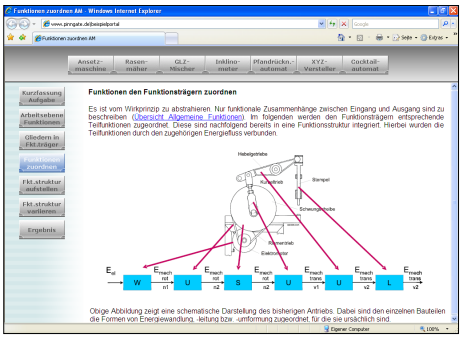


Figure 6. Screenshot of the configures hypertext system

The hypertext system contains seven demonstrative examples, introducing a step by step description of the methods function analysis, function synthesis and function variation. The content structure was extracted from the procedure of method application to help the reader directly transfer the content to a specific, seperate development case. Thus, the systems is based on procedural structure modules. Four of the integrated demonstrative examples were newly created reflecting the same content structure as the examples which were taken from the content base. That way the efforts for developing and describing new examples could be decreased. Additionally the coherence of the content was increased by integrating additional content modules as the system is meant for novices. At present the portal contains seven demonstrative examples, which form a net-like structure (145 pages). The modular structure of the system allows an integration and elimination of single examples without difficulty.

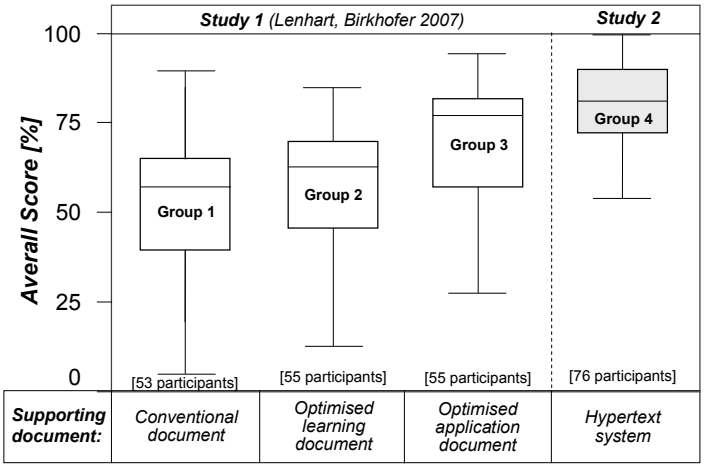


Figure 7. Results of the design task

The effectiveness of the hypertext system, especially regarding the learning efficiency and the acceptance of the reader was examined with an empirical study. 76 novice participants were to solve a design task by using the method of function analysis with a subsequent variation. They were supported

only by the hypertext system, which contained all necessary information. The study conditions were similar to those of a previous study on the effectiveness of printed documents [Lenhart/Birkhofer 2007]. The results were determined by a standardized assessment scheme for the task. Additionally the participant had to fill out a questionnaire about the subjective impression on the document. In summary it can be stated that the results were significantly better than those of conventional documents (cf. Fig. 7). The system was rated with the highest scores indicating acceptance.

5. Conclusion

In this paper a procedural model for a scenario-specific modularisation and configuration is introduced. The model helps to decrease the amount of effort necessary to generate individual documents by providing precise instructions and a standardised procedure of how to implement user requirements as well as situation specific document requirements and by providing suitable content modules. It is shown that the generation of scenario-specific documents and a standardised configuration process, which is based on a modularisation approach, are not incompatible. Instead the modularisation is identified as a prerequisite to generate the required spectrum of individual documents. Otherwise the generation could not be done within a reasonable amount of effort.
By considering a set of scenario-specific design recommendations, the described procedure enables the author to generate scenario-specific documents even if he is not familiar with the underlying cognitive conditions. In conclusion the configuration model and the modularisation approach build an important key prerequisite to generate user-specific documents with a reasonable amount effort and without constraining the author's creative freedom.

References

ADL (ed.): "SCORM 2004 3rd Edition Documentation Suite", online: http://www.adlnet.gov /scorm/20043ED/Documentation.aspx, 2004.

Ballstadt, S.: "Wissensvermittlung : die Gestaltung von Lernmaterial", Beltz, PsychologieVerlagsUnion, Weinheim, 1997.

Berger, B., "Modularisierung von Wissen in der Produktentwicklung", VDI Verlag, Düsseldorf, Germany, 2004.

Cisco Systems (ed.): "Reusable Learning Object Strategy (2003)", online: business.cisco.com/servletwl3 FileDownloader/iqprd/104108/104108_kbns.pdf, 2003.

Cross, N.: "Expertise in Design: an overview", in: Design Issues, Vol. 25, No. 5, pp. 427–441, 2004.

L'Allier, J.: "Frame of Reference: NETg's Map to Its Products, Their Structures and Core Beliefs." (1997) online: www.netg.com/research/whitepapers/frameref.asp, 1997.

Lenhart, M.; Birkhofer, H.: "Levels of Expertise in Product Development – Implications for the Design of Instructional Material", in: Proceedings of ICED 2007, Paris, 2007.

Lenhart, M.; Birkhofer, H.: "Classification of Users in the Context of Knowledge Transfer in Product Development", in Marjanovic, Dorian (ed.): DESIGN 2006, Dubrovnik, Croatia, 2006, Vol. 2, pp. 1187–1194.

Pahl, G.; Beitz, W.: "Engineering Design: A Systematic Approach" Springer, Berlin, 2006.

Wagner, E.: " Steps to Creating a Content Strategy for Your Organization", The e-Learning Developers' Journal, October 2002.

Dipl.-Wirtsch.-Ing. Marko Lenhart,
Research Associate
Technische Universität Darmstadt, Department of product development and machine elements
Magdalenenstraße 4, 64289 Darmstadt, Germany
Tel.: +49 6151 16-3383
Email: lenhart@pmd.tu-darmstadt.de
URL: http://www.pmd.tu-darmstadt.de