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- MIKE can be used during the operation of the knowledge management system, e.g. for modeling of new knowledge, that has to be integrated somewhere into the system. According to the philosophy of MIKE this means incorporating a Knowledge Engineer into the process. We therefore have to distinguish two modeling tasks: modeling mission critical knowledge and modeling simple knowledge as used in everyday questions (like in Answer Garden). MIKE is usually more suited to the first task.

In the following we mainly focus on the first aspect.

5.2 Drawbacks of MIKE

MIKE at described above has several drawbacks when developing knowledge management systems:

- MIKE is aiming at conventional KBS. Also business process modeling primitives for MIKE are defined, there is no possibility to model other techniques besides KBS's. But as shown above the development of a knowledge management system includes many different techniques.
- Knowledge is modeled by a knowledge engineer in the modeling phase. Furthermore the knowledge representation in the modeling phase and in the final system is usually totally different. Knowledge Management Systems live from the fact, that knowledge is integrated in the whole system in a dynamic way, e.g. the organizational memory is extended when necessary within the normal workflow.
- MIKE (resp. the concept of a problem solving method) presupposes only the existence of one user who only partially interacts with the final system. This, however, is not true for knowledge management systems: they are oriented towards the maximum support for knowledge workers, but this is only possible with a high degree of interaction. This interaction is done with the system as well as with other humans, often in a nonformal way.

6 Conclusion and Future Work

The design process for industrial design has been modeled and analysed. From this analysis conclusions for a knowledge management system for process support are drawn. Techniques usable for a knowledge management system are e.g. case based reasoning, document management, conventional knowledge based systems, and CSCW-tools. Also there are many proposals for realizing corporate memory with each single technology, there isn‘t an integrated approach like our proposal. However, the final proof of concept is the implementation, which is ongoing work.

Also work is necessary to extend MIKE to a methodology for knowledge management systems: using results presented in [Sta96], where tools are integrated into the framework by converting them to agents. Then they are modeled with a special agent modeling tool. Together with the enterprise reference scheme presented in [DES96][DES97] for business processes and knowledge based systems this could deliver a general framework for modeling knowledge management systems. To enable prototyping the resulting model should be executable in some sense, at least it should enable validation.

straints are satisfied. To link the KBS's for parametric design to the overall process, the input/output of the problem solving method used by the parametric design problem solver has to be connected to the overall design process. For an example cf. [DES97].

4.6 CSCW-Techniques

Because the ergonomic knowledge is large, informal, sophisticated and changing a system can never have complete knowledge. Therefore techniques have to be established, which enable a user to ask questions easily to appropriate experts. This is the focus of systems like answer garden ([AcM90][AcM96]): a knowledge map of the enterprise is build and if a question can not be answered by the system, the question is routed forward to an expert. This realizes up another part of the organizational memory.

5 Drawbacks of MIKE

5.1 MIKE: a Methodology for Developing Knowledge Based System

The current MIKE (Model-based and Incremental Knowledge Engineering) methodology as described in [AFS96][Neu93] defines an engineering framework for eliciting, interpreting, formalizing, and implementing knowledge in order to build KBSs. It aims at integrating the advantages of life cycle models, prototyping, and formal specification techniques into a coherent framework for the knowledge engineering process. Subsequently, we will discuss the main principles and methods of MIKE.

In contrast to other approaches which assume that the expert creates the model himself, it is assumed that the knowledge engineer is the moderator of this modelling process. Within the modelling process a large gap has to be bridged between informal descriptions of the expertise which have been gained from the expert using knowledge elicitation methods and the final realization of the KBS. Dividing this gap into smaller ones reduces the complexity of the whole modelling process because in every step different aspects may be considered independently from other aspects.

The knowledge gained from the expert in the elicitation phase is described in natural language. It mainly consists of interview protocols, protocols of verbal reports, etc. These knowledge protocols define the *elicitation model* ([Neu93]). This knowledge represented in natural language must be interpreted and structured. The result of this step is described semi-formally in the so-called *structure model* ([Neu93][Neu94]), using predefined types of nodes and links.

According to the KADS approach the knowledge-level description of the functionality of the system is given in the *model of expertise* (cf. [SWB93]). For describing the model of expertise in a formal way the formal and operational specification language KARL ([Ang93][Fen95]) has been developed. KARL is based on first order logic and dynamic logic and offers language primitives for each of the three different layers of the model of expertise. The contexts of the structure model correspond to the domain-, task-, and inference layer of KADS model of expertise.

For designing KMS's the techniques used in MIKE can be used in two ways:

- MIKE can be used for modeling and specifying the knowledge management system itself.

links are enriched with semantics (for example: attribute values like "solves a problem ..." or "in opposition to ...").

In the same way ergonomic knowledge is available: by means of an ontology the actual project documents are linked to the document base, which contains the ergonomic knowledge in a semi-formal form.

4.2 Design Decision Storing

We consider the (almost) complete and retrievable storing of (almost) every design decision case made as an important knowledge support task in the design field. This enables the reusability and maintainability of former designs, because reasons for design decisions are known and can be reused (cf. [Lan94]).Traceability of design decisions should be primary based on links respectively link chains between documents (respectively their structured elements). A correspondingly designed user interface has to support searching and assignment of these links. Primary goal is the (almost) complete and retrievable storing of design decision cases. The semantic network suggested a "well-suiteable track" to cultivate this *Corporate Memory* by means of techniques developed for case based reasoning. By this means we are expecting to reach a significant higher degree of knowledge reusing (directly and/or after adapting), when a comparable task will appear in the future.

At current stage we are implementing these functionality as an ERBUS-client able to store not only the results but also the history and starting-point of design decisions in a complete and retrievable manner as an extension of an existing Document Management System.

4.3 Case-Based Reasoning

Reference designs lead naturally to the area of cased based reasoning: designs and requirements elaborated in former projects are stored in a case base, and retrieved with appropriate similarity measures. To apply case based reasoning appropriate attributes of the documents have to be defined, which are useful for case retrieval.

4.4 Workflow & Design Process Management

Although the modelled design process is often carried out by one person, the introduction of a workflow management system often makes sense: the design department is usually integrated in enterprise wide business processes, e.g. with an engineering department etc. So the seamless integration of the design processes can be guaranteed.

4.5 Parametric Design

At the "Technical Elaboration" step of the design process most of the design object components, possible assignments for the components, constraints and requirements are known. This configuration enables the usage of a problem solving method for parametric design ([MoZ96]). The tasks of parametric design can be described as follows: given a set of parameter (e.g. of a design object), a valid value range for each parameter, and a set of constraints with respect to the values of the parameters. Find an assignment from the value range to the parameters, such that all conissues (problems) are identified and solutions are proposed based on the reference designs and rules established for the ergonomic consultation. Eventually, a list of requirements is being drafted, containing properties and their respective values. Created documents should be managed by intelligent document/database management systems and they should be available for use in further projects.

The designer's required knowledge and abilities are particularly complex during stages 4 - 8. In some areas, such as ergonomics or production technology and construction, specific information is difficult to obtain and probably not contained in to KMS. Therefore consulting an expert would be necessary and should be supported.

During stages 4 to 6, detailed information and refined knowledge the elaboration of the tasks is required. This could be derived from information obtained from available reference designs as well as from the properties defined in stages 1 and 2.

The technical elaboration can be a rather cumbersome task, because the overall structure is defined but the details are still open. However, because components and requirements of the design object (the goal) are well known in stages 7 and 8, one alternative is to support the elaboration with a KBS for parametric design (cf. [MoZ96]).

Support throughout stages 1,2,9 and 10 will be given mostly in the form of provision of information and processing of documents (resp. old designs). Needs for ergonomic consultation can arise in stage 1 and 2 in the context of the definition of requirements.

During all other stages need for ergonomic facts can emerge. This knowledge is complex and in part highly sophisticated. A comprehensive processing which focuses on practical needs can cover most of the knowledge required by the designer. The demand for the knowledge-based component depends upon the depth of consultation desired during the various stages.

The industrial design process, in general, is very sensitive to input from the outside world. Therefore, means of support, ranging from information research to consultancy, should be adaptable to changes in the real world.

A task not directly modelled in figure 2 is the maintenance and revision of the design object. The collection of the major design decisions during the whole design process together with a documentation helps to avoid doing work twice.

4 Tools & Techniques for Realising Knowledge Management in ERBUS

4.1 General System Requirements

The results of single design stages in the modelled process are represented by more or less structured documents. These are usually simple textfiles as well as complex CAD-models or SGML-documents. To enable an efficient document management the retrieval of documents has to be supported. The documents are annotated with parts of an ontology (cf. [FES97]). This can be used for retrieval operations. Furthermore the documents linked using a hypertext system, where

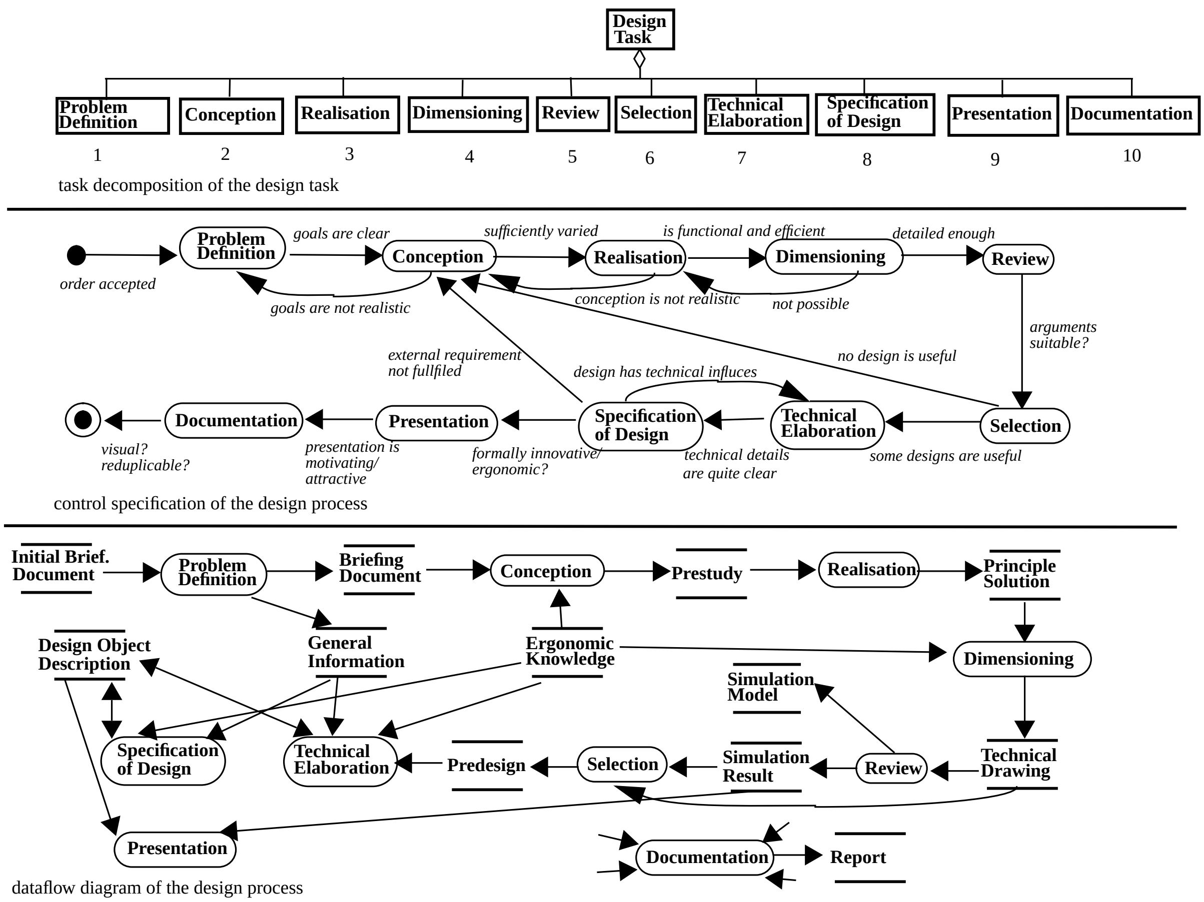

Fig. 2 . Design Process

ling process with modelling primitives and tools. Therefore the first step is just business process modelling as performed in [Sch94] or described in [KiB94]. The process is described in OMT (cf.[RBP+91][KKM95][BKM94]), using an generic reference schema for enterprises (cf. [DES97]). Because only small companies were examined, we only modelled a small subset of the whole set of views: the data view (cf. figure 1), describing the structure of objects and documents used in the processes and the process view itself (cf. figure 2). For the description we use a task decomposition, a statechart to express control over the subtasks, and a dataflow diagram to express the dataflow between the subtasks. Of course is design a creative and highly cyclic process, however, certain behaviour patterns can be identified. Depending on the type of tasks and the class of design (cf. [VDI86]) some stages or the process model may be left out altogether of may deserve less emphasis.

3 Identifying Tasks to Support

Using the modelled data view and the process (cf. figure 1 and figure 2) possibilities for supporting the task can be identified. Realising these possibilities usually introduces new data objects or new process steps.

E.g. throughout the stages 1 and 2 support should be given for the elaboration of briefing and requirements documentation as well as for conceptualisation. This can be done by reference design documents, collected in former projects and reused in the actual project. For this purpose similar properties and problem solutions are identified within the reference design documents. The KMS will then provide a proposal which can be modified. At the same time, ergonomic trial products. However, in the course of the project it turned out that "just" a KBS is not enough: large portions of knowledge can only be represented informally, knowledge is built up through lessons learned and the made experience, and many process steps in the design process have to be supported and integrated to avoid media breaks and to encourage the designer to use the system. Therefore we are aiming now for a knowledge management system, incorporating many techniques.

1.2 Knowledge Management

The development of knowledge-based systems is dominated by a technology-oriented approach, aiming at a complete modelling and implementation of human problem solving methods. This approach does not address the question of usefully supporting the human work processes. To remedy this knowledge management is aiming at the improvement of knowledge work processes (cf. [Dav96]). So achieve this goal several techniques have to be integrated, rather than focusing on one single technique: e.g. business process reengineering (cf. [Sch94]), knowledge based systems with problem solving methods, workflow management systems, CSCW-techniques like answer garden systems (cf. [AcM90][AcM96]), hypertext and database resp. document management systems (cf. [Sku97]). However, the task to support are not pretty standard, then specialized techniques are probably not applicable. So techniques like those mentioned above have to be integrated in an overall framework, but this framework has to be so flexible, that it can be adjusted to most business processes. Furthermore it is usually too expensive to built a knowledge management system from scratch - instead existing products and components have to be used to construct a knowledge management system (KMS).

The rest of the paper is organized as follows: at the first step we model the design process used in industrial design. At the next step we identify possible tasks to support and approaches for this support. From the results of the former steps drawbacks of current knowledge engineering methodologies, namely MIKE (Model Based Incremental Knowledge Engineering), with respect to building knowledge management systems, are shown.

2 Modelling the Design Process

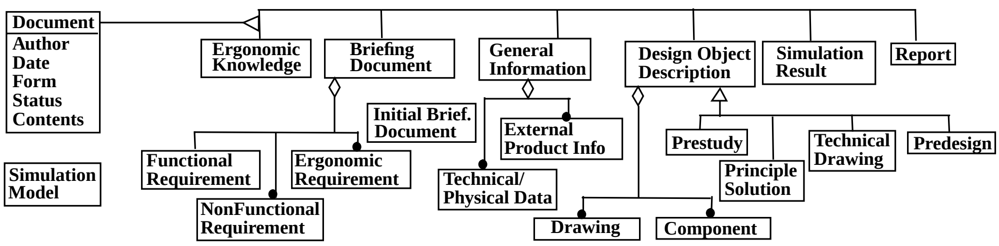

Fig. 1 . Data View

As Kühn and Abecker stated in [KüA97] the first thing to ask is: *What are the tasks to be supported?* To answer this question, i.e. for the requirements elicitation of the overall system the process of industrial design was modelled and analysed for support needs in some design enterprises. This is also the first step, where a general methodology has to start: it has to support the model-

ERBUS - Towards a Knowledge Management System for Designers[1]

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Abstract

The goal of the BMBF project WORKS is to develop a methodology and a prototype for knowledge management systems: ERBUS is aimed at the support of designer and engineers, especially in ergonomic questions. Because of the nature of the knowledge available in ergonomics, it turned out that a conventional knowledge based approach was insufficient. Instead an integrated approach is necessary, which supports the whole design process and different kinds of knowledge. This paper delivers first results of the project: requirements for a general methodology for building knowledge management systems and tools and techniques for ERBUS.

1 Introduction

1.1 Outline of the project

The aim of the project WORKS (**W**ork **Or**iented Design of **K**nowledge **S**ystems) was to build a a knowledge based system ERBUS (**Er**gonomie-**B**eratungs und **U**nterstützungs-**S**ystem) to support industrial designers concerning ergonomic question. This is due to the fact, that a large amout of ergonomic knowledge exists, but this knowledge is often neglected from the designer of indus-

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