

**FABRICATION OF SCAFFOLD STRUCTURES BY RAPID PROTOTYPING METHODS**Pelzer R., Ott A. - *Technische Universitaet Muenchen (DEU)* 453

The research group Fortepro is developing a process for the fabrication of custom-made implants with autogenous cells. These implants will replace bone defects at the head areas and the musculoskeletal system. They are made by hydroxyapatite and after implantation should be replaced by endogenous bone material and build new tissue. A key requirement in this field is the development of scaffold structures on which cells can adhere. The aim of the institute Feingerätebau und Mikrotechnik is to fabricate these scaffolds with Rapid Prototyping technologies to control the internal porosity of the scaffolds. The fabrication of the implants can be done directly with 3D-printing or indirectly by stereolithography (STL) by casting.

**QUALITATIVE COMPARISON OF VIRTUAL AND AUGMENTED PROTOTYPING OF HANDHELD PRODUCTS**Verlinden J., Van den Esker W., Wind L., Horváth I. - *Delft University of Technology (NLD)* 533

The concept of Augmented Prototyping combines Rapid Prototyping techniques to obtain 3D physical objects (e.g. Stereolithography, CNC milling), with Augmented Reality systems. In this article, a comparison is made between the performance of augmented and virtual prototyping. This is done by a design review experiment of a handheld voice recorder. Two prototypes were developed, 1) a screen prototype based on Macromedia Director, 2) an augmented version that employed a video projector to project the screen on a wooden mock-up. In total, 9 subjects participated. Although not statistically sound, this evaluation indicated that the Augmented Prototyping condition yields more feedback, involving aspects of both cognitive and physical ergonomics.

**VIRTUAL PROTOTYPING OF POSITIONING AND MEASUREMENT SYSTEMS FOR HIGHEST PRECISION APPLICATIONS**Höhne G., Brix T., Lotz M. - *Technische Universität Ilmenau (DEU)* 149

The paper presents concepts for a computer-based design of positioning and measuring machines as virtual prototypes to support a phase-overlapping multi-stage design. The basic concept is the modularisation at all levels of abstraction during the design process. For a consistent description of the virtual prototypes a constraint-based and catalogue oriented method is used. The modelling follows the described four-stage process of synthesis. It is thus possible even at the initial planning stage to make important decisions on the possible optimum design.

**SHAPE MODIFICATION OF SCULPTED GEOMETRIC MODELS OF ARBITRARY TOPOLOGY**Veelo B.N. - *Norwegian University of Science and Technology (NOR)* 525

The challenges that a designer faces in modelling shapes of arbitrary topology, are well supported by the so-called H-rep concept, which is based on the tangent plane continuous interpolation of an arbitrary network of intersecting curves. Until recently, making general design changes in stages of detailed design was not well supported. A simple and efficient method is proposed to overcome this limitation in the H-rep, acting on points positioned on the surface. An effective design tool has evolved that allows feature curves to be manipulated regardless of detail, without negative effects on other design features.

**VIRTUAL PROTOTYPING OF SELF-OPTIMIZING MECHATRONIC SYSTEMS**Gausemeier J., Müller W., Paelke V., Bauch J., Shen Q., Radkowski R. - *University of Paderborn (DEU)* 219

Future mechatronic products will comprise configurations of solution elements with an inherent partial intelligence. The complexity of these systems and the necessity to efficiently analyze and explore a large number of potential behavior patterns requires the creation of new development methods and tools. In this paper we introduce a new concept for the solution element based design and analysis of self-optimizing systems. Our tool uses virtual reality, simulation and visualization techniques to facilitate a more intuitive approach to virtual prototyping in the conceptual design phase.

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### CONCEPTUAL DESIGN - ENHANCEMENT OF A DESIGN ASSISTANT SYSTEM FOR LIGHTWEIGHT STRUCTURES

Hauck C., Meerkamm H. - *University of Erlangen-Nuremberg, Germany (DEU)*

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Aim of the actual research period within the collaborative research group 396 is to enhance the application area of an assistant system for lightweight components from the late design stages into the conceptual design stage. Starting from the classic design process approach this paper describes different methods to synthesize (generate) and analyze principle solutions for lightweight components. Further the potential and difficulties of functional modelling during the conceptual design stage are shown. All developed methods are verified within an implemented prototype of the engineering workbench.

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### AN ALTERNATIVE APPROACH FOR THE GENERATION OF INNOVATIVE CONCEPT FOR PRODUCT DESIGN

Prat C., Ngassa A., Bigand M., Yim P. - *Ecole Centrale de Lyon (FRA)*

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Creativity tools can help engineers to mobilize all their technical knowledge to find technological solutions, but they cannot engender the exact solution, so we think it is possible to improve designer's creativity by expanding their access to information. Scanning and monitoring the environment will help engineers to know what is happening outside their enterprise and competitive intelligence will permit proactivity by acting on the environment. Our approach wants to be practical and allows better integrating of creativity's process in the early phases of the new product design process.

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### THE ROLE OF DESIGN IN UNIVERSITY INDUCED INDUSTRIAL INNOVATION

Hein L. - *Technical University of Denmark (DNK)*

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Performance evaluation is being imposed on universities worldwide, and metrics for education and research are being developed and implemented. At the same time, many universities add a new dimension to their objectives: To have a positive impact on innovation in industry. At the present there is only a limited understanding of the quantitative nature of 'university induced industry innovation', and a strict metric is not available. It is argued that the first type of assessment must be based on indicators, and an example hereof is presented. It is concluded that indicators may be less applicable to design as to the other more technology oriented areas of a university.

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### INFORMATION MODEL FOR THE MECHATRONIC PRODUCT FOCUSING THE FUNCTIONAL ABSTRACTION

Zimmerman T., Hallin K., Malmqvist J. - *Chalmers University of Technology (SWE)*

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Mechatronic products with their diversity of cooperating technologies set new demands on effective information management. A key enabler for product data representation is the presence of information models that captures the phenomena of mechatronic design. This work proposes the introduction of transformational-based behaviour concepts in information models supporting implementation of PDM systems. An incorporation of this dimension clarifies the functional relation between different technical solutions such as hardware and software, thus facilitating coordination of different design tasks in an information management perspective. A phenomenon model for the mechatronic product is introduced and formalised into an information model.

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### POTENTIAL OF KNOWLEDGE TWISTING

Zavbi R. - *Faculty of Mech. Eng., Ljubljana (SVN)*

563

Considering one of the objectives of product design, which is to generate as many alternative solutions as possible in order to be able to select those which are truly the best, it makes sense to look for additional methods that will enable the generation of alternative solutions. It is believed that knowledge twisting supports this objective. Knowledge twisting is a kind of manipulation of Physics P/Structure S/Design D (as mental objects) in order to achieve new Function(s) F . It is believed that awareness of the existence of alternative concepts for generating solutions will contribute to the search for straightforward methods for their implementation.

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#### **SIMULATING DESIGN PROCESSES TO INCREASE MANAGERS' UNDERSTANDING**

O'Donovan B., Eckert C., Clarkson P.J. - *University of Cambridge (GBR)* 447

Beginning a design project is challenging. Managers need to understand where the risks lie in the new process. They need to plan tasks and allocate resources to them. Most products are designed by modification, so that designers have some idea what the target product will look like. Design managers can draw on this to describe what tasks they will need to undertake and the information that will be required to do so. However this is not enough, they need to find a sequence of tasks that minimises the risk of running over time and over budget with given resources. Inefficiencies arise when resources are used inappropriately or are missing, thereby delaying the process. This paper describes a new approach to such planning.

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#### **STUDY OF THE DESIGNER'S COGNITIVE PROCESSES DURING THE LATER PHASES OF THE MECHANICAL ENGINEERING DESIGN PROCESS**

Motte D., Andersson P.-E., Bjärnemo R. - *Lund Institute of Technology at Lund University (SWE)* 421

An increasing number of studies have been focusing on the cognitive abilities and limitations of the designer during the design process, yet thus far only for the conceptual design phase. This paper deals with the embodiment design and detail design phases. We focus on the problem-solving process - strategies and basic steps - around the synthesis activity. Six experiments have been carried out, applying the verbal protocol analysis method as adapted to embodiment design and detail design. The results of this study show the specificities of the problem-solving activities of the later phases of the design process.

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#### **ON THE SUPERIORITY OF OPPORTUNISTIC DESIGN STRATEGIES DURING EARLY EMBODIMENT DESIGN**

Bender B., Blessing L. - *Technical University of Berlin (DEU)* 117

The prescriptive tradition of German Design Methodology has been challenged by the results of empirical research showing that strict hierarchical approaches can hardly be found in real design processes. Thus, many authors come up with proposals of more flexible procedures. But do these strategies enhance design performance? To answer this question, we investigated individual design procedures of N=71 engineering design students to determine the applicability of Design Methodology in early design stages. We could approve that an opportunistic and associative design procedure is vast superior to a strict hierarchical approach and seems to optimal to cope with the complexity of design problems and to reduce 'cognitive load' in problem solving.

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#### **ONE FOOT IN JAIL: MITIGATING THE INFLUENCE OF ERRORS ON THE OUTCOME OF DESIGN PROCESSES FOR INDUSTRIAL PLANT**

Mayer H., Stark H. L., Ford R. - *HM Industrial Design & Equipment Pty. Ltd. (AUS)* 389

From the perspective of practicing designers of industrial plant, there is a need for design science to acknowledge the fact that a mountain of decisions has to be got through, while minimising errors and omissions to manageable levels, and that these decisions need to be made in varying decision environments. On the basis of experience and observation, we reconceptualise the design process and decision environments within which engineers strive to manage their error outcomes. A characteristic decision map is proposed, with which the risks of errors, and other difficulties associated with a design task, can be assessed in terms of the decision environments in which the decisions are to be made, so that these difficulties can be managed.

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#### **ENGINEERING DESIGN USING BIOLOGICAL PRINCIPLES**

Lindemann U., Gramann J. - *Technische Universität München (DEU)* 355

Nowadays "bionics" is a well known word, the problem is that there are different definitions of bionics. We wanted to analyse biological principles or use findings of biology to improve the design of products within mechanical engineering. We ran in total six case studies starting with a given technical problem or with a given phenomena in nature. We tried to optimise the suction nozzle of vacuum cleaners. The design of the proboscis of flies and the tongue of snails helped us to find an improved technical solution. Another case study was following the biological principle is called "thermal zoning". The result is a procedural model of bionic supported by a new checklist with function as input and associations in biology as output.

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**THE DECOMPOSITION AND LINKAGE OF DESIGN METHODS AND PROBLEMS**López-Mesa B., Eriksson S., Thompson G. - *Lulea University of Technology (SWE)* 367

Academic design methods appear not to adapt to industrial design activities. Methods originating in industry are naturally adapted to the problem but their completeness and reliability are questionable. In this paper the way methods originating in industry are linked to design problems is analysed by the study of seven successful solution developments in industry. The definition of a method comprising alternative sub-methods and the conditions in which they are useful increases the flexibility of the method to adapt to different design situations. Fundamental characteristics of problem conditions that define the usability conditions of methods and sub-methods are presented.

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**A STANDARDISING APPROACH TO DESCRIBE AND TO COMPARE DESIGN MODELS FOR MECHATRONICS**Moehringer S. - *Simon Moehringer GmbH (DEU)* 415

A variety of design models influence the proceeding in mechatronics. Facing the number of existing design models and their heterogeneous representation it is difficult to identify and to compare the particularities. This contribution introduces a standardising approach to describe and to compare design models. Thanks to the graphical representation in a cube, the points in common and the differences become obvious much faster. The comparison shows very little differences on the macro-level of design models. They structure the design process in phases/activities and related results. The differences, mainly implemented design strategies, can be visualised as third dimension. The models provide hardly any support on the micro-level.

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**SELECTING AND COMBINING METHODS FOR COMPLEX PROBLEM SOLVING WITHIN THE DESIGN PROCESS**Franke H.-J., Deimel M. - *Technical University of Braunschweig (DEU)* 213

The paper describes two approaches to select easily methods for the support of single working steps within the design process. Further, it is essential for the desired support of the entire process, to combine methods to a spanning sequence. Because of this, a concept was developed which combine methods compliantly using the correspondence of output information of a method with input information of the following method. Beyond, a method combination is appropriate to increase the number and result quality of complex working steps, e.g. while searching for working principles. For this reason, a systematically established guideline for the successive application of various methods is presented which supports the search for working principles.

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**A STUDY REGARDING THE USE OF METHODOLOGY DURING A DESIGN PROCESS**Koch M., Meerkamm H. - *University of Erlangen-Nürnberg (DEU)* 317

The design methodology is assumed to be known and used during every process of design. But very often theory and practice differ in many points. To make these points clear this paper monitors a designer proceeding through a real design task. This analysis results in the cognition that most problems occur especially in the early stages of design, when the designer tries to use the design methodology. Especially the steps of defining functions, arranging functions and drawing conclusions from the function structures are a source for mistakes and wrong decisions. This calls for a more intensive use of software tools which support the designer in using and taking advantages from the design methodology.

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**DESIGN SUPPORT BY IMPROVING METHOD TRANSFER - A PROCEDURAL MODEL AND GUIDELINES FOR STRATEGIC PRODUCT PLANNING IN SMS ENTERPRISES**Braun T., Gausemeier J., Lindemann U., Orlik L., Vienenkötter A. - *Technische Universität München (DEU)* 143

To ensure sustainable business success, SMEs have to improve their strategic competence. This is actually achievable by integrating strategic product planning into their corporate management. In tight cooperation with "typical" SMEs, we elaborated a procedural model for systematic strategic product planning, which consists of following crucial steps: As the result of a short strategic analysis a strategic direction is selected. An adequate generic guideline, consisting of process-steps is assigned to the strategic direction. Different method alternatives are assigned to process-steps. Supported by means of method selection and adaptation the suggested generic guideline gets adapted to the prevalent user- and situation-specific requirements.

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## REFLECTIONS ABOUT REFLECTIVE PRACTICE

Eder W. E., Hubka V. - *Royal Military College of Canada (CAN)* 177

Reflection is an essential characteristic of designing, but only a part of that process. Few attempts have been made to specify what questions should be useful in reflection. This paper brings the concept of reflection into a meaningful relationship to other design-related processes. Connections to several models of problem-solving and to more complete models of designing are drawn, especially to Design Science and the Theory of Technical Systems. In this way, we hope to show where and how reflection can be usefully employed during the possible design processes for systematically and methodically conceptualizing and embodying the technical system, and for other forms of designing.

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## KNOWLEDGE AND DATA REUSE IN SHIP SYSTEM DESIGN AND ENGINEERING

Nieuwenhuis J. J., Nienhuis U. - *Schelde Naval Shipbuilding (NLD)* 441

The objective of this paper is to find the most effective way of implementing knowledge and data reuse in ship design and engineering, to achieve a decrease in ship development time and costs. The paper focuses at ship systems and treats the different kinds of knowledge and data involved in ship system design and engineering, a number of possibilities to implement reuse and the consequences of reusing knowledge and data. In this paper a qualitative approach is followed, however further work is underway to implement a more quantitative approach to make a better comparison between the different reuse possibilities.

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## GEOMETRIC MODELLING OF MECHANICAL PARTS AFFECTED BY SHAPE ERROR

Di Stefano P., Di Angelo L. - *University of L'Aquila (ITA)* 157

In this article an original method for automatic generation of CAD models affected by shape errors is described. The model is suited for the generation of a random error conditioned by some requirements. In order to analyse the possibility to control the main characteristics of the geometric error, some experiments has been conducted for different values of the model parameters. The results of these experiments have been used to define a function that correlates the model parameters with the technical parameters. The proposed method can be used in the analysis of industrial applications where the shape error affects the product functionality. A promising utilisation is in Monte Carlo simulations to generate the instances to be analysed.

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## PROPERTIES AND QUALITY OF TECHNICAL SYSTEMS

Hosnedl S., Vanek V., Stadler C. - *University of West Bohemia (CZE)* 279

Any technical product - technical object system (TS) and its life cycle processes are needed to fulfil many requirements, which can be stated, generally implied or obligatory. This paper presents a systematic and user friendly knowledge support for the engineering design of TS to achieve more transparent relations among these requirements, relevant TS properties/quality characteristics, and the required TS life-cycle quality, cost and time. The final aim is to improve the efficiency and effectiveness of the TS operational and other TS life-cycle processes. The principles of knowledge support, which has proved its usefulness in many university and industrial engineering design projects, are systematically derived and explained.

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## MODELS, METHODOLOGY AND FINDING FOCUS: DEALING WITH THE CHALLENGES OF PhD RESEARCH

Flanagan T.L., Jänsch J.F.P. - *Darmstadt University of Technology (DEU)* 297

This paper discusses the summer school on engineering design research from a student perspective. The two-week course is aimed at postgraduate students who have completed 30-40% of their planned research duration. During the course, it became apparent that many design-research students encounter similar challenges. The course provided models and techniques aimed at clarifying the scope and contribution of the research work as well as research methodology to structure the PhD project. Lectures on design theory, advice from course leaders and overview gained from general discussions were also invaluable. We firmly believe that the course will strongly influence and improve our own research and that of the other students over the coming years.

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**THE BENEFITS OF PREDICTING CHANGE IN COMPLEX PRODUCTS: APPLICATION AREAS OF A DSM-BASED PREDICTION TOOL**

Jarratt T., Eckert C., Clarkson P.J. - *University of Cambridge (GBR)*

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Most designers struggle to fully understand a complex product. Throughout the entire life cycle of a product engineers are frequently required to predict how changes could propagate. Currently, few methods or tools are available to support this process. This paper describes part of an ongoing research project that aims to support designers by (1) giving them a better understanding of the linkages between components within their product and (2) helping them to assess the risk of change propagation. The paper gives an overview of a DSM-based method of modelling products, discusses other potential applications of it within the design process and describes a developmental computer tool for visualising linkages and predicting change propagation.

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**EVALUATION OF A LIFE CYCLE ASSESSMENT TOOL - ADJUSTING THE SOFTWARE DEVELOPERS' VIEW TO THE EXPECTATION OF THE USER**

Felsing T., Dick M., Birkhofer H., Rüttinger B. - *Darmstadt University of Technology (DEU)*

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In this paper, the results of the evaluation of a Life Cycle Assessment Tool - the "Product Develop Environment (PDE)" - are presented. This evaluation was done with a mix of qualitative and quantitative methods and included a comparison of ecological product development experts and novices. Overall, the results give some worthy indications about the usability of the PDE. As the data show, some further revision steps have to be done. The application of a mix of quantitative and qualitative methods was very successful because the different types of data complement each other very well. The comparison of experts and novices shows interesting differences between their assessments and their well-being after working with the PDE.

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**STUDIES OF INTUITIVE INTERACTION EMPLOYING OBSERVATION AND CONCURRENT PROTOCOL**

Blackler A., Popovic V., Mahar D. - *Queensland University of Technology (AUS)*

135

This paper explores intuitive interaction with products from a methodological standpoint. Intuitive use of products involves utilising knowledge gained through other products or experiences. The nature of intuitive interaction presents certain problems with its study because it is product features that users have relevant prior experience with rather than a whole product. The challenge was to find ways of recording and coding observations so this level of detail could be extracted from user tests. This was accomplished using specialist observation software. These methods have twice proved successful in studying this complex topic and gaining reliable results. Details of the methods used and implications of the results gained are discussed.

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**AESTHETICS IN A FORMALISED REVERSE DESIGN PROCESS**

Faisst K.G., Dankwort C. W. - *University of Kaiserslautern (DEU)*

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Aesthetics of a product cannot be considered as independent of the person, looking at or acting with it. This leads to the approach to treat both person and object as one unit (in analogy to Quantum physics). The concentration on product properties is important for the concept of Engineering in Reverse: the product properties themselves are the key to control/optimize the design (not any longer the modification of CAD geometry). Here, aesthetic shape design can be done in the same process step together with engineering design. A developed structure for aesthetic product design is mapped with a formal approach of Engineering objects (EO) to prove formal consistency. This is of interest to open an extended use of EO in the product life cycle.

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**GUIDELINES FOR THE DEVELOPMENT OF INDIVIDUALIZED PRODUCTS**

Ponn J., Baumberger C., Lindemann U. - *Technische Universität München (DEU)*

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In order to cope with higher competition and the necessity of increasing customer orientation, companies have begun to individualize their products. This trend brings about new challenges for product development. Flexible product structures enable a fast derivation of individualized products, the so-called product adaptation. Adaptation processes demand for methodological support in order to comply with general and specific requirements, and to guarantee that adapted products fit exactly to specific customer needs. Here, design guidelines promote efficient processes and high product quality. This contribution presents an approach dealing with the form and the content of design guidelines supporting the individual product adaptation process.

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## THE TERM PLATFORM IN THE CONTEXT OF A PRODUCT DEVELOPING COMPANY

Kristjansson A. H., Jensen T., Hildre H. P. - *Norwegian University of Science and Technology (NOR)* 325

In the paper, we demonstrate that 1) there exist a number of different types of platforms, 2) within the same type of platform, there often exist ambiguous nuances, and 3) the term platform has an imprecise meaning. We find, that to objectively evaluate, and benchmark, platforms, a terminology has to be defined which takes account of platforms existing in different contexts and scopes. The lowest common denominator for the platform concepts we presented in the paper is used as a basis for a new definition of a platform; it is a collection of assets that are reused to achieve a strategic advantage. We argue that it serves well as a starting-point to assess the performance of platforms in product developing organizations.

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## ASSEMBLY-ORIENTED DESIGN IN AUTOMOTIVE ENGINEERING

Vielhaber M., Burr H., Deubel T., Weber C., Haasis S. - *DaimlerChrysler AG (DEU)* 539

The current engineering process in the automotive industry is chiefly part oriented. What counts most, however, is the optimisation of complete assemblies. Assembly-oriented design (AOD) is introduced as an approach which optimises the development process in a way that benefits both development itself and downstream processes. It breaks with the paradigm of part-orientation prevailing today and promotes a top-down approach towards the creation of complex assemblies; it combines different aspects of methodology and engineering system design. Whereas design for assembly (DFA) subordinates development to the optimisation of the production process, AOD promotes an integrative approach which offers potentials along the complete process chain.

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## METHODS OF MONITORING THE TESTING STATUS OF VARIANT RICH PRODUCTS

Baumberger C., Lindemann U., Pulm U., Skull M., Stetter R., Kaindl W. - *Technische Universitaet Muenchen (DEU)* 111

Today development projects in automotive industry are highly distributed and several packages are completely handled by system suppliers. Moreover the illustrated situation is aggravated by an increasing number of models and variants. Two methods for supporting designers in that situation will be introduced. The first focuses on a test design which helps to select crucial variant characteristics and to plan the experimental set up accordingly. The second compiles information on product tests regarding organisational resources, required prototypes, milestones, testing results and integrates them into a common information platform for the overall controlling of the design project status.

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## PRODUCT PLATFORM PERFORMANCE IN MEETING WITH THE MANUFACTURING

Jensen T., Hildre H. P. - *Norwegian University of Science and Technology (NOR)* 309

The existing product family design methods focusing mainly on customer satisfaction and "part" reuse and marginally on the production. This paper presents a method evaluating the match between the product platform and the production. The Manufacturing Change Performance Index (MCPI) analysis is based on mapping the customer needs to engineering needs and hence finds the design variation parameters. The manufacturing is then checked against this proposed variations and their extreme values by an evaluation, leading to the MCPI. This method makes it possible to explore different production processes for the platform, explore the solution space for different platforms and finding out how flexible the production equipment is.

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## COMBINING DESIGN AND CREATIVITY TOOLS

Lambeck P., Bertsche B. - *University of Stuttgart (DEU)* 1121

Different levels of creativity are required during the design process. Since most creativity techniques rely on the interaction of several people, the aim of the project described in this paper was to introduce creativity tools into a design system for distributed designers working together on one task using a common, new type of design system. The different tools and their adaptation for designers in different location is described and the experiences with these sessions are discussed. It has been shown that creativity tools can be used for distributed designers with some limitations depending on the available means of communication but overall good results.

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## MODELLING OF PRODUCT-SERVICE SYSTEMS (PSS) BASES ON THE PDD APPROACH

Weber C., Steinbach M., Botta C., Deubel T. - *University of Saarland (DEU)* 547

The term "Product-Service Systems" (PSSs) was recently coined for products consisting of material components as well as services (non-material components). They are of increasing interest from a business point of view. Neither in science nor in practice, however, an integrated approach to describe PSSs and the processes to develop them (a "design theory and methodology of PSSs") exists. In this paper, the authors outline first ideas for a systematic description and integrated development of PSSs. They are based on findings from engineering as well as business administration sciences, the concept of Property-Driven Development (PDD), originally for material products only, presenting a useful framework for the integration of viewpoints.

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## PRECONCEPTIONS ABOUT DESIGN AMONG DESIGNERS AND CLIENTS

Lauche K. - *University of Aberdeen (GBR)* 343

Preconceptions about design influence how designers see their own role and how clients and colleagues from other disciplines perceive them. Industrial designers in particular often feel that their environment does not value their contributions. Four cases studies from collaborative projects between a university and companies were analysed by interviewing both parties. The transcripts were content analysed for each case to extract preconceptions. The results indicate a shift in the design task from products to the design of processes and the use of software. They also show the need for commercial awareness and timely responses. Potential consequences for collaborative projects and design education are discussed.

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## RECOGNIZING THE NEEDS FOR IMPROVING THE PORTFOLIO MANAGEMENT FOR NEW PRODUCTS IN THE INDUSTRY

Larsson F., Mortensen N.H., Andreassen M.M. - *Technical University of Denmark (DNK)* 337

The lack of sound portfolio management for new products increases the probability that the company's product portfolio will have a potential low business value. This research reveals that portfolio management for new products seems to be a problem in the Danish industry. Existing methods described in the literature do support many important dimensions. However, the linkages between the dimensions are frugal which makes it difficult to explicate and understand the linkage from technology to a business system. The authors assume that the existing approaches to portfolio management can be enriched by adding models that explicitly show leitmotif from technology to a business system. Aspects to further clarify are identified.

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## A METHOD AND A COMPUTERIZED TOOL FOR SERVICE DESIGN

Sakao T., Shimomura Y. - *Mitsubishi Research Institute, Inc. (JPN)* 497

Although services are getting more and more focus in industries, very few researches on dealing with services from the viewpoint of design have been achieved. This paper aims at proposing a service design method and a computerized tool for service design based on the model which the authors already proposed. The proposed design method contains detailed procedures to complete a service model. The implemented tool enables designers to describe and store service models. It was shown that both of the method and the tool have a potential to help service designers, but further verification is needed through applying service examples.

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## ARE YOU BEING SERVED? RESEARCH INTO SERVICE DESIGN MANAGEMENT COMPARED TO PRODUCT DESIGN AND THE DEVELOPMENT OF BS 7000 ...

Hollins B. - *University of Westminster (GBR)* 273

Research of managers responsible for the design process in the service sector around London show they are operating at a suboptimal level and as such, are not developing their new services effectively. These findings will be described. The results were used in the compilation of the new British Standard on the management of service design. The resulting more user friendly' structure will be presented to the conference. In services by definition, production and consumption occur together, the customer often interacts directly with the supplier. Interface differences observed in the delivery of services within developed and developing countries will be described. Conclusions have been drawn that can improve the overall design of services.

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## **'FUTURE FACTORIES': SUPPORTIVE TECHNOLOGIES AS CREATIVE PROCESSES**

Atkinson P., Unver E., Dean L.T - *University of Huddersfield, UK (GBR)*

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Envisage a future where you could visit a 'Future Factories' website, which would display a range of products in constant metamorphosis. At any given moment you could pause the animation and view a rotatable, three-dimensional computer model of the product. If you wished, you could then order the design, and the product you had selected would be manufactured automatically, exactly as you had seen it on screen, and delivered directly to you. An original. A one-off. A work of art? The outputs from this practice-based research project consist of a number of inspirational products which have been exhibited internationally. This paper addresses the technical, theoretical and contextual issues raised by the content of the project.

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## **BIONIC DESIGN - THE HUMAN TOUCH OF TECHNOLOGY**

Thallemer A. - *Festo AG & Co. KG (DEU)*

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The term "Bionik" stems from BIOlogy and the German term for technology: "techNIK". Opposite to biomimicry, where the nature is just serving as role model to be copied, Bionic stands for natural inspiration sources. The latter derives its ideation from the living world not by mere copying but by rational, scientific reasoning deduced from those examples. Advantage being, that nature has had billion years of development time and trial & error feedback loops in order to perfectly optimize its "products". Biomimesis is only depicting in a superficial, phenomenological approach feigned similarities between nature and its technical counterpart. See how nature has inspired our problem solving: The Human Touch of Technology.

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## **COMPLEXITY MODELS IN DESIGN**

Earl C., Eckert C., Johnson J. - *Open University (GBR)*

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Complexity has many formal and informal meanings. Several formal models of complexity can be applied to designs and design processes and conversely. First designing provides insights into how to respond to complex systems – how to manage, plan and control them. Second, the overwhelming complexity of many design projects lead us to examine how better understanding of complexity science can lead to improved designs and processes. This is the focus of this paper. First an outline of some observations on where complexity arises in design is presented, followed by a discussion on the development of scientific and formal meanings of complexity. We indicate how these can help in understanding design processes and improving designs.

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## **DESIGN, PRODUCT DEVELOPMENT, INNOVATION: ALL THE SAME IN THE END? A SHORT DISCUSSION ON TERMINOLOGY.**

Marxt C., Hacklin F. - *ETH Zürich (CHE)*

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The spectrum of terminology to describe this professional and academic field is manifold. Terms like design, engineering design, product development, and innovation are widely accepted and used. Whereas some of these terms are common in the business area, others are rather used in the engineering field. Based on the terminologies from exponents of the design science as well as other communities, the paper tries to broaden the view on what "design" means. Additionally, the paper highlights the accordance and differences between the terms design, product development and innovation, and attempts to derive implications for organising research practice in such a broader context. The paper should be seen as starting point for a wider discussion.

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## **PRODUCT-DEVELOPMENT COMPLEXITY METRICS: A FRAMEWORK FOR PROACTIVE-DFA IMPLEMENTATION**

Rodriguez-Toro C.A., Jared G., Swift K. - *Cranfield University (GBR)*

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Designers need computer support in the earlier stages of the process when decisions have a more significant effect on outcomes. In this paper a taxonomy of assemblability and manufacturability analysis is proposed. This provides a framework for the definition of product complexity metrics which may be used to evaluate a design as it is developed. A proposed assembly complexity metric related to product structure is elaborated in more detail.

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## INFORMATION REQUESTS AND CONSEQUENT SEARCHES IN AEROSPACE DESIGN

Auricchio M., Wallace K. M. - *Cambridge University (GBR)*

105

Making requests for information and undertaking searches to satisfy them is an essential part of the design process. The way in which engineering designers make requests and how they interact with external information repositories is explored by conducting empirical research in a large industrial aerospace company. Coding schemes for the context of a request and the sources used by engineering designers were developed, however for the type of a request a previously published coding scheme was adopted. Findings show that the context and type of a request significantly influence which access route is selected to answer a request.

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## DRIVING PRODUCT COMPLEXITY AT AN OPTIMAL DEGREE BY A SET OF KEY FIGURES

Graessler I. - *Robert Bosch GmbH (DEU)*

233

Using an automotive supplier of electronic and mechatronic components as an example, a solution approach of Complexity Controlling in Product Development is described. Its principle is based on a set of key figures continuously balancing planned and realized re-use. Nature of product complexity implies that it may never be fully described or counted. However, the proposed set of key figures offers a pragmatic solution approach for daily development. Re-use is enhanced by creating transparency and comparing planned with realized degree of re-use. Thus product complexity is pro-actively driven to an optimal degree and high cost reduction potentials are opened up.

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## SIMULATION IN PRODUCT DESIGN: AN ITERATIVE QUESTION-ANSWER DRIVEN PROCESS

Andersson K. - *KTH (SWE)*

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In order to support a question-answer driven simulation process, a design process model capable of describing problem statements, model specifications, simulation models and problem answers as separate objects is introduced. This enables a granularity level of information that allows traceability on an object-to-object level between the attributes in the requirements specification and the estimated product properties. This also offers traceability and reuse of partial result created during the verification of a specific requirements attribute as well as a possibility to study the effects that changes in the requirements specification have on product properties.

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## ADAPTIVE SYSTEM MANAGEMENT

Naumann T., Vajna S. - *Otto-von-Guericke University Magdeburg (DEU)*

435

This paper considers product development as a complex, dynamic system. Within this system, certain characteristics of an object system are synthesised within several processes by an action system in order to fulfil required properties. The high dynamics of these processes are determined by several contradictions: From the different systems, the requirements and their ongoing changes as well as from the interrelation of intuitive/opportunistic and structural/methodical episodes in engineering design. With the new approach described here, which has been derived from system theory and complexity management, a holistic, adaptive feedback planning and managing becomes possible.

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## C-K THEORY IN PRACTICE : LESSONS FROM INDUSTRIAL APPLICATIONS

Hatchuel A., Le Masson P., Weil B. - *Ecole des Mines (FRA)*

245

Hatchuel and Weil presented recently a new design theory, called C-K theory. In this paper we discuss applications of C-K theory to innovative and contrasting design situations: i) A science based product (Mg-CO2 engines for Mars exploration) ii) Creativity based products ("smart tools" developed by a start-up). We show how C-K theory can have both a descriptive-interpretative power and a prescriptive-normative power for innovative design activities: C-K theory helps to control the structuring of upstream design phases and it supports the simultaneous exploration of functions (constraints) and design parameters. The theory helps to highlight two different design strategies that fit each design situation (depth-first or breadth first).

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## DIGITAL DESIGN STRATEGIES

Bier H. - *Delft University of Technology (NLD)* 123

This paper explores the implications of digital technology in architectural design, looking at techniques of digital design and their influence on design thinking. It not only explores 3D modelling tools and their intrinsic morphogenetic features but redefines strategies of design and examines their implementation in education. It implies critical analysis and assessment of 3D modeling programs as design tools employed in a workshop involving architecture students from the universities of Innsbruck and Karlsruhe.

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## AUTOMATING THE PRODUCT DESIGN CYCLE FOR CUSTOM MADE PRODUCTS

Bilalis N., Katsigiannis J.A., Georgilakis P.S., Souflaris A.T., Antoniadis A. - *Technival University of Crete (GRC)* 129

The reduction of development time and cost is a very important task in manufacturing industry. We evaluate a CAD/CAE application for automating the whole design process. The process is modelled using Top-Down design methodology and skeleton models. Product design depends on limited input parameters, obtained from product specification and customer needs. Using parametric design, the 3-D solid model of the product assembly, the drawings, the customised BOM for all subsystems, and the G-Codes for all sheet metal parts are automatically calculated. The new methodology significantly contributes to the complete automation of the design. The superiority of the proposed methodology is obvious comparing with the existing 2-D design methodology.

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## INFORMATION - A TAXONOMY AND INTERPRETATION

Eder W. E., Hosnedl S. - *Royal Military College of Canada (CAN)* 169

This paper presents the authors' opinions on the nature of information in order to explore a consistent set of terminology for this area. The contents of information can concern tangible objects and process objects. The constituents of information include data, observations, evidence, rules, theories, knowledge, experience, etc. Various processes form the relationships among these constituents to show how information can be transformed and codified. Information can be stored in tangible records. A model of communication is proposed. Characteristic dimensions of messages show their types, modes, location, structuring, complexity, etc. Using information leads to knowing, information in the human mind.

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## EXPECTED AND REALIZED COSTS AND BENEFITS WHEN IMPLEMENTING PRODUCT CONFIGURATION SYSTEMS

Edwards K., Riis J. - *Technical University of Denmark (DNK)* 183

This paper reports preliminary findings from a study of a number of Danish firms, which have or are in the process of implementing product configuration systems. 20 firms were selected and 15 responded positively and as of writing 10 interviews have been completed. Data are presented which illustrate the relative costs and benefits in each firm. It is observed that expected and realised benefits are consistent: 1) Improved quality in specifications, 2) Using less resources, and 3) Lower turnaround time.

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## DESIGN BY FUNCTION: A METHODOLOGY TO SUPPORT DESIGNER CREATIVITY

Giampa F., Muzzupappa M., Rizzuti S. - *University of Calabria (ITA)* 225

The methodology, described in this paper, aims at offering the necessary potential to support the conceptual design phase, providing the typical guidelines of the functional approach, and leading the designer to think in terms of functions and not in terms of components, in order to allow him/her to work on a wider level of abstraction where his/her creativity is more prolific. For this purpose, a classification of mechanical and electro-mechanical parts has been carried out on the basis of the performed function in an assembly.

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**AN EVOLUTIONARY APPROACH FOR FUNCTIONAL LEVEL CONCEPTUAL DESIGN OF PRODUCTS**

Guroglu S., Erden A. - *Atilim University (TUR)*

239

The conceptual design phase of the product development period involves the completion of functional, structural and behavioural construction of the artifact. A drawback of designing the artifact in functional domain is the possibility of generation of physically unrealizable solutions. The automation of the conceptual design phase at functional level necessitates the development of an intelligent search strategy. For this purpose, this paper introduces an evolutionary strategy and its computer implementation for the functional level conceptual design of engineering products.

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**DESIGN RESEARCH FOR INNOVATION: INTEGRATING CREATIVITY AND PRODUCT DEVELOPMENT PROCESSES**

Ingaramo M. O., Rampino L. - *Politecnico di Milano (ITA)*

285

This paper is to define the role of the Product Design Research Unit of the Politecnico di Milano within new products development processes. We illustrate the phases that make up the design research activity conducted by the Research Unit. Our aim is to show how product innovation can be reached starting from a clear definition and analysis of the context surrounding the product and using the design activity as a creativity tool. We provide two examples of our research activity showing how the RU leads the product innovation process. We suggest that Design and Creativity Management inside companies should deal not only with internal resources, but also with external resources and tools that can be found into academic research prerogatives.

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**DEFINITION AND DESCRIPTION OF VARIABILITY IN CONCEPTUAL DESIGN OF MODULAR PRODUCT FAMILIES**

Kunz A., Sekolec R., Meier M. - *Swiss Federal Institute of Technology Zurich (CHE)*

331

An often-used measure to achieve a more cost-effective realisation of product variety is the development of modular product families. Due to the fact that 70% of the product costs are determined in early stages of the design process, it is important to define and describe the required variability of the product family in an early process step of product design. Based on the described variability different measures for assessing, controlling, avoiding and reducing this variability can take place on a conceptual design level. By characteristics and parameter values a conceptual definition and description of the variability of modular product families can be accomplished. Based on this description an adequate product structure can be designed.

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**INTEGRATING OPERATIONAL COMPLEXITY IN DESIGN PROCESSES AND IMPROVING DESIGN RISK IDENTIFICATION**

Lauche K., Busby J.S., Bennett S.A. - *University of Aberdeen (GBR)*

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Simplifying strategies are useful and often necessary to make the design process tractable. They are also a generic human reaction to cope with complexity. Yet if a design is modified or put to use in combination with other designs and in interaction various human operators, some of these assumptions may be invalidated, leading to serious risks. The midair collision over Überlingen in 2002 is discussed as an example where members of multiple organisations and several layers of defence systems failed to interact as intended. Based on document analysis, aspects of complexity and presumed simplifying strategies are analysed. A method of improving risk identification by reflection on simplifying strategies is proposed.

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**ENGINEERING DESIGN PROBLEM IN A CO-EVOLUTIONARY MODEL OF THE DESIGN PROCESS**

Lonchamp P., Prudhomme G., Brissaud D. - *Grenoble University (FRA)*

361

While traditional stage-based models of the design process assume it starts with a design problem definition that prescribes downstream activities, another approach has been emerging, that considers co-evolution of both the problem and solution representations. This paper proposes a so-called co-evolutionary model of the design process based on four activities. A design corpus is used to illustrate the content of this contribution and to validate the relevance of the co-evolutionary paradigm. This model is eventually questioned to support the use of design tools in better accordance with the issues exposed, i.e. dynamic and cognitive aspects of the design process, together with the nature of design problem.

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### A PROCESS MODEL FOR DESIGNING FUZZY PRODUCT STRUCTURES

Maurer M., Pulm U., Lindemann U. - *Technische Universitaet Muenchen (DEU)* 383

The strategy of mass customization tries to satisfy each customer with his individual designed product and to keep up with mass produced products in product quality, prices, and delivery time. To meet these demands it is necessary to adapt conventional product structures and to put the focus on flexible pre-designing and integration of degrees of freedom. With the presented work we introduce a process for designing highly variable product spectra and adapt the methodology of established matrix analyses. Starting from a collection of product elements or a basic product, the designer generates sub-matrices by element type and is able to identify possible conflicts due to varied criteria, e.g. structural embedding or degree of variability.

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### ADAPTING A DESIGN PROCESS TO A NEW SET OF STANDARDS – A CASE STUDY FROM THE RAILWAY INDUSTRY

Meissner M., Meyer-Eschenbach A., Blessing L. - *Technical University Berlin (DEU)* 401

Since coming into effect in 1999, EN 50126 ff. define procedures for the management of the reliability, availability, maintainability and safety (RAMS) of railway applications. As a result, companies need to verify that not only their products, but also their design process has been in accordance with this standard. This study explores the factors that contribute to the difficulties a major German manufacturer of railway applications is currently experiencing in introducing a new design process that has been adapted to comply with the new standard. These difficulties are mainly expressed by increased development time and costs – but possibly not only due to obvious reasons such as increased testing and documentation efforts.

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### MATHEMATICAL ANALYSIS OF INFORMATION FLOWS IN DESIGN AND EDUCATION

Miki H., Kakuda Y., Kikuchi M. - *Kenmei Women's Junior College (JPN)* 409

Education seems to be closely parallel to design. In design activities, we try to seek a solution of design by which we can produce entities according to specifications. Similarly in educational activities, we try to plan an educational practice which enables students to behave according to educational objectives. We gave the mathematical formulation of education; furthermore we found that design and education have the structure in common in our formulation. By focusing on normative methods to education in our formulation, we try to clarify the role of normative aspects of education, which is concerned to the effectiveness of education. And then, we show that an information flow in education must be regarded as the normative part of it.

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### VIRTUAL PHYSIOLOGICAL ANTHROPODYNAMICS

Muftić O., Milčić D., Baksa S. - *University of Zagreb, FMENA (HRV)* 429

A new biomechanical three-dimensional (3D) model for the human body based on computer-generated virtual model is proposed. Using maps obtained from the special kinds of photos of the body of a real subject, it is possible to attribute personality to the virtual character, while computer animation offers dynamic of movements and characteristics within the confines of space and time of the virtual world. A new approach to computer-generated animation of virtual 3D characters called «VatoSABA» (1. version) using in one software package minimal costs and ease of operation, characteristic for key frame animation, as well as accuracy and speed, that is characteristic for motion capture systems. As an example is presented simple 3D model of the human jaw.

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### GENERIC PRODUCT STRUCTURE OF THE CONFIGURABLE PRODUCT

Pavličić D., Štorga M., Bojčetić N., Marjanović D. - *University of Zagreb, FMENA (HRV)* 459

This paper concentrates on the generic product structure of the configurable product. A generic product structure refers to the data description that represents modular product architectures, requirements, constraints and their values. The modular architecture used in the generic product structure consists of the generic modules and the instances of the generic modules. The generic modules enable defining a configurable product on which all variants of the product family are based. Further diversification of generic modules into module instances enables defining each module instance by the customer's demands. A concept of the generic product structure is developed according to the STEP standard.

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### IMPROVING PRODUCT DESIGN VIA A SHAPE GRAMMAR TOOL

Prats M., Garner S., Jowers I., Earl C. - *The Open University (GBR)*

477

Modern computer methods of design provide a powerful tool for communicating design concepts in a quantitative manner, but lack the flexibility to allow designers freedom to thoroughly explore a design space. On the other hand, traditional methods such as sketching allow designers freedom to quickly explore ideas but provide no quantitative information about a concept. We present a shape grammar tool that has the potential to bridge the gap between traditional sketching techniques allowing designers the freedom to explore a design space, whilst providing quantitative information about the designs produced. Examples from car design are described to illustrate the application of the shape grammar tool.

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### A NEW CONCEPT OF SUPPORTING COMPLEX MODEL BUILDING IN VAGUE DISCRETE INTERVAL MODELLING

Rusák Z., Horváth I. - *Delft University of Technology (NLD)*

491

To support shape conceptualization vague discrete interval modelling is proposed. Dedicated operators (i.e. positioning and constrained instantiation operators) are being developed to assist the designer in building complex products that cannot be parameterized. Position operators facilitate specification, maintenance and modification of positional relations between interval shapes. Constrained instantiation operator supports selecting various product alternatives and at the same time maintaining positional and geometric constraints of the product. This paper presents the fundamentals of positional relations between vague shapes, the concept of position and constrained instantiation operators, and their application to industrial design.

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### QUESTION-DRIVEN MODELING

Sellgren U. - *Royal Institute of Technology (KTH) (SWE)*

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Models are important tools in any complex cognitive activity. Modeling, which is an act of structuring and simplifying information, is a bottleneck and a significant barrier in most model-based engineering approaches. This paper presents an approach to question driven modeling as an enabler of model-based design reasoning. It is based on scenario activity modeling and utilization of product data management (PDM) technology to manage the information objects that are created and used in the scenario activities. Tests of question-driven modeling have been performed on an industrial case and the tentative results are promising.

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### DEFECT IN POLYMER MATERIALS AS DESIGN PROCESS CONSEQUENCE

Španièek Ð., Indof J. - *University of Zagreb, FMENA (HRV)*

511

Due to their good properties polymer materials (both polymer and polymer composites) are present in almost all area of human activity. Their final properties are processing-sensitive. In order to detect possible defect as processing consequence optical polarizing microscope was used to analyse tested materials (polybutene, poly (butylene terephthalate). Furthermore, composite voids content and its influence on properties were obtained.

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### TRUSS DIMENSIONING WITH AN UNCERTAINTY REDUCTION PARADIGM

Yannou B., Hamdi A. - *Ecole Centrale Paris (FRA)*

555

Constraint Programming (CP) over reals are sophisticated evolutions of interval analysis well appropriate to model and propagate uncertainties between design and performance variables during the preliminary design stage. The resulting approximate design space is easy to represent and may bring a better comprehension of the often complex coupling between variables and of the nature of trade-offs. This article details the scenario of an interactive preliminary dimensioning of a truss structure in a CP environment. The interactive nature of communication between the designer and its emerging design, the flexibility for hypothetical reasoning and the synthesis capabilities (back-propagation from performances to design parameters) are revealed.

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