
THE PROTO-THEORY OF DESIGN: THE METHOD OF ANALYSIS OF THE ANCIENT GEOMETERSKoskela L.J., Kagioglou M. - *University of Salford (GBR)*

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It is contended that the ancient method of analysis and synthesis, developed originally by Greek geometers, provides a proto-theory of design, which unfortunately has largely been forgotten in the modern period. For justifying this claim, six central features of the method of analysis and synthesis are discussed and compared to recent developments in design theory and methodology. It is shown that various issues covered by the method analysis and synthesis have recently been rediscovered in the design science, but without any connection to it. It is argued that further development and unification of the design science requires that we return to the proto-theory of design and start to validate, criticize and expand it.

THE HISTORICAL HERITAGE: A TOOL IN THE ABSTRACTION PROCESS IN THE MODERN DESIGNRosa F., Rovida E. - *Politecnico di Milano (ITA)*

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The abstraction process is very important in innovative design, since it could help the designer to invent new solutions, instead of following known procedures and solutions. In this paper, the authors will develop some proposals about using constructive solution historical evolution studies in overcoming this designer psychological inertia. A search among historical constructive solutions would lead the designer to the individuation of the historical evolution of the specific problem solutions. Studying this evolution, the designer could derive the general principle and then follow an abstraction process. Then, according to the TRIZ method, the designer could find a general solution, and finally a specific solution.

LEONARDO DA VINCI – PRECURSOR OF ENGINEERING DESIGNTarelko W. - *Gdynia Maritime University (POL)*

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In our opinion, engineering design has its precursors in the Renaissance. The most prominent representative of this period was Leonardo da Vinci. One of the most innovative aspects of Leonardo's engineering design contribution is his analysis of the components of machines. He was the first to regard machines not as an indivisible whole, but as an assemblage of distinct parts. He reasoned that by understanding how each separate machine part worked, he could modify them and combine them in different ways to improve existing machines or create inventions no one had ever seen before. We could formulate the assertion that Leonardo was a precursor of the innovative method searching new solutions by means of the so-called morphology matrix.

INDUSTRIAL RELEVANCE OF DESIGN SCIENCE - AN EMPIRICAL STUDYPreiss M., Avak B., Imelli P. - *ETH Zürich (CHE)*

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The industrial relevance of design science has always been vividly discussed. That is why an empirical study on the industrial perception of design science in the Swiss manufacturing industry has been carried out. Ten CTOs and development leaders from leading Swiss companies have been interviewed regarding the level of recognition, knowledge transfer, and topics of design science. Generally, there seems to be no clear idea on design science in industry despite its topics being considered as important and interesting. Knowledge transfer primarily occurs through applied research projects with academia. Academic publications are hardly read in industry. Based on these findings, several avenues for industry - oriented research are identified.

THE DESIGN OF SCIENCE BASED PRODUCTS: AN INTERPRETATION AND MODELLING WITH C-K THEORY

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The paper addresses the design of Science Based Products (SBPs): these products need the efficient introduction of scientific research within the design process, as well as functional and testing innovations. First, we show that classic design theories are not adapted to SBPs which require more powerful design theories like C-K theory (Hatchuel and weil 2003). Second, we model the design of SBPs as a sequence of Design spaces, ie specific subsets of the initial SBP concept where design learning is possible. This can be easily and fruitfully modelled with C-K theory, as it allows several learnings to interact with conceptual expansions in the same design process. We discuss these findings in a real design project: new bio-climates in cars.

TRANSLATION BETWEEN LINGUISTIC STRUCTURES AND SHAPE STRUCTURES FOR BIDIRECTIONAL DESIGN

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In upstream design, designers generate new images. This process is important in forming the whole design object. In this process they use verbal image and nonverbal image in their mind. We hope to support design by matching between language and shapes. For this purpose, we believe the bottom-up approach is better because designer's mind is dynamic. The Statistical Machine Translation is known in Natural Language Processing as such method. We proposed Linguistic Relational Model (LRM) to analyze verbal data, and chose CSG as nonverbal data. Then we match between LRM and CSG by statistical approach. In order to evaluate this method, we create transcription data for LRM and calculate the accuracy of our method.

RESEARCH APPROACHES ON PRODUCT DEVELOPMENT PROCESSES

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For researchers to be able to understand what happens in a product development project with its complex nature, to be able to reflect upon it, and to provide useful recommendations for improvements of development processes, a close participation in ongoing processes is crucial. An Insider Action Research (IAR) approach facilitates the possibilities to contribute both to science and to the art of practise. Performing IAR studies means that the researcher is within an excess of data flow difficult to handle. (S)he also gets much insight into the game behind the scenes (tactics, politics, gossips, relations, etc.), which can cause publicity and loyalty problems towards the people in the project and the company in which the project takes part.

A METHOD TO CHART THE STRUCTURE OF DESIGNERS' CLAY MODELING PROCESSES

Wiegiers T., Dumitrescu R., Song Y., Vergeest J.S.M. - *Delft University of Technology (NLD)*

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CAD is used for the design of nearly any product, but not often in the earliest phases of design. Physical modeling is still very popular for ideation. What makes physical modeling different ? A method is developed to investigate what types of activities are performed during physical modeling. The method is applied on a clay modeling process for verification. The method it is possible to identify activities, activity patterns and repetitive sequences of patterns. Finally, parts can be identified that consist of the sequences that were used to model a certain shape element. This data can, for example, be used to compare different modeling methods and to propose new CAD methods that connect to the physical skills of the designer.

THE DEVELOPMENT OF THE GUIDELINE VDI 2221 - THE CHANGE OF DIRECTIONJänsch J., Birkhofer H. - *Darmstadt University of Technology (DEU)*

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Design guidelines, especially the VDI 2221, have been developed over the past 50 years. Analyzing this development gives interesting insights into the changing character of the design guidelines. Special insights are obtained concerning the intention and direction of the guidelines. These insights give, on the one hand, explanations for the still reserved application and acceptance of design guidelines, and on the other hand, evidence of their improvement. This paper aims to give an overview of the development of the design guidelines in German-speaking lands, point out certain aspects of changes (aim, advice, instructions, terminology, and description) and provide ideas about the consequences and potentials of these changes.

STRATEGIC ASPECTS OF DESIGN METHODOLOGIES: UNDERSTOOD OR UNDERRATED?Schmidt-Kretschmer M., Blessing L. - *Technical University Berlin (DEU)*

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The potential of design methodologies (DM) does not seem to be recognised or is underestimated and so far only little used. The goal of the paper is to discuss and to analyse the problem of user acceptance to promote understanding of long-term effects or strategic aspects of DM. Strategic aspects of design methodologies have not taken into consideration until now, neither in objectives nor in comments on DM. The comparison of requirements and objectives of DM, the experiences of the authors of DM and the results of descriptive studies gave an initial indication of potential user acceptance problems. In a first step, fundamental concepts were defined, a representation model was discussed and possible strategic aspects of DM were specified.

DESIGN METHODOLOGY - DEMONSTRATION OF APPLICATIONEder W.E. - *Royal Military College of Canada (CAN)*

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Design methods have been suggested for many years, but have received limited use. The regions of design engineering, integrated product development, and industrial design are briefly compared. A continuing development is based on Engineering Design Science, and is demonstrated on a case example of conceptualising a large system. These methodologies assume a novel design problem, emphasize the major design phases, and show clearly how the gaps can be bridged. Only those parts of this designing process that are useful are employed. This cannot possibly be done in a linear procedure; feedback, iteration (repeating the operations with better understanding) and recursion (dividing a problem into parts, solving, and re-combining) are needed.

DEFINING AN ADAPTIVE PRODUCT DEVELOPMENT METHODOLOGYMeißner M., Blessing L. - *Technical University Berlin (DEU)*

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To generate company-specific, project-specific and individualised methodical supported product development processes, influences from the context of product development have to be considered. Recent literature provides sets of context criteria as basis for characterising development situations and gives sparse hints in how far characteristics of product development processes should change. The proposed approach towards an adaptive methodology should allow a more flexible and more detailed adaptation to the development context. Subdividing the methodology into modules enables local teams to adapt as practitioners their part of the methodology.

A GRAPH GRAMMAR BASED FRAMEWORK FOR AUTOMATED CONCEPT GENERATION

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During conceptual design, designers envision a breadth of solution principles to all the functional requirements of an artifact, and then combine them together into feasible concept variants. We conjecture that computational design tools could be developed to help designers navigate the design space in creating configurations from detailed specifications of function. In this research, a methodology is developed that extracts design knowledge from an online library of engineering artifacts in the form of grammar rules. From an initial implementation of 170 rules derived from 17 products, we demonstrate a computational process that builds new design configurations by borrowing concepts from how common functions are solved in related designs.

USING SIMILARITY RATIOS FOR FINDING, EVALUATING AND OPTIMIZING PRINCIPLE SOLUTIONS

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The paper shows that similarity ratios support holistically the methodical synthesis of solutions. Partial solutions can be described and selected on the basis of dimensionless characteristics. The usage of ratios simplifies the representation of technical systems because of the reduction of parameters. The characteristics used can be aggregated to ratio relations for the representation of principle solutions. The aggregated ratios are mathematically formalized and thus compressed solution knowledge which is appropriate for dimensioning and comparative calculations. The coupled ratios can be used as fixed solution principles for subsequent design processes, e.g. in design catalogues. The configuration of the dimensionless groups reveals the structural properties of solutions, which enable simplified approaches for variations and optimizations.

COMPUTATIONAL SUPPORT OF SYNTHESIS AND ANALYSIS OF BEHAVIOUR OF ARTEFACTS USING PHYSICAL EFFECTS: SOME CHALLENGES

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The report summarises a study of several artefacts to identify the difficulties associated with their synthesis and analysis directly using physical phenomena/effects and what could be done to support a designer in synthesis and analysis of these artefacts. The study highlights some major reasons as to why analysis/synthesis using physical phenomena of effects is difficult, and in some cases impossible. It then discusses, how, given the above difficulties, support synthesis and analysis by designers could be supported.

INFLUENCE OF TASK INFORMATION ON DESIGN IDEA GENERATION PERFORMANCE

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The design brief encapsulates the essential information concerning the design problem to which a designer seeks a solution. The general objective of this paper is to demonstrate the coupled nature of problem formulation and conceptual design activities. We present a design experiment that highlights the importance of brief structuring, by demonstrating how changes in design brief content affect succeeding idea generation. More precisely, we study the effects of two information-objects: the requirements list and visual description of use context. The results of the experiment clearly demonstrated that design idea generation performance is affected by the information contents of the design brief.

USE OF KNOWLEDGE TWISTING FOR SYNTHESIS OF ALTERNATIVE ELEMENTARY SOLUTIONS

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There is a positive correlation between the number of generated alternative product concepts and their quality, so it makes sense to seek formal methods that will enable the generation of alternative solutions. The crucial property of these methods should be the generation of a large number of alternative solutions without a combinatorial explosion. This paper presents a method that does not require a prior synthesis of function structure to describe the functioning of a future product in component-neutral terms. In this way, we can avoid problems related to function structure that is synthesized in advance. Empirical analysis has shown that the use of this method does not lead to a combinatorial explosion.

HEURISTICS FOR CHANGE PREDICTIONKeller R., Eckert C.M., Clarkson P.J. - *University of Cambridge (GBR)*

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Effective change management is a key to successful design development. As products and parts of products change, others can be affected, leading to further - often unexpected and costly - changes. These knock-on effects can jeopardise the timely delivery of projects and carry therefore a great risk for the entire design process. Predicting change propagation is difficult as designers do not have the overview and hidden dependencies between components are overlooked. This paper introduces simple graph theoretical heuristics as a means to predict knock-on changes. The heuristics are validated on the basis of the existing change prediction method and real world product models.

EVOLUTIONARY ALGORITHMS IN DESIGNStankoviæT., StošićM., MarjanoviæD. - *University of Zagreb (HRV)*

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Within this paper an effort was made in presenting the reasons why evolutionary algorithms and especially genetic algorithm present suitable basis for creation of design tools which should aid designer in conception phases of design processes. After the introduction in the second chapter the motivation for applying the genetic algorithms is being discussed. Further, in the third chapter, the evolutionary design process is being compared with the human performed design process. Then a case study is presented with the simplified process of conceptual design being conducted as an optimisation process where the goal of fitness function was the obtaining of functionality by following a set of rules. Finally, in the end a few conclusions were drawn and the guides for the future research work were placed.

A GRAPH-BASED APPROACH TO CHECK A PRODUCT FUNCTIONAL NETRizzuti S., De Napoli L., Rocco C. - *University of Calabria (ITA)*

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In the conceptual design, a product can be viewed as a functional net, defined in the classic active verb-object way, by mean of functional elements and links associated to the flow of energy, material and signals and link of force. In order to assure the validity of the links at different levels, in the paper the graph theory is employed to check the suitability of a functional net, treated as a collection of sub graphs, each defined on a type of link. In order to verify the functional net it is necessary to identify each subnet, characterized by the same kind of link, and check each one using a set of formal relations that represent the feature of each link. Based on these relations a set of controls have been implemented for each subnet.

SERVICEABILITY ANALYSES IN VIRTUAL ENVIRONMENT FOR THE AUTOMOTIVE INDUSTRYBruno F., Luchi M.L., Milite A., Monacelli G., Pina M., Sessa F. - *University of Calabria (ITA)*

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The paper describes an industrial application of VR techniques in the field of Digital Mock-Up (DMU) analyses, reporting the results obtained with the development of a software application that allows Elasis engineers to evaluate important design parameters in the serviceability studies. These analyses can be conducted during the early stages of the design process using DMUs and finding the difficulties related to the serviceability tasks. Using VR techniques it is possible to simulate the entire operative context in which the human operator works during the assembly/disassembly task. In this way a designer can directly verify some potential difficulties in component reachability, in posture and visibility.

AN INTEGRATED APPROACH FOR THE QUALITY MEASURE OF INDUSTRIAL PRODUCTSFargnoli M., Bisillo S., Geraci D. - *University of Tokyo (JPN)*

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One of the most significant key factors in the development of high Quality products is represented by the ability to correctly evaluate them before putting on the market. Bearing this in mind, the paper discusses the results of a two year research work aimed at the development of design tools for the measurement of the quality level of products in design stages. After brief discussion about the definition of Quality and its conception from different perspectives, the analysis of a measurement ratio based on the evaluation of indicators concerning the most significant properties of products was carried out throughout the development of an original software tool for the application of such criteria.

MONITORING TOOL FOR A REACTIVE CUSTOMER ORIENTATED QUALITY MANAGEMENTFelgen L., Gahr A., Lindemann U. - *Technical University Munich (DEU)*

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The high quality of products is an important condition for economic success of automotive industry. Regarding this challenge a reactive, customer orientated quality planning method has been developed. The method supports the systematic evaluation of field data and the identification of critical properties by assigning field problems of actual onto succeeding car systems. By using a modified FMEA the critical properties can be projected from a system-level, to a design-level and finally to a process-level view. Risk reducing measures can be defined on every of these levels. To monitor the defined measures a computer based tool has been developed. The functionalities of this tool are presented in this paper.

COMMUNICATION MEDIA IN DISTRIBUTED COLLABORATION – ANALYSIS OF DESIGN EXPERIMENTSGrieb J., Lindemann U. - *Technical University Munich (DEU)*

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Communication media play an important role in distributed working design teams. We carried out design experiments to find out which communication media are used in what combination depending on the design process situation. This paper covers the setup of the distributed design experiments, the capture of the data using video analysis and questionnaires, the analysis of the data and the presentation of the results. The results show that some media which are widely used in industry are substituted in a synchronous working distributed team. Especially during conceptual design situations the use of electronic sketching for communication was more important than initially suspected.

NOVELTY METRICS IN ENGINEERING DESIGN EXPERIMENTSLópez-Mesa B., Vidal R. - *Universitat Jaume I (ESP)*

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The KAI inventory is a broadly researched tool to measure the adaptive-innovative problem solving style of individuals. A key component that distinguishes adaptors from innovators is their tendency to produce a narrower number of novel ideas. In a design experiment, both the problem-solving style of designers, and the novelty of their outcomes were measured. The latter was done with the KAI inventory, and the former with an analytical method assessing novelty of solutions with respect to the current paradigm. Surprisingly, there was no match between the results. A complementary new method to measure the non-obviousness of solutions is proposed here. There is a match between this new method and the KAI inventory. Implications are discussed.

DESIGNERS, WILL THEY EVER USE GOOGLE AGAIN?Vroom R.W., Maas J.A.M., van Nieuwenhuijzen A.G.P. - *Delft University of Technology (NLD)*

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Industrial Design Engineers have problems finding useful information on the Internet in a short amount of time. To help designers, a Conceptual Design Engineering Toolbox (C-DET) is being set up including a knowledge portal to find appropriate sites, books, experts, tools etc. In a short time. Four search categories have been developed for C-DET, each providing the designer with a navigation tree to find useful information. We have studied whether the information in the Product Domains category could be supported by using start pages. After some use tests, we concluded that for finding information about a product, C-DET and start pages are a good solution.
