

# Daily Book of Abstracts

**Tuesday**

**6 August 2019**

iced

responsible  
design for  
our future

## Themes

'Responsible design for our future' is the general theme of the conference. It manifests itself at four different levels, ranging from society as a whole to the individual future designer. They are:

Responsibility for **future designers**

Responsibility for **our future society**

Responsibility for **our future products, production and service systems**

Responsibility for **the future organisation**

In this Daily Book of Abstracts, you will notice that on top of every right page, all Discussion and Podium sessions are allocated to a specific sub-theme. 'Responsibility for future designers' refers to topics related to design creativity and how can we build an educational system that stimulate lifelong learning. 'Responsibility for our future society' is about the role of design engineering in solving grand societal challenges in areas such as healthcare, sustainability or mobility. The third subtheme is 'Responsibility for our future products, production and service systems', focusing on systems design, service design and design methods and tools. Finally, 'Responsibility for the future organisation' addresses how companies should organise their design (engineering) departments and processes so that they are capable of managing and realising responsible products and services.

## How to use this daily book of abstracts?

On behalf of the entire community we would like to express our gratitude to the work performed by our Scientific Committee. The reviews of the Scientific Committee were used by the Programme Committee to make informed accept/reject decisions for each submission and by the authors to make the appropriate amendments to their papers.

In addition, the reviews also allowed the Programme Committee to acknowledge the top 10% of papers based on the scores given by the reviewers. This is indicated by the following sign:



Following our topic "Responsible Design for our Future", there is only a reduced number of printed versions of the daily book of abstracts available, as our preferred point of access is via the conference app. For the most updated information, please check the Guidebook Conference app, available in the App Store and on Google Play, by searching ICED19. For all general information, please consult the Conference Book Bambook. It includes an overview of the conference agenda, information about the keynote speakers, refreshments, lunches and social events. Finally, the daily books of abstracts are dedicated to single days of the conference, to provide you with a printed version of all sessions and corresponding papers, divided per day. All papers are open access and, therefore, online. In this daily book of abstracts, you are able to access them via individual QR codes.

## TUESDAY, AUGUST 6

P-Additive Manufacturing   Process Hall 4	P-Design Management   Approaches & Tools Hall M	P-Responsible design IDE Arena	P-Ontologies   Approaches Hall K	P-Robot design Hall 5	P-Machine Learning & NLP   Machine Learning Hall 6	P-Process-oriented Tolerancing & Robust design   Proc. tolerancing Hans Dirken	P-User-centred Design   Human Factors Wim Crouwel
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COFFEE BREAK

P-Additive Manufacturing   Structures Hall 4	P-Design Management   Design Theories Hall M	P-Design Methods   Function Modelling IDE Arena	P-Future mobility   Autonomous Driving Hall L	P-Industry 4.0   Trends & Tools Hall 5	P-Machine Learning and NLP in Design   NLP Hall 6	P-Process-oriented Tolerancing & Robust design   Robust Design Hans Dirken	P-User-centred Design   Strategies Wim Crouwel
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LUNCH

MEETING THE DESIGN JOURNALS EDITORS  
Joost van der Grinten

TIME OFF

D-Additive Manufacturing   Applications Hall 4	D-Design Management   Case studies Hall M	D-Design Methods   Applications IDE Arena	D-Design Education   Creativity Wim Crouwel	D-Ethics & Impact on Society Bernd Schierb.	D-Future Mobility   Energy-efficient Hall L	D-Healthcare   Approaches Hans Dirken	D-Knowledge Management Hall 5	D-Ontologies   System Hall K
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COFFEE BREAK

D-Additive Manufacturing   Methods Hall 4	D-Design Management   Industry Hall M	D-Design Methods   Inclusive IDE Arena	D-Design Education   Educ. & Prot. Wim Crouwel	D-Agile Approaches   Approaches Bernd Schierb.	D-Design Creativity Hall 6	D-Healthcare   Exploration Hans Dirken	D-Industry 4.0   Applications Hall 5	D-Knowledge-based Engineering Hall K
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TRANSITION

D-Additive Manufacturing   Potentials Hall 4	D-Design Management   Effects Hall M	D-Design Methods   Prototyping IDE Arena	D-Design Education   Game-based Wim Crouwel	D-Agile Approaches   Development Bernd Schierb.	D-Data-enabled Design & Data-driven Design Hall L	D-Healthcare   Applications Hans Dirken	D-Human Behaviour in Design Hall 5	D-Design Cognition Hall K
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TRANSITION

KEYNOTE 3 STEVEN EPPINGER & ANJA MAIER Auditorium Aula

TRANSITION

YOUNG MEMBERS EVENT  
(18:45-20:30)  
ID Kafee

## Podium Sessions Tuesday 6 August 2019 9:00 – 10:30

### Additive Manufacturing | Process

6

Pulse Building, Hall 4

### Design Management | Approaches & Tools

8

IDE Faculty, Hall M

### Responsible Design

10

IDE Faculty, IDE Arena

### Ontologies | Approaches

12

IDE Faculty, Hall K

### Robot Design

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Pulse Building, Hall 5

### Machine Learning and NLP in Design | Machine Learning

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Pulse Building, Hall 6

### Process-oriented Tolerancing and Robust Design | Process-oriented Tolerancing

18

IDE Faculty, Hans Dirken

### User-centred Design | Human Factors

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IDE Faculty, Wim Crouwel



## Methodical approach for process selection in additive manufacturing

**Nadine Wortmann (1), Christoph Jürgehake (2), Tobias Seidenberg (2), Roman Dumitrescu (2), Dieter Krause (1)**

1: Technische Universität Hamburg, Produktentwicklung und Konstruktionstechnik; 2: Fraunhofer Research Institute for Mechatronic Systems Design IEM

In recent years, rapid technical progress has led to additive manufacturing achieving a high degree of technological maturity that enables a broad range of applications. This is reinforced in particular by the advantages of the technology, such as the production of complex components, smaller quantities and fast reaction times. However, a lack of knowledge of the various process techniques, such as insufficient potential assessment, specific design guidelines or even of process restrictions, often lead to different errors.

This paper presents a methodological approach to support designers in the manufacturing process selection of specific parts at an early stage of product development. In a four-stage procedure, potential part candidates are first identified and part classes formed on the basis of characteristics. Building on this, AM thinking is to be stimulated, for example, with the aid of design guidelines. A comparison between conventionally and additively manufactured parts can be made using a simplified cost model. The results are incorporated into a process model that supports companies in the systematic selection of manufacturing processes.



## Optimization approaches in design for Additive Manufacturing

**Stefano Rosso, Gianpaolo Savio, Federico Uriati, Roberto Meneghella, Gianmaria Concheri**

Università degli Studi di Padova

Nowadays, topology optimization and lattice structures are being re-discovered thanks to Additive Manufacturing technologies, that allow to easily produce parts with complex geometries.

The primary aim of this work is to provide an original contribution for geometric modeling of conformal lattice structures for both wireframe and mesh models, improving previously presented methods. The secondary aim is to compare the proposed approaches with commercial software solutions on a piston rod as a case study.

The central part of the rod undergoes size optimization of conformal lattice structure beams diameters using the proposed methods, and topology optimization using commercial software tool. The optimized lattice is modeled with a NURBS approach and with the novel mesh approach, while the topologically optimized part is manually remodeled to obtain a proper geometry. Results show that the lattice mesh modelling approach has the best performance, resulting in a lightweight structure with smooth surfaces and without sharp edges at nodes, enhancing mechanical properties and fatigue life.



## A Method For Analyzing The Influence Of Process And Design Parameters On The Build Time Of Additively Manufactured Components

**Martin Hallmann, Benjamin Schleich, Sandro Wartzack**

Friedrich-Alexander-Universität Erlangen-Nürnberg

When using additive manufacturing processes, the choice of the numerous settings for the process and design parameters significantly influences the build and production time. To reduce the required build time, it is useful to adapt the parameters with the greatest influence. However, since the contribution of the individual parameters is not readily apparent, a sensible choice of process and design parameters can become a challenging task.

Thus, the following article presents a method, that enables the product developer to determine the main contributors to the required build time of additively manufactured products. By using this sensitivity analysis method, the contributors of the individual parameters can be analyzed for a given parametrized CAD model with the help of an analysis-based build time estimation approach. The novelty of the contribution can be found in providing a method that allows studying both design and process parameters simultaneously, taking the machine to be used into account. The exemplary application of the presented method to a sample part manufactured by Fused Deposition Modeling demonstrates its benefits and applicability.



## Print-on Strategies to bond Injection Molded Parts with Structures produced by Fused-Deposition-Modeling

**Alina Richter (1), David Kessing (2), Fabian Fischer (1), Lukas Pelzer (3), Klaus Dilger (4)**

1: Volkswagen AG, Group Research; 2: Institute for Machine Elements and Systems Engineering, RWTH Aachen University; 3: Institute of Plastics Processing, RWTH Aachen University; 4: Institute of Joining and Welding Technology, Technical University Braunschweig



The biggest advantage of Additive Manufacturing is the individualization of products. Mass Customization is well known as a promising future application. The use of Additive Manufacturing for assembly groups is mostly not reasonable, however combining it with conventional manufacturing processes can lead to new opportunities.

This paper works out concepts to join, by using similar material combinations, an injection molded part with an additive deposited geometry by the Fused-Deposition-Modeling (FDM) process. Therefore, two of the main industrially used polymers, acrylonitrile butadiene styrene (ABS) and polypropylene (PP), are selected for further study. In particular, this investigation focuses on the procedural potentials and surface preparation of the injection molded part. By the variation of adhesive bonding, the fusion of similar materials can be identified and tested in several series of testing. First in general a direct joining function by the FLM process will be tested. After proving this hypothesis, the results will be summarised in a recommendation of joining similar materials, which are manufactured in different ways.



## Abductive inferences in strategic design decisions

*Ehud Kroll (1), Lauri Koskela (2)*

1: ORT Braude College; 2: University of Huddersfield

The overall strategy of designing is addressed. The design decisions that have a major impact on the direction in which the process evolves are termed “strategic”, and here we study them from the perspective of abduction. The aim is to clarify the role of abduction (in the sense of inference to the best explanation) in strategic decision making in design. Four cases are used for demonstration and discussion: functional decomposition in novel situations; the ordering of subfunctions in a function structure; the order of development of design tasks; and managing the design iterations. We focus on two specific design strategies: systematic design and parameter analysis, and show that strategic abductions often take place within the chosen strategy for the sake of efficiency of the process. Such abductions are often triggered by rules (like focusing first on the issue with greatest uncertainty in the total design task) that derive from Peirce’s principle for economy of research. It is found that strategic abductions may have a decisive impact on the outcome of a design process. Two potential ways of improving design strategies and related strategic abductions are discussed.



## An introductory review of methods for the articulation of strategy in design

*Luca Simeone*

Aalborg University

This paper presents an introductory review of methods to articulate strategy in design. Articulation is here seen as a process in which strategy is more or less strictly and explicitly identified and described, e.g. in relation to key ideas, directions to follow, goals and expected results. The paper surveys existing literature in design research and identifies two broad categories of methods for the articulation of strategy: (1) structured frameworks, and (2) vocabularies and principles.



## Automated exploration of design solution space applying the Generative Design Approach

*Haibing Li, Roland Lachmayer*

Leibniz Universität Hannover

Design is a complex problem-solving activity that transforms design restrictions and requirements into a set of constraints and explores the feasible solutions to satisfy those constraints. However, design solutions generated by traditional modeling approaches are hardly to deal with such constraints, particularly for the exploration of the possible design solution space to enhance the quality of the design outputs and confront the evolving design requirements. In this regard, the Generative Design Approach (GDA) is considered as an efficient method to explore a large design solution space by transforming the design problem into a configuration problem. Fundamentally, GDA explores and stores all the necessary knowledge through a design skeleton and a set of design elements. Thus, design solution space is easily explored by configuring variable design elements via iterative design processes. Further, the output model is not only a design solution but also a design concept that designers could manipulate to explore unconsidered design configurations. Finally, a crank creation as a running example confirmed that GDA provides concrete aids to enhance the diversity of design solutions.



## Computational Simulation as an organizational prototyping tool

*Clio Dosi, Manuel Iori, Arthur Kramer, Matteo Vignoli*

University of Modena and Reggio Emilia

This case study deals with a redesign effort to face the overcrowding issue in an Emergency Department (ED). A multidisciplinary group of healthcare professionals and engineers worked together to improve the actual processes. We integrate the simulation modeling in a human-centered design method. We use the simulation technique as a learning and experimentation tool into a design thinking process: the computational discrete event simulation helps explore the possible scenarios to be prototyped. We used the simulation to create a virtual prototyping environment, to help the group start a safe ideation and prototyping effort. Virtual prototyping injected into the organizational context the possibility of experimenting. It represented a cognitive low-risk environment where professionals could explore possible alternative solutions. Upon those solutions, we developed organizational prototyping tools. Top management and head physicians gained confidence for a more grounded decision making effort and important choices of change management and investments have been made.



### Towards Responsible Design with Internet of Things Data

*Jacky Bourgeois, Gerd Kortuem*  
Delft University of Technology



Recent advances in sensing and networking technologies, namely the Internet of Things (IoT), have become key enablers of data-intensive design processes. However, the recent introduction of the General Data Protection Regulation (GDPR) in Europe has raised concerns that the GDPR might hamper data-intensive design processes. In this paper, we map the challenges of enabling ethical and compliant design of product-service systems with personal IoT data. Specifically, we present a 4-year project led by EON, an international energy provider, to design innovative home energy systems that leverage emerging technologies such as solar panels, electric vehicles and home batteries. We present our 6-stage approach to design, centred on IoT data. We highlight the barriers of responsible design with data and identify three novel trust principles for compliant use of personal IoT data in design (private-by-default, analytics transparency and Accountable analytics).



### Towards a Theory for Unintended Consequences in Engineering Design

*Hannah Walsh (1), Andy Dong (2), Irem Tumer (1)*  
1: Oregon State University; 2: University of Sydney



Conventional failure analysis ignores a growing challenge in the responsible implementation of novel technologies into engineered systems - unintended consequences, which impact the engineered system itself and other systems including social and environmental systems. In this paper, a theory for unintended consequences is developed. The paper proposes a new definition of unintended consequences as behaviors that are not intentionally designed-into an engineered system yet occur even when a system is operating nominally, that is, not in a failure state as conventionally understood. It is argued that the primary cause for this difference is the bounded rationality of human designers. The formation of unintended consequences is modeled with system dynamics, using a specific real-world example, and bifurcation analysis. The paper develops propositions to guide research in the development of new design methods that could mitigate or control the occurrence and impact of unintended consequences. The end goal of the research is to create a new class of failure analysis tools to manage unintended consequences responsibly to facilitate engineering design for a more sustainable future.



### Design interventions for promoting the mental health of young academics

*Sanghyun Ma, Mintra Ruensuk, Chajoong Kim*  
Ulsan National Institute of Science and Technology

It is essential to graduate students to contribute researching in their academic field. Although it leads to the success of academic career path, the students are more at high risk of mental health problems. Thus, this study attempted to reveal underlying causes of the problems, figure out coping techniques and explore design interventions that can improve of graduate students' mental health quality. We conducted interviews with one health professional expert and twenty-five graduate students. Design Sheet was created to elicit design solution ideas and distributed to ten professional designers. From the research, we have found out that graduate students are suffering from multiple reasons however there are unmet mental health needs among graduate students. By the end of the paper, we propose five design guidelines for designers to make products or services to promote mental health of graduate students.



### Transparency in Responsible Design: Avoiding Engineering Overconfidence and Supporting Societal Acceptance

*Pieter Vermaas*  
Delft University of Technology

In this contribution it is argued that in responsible design engineers should be transparent towards stakeholders about the goals they intend to realise with their designs. The emergence of responsible design in, e.g., value-sensitive design, design for values, social design, nudging and positive design, is to be welcomed. It has however the weakness of overconfidence which may lead engineers to suspend earlier commitments to society as given in engineering codes of conduct and ethics, and practices of seeking informed consent and taking blame. It is argued that these earlier commitments lead to the requirement that engineers should be transparent about the goals in responsible designs. Providing this transparency support moreover the societal acceptance of responsible design since it positions engineers doing responsible design as subscribing to values such as respect, honesty and trust. I illustrate the argument with a case of social design and a case of nudging.



## Integrating The Mechanical Domain Into Seed Approach

*Fabian Dworschak, Patricia Kügler, Benjamin Schleich, Sandro Wartzack*  
Friedrich-Alexander-Universität Erlangen-Nürnberg



Data-driven technologies have found their way into all areas of engineering. In product development they can accelerate the customization to individualized requirements. Therefore, they need a database that exceeds common product data management systems. The creation of this database proves to be challenging because in addition to explicit standards and regulations the product design contains implicit knowledge of product developers. Hence, this paper presents an approach for the semantic integration of the engineering design (SeED). The goal is an automated design of an ontology, which represents the product design in detail.

SeED fulfils two tasks. First, the ontology provides a machine-processable representation of the products design, which enables all kind of data-driven technologies. Among other representations, the ontology contains formal logics and semantics. Accordingly, it is a more comprehensible solution for product developers and knowledge engineers. Second, the detailed representation enables discovering of intrinsic knowledge, e.g. design patterns in product generations. Consequently, SeED is a novel approach for efficient semantic integration of the product design.



## Using a design ontology to identify the terms that represent the design results across research communities

*Maiara Rosa, Henrique Rozenfeld*  
São Carlos School of Engineering, University of São Paulo

This paper is contextualized in a research project that aims to create a new paradigm to support the design process, substituting the sequential nature of design process models by a flexible structure. To implement this paradigm, we must identify the final and intermediate results of the design process, such as documents, models, artefacts, among others. However, design research is wide and multidisciplinary, resulting in non-uniformity of the terminology across research communities, what hinders the results identification by means of a literature review. This paper aims to identify the terms employed by different research communities to refer to the intermediate and final results of the design process, structuring synonym terms across research communities and establishing how those terms interrelate in the design ontology. Using literature review, the following terms were analysed: design objects, elements, deliverables, entities, information, components, data, and artefacts. The results provide a holistic view of how the terms are employed throughout research communities, supporting the creation of search strings and pointing out opportunities for improving the design ontology.



## Engineering Knowledge Graph for Keyword Discovery in Patent Search

*Serhad Sarica (1), Binyang Song (1), En Low (2), Jianxi Luo (1)*  
1: Singapore University of Technology and Design, Engineering Product Development Pillar; 2: Singapore University of Technology and Design

Patent retrieval and analytics have become common tasks in engineering design and innovation. Keyword-based search is the most common method and the core of integrative methods for patent retrieval. Often searchers intuitively choose keywords according to their knowledge on the search interest which may limit the coverage of the retrieval. Although one can identify additional keywords via reading patent texts from prior searches to refine the query terms heuristically, the process is tedious, time-consuming, and prone to human errors. In this paper, we propose a method to automate and augment the heuristic and iterative keyword discovery process. Specifically, we train a semantic engineering knowledge graph on the full patent database using natural language processing and semantic analysis, and use it as the basis to retrieve and rank the keywords contained in the retrieved patents. On this basis, searchers do not need to read patent texts but just select among the recommended keywords to expand their queries. The proposed method improves the completeness of the search keyword set and reduces the human effort for the same task.



## Applying Engineering Design Ontology for Content Analysis of Team Conceptual Design Activity

*Tomislav Martinec (1), Stanko Škec (1,2), Jelena Šklebar (1), Mario Štorga (1,3)*  
1: University of Zagreb; 2: Technical University of Denmark; 3: Luleå University of Technology

Studies of design activity have been dominantly reporting on different aspects of the design process, rather than the content of designing. The aim of the presented research has been the development and application of an approach for a fine-grain analysis of the design content communicated between designers during the team conceptual design activities. The proposed approach builds on an engineering design ontology as a foundation for the content categorisation. Two teams have been studied using the protocol analysis method. The coded protocols offered fine-grain descriptions of the content communicated at different points in the design session and enabled comparison of teams' approaches and deriving some generalisable findings. For example, it has been shown that both teams focused primarily on the use of the developed product and the operands within the technical process, in order to generate new technical solutions and initial component design. Moreover, teams exhibit progress from abstract to concrete solutions as the sessions proceeded and focused on the functional requirements towards the end of the sessions.



## Development of Virtual Pipe Simulation System for Inspection Robot Design

**Satoshi Miura (1), Kazuya Kawamura (2), Masakatsu Fujie (1), Shigeki Sugano (1), Tomoyuki Miyashita (1)**

1: Waseda University; 2: Chiba University



Pipe inspection robots have been developed to reduce the cost and time required for gas pipe inspection. However, these robots have been developed using a scrap and build method and are not used in practice. In this paper, we propose a method of virtual pipe inspection simulation to clarify the parameters that are important in increasing the robot's ease of use. This paper presents the results obtained by a feasibility study with regard to pipe simulation. We developed a virtual pipe by simulating eight actual turns of an external gas pipe, and a robot equipped with camera at the tip. In the experiments, three individuals working in the field of gas inspection carried out the operation. We obtained questionnaire, time, and brain activity data. The results revealed various important points that must be considered in practical simulation and robot design. In conclusion, the virtual pipe simulation can be useful in developing the design of a pipe inspection robot.



## AI Motion Control – A Generic Approach to Develop Control Policies for Robotic Manipulation Tasks

**Philip Kurrek (1), Mark Jocas (1), Firas Zoghlami (1), Martin Stoelen (2), Vahid Salehi (1)**

1: University of Applied Sciences Munich; 2: University of Plymouth

Current robotic solutions are able to manage specialized tasks, but they cannot perform intelligent actions which are based on experience. Autonomous robots that are able to succeed in complex environments like production plants need the ability to customize their capabilities. With the usage of artificial intelligence (AI) it is possible to train robot control policies without explicitly programming how to achieve desired goals. We introduce AI Motion Control (AIMC) a generic approach to develop control policies for diverse robots, environments and manipulation tasks. For safety reasons, but also to save investments and development time, motion control policies can first be trained in simulation and then transferred to real applications. This work uses the descriptive study I according to Blessing and Chakrabarti and is about the identification of this research gap. We combine latest motion control and reinforcement learning results and show the potential of AIMC for robotic technologies with industrial use cases.



## Systematic generation of a 3D DSM by extracting social robot behaviors from literature

**Ilayda Ozer, Zuhai Erden**

Atilim University

Social robots are in direct communication and interaction with people, thus it is important to design these robots for different needs of individuals or small groups. This has revealed the need to develop design methods for personalized or mass-individualized social robots, which are expected to respond to many different needs of people today and in the future. In this paper, a previously developed 3D DSM model is implemented in the systematic conceptual design of social robot families. The model is independent of any physical elements and based on behavioural elements as perception, cognition and motoric action. The data regarding 45 different social robots from 80 articles in the literature is used to identify these three behaviours of the existing social robots and the mutual relationships among these different behaviours are defined in order to develop a 3D DSM structure to be used as a basis for designing social robot families. The resulting novel 3D DSM is a general-purpose, basic model that can be used to identify behavioural modules to design social robot families.



## Usage Identification of Anomaly Detection in an Industrial Context

**Firas Zoghlami (1), Philip Kurrek (1), Mark Jocas (1), Giovanni Masala (2), Vahid Salehi (1)**

1: University of Applied Sciences Munich; 2: University of Plymouth

The use of flexible and autonomous robotics systems is the solution for the automation task of the production and intra-logistics environments. This dynamic context requires the robot to be aware of its surroundings through the whole task, also after accomplishing the gripping action. We present an anomaly detection approach based on unsupervised learning and reconstruction fidelity of image data. We design our method to enhance the dynamic environment perception of robotics systems and apply it in a palletizing robot, in order to perceive and detect changes to its surrounding and process after the gripping step. Our proposed approach achieves the performance targeted by the considered industrial requirements.



## Human-in-the-loop Design with Machine Learning

**Pan Wang (1), Danlin Peng (1), Ling Li (2), Liuqing Chen (1), Chao Wu (3), Xiaoyi Wang (3), Peter Childs (1), Yike Guo (1)**

1: Imperial College London, United Kingdom; 2: University of Kent, United Kingdom; 3: Zhejiang University, China



Deep learning methods have been applied to randomly generate images, such as in fashion, furniture design. To date, consideration of human aspects which play a vital role in a design process has not been given significant attention in deep learning approaches. In this paper, results are reported from a human-in-the-loop design method where brain EEG signals are used to capture preferable design features. In the framework developed, an encoder extracting EEG features from raw signals recorded from subjects when viewing images from ImageNet are learned. Secondly, a GAN model is trained conditioned on the encoded EEG features to generate design images. Thirdly, the trained model is used to generate design images from a person's EEG measured brain activity in the cognitive process of thinking about a design. To verify the proposed method, a case study is presented following the proposed approach. The results indicate that the method can generate preferred designs styles guided by the preference related brain signals. In addition, this method could also help improve communication between designers and clients where clients might not be able to express design requests clearly.



## Adding Implicit Measurement Methods to Interactive Optimizations in Industrial design - A Concept, First Tests, and Comparison Using Two Simple Case Studies

**Martin Wiesner, Andreas Petrow, Sándor Vajna**

Otto von Guericke University Magdeburg

In this article, a new approach to interactive optimization in industrial design is presented in which, for the first time, implicit preference acquisition methods are integrated. Suitable methods for preference acquisition will be selected, adapted and combined with an own PSO-inspired algorithm. The application of implicit preferences as well as the combined application of implicit and explicit preferences in an interactive optimization represents the main novelty of this contribution since this has not yet been carried out according to the current state of knowledge. Two case studies will be used to test this new approach with regard to convergence and acceptance, and a comparison will be made between the three different kind of optimization (implicit, explicit as well as a combination of both) in terms of their results.



## A survey on the applications of machine learning in the early phases of product development

**Seyed Sina Shabestari, Michael Herzog, Beate Bender**  
Ruhr University Bochum

Machine learning has shown its potential to support the knowledge extraction within the development processes and particularly in the early phases where critical decisions have to be made. However, the current state of the research in the applications of the machine learning in the product development are fragmented. A holistic overall view provides the opportunity to analyze the current state of research and is the basis for the strategic planning of future research and the actions needed. Hence, implementing the systematic literature survey techniques, the state of the applications of machine learning in the early phases of the product development process namely the Requirements, functional modelling and principal concept design is reviewed and discussed.



## Business model innovation for circular economy: integrating literature and practice into a conceptual process model

**Marina de Padua Pieroni, Tim McAloone, Daniela Pigosso**  
Technical University of Denmark



A key question regarding business model innovation/development for circular economy is "how to make it happen in practice"? By systematically reviewing 92 approaches from circular economy and sustainability literature and practice, this research identifies requirements and proposes a holistic and systemic process for business model innovation for circular economy. This conceptual process model was consolidated based on the integration of the unique elements of sixteen existing process models. It comprises three-stages (sense, seize, transform) based on a dynamic capabilities view, and envisions 33 activities, 21 deliverables, 88 techniques/tools and 13 enablers or catalyzers for change. Besides enabling the view of processes and procedures with behavior and learning skills required to inspire circular economy thinking in business model innovation, it highlights the importance of 'formalized' decision-making procedures and includes activities to integrate sustainability thinking and to support the identification of required changes in product innovation/development.



## A concept for process-oriented interdisciplinary tolerance management considering production-specific deviations

*Bjoern Heling, Thomas Oberleiter, Andreas Rohrmoser, Christoph Kiener, Benjamin Schleich, Hinnerk Hagenah, Marion Merklein, Kai Willner, Sandro Wartzack*

*Friedrich-Alexander-Universität Erlangen-Nürnberg*

To meet rising customer requirements, increasingly complex products have to be virtually validated. To achieve this within the framework of virtual product development, a wide range of aspects has to be taken into account. In this context, tolerance analysis has established itself as a proven tool to evaluate the consequences of geometric part deviations on geometric product characteristics. Existing approaches, however, do not sufficiently take into account production-specific deviations, leading to time-consuming iterations during the product development process. Therefore, the focus of this contribution is on process-oriented interdisciplinary tolerance management that allows the integration of manufacturing simulations into the tolerance analysis. In contrast to the conventional approach, this novel methodology allows to avoid unnecessary iterations in the context of product development and validation. Following the presentation of the novel procedure, the application on a case study of an X-ray shutter is carried out, whereby surrogate models are integrated in order to reduce the computing time.



## Implementation of parameterized work piece deviations and measurement uncertainties into performant meta-models for an improved tolerance specification

*Andreas Michael Müller (1), Thomas Oberleiter (2), Kai Willner (2), Tino Hausotte (1)*

*1: Friedrich-Alexander-Universität Erlangen-Nürnberg, Institute of Manufacturing Metrology; 2: Friedrich-Alexander-Universität Erlangen-Nürnberg, Chair of Applied Mechanics*

Geometrical work piece deviations are unavoidable and directly affect the function and quality of technological products. Tolerance management is regarded as a crucial subtask of the development of technological products, because it ensures the function as well as a sufficient product quality while maintaining reasonable production costs. That means, that geometric tolerances as an essential part of the product description greatly affect the functional capability, manufacturability, mountability, verifiability and the costs of the final product. The research group FOR 2271 was founded to enable the computer-aided specification of tolerances, which meet the requirements of production, assembly, verification and function by close cooperation between the departments responsible for product design, assembly and metrology. The aim of this contribution is to determine the manufacturing process scatter as well as the measurement uncertainty and establish ways and means to include that information into efficient meta-models, ultimately enabling improved and accurate tolerance analyses.



## A methodology for the application of virtual evaluation methods within the design process of cold forged steel pinions

*Andreas Rohrmoser (1), Björn Heling (2), Benjamin Schleich (2), Christoph Kiener (1), Hinnerk Hagenah (1), Sandro Wartzack (2), Marion Merklein (1)*

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Gears are essential machine elements in the drivetrain and transmission technology. The operational behaviour of a gear pairing is influenced by the design of the gear kinematics as well as the component properties. With regard to an improvement of performance and service life, the targeted modification of tooth geometry and component properties offers a promising approach. Thus, the achievable geometric and mechanical component properties are influenced by the manufacturing process, which must be taken into account in the design process. The application of virtual evaluation methods is suitable for this purpose. For the manufacturing of steel gears, cold forging provides the potential of achieving beneficial mechanical properties in a highly productive process. Major challenges for the industrial application are the short service life of the cost-intensive tools and the low geometric accuracy in comparison to machining processes. Within this study the design of the tooth geometry as well as the associated forming tool are investigated. The aim is to derive recommendations regarding an optimization of the resulting component properties and operational behaviour.



## New Approach on the Allocation of Wear Allowances – a Case Study

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To maintain functional tolerances of gear sets over their lifetime, especially in polymer-steel gear sets, the wear behaviour must be considered. The state of the art in wear modelling does not take the run-in behaviour of polymer-metal contacts into account. This results in oversizing of wear allowances in the stationary wear phase and undersizing in the run-in phase. Therefore, a modified wear model is presented in this paper. With this method the issues of over- and undersizing can be eliminated. The method is then applied in a case study to show two things. Firstly, using the presented method the calculated necessary wear allowances were reduced by 30%. Secondly, the effect of surface structures on the wear behaviour was investigated. It is shown that the run-in process is not dependent on roughness in sliding direction, but on overall contact area. Thus, the state of the art, i.e. tolerating only the roughness in sliding direction, is insufficient. Considering the process-induced surface topology during design of gear sets can decrease run-in wear. Together with the optimised wear model, this allows wider manufacturing tolerances and thus lower costs during production.



## A Review of Affordances and Affordance-Based Design to Address Usability

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Maier and Fadel pioneered Affordance-Based Design (ABD) based on Gibson's revolutionary theory of affordances and Norman's deployment of the concept in his book, "The Design of Everyday Things". Gibson (1979) introduced the affordance concept into the discipline of Ecological Psychology to address the interactions between an object and an agent. The Ecological approach includes the direct perception of affordances for the user along with a consideration of the users' biomechanics. However, as the concept of affordance was imported and utilized in different disciplines, including engineering design, some important aspects of Ecological theory were omitted. This paper is an attempt to review the definitions and different utilizations of the affordance concept focusing on the design of usable products to identify the different views and the missing elements. After addressing the divergent viewpoints of affordances, we provide recommendations to improve the usability aspects in ABD by considering direct perception and ergonomics. We claim that a design (based on affordances) that fails to address both criteria may result in a product that is less usable.



## Towards virtual assessment of human factors: A concept for data driven prediction and analysis of physical user-product interactions

Alexander Wolf, Nicole Binder, Jörg Miehling, Sandro Wartzack  
Friedrich-Alexander-Universität Erlangen-Nürnberg

The early consideration of human factors in product development hugely favours the development of products, which excel with a positive user experience. The virtual environment of product development however, still has significant gaps in the virtual assessment and simulation of human factors, especially for user-product interactions composed of human movements. This motivates us to introduce a concept for data-driven prediction and analysis of user-product interactions. Heart of the concept is a predictive component that models the interaction between the user, represented by a musculoskeletal model, and the product, represented by product characteristics. We describe the implementation of this concept based on a pilot study for a lifting task. Motion capturing was performed to build a database and compare the results of our novel approach. The resulting kinematic and dynamic quantities show similar curve profiles with a small constant offset to the measured data. This indicates that the concept enables the virtual comparison of different designs or concepts regarding human factors.



## Exploring the influence of the level of technology and expected functions in product semantic

SoJeong Kim (1), JungKyoon Yoon (2), Chajoong Kim (1)

1: Department of Creative Design Engineering, Ulsan National Institute of Science and Technology; 2: Department of Design and Environmental Analysis, Cornell University

This study attempted to explore how pragmatic and hedonic values are influenced by the level of technology and what particular functions have to be considered in the context of smart technology-driven design in terms of Pragmatic Value (PV) and Hedonic Value (HV). An on-line questionnaire survey was developed to answer the research questions. A total of 104 respondents participated in the survey. As target product for the study, analog watch and smart watch were selected as representative of low and high technology respectively. Semantic Differentials on PV and HV were used and expected functions were investigated via an open question. The results indicate that there are some differences between analog and smart watches in terms of PV and HV. Regarding expected functions, significant differences were identified in the study. The findings from the study could provide a better understanding of the relationship between PV and HV in terms of level of technology. If it is considered in product development process, it may contribute to an increase of user satisfaction with smart-technology based product and service.



## A New Method of Human Response Testing to Enhance the Design Process

Saleh Kalantari  
Cornell University

This paper presents a new method of human-response testing to enhance the success of designs. Rather than waiting until after a building is constructed to see how the design will affect human users, we developed a high-resolution virtual-reality platform to present design variations to the study participants. This technique allowed us to make very precise adjustments in design variables (e.g., the ceiling height, or the placement of windows) within the same overall structure, thereby obtaining more empirically rigorous comparisons than is possible in traditional post-occupancy studies of completed buildings. In addition, this approach allowed us to collect a variety of biometric data, such as EEG signals, heart rate, head motions, and other indicators of attention and stress, while the study participants interacted with the virtual environments. The overall outcome of this research method will be to improve the human quality of the built environment and to promote data-driven innovation in the design field.

**Podium Sessions**  
**Tuesday**  
6 August 2019  
11:00 – 12:30

<b>Additive Manufacturing   Structures</b> <i>Pulse Building, Hall 4</i>	<b>24</b>
<b>Design Management   Design Theories</b> <i>IDE Faculty, Hall M</i>	<b>26</b>
<b>Design Methods   Function Modelling</b> <i>IDE Faculty, IDE Arena</i>	<b>28</b>
<b>Future Mobility   Autonomous Driving</b> <i>IDE Faculty, Hall L</i>	<b>30</b>
<b>Industry 4.0   Trends &amp; Tools</b> <i>Pulse Building, Hall 5</i>	<b>32</b>
<b>Machine Learning and NLP in Design   NLP</b> <i>Pulse Building, Hall 6</i>	<b>34</b>
<b>Process-oriented Tolerancing and Robust Design   Robust Design</b> <i>IDE Faculty, Hans Dirken</i>	<b>36</b>
<b>User-centred Design   Strategies</b> <i>IDE Faculty, Wim Crouwel</i>	<b>38</b>



## Additive manufacturing of heterogeneous lattice structures: an experimental exploration

Francesco Leonardi (1), Serena Graziosi (1), Riccardo Casati (1), Francesco Tamburrino (2), Monica Bordegoni (1)

1: Politecnico di Milano; 2: University of Pisa

3D printed heterogeneous lattice structures are beam-and-node based structures characterised by a variable geometry. This variability is obtained starting from a periodic structure and modifying the relative density of the unit cells or by combining unit cells having different shapes. While several consolidated design approaches are described to implement the first approach, there are still computational issues to be addressed to combine different cells properly. In this paper, we describe a preliminary experimental study focused on exploring the design issues to be addressed as well as the advantages that this second type of heterogeneous structures could provide. The Three-Point-Bending test was used to compare the behaviour of different types of heterogeneous structures printed using the Fused Deposition Modeling (FDM) technology. Results demonstrated that the possibility of combining multiple unit cells represents a valid strategy for performing a more effective tuning of the material distribution within the design space. However, further studies are necessary to explore the behaviour of these structures and develop guidelines for helping designers in exploiting their potential.



## Design of Shoe Soles Using Lattice Structures Fabricated by Additive Manufacturing

Guoying Dong, Daniel Tessier, Yaoyao Fiona Zhao

Department of Mechanical Engineering, McGill University



Additive manufacturing (AM) has enabled great application potential in several major industries. The footwear industry can customize shoe soles fabricated by AM. In this paper, lattice structures are discussed. They are used to design functional shoe soles that can have controllable stiffness. Different topologies such as Diamond, Grid, X shape, and Vintiles are used to generate conformal lattice structures that can fit the curved surface of the shoe sole. Finite element analysis is conducted to investigate stress distribution in different designs. The fused deposition modeling process is used to fabricate the designed shoe soles. Finally, compression tests compare the stiffness of shoe soles with different lattice topologies. It is found that the plantar stress is highly influenced by the lattice topology. From preliminary calculations, it has been found that the shoe sole designed with the Diamond topology can reduce the maximum stress on the foot. The Vintiles lattice structure and the X shape lattice structure are stiffer than the Diamond lattice. The Grid lattice structure buckles in the experiment and is not suitable for the design.



## Conception of Design Principles for Additive Manufacturing

Filip Valjak, Nenad Bojčetić

University of Zagreb



Additive Manufacturing (AM) brought new design freedom and possibilities that enable design and manufacturing of products with new forms and functionalities. To utilise these possibilities a new design approach emerged, Design for Additive Manufacturing (DfAM), that contains methods and tools for supporting AM oriented design process. Designers working with AM are aware of the need to apply DfAM and AM possibilities in conceptual design phase where they have the most significant influence on product architecture and form but are facing a lack of suitable DfAM approaches for early design phases. Therefore, the presented research is investigating possibilities of storing and representing AM knowledge in the form of design principles to be used in the conceptual design phase. The paper proposes conceiving of Design Principles for Additive Manufacturing repository where formalised AM knowledge is stored in the form of design principles and structured based on function criteria. In the paper, various elements of design principle representation are discussed, as well as their role in the conceptual design process.



## A Methodical Approach to Support Conceptual Design for Multi-Material Additive Manufacturing

Hagen Watschke, Sebastian Kuschmitz, Julius Heubach, Guido Lehne, Thomas Vietor

Technische Universität Braunschweig, Institute for Engineering Design

Additive manufacturing (AM) opens new possibilities for innovative product designs. However, due to a lack of knowledge and restrained creativity because of design fixations, design engineers do not take advantage of AM's design freedom. Especially multi-material AM provides new opportunities for functional integration that hardly considered in ideation. To overcome barriers in the development of solution ideas and utilizing such new design potentials, new design methods and tools are needed. Therefore, in this contribution, a methodological approach for a function-oriented provision of solution principles specific to material extrusion is presented. A tool is developed to facilitate effective guidance in developing solution ideas and to foster a realistic concretization by providing a combination of opportunistic and restrictive AM knowledge. Besides general levers of AM, process-specific design opportunities support the design engineers in exploiting AM's potentials, especially those who are not familiar with Design for AM. Finally, the applicability of the methodological approach is evaluated in an academic study by means of redesigning a hand prosthesis with a grab function.



### Extended Sequence Modelling in Design Engineering – Gaining and Documenting Knowledge about Embodiment Function Relations with the C&C<sup>2</sup>-Approach

Sven Matthiesen, Patric Grauberger, Lukas Schrempp  
 Karlsruhe Institute of Technology, Institute of Product Engineering

In embodiment design, functions are implemented in a technical systems embodiment. For doing so, design engineers need to understand the relations of embodiment and function. Many systems change their states during function fulfilment which complicates their relations and leads to ambiguity in design decisions. The challenge for design engineers is that they often need to make important decisions about the design before they can use sophisticated analytical models to investigate them. This contribution presents a structure for the C&C<sup>2</sup>-Sequence Model as a non-analytical model to support design engineers in modelling embodiment function relations. This structure contains four dimensions that are derived from the state of the art and preliminary work. It enables the structuring of gained knowledge about embodiment function relations and supports their communication in design engineering teams. Two development projects in academic and corporate environment are conducted using the structure to investigate its applicability. In these projects, design engineers were able to document and use gained knowledge about the investigated complicated systems.



### Innovative Design Within Tradition - Injecting Topos Structures In C-K Theory To Model Culinary Creation Heritage

Armand Hatchuel, Pascal Le Masson, Benoit Weil, Daniel Carvajal-Perez  
 MINES ParisTech PSL



In “Grande cuisine” creation and tradition co-evolve in a rich number of ways. Great chefs still use recipes from the 19th century and may also reinvent gastronomy itself. The creation heritage of culinary Art is the paradoxical capacity to both “respect” tradition and “break” its rules. Building on C-K theory, we show that such creative heritage needs multiple and independent layers of knowledge that “speak” of basic fixed objects. These properties correspond to general mathematical structures that we find in Topos theory. Thus, C-K/Topos predicts creative design strategies that can respect tradition in different ways. It also proves a form of “innovation within tradition” - “sheafification” in Topos words- that is not a compromise and builds on tradition itself. These findings fit with the lessons of great books of gastronomy. C-K/Topos has a wide scope of validity: it applies to any innovative design that needs preserving systemic structures, like engineering systems or social and environmental systems. C-K/Topos models with a high generality how local and radical innovation can warrant systems incremental change. C-K/Topos will have implications for teaching and research.



### A theory-driven design research agenda: Exploring dual-process theory

Philip Cash, Jaap Daalhuizen, Dagny Valgeirsdottir, Robin Van Oorschot  
 Technical University of Denmark

Design research faces a critical ‘impact gap’ where the potential for scientific and practical impact is yet to be fully realised. A key means of bridging this gap is the adoption of fundamental theory from other fields to support clarification and synergy in design research. In this paper we examine one of the main candidates for adoption: dual-process theory of cognition. Cognition forms a common element across much of the design literature and leads to fundamental dual-process theories of reasoning. While dual-process theory has started to be recognised in design research, its widespread recognition and potential utility have not been widely explored. Following a conceptual theory development approach we identify and logically describe interactions between dual-process theory and design research. We conclude the paper with a proposition of a design research framework with a core rooted in dual-process theory, and based on this, an agenda for theory-driven design research. This contributes to the debate on how to improve impact, and theoretical and scientific rigour in design research, and provides a concrete agenda for discussion and development within the community.



### Speculative and Critical Design – Features, Methods, and Practices

Leon Karlsen Johannessen, Martina Maria Keitsch, Ida Nilstad Pettersen  
 Department of Design, Faculty of Architecture and Design, Norwegian University of Science and Technology

Speculative and Critical Design (SCD) confronts traditional design practice. Instead of reproducing and reinforcing contemporary perceptions of products and services, SCD seeks to change them, with the goal to spur a public debate e.g. on what is a preferable societal development. SCD methods comprise among others speculative narratives and design of critical objects. However, the theoretical fundament of SCD is feeble, and concepts and methods are upheld of mere examples. The article aims to present the features, methods, and practice of SCD, and locate it in the design field. Following the introduction, section 2 presents features and SCD methods and practices. Section 3 links SCD to traditional design and identifies benefits and challenges relating to its role as a supplement to today's design practice. The final section suggests topics for further SCD research. The article benefits designers in search for alternatives to commercially oriented design approaches. Findings indicate that SCD can contribute to creating new societal roles for designers, foster innovation in the relationship between designers and users, and encourage creativity through imaginative aesthetics.



## Connecting functional and geometrical representations to support the evaluation of design alternatives for aerospace components

Jakob R. Müller, Massimo Panarotto, Ola Isaksson  
Chalmers University of Technology

Novel product concepts are often down-selected in favour of the incremental development of available designs. This can be attributed to the fact that for the development of a new product, simulations and analysis based on high-fidelity CAD models are required, which are expensive to create. To solve this problem, the use of a function model (FM) as intermediate step between ideation and embodiment is suggested. The approach has been examined in a case study with an aerospace company for the development of a turbine rear assembly, using multiple workshops and interviews with practitioners from the company. A multitude of novel solutions, even extending the functionality of the legacy design, were captured. The FM approach proved to support the representation, analysis, and configuration of 102 different concepts. Although supported by the FM model, the embodiment still showed to be a bottle neck for further development. The subsequent interviews with practitioners showed that the benefits of the approach were seen, but experienced as too complex. Further work will concern a more systematic connection between the FM and CAD model, in order to automate of the embodiment process.



## A Comparison of Design Activity of Academics and Practitioners Using the FBS Ontology: A Case Study

Ada Hurst (1), Oscar G. Nespoli (1), Sarah Abdellahi (2), John S. Gero (2)  
1: University of Waterloo; 2: University of North Carolina

Academics teach engineering design based on design theory and best practices, practitioners teach design based on their experience. Is there a difference between them? There appears to be little prior work in comparing the design processes of design academics and practitioners. This paper presents a case study in which the design activity of a team of academics was compared to that of a team of practitioners. The participants' verbalizations during team discussions were coded using the Function-Behaviour-Structure (FBS) ontology. A qualitative comparison reveals that the team of practitioners constructs the design space earlier and generally spends more time in the solution space than the team of academics. Further, the team of practitioners has a significant number of direct transitions from function (F) to structure (S), while no such transitions are observed for the team of academics. Given that this is a single case study, the results cannot be used as the basis for any generalizations on how academics and practitioners compare. This is a successful proof of methodologies that lay the foundation for a series of hypotheses to be tested in a future study.



## Holistic digital function modelling with graph-based design languages

Michael Elwert (1), Manuel Ramsaier (1), Boris Eisenbart (2), Ralf Stetter (1)  
1: University of Applied Sciences Ravensburg-Weingarten; 2: Swinburne University of Technology

Graph-based design languages offer a promising approach to address several major issues in engineering, e. g. the laborious manual transfer between CAD and CAE. Such languages generate a digital meta- or system model storing all relevant information about a design and feed this into any relevant CAE tool as needed to simulate and test the impact of any design variation on the resulting product performance. As this can be automated in digital compilers to perform systematic design variation for an almost infinite amount of parameters, such graph-based languages are a powerful means to generate viable design alternatives and thus permit fast evaluations. To leverage the full potential of graph-based design languages, possibilities are presented to expand their applicability into the domain of product functions. This possibilities allow to cohesively link integrative function modelling to product structures. This intends to close the gap between the early, abstract stages and the systematic, concrete design generation and validation with relevant CAE tools. In this paper, the IFM Framework was selected as integrated function model to be linked with the graph-based design languages.



## Functional analysis in embodiment design - an investigation of embodiment function relations in testing activities

Patric Grauberger, Katharina Voß, Sven Matthiesen  
Karlsruhe Institute of Technology, Institute of Product Engineering

Testing contributes to success of engineering design as it plays an important role in gaining insights about the system in development. Literature indicates that for success in engineering design, gaining insights about relations of embodiment and function is crucial. In this contribution, an investigation of how insights about embodiment function relations are gained in testing, is conducted. For this, the testing documentation in a student development project is analysed. The results show a correlation of gaining insights about embodiment function relations to success in engineering design. Potential for improvement in data acquisition and processing is uncovered, which will be used in a succeeding study to investigate this issue in more detail.



### A matrix-based approach to investigate the geometrical dependencies between non-driving-related tasks and future vehicle concepts

Niko Seebach (1,2), Marcel Rück (1), Frank Arlt (1), Beate Bender (2)  
 1: BMW AG; 2: Ruhr-University Bochum

Caused by the technology of automated driving the user is temporarily released from driving and can perform non-driving-related tasks (NDRTs), such as sleeping or working. The aim of this paper is to describe the geometrical interdependencies between NDRTs and different vehicle types, to be able to integrate them in the geometric package of the early phase of the vehicle conception. To address the objective a literature based study of existing approaches for vehicle conception and NDRT-studies was carried out. Additionally interviews with n=15 experts from the automotive conception department and a databased analysis of n=259 vehicles was conducted. Based on these investigations 91 geometrical characteristics for NDRTs and vehicle types were determined and combined through a matrix-based approach. By analysing the approach highly connected characteristics such as the torso angle were identified and equations were set up to describe the relations. The approach can be used for different NDRTs such as relaxing and working and different vehicle types such as sporty cars or SUVs in order to integrate them into the package.



### Explore User Behaviour In Semi-Autonomous Driving

Yuan Shi, Jeyhoon Maskani, Giandomenico Caruso, **Monica Bordegoni**  
 Politecnico di Milano

The control shifting between a human driver and a semi-autonomous vehicle is one of the most critical scenarios in the road-map of autonomous vehicle development. This paper proposes a methodology to study driver's behaviour in semi-autonomous driving with physiological-sensors-integrated driving simulators. A virtual scenario simulating take-over tasks has been implemented. The behavioural profile of the driver has been defined analysing key metrics collected by the simulator namely lateral position, steering wheel angle, throttle time, brake time, speed, and the take-over time. In addition, heart rate and skin conductance changes have been considered as physiological indicators to assess cognitive workload and reactivity. The methodology has been applied in an experimental study which results are crucial for taking insights on users' behaviour. Results show that individual different driving styles and performance are able to be distinguished by calculating and elaborating the data collected by the system. This research provides potential directions for establishing a method to characterize a driver's behaviour in a semi-autonomous vehicle.



### Mixed-Method Design for User Behavior Evaluation of Automated Driver Assistance Systems: An Automotive Industry Case

Julia Orlovskaya (1), Fjolle Novakazi (1,2), Casper Wickman (1,2), Rikard Soderberg (1)  
 1: Chalmers University of Technology; 2: VOLVO Car Corporation

Automotive systems are changing rapidly from purely mechanical to smart, programmable assistants. These systems react and respond to the driving environment and communicate with other subsystems for better driver support and safety. However, instead of supporting, the complexity of such systems can result in a stressful experience for the driver, adding to the workload. Hence, a poorly designed system, from a usability and user experience perspective, can lead to reduced usage or even ignorance of the provided functionalities, especially concerning Adaptive Driver Assistance Systems. In this paper, the authors propose a combined design approach for user behavior evaluation of such systems. At the core of the design is a mixed methods approach, where objective data, which is automatically collected in vehicles, is augmented with subjective data, which is gathered through in-depth interviews with end-users. The aim of the proposed methodology design is to improve current practices on user behavior evaluation, achieve a deeper understanding of driver's behavior, and improve the validity and rigor of the named results.



### Quantitative characterisation for non-driving-related activities in automated vehicles

Florian Fitzen (1), Jan Reimann (1), Maximilian Amereller (1), Kristin Paetzold (2)  
 1: BMW AG; 2: Bundeswehr University Munich

The technological progress to automated driving not only influences the motion of the vehicle itself but also enables passengers to productively shape their driving time in a new way as they are not occupied with driving tasks anymore. Therefore, non-driving-related activities such as sleeping, working on a notebook or watching movies, become relevant user scenarios for functionally designing the automotive interior. For this purpose, a non-driving-related activity can be described by functions, which support the users in performing their intentional tasks, and function carriers, which fulfil one or several functions. Basing on previous research findings, a quantitative survey is conducted in order to identify relevant and prioritised functions and function carriers. Five non-driving-related activities are taken into account: 'Making a call', 'sleeping', 'watching a movie', 'talking to passengers' and 'working on a notebook'. Results show a significant difference between general relevancy and specific prioritisation of functions and function carriers. In this contribution, the setup of the study is described, the outcome exemplified and further research steps are deduced.



### Industry Trends to 2040

**Claudia Eckert (1), Ola Isaksson (2), Sophie Hallstedt (3), Johan Malmqvist (2), Anna Öhrwall Rönnbäck (4), Massimo Panarotto (2)**

1: The Open University; 2: Chalmers University of Technology; 3: Blekinge Institute of Technology; 4: Luleå University of Technology

The engineering design community needs to development tools and methods now to support emerging technological and societal trends. While many forecasts exist for technological and societal changes, this paper reports on the findings of a workshop, which addressed trends in engineering design to 2040. The paper summarises the key findings from the six themes of the workshop: societal trends, ways of working, lifelong learning, technology, modelling and simulation and digitisation; and points to the challenge of understanding how these trends affect each other



### A framework for designing work systems in Industry 4.0

**Bzhwen A Kadir (1), Ole Broberg (1), Carolina Souza da Conceição (1), Nik Grewy Jensen (2)**

1: Technical University of Denmark(DTU); 2: Dansk IngeniørService A/S

The introduction of new digital technologies in industrial work systems and increasing implementation of Cyber Physical Systems are evoking new and unknown challenges and opportunities related to aspects of human work and organisation. To ensure human wellbeing and overall system productivity, there is a need for interdisciplinary methods and approaches for dealing with the challenges and taking advantage of the opportunities. In this paper, we present a conceptual framework for designing Industry 4.0 enabled work systems, which serves to accommodate this need. The framework combines elements and principles of Design- and Lean thinking methodologies and Human Factors and Ergonomics, thus making it a practical, systematic, and iterative, human centred approach. We use examples from a retrospective industrial case study to illustrate elements of the framework and provide several implications for practitioners.



### Development of a quantitative evaluation tool to support the development process of industry 4.0 production equipment

**Esra Ünal, Christian Köhler**

htw saar, Saarland University of Applied Sciences

One of the main problems in the implementation of Industry 4.0 is the assessment of the added technical and economic value of the new digital and other technological opportunities. This can already be observed during the elaboration of solution alternatives during the development of new industry 4.0 work systems. In order to support the developers of these systems in their decision-making, this contribution introduces a quantitative evaluation approach based on the combination of an extension of the CPM/PDD approach with an industry 4.0 maturity model and an identification scheme for process losses.



### The Direction of Industry: A Literature Review on Industry 4.0

**Robert Lawrence Wichmann (1), Boris Eisenbart (1), Kilian Gericke (2)**

1: Swinburne University of Technology; 2: University of Luxembourg

With the rapid success of the digital enterprises in the 21st Century, industrial manufacturing is expected to be approaching the fourth industrial revolution, coined Industry 4.0 (I4.0). The instrumental technology that will drive this evolution is the integration of the physical and digital factory into one cyber physical system. There is consensus among academics and industry alike that there will be an integral paradigm shift in how offerings will be developed and manufactured. While there is much confidence that the future factory will have unprecedented capabilities to satisfy complex customer demands, there is little agreement on how individual organisations can utilise these trends. This paper presents a literature review identifying reoccurring themes and trends of I4.0 and their expected effect on future manufacturing. Central characteristics, challenges and opportunities are identified and discussed. The findings can provide support in developing actionable strategies for industry to direct I4.0 endeavours.



## Automatic Identification of Product Usage Contexts from Online Customer Reviews

*Dedy Suryadi, Harrison Kim*

*University of Illinois at Urbana-Champaign*



There are three product design contexts that may significantly affect the design of a product and customer preferences towards product attributes, i.e. customer context, market context, and usage context factors. The conventional methods to gather product usage contexts may be costly and time consuming to conduct. As an alternative, this paper aims to automatically identify product usage contexts from publicly available online customer reviews. The proposed methodology consists of Preprocessing, Word Embedding, and Usage Context Clustering stages. The methodology is applied to identify usage contexts from laptop customer reviews, which results in 16 clusters of usage contexts. Furthermore, analyzing the review sentences explains the separation of "playing games" –which is more related to casual gaming, and "gaming rig" –which implies high computing power requirements. Finally, comparing customer review with manufacturer's product description may reveal a discrepancy to be investigated further by product designer, e.g. a customer suggests a laptop for basic use, although the manufacturer's description describes it for heavy use.



## An affordance-based online review analysis framework

*Tianjun Hou (1), Bernard Yannou (1), Yann Leroy (1), Emilie Poirson (2)*

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One of the main tasks of today's data-driven design is to learn customers' concerns from the feedback data posted on the internet, to drive smarter and more profitable decisions during product development. Feature-based opinion mining was first performed by the computer and design scientists to analyse online product reviews. In order to provide more sophisticated customer feedback analyses and to understand in a deeper way customer concerns about products, the authors propose an affordance-based online review analysis framework. This framework allows understanding how and in what condition customers use their products, how user preferences change over years and how customers use the product innovatively. An empirical case study using the proposed approach is conducted with the online reviews of Kindle e-readers downloaded from amazon.com. A set of innovation leads and redesign paths are provided for the design of next-generation e-reader. This study suggests that bridging data analytics with classical models and methods in design engineering can bring success for data-driven design.



## Approaches to automatically extract affordances from patents

*Filippo Chiarello (1), Ilenia Cirri (1), Nicola Melluso (1), Gualtiero Fantoni (1), Andrea Bonaccorsi (1), Tommaso Pavanello (2)*

*1: Università di Pisa; 2: Erre Quadro s.r.l.*

The importance of affordance in Engineering design is well established. Artifacts that are able to activate spontaneous and immediate users' reactions are considered the outcome of good design practice.

A huge effort has been made by researchers for understanding affordances: yet these efforts have been somewhat elusive. In particular, they have been limited to case studies and experimental studies, usually involving a small subset of affordances. No systematic effort has been carried out to list all known affordance effects. This paper offers preliminary steps for such an ambitious effort. We propose a set of three different approaches of Natural Language Processing techniques to be used to extract meaningful affordance information from the full text of patents: 1) a simple word search, 2) a lexicon of affordances and 3) a rule-based system.

The results give in-depth measures of how rare affordances in patents are, and a fine grain analysis of the linguistic construction of affordances. Finally, we show an interesting output of our method, that has detected affordances for disabled people, showing the ability of our system to automatically collect design-relevant knowledge.



## Supporting knowledge re-use with effective searches of related engineering documents – a comparison of Search Engine and Natural Language Processing-based algorithms

*Ivar Örn Arnarsson (1), Otto Frost (2), Emil Gustavsson (2), Daniel Stenholm (1), Mats Jirstrand (2), Johan Malmqvist (1)*

*1: Chalmers University of Technology; 2: Fraunhofer-Chalmers Centre*

Product development companies are collecting data in form of Engineering Change Requests for logged design issues and Design Guidelines to accumulate best practices. These documents are rich in unstructured data (e.g., free text) and previous research has pointed out that product developers find current IT systems lacking capabilities to accurately retrieve relevant documents with unstructured data. In this research we compare the performance of Search Engine & Natural Language Processing algorithms in order to find fast related documents from two databases with Engineering Change Request and Design Guideline documents. The aim is to turn hours of manual documents searching into seconds by utilizing such algorithms to effectively search for related engineering documents and rank them in order of significance. Domain knowledge experts evaluated the results and it shows that the models applied managed to find relevant documents with up to 90% accuracy of the cases tested. But accuracy varies based on selected algorithm and length of query.



## Robustness Evaluation of Product Concepts based on Function Structures

*Stefan Goetz, Jonas Hartung, Benjamin Schleich, Sandro Wartzack*  
Friedrich-Alexander-Universität Erlangen-Nürnberg

Due to the varying environment conditions as well as the manufacturing induced deviations, the properties of products vary. In order to still meet the increasingly tightening of functional requirements, tolerancing as well as Robust Design practices became integral parts of the product development. However, despite the fact that the robustness of a product is mainly determined by its conceptual design in early design stages, these activities are usually carried out at the end of the design process. In order to overcome this shortcoming, this contribution shows a method that supports the selection of robust principal solutions and thus contributes to the design of product concepts, which are less sensitive to variations. The novelty lies in the adaptation and combination of robust design criteria for the quantitative robustness evaluation in the conceptual design stage. First the product characteristics, which are relevant for the product robustness are determined on the basis of the function structure. By using an adopted VMEA and a newly developed evaluation matrix, this allows a thorough robustness evaluation of product concepts. The method is exemplary shown for a lifting table.



## Functional Trade-offs in the Mechanical Design of Integrated Products - Impact on Robustness and Optimisability

*Nökkvi S. Sigurdarson (1,2), Tobias Eifler (1), Martin Ebro (2)*  
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It is generally accepted in industry and academia that trade-offs between functional design objectives are an inevitable factor in the development of mechanical systems. These trade-offs can have a large influence on the achievable robustness and performance of the final design, with many products only functioning in narrow sweet-spots between different objectives. As a result, the design process of multi-functional products can be prolonged when designers concurrently attempt to find sweet-spots between a number of potentially interdependent trade-offs. This paper will show that designers only have six different approaches available when attempting to manage a trade-off while trying to ensure robustness and a sufficient performance. These fall within one of three categories; accept, optimise, or redesign. Selecting the wrong approach, can result in consequences downstream which can be difficult to predict, amongst others a lack of robustness to geometric variation, constrained performance, and long development lead time. This points to a substantial potential in the synthesis of design methods that support the identification and management of trade-offs in early product development.



## Analysis and Synthesis of Resilient Load-carrying Systems

*Fiona Schulte, Eckhard Kirchner, Hermann Kloberdanz*  
Technische Universität Darmstadt

Resilient systems have the capability to survive and recover from seriously affecting events. Resilience engineering already is established for socio-economic organisations and extended network-like structures e. g. supply systems like power grids. Transferring the known principles and concepts used in these disciplines enables engineering resilient load-carrying systems and subsystems, too. Unexpected load conditions or component damages are summarised as disruptions caused by nescience that may cause damages to the system or even system breakdowns. Disruptions caused by nescience can be controlled by analysing the resilience characteristics and synthesising resilient load-carrying systems. This paper contributes to a development methodology for resilient load-carrying systems by presenting a resilience applications model to support engineers analysing system resilience characteristics and behaviour. Further a concept of a systematically structured solution catalogue is provided that can be used for the classification of measures to realise resilience functions depending on system adaptivity and disruption progress. The resilience characteristics are illustrated by 3 examples.



## Sequential updating of quantitative requirements for increased flexibility in robust systems design

*Matthias Funk (1), Marcus Jautze (2), Manfred Strohe (2), Markus Zimmermann (3)*

1: BMW, Department of Preliminary Design for Vehicle Dynamics; 2: Hochschule Landshut University of Applied Sciences, Mechanical Engineering; 3: Technische Universität München, Laboratory for Product Development and Lightweight Design

In early development stages of complex systems, interacting subsystems (including components) are often designed simultaneously by distributed teams with limited information exchange. Distributed development becomes possible by assigning teams independent design goals expressed as quantitative requirements equipped with tolerances to provide flexibility for design: so-called solution-spaces are high-dimensional sets of permissible subsystem properties on which requirements on the system performance are satisfied. Edges of box-shaped solution spaces are permissible intervals serving as decoupled (mutually independent) requirements for subsystem design variables. Unfortunately, decoupling often leads to prohibitively small intervals. In so-called solution-compensation spaces, permissible intervals for early-decision variables are increased by a compensation mechanism using late-decision variables. This paper presents a multi-step development process where groups of design variables successively change role from early-decision to late-decision type in order to maximize flexibility. Applying this to a vehicle chassis design problem demonstrates the effectiveness of the approach.



## Roadmap to consider physiological and psychological aspects of user-product interactions in virtual product engineering

**Sandro Wartzack, Tina Schröppel, Alexander Wolf, Jörg Miehling**  
Friedrich-Alexander-Universität Erlangen-Nürnberg

To successfully facilitate user-centred design, a multitude of different aspects has to be considered, from purely physiological to psychological-emotional factors. The overall aim is to increase the customer satisfaction by enhancing the fit between products and their users in the respective context of use. Further virtualisation of user-centred design processes holds the potential to convey the concepts of frontloading and predictive engineering from classical product engineering. Our vision is to facilitate a comprehensive consideration of user-product interactions in virtual product engineering operationalised by the mission to develop methods and tools to assess and design user-product interactions according to physiological and psychological aspects. A variety of work has already been done to model musculoskeletal user groups, to configure, predict, simulate and optimise physical user-product interactions, to integrate such models into CAD or to map individual subjective values to product design. Nevertheless, there are still research areas to be addressed to enable a comprehensive implementation of the mentioned approach. These are discussed in the present contribution.



## Is Organizational Design a Human-centered Design Practice?

**Jan Michel Kurt Auernhammer, Larry Leifer**  
Stanford University

In recent years design has had a renaissance in business and management research and practice. Several authors have discussed if management is a design practice and how far design ought to go to design behaviors. This article discusses, evaluates and explores organizational design as a human-centered design practice. Relevant theoretical concepts of organizational theory, design approaches and practices are discussed to evaluate gaps in management practices and potential opportunities for design practice. The study collected and analyzed data from two organizations. The researched revealed several propositions, which provide insights of the usefulness, appropriateness and value of a human-centered design practice to organizational design.



## Evaluating Innovative Projects For And With Elderly People: Insights From Participatory Design Contests

**Camille Jean (1), François Cluzel (2), Flore Vallet (2,3), Bernard Yannou (2)**

1: Arts et Métiers ParisTech; 2: CentraleSupélec, Université Paris-Saclay; 3: IRT SystemX, Paris-Saclay

Societies are challenged worldwide to maintain or improve the life of an ageing population. In the meantime, it is an opportunity for businesses to develop products and services for the elderly. Participatory design - or co-design - promotes not only to design for, but also with and by older adults. Current studies tend to emphasize more field investigations and co-ideation than evaluation of co-designed outcomes with seniors. We are interested in two 24 hours-innovation contests in 2017 and 2018, yearly involving 10 teams of 3 students, elderly persons as potential beneficiaries and innovation experts. The aim of this paper is to analyse the variability of evaluation of generated projects between the elderly people and the innovation experts. The comparative analysis relies on the grades and ranking of projects against five criteria. Results show that elderly people provide consistent evaluations, but with a positioning slightly shifted compared to the experts. We conclude on recommendations for the evaluation process with a jury including seniors.



## The Personification of Big Data

**Phillip Douglas Stevenson, Christopher Andrew Mattson**  
Brigham Young University

Organizations all over the world, both national and international, gather demographic data so that the progress of nations and peoples can be tracked. This data is often made available to the public in the form of aggregated national level data or individual responses (microdata). Product designers likewise conduct surveys to better understand their customer and create personas. Personas are archetypes of the individuals who will use, maintain, sell or otherwise be affected by the products created by designers. Personas help designers better understand the person the product is designed for. Unfortunately, the process of collecting customer information and creating personas is often a slow and expensive process. In this paper, we introduce a new method of creating personas, leveraging publicly available databanks of both aggregated national level and information on individuals in the population. A computational persona generator is introduced that creates a population of personas that mirrors a real population in terms of size and statistics. Realistic individual personas are filtered from this population for use in product development.

## Discussion Sessions

Tuesday

6 August 2019

14:00 – 15:00

<b>Additive Manufacturing   Applications</b> <i>Pulse Building, Hall 4</i>	<b>42</b>
<b>Design Management   Case Studies</b> <i>IDE Faculty, Hall M</i>	<b>44</b>
<b>Design Methods   Applications</b> <i>IDE Faculty, IDE Arena</i>	<b>46</b>
<b>Design Education   Creativity</b> <i>IDE Faculty, Wim Crouwel</i>	<b>48</b>
<b>Ethics and Impact on society</b> <i>IDE Faculty, Bernd Schierbeek</i>	<b>50</b>
<b>Future Mobility   Energy-efficient Mobility</b> <i>IDE Faculty, Hall L</i>	<b>52</b>
<b>Healthcare   Approaches</b> <i>IDE Faculty, Hans Dirken</i>	<b>54</b>
<b>Knowledge Management</b> <i>Pulse Building, Hall 5</i>	<b>56</b>
<b>Ontologies   System</b> <i>IDE Faculty, Hall K</i>	<b>58</b>



## Design of a custom-made cranial implant in patients suffering from Apert syndrome

**Marco Mandolini (1), Agnese Brunzini (1), Eleonora Brandoni Serrani (1), Mario Pagnoni (2), Alida Mazzoli (1), Michele Germani (1)**

1: Università Politecnica delle Marche; 2: Università degli Studi di Roma La Sapienza

This study defines a methodological procedure for the design and manufacturing of a prosthetic implant for the reconstruction of a midsagittal bony-deficiency of the skull due to the Apert congenital disorder. Conventional techniques for craniofacial defects reconstruction rely on the mirrored-image technique. When the cranial lesion extends over the midline or in case of bilateral defects, other approaches based on thin plate spline interpolation or constrained anatomical deformation are applied.

The proposed method uses the anthropometric theory of cranial landmarks identification for the retrieval of a template healthy skull, useful as a guide in the successive implant design. Then, anatomical deformation of the region of interest and free-form modelling allow to get the customized shape of the implant. A full bulk and a porous implant have been provided according to the surgeon advises. The models have been 3D printed for a pre-surgical analysis and further treatment plan. They fulfilled the expectancies of the surgeon thus positive results are predictable. This methodology results to be reproducible to any other craniofacial defect spanning over the entire skull.



## Mechatronics Enabling Kit for 3D Printed Hand Prosthesis

**Tat Hang Wong (1), Davide Asnaghi (2), Suk Wai Winnie Leung (1)**

1: Division of Integrative Systems and Design, Hong Kong University of Science and Technology; 2: Department of Bioengineering, University of California Berkeley

New advances in both neurosciences and computational approaches have changed the landscapes for smart devices design serving mobility-related disabilities. In this paper we present the integration of affordable robotics and wearable sensors through our mechatronic product platform, Sparthan, to enable accessibility of the technology in both the power prosthesis and neurorehabilitation space. Sparthan leverages 3rd party EMG sensors, Myo armband, to process muscles sensor data and translate user intention into hand movements. Key innovation includes the modularity, scalability and high degree of customization the solution affords to the target users. User-centered design approaches and mechatronic system design are detailed to demonstrate the versatility of integrative systems and design. What started off as an engineering research endeavor is also positioned to be deployed to deliver real-world impact, especially for prosthesis users in developing countries.



## Drivers and Guidelines in Design for Qualification using Additive Manufacturing in Space Applications

**Christo Dordlofva (1), Olivia Borgue (2), Massimo Panarotto (2), Ola Isaksson (2)**

1: Luleå University of Technology; 2: Chalmers University of Technology

In recent years, reducing cost and lead time in product development and qualification has become decisive to stay competitive in the space industry. Introducing Additive Manufacturing (AM) could potentially be beneficial from this perspective, but high demands on product reliability and lack of knowledge about AM processes make implementation challenging. Traditional approaches to qualification are too expensive if AM is to be used for critical applications in the near future. One alternative approach is to consider qualification as a design factor in the early phases of product development, potentially reducing cost and lead time for development and qualification as products are designed to be qualified. The presented study has identified factors that drive qualification activities in the space industry and these "qualification drivers" serve as a baseline for a set of proposed strategies for developing "Design for Qualification" guidelines for AM components. The explicit aim of these guidelines is to develop products that can be qualified, as well as appropriate qualification logics. The presented results provide a knowledge-base for the future development of such guidelines.



## Design automation for customised and large-scale additive manufacturing: a case study on custom kayaks

**Drew Lithgow (1), Cara Morrison (1), George Pexton (1), Massimo Panarotto (2), Jakob R. Müller (2), Lars Almefelt (2), Andrew McLaren (1)**

1: University of Strathclyde; 2: Chalmers University of Technology

Additive Manufacturing (AM) offers the potential to increase the ability to customise large-scale plastic components. However, a substantial amount of manual work is still required during the customisation process, both in design and manufacturing.

This paper looks into how the additive manufacturing of mass customised large-scale products can be supported. Data was collected through interaction with industrial partners and potential customers in a case study regarding the customisation of kayaks.

As a result, the paper proposes a model-based methodology which combines design automation with a user interface.

The results point to the benefit of the proposed methodology in terms of design efficiency, as well as in terms of displaying results to the end user in an understandable format.



## Experimentation throughout the product development process – lessons from food and beverage ventures

Ville Kukko-Liedes, **Maria Mikkonen**, Tua Björklund  
Aalto University

Established companies turn to new ventures for bolstering exploration activities, but we know relatively little of the product development processes of startups and new ventures and how different stakeholders are utilized in these. The current study investigated the product development activities and experiments of eight Finnish food and beverage ventures in a multiple case study based on 22 interviews. How the developed products fit into the existing portfolio and experience of the ventures seemed to define their enacted development process. Internal experimentation was a constant feature, although the type of experiments varied between different phases of the development process. External-facing experiments were less frequent and more for validation than concept generation. On the other hand, they also carried important market creation functionalities. The results suggest that more nuanced terminology around experimentation would be useful to determine what type of experiments serve different goals in the development process.



## The design process at Le Corbusier, case of the Ronchamp chapel

Nadjat Outmoune (1,2,3), **Abdelmalek Arrouf** (1,2)

1: Laboratory of architectural and urban phenomena modeling and studying;  
2: University of Batna; 3: University of Biskra

This work falls within the empirical studies of design activity. Its project is to understand Le Corbusier's designing way and how does he work and structure his design processes. Doing so, it jumps above the descriptive and doctrinal knowledge of objects produced by "Le Corbusier" to study the actions and mechanisms that led to them.

To achieve its aim, this study uses genetic method, developed by P.M. De Biasi of literary origin, this research method is made of three stages. The first one, which is of empirical nature, is one of data gathering. It leads to the establishment of genesis tables and to the classification of the all collected documents. The second stage, makes the analysis of all the collected documents one by one. It allows the restitution of the creative process of one projects "Le Corbusier" which is "la chapelle de Notre Dame du haut de Ronchamp". The last stage is finally that define the design processe of the this project.

The results show that the design activity of "Le Corbuiser" obeys the overall logic of one generic model which may be called his individual designing style.



## Mapping the progress in agile product development: A multi-case study

Tobias Sebastian Schmidt (1), Jan Behrenbeck (2), Kevin Burger (2), Rafael Hostettler (2), **Kristin Paetzold** (1), Markus Zimmermann (2)

1: University of the German Federal Armed Forces Munich; 2: Technical University of Munich

The more dynamic and unpredictable the development constraints, the more agile the development project should be to cope with and utilize inherent change. Especially in such contexts, aligning with the project's mission and vision, committing to next steps, and documenting the development path is challenging. To support the decision making process of self-organized agile development teams with an overview, a recent research paper proposes the Progress Map. The investigation at hand applies the Progress Map in semi-industrial development projects to empirically validate its applicability and performance in the form of a multi-case study. The results indicate that, given future refinements, this instrument can be valuable to plan, document, and communicate the progress of an agile development project.



## Reflection-in-Action when designing organizational processes: prototyping workshops for collective reflection-in-action

**Frithjof Eberhard Wegener**, Milene Guerreiro Gonçalves, Zoë Dankfort  
Delft University of Technology, Faculty of Industrial Design Engineering

In this paper on designing organizational processes, we combine insight on reflection-in-action with the role of reflection and experimenting from the organizational routine dynamics literature. Illustrated through a case at a strategy consultancy, we show how a prototyped workshop can elicit reflection-in-action when designing organizational processes. The artifacts used in the prototyped workshop made previous implicit assumptions about the work more explicit. This led to on the spot reflection-in-action of how to improve the prototype. This shows how collective reflection-action can be created by creating a space for reflection, that simultaneously allows for experimentation. Future research between design science and organizational science would thus be fruitful when studying the role of collective reflection-in-action when prototyping organizational processes.



## Designing digital technology for service work: systematic and participatory approach

**Kentaro Watanabe, Ken Fukuda**

*National Institute of Advanced Industrial Science and Technology*

Digital technology is dramatically changing our life, industry, and society. Recent evolution of digital technology is expected to significantly impact service work, such as healthcare and social welfare. Meanwhile, an insufficient understanding of service work and workers' needs leads to the failure of technology development and integration. To make digital technology better fit to values and work practices of service workers, various studies have been conducted, especially in the field of participatory design, interaction design, and service design. However, the contribution of engineering design to this topic is still limited. This paper proposes an engineering design approach to design digital technology for better integration in service work. This study combines a modelling method to represent specifications of digital technology and the participatory approach in alignment with the changing service work and workers' values. A case study of the mobile application system for elderly-care professionals is introduced to exemplify the effectiveness of the proposed method. This study intends to foster innovation of service work through digitalization.



## Analysing and Solving the Reduced-ability and Excessive-use Dilemmas in Technology Use

**Shigeru Wesugi**

*Waseda University*

Technology use provides great benefits by extending human ability, but the negative effects cannot always be ignored. The author examined the dilemmas of technology use based on Shibata's analysis of McLuhan's extension theory and indicated two types of dilemmas in continuous technology use. First is the decreased human ability as the innate functionality is substituted by the technology. Second is excessive utilisation of the technology, which may instil a false sense of naturally extended ability.

Subsequently, the author considered and suggested approaches for mitigating both types of dilemmas. The decreased-ability dilemma might be resolved by continuously utilising the technology and designing technology relevant to the degree of human ability. Meanwhile, the excessive-utilisation dilemma might be resolved by regulating the technology use and designing technology that achieves the desired disposition change in users.

Finally, the possibility of advancing the existing design approaches to further resolve the dilemmas was discussed.



## Rhetorical design game for expectation alignment

**Mikael Koskela, Ergo Pikas**

*Technical University of Denmark*

While the form of building construction delivery known as Integrated Design-Build (or Integrated Project Delivery) is necessary for handling the complexity of modern projects, it raises up a host of problems due to the amount and variety of stakeholders that are brought together to co-design. Namely, the difficulty in forming a shared mental model of expectations regarding the project can cause disappointment in the results, as well as time and cost overruns. This paper is about creating an intervention to alleviate those issues. Employing knowledge from the field of rhetoric in design, and of mental models, two Integrated Design-Build workshops were analyzed to extract a set of rhetorical topics (topoi) to all such sessions. A design game was formulated around the empirical data by an iterative design process, following established design game theory. The game was found to indeed more than double the alignment of a group's individual mental models, though more testing is needed to validate this.



## Assessing Concept Novelty Potential with Lexical and Distributional Word Similarity for Innovative Design

**Yutaka Nomaguchi, Takahiro Kawahara, Koki Shoda, Kikuo Fujita**

*Osaka University*

Generating novel design concepts is a cornerstone for producing innovative products. Although many methods have been proposed for supporting the task, their performance depends on human ability. The goal of this research is to build a method supporting designers to generate novel design concepts with the knowledge of what factors have positive effects on the novelty. Toward the goal, this research assumes that the more distant two function concepts chosen, the more novel idea would come up with by the combination of the two concepts. Based on the assumption, this paper introduces a notion of novelty potential of the combination of two function concepts, and proposes a method to assess it by the function similarity. It is calculated with the integration of a lexical database for natural language called WordNet and a distributional semantics method called word2vec. The proposed method is adapted to case studies in which students perform design concept generation for given design tasks. The correlation analysis is performed to verify the assessment performance of the proposed method. This paper discusses its possibility based on the results of the case studies.



## Teaching and Learning Design Methods: Facing the Related Issues with TRIZ

Lorenzo Fiorineschi, Francesco Saverio Frillici, **Federico Rotini**  
University of Florence

Design methods are claimed to support designers but, although they are largely taught in academia, their industrial uptake is still lacking. Many reasons have been identified about this flaw and some potential suggestions have been proposed and discussed in literature to overcome the problem. However, a further evidence is that although many students learn such methods from years, they partially or totally abandon the learned methods in their professional careers. This could partially explain the gap between academic and industrial diffusion of design methods. Literature provides suggestions for improving the learning experience of students but different didactical contexts may need more tailored solutions. The work shown in this paper exploits the problem solving potentialities of the TRIZ toolset to provide hints for improving a course focused on teaching a systematic conceptual design method. A set of suggestions has been obtained together some guidelines for applying the considered TRIZ tools to other didactical contexts.



## Heuristic Evaluation Of Ambient Devices Using Smart Materials

Lucas Marques-Lima (2), **Jenny Faucheu (1)**  
1: Mines Saint-Etienne, Univ Lyon; 2: Independent designer and researcher

Teaching “calm technology” and “smart materials” as prospective trends in product design is the motivation of the educational workshop presented in this paper. Materials can trigger creative thinking. Indeed, concepts can be generated ideas that come from the encounter with a material showing the material’s unexpressed potential. However, a smart material is a complex hybrid object. It is a highly technical matter that requires years of R&D to be developed and matured. It is also a highly social matter, that blurs the traditional boundary between matter and function in a product, creates an experience, and enhances sensations. The workshop presented in this paper is an opportunity for the students to analyze the complexity of user experience related to ambient devices using smart materials. In order to provide a guideline to perform this analysis, an approach based on heuristic evaluation is proposed to the students.



## Future Learning and Design Creativity Competency

Yukari Nagai (1), Akio Shimogoori (2), Minatsu Ariga (1), **Georgi V. Georgiev (3)**

1: Japan Advanced Institute of Science and Technology; 2: National Institute of Technology, Hakodate College; 3: University of Oulu

In this study, we discuss a structure for developing the skills and competencies required by the learning framework of the Organisation for Economic Co-operation and Development (OECD) for future education. Given the broad range of skills and the numerous competencies required to meet the demands of future society, the proposed wider and higher-level framework is based on STEAM (science, technology, engineering, art and design, and mathematics) and addresses the limitations of conventional computational thinking by tackling some of the skills and competencies. This is done by proposing the enrichment of STEAM educational approach with art thinking, which may be defined as a creative human-centred discovery process. To explore such enrichment, we conducted a workshop on art thinking. The motivation of the workshop was to explore whether art thinking can overcome some of the limitations of computational thinking regarding future education in the OECD learning framework. We discuss STEAM as focusing on design creativity competency, and we outline the development of educational activities such as workshops to promote competencies in the perspective of OECD framework.



## Impact of inventive design education through the correlation between students' grades and individual talent

Niccolo Becattini, Gaetano Cascini  
Politecnico di Milano

[This paper aims at assessing the impact of inventive design education on students attending a class on Methods and Tools for Systematic Innovation. The study stems from the difficulty to understand how much personal inventive talent influences the final evaluation, especially in a context where students are asked to solve open problems, as conceptual design ones. To overcome the potential bias due to the individual talent, the authors propose to determine the impact of their teaching activity by means of an ex-ante/ex-post correlation analysis. Several cohorts of students along the years have been asked to solve some design problems at the beginning of the course, when no topics have been thought yet. An adapted creativity metrics enriched to map course contents measures the students' performance at the beginning of the class (ex-ante). These results get correlated to the students' final grades (ex-post) in order to highlight areas where teaching has a stronger impact and those where talent remains predominant.



### Design requirements to educate and facilitate junior design professionals to reflect more effectively on critical situations and conflicts at work

Lenny van Onselen (1,2), Christine De Lille (1,2), Dirk Snelders (2)  
1: The Hague University of Applied Sciences; 2: Delft University of Technology

Junior designers are not trained to cope with critical situations and conflict at work. Most design schools do not educate their design students to prepare them for (potential) conflict. As a result, junior designers often do not have conflict-handling skills to handle critical situations and conflicts. While some tools and methods exist to help them make responsible design choices, these often address value differences underlying (potential) conflict without taking the perspective of the designer, and thus without supporting young designers to start by reflecting on their own intrinsic values.

The aim of this study is to find a way to help junior designers to reflect effectively on critical situations, thereby improving their conflict-handling skills. Data was collected through four steps in an action research. Researchers collaborated with an identity programme for junior design professionals. Insights from try-outs and small interventions were transferred into design requirements for an approach to educate and facilitate junior design professionals to reflect more effectively on critical situations.



### Exploratory study of the integration of frugal innovation in the design of products for the BoP

Luis Miguel López Santiago (1), Serge Rohmer (1), René Díaz Pichardo (1,2), Tatiana Reyes (1)

1: Université de Technologie de Troyes; 2: South Champagne Business School

The bottom of the pyramid (BoP) consists of 1.4 billion people living less than 1.25 USD per day. Fulfilling unmet needs of BoP people involves the design of products as a main activity. Designing products for the BoP faces two main problems. First, there is a general lack of understanding of the needs of users and second, traditional design methods may be limited in addressing the BoP context. Frugal innovation is positioned as a very interesting approach with the potential to adequately respond to the design challenges of the products for the BoP. However, studies in engineering design based on frugal innovation are still limited. In response to these issues, through an analysis and review of the literature, an exploratory mapping of the proposals in frugal innovation and the characteristics of the BoP was conducted. On the basis of the results, this paper defines a set of eight frugal criteria design and an identification of three dimensions that characterize a BoP context and two roles of BoP people. Finally, an association of BoP dimensions and roles with the key criteria of frugal design is proposed.



### Ethics and Strategy in Decision-Based Design Frameworks: Problems and Solutions

Daniel Hulse, Christopher Hoyle, Irem Tumer  
Department of M.I.M.E., Oregon State University

Engineering Design decisions impact customers, the environment and society at large in ways that have profound ethical and strategic implications for designers. Previous research in decision-based design has proposed the decisions should be made on the basis of maximizing the expected utility of the design to the designer. This paper discusses ethical and strategic challenges for these frameworks across five levels: the axioms that underlie utility, the definition of utility, the consideration of multiple stakeholders, the modeling scope, and resulting design framework implementation. Based on these problems, solutions are suggested to account for each in the development of improved, ethically-informed frameworks. Challenges presented here do not prohibit the prudent use of decision-based design frameworks per se, but instead point to cases that must be addressed in practice while providing grounds for further research towards the development of decision-based design frameworks that are ethical by design.



### Can Ethics Enhance Creative Design Activity?

Kaira Sekiguchi (1), Koichi Hori (1,2)

1: University of Tokyo; 2: RIKEN Center for Advanced Intelligence Project

This study exhibits that there exists generative ethics in which ethical thinking will allow us to change our perspectives to consider the artifacts' social effects in design, thereby enhancing our activity to generate novel and practical design ideas.

As an example of practicing the generative ethics, a case for addressing the increasing requirement to properly introduce "artificial intelligence" (AI) systems in society was considered. We applied the ethical design theory to promote the practice of ethical AI design by engineers. To achieve this, we implemented a creativity support tool that can be used based on the knowledge base of AI ethics. To confirm the validity of the theory and the tool, we conducted user experiments in which the AI research students had to consider the effects of their own research projects with using the tool. We could confirm that the tool actually induced the users to consider social impacts. Some students revealed in response to the questionnaire that the experiment provided them with an opportunity to reconsider their own research theme.

In this study, the ethical design theory and tool will be briefly reviewed, and the experiments will be discussed.



## Conceptual Design of Urban E-Bus Systems with Special Focus on Battery Technology

**Dietmar Göhlich (1), Tu-Anh Fay (1), Sangyoung Park (2)**

1: Department of Methods for Product Development and Mechatronics Technische Universität Berlin; 2: Department of Smart Mobility Systems Technische Universität Berlin

Many cities have announced ambitious plans to introduce zero-emission electric bus systems. The transformation process to electric bus systems opens up a vast design space as different charging strategies, charging technologies and battery types are available. Therefore, a profound assessment strategy is necessary to find a “most suitable system solution” under given strategic and operational requirements.

In this study, we present a new methodology for conceptual design of urban electric bus systems. First, the available e-bus technologies are analysed with a special focus on charging systems, battery technology and aging. Relational functional analysis is used to derive a suitable simulation model. Based on the operational requirements, an energetic simulation of the e-bus is carried out, and the required battery capacity is obtained. Subsequently, the design space is reduced by applying a qualitative cost-technology compatibility matrix taking cost and battery aging into account. The applicability of the model is shown for an exemplary realistic operational scenario to identify three most expedient concepts, which are finally validated with an in-depth analysis.



## Towards holistic energy-efficient vehicle product system design: the case for a penalized continuous End-Of-Life model in the Life Cycle Energy Optimisation methodology

**Hamza Bouchouireb (1), Ciarán J. O’Reilly (1), Peter Göransson (1), Josef-Peter Schöggel (2), Rupert J. Baumgartner (2), José Potting (1)**

1: KTH Royal Institute of Technology; 2: University of Graz

The Life Cycle Energy Optimisation (LCEO) methodology aims at finding a design solution that uses a minimum amount of cumulative energy demand over the different phases of the vehicle’s life cycle, while complying with a set of functional constraints. This effectively balances trade-offs, and therewith avoids sub-optimal shifting between the energy demand for the cradle-to-production of materials, operation of the vehicle, and end-of-life phases. The present work describes the extension of the LCEO methodology to perform holistic product system optimisation. The constrained design of an automotive component and the design of a subset of the processes which are applied to it during its life cycle are simultaneously optimised to achieve a minimal product system life cycle energy. A subset of the processes of the end-of-life phase of a vehicle’s roof are modeled through a continuous formulation. The roof is modeled as a sandwich structure with its design variables being the material compositions and the thicknesses of the different layers. The results show the applicability of the LCEO methodology to product system design and the use of penalization to ensure solution feasibility.



## Design for Monitoring of a Research Vehicle

**Nobert Kukurowski (1), Ralf Stetter (2), Marcin Witczak (1)**

1: Institute of Control and Computation Engineering, University of Zielona Góra; 2: University of Applied Sciences Ravensburg-Weingarten

In recent years, more and more technical systems dispose of some form of intelligence which allows to control and diagnose the processes and states in such systems. One important prerequisite for both control and diagnosis is monitoring, i.e. a systematic observation, surveillance or recording of entities of a technical product or its surroundings by any technical means. Current investigations were able to clarify that the design of a technical system can ease the control and diagnosis of this system. The same is true for monitoring; this fact will be demonstrated in this paper on the example of a research vehicle which is intended to foster the development of mapping systems and algorithms. In a sense, the main objective of this vehicle is also a kind of monitoring. Due to its unique design, this vehicle is able to navigate on all kind of terrains. It is equipped with several forms of sensors, which are consciously mounted at certain positions on the vehicle in order to allow a detailed detection of the surroundings. The investigation, how design can ease monitoring, was supported by a well-known model of product concretization and concrete insights could be found on all levels.



## Energy Efficient Motion Design and Task Scheduling for an Autonomous Vehicle

**Elias Xidias, Philip Azariadis**

Department of Product & Systems Design Engineering, University of the Aegean

This paper describes an approach for designing an energy efficient motion and task scheduling for an autonomous vehicle which is moving in complicated environments in industrial sector or in large warehouses. The vehicle is requested to serve a number of workstations while moving safely and efficiently in the environment. In the proposed approach, the overall problem is formulated as a constraint optimization problem by using the Bump-Surface concept. Then, a Pareto-based multi-objective optimization strategy is adopted, and a modified genetic algorithm is developed to determine the Pareto optimum solution. The efficiency of the developed method is investigated and discussed through simulated experiments.



## Design for Mass Adaptation of the Neurointerventional Training Model HANNES with Patient-Specific Aneurysm Models

**Johanna Spallek (1), Juliane Kuhl (1), Nadine Wortmann (1), Jan-Hendrik Buhk (2), Andreas Maximilian Frölich (2), Marie Teresa Nawka (2), Anna Kyselyova (2), Jens Fiehler (2), Dieter Krause (1)**

1: Hamburg University of Technology; 2: University Medical Center Hamburg-Eppendorf

A neurointerventional training model called HANNES (Hamburg ANatomical NEurointerventional Simulator) has been developed to replace animal models in catheter-based aneurysm treatment training. A methodical approach to design for mass adaptation is applied so that patient-specific aneurysm models can be designed recurrently based on real patient data to be integrated into the training system.

HANNES' modular product structure designed for mass adaptation consists of predefined and individualized modules that can be combined for various training scenarios. Additively manufactured, individualized aneurysm models enable high reproducibility of real patient anatomies. Due to the implementation of a standardized individualization process, order-related adaptation can be realized for each new patient anatomy with modest effort. The paper proves how the application of design for mass adaptation leads to a well-designed modular product structure of the neurointerventional training model HANNES, which supports quality treatment and provides an animal-free and patient-specific training environment.



## Robotic care: a low cost design to assist therapy for brain stroke rehabilitation

**Pablo Prieto (1), Fernando Auat (2), Maria Escobar (2), Ronny Vallejos (3), Paula Maldonado (4), Cristobal Larrain (4), Martin Serey (1)**

1: Universidad Técnica Federico Santa María. Engineering Design Department.; 2: Universidad Técnica Federico Santa María. Department of Electronic; 3: Universidad Técnica Federico Santa María. Department of Mathematics; 4: Peñablanca Hospital.

A low cost robotic-assisted prototype for finger and hand rehabilitation of people affected by a stroke is presented. The system was developed by a team of undergraduate students led by a Design lecturer in collaboration with the Rehabilitation Unit of the Peñablanca Public Hospital in Chile.

The system consists of a flexion sensor equipped glove, a hand exoskeleton and an Arduino control unit. The patient wears the glove in his healthy hand. When s/he performs movements with the healthy hand, the sensors register the flexion of the fingers and send this information to the servo motors installed in an exoskeleton attached to the affected hand. In this way, the affected hand reproduces the movement of the healthy hand. The system uses a combination of the mirror therapy (the patient sees his/her affected hand moving in the same way that the healthy hand does) and passive exercising (as the exoskeleton produces the movement of the hand affected by the stroke). The combination of two types of therapy in a single low cost system makes the present work unique. In the near future, the developed prototype will be used to validate the effectiveness of the new proposed robotic therapy.



## Design Principles to Increase the Patient Specificity of High Tibial Osteotomy Fixation Devices

**Sanjeevan Kanagalingam (1), Duncan Shepherd (1), Miguel Fernandez-Vicente (2), David Wimpenny (2), Lauren Thomas-Seale (1)**

1: School of Engineering, University of Birmingham; 2: Manufacturing Technology Centre, Coventry

High stiffness fracture fixation devices inducing absolute stability, activate inefficient primary healing and stress shielding. Taking High Tibial Osteotomy as a representative example, review of the clinical literature and mapping the fracture healing process revealed two physically contradicting requirements, which are only partially met by current techniques. Stiffness of the fixation is required immediately after fracture, however in the remodelling phase this can cause stress shielding. Stability is required immediately after fracture, however in the ossification phase less stability is required to stimulate secondary (and more efficient) healing. This study evaluates the use of the TRIZ Inventive Design Principles to overcome these physical contradictions. Six designs concepts were evaluated, of which the Macro-Geometry stiffness modulated design was ranked the highest. This was achieved through spatial decomposition of the problem utilising the Inventive Principles of Asymmetry, Extraction and Local Quality. This study offer perspectives on how to increase the patient specificity of fixation utilising the increased topology freedom of design for additive manufacture (AM).



## An affordable insulin pump for type-1 diabetic patients: A case study of user-in-the-loop approach to engineering design

**Deval Karia, Rohit S Nambiar, Manish Arora**

Indian Institute of Science Bangalore

Continuous subcutaneous insulin infusion using an insulin pump has been documented to have significant clinical benefits as a treatment plan for type 1 diabetes mellitus patients. However, despite this, adoption in resource constrained settings like India is severely limited. This is often attributed to the costs associated with the device.

The usage of such a device is closely associated with a patient's lifestyle and its design demands a more user-centric approach to engineering design. The stakeholder involvement is needed for validation and guiding the product development direction. In this paper, we've outlined a user-in-the-loop approach to engineering design using the design of an insulin pump as a case study.



## Development Methodology for Optomechatronic Systems using the Example of a High-Resolution Projection Module



**Peer-Phillip Ley, Marvin Knöchelmann, Gerolf Kloppenburg, Roland Lachmayer**

*Institute of Product Development*

In the last few years there has been a noticeable change in the development of headlamp systems in the field of vehicle lighting technology. Starting with adaptive front-lighting systems via Matrix LED systems, high-resolution headlamps will provide more safety in road traffic in the near future. For the implementation of high-resolution headlamps various spatial light modulators and light generating technologies can be applied. The emitted light of the light source is directed via an illumination optics onto the modulator and a projection optics is applied to image the spatial light modulator into the traffic area. The formerly mechatronic systems are thus increasingly become opto-mechatronic systems. Therefore, the optic design must be taken into account in the early development phase of these systems.

In this paper we present a methodical approach to describe the optic design for optomechatronic systems. This approach can be used to develop efficient and high-intensity optomechatronic systems using various spatial light modulators and light generating technologies. Conclusively we demonstrate an exemplary application of the methodology on a high-resolution projection module.



## A model-based approach to identify barriers in design knowledge reuse

**Thomas Jordan (1,2), Beate Bender (1), Michael Herzog (1), Young-Woo Song (1)**

*1: Chair for Product Development, Ruhr University Bochum, Germany;  
2: Komatsu Germany GmbH*

Today, information and knowledge as competitive factors influence the success of companies as much as traditional production factors like human resources or physical capital. However, the reuse of design knowledge still represents a major challenge for engineering organizations. That is, because barriers exist hindering a successful knowledge reuse. On the basis of a literature review, the research depicted in this paper analyses the relation between single information conveying design knowledge and barriers hindering a successful knowledge reuse. Developing a model-based approach, we propose a micro logic containing three steps and underlying methods enabling practitioners to identify situation-specific barriers within their organization. We illustrate the industrial application of the approach in a case study at a mining machinery OEM.



## The Construction Of Design Science Knowledge Graphs - Based On National Natural Science Foundation Of China

**Jiang Xu (1), Gang Sun (1), Xifan Ou (1), Jingyu Xu (1), Han Lu (1), Pujie Su (1), Qiushi Wei (1), Man Ding (2)**

*1: Tongji University; 2: Hebei University of Technology*

In the era of knowledge networking, the structure and production mode of knowledge are constantly changing. This article creatively introduces the knowledge mapping method in design research, and based on the perspective of the National Natural Science Foundation of China (NSFC) to compile literature, uses word frequency analysis, co-word analysis, and citation analysis to construct knowledge graphs of design science. This study graphically shows the distribution and flow law of knowledge within design discipline and probes into the research frontier and evolution trend of Chinese design science.



## Approaching Knowledge Dynamics Across the Product Development Process with Methods of Social Research

**Wei Min Wang, Frauke Mörike, Jannis Hergesell, Nina Baur, Markus Feufel, Rainer Stark**

*Technische Universität Berlin*

Knowledge is a crucial factor in state-of-the-art product development. It is often provided by stakeholders from diverse disciplinary and individual backgrounds and has to be integrated to create competitive products. Still, it is not fully understood, how knowledge is generated, transformed, transferred and integrated in complex product development processes. To investigate the dynamic interrelations between involved stakeholders, applied knowledge types and related artefacts, researchers at the TU Berlin conducted and evaluated a student experiment to study basic phenomena of development projects. In relation to research methods and instruments applied in this experiment, various improvement opportunities were identified. In this paper, the experimental setting and its results are critically analysed from a social science perspective in order to generate improved research design. Based on the results of this analysis, a first set of methods and instruments from social sciences are identified that can be applied in further experiments. The goal is to develop a methodological toolbox that can be used to approach research on knowledge dynamics in product development.



## Towards an Ontology of Cognitive Assistants

*Torsten Maier, Jessica Menold, Christopher McComb*  
The Pennsylvania State University

Cognitive assistants such as IBM Watson and Siri are at the forefront of social and technological innovation and have the potential to solve many unique problems. However, the lack of standardization and classification within the field impedes critical analysis of existing cognitive assistants and may further inhibit their growth into more useful applications. This paper discusses the development of an ontology, its classes, and subclasses that may serve as a foundation for defining and differentiating CAs. Specifically, the four suggested classes include: learning, intelligence, autonomy, and communication. Various assistants are described and categorized using the proposed system. Our novel ontological framework is the first step towards a classification system for this burgeoning field.



## A pragmatic approach towards leveraging employee competences by use of semantic web technologies

*Felix Ocker, Birgit Vogel-Heuser*  
Technical University of Munich

Global competition in combination with the increasing specialization of labor requires organizations to leverage their employees' competences. The approach presented in this paper empowers organizations to do so in two ways. First, we give employers a lean tool to allocate their employees to current and upcoming projects and make informed decisions whether they should take on new projects. Secondly, we provide the means to identify potential areas for innovation by identifying blind spots of technology transfer. The approach presented relies on semantic web technologies, i.e. an ontology built in OWL and SPARQL queries. To increase usability, we realized a user interface based on a semi-formalized spreadsheet and a python script for the transformation.



## Territorial knowledge ontology as a guide for the identification of resource of the territory toward sustainability

*Amer Ezoji, Nada Matta*  
University of Technology of Troyes

Representation of territorial knowledge based on the ontology is an approach which explains the nature and reasoning of this knowledge for sustainability. This research proposes an ontology of domain according to the principles for modelling an ontology. This proposed ontology is named DOTK (descriptive ontology for territorial knowledge). DOTK ontology has specialized the entities of territorial knowledge for sustainability and its aim is enhancing the sustainable knowledge of actors within industries. This ontology is a guide for identifying an operational ontology of real example. This research show that ontology of domain can assist to the identifying of tangible and intangible resources of the local territory. So, these identified resources can help the industries and territory for sustainable objectives and improve the available territorial knowledge within local or regional industries.



## Cascading Forgetting In Product Development Challenges And Evaluation

*Patricia Kügler (1), Claudia Schon (2), Benjamin Schleich (1), Steffen Staab (2), Sandro Wartzack (1)*  
1: Friedrich-Alexander-Universität Erlangen-Nürnberg; 2: University of Koblenz-Landau

Vast amounts of information and knowledge is produced and stored within product design projects. Especially for reuse and adaptation there exists no suitable method for product designers to handle this information overload. Due to this, the selection of relevant information in a specific development situation is time-consuming and inefficient. To tackle this issue, the novel approach Intentional Forgetting (IF) is applied for product design, which aims to support reuse and adaptation by reducing the vast amount of information to the relevant. Within this contribution an IF-operator called Cascading Forgetting is introduced and evaluated, which was implemented for forgetting related information elements in ontology knowledge bases. For the evaluation the development process of a test-rig for studying friction and wear behaviour of the cam/tappet contact in combustion engines is analysed. Due to the interdisciplinary task of the evaluation and the characteristics of semantic model, challenges are discussed. In conclusion, the focus of the evaluation is to consider how reliable the Cascading Forgetting works and how intuitive ontology-based representations appear to engineers.

## Discussion Sessions

Tuesday

6 August 2019

15:30 – 16:30

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## Hybrid Prototyping: Pure Theory or a Practical Solution to Accelerating Prototyping Tasks?

*David Mathias, Ben Hicks, Chris Snider*  
University of Bristol

Physical prototyping is critical activity in the produce development process, but the cost and time required to produce prototypes hinders its use in the design process. Hybrid prototyping through coupling LEGO and FDM printing is presented as an approach to address these issues. After establishing the separate design rules for FDM printing and LEGO, this paper created a new set of rules called Design for Fabrication (DfF) for hybrid prototyping. These cover the three main considerations (Technical, Process, and Design) that the designer and process planning must include to practically implement LEGO and FDM hybrid prototyping. The DfF rules were considered in a prototype of a computer mouse. While the fabrication time was not reduced as expected, it showed that the rules could be practically implemented in a real-world example. Additional considerations were identified that are to be included in the DfF rules.

Further work is required to realise the predicted step-change reduction in fabrication time. The first approach is to leverage multiple printers to parallelise the printing. The second is to reduce fidelity while maintaining high fidelity in key regions of interest.



## Methods and principles of product design for small-scale production based on 3D printing

*Jure Salobir, Jože Duhovnik, Jože Tavčar*  
University of Ljubljana

Technology of 3D printing is opening the possibility for small-scale production in quantities between ten and several hundred pieces. The technology of adding material enables the production of complex and integrated functional concepts in a single-pass process, which consequently potentially reduces the need for assembly operations. Design approaches and manufacturing processing are not mastered well because of a constant stream of new materials and manufacturing options. Well-designed products need to consider attributes of 3D printing as early as the conceptual phase. The cost of the product can be reduced with a systematic research and considering principles for small-scale production. In a cheaper, alternative production process the quality range of products is often lower. It has to be compensated with appropriate construction solutions which are less tolerance-sensitive. Therefore, in order to support the designer, to reduce the costs and design time of the product, a computer program was created to provide the user with an insight into the appropriate 3D printing technology. For simplifying the use, the program is also integrated into the product development process.



## A Design Case Study: 3D Printer Software Interface Design based on Home Users preferences Knowledge

*Xuenan Li, Danhua Zhao, Jianghong Zhao*  
School of Design, Hunan University

The rapid development of 3D printing technology has an impact on all aspects of modern manufacturing, design and society. However, the home use of 3D printers is still limited by the difficulty in deploying the software and the technology which both need professional understanding and training. How to enable non-technical home users to use 3D printers without the need for training, becomes an urgent problem for both academics and the industry. This paper is concerned in an investigation into home use of 3D printers, their needs and preferences, their impacts on the interaction design of 3D printing. First, a questionnaire survey supported by 127 non-technical users is conducted to understand their preferences on several key steps of the 3D printing procedure. Then, we integrate the survey results into the interaction design process to improve the usability of the 3D printing software. Finally, the advantage of our implementation is tested via the user satisfaction and feedback towards the post-use period. Our design project shows a simple method to extend 3D printing interactive software to non-technical users, and pushes forward the landscape of the home use of 3D printers.



## When Design Never Ends – A Future Scenario For Product Development

*Patrick Pradel, Robert Ian Campbell, Richard Bibb*  
Loughborough University

One of the foundations of product design is the division between production and design. This division manifests as designers aspiring to create fixed iconic archetypes and production replicates endlessly in thousands or millions. Today innovation and technological change are challenging this idea of product design and manufacturing. The evolution of Rapid Prototyping into Additive Manufacturing (AM), is challenging the notion of mass manufacture and consumer value. As AM advances in capability and capacity, the ability to economically manufacture products in low numbers with high degrees of personalisation poses questions of the accepted product development process. Removing the need for dedicated expensive tooling also eliminates the cyclical timescales and commitment to fixed designs that investment in tooling demands. The ability to alter designs arbitrarily, frequently and responsively means that the traditional design process need not be applied and because of this, design processes and practice might be radically different in the future. In this paper, we explore this possible evolution by drawing parallels with principles and development models found in software development.



## Innovative design in factory - new methods to go from closed to expandable prescriptions at the shop floor level

*Honorine Harlé (1), Pascal Le Masson (1), Benoit Weil (1), Sophie Hooge (1), Kevin Levillain (1), Guillaume Bulin (2), Thierry Menard (2)*

1: MINES ParisTech; 2: Airbus, Saint-Nazaire

This paper explores the question of the design activity at the shop floor level. The design activity has been confined for a large part in the design and the methods office. However, a certain form of design adapted to the factory remains. It is necessary to solve the problems which appear during the manufacturing process and to improve the productivity. However another form of design can emerge; it has a stronger impact on the factory, since the rules of the manufacturing system are modified under its effect. The paper studies 21 cases of design in the Airbus factory at Saint-Nazaire. It shows that the design activity does exist at the shop floor level. It characterizes this activity distinguishing two types of design which can co-exist in a factory. It shows that the type of results reached is not the same according to the type of design implemented.



## Role Model for Systems Engineering Application

*Iris Gräßler, Christian Oleff, Julian Hentze*

Paderborn University - Heinz Nixdorf Institute

Twenty-three years ago, Sheard published a very well-known description of Systems Engineering roles. Each role represents and defines activities and tasks to be taken into account for performing Systems Engineering through the entire system life cycle. As today's more and more complex systems require different considerations and approaches, these activities and tasks have changed and thereby the description of the role model need to be updated. This work introduces the "Role Model for Systems Engineering Application", which is adapted to today's circumstances, with the intention to give practitioners guidance in applying Systems Engineering. For this purpose, results from literature as well as from research projects and industrial applications experience were analyzed and combined to an updated role description.



## A methodology for implementing a product-centred bid model for suppliers

*Delphine Guillon (1,3), Christophe Merlo (2), Eric Villeneuve (1), Elise Vareilles (3), Michel Aldanondo (3)*

1: Univ. Bordeaux, ESTIA; 2: Univ. Bordeaux, ESTIA IMS; 3: CGI, Univ. Toulouse, IMT Mines Albi

Early phases of product development are critical for next phases and impact the product definition. During bid process, suppliers generate offers for a customer that must both meet customer's requirements and be realizable in terms of technical aspects, costs and due date. Our aim is to propose a methodology for implementing a generic bid model, composed of context parameters, customer's requirements, the product i.e. technical solution, its delivery process, and associated risks. Key Performance Indicators allow to evaluate different solutions. The bid model is exploited with two different approaches. First, we use Constraint Satisfaction Problems to formalize expert knowledge and identify variables/constraints and relations. Second, we use case database to reuse past experiences. This model and the methodology are applied with a company developing harbour cranes. An initialisation phase allows to define existing bid process. Then, the generic model is adapted through a specialisation phase, using specific knowledge from company's experts. Finally, the specific model is implemented and tested in an implementation phase. Future work will be focused on a software tool development.



## How A Better Understanding Of Relation Can Increase Responsibility Between Stakeholders?

*Sylvain Bolifraud, Julie Stal-Le Cardinal*

École Centrale Paris

Construction projects are complex and subject to a lot of conflicts. The misunderstanding between actors is one cause of these conflicts. To understand actor's interrelation is fundamental. In this paper, we used FACt Mirror method to analyse the relation between the two main actors, Owner and Contractor. Based on the method we built a survey about Fears, Attractiveness and Temptations of treason of each actor, The Mirror effect of the method allows us to evaluate what is the thought of an actor about the other and to measure differences between actors' thought on a specific aspect of the relation. Our results allow us to have a better understanding of the relation between Owners and Contractors on a construction project. Moreover, we point out specific aspects of the relation which need to be studied to improve the understanding.



## Participatory and Inclusive Assistive Technology Innovation Clinics in Design Schools

**Tigmanshu Bhatnagar (1), Rohit Patel (2), Bhavik Roopchandani (3), Faisal Ashraf (4)**

1: University College London; 2: Indian Institute of Technology Delhi; 3: National Institute of Technology Kurukshetra; 4: v-shesh Access Services Private Limited

People living with disabilities can have needs for Assistive Technology (AT) that are out of the scope of occupational therapists, commercial markets and charitable distributions. For such needs, designers, engineers, makers and clinicians in the local community can design and fabricate AT through an inclusive, participatory, user centred design process. By tapping into the skills, creativity, facilities and knowledge of local design, medical, engineering and management schools, we can make clinics for AT innovation, practical design education, business incubation and product provision. Through two case studies, we demonstrate the necessary steps towards this novel approach to compassionately design, fabricate and deliver bespoke and scalable AT innovations. The practice is multidisciplinary, it empowers people with disabilities to creatively challenge their problems, contributes to design education and requires a system to ensure product quality and follow ups. We envision that over years, this practice can become a movement that is able to systematically knit the patched ecosystem for AT, while contributing to the global understanding of design for people with disabilities.



## The Economic Explanation of Inclusive Design in Different Stages of Product Life Time

**Fang Li (1,3), Hua Dong (2)**

1: College of Architecture and Urban Planning, Tongji University; 2: College of Design and Innovation, Tongji University; 3: Institute of International Exchange, Shanghai Open University

The static data obtained from user research are not sufficient to accurately reflect the change of the user's needs and capabilities in different contexts. Not paying enough attention to the economic feasibility of design solutions makes inclusive design face challenges in commercialization. In this paper, the user's demand is regarded as a function of the dynamic interaction between the user's characteristics and the environment. The inclusion problem is defined from an economic perspective. By distinguishing the stages before and after the delivery of a product, different economic properties of the product are defined. Then the two stages are analysed from the perspective of investment and consumption respectively, and the competition criterion of inclusivity distribution and the reasons for exclusion are deduced. According to the causes of different problems in the two stages, the research direction of inclusive solutions is pointed out, and the economical sustainability of inclusive design is analysed. This paper emphasizes that the goal of inclusive design lies not only in the partial and temporary elimination of exclusion, but also in how to distribute the freedom of choice.



## Understanding inclusive design education

**Nicky Wilson, Avril Thomson, Angus Thomson, Alexander Holliman**  
University of Strathclyde

There is a need for responsible engineering design to accommodate the diverse user requirements that come with the global phenomenon of population ageing. Inclusive design can address these diverse requirements through the consideration of a wide diversity of user needs within the design process. However, uptake of inclusive design in industry is limited, with designer awareness of the approach and its associated methods and tools noted as barriers to its uptake. This research aims to understand the current approach to inclusive design education within UK Higher Education Institutions, utilising interviews with design educators and a student survey. The study concluded that teaching of inclusive design varied between institutions with conflicting responses from academics and students relating to the methodologies taught. This study recommends that greater transparency should be encouraged between institutions to encourage the development of a cohesive inclusive design education strategy, in addition to the development of a framework to aid the implementation of appropriate inclusive methods and tools within the design process.



## Alarm Compliance In Healthcare: Design Considerations For Actionable Alarms (In Intensive Care Units)

**Rosana Sanz-Segura (1), Eduardo Manchado Pérez (1), Elif Özcan (2)**

1: School of Engineering and Architecture, University of Zaragoza; 2: Faculty of Industrial Design Engineering Delft University of Technology, Department of Intensive Care Erasmus Medical Centre

Intensive care units are technologically advanced environments that are designed to safeguard the patient while their vitals are stabilized for further treatment. Audible and visual alarms are part of the healthcare ecology. However, these alarms are so many that clinicians suffer from a syndrome called 'alarm fatigue' and often do not comply with the task alarm is conveying. Measuring compliance with rules in the workspace and determining the success of a system belongs to the field of ergonomics and is based on data collected through task observations and scoring. In this paper, we will explore compliance with critical alarms by not only from their potential success or failure perspective but also from the perspectives of the clinician capacity, needs, and motivations to comply with alarms in critical environments. We will finally, reflect on further possible design strategies to increase compliance in critical care that are beyond following rules per se but through intrinsic motivation.



## Capturing Prototype Progress in Digital Fabrication Education

Yazan A M Barhoush (1), Jørgen Falck Erichsen (2), Heikki Sjöman (2), Georgi Georgiev (1), Martin Steinert (2)

1: University of Oulu; 2: Norwegian University of Science and Technology

The early (pre-requirement) stages of product development can provide relevant insights into the creative design process. At these stages, the communication of ideas during the prototyping process can serve as a rich source for information. In this paper, we attempt to document physical prototypes generated during the design process. We describe the design and preliminary testing of Protobooth Oulu: a system that can be used for documenting the process of prototyping products through capturing process output 'snapshots' in time at the early stages of product development. Our primary motivation is to facilitate documentation and reflection from an educational perspective. We tested the system during a course on digital fabrication in a FabLab environment, where ten teams documented their coursework over the course of six weeks. Managing to capture prototypes over time, analysis of the captured data showed evolution and major changes in the prototypes. Such data can be used for understanding the process of prototyping and consequently provide means to improve prototype and overall creative performance. We outline a future Protobooth system in terms of functionality.



## University education in Additive Manufacturing and the need to boost design aspects

Yuri Borgianni (1), Lorenzo Maccioni (1), Pasquale Russo Spina (1), ManikandaKumar Shunmugavel (1,2)

1: Free University of Bolzano-Bozen, Faculty of Science and Technology; 2: School of Engineering, Faculty of Science, Engineering and Built Environment, Deakin University,

Additive Manufacturing (AM) is a potentially revolutionary technique in industry with claims of high skills shortage in the recent days. It is assumed that full exploitation of AM capabilities can be made possible by a paradigm shift steered by engineering design. Future generations of engineers might benefit from Design for Additive Manufacturing (DfAM), which targets AM potential and enables design freedoms. In this context, the paper investigates AM education for a better understanding of the main AM-related subjects taught in universities. To this scope, the authors gathered 52 syllabi of courses taught in highly-ranked technical universities worldwide that relate to AM. From the investigation, it emerges that AM is the core discipline of the course in 42 out of 52 cases and considered widely as an independent domain to date. As for taught subjects, it was found that design aspects in AM and DfAM are poorly focused on, while manufacturing and process areas are the most popular. This poses a challenge especially to the design community, as the current situation might limit the exploitation of AM capabilities.



## Biomimicry Design Education Essentials

Laura Stevens (1), Marc de Vries (2), Mark Bos (1), Helen Kopnina (1)

1: The Hague University of Applied Sciences; 2: Delft University of Technology

The emerging field of biomimicry and learning to design with and for nature has expanded in recent years through a diversity of educational programs. Inspiration following natural forms may give the appearance of being sustainable, but the question remains, how sustainable is it? Misunderstanding the function of these forms may leave designers with products not as sustainable as desired. Biomimicry education addresses these issues by integrating three essential elements into their design thinking phases and by using analogical transfer while doing so. This field learns from nature as model, nature as measure, and nature as mentor, throughout the design process. Through examination, analyses and verification of students designs and reflective processes at The Hague University of Applied Sciences, this research considers nature's analogies in educational factors, determining which elements are influential when incorporating biomimicry into design education.



## Educate for Technological Innovation

Frido Smulders, Bertien Broekhans, Aldert Kamp, Hans Hellendoorn, Hans Welleman

Delft University of Technology

At Polytechnics design & engineering students are taught about state-of-the-art technical knowledge. Students become qualified engineers and learn to innovate artifacts related to their domain. Not taught is how to develop new engineering knowledge within a multidisciplinary context of stakeholders, companies and regulations. In short, students don't learn to innovate technology. What is taught today is the result of a technological innovation of yesterday. This is not sufficient for industry to innovatively deal with society's grand challenges. The paper describes a project that aims to educate all Delft University of Technology graduate students in the verb of innovating technology, that is, the development of new technologies from inventions in the labs to full-fledged application in business. Such along three dimensions: technical, human and business. The educational portfolio consists of three modules in line with growth along Bloom's taxonomy and online materials on theoretical backbones. All modules apply the notion of technological innovation journeys (Tijo's). Tijo's are rich descriptions of the developmental journey of new technology and are based on inventions from the university's own labs.



## Sprinting out of stuckness: Overcoming moments of stuckness to support the creativity flow in agile team settings

**Ashni Shah, Alfonso Huidobro Pereda, Milene Gonçalves**  
Delft University of Technology

Multidisciplinary agile teams working in fast paced, delivery-oriented sprint cycles of two weeks can experience moments of stuckness. Typically, these moments can be characterised by the inability to continue, which can be quite detrimental in agile settings, where time is pressured. This paper aims to explore these moments of stuckness, to understand when and why they occur and to understand the different strategies Scrum teams use to overcome them, both on a personal as well as team level. A combination of interviews and observations were conducted with six Scrum team members and two experts to understand their process and experiences while working in an agile set up. We have identified five strategies, which strongly rely on agile values of collaboration, communication, and creativity. These are: looking for expert guidance, open communication, creating spike stories, visual communication and incubation. The findings from this study provide both practice and academia with a deeper understanding into how can creativity be supported in agile settings.



## Interview study on the agile development of mechatronic systems

**Kristin Govert (1), Jonas Heimicke (2), Udo Lindemann (1), Albert Albers (2)**  
1: Technical University of Munich; 2: Karlsruhe Institute of Technology

In order to be as responsive as possible to changes in the dynamic context of mechatronic system development, companies are increasingly integrating agile approaches into their development processes. They are confronted with the challenges of adapting approaches that originate in software development to the conditions of physical development, without neglecting the experiences gained over many years regarding product and process knowledge. In addition, agile development approaches must be integrated into existing processes through a systematic implementation strategy. In order to gain an initial understanding of the current situation in mechatronic companies with regard to agile development approaches, an interview study was conducted with 18 participants from real development practice. This could show that the companies in mechatronic system development are currently at the beginning of agile transformation and need approaches that are modelled on the basis of real development projects and are best possible tailored to the needs of these companies through a clear technical orientation. The findings gained are not universally valid, but represent a basis for further research work.



## Budgeting for Agile Product Development

**Maximilian Vierlboeck, Kristin Gšvert, Jakob Trauer, Udo Lindemann**  
Technical University of Munich

Recent reports and predictions indicate a consistent and continuous growth in the field of Research and Development. Such growth leads to increased resource investments, which have to be managed effectively to eventually achieve value maximization. This management is cohesive with budgeting. In changing environments, said effectiveness can be difficult to attain. Agile development is supposed to provide the necessary flexibility for uncertain situations and has recently seen a stark adoption incline. Unfortunately, budgeting and resource allocation have not yet been resolved for agile approaches: a comprehensive research including recent publications showed a lack of models and frameworks for the adoption and application of budgeting with agile development. Due to this lack of a comprehensive approach, as well as limitations and restrictions of existing research, this paper describes the design of a budgeting approach suitable for and compatible with agile product development. The developed solution, the Structured Agile Budgeting Process, provides a holistic and interdisciplinary way to allocate resources while still allowing the flexibility and benefits of agile development.



## Comparison of existing agile Approaches in the Context of Mechatronic System Development: Potentials and Limits in Implementation

**Jonas Heimicke, Manuel Niever, Valentin Zimmermann, Monika Klippert, Florian Marthaler, Albert Albers**  
Karlsruhe Institute for Technology, Institute of Product Engineering

The development of mechatronic systems has always been characterized by continuous handling of uncertainties. This challenge, which is associated with dynamic changes in the development context, is increasingly met by companies in the development of physical systems with the implementation of agile approaches in their development processes. However, since established approaches have their origin in software development, they reach various limits in the context of the development of mechatronic systems, e.g. due to the physical properties of the systems. Other features, such as transparent and flexible project management or targeted and early involvement of customers and users in development processes, can also be implemented in mechatronic system development. In order to derive the potentials and limits of existing agile approaches for the context of mechatronic system development, the present paper compares existing approaches with regard to relevant factors from the context of mechatronic system development. The aim is to create a basis for the targeted development, adaptation and use of agile approaches in the field of mechatronic system development.



### The Novelty Perspectives Framework: A new conceptualisation of novelty for cognitive design studies

Laura Hay, Alex Duffy, Madeleine Grealy  
University of Strathclyde

Novelty can be evaluated from the perspective of the designer who creates a concept (personal novelty), and people who perceive it post-creation (socio-novelty). In each case, the extent to which the concept is new compared to known artefacts is judged. The designer's evaluation is based on the same knowledge from which the concept was produced. Thus, if the concept is novel to the designer, creative cognitive processing must have occurred, i.e. something new was created in the mind. Evaluations made by other people are based on their own knowledge, which may differ from the designer's. Thus, concepts they view as novel are not necessarily the output of creative cognition. In this paper, we posit that personal novelty is directly related to designer cognition, whilst socio-novelty is not. However, existing metrics focus on the latter, and may be misleading in cognitive studies. To stimulate discussion, we formalise personal and socio-novelty in the Novelty Perspectives Framework. Empirical data suggests that the perspectives may be distinguished in practice. Future implications of the NPF are explored, highlighting the potential for insights at both the cognitive and neural level.



### An Exploration of the Relations between Functionality, Aesthetics and Creativity in Design

Ji Han, Hannah Forbes, Dirk Schaefer  
University of Liverpool



Creativity is often said to play a vital role in the product design process, while functionality and aesthetics are considered key factors of actual products. Functionality refers to the performance of a product, and aesthetics represents the visual and ergonomic appeals of the product. However, there appears to be an elusive relation between creativity, functionality and aesthetics. This study explores how functionality, aesthetics and creativity are related to one another in design. Through exploring the definitions and assessments of creativity in design, this study reveals that novelty, usefulness and surprise are the three core elements of design creativity. A case study involving experts evaluating design samples in terms of novelty, usefulness, surprise, functionality, aesthetics and overall creativity is conducted. The results imply that there are no statistically significant relations between creativity, functionality, and aesthetics. Considering the three core elements of design creativity, the results indicate that creativity is only statistically significantly related to novelty. Moreover, our results suggest that creativity and novelty are measuring the same construct.



### Creative Space: A Systematic Review of the Literature

Katja Thoring (1,2), Pieter Desmet (1), Petra Badke-Schaub (1)

1: Delft University of Technology; 2: Anhalt University of Applied Sciences

This paper provides an overview of the state-of-the-art research about creative work and learning environments. We conducted a systematic literature search within the Scopus database and identified a total of 70 relevant sources discussing creative spaces within academic, practice, or other innovation environments. Among the included sources are 48 academic publications and 22 sources from company research and illustrative coffee-table books that are discussed separately. We analyse the academic sources regarding their theoretical contribution, as well as regarding their scope. Finally, the included sources are categorized according to three areas of interest: (1) the addressed space types for different creative activities, (2) abstracted requirements for creative spaces, and (3) concrete characteristics and configurations of a creative space. The results provide an in-depth insight into the current state of research on the topic of creative spaces. Practitioners, educators, and researchers can use the presented overview to investigate the possible impact of creative workspace design and to identify research gaps for conducting further research in the field.



### Semantic measures for enhancing creativity in design education

Georgi Georgiev (1), Hernan Casakin (2)

1: Center for Ubiquitous Computing, University of Oulu ; 2: School of Architecture, Ariel University

Analysing verbal data produced during the design activity is helpful to gain a better understanding of design creativity. To understand exchange of information in terms of creative outcomes, a semantic analysis approach was used to measure the semantic content of communications between students and teachers. The goal was to use this tool to analyse design conversations, and to investigate their relation to design creativity, assessed in terms of originality, usability, feasibility, aesthetics, elaboration, overall value and overall creativity. Abstraction, Polysemy, Information Content and Semantic Similarity were employed to explore 35 design conversations from the DTRS10 dataset. Main findings suggest that a significant relationship exists between Information Content and Originality, and between Information Content and Overall creativity of the produced design outcomes. Significant relations were also found between Abstraction, Polysemy, Information Content, and Feasibility, as well as between Semantic Similarity and Overall Value of the outcomes. Implications for the use of semantic measures for encouraging creativity in the design studio are discussed.



## Exploring Healthcare Systems Design Research And Practice: Outcomes Of An International Meeting

**Alexander Komashie (1), Guillaume Lame (1), Francois Patou (2), Nicholas Ciccone (2), Anja Maier (2), P. John Clarkson (1)**

1: University of Cambridge; 2: Technical University of Denmark

Current healthcare delivery challenges are multi-faceted, requiring multiple perspectives to be addressed using a systems approach. However, a significant amount of healthcare systems design research work is carried out within single disciplines or at best a few disciplines working together. There appears to be little deliberate attempt to draw together a wide range of disciplines committed to working together to overcome differences and tackle some of the complex challenges in healthcare delivery. In this paper, we report on the initial outcomes of such an international initiative that, in the form of a workshop held at the University of Cambridge, brought together researchers and practitioners from a wide range of disciplines to explore the foundations of a community for Healthcare Systems Design Research and Practice.



## Design considerations for therapeutic devices - An investigation of pre-schoolers' preferences for an artefact's basic characteristics

**Emanuel Balzan (1), Philip Farrugia (1), Owen Casha (1), Liberato Camilleri (1), Andrew Wodehouse (2)**

1: University of Malta; 2: University of Strathclyde

Toys are children's first consumer products and while playing they acquire numerous skills, learn about their environment and socialise with other children and adults. Toys are adapted and used by clinicians as therapeutic devices because they allow them to create bonds and communicate with children. Aesthetical aspects should be considered early in the design process, especially since pre-schoolers' views are still dominated by the appearance of artefacts, also known as, the perceptual salient characteristics. The study of emotions mediates the understanding of the relationships between a product, user and the process with which consumers set up preferences over products. Decisions taken in each design stage will influence whether therapeutic devices will be enjoyed by children. An experiment was carried out to test out pre-schoolers' preferences on individual attributes: form, dimension, material (hardness and weight) and surface (appearance and texture). This study exposed dominant characteristic preferences and the fact that some are influenced by gender and age. Employing these findings in therapeutic devices will enable clinicians to better engage the children during therapy.



## Decision Support for Re-designed Medicinal Products - Assessing consequences of a customizable product design on the value chain from a sustainability perspective

**Maria Siiskonen (1), Matilda Watz (2), Johan Malmqvist (1), Staffan Folestad (3)**

1: Chalmers University of Technology; 2: Blekinge Institute of Technology; 3: AstraZeneca Gothenburg

Despite advances in pharmacological research providing means for individually customized patient attribute treatments, the 'one-size-fits-all' paradigm remains. Customization is associated with cost increases and the value assessment of customized medicinal products shows upon a narrow economic focus. Inspired by value models, emerging in manufacturing industry research, this study suggests a novel methodology encompassing a full sustainability perspective, including the social, economic and ecological dimension, for design decision support for medicinal products. A concept screening matrix is adapted, using sustainability criteria as value indicators. The focus is to create value for the whole pharmaceutical value chain whilst keeping the core purpose of medicinal products, i.e. to bring societal benefits. An illustrative case study presents an application of the methodology on a commercial product for curing hypertension. The traditional product design for hypertension treatment is compared to a customized product design. Results indicate that a customized product design is preferable if value is to be created from a social or/and an ecological sustainability perspective.



## Spatial variability of human health impacts: application to a biorefinery process implementation

**Florian Bratec (1,2), Tatiana Bratec (1), Pauline Marty (1), Nadege Troussier (1), Rene Diaz-Pichardo (1,3)**

1: University of Technology of Troyes; 2: Altermaker; 3: Y Schools

More and more attention is paid nowadays to the human health concerns, associated with environmental problems arising from the fossil fuel use. The world scientific community offers new alternatives that, despite being more environmentally friendly, require an analysis of their potential environmental impacts. For example, biorefineries are becoming increasingly widespread nowadays offering a large gamma of bio-based products. However, it is necessary to take into account what potential effects such facility may have on the human health, depending on its geographical location since different territories may be more or less sensitive to its installation. Our study describes a new bioprocess implementation in terms of impact on human health through three countries: France, Belgium or China. In order to understand what territory can be more appropriate to the industrial process installation in terms of its effects on the human health, we propose to use the spatialized life-cycle analysis methodology.



## Aspects of body metrics data management in the long term for the European fitness industry

**Benjamin-Julia Guérineau (1,2), Kousay Samir (3), Marvin Richrath (4), Pr. Kristin Paetzold (5), Joaquín Montero (5)**

1: Université de technologie Compiègne; 2: École de technologie supérieure de Montréal; 3: KTH Royal Institute of Technology; 4: Universität Bremen; 5: Universität der Bundeswehr München

The dawn of the fourth industrial revolution, mostly known through the German initiative “Industrie 4.0”, builds on a set of technologies emerging from software and information and communication technologies (ICT); paired with the growth of the Internet-of-Things (IoT), the so-called “smart products” are expanding on the market. These smart products integrate data collection and processing capacities. Additionally, the collected data have their own lifecycle, and can be classified as sensitive data. In that sense, companies developing hardware products may need support to step in “smart products” development. Digital transformation strategy is a possible overall support for companies. However, regarding smart product development and IoT data management, no studies to date have addressed formalized guidelines to support companies. This article proposes a set of guidelines focusing on IoT data management to support hardware companies in their transformation towards smart products. The proposed guidelines are exemplified on a fitness industry case which is using wearable devices collecting body metrics, considered as sensitive data.



## AI-based learning approach with consideration of safety criteria on example of a depalletization robot

**Mark Jocas (1), Philip Kurrek (1), Firas Zoghalmi (1), Mario Gianni (2), Vahid Salehi (1)**

1: Munich University of Applied Sciences; 2: University of Plymouth

Robotic systems need to achieve a certain level of process safety during the performance of the task and at the same time ensure compliance with safety criteria for the expected behaviour. To achieve this, the system must be aware of the risks related to the performance of the task in order to be able to take these into account accordingly. Once the safety aspects have been learned from the system, the task performance must no longer influence them. To achieve this, we present a concept for the design of a neural network that combines these characteristics. This enables the learning of safe behaviour and the fixation of it. The subsequent training of the task execution no longer influences safety and achieves targeted results in comparison to a conventional neural network.



## Definitions and Attributes of Smart Home Appliances

**Sojung Kim (1), Joon Sang Baek (2)**

1: UNIST; 2: Yonsei University

The status of Smart Home Appliances (SHAs) in the smart home industry has been raised as major components of a smart home. To design a good SHA, diverse stakeholders in the smart home ecosystem need to have a common understanding of smart homes and SHAs. However, the studies on what they are, especially those reflecting practitioners’ point of view, have been scarce. In this research, we conducted systematic literature reviews and practitioner interviews using the concept mapping method to identify the attributes of SHAs depending both on academia and industry. In addition, we suggest a framework of the smart home ecosystem which describes how those attributes are revealed in the relationships among SHAs, users, and external stakeholders. Since all of the interviewees are Korean SHA development professionals, the findings from this research could have been limited to the current status of the Korean SHA industry. Nonetheless, we expect that this research would contribute to building a consensus on what smart homes and SHAs are and provide the designers and developers of SHAs with systematic perspectives on smart homes.



## Designing products with a focus on self-explanatory assembly, a case study

**Davy Daniël Parmentier (1), Jan Detand (1), Jelle Saldien (1,2)**

1: Department of Industrial Systems Engineering and Product Design, Ghent University; 2: IMEC-MICT-Ghent University

Designing products with a focus on self-explanatory assembly can reduce the use of procedural instructions and the associated problems. This paper describes how different groups of students, in two different design-engineering courses designed or redesigned products in an attempt to make the assembly of the product self-explanatory. The design outcomes are discussed in relation to the design context and linked to existing theory on design for meaning.



### Approach for a machine-interpretable provision of standard contents using welded constructions as an example

Thivakar Manoharan, **André Loibl**, Arun Nagarajah, Peter Köhler  
Universität Duisburg-Essen

In order to meet the quality standards required in today's product development process, the designer must be able to draw on the knowledge contained in standards at all times. However, in today's digital work environment, these are usually only available in paper or PDF form. To support the designer during the product development process, a research project examine how knowledge from standards can be made available digitally and integrated into his working environment. This paper presents a concept with a RESTful service as a central knowledge base, which provides knowledge in the form of microservices. The implementation is carried out using welding assemblies as an example. To achieve the high-quality requirements and to implement them, the standard contents had to be prepared in a machine-interpretable and cross system way.



### A knowledge based approach to support the conceptual design of ETO products

Miriam Nardelli (1), Paolo Cicconi (1), Andrea Savoretti (1), Roberto Raffaelli (2), Michele Germani (1)

1: Università Politecnica delle Marche; 2: Università degli studi eCampus

The ever-increasing competitiveness, due to the market globalization, has forced the industries to modify their design and production strategies. A key point is the development of products that fulfil the individual customer needs as close as possible. ETO companies manufacture new products according to the customer technical requirements given in the request for proposal. Computational Design Synthesis is the research area focused on activities to automate the design phase in the production of products such ETO structures. In this context, Knowledge Based Engineering applications are usually applied to automate design routines and to implement a multidisciplinary product design. Knowledge should be elicited and formalized, so that it can allow the past cases retrieval and the connection between customer specifications and the product configuration tasks. This paper proposes an approach for the rapid definition of the product structure related to a ETO product, including the early cost evaluation in configurations. The research scope aims at defining a framework to support the knowledge repository, which is the Knowledge Based used to design new products and estimate their costs.



### Towards a reconfiguration framework for systems engineering integrating use phase data

Lara Qasim (1,3), Andreas Makoto Hein (1), Marija Jankovic (1), Sorin Olaru (2), Jean-Luc Garnier (3)

1: CentraleSupélec, Laboratoire Génie Industriel; 2: CentraleSupélec, Laboratoire de Signaux et Systemes; 3: Thales Technical Directorate

One of the aims of systems engineering is to develop systems with a number of pre-defined configurations, in order to operate effectively and efficiently in different contexts and environments. Early in the design phase, system reconfiguration allows to propose and optimize these configurations. With regard to the literature review and industrial observation, pre-defining the standard configurations without relying on hints from end users has been raised as a major difficulty within the industry. In this paper, we propose a reconfiguration framework which considers data collected from the use phase in order to generate valid and optimized configurations with regard to stakeholders needs.



### Early Stage Digital Twins for Early Stage Engineering Design

David Edward Jones, Chris Snider, Lee Kent, Ben Hicks

University of Bristol

While extensive modelling - both physical and virtual - is imperative to develop right-first-time products, the parallel use of virtual and physical models gives rise to two interrelated issues: the lack of revision control for physical prototypes; and the need for designers to manually inspect, measure, and interpret modifications to either virtual or physical models, for subsequent update of the other. The Digital Twin paradigm addresses similar problems later in the product life-cycle, and while these digital twins, or the "twinning" process, have shown significant value, there is little work to date on their implementation in the earlier design stages. With large prospective benefits in increased product understanding, performance, and reduced design cycle time and cost, this paper explores the concept of using the Digital Twin in early design, including an introduction to digital twinning, examination of opportunities for and challenges of their implementation, a presentation of the structure of Early Stage Twins, and evaluation via two implementation cases.

## Discussion Sessions

Tuesday

6 August 2019

16:45 – 17:45

<b>Additive Manufacturing   Potentials</b> <i>Pulse Building, Hall 4</i>	<b>82</b>
<b>Design Management   Effects &amp; Influences</b> <i>IDE Faculty, Hall M</i>	<b>84</b>
<b>Design Methods   Prototyping</b> <i>IDE Faculty, IDE Arena</i>	<b>86</b>
<b>Design Education   Game-based learning</b> <i>IDE Faculty, Wim Crouwel</i>	<b>88</b>
<b>Agile Approaches and Agility   Development Applications</b> <i>IDE Faculties, Bernd Schierbeek</i>	<b>90</b>
<b>Data-enabled Design and Data-driven Design</b> <i>IDE Faculty, Hall L</i>	<b>92</b>
<b>Healthcare   Applications</b> <i>IDE Faculty, Hans Dirken</i>	<b>94</b>
<b>Human Behaviour in Design</b> <i>Pulse Building, Hall 5</i>	<b>96</b>
<b>Design Cognition</b> <i>IDE Faculty, Hall K</i>	<b>98</b>



## Goal oriented provision of design principles for additive manufacturing to support conceptual design

Felix Schumacher (1), Hagen Watschke (2), **Sebastian Kuschmitz (2)**, Thomas Vietor (2)

1: BMW AG; 2: Technische Universität Braunschweig

Additive Manufacturing (AM) offers a new degree in design freedom. However, in order to exploit AM's potentials in end-use products a methodical approach and suitable tools especially during conceptual design are needed. This paper presents a methodology for application in industrial practice, which should support the component conception for additively manufactured products. The approach focuses on a benefit-oriented preparation and provision of knowledge. In addition to general design methods for abstraction and promotion of creativity, AM-specific tools are introduced which support the provision of solution principles and process-specific restrictions. A broad applicability of the solution principles is ensured by an expansion of the solution space through abstraction. Consequently, product developers are sensitised to the new design possibilities of AM, on the one hand. On the other hand, they are supported in a holistic exploitation of design potentials in ideation in order to foster innovative solution ideas. Finally, the methodological procedure and the developed tools will be demonstrated in a workshop by using an example from industrial practice of the automotive sector.



## Automated Candidate Detection for Additive Manufacturing: A Framework Proposal

Thomas Daniel Page, Sheng Yang, **Yaoyao Fiona Zhao**

McGill University

As additive manufacturing (AM) continues to grow in its abilities, so does the need for a quick and effective method of determining how it should be applied. Over time, these methods are naturally developed and passed on as tacit knowledge. However, with the rapid advancement of AM technologies, identifying parts which are eligible for AM as well as gaining insight on what value it may add to a product needs to be modelled in an objective and transferrable way. This paper presents a framework for determining the candidacy of a part or assembly for AM, represented by its economic feasibility and potential for AM-specific benefits. A set of selection criteria is developed with the goal of fast-screening in mind; that is specific data which can be automatically extracted from CAD models and resource planning databases. A case study is performed to validate the criteria and decision model chosen, as well as gain insight to the potential for a more widespread application. The decision model successfully identified economic feasibility and AM potentials, which suggests the results of the case study show promise for a semi-automatic decision support system for identifying AM candidates.



## Model for evaluating additive manufacturing feasibility in end-use production

**Matti Ahtiluoto (1)**, Asko Uolevi Ellman (2), Eric Coatanea (2)

1: Enmac Ltd.; 2: Tampere University of Technology

In practical design work, a designer needs to consider the feasibility of a part for a manufacturing using additive manufacturing (AM) instead of conventional manufacturing (CM) technology. Traditionally and by default parts are assumed to be manufactured using CM and using AM as an alternative need to be justified. AM is currently often a more expensive manufacturing method than CM, but its employment can be justified due to number of reasons: improved part features, faster manufacturing time and lower cost. Improved part features means usually reduced mass or complex shape. However, in low volume production lower manufacturing time and lower part cost may rise to the most important characteristics.

In this paper, we present a practical feasibility model, which analyses the added value of using AM for manufacturing. The approach is demonstrated in the paper on four specific parts. They represent real industrial design tasks that are ordered from an engineering office company. These parts were manufactured by Selective Laser Mating (SLM) technology and the original design done for conventional manufacturing is also presented and used for comparison purpose.



## Exploitation of AM-potentials by linking manufacturing processes to function-driven product design

**Jannik Reichwein (1)**, Jerome Kaspar (2), Michael Vielhaber (2), Eckhard Kirchner (1)

1: Technische Universität Darmstadt, Product Development and Machine Elements, Germany; 2: Saarland University, Institute of Engineering Design, Germany

"Additive Manufacturing (AM) processes had an extensively and substantially technological growth over the past years that directly influences the continuously increased and manifold possibilities for processing new and innovative products. However, additively manufactured products mostly are still fabricated with only small adaptations compared to conventional parts, and thus waste many design potentials although specific design guidelines have been widely developed to restrict geometrical deficiencies or suggest improvements in component design.

As a result, this contribution furtherly aims to systematically consider AM potentials already on the functional level of product development offering significant but until now still not or just insufficiently exploited potentials. Therefore, the presented approach uses the already proven Design Pattern Matrix (DPM) approach for conventional technologies extended by a concurrent selection of materials and processes specifically for AM. Here, the DPM derives information about the manufacturing process in form of design elements and links them to the function carriers of the product including a methodological determination of requirements."



## The PSI network model for studying diverse complex design scenarios

**Yoram Reich (1), Eswaran Subrahmanian (2)**

1: Tel Aviv University; 2: Carnegie Mellon University

Design pervades our world in variety and complexity that is difficult to grasp. Different disciplines and researchers take one or few perspectives to study, model, and try to understand design, why it fails and when it succeeds. However, without a comprehensive model, the value of such approaches is limited. We created a framework  $\mathcal{D}$  the PSI (Problem, Social and Institutional Spaces) framework  $\mathcal{D}$  that includes several models, ranging from simple to complex, networked, and hierarchical or recursive that can be used to model all design scenarios. In what follows, we demonstrate the network version of this framework, how it is used, and what insight it can present. The diversity of situations we present, mergers and acquisitions of companies, collaborations between industry and university, large multi-organizational projects, and a very complex project, as well as other cases we do not present here, confers the validity of utility and potential of the PSI framework.



## Analysis Of The Consequences Of Disrupting Events On Ongoing Product Development Projects: The Cascading Effects Of Severe Influences

**Fausto Guaragni (1,2), Roland Ortt (2), Kristin Paetzold (1)**

1: Bundeswehr University Munich; 2: Delft University of Technology

The initial planning of the development of complicated products usually requires time and efforts. However, even the most accurate plans are not able to cope with all the uncertainties that might arise during an ongoing project. If a severe uncertainty affect the development project a critical situation arises and a disruption might happen. The present literature does not offer a comprehensive solution on how to investigate these type of events after they occurred. This contribution presents a model that aims to analyse and better understand disruptions that affect ongoing product development projects.



## A Matter of Factor: A Proposed Method for Identifying Factors That Influence Design Effort Levels in Product Design

**Alexander Holliman, Avril Thomson, Abigail Hird, Nicky Wilson**

Department of Design Manufacture and Engineering Management, University of Strathclyde

Design effort, the amount of time required to complete a project or task (Salam et al., 2009; Salam and Bhuiyan, 2016), is a required resource for any design project which can be influenced by a number of factors. Estimating design effort is a significant challenge that can be mitigated through an understanding of these influential factors. This understanding is held as tacit knowledge by experts, earned through experience; yet, although these factors vary in type and impact, understanding their details can provide insight and improve future estimations. Some previous methods to estimate design effort identify these factors, either from: expert opinion, or historical data analysis with each approach has advantages and disadvantages. This paper is comprised of three parts: A review of published methods and tools for estimating product design effort and whether they consider and identify influential factors; an analysis of possible trends in the identification of factors influencing product design project length; and a new method for identifying the influential factors of product design project length.



## Creation of a framework of design tool characteristics to support evaluation and selection of visualisation tools

**Wenwen Zhang, Charlie Ranscombe, David Radcliffe, Simon Jackson**

Swinburne University of Technology

In Industrial Design, new design visualisation tools are emerging offering significant benefits to the designers. However, studies show alongside some benefits, new tools can also inhibit designers' creativity or cause time inefficiency if used in the wrong context. Thus, understanding which tools to use and when during the design process is increasingly necessary to ensure the best use of resources in design practice. Existing research on understanding the performance of design tools and the resulting frameworks for comparing tools are either specific to certain tools or highly generalised making evaluation across different design tools challenging. As such, this paper reports the creation of a more comprehensive framework of design tool characteristics to facilitate a better understanding of design tools and their uses. Demonstration of application of the framework is also given in the form of a case study on the use of Digital Sketching and its comparable tools with four practising designers. In conclusion, we show how the Design Tool Characteristics (DTCs) framework is an effective way to understand design tools, with further implications for design tool development.



## The effects of representation mode on conceptual coherence in the design of physical products

*Yen Mai Thi Trinh, Christer Westum Elverum*  
Norwegian University of Science and Technology

Coherence is important in the design of products, because it makes them easier to understand for their users. Designers can use different representation modes to express ideas about coherence. However, perception of a representation can be influenced by its mode. Therefore, designers must be aware of the influences that different representation modes can have on perception of coherence. The aim of the present study was to investigate the effects of experienced modality on perception of conceptual coherence. In the study, participants were divided into two conditions for two representation modes: written word and physical object, both representing the same concepts. Each participant was presented with the concepts as words or objects and asked to list the properties of each concept. The results showed that between the two conditions, frequencies of responses were similar while frequencies of response contents were dissimilar and sometimes contrary. The main findings suggest that the effects of the modalities, written word and physical object, do not differ significantly for mental activity, but do differ considerably for semantic processing in ways that has implications for design.



## The Process And Operations Of Shape Generation And Manipulation During The Architectural Designing Activity

*Walid Bouhelis, Abdelmalek Arrouf*  
University of Batna 1

This piece of work is concerned with how shapes are generated, explored and transformed during the architectural designing process. It postulates that the relations and connections between sketches, produced during the design activity, can be defined in terms of shape transformations and described according to a closed list of shape operators. These latter provide a formal description of the shape exploration process and allow a deep understanding of its logic. To achieve its goal, this study creates a model to describe the different shape transformations, performed by designers, during the sketching activity.



## A Comparison Of Contemporary Prototyping Methods

*Euan Ross Coutts (1,2), Andrew Wodehouse (2), Jason Robertson (2)*  
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Prototypes are a common feature of many product design and development endeavours. An ever widening range of prototyping options are available to designers and engineers. May particular options be superior to others, or more appropriate for particular endeavours? This paper reviews current literature on the nature of what constitutes a prototype and the benefits they offer to the discipline. They principally facilitate communication, aid learning, help gain and provide feedback, inform decision making and generally provide superior design outcomes. In order to determine if any particular manner of prototype is preferable for achieving these benefits a comparative study of some of the contemporary prototyping methods is subsequently conducted: A 3D printed prototype (physical prototype), a CAD prototype (represented using a computer monitor), an augmented reality prototype (represented using a tablet device) and a virtual reality prototype (represented using a stereo projector and polarised glasses). The results indicate that while all provide benefits, overall the physical prototype performs best and the augmented reality prototype performs most poorly.



## Prototyping Canvas: Design Tool for Planning Purposeful Prototypes

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While prototypes are critical to the creation of successful products and innovative solutions, building a prototype is characterized by large sunk costs and a plethora of unknowns. The versatility and effectiveness of prototypes paired with the ambiguous nature of developing a prototype can lead to wasted resources. Recent studies support this claim, demonstrating that under certain circumstances, designers often prototype without a clear purpose, building prototypes as a function of the design process rather than as a function of the design. These findings motivated the creation of the Prototyping Canvas, a tool to aid designers in planning for purposeful prototypes by identifying critical assumptions and questions to guide development. Business and engineering design literature influenced the development of the canvas, which was first tested with a client project in the SUTD-MIT International Design Centre (IDC). The feedback and insights from the design team guided revisions to the canvas. The updated canvas was then validated with 55 professionals during a design project sprint. The purpose of this paper is to present the Prototyping Canvas as a valid and effective design tool.



## Iterative Course Design in MOOCs: Evaluating a protoMOOC

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This paper describes an iterative approach to course design in an effort to improve the learner-centered conceptualization of Massive Open Online Courses (MOOCs). The research team built a (design research) MOOC prototype and used three measurement tools to gather user feedback. The authors categorized this feedback and translated it into 57 improvement tasks, which they implemented in the public version of the MOOC. They discuss the protoMOOC iteration approach, underline its applicability, and suggest it as a method for fellow MOOC designers.



## Renewal Of Design Teaching Resources By The Practice Of Environmental Scanning

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Teachers' resources renewal is a critical aspect of design education. Design teachers update and renew their resources to keep their lectures and project topics up to date, in line with contemporary issues and societal changes, and to assure their lifelong learning and professional development. Yet, few studies were published on resource renewal process in design education. Researches usually focus on teaching resources and cultural capital qualification. This paper analyses the resource renewal process in design education. Our methodology comprehends the construction of a conceptual framework based on Environmental Scanning, which was studied through a qualitative study involving fifteen design teachers in France. Our results show that design teachers update and renew teaching resources according to their personal areas of interest and students' needs. Their renewal process is different depending on whether they are creating lectures and topics, they are working with other teachers or with external partners. Relationships and networks appear important, teachers rely on their network of colleagues, design practitioners and project partners to access emerging issues.



## Analysing The Relevance Of Serious Game Elements For Effectively Teaching Innovation Processes

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Serious games (SGs) as a new educational format have gained interest among many scholars from diverse fields. SGs seem to be useful tools for teaching innovation processes (IP) as they guarantee intrinsic motivation and provide situated learning. So far, there is no guideline on designing IP games and lowering their development time while ensuring their effectiveness. To fill this gap, we should first analyse the existing IP games with evaluation methods and synthesise their commonalities. Numerous methods have been put forward in the literature to assess digital SGs; however, most of the SGs for IP are board games. That is why we explore in this paper the use of Serious Game Design Assessment (SGDA) framework to analyse IP board games. According to the case study on an open innovation board game, we suggest applying this method to examine the a priori relevance of game elements (components that make up a game system). Moreover, we make recommendations to complement the SGDA framework with Game and Learning Mechanics, and real-world information. This contribution should help designers transform traditional educational supports into serious board games for teaching IP.



## Game-Based Learning of Knowledge Reuse in Engineering Education

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This paper presents an educational game fostering a new experience-based approach to teaching knowledge transfer using a codification strategy alone. The goal is to address and highlight some common issues and challenges that occur during knowledge transfer in product development and that are often difficult for especially students to grasp through exclusively a theoretical teaching approach. The game is introduced to 60 students in the final year of their Master's curriculum. In parallel, the game has been applied in a similar setting in a comparable higher educational institution, as well as in a product development organization. "Sometimes you win—other times you lose and learn."



## Combining Scrum and Design Thinking for a highly iterative and user-centric hardware development project

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User-centric development is essential to any product development project, especially in order to keep up with today's ever-changing product cycle. This paper explores the potential of combining specific aspects of Scrum and Design Thinking to maximise user integration as well as implementing short iterations in hardware development projects, in this use case a three-month development project at a German high-end homeware manufacturer. In addition to observations regarding the application of those approaches this paper will then offer a range of newly developed user-centric methods to efficiently integrate the user's perspective in future development projects, as well as feedback from the product developers at the company and comparisons to current methods. This use case was furthermore able to illustrate how the employment of such methods made short and sprint-like development cycles within hardware development attainable. These user-centric methods developed within the use case can be applied to future application- and user-oriented projects in order to speed up the product development process and ensure that the product or service matches the users' needs and desires.



## Agile Development of a Microtiter Plate in an Interdisciplinary Project Team

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The industry is currently changing rapidly. Both customers and employees are focusing much more on their own needs. On the one hand, this requires individualized products and, on the other hand, development processes need to be aligned not only more efficiently but also more closely to the needs of employees. Agile development combines these two characteristics and the second point can be further improved through analyses for collaboration. This is not only necessary for consumer products, but also in medical technology, more and more individualized solutions are required to better help patients. This is also the case with the examination of cells using micro titer plates, which is the subject of this project. Due to the interaction of research activities both on the process and on the product side, this paper presents research results regarding agile product development and collaboration analysis of physical products on the one hand and research results regarding additive and biocompatible production of microtitration plates on the other hand.



## Current challenges of Agile Hardware Development: What are still the pain points nowadays?

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Originally developed for the software industry, agile development is being applied in the hardware field nowadays as well due to its benefits when having to deal with volatile, uncertain, complex and ambiguous (VUCA) conditions. However, certain complications arise when applying the concept of agility in the hardware. In this publication, based on the challenges identified by Ovesen in 2012, the current challenges of agile development for hardware are gathered using an embedded design approach, ensuring its actuality based on the latest surveys and empirical data. The current state regarding the challenges is displayed and its interrelations as well as their advancements compared to seven years ago is discussed. Moreover, an attempt to explain the difficulties of applying agile development is given by a hardware-related complexity model.



## Agile Product Development: Features Identification and Application in the Electricity Sector

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The electricity sector is in the midst of a structural change driven by new technologies. In Brazil, the electricity sector regulation has mechanisms to foster innovation, including investments in R&D. Recently, the regulatory agency and the industry have been calling for approaches to increase the rate at which R&D departments generate solutions that end up being adopted. As a result, novel approaches to R&D project management have entered the agenda. In this context, the objective of this paper is to characterise Agile Product Development and its application in a highly regulated sector. The paper presents a systematic literature review with the debates about Agile and new product development. Then, a case study exploring an early adoption of the Agile approach in R&D project management in the Brazilian electricity sector is presented. Results include the identification of the Agile features most frequently mentioned in the literature. Moreover, the case study explores the Agile features that were more easily absorbed in early adoption, such as iterative patterns, and discusses implementation challenges in team structure, feedback loops, and communication.



### How do Digital Engineering and included AI based assistance tools change the product development process and the involved engineers

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Current trends in product development are digital engineering, the increasing use of assistance tools based on artificial intelligence and in general shorter product lifecycles. These trends and new tools strongly rely on available data and will irreversibly change established product development processes. One example for such a new data driven tool is the plausibility check of linear finite element simulations with Convolutional Neural Networks (CNN). This tool is capable of determining whether new simulation results are plausible or non-plausible according to numeric input data. The digitalization and the increased use of data driven tools employing algorithms known from Artificial Intelligence also shifts the roles of many involved engineers. This paper describes and highlights this transition from current product development processes to a data driven / simulation driven product development process. Particularly, the shifts and changes of different roles and domains are illustrated and an example for changing roles in the design and simulation department is described. Furthermore, required adjustments in the design process are derived and compared to the current status.



### Data Driven Product Portfolio Analysis of Electric Motors Based on Product Platforms Using Knowledge-Based Systems

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For a company it is necessary to know, which products can be configured using carry-over-parts or the same technology. This can become quite relevant in the context of automobile electrification, where complex mechatronic systems are used. Consisting of various mechanical components, these systems perform the required function while being actuated by electronically controlled motors. To solve this, a novel mechanism for data driven portfolio analysis based on product platforms using knowledge-based systems is proposed in this paper. Further, the mechanism is tested by applying it to an electrical motors' case study. Using this method, all possible combinations of a product platform are calculated and finally displayed in different product portfolios. Additionally, all the non-feasible motor designs are removed from the solutions portfolio using the acquired knowledge base and performing design checks. The latter are employed for penalising and eliminating from the pareto-front of the designs, which violate the thermal, mechanical and acoustic constraints. The generated product portfolio can be used further to expand the systems engineering collaboration and support decision-making.



### Towards an approach integrating various levels of data analytics to exploit product-usage information in product development

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By applying data analytics to product usage information (PUI) from combinations of different channels, companies can get a more complete picture of their products' and services' Mid-Of-Life. All data, which is gathered within the usage phase of a product and which relates to a more comprehensive understanding of the usability of the product itself, can become valuable input. Nevertheless, an efficient use of such knowledge requires to setup related analysis capabilities enabling users not only to visualize relevant data, but providing development related knowledge e.g. to predict product behaviours not yet reflected by initial requirements. The paper elaborates on explorations to support product development with analytics to improve anticipation of future usage of products and related services. The discussed descriptive, predictive and prescriptive analytics in given research context share the idea and overarching process of getting knowledge out of PUI data. By implementation of corresponding features into an open software platform, the application of advanced analytics for white goods product development has been explored as a reference scenario for PUI exploitation.



### Data Materialisation: A New Undergraduate Course for a Data Driven Society

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Universidad Adolfo Ibañez

Traditionally, data has been presented in textual format and the interaction with the user confined to the keyboard or touch screen to input data and the screen to deliver information. However, with the advent of a data-driven society, an opportunity for more natural and efficient ways of presenting data and interacting with it has emerged. Although the area of Human-Computer Interaction has existed for a long time, its focus has always been on the interaction with an artefact (the computer). Today instead, we face the challenge of interacting with an intangible object: data. As a result, a key requirement emerges: How do we make legible the enormous amounts of data produced per day to ordinary people? Designers, able to devise natural and smooth interaction experiences, should play a relevant role in this new scenario. However, they might lack the basic technical knowledge required to understand the possibilities of these new systems. In this paper we present a brief how-to manual for an undergraduate course on data materialisation: the process of transforming an intangible object (data) in an artefact that can be interacted with in a physical way.



### Three approaches to design engineering in the health domain: a systemic perspective

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This paper proposes a categorization of existing approaches to healthcare-related engineering design based on systems thinking principles. Three existing approaches to healthcare-related engineering design are isolated which contribute differently to health systems fundamental purposes and interconnections. The three approaches are labeled as ‘silent’, ‘overt’, and ‘convergent’ health design. Each approach is defined and illustrated through an example. Following, practical advantages and disadvantages of each approach are discussed. A reflection is offered on the expected relevance of the convergent health design approach for present and future societal challenges in the health domain, and specifically on the recently growing field of e-health. Finally, open methodological challenges related to convergent health design are outlined and characterized as opportunities for future research.



### Navigating Matters Of Concern In Participatory Design

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Among 75-90% of residents in Danish nursing homes are diagnosed with dementia. This article explore how a team of five 3rd semester bachelor’s design students sought to improve quality of life for elderly people with dementia in a nursing home through a co-design process of a new sensory stimulation technology. Participatory Design researchers agree that it is important to involve diverse actors in the design process such as elderly with dementia, nursing home management, nursing staff etc. But when involving many different actors in designing new products, services and systems the challenge is to navigate the many perspectives and concerns of these actors, which is often conflicting and hence needs negotiating. We draw upon the ANT framework to analyse how ‘matters of concern’ (MoCs) are negotiated and to discuss how designers navigate by staging and facilitating design interactions to support negotiation of MoCs among numerous actors during the design process.



### Tailor-Made Design Guidelines for Human Factors and Usability for Medical device application: A Proposed Methodology

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With increasing level of advancement and complexity in medical devices, there is a need for methodology, tools and techniques in practice to integrate Human Factors and Usability (HF/U) elements in design due to its increasing diversity of users and rapidly changing interface types. This paper proposes a methodology to develop a tailor-made HF/U design guidelines for medical device development with various sources and to develop heuristics for evaluation and score the product usability throughout the development process.



### Design for Health 4.0: Exploration of a New Area

*Melania Bause, Bahar Khayamian Esfahani, Hannah Forbes, Dirk Schaefer*  
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Driven by networked Electronic Health Record systems, Artificial Intelligence, real-time data from wearable devices with an overlay of invisible user interfaces and improved analytics, Health 4.0 is changing the healthcare industry. The focus on collaboration, coherence, and convergence that will make healthcare more predictive and personalised. Furthermore, Health 4.0 realises the value of data more consistently and effectively. It can pinpoint areas of improvement and enable more informed decisions. What it also does is help move the entire healthcare industry from a system that is reactive and focused on fee-for-service to a system that is value-based, which measures outcomes and ensures proactive prevention. In this paper, the authors will first explore the realm of the emerging area of Health 4.0 and identify its opportunities and challenges. This includes understanding the relevant base technologies as well as the design principles for the realization of smart healthcare product, systems and product-service-systems of the future. Following on from there, the authors focus on the role of design in the specific context of healthcare.



### A Neutral Form for Experiential Material Characterisation

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Materials experience in design involves the meanings that materials convey to users through its expressive characteristics. Such meaning evoking patterns are influenced by parameters such as context, product (e.g. shape) and user. Consequently, there is a need to standardise experiential material characterisation and large-scale data collection, by means of a meaning-less or 'neutral' demonstrator to objectively compare materials. This paper explores the conception of this neutrality and proposes two opposing strategies: neutrality through complexity or through simplicity. In a pre-study with 20 designers, six associative pairs are selected as neutrality criteria, and shaped in 240 forms by 20 (non) designers in a main workshop. Following the simplicity strategy, these forms are averaged out in three steps by a team of five designers, based on a consensus on of delicate-rugged, aggressive-calm, futuristic-calm, masculine-feminine, traditional-modern, and toylike-professional, resulting in a selection of four averaged neutral forms. Finally, future research will focus on complexity to increase interactivity, so that consumers might be triggered in extensive material exploration.



### Early-Career Engineers' Perceptions Of Support For Innovation At The Workplace - What Seems To Matter

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Previous research has shown the importance of contextual factors for increasing employee innovativeness, but to effectively support innovative behavior, we need to also understand what forms of support are perceived as meaningful by the employees themselves. The current study investigated the experiences of 35 early-career engineers in creating, championing and implementing new ideas at the workplace. They reported relatively few instances of support that had been experienced as helpful, and nearly all of these were related to either managerial or co-worker support. This support ranged from encouragement and positive feedback to tangible help in troubleshooting and finding resources, and, in the case of managers, providing sufficient autonomy and responsibility to enable the interviewees to pursue their ideas. Managerial support was most frequently reported by those working in self-described innovative positions, whereas co-worker support was more commonly reported by those working in self-described innovative environments. Formal processes and incentives were less likely to have been perceived as helpful than informal interactions with managers and co-workers.



### From Innocent Irene to Parental Patrick: Framing User Characteristics and Personas to Design for Cybersecurity

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With the surging number of digital devices penetrating our daily routines, the risks inherent to cybersecurity—the protection of data on digital products connected to the Internet—have also increased since these devices (e.g., connected home devices, personal monitoring) collect, process, analyze and store users' sensitive personal information. Thus, there is a pressing need to assist users in being aware of and dealing with potential cybersecurity threats. With the proposition that fulfilling the need starts with developing an in-depth understanding of the user behaviors in the context of cybersecurity, an exploratory study was conducted that employed three mixed qualitative and quantitative research methods—a trend analysis, an interview study, and an online survey study. The paper reports the user characteristics on (1) awareness levels of cybersecurity issues, (2) uses of digital devices, and (3) means of dealing with the privacy issues in product use. The results of the studies were translated into eight personas that systematically reflect distinct characteristics of users, which can help designers empathize with their potential users vulnerable to cybersecurity risks.



### Understanding behavioural design: Integrating process and cognitive perspectives

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Behavioural design is a crucial research area due to its potential in leveraging the positive outcomes of traditional design. Current need for theory building requires discerning the unique characteristics and challenges of behavioural design. To contribute towards this goal, the paper structures the conceptual and operational uniqueness of the behavioural design using the process and cognitive perspective. Process model uses the basic design cycle to discern the tasks and stages of behavioural design. Cognitive perspective uses dual process theory and cognitive strategies used by designers. Integrated model of process and cognitive perspective is the crucial contribution of this paper. A case study involving interview of lead designers from five behavioural design consultancies has been used to present and elaborate the usefulness of the integrated model of behavioural design. Integrated perspective links the process characters like incomplete analysis, simulation and evaluation stages, over reliance on the prescriptive methods, and unequal emphasis to multiple disciplines, with incomplete analytical process, and solution and knowledge driven strategy along cognitive perspective



### Looking for Inspiration: Understanding the Information Evaluation and Seeking Behavior of Novice Designers During Creative Idea Generation

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Information usage is a key aspect of creative cognition and has been shown to influence design outcomes. The goal of this study was to investigate the information seeking behavior of student designers while validating a previously developed "Typology of Design Information" framework. Participants were asked to use and evaluate pieces of information during the idea generation process. Results show a discrepancy between the information that participants naturally sought out and their perceived utility (helpfulness) of the information. However, individually significant relationships between perceived utility and behavior were found with features generated by participants, suggesting that even though participants' perception of the utility of information pieces and their actual behavior are not related, both constructs have an identifiable influence on design outcomes. This study advances the Typology of Design Information framework by empirically exploring the link between the types of information used by novice designers and the ideas generated, and it illustrates that participants employ complex cognitive behavior when engaging with design information to generate novel ideas.



### Semantic analysis approach to studying design problem solving

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To objectively and quantitatively study transcribed protocols of design problem solving conversations, we propose a semantic analysis approach based on dynamic semantic networks of nouns constructed with WordNet 3.1 lexical database. We examined the applicability of the semantic approach focused on a dynamic evaluation of the design problem solving process in educational settings. Using a case of real-world design problem-solving conversations, we show that the approach is able to determine the time dynamics of semantic factors such as level of abstraction, polysemy or information content, and quantify convergence/divergence of semantic similarity in design conversations between students, instructors and real clients. The approach can also be used to evaluate the aforementioned semantic factors for successful and unsuccessful ideas generated in the process of design problem solving, or to assess the effect of external feedback on the developed design solution. The proposed semantic analysis approach allows fast computation of the semantic factors in real time thereby demonstrating a potential for both monitoring and support of the design problem solving process.



### Exploring the effect of combinational pictorial stimuli on creative design performance

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Visual stimuli can be useful in supporting design ideation process. However, researchers still know very little about how stimuli should be delivered to designers during the early design stage. This question is crucial to the effective use of stimuli because previous researches have proved that ill-presented stimuli can have a negative impact on design creativity. Therefore, an empirical study was conducted with the aim of exploring if and how combinational pictorial stimuli can affect designers' creative performance. Results from a total of 36 participants show that the design outcomes presented by the group exposed to combinational pictorial stimuli were more creative than those given by the group exposed to no stimuli or randomly presented pictorial stimuli. These results imply that the form of stimuli delivery can affect creative design outcomes and combinational pictorial stimuli best support design creativity among these three conditions. These findings give us a better understanding of the roles that visual stimuli play in design, which is expected to bring us important implications for both design education and design support tool development



### Patent Classification as Stimulus for Inspiring New Applications of Existing Knowledge

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This paper aims to provide suggestions for the identification of potential new applications for the existing knowledge. A method is presented for extracting information about a product or technology, processing the international patent database (IPD) and extracting useful hints for potential new applications. The approach uses the Cooperative Patent Classification as stimulus for inspiring new potential fields towards which export existing product or technologies. Although some limits inevitably affect the approach, relevant directions for future developments have been inferred for a more comprehensive exploitation of both the firm internal knowledge and the suggestions provided by the international patent database. The achieved results can support firms in expanding market opportunities for their products or technologies.

