Daily Book of Abstracts

Thursday
8 August 2019

iced

responsible
design for
our future

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:

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?

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.

THURSDAY, AUGUST 8

P-**Coll. Design & Group Creativity** | Approaches	P-**Design for Car Circularity** | Methods	P-**Design Education** | Around the Globe	P-**Design for Emotion and Experience** | Mobility	P-**Multi-criteria Evaluation**	P-**Design Thinking** | Strategies	P-**Innovation Networks** | Investigations & Challenges	P-**Design Methods** | Design for X
●	●	●	●	●	●	●	●
Hall 6	*Hall 5*	*Wim Crouwel*	*Hans Dirken*	*Bernd Schierb.*	*Hall K*	*Hall L*	*IDE Arena*

COFFEE BREAK

P-**Coll. Design & Group Creativity** | Computational Studies	P-**Computational Design**	P-**Design Education** | Student Experience	P-**Design for Emotion and Experience** | Innovation	P-**Neuro-cognition**	P-**Open Innovation**	P-**Sketching & Framing** | Sketching	P-**VR & Design** | Virutal Reality
●	●	●	●	●	●	●	●
Hall 6	*Hall 5*	*Wim Crouwel*	*Hans Dirken*	*Hall K*	*Hall L*	*Bernd Schierb.*	*IDE Arena*

LUNCH

TIME OFF

D-**Coll. Design** | Team & Members	D-**Design for Circularity** | Eco-Innovations	D-**Design Tools** | CAD/CAE	D-**Design for Emotion** | Behaviour	D-**Design Thinking** | Implementation	D-**Req. Eng.** | Requirements Alicitation	D-**Meth. of Des. Research** | Approaches	D-**Sketching & Framing** | Reframing	D-**Design Methods** | Approaches (2)
●	●	●	●	●	●	●	●	●
Hall 6	*Hall 5*	*Wim Crouwel*	*Hans Dirken*	*Hall K*	*Hall 4*	*Hall M*	*Bernd Schierb.*	*IDE Arena*

COFFEE BREAK

D-**Coll. Design** | Workspaces	D-**Decision Making**	D-**Design Tools** | Modelling Approaches	D-**Innovation Networks** | Evaluation	D-**Req. Eng.** | Management	D-**Meth. of Des. Research** | Surveys	D-**Service Design**	D-**VR & Design** | Augmented Reality
●	●	●	●	●	●	●	●
Hall 6	*Hall 5*	*Wim Crouwel*	*Hall L*	*Hall 4*	*Hall M*	*Bernd Schierb.*	*IDE Arena*

TRANSITION

KEYNOTE 5 **EVA DECKERS** *Auditorium Aula*

PLENARY: CLOSING

TRANSITION

FAREWELL RECEPTION
(18:15-20:00)
IDE Main Hall

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Assessing Regulatory Focus Differences in Creative Ideation: An examination of prevention and promotion mindsets on novelty and usefulness

*Rianne Wally Meurzec (1), Brandon Koh (2), Georgios Koronis (1), Jacob Kai Siang Kang (1), **Christine Yogiaman (1)**, Arlindo Silva (1)*
1: Singapore University of Technology and Design; 2: Singapore Management University

The purpose of this work is to compare impact of regulatory focuses, namely preventive and promotional contexts, on creative ideation measured by novelty and usefulness. The study consisted of Singaporean students from an undergraduate university, and assessed their personality using the Big Five, Regulatory Focus, Creativity type and creativity outcomes measured with the Consensual Assessment Technique by completing a Collaborative Sketch exercise. Participants were randomly assigned to either the preventive, promotional or a baseline condition and tasked with a design problem necessitating a solution in the form of sketches. This study found the three conditions to yield significantly different novelty scores, but not usefulness scores. The most impactful condition on novelty was the baseline, indicating novice designers are capable of creating novel products and services. Those in the promotion condition created the second most novel sketches, or design solutions, followed lastly by the prevention condition. This may be so as novice designers consider larger space of solutions and may generate more ideas. This research is useful in creative pedagogy and for design professionals.

Methodological Design: Effects Of A Morphological Approach For Different Students And Professionals

Wim Zeiler
TU Eindhoven

In connection with a design research project for professional in the Dutch building industry, an educational project was developed, the multidisciplinary master project Integral Design, to prepare our Master students better for their professional life. The concept of an earlier developed integral design workshop for professionals was implemented within the start-up workshop of our mastersÕ project integral design. The frame work of the approach is described as well as the positive effects on the collaboration between the design team members from different disciplines as result of the morphological approach of the Integral Design method. This method was also applied during workshops in different courses about design methodology As basically the same set-up for the workshop was used this allowed us to compare the results of the different students and analyse them. During the different workshop series the effects on the outcome of the conceptual phase of the design process has been investigated. The results of this analysis are presented in the paper and showed some remarkable similarities as well as some differences among the different student groups.

Design for empathy: a co-design case study with the Finnish parliament

Enni-Kukka S E Tuomala, Weston L Baxter
Imperial College London

Globalisation and the mixing of people, cultures, religions and languages fuels pressing healthcare, educational, political and other complex sociocultural issues. Many of these issues are driven by societyÕs struggle to find ways to facilitate deeper and more emotionally meaningful ways to help people connect and overcome the empathy gap which keeps various groups of people apart. This paper presents a process to design for empathy Ð as an outcome of design. This extends prior work which typically looks at empathy for design Ð as a part of the design process, as is common in inclusive design and human centered design process. We reflect on empathy in design and challenge the often internalised role of the designer to be more externalised, to shift from an empathiser to become an empathy generator. We develop and demonstrate the process to design for empathy through a co-creation case study aiming to bring empathy into politics. The ongoing project is set in the Parliament of Finland, and involves co-creation with six Members of the Parliament from five political parties. Outcomes of the process and case study are discussed, including design considerations for future research.

Different approaches to democratise design – are they equal?

***Mark Goudswaard (1),** Hannah Forbes (2), Lee Kent (1), Chris Snider (1), Ben Hicks (1)*
1: University of Bristol; 2: University of Liverpool

The democratisation of design permits greater stakeholder involvement in what has traditionally been a domain reserved for experts; the design process itself. This is enabled by technological advances in fields such as 3D printing, virtual reality and high-speed peer to peer communication technologies which have fuelled the development of new and innovative design methods. This paper compares and contrasts different approaches to the democratisation of design, and in particular, those that aim to involve wider stakeholders in the design process itself. Three different approaches(design by play, design by generation and crowdsourcing for design) are defined and contextualised within existing design frameworks and their respective suitabilities to democratise different design phases are considered. An exemplar use case of each approach is presented in order to assess how stakeholder engagement is affected by each democratising strategy. The discussion compares and contrasts the approaches with respect to their applicability and utility for different stages of the design process and how the power dynamics of the design process are altered when the different approaches are employed.

A theoretical foundation for developing a prescriptive method for the co-design of circular economy value chains

Fenna Blomsma, *Daniela C. Pigosso, Tim C. McAloone*
Technical University of Denmark

In order to operate in line with the circular economy (CE) concept, companies and other stakeholders need to work together to enable the circulation and cascading of resources. Although the need for proactive stakeholder management is a common theme in recent work on CE, little work has been dedicated to creating prescriptive methods for the co-design of CE value chains (CEVCs) focusing on selecting strategic partners, when to engage them and in what capacity. Following calls to connect the emerging CE literature with literature from existing bodies of knowledge, this paper explores the theoretical foundations of a CEVCs co-design method. Specifically, this paper explores resource-base view (RBV); resource dependency theory (RDT); and actor-network theory (ANT), and synthesises an outline for the co-design process of CEVCs. Reflections on the process link it to the extant co-design literature and explain how the process can be used for method and tool development.

Circular PSS strategies: an exploration of the integration of territorial resources

Estephania Elizabeth Delgadillo Jaime (1), Tatiana Reyes Carrillo (1), Rupert Baumgartner (2)
1: University of Technology of Troyes; 2: University of Graz

Product service systems (PSS) are frequently cited as key strategies in the transition towards the circular economy (CE). The main aim of the CE is sustainable development (SD), hence, this paper intends to highlight the importance of considering the territory in the design and implementation of circular PSS strategies for ensuring SD. This research is in an early stage, thus, a literature review was conducted to define the main characteristics of circular PSS, and the concepts of the territory, territorial and local resources from a PSS perspective. In addition, an analysis of the state-of-the-art approach of the integration of the territorial scale in the design and development of PSS strategies was conducted. This study contributes to the understanding of the territory and its relevance in the local value creation in circular PSS strategies. Furthermore, the results highlight the relevant role of collaboration and the importance of intangible resources in the mobilisation of other resources in the design of circular PSS strategies.

Staging co-design for a circular economy

Signe Pedersen, Christian Clausen
Aalborg University

In recent years major companies such as Philips, H&M and Google have adopted a circular economy agenda to promote sustainability. Design consultancies such as IDEO has developed and promoted a circular design guide to help companies in this endeavour. However, designing for a circular economy often require design and reconfiguration of entire value chains Ð making the transition towards a circular economy rather difficult. In this paper we analyse a development project from the Danish island of Bornholm to investigate how to align diverse actors across the value chain in a process of co-creating systems for a circular economy. We combine design, value chain considerations and circular economy mindsets to informing negotiations of concerns among actors in the value chain. Such strategical navigation might involve: 1. Staging initial spaces for dialogue with central actors from the value chain and initiates a process of mapping out their concerns 2. Staging a re-alignment space where the diverse actors can meet and interact to discuss and negotiate their concerns and their roles in the network 3. Design and enactment of a number of objects to faciliate negotiations

Testing the robustness of circularity indicators: empirical insights from workshops on an industrial product

*Michael Saidani, **François Cluzel,** Yann Leroy, Bernard Yannou*
Laboratoire Genie Industriel, CentraleSupélec, Université Paris-Saclay

Monitoring properly the circularity performance of technical products is a point of increasing importance. Yet, evaluating the circularity potential of products during (re)design and development phases is a challenging task. In this study, several C-indicators are experienced by doctoral students and industrialists through two workshops on a real-world industrial product. The values obtained for each indicator are collected and analyzed: as all participant are working on the same technical product with the same dataset, the circularity scores calculated are compared to discuss the reliability and the uncertainty related to these indicators. These new empirical insights are put in parallel with the existing critical analyses of C-indicators from literature. As a result, future research directions on circularity indicators are advanced and discussed, including: the integration of uncertainty considerations into the assessment methodology of circularity indicators; the uptake by industry of such indicators during product design and development; the link between circularity and sustainability scores.

Design education in Singapore – issues, solutions and recommendations

*Paula Silva, Sumbul Khan, **Lucienne Blessing***

Singapore University of Technology and Design, SUTD-MIT International Design Centre

Design is increasingly being viewed as a vital competency and a strategic resource. Therefore, there is a need to consider a systematic implementation of design in the educational system. In this paper, we present findings from two workshops conducted at a conference, the Design Education Summit, targeted at Singaporean educators, on the implementation of design in the Singaporean education system. Our research aims to understand the main issues in providing design education and whether these issues show similarities and/or differences across levels/types of education. Furthermore, the study aims to reach possible solutions and be able to propose recommendations. The main issues are the inclusion of design education within the curriculum, the support needed, the change of mindsets across all stakeholders, and assessment of design learning. The differences/similarities were also compiled and reported. The proposed solutions range from ways to introduce design thinking as part of the culture of the institute, to changing mindsets and collaborations inside and outside the school system. The results of the workshops are summarized into a set of action items and recommendations.

The 'Responsibility' Factor In Imagining The Future Of Education In China

***Ellen De Vos (1,3),** Xin Xin (2), Lieven De Marez (3,4), Marina Emmanouil (1)*

1: Department of Industrial Systems Engineering and Product Design, Ghent University; 2: Beijing Normal University; 3: Department of Communication Studies, Research group imec-mict-UGent, Ghent University; 4: imec

Design and creativity have been a considerable force for improving life conditions. A lot of effort has been invested in explaining the design process and creativity mainly through the design thinking methodology, but design accountability and responsible actions in the design process are, yet, to be fully explored. The concept of design ethics is now increasingly scrutinized on both the level of business organization and of the individual designer. A 4-day design workshop that involved creativity techniques provided the base to explore responsibility in the fuzzy front end of the design process. The future of education in 2030 was defined as the workshop's theme and fifty-six students from China were asked to create detailed alternative scenarios. A number of imagination exercises, implementation of technological innovations and macro-environment evolutions employed in the workshop are discussed. The aim was to incite moral and responsible actions among students less familiar with creative educational contexts of student-led discovery and collaborative learning. This paper reflects on the use of creativity methods to stimulate anticipation in (non)design students.

The Finnish Product Development Teachers´ Perceptions of Their Pedagogical Content Knowledge in Higher Education

*Elina Mäkelä, Petra Auvinen, **Tero Juuti***

Tampere University

The paper concerns the Finnish product development teachers« perceptions on their pedagogical content knowledge in higher education settings. The aim is to describe and analyse what kind of pedagogical content knowledge the teachers have and, therefore, to provide a better understanding of the type of knowledge unique to product development teaching. The model of pedagogical content knowledge used here includes the components of product development content knowledge, pedagogical knowledge and pedagogical content knowledge. Based on seven teacher interviews, the main content knowledge concerns the process of product development, its different phases and methods as well as the usage of different software programs. The teachers use diverse teaching methods and their attitude towards educational technology is mostly positive. Course learning outcomes and working life are acknowledged when planning teaching, but only a few teachers take curriculum into account and participate in curriculum design. Even though the teachers use different evaluation methods in teaching, new ways of evaluation are needed. This may be something that innovative educational technology tools can make possible.

A "lattice" approach to design education: Bringing real and integrated design experience to the classroom through Engineering Design Days

*Ada Hurst, **Chris Rennick**, Sanjeev Bedi*

University of Waterloo

While design is fundamental to engineering practice, modern training in engineering design has almost exclusively moved to the classroom, providing students little exposure to holistic, real-world design experiences that are well-integrated with the rest of the academic curriculum. In this paper, we perform a short review of how the model of engineering education in Canada has evolved over the last two centuries, identify the current deficiencies in teaching design in engineering curricula, and review how Chairs in Design Engineering at various Canadian engineering schools have tackled this identified need. We then describe in detail how this problem is being addressed at the University of Waterloo through Engineering Design Days. This approach is presented as a design "lattice" around which other curriculum threads (math, natural sciences, engineering science, design etc.) can grow in an integrated way. Different Design Days examples from various engineering programs are described to illustrate the general structure. We conclude by assessing the program's impact and identifying opportunities for future development and assessment of the program's effectiveness.

Visualising User Experiences: Analysing Embodiment of UX in Autonomous Vehicle Concepts

Charlie Ranscombe (1), Jacob Rodda (1), Mark Johnson (2)
1: Swinburne University of Technology; 2: Ford Design

The prospect of autonomous vehicles and associated technologies has disrupted traditional modes of vehicle operation and ownership. This requires automotive designers to shift their focus from designing vehicle form to consider the design of transport experiences. As such, there is a need to explore how best to support automotive designers in communicating user experiences (UX) alongside the physical design of vehicles. This paper presents an industry case study conducted with Ford Design Asia Pacific to assess the embodiment of UX in early concepts. Attributes of generalised model for UX are mapped to designers' storyboard illustration for the experience of an advanced concept for an autonomous vehicle interior. Results show how a mix of captions, sketches of users and contextual features illustrate different attributes of user experience. From findings we conclude firstly, the need to develop a toolkit to help designers communicate descriptions of as yet designed interactions. We also conclude that sketching contextual features of experience can provide a starting point to develop aspects of UX that can be used to differentiate and identify the Ford brand.

Optimization of the sound of electric vehicles according to unpleasantness and detectability

Jean-François Petiot, Killian Legeay, Mathieu Lagrange
Ecole Centrale de Nantes, LS2N (UMR CNRS 6004)

Electric Vehicles (EVs) are very quite at low speed, which can be hazardous for pedestrians. It is necessary to add warning sounds but this can represent an annoyance if they are poorly designed. On the other hand, they can be not enough detectable because of the masking effect due to the background noise. In this paper, we propose a method for the design of EV sounds that takes into account in the same time detectability and unpleasantness. It is based on user tests and implements Interactive Genetic Algorithms (IGA) for the optimization of the sounds. Synthesized EV sounds, based on additive synthesis and filtering, are proposed to a set of participants during a hearing test. An experimental protocol is proposed for the assessment of the detectability and the unpleasantness of the EV sounds. After the convergence of the method, sounds obtained with the IGA are compared to different sound design proposals. Results show that the quality of the sounds designed by the IGA method is significantly higher than the design proposals, validating the relevance of the approach.

Using Personas in the Design Process. Towards the Development of Green Product Personality for In-Car User Interfaces

Franka Wehr, Martin Luccarelli
Research Center for Interactive Materials, School of Textiles & Design, Reutlingen University

The desire to combine advanced user-friendly interfaces with a product personality communicating environmental friendliness to customers poses new challenges for car interior designers, as little research has been carried out in this field to date. In this paper, the creation of three personas aimed at defining key German car users with pro-environmental behaviour is presented. After collecting ethnographic data of potential drivers through literature review, information about generation and Euro car segment led to the definition of three key user groups. The resulting personas were applied to determine the most important interaction points in car interior. Finally, present design cues of eco-friendly product personality developed in the field of automotive design were explored. Our work presents three strategic directions for the design development of future in-car user interfaces named as a) foster multimodal mobility; b) emphasize the interlinkage economy - sustainable driving; and c) highlight new technological developments. The presented results are meant as an impulse for developers to fit the needs of green customers and drivers when designing user-friendly HMI components.

From the car style pregnancy towards the brand country origin recognition

Jean-Bernard Bluntzer (1), Egon Ostrosi (2)
1: Université de Bourgogne Franche-Comté, Pôle Transports et Mobilités, ERCOS/ELLIADD; 2: Université de Bourgogne Franche-Comté, Pôle Industrie 4.0, ERCOS/ELLIADD

In the modern automotive industry, a car's style clearly defines its brand. In the context of globalization, a question has recently emerged concerning the relationship between a country's culture and the car style of a particular brand. The style is one way to place car morphologies into a meaningful structure, called the "telling structure." This research hypothesizes that a stylist tries to compress a car's form and make it a refined unicum that is streamlined with some inherent features, which express a brand's cultural aesthetics. Using the cognitive paradigm that an end user transforms explicit references into implic-it references and that the telling structure of a car's design features influences the recognition of the brand, this research demonstrates a novel method to ad-dress this hypothesis. Results from this study show that there is a relationship between the brand's country of origin and the perceived recognition of a car. However, a country's brand culture is not always represented by the style of the cars. In particular, the results indicate that some cars can actually lose their cultural identity, especially in the context of a worldwide market.

Pugh Controlled Convergence and Social Choice Theory

John Morgan Nicholson, Paul Collopy
The University of Alabama in Huntsville

The Pugh Method of Controlled Convergence is evaluated based on social choice theory, both from an axiomatic basis, and by examining all possible cases of attribute ranks for a range of numbers of alternatives and numbers of attributes. The evaluation shows that, for a typical Pugh application, concept selection varies with the arbitrary choice of datum or is simply incorrect in about one-third of the cases. While there are merits to the iteration steps and creation of new alternatives within the Pugh method, a simpler and more expressive concept ranking procedure can give far superior results.

On Vehicle Evaluation and Design using Data Envelopment Analysis with Hierarchical Concepts

Victor Parque, Kazuhiro Honobe, Satoshi Miura, Tomoyuki Miyashita
Department of Modern Mechanical Engineering, Waseda University, Japan

In recent years, product complexity in terms of function and structure has been driven by technological development in complementary components. Designing unbiased product evaluation metrics being to grasp the complex relationships of product features, and able to capitalize on market needs has become a challenge in industrial practice. In this paper, we propose a hybrid framework in which evaluation models are generated by integrating Interpretive Structural Modeling (ISM), Hierarchical Clustering and Data Envelopment Analysis (DEA). Whereas ISM constructs hierarchical digraphs (skeletons), Hierarchical Clustering reduces dimensionality of pairwise comparisons (correlations) of design variables, and suggests possible evaluation configurations, and DEA computes weights to provide optimal evaluation metrics. Our computational experiments using more than twenty thousand vehicles from 1982 to 2013 confirmed the feasibility and usefulness of DEA with hierarchical concepts to generate the optimal vehicle evaluation metric, and to suggest configurations for vehicle design layouts.

Usability evaluation of software tools for engineering design

Helena Hashemi Farzaneh, Lorenz Neuner
Technical University of Munich

Much of the work in design research focusses on the development of methods and tools to support engineering designers. Many of these tools are nowadays implemented in software. Due to the strongly growing use of computers and smart devices in the last two decades, the expectations of users increased dramatically. In particular users expect good usability, for example little effort for learning to apply the software. Therefore, the usability evaluation of design software tools is crucial. A software tool with bad usability will not be used in industrial practice. Recommendations for usability evaluation of software often stem from the field of Human Computer Interaction. The aim of this paper is to tailor these general approaches to the specific needs of engineering design. In addition, we propose a method to analyse the results of the evaluation and to derive suggestions for improving the design software tool. We apply the usability evaluation method on a use case - the KoMBi software tool for bio-inspired design. The case study provides additional insights with regards to problem, causes and improvement categories.

Interdependencies within the System of Objectives of a Product Generation in Industrial Practice

*Albert Albers, **Natalie Peglow**, Markus Spadinger*
Karlsruhe Institute of Technology

One challenge in product development is the megatrend of product individualization in the automotive supplier industry. Requirements for a variant by the customer may differ from those by the provider wherefore conflicting goals can arise. To cope with variant requests in the quotation phase systematically, a method to evaluate variants is necessary. Based on evaluation criteria the requirements from the stakeholders are valued. While evaluating, an already criterion can have an impact on assessing the remaining criteria. For this reason, the present investigation emphases the interdependencies between the evaluation criteria in industrial practice representing interdependencies within goals, requirements and boundary conditions in an early stage of product development. Analysing decisive factors supports to identify subsequent activities in the development process of a variant. Experts of an international automotive supplier developed impact matrices and a scenario technique tool is used to interpret the matrices. In context of the model of PGE - Product Generation Engineering, findings derive to ensure a comprehensive basis for decision-making concerning a variant-request.

Feature Engineering for Design Thinking Assessment

Reviewers' favourite

Ryan Arlitt (1), *Sumbul Khan (2), Lucienne Blessing (2)*
1: Technical University of Denmark; 2: Singapore University of Technology and Design

As design and design thinking become increasingly important competencies for a modern workforce, the burden of assessing these fuzzy skills creates a scalability bottleneck. Toward addressing this need, this paper presents an exploratory study into a scalable computational approach for design thinking assessment. In this study, student responses to a variety of contextualized design questions Ð gathered both before and after participation in a design thinking training course Ð are analyzed. Specifically, a variety of text features are engineered, tested, and interpreted within a design thinking framework in order to identify specific markers of design thinking skill acquisition. Key findings of this work include identification of text features that may enable scalable measurement of (1) user-centric language and (2) design thinking concept acquisition. These results contribute toward the creation of computational tools to ease the burden of providing feedback about design thinking skills to a wide audience.

Measuring Systems Engineering and Design Thinking Attitudes

Melissa T. Greene, *Richard Gonzalez, Panos Y. Papalambros*
University of Michigan

Systems engineering and design thinking have been widely seen as distinctly different processes, systems engineering being more data-driven and analytical, and design thinking being more human-centred and creative. We use the term 'design thinking' to encompass the plurality of human-centered design processes that seek to unpack the core values behind design decisions. With the increased awareness that both systems engineering and design thinking need each other, the effects of a possibly persisting distinction on engineers' attitudes toward these two processes are not well understood. In this paper, we describe the development and validation of a scale for measuring individual attitudes about systems engineering and design thinking. Thematic analysis of engineering and design literature is used to derive a Likert scale reflecting these attitudes. We use exploratory and confirmatory factor analysis to test and confirm this two-factor thematic representation, resulting in a 9-item Systems Engineering and Design Thinking Scale measure of attitudes.

Seeking Insights Into An Unknown Future: Exploring Designers' Strategies To Discover Key Insights

Line Sand Knudsen, *Louise Møller Haase*
Aalborg University

Insights play a significant role in creation of new products. Insights provide the designer with an understanding of the user, market, technologies and trends, and how these might change over time. This information is critical for the designer to get an understanding of how and why present products succeed or fail. Hence, insights serve as both triggers and drivers for envisioning future products, but they are also fundamental to ensure that new products created will provide meaningful experiences to the users. In design literature, there is a significant amount of research on how to gather information about the user, market, trends, etc. However, very little research is focused on how the designer addresses this information to discover or uncover key insights. Through interviews with expert designers behind twelve products, we identified three strategies that designers use to discover insights. We found that designers search for insights that could be used to: 1) establish the productÕs future identity, 2) identify core challenges based on the new identity in the existing user experience and 3) identify solutions that could meet the core challenges and accentuate the new identity.

From Tinkering Methods to Design Thinking: Primordial Thoughts in Design Research

Jean Henrique de Oliveira Menezes
University of California, Davis

Design thinking as explored by Bernard Roth from the Stanford d.School, Roger Martin from the Rothman School of Management, and the IDEO merger trio by Tom and David Kelley, as well as current its CEO Tim Brown, dominates the narrative of the contemporary schools of design thinking since the late `90s. This article aims to investigate the underlying philosophies, authors, and events that laid the foundation in which these contemporary designers based their strategies on planning for complex environments. To satisfy this intent, the turbulent origin of design methods is explored, following the post-war environment that allowed these ideas to flourish, the generations of methods in design from the `60s to the `90s, and the encroachment of design methods to the embodiment of a commercialized design thinking methodology.

Challenges with supplier involvement in product development: a supplier's perspective

Filip Flankegård (1), *Glenn Johansson (1,2), Anna Granlund (1)*
1: School of Innovation, Design and Engineering, Mälardalen University, Sweden; 2: School of Engineering, Jönköping University, Sweden

Studies of supplier involvement in product development have revealed potential benefits including faster time to market, reduced cost and increased quality. However, existing literature has mainly focused on the customerÕs perspective on advantages, disadvantages and factors to be considered when involving suppliers in product development. This paper addresses the supplierÕs perspective by answering following research question: How do challenges that originate from involvement in customer's product development affect a supplier? The question is answered through a single case study at a supplier that develops and manufacture products primary used in capital goods. Thirteen challenges are identified, classified as being internal or external, and categorised into five areas: (A) Customer requirements, (B) Information exchange between customer and supplier, (C) Product variety management, (D) Design-manufacturing integration and (E) Processes and work instructions. The findings suggest that internal challenges need as much attention as external ones that originate from the customer. Also, an indication of when the challenges affect the supplier during product development is presented.

Perceived Culture of Networked Knowledge Hubs

Pauliina Mattila (2), Floris van der Marel (1), Maria Mikkonen (1)
1: Aalto University; 2: Swinburne University of Technology

While the construction of knowledge hubs has gained recent traction, little is known on how networked actors perceive their collective culture. Authors looked at the topic through a single case study, the Design Factory Global Network, a network of 24 autonomous yet connected hubs for passion-based co-creation in an educational setting. Data was collected via questionnaires, asking 1) to describe their Design Factory in three distinct, words, 2) explicate these with exemplary stories, and 3) express future development wishes. 98 stories and future wishes were shared by representatives from 15 Design Factories. Excerpts reflecting cultural levels (attitudes, norms, manifestations) were identified and made sense of by looking at which level of stakeholder relationship (internal, host, network, wider environment) they targeted. 78 attitudes, 114 norms and 95 manifestations were mentioned, mostly targeting the internal community and the host levels. Authors draw some practical implications for each of the identified level or relationship, contributing to the knowledge of the creation and development of such innovation hubs. In addition, further research directions are proposed.

Designing collaborative research: the exploration of common purposes to foster the generation of cross-disciplinary projects

Juliette Brun (1), *Chloé Salembier (2), Benjamin Loubet (3), Alexandra Jullien (3)*
1: UMR Agronomie, AgroParisTech, Université Paris-Saclay; 2: UMR SADAPT, AgroParisTech, Université Paris-Saclay; 3: UMR ECOSYS, AgroParisTech, Université Paris-Saclay

Despite the increasing demand to develop cross-disciplinary research projects, designing collaborative research still prove to be difficult due to both scientific specialization and organizational issues. In this paper, we explore how innovative design dynamics can be developed between researchers to collectively build research projects that could become common purposes for collaboration. This work relies on a case study led with the newly formed Eco&Phy research team, who applied an innovative design process to initiate collaboration and design its scientific agenda for the next 5 years. This process was built based on both KCP and matching-building methodologies: it included an initialization phase, during which the team strategically chose topics to be explored, and exploration phases, during which researchers collectively developed new knowledge and concepts to build cross-disciplinary projects. At the end of the design process, the team had developed two new research lines that were integrated in its official agenda. In conclusion, the article discusses the relevance of design approaches to develop original collaborative research through dedicated innovation processes.

Investigation of the perception of a radical degree of novelty from the perspective of product users

Thorsten Herrmann, Daniel Roth, Hansgeorg Binz
University of Stuttgart

The dichotomy of radical and incremental innovation has been discussed in numerous literature sources and a great amount of advices on how to handle them in design processes has been provided. Nevertheless, only a minority of literature sources addresses the perception of radicalism from a userÕs perspective, meaning that there is less research on how users or, in other words, consumers perceive a radical degree of novelty of products. Furthermore, there is little research on how this perception can be measured. This paper discusses the aforementioned userÕs perception and proposes a way to derive criteria which users take into account when they decide whether an idea or an innovation is radical or incremental. A concept for an investigative model was developed and applied by using it in the field with 49 test subjects. Consequently, a set of criteria was derived which concretises the decision whether a product was radical or not. The criteria were analyzed statistically and can be used by designers planning to develop a radical innovation in order to check whether the criteria people use to differentiate between radical and incremental products are fulfilled.

Shedding light on game engines and virtual reality for design ideation

Philip Ekströmer, Renee Wever, Patrik Andersson, Johan Jönsson

Linköping University

While pen-and-paper sketches is generally considered the best tool for design ideation, there are certain areas of design where the ideas being generated do not easily lend themselves to sketching. This study reports on two cases that explores the use of game engines in combination with Virtual Reality (VR) to visualize lighting in the automotive industry. In the first case, the exterior lights of a car were visualized using Unreal Engine 4 and evaluated using research through design and expert interviews. In the second case, Unreal Engine VR Editor was used to explore ideation and concept development of interior lighting in long haulage trucks. The insights from the cases suggest that game engines and VR can be used to quickly develop and display ideas, concepts and scenarios in the early phases of the lighting design process. These strengths suggest that game engines and VR also have the potential to support design ideation for other types of design.

Multisensory nudging: a design intervention for sustainable hand-washing behavior in public space

Giulia Wally Scurati, **Siyuan Huang,** Siyu Wu, Tengfei Chen, Yueyao Zhang, Serena Graziosi, Francesco Ferrise, Monica Bordegoni

Politecnico di Milano, Italy

The scarce availability of water in highly populated cities is about to become a social problem. While the water service companies work on improving the distribution network in order to reduce losses, it is evident that one of the main problems is due to an excess of use of this resource by users. This consumption is relatively controlled when excessive consumption is clearly associated, in the consumer mind, with high costs. However, when users are in public places they tend to consume water because of a loss of correlation with costs. In this paper, we describe the design of a device to be installed in public environments, which aims to reduce the consumption of water. The device measures in real time the flow of water and sends the user visual and sound information trying to create a link between consumption and costs. The device has been installed in a university campus bathroom and has been tested. Test results show a reduction in water consumption, especially in the interactive prototype approach compared to the conventional treatment. Further modifications for future development of the interactive device is also discussed.

Design for the passengers' sustainable behaviour in a scenario of the in-flight catering service

Fangzhou You, Tracy Bhamra, Debra Lilley

Loughborough University

This research aims to study the passenger's sustainable attitudes, in-flight catering behaviour, and to develop a persuasive model for behaviour change. Current studies towards the in-flight catering waste are primarily focused on dealing the recyclable materials such as cupboard, newspaper and food packaging. In a survey of 624 respondents, the environmental attitude was a poor predictor of environmental behaviour. The survey data were used to develop the persuasive model based on Persuasive Technology. Four phases of the in-flight catering are based on data from the passenger survey. In-flight touchpoints performed with persuasive function is proposed to raise awareness of food waste classification onboard. This study illustrates how persuasive strategies can change the passenger's food-wasting behaviour.

The experience of autonomy with durable products

Juan Carlos Ortiz Nicolas (1), Jan Schoormans (2)

1: National Autonomous University of Mexico; 2: Delft University of Technology

A study to understand the experience of autonomy with durable products was undertaken based on qualitative research. The study involved thirteen participants, who selected a durable product that enhanced autonomy. Using in-depth interviews, the map of experience and interaction properties the experience was studied. Our findings indicate that there are three structures involved in the experience of autonomy: orchestration, control and product integration. The three structures are described in detail. It was also identified that the experience of autonomy enhances positive experiences and stimulates wellbeing. Designers can apply the three structures of autonomy to underscore design decisions.

Podium Sessions
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8 August 2019
11:00 – 12:30

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Improvement of collaboration between testing and simulation departments on the example of a motorcycle manufacturer

*Julian Ralf Schönwald (1), Christian Forsteneichner (2), David Vahrenhorst (1), **Kristin Paetzold (1)***
1: Universität der Bundeswehr München; 2: BMW Motorrad

In testing and simulation departments in product development (PD) data types, data structures and data storage are often very different. Exchange of data and information is normally not automated and often not supported by management systems. This can lead to loss of time and information. A literature study in combination with 20 expert interviews and the analysis of documents as well as data storage structures and IT systems in a PD department of a motorcycle manufacturer were performed. Test and simulation processes were classified and standardized, documentation formats analyzed, standards in Test Data Management (TDM) and Simulation Data Management (SDM) as well as verification and validation processes compared. IT support in SDM is better than in TDM. An integration of TDM and SDM could lead to improved collaboration between testing and simulation departments. Options for this integration could be specific ontologies, object-oriented interfaces, a higher-level intermediate application, use of a common standard or integration of one standard into another one.

A computational study of the effect of experience on problem/solution space exploration in teams

***Marija Majda Perisic (1),** Tomislav Martinec (1), Mario Storga (1,2), John S Gero (3,4)*
1: University of Zagreb; 2: Luleå University of Technology; 3: University of North Carolina at Charlotte; 4: George Mason University

This paper presents the results of computational experiments aimed at studying the effect of experience on design teams' exploration of problem-solution space. An agent-based model of a design team was developed and its capability to match theoretically-based predictions is tested. Hypotheses that (1) experienced teams need less time to find a solution and that (2) in comparison to the inexperienced teams, experienced teams spend more time exploring the solution-space than the problem-space, were tested. The results provided support for both of the hypotheses, demonstrating the impact of learning and experience on the exploration patterns in problem and solution space, and verifying the system's capability to produce the reliable results.

Extracting and analysing design process data from log files of ICT supported co-creative sessions

Niccolo Becattini (1), Gaetano Cascini (1), Jamie Alexander O'Hare (2), Federico Morosi (1), Jean-Francois Boujut (3)
1: Politecnico di Milano; 2: University of Bath; 3: Grenoble Institute of Technology

The observation of designers' behaviour in collaborative design activities and the analysis of protocols improved the understanding of how novel ideas emerge, what occurs among designers and, indirectly, what methods have a good impact on the outcomes. Yet, protocol analysis requires recording the design sessions, often in a simulated environment, thus introducing a bias in the observation. Moreover, the analysis takes up to 1000 times the duration of the observed design session. These limitations definitely hinder the scalability of this practice to large experiments in real operational environments. This paper investigates the possibility to use the data collected in log files, automatically recorded during collaborative design sessions assisted by an ICT design support tool, as a means to extract relevant information about the design process and ultimately to infer insights about co-designers' cognition during the session. In this perspective, the paper proposes a set of metrics tailored to an Augmented Reality-based collaborative design tool. The study has been carried about by processing the data collected in 5 real case studies conducted in three different design companies.

Comparison Of Rep Rap And Davinci OSD Repositories: Is Any Influence From Academic Origin?

*Claudia Andressa Cruz Affonso (1), Gisele Rodrigues Atayde (2), **Daniel Amaral (2)***
1: Federal Institute of Education; 2: University of Sao Paulo, Integrated Engineering Group

The open source design (OSD) is an autonomous community dedicated to design new hardware products, peer-to-peer, with collaborative design and intellectual property copyleft, using web platforms to share projects. The research about these platforms indicates absence of important configuration management features as versioning, headlines and coding. One possible explanation for such finding is that these products are developed by non-designers. This argument was investigated comparing projects from two OSD communities, on the same theme, but with different origins. The hypothesis is that academically-influenced communities present better design management practices for repositories than others created by non-specialists. The hypothesis was not verified and the results show that there is no difference in the proportion of BO types or level of detail. However, it was identified five distinct characteristics: those of academic origin the communication is better detailed, the purpose is associated with methodological support, the structure of information promotes redundancy, the target-audience is the technicians and the success of project is associated with the number of interactions.

Exploring the Application of Network Analytics in Characterizing a Conceptual Design Space

Joshua T. Gyory, *Kosa Goucher-Lambert, Kenneth Kotovsky, Jonathan Cagan*
Carnegie Mellon University

The ability to effectively analyse design concepts is essential for making early stage design decisions. Human evaluations, the most common assessment method, describe individual design concepts on a variety of ideation metrics. However, this approach falls short in creating a holistic representation of the design space as a whole that informs the underlying relations between concepts. Motivated by this shortcoming, this work leverages network theory to visualize and characterize features of a conceptual design space. To illustrate the utility of network theory for these purposes, a network composed of a corpus of solutions to a design problem and their semantic similarity is derived, and its design properties (e.g., uniqueness and innovation potential) are studied. This network-based approach not only characterizes features of individual designs themselves, but also uncovers more nuanced properties of the design space through studying emerging clusters of concepts. Overall, this work expands on developing research in design, demonstrating the value in applying network analytics to a conceptual design space as an engineering support tool to aid design decision-making.

Functorial Model Management

Spencer Breiner (1), ***Blake Pollard (1,2),*** *Eswaran Subrahmanian (1,2)*
1: National Institute of Standards and Technology; 2: Carnegie Mellon University

In this paper we use formal tools from category theory to develop a foundation for creating and managing models in systems where knowledge is distributed across multiple representations and formats. We define a class of models which incorporate three different representations---computations, logical semantics, and data--as well as model mappings (functors) to establish relationships between them. We prove that our models support model merge operations called colimits and use these to define a methodology for model integration.

Estimating the Impact of Design Automation: the Influence of Knowledge on Potential Estimation

Eugen Rigger (1,2), *Alexander Lutz (2), Kristina Shea (2), Tino Stankovic (2)*
1: V-Research GmbH; 2: ETH Zurich, Engineering Design and Computing Laboratory

Assessing the impact of design automation on design practice prior to its implementation is difficult and subject to uncertainties. One reason for this is the designers' lack of knowledge about design automation. In this work, an industrial case study focusing on conceptual design of hydraulic circuits is conducted to assess the impact of the designers' knowledge on design automation potential estimation. In particular, the impact of demonstrating a prototypical implementation of a design automation application is investigated as a means to enhance the designers' knowledge about design automation. In this respect, a given set of metrics is rated twice to enable a comparative study: prior to and after introducing the design automation prototype. The yielded results show that the knowledge impacts the rating and supports reliability of potential estimation. Further, it is shown that designers acknowledge design automation potential for the early stages of design given sufficient knowledge about design automation. Yet, the results also indicate that careful attention needs to be put on the aspects covered by the prototype in order to avoid biasing participants.

Knowledge Management for Problem Solving Using Semistructured Contradiction Matrix Based on Physical Quantity Description

Tamotsu Murakami
University of Tokyo

A Contradiction Matrix of TRIZ that classifies problems to solve as contradictions of features is an effective framework of knowledge management for problem solving. The features, however, may have a problem of completeness because they may not cover contradictions about all physical phenomena. In addition, rigidly structured Contradiction Matrix may have a problem of searchability because a relevant contradiction may not be properly searched if a recorder and a retriever describe it differently. To solve these problems, this paper proposes a semistructured contradiction matrix using not TRIZ features but physical quantities in SI unit. To enable not only exact match but also partial match in searching for relevant contradictions, dimensional similarity and qualitative value similarity of physical quantity and similarity between contradictions are defined. The proposed method is implemented as software in Python and contradictions are described in XML and stored in a semistructured matrix. From the result of similarity calculation between stored contradictions, possible effectiveness of the proposed method is confirmed.

Assessing the authenticity of the student learning experience

Katherine Mary Bissett-Johnson (1), David F Radcliffe (2)
1: Swinburne University of Technology; 2: Purdue University

Authentic learning is an approach to teaching where the learning is embedded in a real world context, in real situations or simulations, and offers students opportunities for problem solving challenges much like they will encounter in real life. This paper discusses and reflects upon the development a course designed to teach Socially Responsible Design approaches, methods and tools to Product Design Engineering students using global projects. Our research question was to investigate if this Socially Responsible Design course, it's structure, delivery, learning activities and assessments combined to deliver an authentic learning experience. Through informal interviews with staff, review of student reflections, review of university student feedback comments and consideration of final outcomes, all within the framework of Herrington and Oliver's nine elements of authentic learning, we found that this course did provide an authentic learning experience for many reasons. This study offers academics a frame work for reviewing existing and future courses with a view to creating or enhancing authentic learning experiences using project based learning

PhD Research Learning in Product Architecture Design

Olga Sankowski (1), Kevin Otto (2), Seung Ki Moon (3), Dieter Krause (1)
1: Hamburg University of Technology; 2: Aalto University; 3: Nanyang Technological University

The field of design research has been expanding into a wide diverse range of multidisciplinary topics. It takes substantial time for young researchers to attain a cumulative overview of state of the art on ever more complex methodologies. Teaching doctoral candidates in summer schools is an approach being taken by the design society to support them attaining an immersed understanding of a chosen research field as well as to help them formulate their own line of research. The aim for a new researcher is to form exchanges and collaborations with other researchers. The 'International Summer School on Product Architecture Design - PAD 2018' was such an effort, where 17 international PhD researchers and three international faculties met for a week and explored research in product architecture through hands-on exercises. We surveyed the researchers for effectiveness of the summer school and found that structure and concept of the summer school was effective for providing a background baseline of state of the art. We found there was a significant but less impact on individual participant«s research. We have yet to understand if the creation of collaborations among participants will occur.

Student Reflections on Needs Finding in Community-based Design Work

Robert P. Loweth, Shanna R. Daly, Kathleen H. Sienko, Jiangqiong Liu
University of Michigan

Reflection is an important component in design skill development that helps designers better understand their design problem, develop better solutions, and improve their design approaches. This study explored the information that a student design team reflected on as part of a needs finding experience and the outcomes from these reflections. During the needs finding experience, the team exhibited reflection-in-action behavior as they used available data to form and iterate on explanatory hypotheses about potential community needs. After the needs finding experience, the team exhibited reflection-on-action behavior as they drew connections between their interview approaches and stakeholder responses and discussed changes they might make in the future. The team also identified situations where contextual factors of the stakeholder impacted their interviews, but during these reflections did not indicate how they might adapt their approaches to account for such factors in the future. These findings show that student designers can use reflection as a tool to improve their needs finding process but would benefit from pedagogical structures that might help them reflect more effectively.

Students' comprehension of design collaborations with external organizations

Laura Gottlieb, Yvonne Eriksson
Mälardalen University

This pilot study examines how design students comprehend collaborations with external organizations— the roles and involvement of different actors in a design process. The study looks at two undergraduate courses where a total of 33 design students collaborate with a municipality and governmental agency. Data focuses on the students' terminology in regard to the external organizations and is collected through questionnaires, voice recording, workshops and written assignments. The data analysis is both quantitative and qualitative, focusing on the word frequency and semantics of the terminology. The results show that the students were not used to working closely to external organizations. This is reflected in the prevalent use of the term "client" instead of "collaborative partner". Not working closely with organizations nor users is reflected in the students' inabilities to handle the complexities that emerge when working with multiple stakeholder and users. At the end of the paper, suggestions are made of ways to develop students' comprehension of ways to involve external organizations and users in the design process.

A Law Of Functional Expansion - Eliciting The Dynamics Of Consumer Goods Innovation With Design Theory

Pascal Le Masson, *Kenza El Qaoumi, Armand Hatchuel, Benoit Weil*
MINES ParisTech

For more than two decades, mobile phone industry has shown that innovation is not only functional optimization and combination but can also be a "functional expansionÓ. Sometimes called radical or disruptive innovation, this phenomenon leads to the development of new method for engineers and designers. However, the intensity remains undemonstrated: is functional expansion a rare phenomenon (few products during very short periods of time) Ð or is it an intense phenomenon, that even might have accelerated in the last decades? To answer these questions, the paper overcomes two main obstacles: how to measure functional expansion? And what would be a law of functional expansion, that would enable to test the importance and newness of the phenomena? Building on recent advances on the measurement of innovation and on new computational models of design derived from most advanced design theories, this paper presents unique data on functional expansion of 8 consumer products and tests that functional expansion significantly accelerated in the mid 1990s. The paper confirms quantitatively that our societies are now in a new design regime, a regime of innovative design.

Perspectives on innovation: The role of engineering design

Ola Isaksson (1), *Claudia Eckert (2), Olivia Borgue (1), Sophie I Hallstedt (3), Andreas Makoto Hein (4), Killian Gericke (5), Massimo Panarotto (1), Yoram Reich (6), Anna B Öhrwall Rönnbäck (7)*

1: Chalmers University of Technology; 2: The Open University; 3: Blekinge Institute of Technology; 4: Université Paris-Saclay; 5: University of Luxembourg; 6: Tel Aviv University; 7: Luleå University of Technology

The aim of the paper is to foster a discussion in the engineering design community about its understanding of the innovation phenomena and the unique contribution that comes from engineering design. The paper reports on the dialouge originating from a series of workshops with participants from different backgrounds in engineering design, systems engineering, industrial design psychology and business. Definitions of innovation are revisited as used in business, management and engineering design contexts. The role of innovation is then discussed related to product development from (i) the management perspective, (ii) a systems architecture perspective and (iii) in relation to sustainable development as one driver of innovation. It is argued that engineering design has a central role in how to realise the novelty aspect of innovation and often plays a critical role in maturing these into the valuable products, and there is a need to articulate the role of engineering design in innovation to better resonate with the business and management research.

The Role of Enabling Technologies in Transformative Innovation

Tucker Marion, *John Friar*
Northeastern University

This study is an exploratory analysis of enabling technologies' influence on the trajectory of industry development using a co-evolutionary model of technology development. When combined, enabling technologies can create new technology-market industry cycles, resulting in transformative innovation. The research approach of this empirical study is to use both primary and secondary data to create a history of the robotics industry and to explore the pre and post changes in the industry from the inclusion of enabling technologies over multiple generations. We propose a new model for understanding the theoretical and practical study of technology development through the lens of enabling technologies and their development and maturity cycles.

Distinction of Domain-Specific and Cross-Domain Linkage Types for Engineering Change Management

Robert Wilms (1,2), *David Inkermann (1), Vadym Finn Cemmasson (1), Michael Reik (2), Thomas Vietor (1)*
1: TU Braunschweig; 2: Volkswagen AG

Engineering Changes (ECs) are substantial elements of the design process of technical products and are in particular relevant for companies due to enormous additional costs and time delays they can cause. In order to better understand ECs and realize efficient Engineering Change Management (ECM), different approaches exist. One aspect of ECM are change propagation analysis, which try to analyze knock-on effects of an EC on other product elements or the development process. How ECs can propagate is in particular difficult to assess for complex products realized within different engineering domains (mechanical, electrical and software engineering). To address this challenge, ECs are classified, strategies to cope with ECs are presented and change propagation approaches are analyzed in this paper. Thereby a lack of indicators for cross-domain propagation is identified. To overcome this issue, the distinction of domain-specific and cross-domain linkage types is proposed and a set of linkage types is presented. Further research is motivated to integrate these linkage types in product models while also considering processes and organizational structures as additional dimensions of ECM.

The Neurocognition of Three Engineering Concept Generation Techniques

Tripp Shealy (1), **John Gero (2)**
1: Virginia Tech; 2: University of North Carolina, Charlotte

Techniques and processes used for concept generation rely on composing new concepts and analysis given situational context. Composition and analysis require distinct neurocognitive function. For instance, jazz composition relies heavily on the right brain, while math relies on the left. Similar to music and math, is concept generation hemisphere dominant? What differences exist when using varying techniques? Twelve graduate engineering students were given three design tasks and instructed to use brainstorming, morphological analysis and TRIZ. A device called fNIRS measured cognitive activation. The results find left hemisphere dominance. More specifically, the left dorsolateral PFC (dlPFC), which is central to spatial working memory and filtering information. Temporal differences do exist. Morphological analysis and TRIZ reinforced the use of the left dlPFC, while brainstorming increased the use of the right dlPFC and medial PFC (mPFC) late during concept generation. The right dlPFC contributes to divergent thinking and mPFC facilitates memory retrieval. One explanation is designers relaxed rule constraints and more deeply searched for associations during brainstorming.

Comparing the Design Neurocognition of Mechanical Engineers and Architects: A Study of the Effect of Designer's Domain

Sonia Liliana da Silva Vieira (1), **John Gero (2),** *Jessica Delmoral (1), Valentin Gattol (3), Carlos Fernandes (4), António A. Fernandes (5)*
1: INEGI Institute of Science and Innovation in Mechanical and Industrial Enginee-ring; 2: Department of Computer Science and School of Architecture University of North Carolina at Charlotte; 3: Austrian Institute of Technology; 4: Faculty of Medicine of the University of Porto; 5: Faculty of Engineering, University of Porto

New tools from neuroscience allow design researchers to explore design neurocognition. By taking the advantage of EEG's temporal resolution we give up spatial resolution to focus on the performance of time-related design tasks. This paper presents results from an experiment using EEG to measure brain activation to study mechanical engineers and architects to compare their design neurocognition. In this study, we adopted and extended the tasks described in a previous fMRI study of design neurocognition reported in the literature. The block experiment consists of a sequence of 3 tasks: problem solving, basic design and open design using a physical interface. The block is preceded by a familiarizing pre-task using the physical interface and then extended to a fourth task using free-hand sketching. Brainwaves were collected from both mechanical engineers and architects. Results comparing 36 mechanical engineers and architects while designing were produced. These results indicate design cognition differences between the two domains in task-related power between the problem-solving task and the design tasks, in temporal resolution and transformed power.

Influence of Information Collection Strategy on Designer's Mental Stress

Mengting Zhao, *Yong Zeng*
Concordia University, Canada

Information collection may affect the design quality and designer's performance through changing the structure of information and the way how information is searched and organized. Based on the theoretical analysis conducted by Wang et al., the present work continues to investigate the influence of designer's natural choice of information collection strategy on his/her mental stress both theoretically and empirically. Designers' stresses are quantified from HRV data and are compared under different information collection strategies.

Using Hidden Markov Models to Uncover Underlying States in Neuroimaging Data for a Design Ideation Task

Kosa Goucher-Lambert (1), *Christopher McComb (2)*
1: University of California, Berkeley; 2: The Pennsylvania State University

Recently, design researchers have begun to use neuroimaging methods (e.g., functional magnetic resonance imaging, fMRI) to understand a variety of cognitive processes relevant to design. However, common neuroimaging analysis techniques require significant assumptions relating temporal and spatial information during model formulation. In this work, we apply hidden Markov Models (HMM) in order to uncover patterns of brain activation in a design-relevant fMRI dataset. The underlying fMRI data comes from a prior research study in which participants generated solutions for twelve open-ended design problems from the literature. HMMs are generative models that are able to automatically infer the internal state characteristics of a process by observing state emissions. In this work, we demonstrate that distinct states can be extracted from the design ideation fMRI dataset, and that designers are likely to transition between a few key states. Additionally, the likelihood of occupancy within these states is different for high and low performing designers. This work opens up the door for future research to investigate the patterns of neural activation within the discovered states.

Open source hardware communities: investigating participation in design activities

Jean-François Boujut, Franck Pourroy, Philippe Marin, Jason Dai, Gilles Richardot
Univ. Grenoble Alpes, CNRS, Grenoble INP, G-SCOP

Open source design of hardware products is an emerging phenomenon that takes more and more importance today's in the society. However, open source (hardware) design implies a tremendous change in both design practices and philosophy because it is partly related to the movements of creative commons and the sharing economy. From this perspective one could think that participation is crucial in the success of open source design projects. In this paper, we analyse 9 case studies in the light of 3 hypotheses. If many studies highlight the potential of the crowd as a resource for design tasks, our study shows that for open source design communities the participation is not massive. In this study, we used an activity-based approach to build our model. As open source design processes are fairly unstructured and based on voluntary participation, it is impossible to adopt a classical task-based model. With the help of this model, we were able evaluate the overall size of the active community, the participation rate with regards to the activities. This study paves the way to deeper and extensive studies on how to support communities engaged in open source design of hardware products.

Understanding Community Behaviors In For–Profit Open Source Hardware Projects

Zhuoxuan Li (1), Warren Seering (1), Tiffany Tao (1), Shengnan Cao (2)
1: Massachusetts Institute of Technology; 2: Northeastern University

Free contributors have successfully shown the potential in large/complex software co-creation in the Free and Open Source Software Movement, triggering many discussions and exploration ventures from academia to industry and to the government. Though many research efforts explored whether the same level of co-creation efforts could take place broadly in the hardware realm, very few research studies focus on profit-seeking hardware projects initiated by companies. In fact, the specific nature of being tangible and profitable makes company-led open source hardware projects suspicious to be really "open" to contributors. Community has been identified as the critical driver in many open projects. By reviewing the evolution of company-community interactions over time and different community behaviors in different open development context, authors in this paper hope to identify best community-company interaction forms for open source hardware companies. Using grounded theory and case studies, we construct a framework to describe and identify company community's different behaviors and different roles.

Does Open Source Hardware Have A Sustainable Business Model? An Analysis of Value Creation And Capture Mechanisms in Open Source Hardware Companies

Zhuoxuan Li, Warren Seering
Massachusetts Institute of Technology

Analyzing value creation and capture mechanisms of open source hardware startup companies, this paper illustrates how an open source strategy can make economical sense for hardware startups. By interviewing 37 open source hardware company leaders, 12 company community members as well as analyzing forum data of 3 open source hardware companies; we realize that by open sourcing the design of hardware, a company can naturally establish its community, which is a key element for a company's success. Establishing a community can increase customer perceived value, decrease product development and sales cost, shorten product go-to-market time, and incubate startups with knowledge, experience and resources. These advantages can compensate for the risks associated with open source strategies and can make open source design a viable product development strategy for hardware startups.

External Technology Searching Methods – A Literature Review

*Kate Alexandra Kujawa, **Kristin Paetzold***
Bundeswehr University Munich

This paper provides a preliminary assessment of the literature available in the field of External Technology Searching. Many methods exist to enable companies to take advantage of new technologies and apply them to achieve a competitive advantage. This literature review focuses on reducing complexity and providing clarity related to the numerous different terms and methodologies used throughout the literature. The main methods found in the literature include: Technology Foresight, Technology Forecasting, Technology Intelligence, and Technology Scouting. However, many additional terms have also been used to describe similar strategies, leading to inconsistency in the use of the terms, resulting in confusion and missed opportunities to innovate for those trying to navigate the field. Synthesis of the results assists in clarifying the differences and conflicts in the literature between the numerous terms. The results serve to display the state of the art on the field and present a basis for further research.

Visualised frames: how sketching influences framing behaviour in design teams

Yujing Yang, Natalie Brik, Peter de Jong, Milene Gonçalves
Delft University of Technology

Visualisation of ideas and emergent designs is an essential ingredient in design practice. Sketching and CAD represent two widely used visualisation tools, each with complementary affordances that dictate their typical use during the design process. Sketching has affordances of fast and fluent visualisation whereas CAD affords easy modification of detailed designs. This paper proposes a hybrid tool, Digital Sketch Modelling, investigating the extent to which it can deliver complementary affordances of both sketching to CAD. Analysis of diary entries made by 62 postgraduate designers using sketching, digital sketch modelling and CAD within a design project forms the basis of the study. Results illustrate how digital sketching over crude 3d digital models, combined with benefits of digital image editing software enhance affordance for easy visualisation of ideas. Concurrently, the level of software used in Digital Sketch modelling led to fewer concerns over the level of difficulty to modify designs, enhancing the affordance for easy modification. As such we conclude Digital Sketch Modelling does combine affordances indicating its potential benefit in use between sketching and CAD.

Digital Sketch Modelling: Proposing a hybrid visualisation tool combining affordances of sketching and CAD

Charlie Ranscombe (1), Wenwen Zhang (1), Jacob Rodda (1), David Mathias (2)
1: Swinburne University of Technology; 2: Bristol University

Visualisation of ideas and emergent designs is an essential ingredient in design practice. Sketching and CAD represent two widely used visualisation tools, each with complementary affordances that dictate their typical use during the design process. Sketching has affordances of fast and fluent visualisation whereas CAD affords easy modification of detailed designs. This paper proposes a hybrid tool, Digital Sketch Modelling, investigating the extent to which it can deliver complementary affordances of both sketching to CAD. Analysis of diary entries made by 62 postgraduate designers using sketching, digital sketch modelling and CAD within a design project forms the basis of the study. Results illustrate how digital sketching over crude 3d digital models, combined with benefits of digital image editing software enhance affordance for easy visualisation of ideas. Concurrently, the level of software used in Digital Sketch modelling led to fewer concerns over the level of difficulty to modify designs, enhancing the affordance for easy modification. As such we conclude Digital Sketch Modelling does combine affordances indicating its potential benefit in use between sketching and CAD.

From Hand-Drawn Sketching to Laser Cutting - A Proof of Concept Prototype and Pilot Study

Sampsa Kohtala, Martin Steinert
Norwegian University of Science and Technology, Norway

Sketching ideas and building physical prototypes are common in early stage product development. They are used for learning, testing ideas, proving concepts and sharing knowledge. Laser cutting is a popular tool for making physical prototypes due to its accuracy, robustness and speed. Computer aided design and vector graphics software are the main tools used for designing parts for laser cutting. Several sketch-based interfaces have been developed to support the process, using tools such as stylus pens with intuitive sketch-like commands. A proof-of-concept prototype for capturing a hand drawn sketch and converting it to a laser cuttable file has been developed. In this pilot study we attempt to discover when drawing design by hand on paper can be better or more efficient than conventional methods, for developing physical prototypes with laser cutting in the context of early stage product development. This includes testing the accuracy of the tool, a pilot experiment comparing drawing speed and accuracy, example use cases utilizing pencil and paper, and a simple design challenge experiment.

The Role of Sketching Activities and Outcomes in Conceptual Design Phase

Marija Nikolić (1), **Stanko Škec (1,2),** *Tomislav Martinec (1), Nikola Horvat (1)*
1: University of Zagreb; 2: Technical University of Denmark

Sketching-related activities are considered as an essential form of communication in the early phases of a design process. In the presented study, it is argued that both the sketching and the sketch-related verbalisations are reflected in the level of elaboration of the sketching outputs. Hence, a protocol study was conducted to analyse the frequencies of different sketching-related activities during team conceptual design sessions and the associated levels of elaboration for each of the sketching outputs in the form of concept drawings. The results show that although teams generate sketches of various number, complexity and clarity, there exist commonalities across the studied experiment sessions. For example, teams share a pattern of developing solutions without transformations or using lateral transformations within the first part of the sessions and using vertical transformations to produce final concepts towards the end of the sessions. Moreover, teams used associated sketch elements to start drawing new sketches and then alternated to other activities, most of all verbal explanation, for the sake of elaboration and better understanding.

Comparing Virtual Reality and Desktop Interface for Reviewing 3D CAD Models

Reviewers' favourite

Nikola Horvat (1), *Stanko Škec (1,2), Tomislav Martinec (1), Fanika Lukačević (1), Marija Majda Perišić (1)*
1: University of Zagreb; 2: Technical University of Denmark

Use of virtual reality (VR) is considered beneficial for reviewing 3D models throughout product design. However, research on its usability in the design field is still explorative, and previous studies are often contradictory regarding the usability of VR for 3D model review. This paper argues that the usability of VR should be assessed by analysing human factors such as spatial perception and taking into consideration the complexity of the reviewed product. Hence, a comparative evaluation study has been conducted to assess spatial perception in desktop interface-based and VR-based review of 3D models of products with different levels of complexity. The results show that participants in VR more could perceive the fit of user interface elements, and estimation of the model dimensions had a lower relative error than in desktop interface. It has been found that various sensory cues are used to perceive the model size and that the employed sensory cues depend on the level of complexity. Finally, it is proposed that differences between a desktop interface and VR for reviewing models are more evident when reviewing models of higher complexity levels.

The reuse of SysML behaviour models for creating product use cases in Virtual Reality

Atif Mahboob (1), *Stephan Husung (2), Christian Weber (1), Andreas Liebal (1), Heidi Krömker (1)*
1: Technische Universität Ilmenau; 2: :em engineering methods AG

An early evaluation of a product along with the consideration of life phase specific actor(s) and environment(s) can help greatly to gain an understanding of the productÕs behaviour and interactions. Virtual Reality (VR) can help designers to examine later life situations of a product by means of use case scenarios. However, preparing a VR-scene is still a time-consuming and cumbersome task. A model based approach that uses behaviour models of SysML to describe a VR-scene can reduce the preparation efforts. Such an approach is helpful if it allows the reuse of already described VR-scenes or their contents. This paper talks about the reusability of SysML behaviour models that constitute a VR-scene. This reusability can only be achieved by the generic definition of model interfaces. Therefore, a new modelling approach is presented to facilitate the reuse of SysML behaviour models to form different use cases of a product in VR. This approach also talks about the interface definitions and the management of variants of SysML models. The presented approach is elaborated by an example model that contains variants and uses instances to build different use cases.

A review of requirements and approaches for realistic visual perception in virtual reality

Benjamin Gerschütz, *Marius Fechter, Benjamin Schleich, Sandro Wartzack*
Friedrich-Alexander-Universität Erlangen-Nürnberg

The amount of new virtual reality input and output devices being developed is enormous. Those peripherals offer novel opportunities and possibilities in the industrial context, especially in the product development process. Nevertheless, virtual reality has to face several problems, counteracting reliable use of the technology, especially in ergonomic and aesthetic assessments. In particular, the discrepancies in perception between the real world and virtual reality are of great importance. Therefore, we discuss these most important issues of current virtual reality technology and highlight approaches to solve them. First, we illustrate the use cases of VR in the product development process. In addition, we show which hardware is currently available for professional use and which issues exist with regard to visual perception and interaction. Derived from the depiction of a perfect virtual reality, we define the requirements to address visual perception and interaction. Subsequently we discuss approaches to solve the issues regarding visual perception and evaluate their suitability to enhance the use of virtual reality technology in engineering design.

Supporting Creativity with Virtual Reality Technology

*Iris Graessler, **Patrick Taplick***
Paderborn University - Heinz Nixdorf Institute - Chair for Product Creation

This contribution includes the development and validation of a Virtual Reality (VR) supported creativity technique: "Sensory Stimulus Environment Technique". Key elements of this technique are the creativity process, a VR tool and the support of the tool (Virtual Creative Environments). The creativity process consists of phases for individual and group-based work. The VR tool "Virtual Creativity" includes functions to support the preparation of Virtual Creative Environments (VCE), the generation and evaluation of new ideas. For the generation of VCE, the tool possesses an environment configurator. Users of this function are supported by Design Rules for VCE. For the validation of the creativity technique, it was used in a product engineering project. The project members procedure two phases of the creativity process (Preparation and Individual Idea Generation) and used "Virtual Creativity" to generate VCEs and ideas to solve their tasks. By questionnaires, functions of "Virtual Creativity" were assessed for generating VCEs and ideas.

Discussion Sessions
Thursday
8 August 2019
14:00 - 15:00

iced

A Computational Framework for Exploring the Socio-Cognitive Features of Teams and their Influence on Design Outcomes

Harshika Singh (1), Gaetano Cascini (1), Hernan Casakin (2), Vishal Singh (3)
1: Politecnico di Milano; 2: Ariel University; 3: Aalto University

The dynamics of design teams play a critical role in product development, mainly in the early phases of the process. This paper presents a conceptual framework of a computational model about how cognitive and social features of a design team affect the quality of the produced design outcomes. The framework is based on various cognitive and social theories grounded in literature. Agent-Based Modelling (ABM) is used as a tool to evaluate the impact of design process organization and team dynamics on the design outcome. The model describes key research parameters, including dependent, independent, and intermediates. The independent parameters include: duration of a session, number of times a session is repeated, design task and team characteristics such as size, structure, old and new members. Intermediates include: features of team members (experience, learning abilities, and importance in the team) and social influence. The dependent parameter is the task outcome, represented by creativity and accuracy. The paper aims at laying the computational foundations for validating the proposed model in the future.

Nature-inspired design for self-organized social systems: A tool for collaborative communities

Sumin Lee (1), **Joon Sang Baek (2)**
1: Ulsan National University of Science and Technology; 2: Yonsei University

This research was motivated by the need to design for self-organized and sustained collaborative communities. A collaborative community is defined as a group of people who are bound by a sense of community and fulfil their unmet needs through collaboration (Baek, Meroni, & Manzini, 2015). A community with limited resources and premature organisational structure and therefore experience an unbalanced workload is fragile. If the community fails to distribute workloads fairly within and the commitment of the sacrificing members is exhausted, it is likely to fall apart. Inspired by the self-organization phenomena in nature, we designed a tool that these communities can use to conceive strategies that contribute to autonomy and collaboration. For validation, we applied the tool to an industrial design student club. The results demonstrate that despite the differences between social and ecological systems, there is a potential to learn from nature to design for self-organized collaborative communities with the condition that one has sufficient knowledge about both the references and the design target. We also discuss the problem-solving and learning effects of the tool.

Collaborative and participatory design: assignment of team members to engineering projects with the consideration of designer's expectations

Guangying Jin, *Séverine Sperandio, Philippe Girard*
IMS, UMR University of Bordeaux

With the trend of global collaboration and development of Internet of Things in industry 4.0, the collaboration relationships between designers is getting more close and important than before. Therefore, when project manager assign designers to design projects, it is very important for them to select design projects with the consider about the expectations of the designers regarding the different projects and collaboration ability for the designers in the projects while it is very important to identify the projects with the consideration of skills, experiences, availabilities and so on. Even though, there are various methods for selecting projects, most of these methods not consider about the expectations of designer and the collaboration ability. Therefore, in this paper, we propose a project selection methodology, which consider about the designers' expectations to the candidate multi-project and collaboration ability in the candidate multi-project. The main objective of our research is to help project manager to find an adaptable and comfortable multi- project to the designer

Coordination in Design Teams as a Lens to Identifying Team Roles

Arianne X. Collopy, *Chengxi Li, Tianyi Liu, Eytan Adar, Panos Y. Papalambros*
University of Michigan

Coordination in system design requires an interplay between different roles. In this work, we identify five design team roles that pertain to the partitioning and coordination of distributed design team tasks. The proposed characterization is based on self-reported responsibilities and communication behaviors from 109 student designers in 22 teams at the conclusion of a semester-long design project. The self-reports capture both how team members viewed their own work as well as communication patterns between team members. We leverage two representations of this data. Through text analysis, we identify keywords describing team member roles and responsibilities. Social network analysis can further distinguish roles based on team communication behaviors. Cluster analysis on both types of data identifies groups of individuals with similar characteristics. The resulting five clusters capture common roles in system design teams that simultaneously capture the diverse responsibilities and communication patterns.

Eco-innovation in biomass research Projects

Gwenola Yannou-Le Bris (1), *Viviane Treves (2), Jean-Marc Meynard (2), Marianne Cerf (2)*
1: AgroParisTech; 2: INRA

This paper tackles two questions. Our first question addresses the multi-actor activity that is visibly required for building radical innovations like eco-innovation. Our second question addresses the tricky issue of how to assess contribution to ecological transition when innovation projects are still in the fuzzy early-upstream phase. In this aim four research projects are selected and analyzed in this paper because they share a common scope—the development of new processes or materials tied to the conversion of biomass. Through the analysis of the actors interactions conducted in these projects, of their perimeters, of their sustainability objectives and of their results we show a limit of the eco-innovation capacity of these projects linked to the limits of their crossdisciplinarity.

Promoting eco-innovation in academic eco-systems

Gwenola Yannou-Le Bris (1), *Romane Jubera (1), Annika Olsson (2), Marianne Cerf (3)*
1: AgroParisTech; 2: Lund University; 3: INRA

University incubators are an opportunity to promote the dissemination of research, change teaching practices and contribute to territorial economic development. In this article we present a structural and dynamic analysis of such an innovation system of a Swedish eco-innovation system by proposing elements for analysing the success of such innovation systems.

From product to dust: looking at the ways to regenerate value in product life cycle

Baptiste Menu (1), *Faucheu Jenny (1), Laforest Valérie (2), Bassereau Jean-François (1)*
1: Mines Saint-Etienne, Univ Lyon, CNRS, UMR 5307 LGF; 2: Mines Saint-Etienne, UMR 5600 EVS, Institut Fayol, F - 42023 Saint-Etienne

The shift from linear to circular patterns is on the way and rise many questions. In the last ten years, reuse and upcycling are gaining more attention. Since reduce and reuse were describe as a priority by the European Union, some leading projects are unveiled in different countries. Scale and quality of those projects push the reuse issue out of the shadow, far from original prejudices who associate waste and reuse to « poverty » and « Do It Yourself ». Although Reuse emerge as a prominent question, the idea and boundaries of « what is reuse » appears to be blur and not clearly understood. This situation lead to general incomprehension, even for professionals. Reuse, repurpose, upcycling and recycling are usually considered to wear the same meaning despite a huge difference on what it implies. In this paper we will examine these different notions through a pedagogical case study. We will draw the different ways to regenerate value at all steps of product life cycle in a precise manner. This allows to better insight the meaning of those issues in the case of student design education. In the same time, it aims to be a tool for teaching sustainable design and waste management.

Analysis and evaluation in the early stages of designing resource efficient offerings: A comparison among large companies and small and medium enterprises

Sergio Andres Brambila-Macias, Tomohiko Sakao
Linköping University, Department of Management and Engineering

In Europe there is a common vision to transform the economy into a sustainable one by 2050 which among other changes, calls for companies to address their offerings in a more resource-efficient manner. Therefore, efforts to provide design support namely, methods, guidelines and tools to specifically address natural resources and impact of products and services have been increasing. Moreover, companies of all sizes should integrate environmental concerns as early as possible to select profitable and environmentally sound offerings. However, knowledge of the analysis and evaluation of resource-efficient offerings seems currently insufficient especially with regards to similarities and differences among different company sizes. In this paper, the study of eight case companies: 3 large companies and 5 SMEs, shows how industry addresses the analysis and evaluation of their offerings. Commonalities among SMEs and large companies include decisions made by strategic or managerial boards, the use of mock-ups and project management skills, among others. These findings could help academics in providing relevant, useful and usable support to industry.

An Exploratory Study Comparing CAD Tools And Working Styles For Implementing Design Changes

Vrushank Shripad Phadnis (1), *Kevin Alfonso Leonardo (1), David Robert Wallace (1), Alison Louise Olechowski (2)*
1: Massachusetts Institute of Technology; 2: University of Toronto

This paper presents the findings of a preliminary study comparing implementation of design changes using various computer-aided design (CAD) working styles. Our study compares individuals' and pairs' completion of a series of changes to a toy car CAD model. We discuss the results in terms of productivity and value added ratio, derived from time-based quantitative data. We also discuss qualitative findings acquired through post-study surveys. Overall, our findings suggest that pairs were less efficient than individual designers due to overheads like communication, history dependency and complex couplings within the CAD model tree. However, it is also noteworthy that within each pair the lead participant's performance was at par with individual participants. Lastly, we also discuss behaviors and patterns that emerge as unique to the synchronous collaborative environment, motivating future work.

Reverse Engineered Design Automation: Applying Knowledge Based Engineering Techniques to a case of Automotive Fixtures Design Configuration

Christian Johansson
Blekinge Institute of Technology

In the production of automotive body components, fixtures are an important part of the ongoing work on geometrical assurance. The fixture is uniquely defined for each component, and the design and configuration of these are time-consuming and takes a lot of effort. The objective with this paper is to explore the use of a design automation approach and application to semi-automate the configuration process of the fixture product. The paper presents an approach to automate the configuration of the fixtures in a flexible way, by reverse engineering the configuration of the fixture product from a generic blueprint that represents the expected outcome of the process, using a knowledge-based engineering approach applied to a computer aided design (CAD) environment. A reverse-engineered design automation toolbox for a CAD-software is developed. The toolbox is developed to lead a user through the configuration process, in the way that the experts want it done, end-to-end, making use of some unconventional solutions from a design automation perspective.

Influence of gas-filled gaps on the thermal behaviour of Dual Purpose Casks

Christian Dinkel (1), *Daniel Billenstein (1),* *Frank Rieg (1), Bernd Roith (2)*
1: University of Bayreuth; 2: Swiss Federal Nuclear Safety Inspectorate ENSI

Basically, the safe dissipation of heat is among others an important protection objective of dual purpose casks. Gas-filled gaps within such casks can play a major role for the thermal behavior as they act as thermal barriers due to the lower heat conductivity of gaseous fluids in comparison to metallic materials. However, additional heat transmission mechanisms, such as natural convection and radiation can also occur in a gaseous medium. This leads to both an expanded modelling and a prolonged computing time in numerical simulations. Within the scope of a research project in cooperation with Swiss Federal Nuclear Safety Inspectorate ENSI a simulation tool for the fast thermal evaluation of dual purpose casks is developed which combines analytical methods and FEA. The innovation is that the thermal effects of gas-filled gaps are considered by using analytical equations. Main focus lies on the implementation of heat radiation as a non-linear transfer mechanism. Therefore, an iterative calculation process is used and the effects of the iteration number is investigated. Furthermore, the influence of radiation in comparison to pure conduction is examined depending on the gap width.

Toward Automated Functional Modeling: An Association Rules Approach for Mining the Relationship between Product Components and Function

Melissa Tensa, *Katherine Edmonds, Vincenzo Ferrero, Alex Mikes, Nicolas Soria Zurita, Rob Stone, Bryony DuPont*
Oregon State University

The objective of this research is to support DfX considerations in the early phases of design. In order to do conduct DfX, designers need access to pertinent downstream knowledge that is keyed to early stage design activities and problem knowledge. Product functionality is one such "key" connection between early understanding of the design problem and component choices which dictate product performance and impact, and repositories of design knowledge are one way to archive such design knowledge. However, curation of design knowledge is often a time-consuming activity requiring expertise in product modeling. In this paper, we explore a method to automate the populating of design repositories to support the overall goal of having up-to-date repositories of product design knowledge. To do this, we mine information from an existing repository to better understand the relationships between the components, functions, and flows of products. The resulting knowledge can be applied to automate functional decompositions once a product's components have been entered and thus reliably provide that "key" between early design activities and the later, component dependent characteristics.

AIM: an Interactive Ashtray to Support Behavior Change through Gamification

*Siyuan Huang, **Giulia Wally Scurati,** Mostafa Elzeney, Yujie Li, Xiaofeng Lin, Francesco Ferrise, Monica Bordegoni*
Politecnico di Milano, Italy

Littering is a highly diffused anti-environmental and anti-social behavior, especially among young people. Furthermore, cigarette butts are one of the most littered items and are responsible for both severe environmental damages and high clean up expenses. The aim of this project is to design an interactive ashtray for the campus environment to limit the cigarette butts littering behavior in an engaging and effective way. Qualitative and quantitative data are collected. Coded observations were implemented through the research process, including the 2 pre (without the prototype) and 2 pros (with the prototype) sessions. Also, user experience test and one to one interview were conducted for deepening the understanding of the littering phenomenon and the reasons behind in the behavior among young people. The prototype indeed reduced the number of cigarette butts littering among observed behaviors of 156 students, especially in male sample. Final results indicate the behavior change of disposers is moderated by other factors, as the environmental cleanliness. Future development is also discussed.

Reviving everyday products by understanding the user behaviour of everyday designing

Soyoung Kim (1), JungKyoon Yoon (2), Chajoong Kim (1)
1: Ulsan National Institute of Science and Technology; 2: Cornell University

Everyday Designing (ED) involves the re-use of existing products for new purposes. In order to gain an understanding of how people perceive and apply product elements as cues for everyday designing and level of appropriation when reusing product for the new purpose, an experiment was conducted. In the experiment, four everyday products were provided for repurpose. The 40 repurposed products from 10 participants were analyzed with the interviews and questionnaire. ED products were reborn with various purposes beyond the original functions of the products. The results indicate that there is a difference between perceived product elements as usual and product elements as cues for everyday designing. Materials and manipulability plays an important role in ED although form-centred perceptions were mainly observed. It seems that the product elements as ED cue and the prior experience of the product seem to affect the level of the product appropriation. Although this study has an exploratory character, it could provide design practitioners with a better understanding of users' ED behaviour, which could contribute to discovering new insight of product and product sustainability.

Revealing Insights of Users' Perceptions: An Approach to Evaluate Wearable Products Based on Emotions

Ting Liao, Kesler Tanner, Erin MacDonald
Stanford University

The wearable products market is growing rapidly. Engaging users on an emotional level may be the key to long-term use and attracting new customers. While researchers have proposed various design approaches to realize design qualities for wearable devices, emotional needs are overlooked in the design process. To bridge this gap, we developed an approach with an online tool that uses a two-axis interactive collage for users to compare and evaluate wearable products with targeted emotion-related descriptive words. This approach enabled us to explore how users perceive products and identify types of emotions that were associated with their preferences for and perceptions of the product's form and visible characteristics. The study demonstrated this design approach to reveal insights into the relationships between product characteristics and design goals, such as user comfort, user delight, and perceived product usefulness. The results showed that products that resemble clothes were perceived as more delightful and comfortable. This study suggests that the approach can be further used to explore other design concepts or goals.

A methodology for multisensory product experience design using cross-modal effect: A case of SLR camera

Takuma Maki, Hideyoshi Yanagisawa
The University of Tokyo

Throughout the course of product experience, a user employs multiple senses, including vision, hearing, and touch. Previous cross-modal studies have shown that multiple senses interact with each other and change perceptions. In this paper, we propose a methodology for designing multisensory product experiences by applying cross-modal effect to simultaneous stimuli. In this methodology, we first obtain a model of the comprehensive cognitive structure of user's multisensory experience by applying Kansei modeling methodology and extract opportunities of cross-modal effect from the structure. Second, we conduct experiments on these cross-modal effects and formulate them by obtaining a regression curve through analysis. Finally, we find solutions to improve the product sensory experience from the regression model of the target cross-modal effects. We demonstrated the validity of the methodology with SLR cameras as a case study, which is a typical product with multisensory perceptions.

Doing it right - critical success factors for design thinking implementation

Danielly De Paula (1,2), *Franziska Dobrigkeit (2), Kathryn Cormican (1)*
1: National University of Ireland - Galway; 2: Hasso-Plattner-Institut

Proficiency in design thinking (DT) can contribute to the success of many companies. Successful implementation of DT can be achieved by identifying its Critical Success Factors (CSFs). Critical success factors are items or actions that should be present in a particular project or situation in order to be successful. However, to date, there has not been any formal study on synthesizing the critical success factors for a successful DT implementation based on existing research. In light of this, the aim of this paper is to develop a conceptual framework that proposes factors that may play a role in influencing the success of the DT implementation. Based on best practices and protocols from thematic analysis, we analyzed and synthesized extant literature in order to recognize research topics from the selected papers and categorize them into specific themes to build a framework. This study significantly contributes to the body of knowledge related to DT by offering the first attempt to identify CSFs for DT implementation, which can allow companies to take required precautions to elude failures or problematic areas and be able to increase the success rate of implementing DT

Interpretations of design thinking across a large organization

Martyna Kosmala, *Floris van der Marel, Tua Björklund*
Aalto University

Design thinking has a prominent role as established corporations ramp up innovation efforts focusing on user needs. Current literature provides a plethora of definitions for design thinking with variations in tools, methods and cultures. This study aims to identify differences in perception and maturity of design thinking across different contexts within a large corporation. The results are based on a thematic analysis of nine semi-structured interviews with industrial and user experience designers in the case company, operating in different countries and three different organizational contexts: lone designers of a region, unit-embedded design team managers and global-level design managers. The results echo the literature in finding no uniform definition of design thinking. Instead, it was seen as a continuous scale of practices, cognitive approaches and mindsets aiming for stronger user-centrism in the organization. Practices and maturity varied between contexts, indicating that to strengthen the role of design in an organization, a deep understanding of the context is crucial for a successful implementation.

How to design for Joy / Satisfaction - Two different approaches on how to tackle the task

Alexander Atzberger (1), *Eleonora Boffa (2), Joaquin Montero (1), Kristin Paetzold (1), Sandor Vajna (3)*
1: Bundeswehr University Munich; 2: KTH Royal Institute of Technology; 3: Otto-von-Guericke University Magdeburg

In the course of the IPD International Summer School, two teams addressed the topic of devel-oping an integrated product, with the constraint of it being joyful for the user. One team has chosen an agile development approach whereas the second team approached it in a plan-driven manner. With the starting conditions for both teams being equal, a direct comparison between the agile and plan-driven development approach can be undertaken. The different courses of action are displayed and the different ways on how to approach the topic of achieving joy for the user are outlined. The results as well as the challenges associated with each approach are dis-cussed and an outlook on the transferability to other fields is given.

Design Thinking: an approach with various perceptions

Sanne Bouwman (1), Jesper Voorendt (1), Boris Eisenbart (2), Seda McKilligan (3)
1: Delft University of Technology; 2: Swinburne University of Technology; 3: Iowa State University

Design Thinking has become increasingly popular across different disciplines. However, what it exactly entails is becoming more and more vague, leading to the term being used for many different approaches and applications. This paper presents an interview study with experts on the application and training of Design Thinking in academia and industry. We find a divide with some seeing Design Thinking as a mere toolbox of methods, while others see it as an umbrella term for the mindset that determines how designers think and act. Subjects unanimously attest the approach large potential to support certain types of businesses, when applied under the leadership of trained designers, but see a lot of danger for the approach to become meaningless if it keeps being advertised as an all-purpose problem-solving tool. The interviewees further share extensive experiences on specific success factors and pitfalls in applying Design Thinking in practice.

User Stories Method and Assistive Technology Product Development: a New Approach to Requirements Elicitation

Isabela Cristina Simões Zacharias, Carina Campese, Thiago Bertolini dos Santos, Lorena Pereira da Cunha, Janaina Mascarenhas Hornos Costa
University of São Paulo

Requirements elicitation for assistive technology (AT) product development must be collaborative and systemic. This process must ensure that the needs of all different users are identified. For this, UCD methods introduce different tools that seek user involvement and their needs identification. One method commonly used in software development is User Stories. The aim of this paper is to analyse the use of User Stories for requirements elicitation in an AT product development project. This method was applied with three types of users: patients, companions and occupational therapists. For the involvement of these users, the method was customized and two main adaptations were adopted: the stories were written by the development team and all user needs were identified through observations of interactions between patients and prototype. As a result, the development team was able to identify numerous product requirements to be used in later development phases. These requirements were generated by the user needs identified with User Stories. Thus, the method with necessary adaptations, was efficient for requirements elicitation in the AT product development process.

Understanding the initial requirements definition in early design phases

Young-Woo Song, Michael Herzog, Beate Bender
Ruhr-Universität Bochum, Chair of Product Development

The definition of initial requirements in the early phase of product development is characterised as a decision process under highest uncertainties. Studies show that projects often deviate from their planned goals or even fail due to ill-defined requirements. Despite the importance and criticality of this task, a detailed description and risk-oriented explanation is missing in the product development literature. The goal of this paper is to develop an explanation model/frame which establishes a link between the development context and an appropriate procedure for the initial requirements definition based on general risk treatment strategies. In a first step, risk-driving context factors with high influence on this task are identified. Then two case studies are compared to analyse the interrelations between their context factors and the applied risk treatment strategies that are implemented in their procedures for defining initial requirements.

Use design performance based on use requirements

Morad Mahdjoub (1), Jean-Bernard Bluntzer (1), Aymeric Bertin (2)
1: Université de Technologie de Belfort-Montbéliard; 2: Alten Technologies

Industrial companies today must operate in an increasingly competitive world and need to rethink their organization accordingly. First, industrial strategies concerning technical management need to change and develop. If we consider the specific management of the product design process, managers use indicators during the lifecycle of the product concerning quality, cost and lead-times. For example, some new indicators concerning performance metrics related to cooperation issues among the design team are set up. Secondly, managers increasingly need to integrate the user in the early phases of the design process. The main benefit of this approach is that it allows designers to innovate more rapidly and robustly. The aim of this paper is to introduce a new approach making it possible to calculate a performance indicator concerning use design. The new indicator will help management drive the design process through the integration of use in the product, helping to enhance the usability of the future product, and consequently improve innovation.

Future-oriented PGE–Product Generation Engineering: An Attempt to Increase the Future User Acceptance Through Foresight in Product Engineering Using the Example of the iPhone User Interface

Florian Marthaler (1), Sven Stahl (1), Andreas Siebe (2), Nikola Bursac (3), Markus Spadinger (1), Albert Albers (1)
1: Karlsruhe Institute of Technology, Institut für Produktentwicklung, Karlsruhe; 2: ScMI – Scenario Management International AG, Paderborn; 3: TRUMPF Werkzeugmaschinen GmbH + Co. KG, Ditzingen

During the process of product engineering, decisions with uncertain consequences have to be made about future development (Albers et al., 2017a). Customer, user and vendor requirements that are already known and those who are relevant for the future have to be recognized and transferred into consistent projects. Classical approaches like customer surveys or market analyses are only partially useful for anticipating or validating future product requirements since they rather evaluate todays situation. Methods of foresight are preferably applied to make decisions under circumstances of uncertainty and to generate future knowledge. The following work treats thus a system that enables the user to deduce future requirements based on trend analyses. The system which was first mentioned in Albers et al. and further developed in Marthaler et al. will serve as the basis. (Albers et al., 2018a; Marthaler et al., 2019). The goal is to present and evaluate a system based on the analysis and identification of trends that allows to identify robust requirements for future product generations and to transfer them into concrete development agreements in the form of a development road map.

Assessing and improving the coverage of a Strategic Research Agenda: A design theory approach

Estelle Rémondeau (1,2), Patrick Cogez (2), Pascal Le Masson (1), Benoît Weil (1)

1: MINES ParisTech - PSL Research University, France; 2: AENEAS, France

Strategic Research Agendas (SRA) bring to the research community a prospective and collective vision of a sector and are intended to provide directions for future research efforts. However, some promising innovative areas are not always foreseen in those documents, which raises the question of the relevance and adequacy of their coverage. While engineering design is often considered to translate SRA guidelines into product development, we believe it can also be of great help regarding the design of an SRA. In this paper, we will first address how to assess the scope of an SRA through a framework based on C-K theory, before exploring how to extend it, if need be. To answer those questions, we will examine a high-quality roadmap: the Electronic Components and Systems Strategic Research Agenda (ECS SRA). Our resulting method will provide us the means to assess SRA coverage and to ensure that interesting research areas are not forgotten unintentionally, in order to allow to a further enrichment of the document if needed.

A Further Exploration of the Three Driven Approaches to Combinational Creativity

Ji Han (1), *Min Hua (2), Feng Shi (2,3), Peter R. N. Childs (2)*

1: University of Liverpool; 2: Imperial College London; 3: The Alan Turing Institute

Combinational creativity is a significant element of design in supporting designers to generate creative ideas during the early phases of design. There exists three driven approaches to combinational creativity: problem-, similarity- and inspiration-driven. This study provides further insights into the three combinational creativity driven approaches, exploring which approach could lead to ideas that are more creative in the context of practical product design. The results from a case study reveal that the problem-driven approach could lead to more creative and novel ideas or products compared with the similarity- and inspiration-driven approach. Products originating from the similarity- and inspiration-driven approach are at comparable levels. This study provides better understanding of combinational creativity in practical design. It also delivers benefits to designers in improving creative idea generation, and supports design researchers in exploring future ideation methods and design support tools employing the concept of 'combination'.

A Systematic Approach to Evaluating Design Prompts in Supporting Experimental Design Research

Apurva Patel, Maria-Vittoria Elena, Joshua Summers

Clemson University

Experiments that study engineering behavior in design often rely on participants responding to a given design prompt or a problem statement. Moreover, researchers often find themselves testing multiple variables with a relatively small participant pool. In such situations multiple design prompts may be used to boost replication by giving each participant an equivalent problem with a different experimental condition. This paper presents a systematic approach to compare given design prompts using a two-step process that allows an initial comparison of the prompts and a post-experiment verification of the similarity of the given prompts. Comparison metrics are provided which can be used to evaluate a level of similarity of existing prompts as well as develop similar problems. These metrics include complexity (size, coupling, and solvability), familiarity, and prompt structure. Statistical methods are discussed for post-experiment verification. Guidelines are provided for a post-experiment survey which may be used for an additional perspective of prompt similarity. The proposed approach is demonstrated using an experiment where two design prompts were used for within-subject replication.

Addressing cognitive challenges in design – a review on existing approaches

Weining Ning, *Joy Goodman-Deane, P.John Clarkson*

Engineering Design Centre, Department of Engineering, University of Cambridge

Insufficient design often causes challenges to users on a cognitive level, hindering them from interacting with products smoothly. There is a lack of effective design tools and supporting materials that can help designers to understand human cognition and how it affects the way that users experience and use products and services. This paper aims to identify current approaches that can be applied to address this issue, and to examine their strengths and weaknesses. This helps to identify future directions for developing and improving cognitive design supports. A literature review was conducted of research publications in the fields of both design and cognition. Four key approaches are identified: cognitive design principles/guidelines, the demand-capability approach, cognitive walkthrough and cognitive modelling. Their strengths and weaknesses are analyzed from a design standpoint. The paper also analyses the underlying causes of the insufficient uptake of cognitive design approaches by designers.

Assessing The Impact Of Abstract Representations And Reframing Of Design Brief Information On Creative Ideation

Jacob Kai Siang Kang (1,2), *Rianne Wally Meurzec (1), Pei Zhi Chia (1), Kristin L. Wood (1,2), Georgios Koronis (1,2), Arlindo Silva (1,2)*
1: Singapore University of Technology and Design; 2: SUTD-MIT International Design Centre

The overarching goal of this work is to support creative ideation in engineering design with the aim of overcoming design fixation. We study the impact of abstract representations and ways to frame the problem in design briefs on the creativity of concept sketches. Framing/Reframing involves shifting perspectives on the design purpose and to reveal insights and opportunities. Two Framing/Reframing techniques are tested: the Ishikawa/Fishbone Diagram to identify root causes and a blend of ParnesÕ Restatement/SCAMPER method to encourage divergence in problem perception. Abstract representations of requirements were used as stimuli to foster transfer and associative thinking. Using a full-factorial experimental design with brief variations, C-Sketch ideas developed by first-year engineering/architecture students were evaluated for their creativity. Our results showed a positive interaction effect for novelty and usefulness when the Fishbone Reframing method was used with abstract representation, but there was no difference in creativity scores when comparing the two Framing/Reframing methods between each other.

Reframing the design process: Integrating goals, methods and manifestation into the co-evolution model

Rosa Storm, *Jeffrey van Maanen, Milene Gonçalves*
Delft University of Technology

In their early years of education, design students may experience difficulties in reframing design problems. Since reframing is linked to creativity, this may be problematic. While there are some models available to describe the reframing process, it is yet unclear how they are supporting design students. This study concerned the development and test of a framing model based on co-evolution transitions, through a two-part study: interviews with expert designers and workshops followed by group interviews with novices. The resulting model offers a way of thinking and a way of working, based on the fluidity of the design process. This study yielded two major insights. Firstly, students tend to perceive the problem space to be fixed once they defined it, even if they discovered disparate information along the way. Secondly, the developed model provides students with guidance and confidence in dealing with complex problems. Our results have a considerable impact on design education, as it is important to reinforce to design students that both the problem and solution understanding are fluid, and this model provides initial steps to help designers structuring their process.

Tackling reframing: the development and evaluation of a problem reframing canvas

Sabine Liana Mensch, *Milene Gonçalves*
Delft University of Technology

The problems of today are increasingly complex in nature. Yet, most support provided by design agencies and innovation consultancies is based on unstructured approaches, guided by the facilitators own intuition. This article presents the Teckel canvas, an approach to guide problem reframing in facilitation to both tackle solution and problem understanding. After synthesising the main insights from prominent reframing methods and models, a meta-process of reframing was created, which was translated into a practical canvas. Two Dutch case studies are examined in which the proposed reframing canvas is tested. When this canvas was used in facilitation, we found out that the medium and message can be reframed separately or together and that the canvas can be used as a tool for overview on the subject. Our findings indicate that an explicit and tangible use of reframing can improve solving complex problems to be more clear, visual and reflective.

Studying Design Thinking as a forthcoming source to innovation speed

Christina Marie Mitcheltree, *Halvor Holtskog, Geir Ringen*
NTNU

With complex technology-intense industries follows an ever-increasing need for rapid innovation processes. Yet, innovation speed and the time from idea to product realization can vary and be unpredictable. Design Thinking (DT) is suggested as a key driver to impact the speed of product innovation within product development projects. To understand and aid the road from early ideas and concepts to value-added products, this paper will provide a literature study on how Design Thinking can facilitate improved product innovation performance through innovation speed. The paper seeks to develop an overview of new insight on DT applicability for improved product innovation capability. This is done by identifying components that comprise DT´s innovative ability and appropriateness to product development contexts beyond the early creative phases of product development. As DT emphasize on visualization and re-framing problems, it contributes to enhanced clarity, meaning and confidence in ideas and decisions. DT in this way may impact strategy formulation and speed up complex innovation processes by pre-experiencing future situations.

Exploring The Impacts Of Industry 4.0 From A Macroscopic Perspective

Rongyan Zhou, *Julie Le Cardinal*
Laboratoire Génie Industriel, CentraleSupélec, Université Paris-Saclay

Industry 4.0 is a great opportunity and a great challenge for enterprises. Nowadays, how to adjust the strategy according to the new situation to deal with the opportunities and challenges brought by Industry 4.0 is a hot topic. The paper investigates what is Industry 4.0 and compares the different fourth industry revolution programs in various countries and takes advantage of bibliometric to investigate which technologies play an important role in Industry 4.0. What is more, the status quo, challenges and development directions faced in various fields in the industrial 4.0 era are elaborated. The paper not only combs the research direction for researchers, but also presents the status quo of practical application for enterprises. The paper contributes to showing a leading role for theory and practice of industry 4.0.

The Product Developer in the Centre of Product Development: A Systematic Literature Review on describing Factors

Albert Albers, ***Jonas Heimicke,*** *Markus Spadinger, Nadine Degner, Katharina Duehr*
Karlsruhe Institute of Technology, Institute for Product Engineering

In the uncertain process of product development, the developer is decisively responsible for product success. He operates in a complex environment that directly influences his synthesis and analysis activities. The context of the socio-technical system of product development has already been extensively researched and defined by a large number of factors. However, the developer is described as part of the context and not as the centre, which means that many of these factors have no interaction with the developer. For the design of methods and tools that support the developer in his activities in the development process, a summarizing understanding of the influences on and by the developer is necessary. In order to create a unified understanding of the developer at the centre of product development, a Systematic Literature Review was conducted. In this article, the procedure and findings are presented. The aim was to identify factors from the literature that significantly influence the interaction of the developer in his environment. As a result, these were documented in a model, which represents the basis for further, human-centred research in the context of product development.

Designing risk management: Applying value stream mapping to risk management

Pelle Willumsen (1), *Josef Oehmen (1), Monica Rossi (2)*
1: Technical University of Denmark; 2: Polytecnic de Milan

Risk management (RM) in new product development (NPD) is often implemented as a standardized framework and ends up being carried out as a tick the box, non-value adding activity. To avoid this problem, RM needs to be tailored to the organization and NPD project. This paper identifies a gap in both understanding and facilitating tailoring, i.e. design of RM systems in NPD. To understand how to design RM systems, we must better understand how RM adds value to NPD activities. We applied Product Development Value Stream Mapping (PDVSM) to RM and conceptualized a Risk Value Stream Mapping (RVSM) framework to support design. Through a state-of-the-art literature review, we identified typical categories of value and waste in RM as well as approaches to model the RM in NPD. We developed and tested components of the RVSM framework based on PDVSM in three case companies. In this paper, results are presented regarding waste, value and potential ways to model the value stream in RM. The framework enables a diagnosis of the current state of RM in companies and supports future design activities pertaining to RM systems. This paper is positioned at the intersection of design, lean thinking and RM

Discussion Sessions
Thursday
8 August 2019
15:30 - 16:30

An Inventory of Creative Spaces: Innovative Organizations and their Workspace

Katja Thoring (1,2), Roland M. Mueller (3), Petra Badke-Schaub (1), Pieter Desmet (1)

1: Delft University of Technology; 2: Anhalt University of Applied Sciences; 3: Berlin School of Economics and Law

Creative workspaces are becoming popular in many organizations. They are believed to support innovation efforts and creativity among employees. This paper presents spatial evidences of creative work environments from real-life organizations, based on an exploratory multi-case study in 18 institutions. The found workspaces were mapped and categorized according to the qualities they might provide for affecting creativity. The resulting inventory of creative spaces contributes to the emerging interest on creative workspace design by presenting inspiring best-practice examples. The shown examples provide the readers with a better understanding how a creative space could be designed in order to provide an environment for an innovative organisation. Related literature was added to explain the possible impact of specific spatial configurations.

Method Toolbox for the multidisciplinary planning and development of adaptive buildings

Clemens Honold, Sophia Leistner, Daniel Roth, Hansgeorg Binz, Werner Sobek

University of Stuttgart

Adaptive buildings constitute an interdisciplinary approach for realizing the next generation of buildings in order to reduce the immense material requirements and energy demand throughout all lifecycle phases. Based on a novel cooperation between the disciplines of Architecture and Civil and Mechanical Engineering, adaptive support structures and skins are developed within the Collaborative Research Centre SFB 1244. A holistic planning process is required in order to reduce the high complexity and achieve a goal-oriented procedure during the planning of such buildings and the development of integrated systems. Part of this research is the development of new specific and the transfer of established methods from different disciplines. The experience gained during the planning of an adaptive, high-rise demonstrator building within the research project has shown that the methods for application must be provided in the form of a method toolbox to present their purpose, application time and results within the planning team. Based on the examination of existing method toolkits, this paper focuses on the development of an approach while considering context-specific requirements.

The impact of viewing images of precedents on the cognitive process of architectural idea generation

Chahinez Djari (1,2), Abdelmalek Arrouf (1,2)

1: Laboratory of architectural and urban phenomena modeling and studying (LEMPAU); 2: University El Hadj Lakhder, Batna1

Among the increasing number of researches about design thinking, several studies, empirically investigate the report between design process and different sources of inspiration. Visualization of Images represents one of the most current stimuli in the architectural design This work focuses on the link between the active part of design process and images of precedents when visualized by the designer at the beginning of his design activity. It aims to identify and measure the impact of such visualization on the cognitive process of ideation. We use the protocol analysis method. Data are collected through design experiment and coded by the semio-morphic coding scheme. Results show that the visualization of images of precedents enhances the productivity of the ideation process. The process consistency is also improved by the apearence of homogeneous phases. Moreover the ideation process becomes more creative cognitively, by making the genesis of primitive chains of actions faster, easier and similar. Accordingly, this paper communicate the effect of a common practice such images' visualization on the architectural design process to get insight on the cognitive befits of this practice.

Designing Physical-Digital Workspaces to Support Globally Collaborative Work

Andrea Tucker (1), Thierry Gidel (2), Cédric Fluckiger (1)

1: Université de Lille; 2: Universite de Technologie de Compiegne

This paper examines some aspects of physical-digital workspaces, focusing on multi-user, multi-touch technologies and how different workspaces impact collaboration. We introduce the concept of globally collaborative work. We chose to use case studies completed by groups of students in an engineering course to test different workspace modalities: the use of a large multi-touch table top in conjunction with a multi-touch board (vertical), the use of tablets with the multi-touch board, and finally the multi-touch board alone. The evaluation criteria are based on modes of interaction which emerge during globally collaborative work sessions: individual work, communication, coordination, cooperation and collaboration. We hypothesized that the workspaces would influence collaborative activity, expecting to see higher rates of collaboration in the table top environment than in the other two modalities studied. However, results showed less co-building and more cooperative work, as students divided their work and later attempted to negotiate a coherent product built on individual contributions. Lastly, we share a few design recommendations based on these results.

Experimental Evaluation of a Debiasing Method for Analysis in Engineering Design

Thomas Nelius, *Sven Matthiesen*

Karlsruhe Institute of Technology

During analysis in engineering design, systematic thinking errors - so-called cognitive biases - can lead to inaccurate understanding of the design problem. With a simplified version of the Analysis of Competing Hypotheses - ACH method and a simplified decision matrix, the confirmation bias in particular can be minimized. To evaluate this method, it was taught to experienced design engineers and mechanical engineering students. During the experimental evaluation the participants analysed a real technical problem. The procedures and results were compared with a previously conducted study with the same task. The design engineers have not changed their approaches and could not further improve their analysis success. The students profited considerably from the training. They have mentioned twice as much supporting evidence and six times as much contradicting evidence through the training indicating a more extensive analysis. As a result, the students showed significantly fewer signs of confirmation bias than without training. The findings suggest that debiasing strategies should be introduced early in engineering design education.

Empowering decision makers to avoid the oversizing of building service systems

Darren Anthony Jones, *Claudia Margot Eckert*

The Open University

Oversizing of building service systems has a direct impact on building efficiency and operational costs. The research of this paper highlights several major contributors to the issue of oversizing. A key factor is the excessive and uncoordinated application of design margins applied during the multiple stages of a building services project; others include, a lack of communication and transparency across the various stakeholder groups, and the use of vague or unreliable data upon which initial project requirements are based. The impact of these factors on system performance and cost, and how these can impede on a building's ability to meet energy efficiency targets are analysed and discussed. The paper emphasises the need to develop robust processes that capture the scope and rationale for the margins applied, and to communicate this knowledge in a clear and unambiguous format, to all project stakeholders. The development of flexible and alternative design solutions that apply diversity principles, such as different backup systems to provide resilience rather than the traditional 'like-for-like' redundancy solutions, are also explored.

Investigating The Influence of the Decoy Effect in Pairwise Comparison in Terms of Idea Selection in the Product Development Process

Narucha Tanaiutchawoot (1), *Nikola Bursac (2), Simon Rapp (1), Albert Albers (1)*

1: Institute of Product Engineering, Karlsruhe Institute of Technology; 2: TRUMPF GmbH+Co. KG

Many activities in the new product development requires the decision making to find the final solution from multiple alternatives and make an evaluation. Even methods to support decision maker are available, the decision can go to the wrong direction because of heuristics. "Decoy effect" is a heuristic that appears in a comparison when 2 of 3 alternatives are similar but different in quality. The alternative that is similar but better in quality is possibly selected. The paper aims to understand the decoy effect by investigating it in the pairwise comparison that is a powerful technique for comparing alternatives. In an experiment, 3 ideas for the next generation of apple peeler are compared in pairs with different sequences. An impact of the decoy alternative on the comparison between other two alternatives, is investigated. Results show low impact of the decoy effect in the pairwise comparison, but this effect induces a high chance of selecting the decoy alternative when comparing the results from this study and the previous study by proposing 3 alternatives in the same sequence. Applying pairwise comparison to avoid decoy effect is thus an idea that will be further investigated.

Integrated and Customer-Oriented Material and Process Selection by Sensory Multi-Criteria Decision-Making

Jan-Henrik Schneberger, *Jerome Kaspar, Michael Vielhaber*

Saarland University, Institute of Engineering Design

Today, product success more than ever depends on the satisfaction of consumer needs. Besides, manufacturers need to shorten development cycles and accelerate product release in order to stay competitive. This is achieved by applying customer-oriented methods allowing for fast and reliable acting. During the early phase of product development, requirements acquisition is crucial for later success of products, since specifications are most influenceable at this point. Referring to the decisive concept generation phase, material and production definition is difficult due to the highly complex interrelations between material properties, production process capabilities, and resulting product characteristics. Especially in the context of lightweight design, concurrent material and processing technology selection must be considered due to its various possible interfaces. Thus, this contribution outlines an integrated approach towards an enhanced material and process related, customer-oriented requirements acquisition during the early phase upstream of product detailing. Here, conventional multi-criteria decision-making and tactile recognition are employed in an agile transformation model.

Using Open Source Code Libraries for Robust Design Analysis

Kevin Otto, Jiahui Wang, Tekin Uyan
Aalto University

The design of systems today often involves computer simulation to assess performance and design margins. Understanding how variability erases design margin is important to assure adequacy of margins, especially in optimization efforts. In this paper, we develop a toolchain using open source code libraries in Python, and encapsulate it in Jupyter notebooks, to provide an open source, interactive uncertainty quantification and sensitivity analysis toolchain. This works generally with simulation tools, where a reference folder is created containing a script that reads an input file of parameter values and runs the simulation. With that easily created, the toolchain executes the necessary uncertainty quantification steps with replicates of that reference folder. This approach fits within a broader workflow outlined that defines the variation modes to study, maps to simulation inputs, and screens the variables for sensitivity before conducting an uncertainty quantification. An example is shown in the simulation analysis of a Stirling engine.

Specifying Process Activities for Multi-Domain Matrix Analysis Using a Structured Textual Format

S.C.M. Knippenberg, L.F.P. Etman, T. Wilschut, J.A. van de Mortel-Fronczak
Eindhoven University of Technology

This paper proposes a method to automatically generate a multi-domain matrix (MDM) from textual activity specifications. The format for specifying these activities is based on a structured grammar derived from natural language and consists of two types of activities: goal activities and transformation activities. A goal activity describes the purpose of an action performed by an actor for the benefit of another actor in the system. A transformation activity describes an activity from the viewpoint of a single actor, who receives, generates, and outputs information or artifacts. If one describes activities using these two types of activity specifications, dependencies can be automatically derived between actors, activities, and parameters of the system and visualized in an MDM. Thus the generated MDM presents an organization DSM (actors), a process DSM (activities), and a parameter DSM (flows of information or objects), as well as the mapping matrices coupling the different domains. An illustrative house construction example demonstrates the effectiveness of the proposed activity specification format. The method may provide an outcome in understanding and managing complex systems.

A Systematic Approach to Model Objectives in Predevelopment Projects

Thilo Oliver Richter, Albert Albers, Johannes Willi Gesk, Jan-Hendrik Witt
Karlsruher Institut für Technologie

This contribution presents a systematic for the elicitation of objectives and the utilization of objectives to identify reference products. The systematic is based on existing meta models. The model of objectives as proposed in this research eases decision-making and outlines the next validation activities. A key success factor is the project transferability between teams, which is often necessary in predevelopment. This is ensured through comprehensibility of objectives which benefits from the linkage between the model of objectives and the knowledge base. The proposed systematic is applied to a predevelopment project which is used as case study. In the case study it has been shown that objectives can be used to identify reference products. The approach is validated in a live-lab setting with seven engineering teams with six graduate students, two engineers of an industrial partner and a research associate. Several workshops were used to train all members of the teams in the systematic. The effects of the systematic are assessed in dedicated interviews, a survey as well as with observation of the engineering teams during milestones and engineering activities between milestones.

Scaling of Technical Systems Using an Object-Based Modelling Approach

Philipp Wolniak (1), Bastian Sauthoff (2), Roland Lachmayer (1), Iryna Mozgova (1)
1: Leibniz University Hannover, Institute of Product Development; 2: Baker Hughes, a GE company

Companies that operate and manufacture products in the technical area are exposed to increasingly challenging market situations. The developed products should be individualized to the customers' needs while offering high quality at an acceptable price. The temporal and especially economic claims are constantly growing, forcing the companies to develop a given product that matches the cost-side as well as the technical requirements in a short period of time. Following an initial development, it is often necessary to provide further product variants regarding a modified geometry or performance. A time and cost efficient way is the scaling of the initially developed product. Existing scaling methods focus on uniform geometry changes, not taking into account influences from non-uniform requirement or geometry alterations. Therefore, this article proposes an approach on how to modell and assess the outcome of a scaled assembly, based on the connection of individual scalable components inside an object-based approach.

How to foster Innovation? A Methodology to identify Fields for Fostering Innovation Capability in Small and Medium-sized Enterprises

Tarık Şahin (1), Leonhard Riedel (2), David Inkermann (1), Dagmar Wilgeroth (2), Reza Asghari (2), Thomas Vietor (1)

1: Technische Universität Braunschweig; 2: Ostfalia University of Applied Sciences

Small and medium-sized enterprises are affected by changing development, production and selling paradigms in globalized industries, where innovation is a driver for sustainable competitiveness. However, innovating is highly challenging for small and medium-sized enterprises, as human resources are very limited and know-how are often highly specialized. It is often unclear which fields and factors provide the capability to innovate and which measures or methods can be applied to promote innovation based on existing competencies. For this reason, the aim of this paper is to present a framework to support the innovation capability of SMEs by identifying promising fields for innovation and providing suitable innovation methods. A particular focus in this paper is a methodology for the description and identification of fields to foster the innovation capability in SMEs as a part of the introduced framework.

Toward Better Design-related Decision Making: A Proposal of an Advanced OODA Loop

Mattia Vettorello, Boris Eisenbart, Charlie Ranscombe

Swinburne University of Technology

To be successful in innovation, organisations need to be dynamically adaptable to novel situations to avoid getting 'left behind'. Yet, they face vast uncertainties stemming from unforeseeable technological shifts or future user and market behaviour, making strategic decision-making on innovation an extremely difficult task. Decision-makers thus increasingly try to control or shape the future, rather than foresee it. This includes thinking ahead and generating potential pathways that will make an innovation viable. This captures the essence of designerly ways of thinking in reasoning toward 'what might be'. Extant literature has been reviewed that discusses alternative strategies how this future-oriented thinking can be applied to become better at selecting novel ideas for development. We observe parallels between divergent thinking, abductive reasoning, analogising and lateral thinking suggested by different authors in this process. The paper continues to propose how these key mechanisms can be embedded within an existing framework for decision-making under uncertainty, the 'OODA Loop', which has seen increasing uptake in such decision-making scenarios.

Ranking absorption practices of knowledge for collaborative innovation: which is the ideal multi criteria decision method

Elizabeth Gendreau (1), Lamiae Benhayou-Sadafiyine (2), Marie-Anne Le Dain (3), **Joshua Summers (1)**

1: Clemson University; 2: Universite Internationale de Rabat; 3: Grenoble Institute of Technology

This paper focuses on evolving an absorptive capacity (ACAP) assessment tool designed to help firms understand their ACAP maturity in processing external knowledge. ACAP maturity is evaluated based on a firm's capacity and willingness to do relevant ACAP practices. Although an earlier version of the ACAP tool was able to evaluate maturity and highlight immature practice, it could not determine how critical these practices were for improvement action. Thus, a means of eliciting the importance of practices and aggregating it with their ACAP maturity evaluations is needed. This paper provides summaries of the subjective weight elicitation methods and aggregation techniques which were identified from the domain of multi-criteria decision making. Criteria for comparing these methods are defined and analyzed to determine the most appropriate methods for the current application. The SRF method for subjective weight elicitation, aggregated with the maturity evaluations through weight sum models, is deemed the most appropriate for the current application. During testing with users, the SRF procedure was found to suffer from various usability concerns which will be investigated in future work.

Orienting Through the Variants of the Shah's A-Posteriori Novelty Metric

Lorenzo Fiorineschi, **Francesco Saverio Frillici,** *Federico Rotini*

University of Florence

Different variants of a-posteriori novelty metrics can be found in the literature. Indeed, such a kind of assessment procedures is often used to extract useful information about creativity and/or idea generation effectiveness. In particular, the metric proposed by Shah et al. in 2003, is one of the most used and discussed in the literature. However, scholars highlighted some flaws for this metric, and some variants have been proposed to overcome them. This paper argues about the variants proposed for the a-posteriori metric of Shah et al., and proposes a selection framework to support researchers in selecting the most suited for their experimental needs. The proposed selection framework also highlights important research hints, which could pave the way for future activities. More specifically, it is still necessary to support the identification of the best-suited abstraction framework to assign weights to attributes, and the assignment of weights should be better supported as well. Moreover, this paper highlights the presence of "uncommonness of key attributes", which needs to be investigated for experimental cases where ideas missing some key attributes are present.

Hybrid Additive Manufacturing - Requirements Engineering Framework for Process Chain Considerations

Jan-Henrik Schneberger (1), *Tobias Häfele (2), Jerome Kaspar (1), Michael Vielhaber (1)*
1: Saarland University, Institute of Engineering Design; 2: University of Applied Sciences Saarland, School of Engineering

Additive Manufacturing (AM) provides significant opportunities for design and functional integration of parts and assemblies. Compared to conventional processes, the AM principle increases design freedom notably. Additionally, numerous processible materials and hybrid processes enable the implementation in different industries, spanning from aerospace over automobile until medical applications. However, there are still handicaps to be addressed, arising from the large diversity of AM principles, post-processing and quality assurance issues, partly insufficient user knowledge, and organizational aspects. Coherently, lacking requirements specification hinders a successful consideration of AM in the early stages of development, and its later implementation. To promote knowledge build-up, this contribution presents a requirements specification framework, which supports developers in determining demands throughout the development process, including those resulting from post-processing and testing operations. By incorporating thorough analyses of general organizational and resort overarching limitations, this contribution promotes a successful implementation of suitable AM strategies.

Fostering creativity in design - An empirical study on improvement of requirement-satisfaction with introduction of InDeaTe tool

Shakuntala Acharya (1), *Apoorv Naresh Bhatt (1), Amaresh Chakrabarti (1), Yukari Nagai (2)*
1: Indian Institute of Science Bangalore; 2: Japan Advanced Institute of Science and Technology

In today's highly competitive market, product success is determined by two critical factors - innovation and sustainability. While innovation looks to rampantly satisfy the consumers' ever growing requirements with creative solutions, sustainability attempts to rationalise the precarious demands of desired requirements on economy, society and environment. InDeaTe - Innovation Design database and Template, a web-based, design process guidance tool, supports design of sustainable systems by incorporating sustainability requirements into the design process. This paper investigates the potential of the tool to improve the usefulness of a design, one of the indicators of the creativity of the solutions, apart from its novelty. Comparative studies are conducted to assess the improvement of 'requirement-satisfaction',a proxy measure for usefulness. Upon introduction of the tool into the design process, significant improvements are reported, thereby reflecting the ability of InDeaTe to increase the usefulness of solutions and foster creativity in design.

A semi-automated requirements reuse and recycling process for Autonomous Transportation Systems R&D

Youssef Damak (1,2), Marija Jankovic (1), Yann Leroy (1), Karim Chelbi (2)
1: CentraleSupélec; 2: AKKA Technologies

The R&D of Autonomous Transportation Systems (ATS) is hindered by the lack of industrial feedback and client's knowledge about technological possibilities. In addition, because of intellectual properties (IP) issues, technology consulting companies can't directly reuse developed functionalities with different clients. In this context, requirements reuse technics presents a good way to capitalize on their knowledge while avoiding IP issues. However, the literature review on requirements reuse processes doesn't propose methods to the application of reuse processes with little information about the system's operational context. In this paper, we present a semi-automated requirement reuse and recycle process for ATS R&D. The process helps designers' copes with the lack of inputs from the clients. Requirements candidates are retrieved from a database using Natural Language Processing and traceability propagation. It is applied to 3 use cases with inputs less than 5 concepts from the client's needs. The results validate its efficiency through number requirements retrieved and the analysis time consumption

Method for Analysing Requirement Change Propagation Based on a Modified Pagerank Algorithm

Iris Gräßler, **Henrik Thiele,** *Christian Oleff, Philipp Scholle, Veronika Schulze*
Paderborn University

Complexity of products and systems is increasing through digitalization, interdisciplinarity as well as high technology maturity and new business models. In consequence, new product development (NPD) projects need to manage and satisfy a large number of requirements from a broad range of stakeholders. Yet, NPD projects are often delayed due to requirement changes. In this paper, a new method for analyzing requirement change propagation is presented. The method is based on the assessment of requirement interrelations structured in a requirements structure matrix by a modified page-rank algorithm. By the method, a high number of strongly interrelated requirements can be analyzed in an efficient manner. Additionally, higher-level interrelations as well as the relative weights of requirements are also incorporated in the analysis. Hereby, an efficient holistic approach towards the analysis of requirement change propagation is proposed.

A Text Mining Based Map of Engineering Design: Topics and their Trajectories over Time

Filippo Chiarello, Nicola Melluso, Andrea Bonaccorsi, Gualtiero Fantoni
Università di Pisa

The Engineering Design field is growing fast and so is growing the number of sub-fields that are bringing value to researchers that are working in this context. From psychology to neurosciences, from mathematics to machine learning, everyday scholars and practitioners produce new knowledge of potential interest for designers. This leads to complications in the researchersÕ aims who want to quickly and easily find literature on a specific topic among a large number of scientific publications or want to effectively position a new research. In the present paper, we address this problem by using state of the art text mining techniques on a large corpus of Engineering Design related documents. In particular, a topic modelling technique is applied to all the papers published in the ICED proceedings from 2003 to 2017 (3,129 documents) in order to find the main subtopics of Engineering Design. Finally, we analyzed the trends of these topics over time, to give a bird-eye view of how the Engineering Design field is evolving. The results offer a clear and bottom-up picture of what Engineering design is and how the interest of researchers in different topics has changed over time.

Integrating the product development process in scientific research. Bridging the research-market gap

David Mesa, Christine Thong, Charles Ranscombe, Blair Kuys
Swinburne University of Technology

Science and technology generated by Universities has many challenges in reaching commercial product applications, as has been explored in a range of literature. Product design has been identified to add value through various types of contributions in addressing these challenges; however, there remains a gap in literature to explore how and when product development activities can practically be applied to technology development. This paper furthers the idea that the product development process can help bridge the gap between the laboratory and commercial applications by proposing a framework for how Ulrich and Eppinger's product development process can integrate with the STAM technology development model. This is a significant step towards understanding how in practice these disciplines can work together to bring science and technology from the laboratory to products in the marketplace.

Formulating Design Recommendations for the Acceptance of the Use and Results of Point-of-Care Testing in Low- and Middle-Income Countries: A Literature Review

*Yvonne Jolanda Melanie Licher, **Jan Simon Visser,** G-Young Van, Jan Carel Diehl*
Delft University of Technology

In low- and middle-income countries (LMIC), diagnostics are not always available in remote areas. Hospitals and healthcare centres are often too far from the community, and waiting times are up to a few hours even for relatively simple procedures. Moreover, travelling to the healthcare centre and taking the diagnostic test is frequently unaffordable. Point of Care Tests (POCTs) can improve the availability, accessibility and affordability of the diagnostics by providing the test at the time and place of patient care. Although many POCTs have been developed already, there remain challenges to enable the healthcare workers (HCW) and the patients to use the device in practice. In this paper, we aim to provide a systemic overview of the barriers and opportunities for the adoption of use and acceptance of the results of POCTs based on the literature. The barriers and opportunities were clustered into six themes and used to draw out recommendations for the future design.

A survey of design reviews: Understanding differences by designer-roles and phase of development

James Chen, Gustavo Zucco, Alison Olechowski
Department of Mechanical & Industrial Engineering, University of Toronto

In this paper, we present the results of a survey of new product development practitioners regarding their design review experiences. We surveyed 128 product development professionals on their experience and preferences in design reviews. We found that the goals and type (location / synchronicity) of design reviews change over the course of a product development project. We found that the majority of design review meetings continue to be held as co-located, live, in-person meetings. For reviewing 3D models, we found that a native CAD package (rather than a viewer, or fixed views, or a physical prototype) is the most commonly used tool. We found a difference between Designers (more likely to be product engineers) and Non-Designers and their access to CAD software, as well as their preference for which tool to use at the design review for 3D model evaluation. We hope that our findings spark future work related to better understanding design reviews and design reviewers in context. Design reviews are an important part of industrial product development processes, so we believe future studies have a large potential to improve these design activities

A CHAT Approach to Understand Framing in Digital Service Innovation

Nick Sturkenboom (1), Ehsan Baha (1,2), Rebecca Price (1), Maaike Kleinsmann (1), Dirk Snelders (1)
1: Delft University of Technology; 2: Meaningwise

Within the third wave of digital service innovation, framing is becoming increasingly complex. Accordingly, design practice finds itself in a transition from designing single service solutions that are shared, to designing systemic solutions that are shareable. We report a case study in which we use Cultural Historical Activity Theory (CHAT) to analyze the framing process that a designer went through when designing a digital service for a Connected Care startup. Results show the importance of the designer's activity awareness and the challenge of dealing with relational complexity when framing the digital service innovation. With this work, we hope to inspire researchers and practitioners with the potential that CHAT has to offer for the reflective practice in digital service innovations.

Employee acceptability of wearable mental workload monitoring in Industry 4.0: a pilot study on motivational and contextual framing

Bram B. Van Acker (1,2), Peter Conradie (1,2), Peter Vlerick (1), Jelle Saldien (1,2)
1: Ghent University; 2: Research group IMEC-MICT-Ghent University

As Industry 4.0 will greatly challenge employee mental workload (MWL), research on objective wearable MWL-monitoring is in high demand. However, numerous research lines validating such technology might become redundant when employees eventually object to its implementation. In a pilot study, we manipulated two ways in which employees might perceive MWL-monitoring initiatives. We found that framing the technology in terms of serving intrinsic goals (e.g., improving health) together with an autonomy-supportive context (e.g., allowing discussion) yields higher user acceptability when compared to framing in terms of extrinsic goals (e.g., increasing productivity) together with a controlling context (e.g., mandating use). User acceptability still panned out neutral in case of the former, however - feeding into our own and suggested future work.

Meaningful Experience in Service Design for the Elderly: SAPAD Framework and its Case Study

Fei Hu (1), Jun Li (1), Wei Wang (1), Keiichi Sato (2)
1: School of Art & Design, Guangdong University of Technology; 2: Institute of Design, Illinois Institute of Technology

A growing trend of aging population of China has brought tremendous pressure on the domestic care system, and community education is one of the important content for elderly services. Based on the framework of SAPAD, the community English class in Guangzhou City is taken for case study. Depth research on three stakeholeders-the elderly, social workers and volunteers are carried out by interview, user observation and field research. 6 levels (physical level, syntactic level, empirical level, semantic level, pragmatic level and social level) are extracted based on SAPAD framework, and the behavior-object-significance mapping is completed. Significant clusters of multiple users at different levels are analyzed, and 16 core significant clusters are jointly built. By linking with clustering results of the syntactic level, 6 new function modules are obtained. Finally, the community elderly education service system is built through personas, service blueprint, touch points and storyboard. The new service system will improve learning efficiency, satisfactions and emotional appeals for the elderly, and work efficiency of social workers and volunteers.

The Concept Of 'Roadmapping Service': Exploring Customer Perspectives Of Roadmapping Through The Service Lens

Maicon Gouvea Oliveira (1), Michele Routley (2), Robert Phaal (2), Glauco Henrique Sousa Mendes (3)
1: Federal University of Alfenas; 2: University of Cambridge; 3: Federal University of Sao Carlos

Roadmapping has been addressed as a management approach used to support strategic and innovation planning of organisations over recent decades. This paper introduces a new standpoint for addressing roadmapping through the application of service theories as a way for tackling the demand for the digitalisation of roadmapping. To this end, the concept of roadmapping as a service offer is developed and employed to analyse three customer perspectives of roadmapping: owners and sponsors, team members, and facilitators. Based on a literature review and interviews with roadmapping experts, customer jobs, pains, and gains are described for each of the perspectives. In the end, the paper provides insights for the understanding of the concept of roadmapping service and opens opportunities for further theoretical and empirical developments around this new path. These results are part of a broader research project exploring the digitalisation of roadmapping.

Investigating the impact of Spatial Augmented Reality on communication between design session participants - A Pilot study

Lorenzo Giunta (1), Fatma Ben Guefrache (2), Elies Dekoninck (1), James Gopsill (1), Jamie O'Hare (1), Federico Morosi (3)
1: University of Bath; 2: Université Grenoble Alpes; 3: Politecnico di Milano

SAR provides an unobtrusive implementation of AR and enables multiple stakeholders to observe and interact with an augmented physical model. This is synonymous with co-design activities and hence, there is a potential for SAR to have a significant impact in the way design teams may set-up and run their co-design activities in the future. Whilst there are a growing number of studies which apply SAR to design activities, few studies exist that examine a particular element of a design activity in a controlled manner. This paper will begin to fill this gap through the controlled study of SAR and its effects on the communication between participants of a co-design activity. To do so the paper compares a controlled design session, using more traditional methods of design representations (3D models on a screen), to sessions run using SAR. The sessions are then analysed to gather information on the gestures used by the participants as well as the overall efficiency of the participants at completing the set design task. The paper concludes that the data gathered tentatively supports a link between the use of SAR and improved communication between design session participants.

Building Tangible Augmented Reality Models for Use in Product Development

Karan Jain, Young Mi Choi
Georgia Institute of Technology

This paper discusses the issues involved with creating a Tangible Augmented Reality representation of a product so that it can be effectively and validly used to support the product design process. The development of a TAR representation entails building the physical model of the product, a digital model of the product, and developing interactions between the digital and physical representations. Different products have different user interactions, which makes developing TAR representation for products challenging since a new interaction needs to be mimicked. Challenges of developing TAR representations are discussed by investigating TAR representations of four consumer products: a space heater, a MP3 player, an electric can opener, and a seat assist cushion. The goal of TAR representations is to not only communicate the functionality of a product but also to improve the time efficiency of prototyping of physical products. Hence, having a good understanding of the user interactions that need to be developed and planning the representation for construction in the modeling software and AR software is crucial to making the process of developing a TAR representation efficient.

Enabling designers to generate concepts of interactive product behaviours: a mixed reality design approach

Santosh Maurya, Yukio Takeda, Celine Mougenot
Tokyo Institute of Technology

To design interactive behaviours for their products designers/makers have to use high fidelity tools like Ôelectronic prototyping kitsÕ, involving sensors and programming to incorporate interactions in their products and are dependent on availability of hardware. Not every designer is comfortable using such tools to ideate and test their concept ideas, eventually slowing them down in the process. Thus, there is a need for a design tool that reduces dependence on complex components of such tools while exploring new concepts for product design at an early stage. In this work, we propose a Mixed Reality system that we developed to simulate interactive behaviours of products using designed visual interaction blocks. The system is implemented in three stages: idea generation, creating interactions and revision of interactive behaviours. The implemented virtual scenario showed to elicit high motivation and appeal among users resulting in inventive and creative design experience at the same time. As a result, designers will be able to create and revise their interaction-behavioural design concepts virtually with relative ease, resulting in higher concept generation and their validation.

Adopting Immersive Technologies for Design Practice: The Internal and External Barriers

*Dieu Hoang (1), Ehsan Naderi (1), Renée Cheng (1), **Bijan Aryana (2)***
1: University of Minnesota, United States; 2: Chalmers University of Technology

In the first quarter of the new millennium, the immersive technologies such as Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR) are only a few steps away from becoming the mainstream tools within the design industry. This study investigated the internal and external barriers of technology adoption within design-oriented businesses. A mixed method was used to collect and analyze the data from the employees of a large design firm. This research confirmed that external barriers such as funding, technical support, training, and business strategy that exist at the organizational level are interrelated with the internal barriers such as designers' and managers' perception and attitude toward the new technologies. The managerial applications were discussed later and the directions for future research were provided.