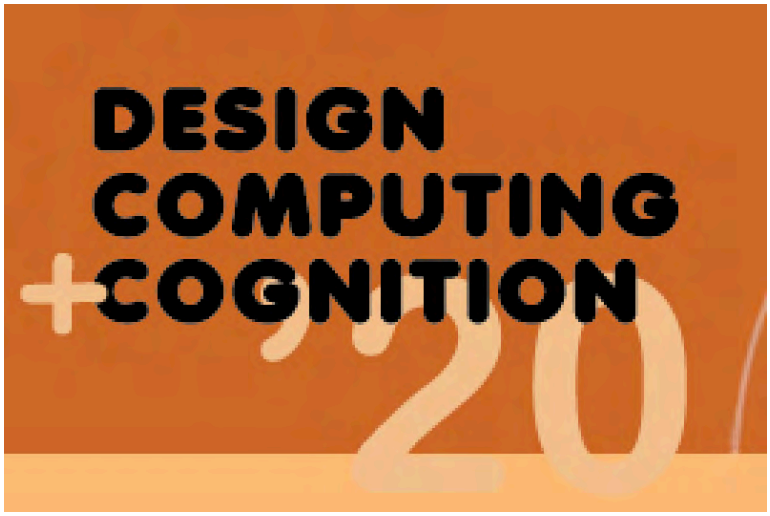

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Extent of Cultural Elements in Engineering Design Requirements of Humanitarian Engineering and Global Development Efforts

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Abstract

Design for global development and humanitarian engineering efforts, take on global challenges by applying engineering and engineering design approaches. The broader goals of design for global development and humanitarian engineering efforts are economic development, improve global access to energy, and social development. To do so, designers and engineers have developed and supplied alternative technologies globally, with hopes that these technologies will aid in reaching the broader goal. However, adoption of the design and engineered solutions suffers in the design for global development and humanitarian engineering context. Adoption suffers because the design solution lacks cultural fit; it does not meet the needs of the end user culturally in design form or function. With engineering design ultimately being about the designer meeting design requirements, the goal of this work is to understand the extent design requirements of design for global development and humanitarian engineering efforts explicitly reflect cultural elements of the end user. This study acts as the first part of a larger study looking to understand what makes design engineers consider culture when developing design solutions. Using hypothesis coding, design requirements of 38 design for global development and humanitarian engineering publications were coded to uncover the presence and extent elements of the end user's culture were explicitly reflected in the design requirements. Of the 383 design requirements, only 70% of the requirements reflected elements of the end user's culture. Of the seven elements of culture considered, economic systems and traditions & customs were the most frequently considered elements of culture. Findings suggest that there is little regard to the end user's culture in explicit design requirements. No correlation was found between adoption rate and the percentage of design requirements that reflect culture. However, due to adoption of design solutions suffering because of a lack of cultural fit, there is a need to further investigate the relationship between design requirements, the end user's culture, and the designer's perception of culture in design projects.

POSTER: THE GAP BETWEEN WHAT DESIGNERS EXPECTED AND WHAT TARGET USERS COULD PROVIDE IN A CO-CREATION DESIGN

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Involving users in an idea generation process may stimulate more creative ideas because users could give feedback of an idea, promote some new innovation and help designers to ensure the vague needs. Therefore, researchers have focused on how to make users and designers cooperate in an effective way. However, little work has so far been done to detect the challenges and benefits from users and designers' aspects, and which kind of role they expect themselves and each other to play. Besides, research on the effect of cooperation between users and designers focuses more on the stage of design evaluation instead of idea generation. Therefore, the present research tried to identify the reason why users and designers generate conflicts in idea-generation stage. To address the questions, our research conducted a design task to observe how users and designers cooperate with each other. Then, two focus groups were conducted to detect why there are some conflicts between designers and users in a cooperation co-creative design.

The data are analyzed by inductive reasoning. We obtained results about what designers expected from users and what users consider they could do. As for designers, (i) they want users to promoted more functional needs or shortcoming of a product and expect users to provide more detailed information in idea generation process. (ii) They hope users could have some relative knowledge about the idea generation process. (iii) They are open to the

new idea generated from users. However, they do not want to receive ideas which they think are common, boring or could not be achieved by technology. (iv) They do not want their ideas to be denied by users because of user experience and the shape of the product in an idea generation process. As for the users, (i) some of them think they could be involved in idea generation process. However, they also think some designers could not respect their idea and make them feel disappointed. (ii) Some users are afraid of disturbing the design process, consider themselves as "tools" which could provide information and think there is less contribution they have done in the process. (iii) The feedback of users is normally in a neutral or a negative valence. In addition, we summarized the reason why some conflicts are generated in idea generation process: (i) Users and designers have different understanding of what they need to do on the idea generation stage; (ii) Designers are creative and try to seek innovation solutions while users are realistic and focus more on practical solutions of the problems the encountered they meet; (iii) Some designers have bias in users and did not consider users as a people who could generate ideas and also, some users do not think they could play a role in idea generation; (iv) Some users with less design developing knowledge have a strong leadership ability and control the process of design. (v) Both users and designers consider themselves as professions in their area and try to persuade each other.

The contribution of the research are the followings: (i) Our research identified the reasons why users may have conflicts with designers; (ii) The research detect what designers expected from users and what users consider they could do; (iii) Our study is the former step to detect a more effective design process for cooperation design, how to help users and designers accept each other in a creative design process from the compulsive accept into real accepted. Finally, we promote some suggestions on cooperation. However, the research is limited in ethnic groups, with only Chinese students participating in. Since characteristics of a person involving culture, age, gender may affect the results, more research on different kinds of people need to be done.

RESTRICTED CROSSOVER BY CLUSTERING TO IMPROVE EVOLUTIONARY ALGORITHM RESOLUTION

An application for optimization of concurrent product and process configuration problem

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1 Introduction: addressed problem

In the manufacturing industry, numerous companies use configuration to propose customizable solutions that meet customers' needs. Configuration is a special type of design where the product is defined given a set of known components that can be assembled given a set of compatibility constraints (Felfernig et al. 2014). Some configuration software allow both to configure the product to deliver to the customer but also the delivery process to produce, test and deliver it. This kind of problem is called concurrent product and process configuration (CPPC) problem. The manufacturing company is then looking for a solution that respect technical and commercial constraints but also that optimize some criteria, as for instance cost, delivery time or carbon footprint. This results in a multi criteria optimization CPPC problem. This kind of problem is characterized by a large number of possible solutions both for the product and the process. Due to this large amount of possible solutions, and therefore the large solution space, we propose, as many authors, to use evolutionary algorithms (EA).

As EA don't take into account constraints, in order to consider constraints between the different parts of the solution, we proposed in previous work to combine EA with a filtering approach under the name "CFB-EA" (Pitiot et al. 2013). In this method, EA is combined with a constraint filtering engine that maintain feasibility of solutions during crossover and mutation, e.g. all generated individuals respect constraints. If a solution doesn't respect constraints, a backtrack process restore its feasibility. Each individual represents one possible solution of the CPPC problem, and each gene represents an instantiated variable of the CPPC problem. However, this approach takes a long time to resolve due to lot of filtering and backtracks. Thus, the objective of the work presented here is to improve the resolution performance by reducing filtering and backtracks.

2 Method

The main idea of our proposal is to use restricted crossover with close individuals (solutions). Indeed, we suppose that close individuals are easier to cross (with less backtracks) than randomly selected individuals. However, cross only close individuals could reduce diversity, and thus lead to local optimum. Some works, as (Chehouri et al. 2017) and (Zhang et al. 2007), have used clustering in EA to define groups of solutions (clusters). Clusters are then used to restrain the parents' selection during crossover. We propose a new way to define and use clusters in multi objective EA.

The objective when defining clusters is to find groups that both minimize the distance between individuals within the same cluster, but also maximise the distance between clusters. The first point makes possible to ensure the similarity of individuals within a cluster, and therefore the possibility of crossover respecting constraints, while the second point makes possible to ensure that a diversity of solutions is maintained. The calculation of the distance between individuals is therefore of importance. The k-mean algorithm is a well-known solution to define clusters. That is why we propose to use this algorithm by adding two original contributions linked to the multi objective context.

First, we use the Z-score to normalize the different objectives. For example, if the cost is between 20 000 and 100 000 € while the delay is between one and six weeks, the Z-score allows to normalize the unit between the two axes to calculate the distance between clusters.

The second originality of our work lies in the fact that clusters are built using only Pareto front individuals. Indeed, the constitution of a cluster composed only of dominated individuals (outside the Pareto front), and then crossover with individuals of these dominated cluster is not relevant when looking for optimal solutions. Clusters are therefore defined initially only with Pareto front individuals. Then each of the individuals outside the Pareto front is added to the nearest cluster centre. Thus, relevant solutions appear in each of the elaborated clusters.

The crossover is then carried out, only between individuals within the same or nearest clusters. A new individual containing all the genes common to both parents is then generated. Then the crossover is carried out on each of the remaining genes (with 50% probability to keep the gene of each parent). When a choice is made on a gene, the compatibility with the constraints is checked by filtering. Thus, all individuals respect constraints.

3 Experimental results

We tested this method on a model instance that come from a benchmark proposed in (Pitiot et al. 2016). This model is a representative one of CPPC problems: 30 variables, 26 configuration constraints with between 1 to 60% allowed tuples (combinations). We choose to use the hypervolume metric to measure both performance and diversity of solution in a single metrics. We applied this method of restricted crossover with three, five or eight clusters. The best results were with five clusters: on the average of the five runs, this method was 68 % faster than CFB-EA to found 99.9 % of final value and the RSD time divided by 3.5. The method was also 33 % faster to find the final value, and the best value was found at each run. This represent a very significant improvement since backtracks during crossover were reduced of 34%.

4 Conclusion and future works

We propose a new way to use clustering in multi objective EA: this method, which is an unsupervised way to restrict crossover, is easy to implement in others multi objective EA.

This method shows very interesting results: compared to CFB-EA, the use of clusters for crossover allows to reduce by 30 % to 60% the computation time, with a better quality of solutions. Besides, we still must compare the results with other existing approaches, as (Chehouri et al. 2017) and (Zhang et al. 2007).

Some perspectives have also been identified. First, we could add one additional parameter: the number of clusters. For now, the number of clusters is set by the user to three, five or eights. Five clusters always achieved better results in all tested cases. But we can imagine an automatic setting of the number of clusters, dynamically adjusted. Second, for now, crossover is restrained to the same or nearest clusters. We could think of a way to dynamically adjust restriction in order to balance exploration / intensification behaviour.

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INVESTIGATING STRATEGIES FOR MASS PROPERTY REPLICATION IN 3D PRINTED PROTOTYPES

A computational study of adding mass into 3D printed parts.

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1. Introduction

Physical prototypes are commonly used within the design community for communication and learning through inferring and presenting design ideas (Yang 2004). They are often considered "*another representation for requirements and solution knowledge*" (Schneider 1995) and are intended to accelerate the design cycle.

In recent years there has been a trend to 3D print these prototypes, often using technologies such as Fused Filament Fabrication (FFF) – commonly referred to as "FDM" and "material extrusion" (Raz 2017). The shift towards this technology has been driven by user's taking advantage of the low cost, short-turnaround times and quick iterations the technology offers (Simonot, Cassaignau and Coré-Baillais 2019). However, the mass properties – mass, balance and inertia – of the parts fabricated using this technology are rarely truly representative of the intended design. Such differences can be significant and arise from the combination of printing in a low-density plastic (such as PLA) and printing a low-density infill to reduce fabrication time and cost.

Poor mass property replication can be unhelpful in applications where realistic mass and small changes can impact interaction and performance respectively, such as in the case of consumer and sports products. Further, in some cases the ability to investigate and optimise mass properties may be desirable. Evidence supporting the need of the designer to consider the mass properties of a part can be found in the "Inclusive design toolkit" (Clarkson *et al.* 2007) available as a book and website.

This paper presents a method of adding mass to 3D printed prototypes. While various strategies can be employed, which include different materials and inserting masses, the method presented in this paper is initially constrained to varying the infill density across a part to allow the intended design's mass properties to be 'best-matched'. Several case studies are given and the method of probing the solution space discussed.

2. Example Parts

Three case studies have been chosen to represent several different applications the method might address, described in Table 1.

Table 1 - Chosen case study designs with reasoning

Design	Reason for Selection
Games Controller (Nintendo Switch)	Both high speed dynamic movement, and slow speed accurate positioning. Mass, balance (in every axis) and inertia important.
Hand Drill	Low speed applications which require a high degree of control and positioning. Mass and balance important. Relatively large and heavy.
Pen	Requires fine, controlled movement. Mass and balance important. Relatively small and light.

3. Computational Method

Solid part files were created for each case study in Autodesk Fusion before being exported as stl files to Blender – an open source software package design for mesh editing and visualisation (Kent 2015). From here a pseudo-random Monte Carlo simulation was run that:

1. Generated a voxel mesh of a random number of elements within Blender to produce discrete elements of a known volume;
2. Generated an infill density for each element that was applied;
3. Mass, balance (in each axis) and moment of inertia were calculated for the whole part;
4. Combinations of input (number of elements and infill density distribution) that met a given success criteria were recorded;
5. Repeat steps 1-3 a given number of times.

The success criteria were changed to observe the effect of requiring multiple mass properties to be matched. The pseudo-random number generator used was a Mersenne Twister Generator.

To maximise the amount of the possible design space the model considered, several key assumptions were made:

- Infill density was between 0% and 100%;
- There was no infill density gradient between elements;
- The minimum shell thickness was 0.4mm (a single line width)
- The minimum element size was 1 mm^3 and maximum element size set so a single element contained the whole part.

Although 0% and 100% infill densities are possible on a 3D printer, they are often avoided due to collapsing overhangs (near 0%) and heat dissipation issues (at 100%). Problems associated with these were ignored for the purpose of this study.

4. Assessment, Conclusions and Further Work

Each case study part was investigated with the aim of best-matching mass, balance (around each axis) and inertia. This was done by considering each property separately and then concurrently through changing the success condition. It was found that designs with overall low densities were easier to replicate than large, dense objects using the method proposed. It was also found that relaxing or removing a mass property requirement improved the chances of a solution being found. Further work is proposed that investigates changing other process parameters (infill pattern, number of top/bottom layers etc.), uses multiple materials and considers what can and can't be printed successfully. Otherwise, alternate methods of adding concentrated masses to parts should be considered.

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ASSURING CONSISTENCY OF BILLS OF MATERIALS USING A VISUAL COMPUTATIONAL APPROACH

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Multiple bills of materials (BOMs) are used at different stages of a product life cycle. For example, a Design BOM would be the first one. Other common ones are as Assembly BOM, Shipping BOM and Maintenance BOM. There are also other BOMs not perceived at the outset. New BOMs are necessary to be consistent with others. We regard multiple BOMs as different ways of seeing a given artifact. The research behind this poster is establishing the design science needed to create such configuration tools. Our vision is for a new generation of BOM editors which, like today's solid modelling systems, allow only valid[1] BOMs to be defined. These editors will be a core part of future design systems that will exploit underlying lattices to overcome issues associated with discrepancies between BOMs that have a detrimental impact on the performance of product development processes by wasting time and creating rework.

The poster builds on previous research (Chau et al. 2016) that successfully embedded bills of materials (BOMs) into design descriptions using boolean lattices (Birkhoff 1967), a construct of order theory. In this way we demonstrated that boolean lattices can be used to underpin a new generation of design tools that allow multiple BOMs to be configured and superimposed on a given design description. However, the lattices we generate are large, even for designs with a relatively small number of parts, and the problem is exponential in that, for a design with n component parts, the resulting lattice has 2^n nodes, that represent parts within a BOM, and many more links between nodes which represent potential part-whole relationships. The software prototypes we produced[2] allow users to visualise the lattices that are generated using Hasse diagrams. However, challenging computational problems arise from the fact that lattices we generate are vast, even for designs with a relatively small number of parts. Our conclusion was that engineers should not see or interact with the lattices. Instead, engineers need BOM configuration tools that allow them to work with BOMs; the lattices should sit in the background, acting as a guide, ensuring that only valid BOMs are created and suggesting sub-structures that are valid and of possible interest for the design concerned.

In this poster we introduce current thinking on how we might support two kinds of BOM related activity: consistency checking of pairs of BOMs, a form of mereological analysis, and creation of new BOMs consistent with others. In both cases we exploit a join-semilattice constructed from individual

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[1] In solid-based CAD systems, users can create shapes that are not the ones they intended but all shapes are valid solids. Similarly, it will be possible to create a BOM that is not the one intended but it will be a valid BOM for the design from which it was generated. A valid reconfigured BOM will be complete and compatible with other BOMs for the same product.

[2] Four versions were developed and are available on GitHub: StrEmbed-4 (https://doi.org/10.5281/zenodo.889272) is the final version, published September 2017).

BOM tree structures. We illustrate these functions in a prototype BOM editor software tool using a test case based on the design of a torch. Further work is planned to explore the use of join-semilattices to reduce computational complexity.

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Impact of a Sketch-Based Tutoring System at Five Universities

Changing Homework Achievement with Mechanix Pedagogy

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1. Abstract

Introductory engineering courses at large universities often have large enrollment numbers, making more detailed feedback to students; classwork and homework difficult. Often times these classes evaluate students' understanding of material using online text-only systems, or through simple multiple choice questions, neither of which provides optimal feedback. Often times these homework systems provide binary correct or incorrect responses. This format of grading gives little to no additional information to assist in students understanding of the material, while doing little to facilitate understanding of missed portions of the content. Additionally, these systems often fail to encourage students to sketch physical systems as simplified representations in the form of free-body diagrams (FBDs). These concerns have some engineering educators believing that students may have limited ability to idealize real-world systems, and have created an opportunity for interactive sketch tools for use in engineering education.

Sketch Mechanix is an online sketch recognition tool built at Texas A&M, Sketch Mechanix is an online sketch Recognition tool built at Texas A&M, which is used to provide introductory engineering students feedback and additional tutoring in the process of drawing free-body diagrams to solve a variety of statics and dynamics problems. The application allows students to virtually draw the FBD and using Artificial intelligence algorithms to give students instant feedback as to whether or not the diagram is missing any components, while also reporting if the proposed solutions to the force values found within the problem are correct. Automated sketch recognition using these AI systems gives iterative real time feedback to students. This feedback is more substantial that other online homework applications, while also being quicker than feedback given by paper submissions graded by the instructor of the class. Additionally, Sketch Mechanix provides a sketch interface that allows for students to draw the FBDs of more complex open ended problem, and through a creative design problem allows for the iterative development of complex truss systems, that would be difficult to provide constructive feedback if a traditional homework method was used.

The application is being used as an educational tool at 5 different universities, with it being deployed in introductory classes in Statics, Aerospace engineering, Dynamics, and mechanics of materials. The classes that deploy Sketch Mechanix as part of the class curriculum randomly separates the class or classes at the university into two separate groups, having once group use traditional homework methods while the other group uses Sketch Mechanix to complete identical problem sets. Students' knowledge is measured using

a comparison of Physics, Statics, and Dynamics Concept Inventories taken both at the start and conclusion of the class. Specifically chosen exam questions are also used to compare students understanding of the material, as well as their ability to free-hand sketch FBD representation of complex problems.

Past data and Preliminary results show that Sketch Mechanix performs just as well as traditional homework methods in improving introductory student's understanding of the material, while also significantly improving at risk student's understanding of difficult concepts and reinforcing all students understanding of the overarching concepts of these introductory courses. The application shows signs of reshaping engineering education, allowing for increased understanding and feedback than what is offered by traditional online homework methods. The intent is to assist in the growth of the modern twenty first century engineering classroom, as the application is poised to assist instruction in classroom environments that are entirely virtual, while also providing more feedback in today's ever modernizing classroom setting and shows signs of being a powerful tool in strengthening a students' ability to conceptualize complex engineering problems.

PARALLEL VS. ITERATIVE PROTOTYPING IN AN INTRODUCTORY UNDERGRADUATE ENGINEERING COURSE

An Investigation into Prototyping Strategies in a Mechanical Engineering Context

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1. Introduction & Background

Engineering design often involves prototyping at various points during the design process. Prototypes allow us to learn about the form, feel, and function of our ideas so that the end-product matches customers' or users' needs as closely as possible. However, it can be unclear exactly how to go about the prototyping process. Two prototyping strategies that commonly show up in design-related literature are parallel prototyping and iterative prototyping (Dow, Glassco, Kass, Schwarz, & Klemmer, 2009; Hartmann et al., 2006; Little, Chilton, Goldman, & Miller, 2010), though few experimental studies have been conducted on the topic because parallel prototyping can be time intensive and expensive (Camburn et al., 2017). A study published by Dow et al. most closely matches the work presented on this poster (Dow et al., 2009). They presented two experiments: a web advertisement design problem and the classic "egg-drop" design problem. Results included a comparison of design success to serial (iterative) vs. parallel prototyping strategies as well as participant self-efficacy. Their results indicated that the parallel condition performed significantly better on the web advertisement problem than the iterative condition and results were generally inconclusive for the "egg-drop" problem. The research presented on this poster adapts this idea to a mechanical engineering design context in an introductory undergraduate course.

2. Methodology

This study involved a design competition integrated into coursework for eight weeks of a semester. The competition required students to design and model a foam ball launcher that would earn them competition points with scoring similar to a game of darts and an added challenge of distance penalties. 3D printing of the students' prototypes was handled by research personnel with utilization of a 3rd party printing service to help handle the volume of prints. The study was conducted in a single classroom environment where students were randomly divided into two experimental conditions: an iterative condition and a parallel condition (each experimental condition were aware of the other). Every student designed three prototypes (two prototypes and a final design) with a comparable amount of time for project deliverables. Notably, students in the parallel condition were required to submit their first two prototypes simultaneously whereas students in the iterative condition were required to submit their 1st and 2nd prototypes in succession. All final prototypes were submitted at the same time for both experimental groups.

Data collection included pre and post engineering design self-efficacy (EDSE) (Carberry, Lee, & Ohland, 2010), competition performance, and an exit survey. This data was then analyzed by comparing results to the two prototyping strategies through a variety of statistical methods including but not limited to ANOVA techniques, t-tests, and chi-squared tests to name a few; inter-rater reliability was also considered and is reported.

3. Results & Discussion

Results from the study show significant benefits to parallel prototyping strategies from a number of different angles. First, students in the parallel condition were statistically significantly more likely to get a foam ball into the target than students in the iterative condition using a chi-squared test. Second, students in the parallel condition showed statistically significant improved engineering design self-efficacy with an increased in Confidence and a decrease in Anxiety while students in the iterative condition showed no change in engineering design self-efficacy. Third, the post survey indicates that students in the parallel condition strongly would have preferred to be in the iterative condition, whereas students in the iterative condition strongly were satisfied with their random assignment. This suggests that the students were largely unaware of the benefits offered by the parallel prototyping strategy.

4. Conclusion

This work takes a first step towards understanding how different prototyping strategies affect the design process. Based on the results, parallel prototyping strategies showed increased confidence, reduced anxiety, and better design success in the competition. In addition, students seem to be unaware of the benefits of parallel prototyping based on exit survey responses. This research provides strong evidence for the benefits of parallel prototyping through a controlled study and a novel approach that informs how prototyping strategies are considered during the design process and serves as a foundation for future research on the effects of various prototyping strategies.

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INTERPRETATION OF LISBON ELEVADOR SANTA DE JUSTA AND SURROUNDING AREAS INTO ARCHITECTURAL SPACE FOR VIRTUAL REALITY AND DIGITAL ART.

A case study in NEOS VR - Social VR Platform

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1. Lisbon City Center and Elevador de Santa Justa / My Research Questions, Method.

Actions from the physical world are moving to the virtual world online. We communicate online, we work with online information, we study, we search for information, we socialize online, we share information online, we relax by reading texts and watching videos, we play games, we shop online. We use websites to search for information in 2D screens of smartphone, tablets and computers. What if in future the online actions will happen in online 3D virtual shared worlds in social VR platforms like NEOS VR? Should virtual reality spaces be designed by architect, artist and with collaboration with IT specialist? What kind of activities will move into virtual reality online worlds? What kind of movements will define new types of activities? In my case study Lisbon, I was focused on movements, flying and teleporting in space on different levels 'VR miradouros'. In my VR case study, elevator Santa de Justa is transformed into a statue where we can teleport ourselves up or down. I worked mainly by using the method research by design, I was searching for supporting materials in literature and art as well.
I spend almost two months in the wonderful city of Lisbon at the ISTAR-Information Sciences and Technologies and Architecture Research Center (ISCTE-IUL). ISTAR had the equipment for virtual reality, so I could test my projects in NEOS VR, with VR headset. My visiting research was under the supervision of Professor Sara Eloy. I was searching for the essence of Lisbon. Of course, Lisbon is a city full of hills. There are old yellow trams and elevators helping people to move easily uphill and downhill in the city center. Today most of the trams and elevators are tourist attractions. One of them is Elevador de Santa Justa. It is a lift that was transporting people from Rossio area to Chafariz do Carmo near Praça Dom Pedro IV square in the center of Lisbon. Elevador de Santa Justa is made of iron with filigree details, it was built in 1902. The history of the surrounding area is very interesting. In November 1755 there was a huge earthquake in Lisbon, there were fires everywhere in the city. After that, a huge tsunami came. This combination of catastrophes destroyed most of the Lisbon*…' From this chaos emerged the Marquês de Pombal who, with the approval of the King, immediately brought order and began to develop efforts to create the new Lisbon. The effort first focused upon the development of four options that included rebuilding the city as it was, reconstructing the city with minimal improvements to the street pattern, undertaking a total rebuilding effort or starting fresh on a new site. '*(Mullin)

New Lisbon around the Baixa was planned as simple straight streets leading to Tagus river and with same rectangular city blocks. If you look at the map today, you can see clearly what was built as new in the city and what remained. Hills were not damaged by the tsunami, so they still have very old, tortuous, devious and oblique street structure. A typical example of that neighbourhood is Alfama. I was interested in the new urban plan from 1755 that surrounds Elevador de Santa Justa because it is a very innovative urban plan that was built much earlier than for example famous Eixample urban plan from Barcelona from 1860. For my case study, I worked with plans, maps, photos. I did a personal observation of the site and the elevator. I visited galleries in Lisbon, and I got inspired by the artist, painter Maria Helena Vieira da Silva and her interpretations, paintings of the cities. My artistic agenda, my goal what I wanted to achieve with the Lisbon

case study, was to show that virtual space can be derived from real site and existing city like Lisbon. My strategy how I interpreted Lisbon and the area around the Elevador Santa Justa was my artistic creative vision. I saw on the paintings of Maria Helena Vieira da Silva (1908-1992) rectangular elements, something like a grid, but irregular, blurred, poetic but related to the existing structure of the city like Lisbon and Paris. I had an idea that some levels like these fields from Silva's paintings, can float in the virtual space in NEOS VR. I was not reproducing the literal model of Lisbon, but I went through my interpretation, using a new medium. In virtual space in virtual reality, we are in a totally different situation than in physical space. The body of our avatar in VR have a new type of possibilities how to move in VR. We can fly in the body of an avatar and we can teleport to places we need. The essence of moving through the city in Lisbon centre is walking up and down or using elevadors and trams. My interpretation of the elevator Santa de Justa and the movement up and down in VR is just creating a virtual statue. This statue is like in an arrow that points to the floating levels that represent viewpoints – miradouros. The miradouros are specifically located in Lisbon to offer views of the city. This fact returns in my NEOS VR world. If an avatar approaches the floating-level with blue tile, the texture changes and shows some photo of the Lisbon miradouros views. Some aspects that I wanted to achieve was to create immersive 3D virtual space in NEOS VR the questions the boundary between digital art and architectural space for virtual reality.
Vincent Guallart writes about the meaning of the word *digital*: *"New Technologies make it possible to transform data flow to the point of creating authentic landscapes. Spaces with or without gravity. The paradigms and the physical laws of the real world are not necessarily applicable to the virtual world. But this virtual world could be a clone of a real world or generate infinite possible spaces, like a world with infinite times and therefore infinite possible, parallel histories. Quasi-real spaces. An acoustic space: a music room. A fractal trajectory. A mountain of infinite dimensions. A cloudy dawn: a city. Settings for virtual meetings and real use. Spaces and computer programs accessible from an intermediate space that can lead to a virtual world full of real content."*

2. My Type of Results

My results are digital 3D model textured in Rhinoceros, renderings from Rhinoceros, digital 2D collages created with vectors and renderings, 3D model textured in NEOS VR. Static functional virtual reality world with the possibility to fly around the model and through the 3D model.
Finally, I think that social VR platform Neos VR shows the opportunity for architects and artist how to test ideas that could never be built in the physical world. I could see Lisbon in a more fantastic way and connect art with architecture in VR. It changed my ideas about how NEOS VR works because I would need more collaboration with VR specialist to solve all problems. I change the Lisbon into floating VR miradouros with arrow statue interpretation of Elevador Santa de Justa.

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Archive online (results for "Elevador de Santa Justa") http://arquivomunicipal2.cm-lisboa.pt/sala/online/ui/SearchBasic.aspx

Pictures in the following pages are digital art interpretations that also resulted in my case study Lisbon.

The first image shows floating VR levels and arrow VR elevator Santa de Justa. The second image shows the top view of the surrounding area, the grid of the city blocks.

"DESIGN IN THE SEMI-WILD":

Exploring a virtual tutor studio pedagogy in engineering design

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Abstract

The opportunity to teach, learn and assess problem finding, framing and construction, remains largely unavailable for students to learn and for tutors to teach and assess during academic terms. The context of professional engineering practice is required in order to learn these important design skills. In this case study we explore a novel adaptation of studio pedagogy where students are located in the wild, in authentic professional practice settings during their cooperative educational internships, while tutors remain on campus. In the wild, students have the opportunity to engage with authentic problems. Virtual technology is used to involve a tutor and for both tutor and student to engage in a weekly virtual studio where tutors and students engage in reflection about the problems they are trying to find, construct and solve.

We characterized the tutor and student interactions for the 13, one hour sessions using topic analysis, and problem-solution interaction analysis amongst tutors and students. We found that reflective conversations in the virtual studio are dominated by student-student interactions that are closely related to movements within the solution space. Where there are interactions between tutors and students, they are closely related to movements in the problem space.

Our study findings suggest that tutor to student interactions *pull* students from the solution space they are so reliably operating in, into the problem space. We nevertheless acknowledge that this was an "in-situ", exploratory study and we are thus cautious that these findings may not generalize to other, similar settings. Future studies could test these findings in more controlled settings.

PROOFING A BASIC SYSTEMS ENGINEERING MODEL THROUGH EMPIRICALLY-BASED COGNITIVE TESTING

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Abstract

The scientific study of engineering systems and design (Kasser 2020) requires both theoretical models and empirical testing. This research addresses the gap in our knowledge of testing theoretical, descriptive models of engineering systems design with design behavior derived from empirical studies. A novel approach to representing theoretical, descriptive models of engineering systems design is utilized to produce a representation commensurable with cognitive modeling. A pilot study has shown the applicability of the approaches to be used and has demonstrated that commensurable quantitative results can be obtained (Kannengiesser & Gero 2015).

This project develops a cognitive characterization of engineering systems and design (ESD) through an empirical protocol analysis approach studying teams of professional systems engineers designing under controlled conditions and compares it to the INCOSE engineering systems design descriptive model (INCOSE 2015). The protocol analysis is based on the hierarchy-augmented FBS ontology-based coding scheme that codes hierarchization of cognitive actions (Kan and Gero 2017). From this empirical data we can determine the systemization of the design activity through decomposition/recomposition actions.

This project involved the following steps: collecting protocols from professional engineers, analyzing the protocols, modelling design cognitive behaviors from the protocols parallel to modelling INCOSE's descriptive model. The table below presents an overview of the project. This poster presents preliminary results from the re-representation of the INCOSE model and the preliminary results from a set of think-aloud protocol studies of systems design by professional engineers, the last part of the project (shaded in the table).

Comparing theoretical models of engineering systems and design with empirical results provides an opportunity to test and refine theoretical models, like INCOSE.

PROBLEM	APPROACH	EXPECTED OUTCOMES
Cognition of engineering systems design of engineers designing to be characterized using an approach that produces commensurable results.	Video protocols of experimental sessions are coded to characterize quantitatively the ESD cognition of teams of professional engineers.	ESD cognition of professional engineers designing is characterized through empirically-based quantitative models.
INCOSE systems engineering model needs to be represented in a representation commensurable with cognitive results.	Translate the INCOSE ESD theoretical, descriptive model into an ontologically-based design model.	INCOSE ESD theoretical, descriptive model now represented in the same form as empirical results.
INCOSE systems engineering model of ESD quantitatively measured against cognitive characterization of ESD.	Use empirically-based models of ESD cognition and INCOSE ESD design model as basis for statistical similarity and difference measurements.	ESD cognition characterized from empirical data and INCOSE ESD model tested against empirical results.

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CULTIVATING MOTIVATION THROUGH DATA VISUALIZATION

An exploration of self-tracking data visualization design strategies that cultivate motivation of doing exercise among college students

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1. Abstract

We are information receivers and, at the same time, data producers. There are more than 160000 tracking apps available on both iOS and Android platforms (Lupton 2016), which provides opportunities to track exercise, weight, diet, sleep, mood, etc. Driven by the ever-increasing availability of these self-tracking data, this study explores the data visualization design strategies that can create an incentive for exercise among college students. The researcher assumes that users at different stages of exercise adoption may need different types of data visualization to trigger their motivation. Therefore, this study adopted the ***Health Action Process Approach*** (HAPA) model (Schwarzer, 2008) and categorized users (college students) into three groups – *Preintenders, Intenders, Actors*. The purpose is to explore what and how visual design strategies for self-tracking data can motivate users at different stages of exercise adoption.

There are two phases in this study. In the first phase, in order to know what data visualization design strategies have been used in existing health & fitness mobile applications and to categorize them, the researcher conducted a *design strategy analysis*. Screenshots were collected from the selected self-tracking mobile applications (n=95). An *Affinity Clustering* was used to categorize those screenshots. By the end of this analysis, a list of common data visualization design strategies under four categories with several subcategories has been defined. Each of those design strategies cooperates with an example screenshot for further analysis. In the second phase, *semi-structured interviews* were adopted to uncover the user-centered values of those proposed design strategies from a human-centered perspective. Interview participants (n=33, out of around 150) were recruited from three undergrad classes at North Carolina State University in Fall semester 2019. Through a screening survey, participants were sorted into three groups: *Preintenders* (n=8), *Intenders* (n=12), and *Actors* (n=13). Video recordings and pictures were captured. Opinions and behaviors were both assessed.

In total, eighteen design strategy concepts were generated under seven themes. A list of design suggestions was created to help design practitioners to visualize self-tracking data for users at different stages of exercise adoption.

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UNDERSTANDING USER EXPERIENCE OF INTERNALLY TILED MOLDABLE ACTIVE TEXTILES

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1.Abstract

Recent technological advances enabling airtight surfaces that can transition from soft to rigid states on demand by using differential air pressure have enabled myriad applications in various fields. Examples are ranging from medical applications such as a moldable medical cast that can be tailored to different users and can be reused (Mitsuda and Matsuo 2005), a wheelchair positioning device to correct the posture of stroke patients (Veneman et al. 2015), wearable variable stiffness structures in rehabilitation context (Sadeghi et al. 2019); to applications in human-computer interaction field and to consumer products such as flexible displays with controllable stiffness capabilities (Matoba et al. 2012), furniture and footwear with reconfigurable jamming parts (Ou et al. 2014). Potential applications based on this fundamental technology can be extended to entertainment industry with active textile surfaces that can be used as wearables with haptic feedback for more immersive gaming experience, or to transportation industry with moldable surfaces, which can be shaped over arbitrary geometries, constraining them for the secure transportation from one location to another. The operation of any of these potential applications using moldable active surfaces requires user interaction. Since there is a shared underlying technology among these applications, the operation principles that affords user interaction can be broken down into three common stages. In order to mold an active surface into an arbitrary configuration, a user needs to be 1) *draping* it over an existing object or group of objects, 2) *shaping* it by conforming the surface to a particular configuration, and 3) *rigidizing* it to maintain the intended configuration by introducing the vacuum pressure in the airtight system. Current studies mostly focus on advancing engineering aspects of moldable active surface technologies in terms of architectural design to improve particular operation performance such as producing better stiffening in isolation without considering user interaction aspects through operation stages. Although technological improvements are crucial for successful product design and development, the nature of the interaction that will take place between users and applications that are equipped with such moldable active surfaces will be of equal importance, coupling the development of technologies and their users' experience. However, researchers often overlook the user experience component of the demonstrated implementations of these technologies in the current state of the art, potentially suggesting inappropriate or unnecessary product solutions.

This study presents a framework linking the technological development of internally tiled moldable active textiles to the user experience aspect of implementing these textiles as user-interacting products. As a part of the study, a class of technological approaches for designing internally tiled active textiles that provide moldability with various tailorable performance-balancing aspects is developed. The architecture of internally tiled moldable active textiles is based on layers of rigid tiles arrayed in regular patterns within an airtight bladder, enabling its stiffness to be controlled as a function of vacuum pressure applied. Because of the ability of adjacent tiles to move relative to each other, it provides a thin profile surface that can be molded into arbitrary complex geometries. In relation with interaction steps, the operation stages for the active textiles are defined as draping, shaping, and rigidizing. Multiple quantifiable engineering performance metrics corresponding to each operation stage are characterized. A half factorial design of experiment investigating the tile geometry parameters on these quantifiable engineering performance metrics is conducted. A predictive modeling approach using empirical data to understand the mechanically complex behavior of the internally tiled active textiles is developed. This analysis produces a model, which relates tile geometry parameters to engineering performance outcomes. This enables a method for selecting a specific set of tile geometry parameters to tailor the trade-offs among engineering performance metrics in order to obtain intended design outcomes in terms of quantified engineering performance metrics.

Subjective perceptual metrics per operation stage are also defined and empirically related to the objective set of engineering performance metrics corresponding to each operation stage. A pilot user experience study is conducted using systematically differentiated active textile prototypes to discover the users' perception of the engineering performance metrics. Data are collected for each operation stage by having users compare systematically randomized pairs of active textile prototypes with different levels of engineering performances to evaluate which active textile prototype within each pair is perceived as providing relatively better performance. A combination of quantified statistical methods such as logistic regression and BTL modelling with MLE analysis is used to produce a model showing the relationship between the subjective data ranking the active textile prototypes' perceived performance per operation stage and objective engineering performance data.

Furthermore, the engineering model can be combined with user experience model. Since the engineering model relates the tile geometry parameters to engineering performance metrics outcomes and the user experience model relates these engineering performance outcomes to subjective perceptual metrics, these two models can be combined. This combination provides the ability to predict user's perception of moldable active textile performance directly from the tile geometry parameters, and thus enables holistic design of the product including both engineering and user experience aspects. General approaches developed in this study applies to the design of many user-interfacing products with multiple stages of operation by providing a systematic link between technology development and user experience aspects of its implementation as or as a part of product.

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CROSSING DOMAIN BOUNDARIES WITH GRAPHS

Finding Hidden Affordances Through Relations

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Abstract

Cognitive maps are accepted methods of representation for abstract reasoning in different degrees of complexity. Increasingly concepts that have matured in the design and architecture domain as cognitive models for perceiving space such as space syntax and visibility graphs or production systems to define solution spaces through combinatorics (i.e. shape grammars) are being used in spatial programming and real-time decoding in robotics and computerised decision making algorithms. (Li, Claramunt and Ray 2010)

Our research approaches the problem of networking available information between Architecture, Engineering and Construction (AEC) expert domains. While doing so, auxiliary meta-models and graph structures that take into account spatial proximity, connectivity relations, self similar structures and assemblages are created. (Bermek, Gentry and Shelden 2019)

To this end we sift and combine IFC data through rule based feature derivation and spatial analysis. IFC is the main interoperability standard in AEC workflows concerning Building Information Modelling (BIM) and is partially Human Readable in a similar fashion to Web Ontology Languages (OWL). Furthermore IFC can be mapped to this latter standard knowledge modelling method or any other Graph Data Base (GDB) directly. (Pauwels and Terkaj 2016)

The advantage of rendering explicit the relations (edges) between the constituents (nodes) of the design product is that of being able to create flexible groupings to establish abstractions without information loss (edge contraction). This is achieved based on inferred or implied relations between the components of the whole. This structure permits generate detailing that is not hierarchically related to defined elements of the design space (subdivision).

Considering the act of designing as a reflective practice that runs across these networks of relations for taking decisions. Our model finds design affordances to be similar attribute sets nested in separate domains. (Donald 1999) A common occurrence of these matchings are the casual knowledge bits spun in visual narratives and touted as “life-hacks” that dominate automated content suggestions of content sharing platforms (e.g. YouTube, Instructables, etc.). (Kate 2016)

The hypothesis is that a structured network of concepts, propositions, limitations and representations of physical elements can be used to automate, propagate or customise design decisions over complex networks. The poster will visually walk through the mentioned processes and provide real world examples and proof-of-concept implementations.

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POSTER. SELFHOOD AND PROXIMITY

Maps of Identity in Self-Organizing Social Systems

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1. Social construction of meaning from collective action

In the attempt to understand how people make sense of the social world, and to dimension the role of designed artifacts in that process, we embrace the metaphor of the social as a boundless and continuous fluid (Mol and Law 1994). Social fluidity is currently explicit in the collective construction of identity, the constant restructuring of the social fabric consequence of social and spatial mobilities, and the continuous reinforcement of values and norms. In all of these, the combination of social actors' traits and their local circumstances determine how accurate their perception of social events is. We believe that simple models of emergent social self-organization serve to study such fluid by observing the turbulence and vortexes of attraction resulting from the concurrent action and interaction of all kinds of human and nonhuman actors (Summers-Affler 2007).

Our approach here is to study the consistency of shared social meaning. Social meaning is derived from individual actions that entail both a subjective and objective facet. While the subjective meaning of an action is the one attributed by the actor, the objective one is the one inferred by the observer of such action (Schutz 1972). Assuming that human actors are intrinsically driven to consistently enact their programs of action, the fluidity of their action flow depends on their constant effort to reconcile the objective meaning of their last performed action and the subjective meaning ascribed to their subsequent one. Our studies reveal that the consistency of aggregated social action is compromised when the distance between the subjective and objective meanings of a critical mass of agents either converge or diverge in streams of action, provoking a sort of social viscosity: the discrepancy between the expected status of the world and the current, collectively enacted status (Salamanca 2019, Salamanca and Nuñez-Corrales 2019)

2. Emerging maps of the self in relation to others

In order to observe and measure the effort to reconcile the discrepancy between subjective and objective meaning of social action we developed a participatory simulation under the premise of perceived chromatic proximity to one another. This simulation informed an agent-based model (ABM) of self-organizing agents that reproduces the dynamics observed in the participatory simulation (Salamanca and Nuñez-Corrales 2019). Our model is an adaptation of Shepard and Cooper's seminal color sorting experiment intended to demonstrate the isomorphic relationship between the similarity space of human internal representation of colors and the similarity space of the perception of the same colors (Shepard and Cooper 1992). In the original experiment each subject was asked to sort a deck of cards by the perceived similarity of two colors displayed on each of them. From the sorted cards the researchers computed similarity correlations and non-metric multidimensional scaling (NMDS) analyses. The results demonstrate the expected isomorphism and revealed that Newton's color wheel is a mental model shared among subjects. In our participatory simulation, subjects impersonate one unique color and are asked to place themselves near or far away from others with similar or dissimilar colors respectively until they find a comfortably distance to all their neighbors in the room. In organizing themselves, a fluid topology

emerges from the trajectories of action until they surprisingly converge in a Newton's color wheel.

The perception-action cycle underlying the self-organizing dynamic is summarized in four stages. Each agent: i) Selects neighbors. ii) Interprets the objective meaning of the current status of the world by computing the chromatic proximity to each neighbor. iii) Assembles the subjective meaning of her following action by translating the chromatic proximity into desired physical proximity. iv) Moves to the estimated position. Then the cycle starts over until the group reaches a minimal discrepancy between the expected and the current physical proximity. The ABM yields two important outputs. First, a dataset and a visualization of the social viscosity of the system over time. Second, a variation of the Unified Distance Matrix (U-Matrix) used in Kohonen maps displaying the temporal discrepancy between the optimal distance to all agents and the current distance. Outputs available at https://smartartifact.com/ColorAgents.

3. Identities from situated interactions

We found phase nucleation (Kelton and Greer 2010) to effectively describe the process of self-organization in our model. Nucleation is the progressive organization of small units into stable structures, known as phases. Convergence and reversions served us to interpret the data yield by the ABM. *Convergence* characterizes how long a group of agents takes to reach a stable color scale. *Reversions* quantify the number of times when social viscosity increases. From a series of ANOVA and MANOVA analyses on independent variables such as the number and selection of neighbors, and the tolerance to imperfect proximity we conclude that the fundamental reason of convergence into a color wheel is the unified color mental model shared by the participants. However, the number of neighbors is critical. The higher the number the interactants the faster the time to convergence. This is viable in the ABM but not feasible in actual social interaction because humans cannot interact concurrently with more than 5 neighbors. In order to speed up social nucleation it would be necessary to use technologies purposely designed to break social isolation and negotiate user's actions based on their identities, in the same fashion recommender algorithms work. Our analysis suggests that tolerance to imperfect compliance with norms and a degree of tolerance with own beliefs decrease coordination efforts. In addition, our research suggests that social viscosity is a proxy measure for the cost of social organization, which can in turn be used to inform the design of socio-technical systems.

We are currently exploring two scenarios that challenge the need for a uniform color model. One investigates the effects of mixing two groups with different color models simulating the interactions of subjects from diverse cultural backgrounds. The other investigates how clean-slate agents unaware of their own color can develop a notion of their identity based on the interactions with their neighbors. Early empirical observations show that clean-slate agents need the lowest degree of tolerance to imperfection in order to effectively participate in self-organizing processes.

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GRASPING CONTEXT IN COLLABORATIVE DESIGN

An approach for handling diverse description in discontinuous design data

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1. The Opportunity in Design

The design and development of a large complex system is a socio-technical process with information as a notable flow (Moscoso 2007).

This flow contains system description in the form of data across multiple environments that is structured to support local processing, through information and software features such as object models, hierarchies, workflows and user views (O'Brien 2010). These features are rarely entirely (and often not at all) architected by the design agents, which results in partial meaning capture due to loss of context and makes description discontinuities in the data difficult to overcome (Harvé 2008). Some of the context that is important to reliable meaning reconstruction is difficult to assimilate into the data (Bellotti and Edwards 2009), for example epistemic uncertainties. In addition to these technology-driven factors, the tendency of larger teams to branch into insular sub-teams with local terminology further exacerbates meaning loss and communication break-down.

The net result is that an enterprise developing a single complex system will often contain several unreconciled information siloes within it. Some consequences of this are that relevant information is unavailable to design agents' as they make decisions in the course of their work and any global design trading that bridges two or more information siloes depends on social mediation, which introduces bias, human error and inhibits optimisation.

2. How the Research Contributes

System description co-evolves with development goals in a situated decision-making dynamic as explained by Gero and Kannengiesser 2004. This precludes treating the problem statically, deterministically or from a single point of view, all of which are prevalent presuppositions in business analysis for information technology investment projects, which Sumner relates often fail due to inability to "meet the goals and requirements of users" (1999). The basic premise of the research is a corollary of Nakata's findings for the case of enterprise description (2001), whereby inclusion of the actors in the process of architecting the system yields better outcomes.

For reliable and fast communication of meaning in complex system development, the context through which members of the design team interact with descriptions of the system must be adequately handled, no matter what information technologies are involved.

The research presents an approach that considers the full context that imparts on situated decision-makers within a complex product development process, as they work to create, transform and combine inherently partial descriptions of the system. The approach uses elicitation and suggestion as each decision-maker interacts with system description data, providing broader discovery and deeper understanding concurrently with capturing and rationalising descriptive language as fragments of contextualising networks of terms, both within and beyond the physical

data. This map of description is managed employing semantic graph methods and can be initiated by ingesting at scale from relevant data sources using techniques from the field of natural language processing (NLP).

This subject of context management is a key theme in the field of artificial intelligence and particularly for moving towards more generalizable and aggregated systems. This research presents a novel approach in which the human role is pivotal to orchestrating the information environment by empowered inclusion in the process of managing the description landscape.

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A PRELIMINARY STUDY OF USER INSTRUCTION LOG IN COMPUTER AIDED ARCHITECTURAL DESIGN

A pilot investigation on Rhino 3D-modeling

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Abstract

It is necessary to understand the nature of design which is a highly sophisticated process for the development of intelligent computer aided architectural design (CAAD). Protocol analysis has long been a dominate method to study design process. As the fast development of CAAD tools, enormous user logs have been produced as by-product in due course which is a valuable resource for the study of computer aided design process nowadays, however little attention was paid on this. In this research, an alternative approach was adopted, user instructions given during the 3D modeling process on 'Rhino' were collected and analyses. A novel data collection approach was applied and new analysis method based on FBS model was proposed to study the CAAD process.
Keywords: design process, design research, CAAD, user log

1. Introduction

It is necessary to understand the nature of design which is a highly sophisticated process for the development of intelligent computer aided architectural design (CAAD). The FBS model that was proposed in the 1990s by Gero is a significant ontology theory in the area of design research(Chandrasekaran B, Josephson JR, Benjamins RV 1990; Gero, J. S. 1990). Through the method of protocol analysis, it has been proven that the design process is iterative in nature. Among many past research works on this topic, one of the most representative thesis was by Gero on the FBS model based approach to the analysis of design protocols (Gero, J. S., & Mc Neill, T. 1998). However, the current research efforts have not yet been applied to the intelligent CAAD work in practice. In recent years, the CAAD tools have been developed at fast pace, playing an essential part in design process. Interestingly, enormous amount of data have been produced as by-product in due course. Meanwhile, human machine integration has emerged a key topic in intelligent CAAD research (Shih, Y. T., Sher, W. D., & Taylor, M. 2017; Lee, H., Kim, J., & Banerjee, A. 2010; Yin YH, Zhou C, Zhu JY 2010) that our design efforts have been both supported and limited by the computer tools that are currently in use. Therefore, it is necessary to take into consideration of such impact and conduct further research in computer design process as part of intelligent CAAD development program.

It has been acknowledged by many researchers that design activities are intuitive. Gero states that the designer's perception plays an important role in creative design (Gero, J. S. 1990). Shah suggested that design works are also driven by, apart from logical thinking, subconscious intuition (Shah JJ 1998). Intuition is a unique feature of biological brain activity (Kahneman, D. 2011),

which cannot be programmed using logic loops. It is problematic to apply verbal report protocol analysis to the intuitive design process due to the fact that the statement given by the designer could inevitably be incomplete. Therefore, an alternative approach was adopted, user instructions given during the 3D modeling process were collected and analyses in this research.

2. Research Method

Automated backstage instructions recording plugin was developed for "Rhinoceros", a widely used design software in the global architecture design industry. Real-time data was collected on:

a) All commands given and the active-view shot at the time

b) Geometric information of the Rhino-objects created in the system

This research was conducted in collaboration with a leading international architecture design company(top 10 listed according to WA100 2019). Two experienced designers responsible for the modeling task of a mixed-use project at conceptual design stage took part. User instruction log was collected for one month that a phased modeling task is completed. The data collected as described above does not contain the reasoning behind the design process. To compensate, using the FBS model, statistical analysis was conducted in both command-oriented and geometry-oriented ways.

3. Results and Discussion

User instruction log in 3D modeling design process is valuable resource for the study of intelligent CAAD nowadays, which have not been paid enough attention in the field. In this research, a novel data collection approach was applied and new analysis method based on FBS model was proposed to study the CAAD process. It was discovered that the computational records of 3d modeling design was in line with the FBS model. More patterns may be discovered by putting individual variable under scrutiny. The results show some similar features of design behavior in CAAD process.

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BIAS EVALUATION MATRIX

A Method for Process Design

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Introduction

Design can be understood as a series of changes made by a designer to solve a problem (Gero 1990). The allocation or deployment of a resource, a change if you will, is defined as a decision. Thus, designers are engaged in making a series of decisions. It follows that a principle objective in the study of design methodology is to aid design teams in decision making. Empirical study has shown that cognitive patterns affect decision making. Example behaviors are fixation, or empathy. These can be managed to improve design outcome. Neuroscience and cognitive psychology researchers have mature models for cognitive behavior and cognitive biases. Cognitive biases have been extensively studied as they represent recurring errors in human responses to given scenarios. This study aims to translate bias models into design as a lens for process improvement. A method to evaluate cognitive bias potential at the process level is proposed. The following research questions are proposed (given a proposed bias taxonomy, and evaluation framework): 1) *Using human assessment by multiple raters, are there significant differences in perceived bias potential between different design methods?* 2) *Do these differences in perceived bias correlate with design performance measures?* Together these will help to identify strategies to mitigate or reduce cognitive bias during design.

A method for evaluating perceived bias in a process is illustrate in Fig. 1. The objective is to propose and evaluate a quantitative measure of bias potential at the process level. This measure should also be meaningful across diverse system scenarios. First, an extensive literature review of state of the art in cognitive psychology was conducted to identify a candidate bias taxonomy. This taxonomy is employed in an evaluation matrix method. The objective is to ultimately develop a tool to gradually compare and refine a process until there greatly reduced opportunities for scenarios in which human judgement is likely to be biased away from a desired or logical response.

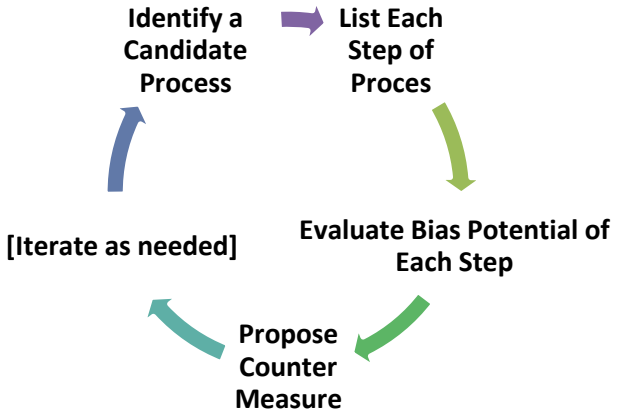

Fig 1. The Concept Methodology for De-biasing Process in design

Methodology and Results

The taxonomy of cognitive biases from Pohl's, Cognitive Illusions is proposed for adoption. It is an extensive collaborative literature review of biases (F.Pohl, 2004). Pohl's taxonomy satisfies several key requirements for a suitable taxonomy in this case: hierarchical clustering (comprehensive), empirical evidence is provided for each type of bias (objective), each bias is validated through multiple replications (suitably verified). There are 21 individually described biases which are more broadly clustered into three basic categories: Memory, Thinking, and Judgement (See Table 1).

The first objective was to test for differences in perceived bias between several design methods as evaluated with the proposed process. A questionnaire was hosted on Amazon's mechanical Turk, crowd survey platform. In each questionnaire the users evaluated whether a step from two differing design methods was more or less subject to bias (See Table 2). The three design methods tested are: Group mind mapping (GMM), Individual Mind Mapping (IMM), and C-Sketch with three steps used to describe each process. They are standardized as preparation, main activity, and follow up for suitability of comparison. A total of 27 one to one comparisons for the evaluation matrix were constructed and 10 iterations for each question, for a total of 270 surveys.

Table 1. Summarized bias taxonomy, (F.Pohl, 2004).

Memory	Thinking	Judgement
• Moses Illusion • Orientation Illusion in memory • Associative memory illusions • Effects of labelling • Misinformation effect • Hindsight bias • Illusions of change or stability	• Conjunction fallacy • Base Rates in Bayesian inference • Statistical formats in Bayesian inference • Confirmation Bias • Illusory correlation • Illusion of control • Biases in deductive reasoning	• Availability • Judgements by representativeness • Anchoring effect • Validity effect • Mere exposure effect • Overconfidence • Pollyanna Principle
"Something is remembered but deviates from the original"	*"[faulty] application of a certain rule like Bayes theorem, hypothesis testing, or syllogistic reasoning"*	*"[a person] is asked to subjectively rate a specific aspect of a given stimulus (e.g. it's pleasantness, frequency, or veracity)"*

Table 2. Bias Evaluation Matrix template

	Rows (perception of bias type)		
Columns (steps of process)	Memory Bias	Thinking Bias	Judgement Bias
Step 1: e.g. Process Preparation			
Step 2: e.g. Core Activity			
Step 3: e.g. Wrap -up			

Results indicate a significant difference in proportions (z value: 2.68) between IMM and 635 in the Memory category at p is 0.00017 (note, $p<0.05$); this could be explained by the fact that mindmapping is purportedly designed to assist in memory retrieval through association. Memory is a critical component in ideation, as evidenced by neuroimaging of the brain during ideation (Kosa 2019). These differences show a similar performance rank between these three methods for ideation metrics (quality) seen in a previous study by one the authors (Choo 2014). In future work, extensive replication efforts are underway to further evaluate the second research question.

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A QUANTITATIVE DEVELOPMENT CYCLE MODEL

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This poster describes a domain-independent product development model that enables objective and quantitative calculation of certain development cycle characteristics. One such characteristic is project resource utilization. Another is design information content as explained by Suh. The model's resource estimation capability is compared to COCOMO and found to provide very similar results for a wide range of input values. The model's calculation of information content is shown to decrease to a minimum value as the modeled development draws close to the desired end product. Suh uses this characteristic to efficiently control the development process; the model adds a bit of formality to the foundation of his methods. This model is a Statistical Agent-based Model of Development and Evaluation (SAbMDE); and it is a constructive model. As such, it provides an explanatory mechanism for the results that it produces rather than merely fitting measured data. SAbMDE appears to be novel with respect to previous design theory and methodology work.

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SYSTEMS THINKING FACTORS AS PREDICTORS OF SUCCESS IN ENGINEERING DESIGN

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1. The Cognitive Profile of Successful Designers

Design is a task performed by a designer, and thus the quality of the design is directly influenced by the knowledge, experience, and cognitive traits that the designer possesses. The cognition underlying successful design has proven difficult to capture, even though its illumination holds great potential for research in engineering design. Systems thinking as a concept has been studied across several fields, and as a result, has been given many definitions. Though a consensus definition has yet to be reached, many have in common two features: it is a cognitive style that deals with systems, and is carried out through a set of cognitive competencies that allow one to understand, solve problems within, and design systems. Moti Frank's Cognitive Competency Model (2012) offers sixteen competencies that are believed to make up systems thinking. Influential and an imperative base for future research, this model was meant to be a theoretical grounding; thus, how these competencies may be measured was not included. To address this concern, Greene and Papalambros (2016) mapped Frank's cognitive competencies to constructs from psychology, offering a basis for future research on cognition within systems thinking. They leave open the possibilities of which psychological tests to leverage. Additionally, research on the relative importance that the different cognitive competencies hold within engineering design is underexplored. Therefore, there is a lack of knowledge of how quantitatively various system thinking factors influence design success.

2. Research Objectives

The objectives of the present study are to address two gaps found in the previous research on systems thinking in engineering design. First, to examine the relationships between a design task representing engineering systems thinking ability and a battery of psychological tests representing Greene and Papalambros' (2016) mappings of Frank's cognitive competencies (2012). Second, to observe which of these competencies are most important when predicting performance on systems design tasks.

3. Engineering Design Task

To quantify performance within engineering design, a design competition was conducted and completed by thirty-four participants. Administered through the Energy3D, a computer-aided design research program (Rahman et al. 2019), participants competed against each other to create a solution to a given design problem. Given the context that the host university desired a proposal for a cost-effective and economically self-sustaining solar energy system for a local dormitory and adjacent parking lot, participants were given the objective to design a large-scale system of solar panels to generate at least 1,000,000 annual kilowatts with a budget of $1,900,000, and a system payback period of under 10 years. Alongside these goals, design constraints were included to emulate the many restrictions present when designing engineering systems in the professional world. More information on the design challenge, and a list of constraints can be found on

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the lab's website: sidilab.net. The nature of participants' design was quantified in three ways: a performance metric (a ratio of annual energy output to the cost of the system), an objective metric (the payback period for the participant's design), and the number of design iterations they employed.

4. Hypotheses

Due to the number of design metrics and hypotheses, this section begins with a brief introduction of each of the psychological tests used and ends with the relationships that we expect to uncover.

The Keep Track test (modified from Miyake et al. 2000) was used to capture participant's working memory, a process used for storage and manipulation of information (Baddeley 1992). As systems are aggregates of variables, success in this realm should be influenced by this construct. Additionally, the more data one can consciously consider at once should decrease how frequently they must test their iterations.

The International Cognitive Ability Resource (ICAR; Condon and Revelle 2014) is a broad measure and consists of four item types, each of which analogous to several of the constructs listed by Greene and Papalambros that reference reasoning ability.

Creativity research is demarcated between two constructs: divergent and convergent thinking. Divergent thinking encompasses idea generation and is studied through four sub-constructs: fluency, originality, flexibility, and elaboration. Convergent thinking is characterized by choosing the correct solution to a problem. To measure the former, we employ the Abbreviated Torrance Test for Adults (ATTA; Goff and Torrance 2002); the latter, the Compound Remote Associates test (Bowden and Jung-Beeman 2003). The two are widely used measures within the field, and both Frank along with Greene and Papalambros cite creativity. Included was a measure of openness to experience, a personality trait shown to positively correlate with several measures of creativity (McCrea and Costa 1999; McCrae 1987).

The Four-Factor Imagination Scale (FFIS; Zabelina and Condon 2019) measures it's the four sub-constructs: fluency, complexity, emotional valence, and directedness. Prospection and hypothetical thinking are both mentioned by Greene and Papalambros, similar to imagination in problem-solving.

As each of the psychological tests was employed to measure the cognitive competencies that make up and contribute to the success of systems thinking, our hypotheses for each construct are similar. For our design performance metric, we expect the following tests to show a positive correlation: the Keep Track test, ICAR, the ATTA and each of the sub-constructs, CRA, the fluency, directedness and complexity of imagination, and openness to experience. For the objective metric, we expect negative correlations between the identical list. Lastly, for the number of design iterations that participants employed, we hypothesize there will be a negative relationship between the Keep Track test and directedness of imagination, and positive correlations with fluency within both the ATTA and the FFIS.

5. Preliminary Results

Before the results of the statistical tests used to address the previous hypotheses, several points must be addressed. First, it is the researcher's intention to collect additional data identical to what has already been gathered; as a result, to avoid bias a predictive model will not be built until the remaining data is collected. Second, due to the large number of hypotheses, they will not each be considered individually in the current abstract; the poster will address all hypotheses. The following are the correlations between the psychological measures and design metrics that reached, or show a trend towards, significance. Against our hypothesis, the performance metric showed a negative correlation with the directedness of imagination (r = -.347, p = .059). Towards our hypotheses for the objective metric, the Keep Track test and number of correct answers on the CRA both showed negative correlations (respectively, r = -.318, p = .105; r = -.382, p = .078). As hypothesized, the number of design iterations was negatively correlated with the Keep Track test, and directedness of imagination (respectively, r = -.337., p = .079; r = -.399, p = .028). Note: r denotes correlation analysis and p denotes p-value. The level of significance adopted is .05.

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DESIGN AND USABILITY OF AN ADAPTED INDOOR ROUTE GUIDANCE SYSTEM

Adapting the route instruction type to the complexity of the decision point.

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and

PHILIPPE DE MAEYER

1. Introduction

The indoor environment can be very complex and as such can make people feel uncomfortable while navigating indoors (Giudice et al., 2010). A well-established theory to quantify building complexity is space syntax (Montello, 2014), which is a collection of theories and methods to quantify the relation between both indoor and outdoor space on the one hand and society on the other hand. Space syntax is known to correlate with wayfinding performance during explorative wayfinding, but few studies have been done on the correlation with wayfinding performance during guided wayfinding. When people are being guided by a wayfinding system on their smartphone, they might behave differently or have different needs, depending on the decision point. An adapted wayfinding system adapts it's characteristics to these changing needs (Reichenbacher, 2003). One of the aspects that can be adapted is the type of route instruction. For example, at very complex decision points a 3D-simulation of the required turn might be more helpful than a map. This research analyzes the relationship between building complexity, quantified through space syntax, and usability of route instructions, resulting in the design of an adapted indoor route guidance prototype.

2. Online survey and field experiment

In a first phase, an online survey was conducted to study the relationship between space syntax and complexity perception during route guidance (De Cock et al., 2019, 2020). Results showed that this relationship depended a lot on the decision point category: taking turns was most complex at convex, central spaces, while this was reversed for starting and ending a route and to change levels. Moreover, apparently the preference for route instruction types during route guidance also depended on the decision point category: symbols + text were preferred to start and end a route, 3D-simulations + text at central decision points and photo + text at other decision points. In a second phase, a web-based adapted route guidance prototype was designed, based on the results of the online survey. A field experiment was conducted, during which people were being guided by the system on a smartphone, while their eye movements were being tracked to measure the induced cognitive load. The participants were divided in two groups, one group received adapted route instruction types and one group saw only photo + text instructions, but both groups received the instruction on their smartphone by use of ultra-wideband sensors. The results of this test revealed that less wayfinding errors were made with the adapted system compared to the non-adapted system. Moreover, cognitive load on complex decision points could be decreased by using 3D-simulations, while cognitive load in convex spaces could be increased by using symbol + text instructions.

3. VR experiment

In the last phase of the research a VR experiment will be conducted, where participants will be guided in a virtual model of a building by the VR version of the adapted route guidance prototype, while their eye movements are being measured by an integrated eye-tracker. In VR, participants are to a certain extent immersed in the environment, similar to a field experiment and environmental parameters can be controlled, similar to an online survey. As such, the VR experiment combines the advantages of the previous two research mediums. The goal of this last study is to cross validate the results of the previous studies.

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MEDIA AFFORDANCES AND TRANSACTIVE MEMORY SYSTEMS IN DESIGN TEAMS

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1. Introduction

Creative design teams are formed not only to design functional products but also to make them novel and innovative. To do so, usually design teams spend a considerable amount of time generating wide range of design solutions. However, sooner or later they must eliminate most of the proposed ideas and narrow down theirvision for a final product. What are the things that affect these kinds of decisions?Previous studies have introduced Transactive Memory Systems (TMS) as one of the main constructs of team cognition. It is widely believed TMS can enhance team performance during the ideation phase.Our goal is to see if TMS play a role in decision making during the ideation phase. In this study, we examine the formation of TMS as a function of media affordances.TMS is the system used by a team for encoding, storing, and retrieving knowledge across different domains (Renand Argote 2011). The collaborative environment included a system (Balakrishnan and Oprean 2015) that draws on the role of design representation in the creative process and its implications for a collaborative environment that supports digitally mediated communicationwhich also impacts the team's formation of TMS. The idea behind this kind of collaborative environment is that multimodal information can help users overcome their working memory limitations, which can result in better communication and decision-making.The limitations of working memory have been the subject of studies for over a century. Working memory can only hold limited amounts of information for a short duration. Having too many pieces of information may result in decreased effectiveness for processing in working memory (Kalyuga et al 1999).

2. Operationalization and Research Hypotheses

The general thesis of TMS is that it can help teams improve problem solving by giving access to more efficient and larger pools of stored information, as well as a much faster recall of relevant information to address an issue (Ren et al 2006). We operationalized TMS as the system that encodes, stores, retrieves, and transfers new information building on Wegner (1995), in this case newly proposed ideas. For more detailed operationalization and coding scheme for TMS see appendix A, and appendix B for the collaborative environment and tools.

Our main hypothesis states that ideas that were encoded, stored, transferred, and retrieved more than other are more likely to be selected. By utilized protocol analysis, we coded a multidisciplinary design team's communication about task, as well as their flow of information while using different media.

3. Results and Discussion

The team included seven students with different backgrounds, see appendix C. The team spent 90 minutes on ideation phase, during which members introduced new ideas, evaluated, and discussed them for further refinement and development(D'souza and Dastmalchi 2016).After ideation, team members discussed and criticized the proposed ideas to select their most creativesolutions and eliminate the rest. To test our first

hypothesis about TMS, we performed Chi-Squaretest of independence to check for frequency difference among different presentation platform, communication modality, encoding medium, and storing data in relation to idea selection.

Presentation platform varied from common or public to individual. Common image platforms were visible to everyone from anywhere in the environment, whereas, individual platform required members to use their individual devices, such as desktops to see a websites or images for example. Our hypothesis was that ideas that were presented from a common image platform should be more likely to be selected, however we found no significant relation. In terms of information transmission and data storage our analysis indicated that cloud storage were utilized more than the portable storage (USB flash memory) during the ideation phase, however no association was found between method of data storage/ transmission and idea selection or rejection. This is due to massive use of cloud storage which also results in violating the basic assumptions for Chi-Square test. In terms of media for data encoding, journals and software were operated in an individual level. In other words, a member would encode the data or 'take notes' from the ideas that was under discussion. This encoding occurred through personal devices (personal computer using word document or personal journal) and the encoded ideas (notes that were taken) were the interpretation of the member who was 'writing the notes' and not necessarily the person who was discussing or proposing the idea. Additionally, the data encoded via software and journals were only available to the owner of the device, unless he/she shared their notes with everyone. E-beam, on the other hand was a medium that was operated in a team level, meaning everything that was encoded through E-beam was product of team discussion and the wording was also from a team effort. Moreover, the information that was encoded via E-beam, was available to everyone immediately. The hypothesis in this section was that ideas that were encoded via E-beam to have a relation with selected ideas. We believed it was more likely for the team members to store the information in their long-term memory if they encode the ideas using E-beam. Our results however, indicated a significant relation between the encoding medium and idea selection. To be more specific, ideas that were encoded through a software, such as Microsoft word or PowerPoint, were more likely to be selected X^2 (1, N=73) = 5.13, $p<0.05$.

One possible explanation is that four out seven of the team members were taking notes about the ideas via software.This indicates hardly any of the proposed ideas could have been missed from being encoded using a software. Moreover, one of the word documents that contained list of proposed ideas was later shared with everyone, right before the idea selection phase. This may also indicate that at least four members had probably stored most of the proposed ideas in their memory as they were taking notes via software. Given the fact that most of the ideas were proposed in the last 30 minutes of the ideation process it is likely that team members still remembered most of the ideas at the time of idea selection session, which was immediately after ideation phase.The stored information in the long-term memory is held in hierarchically ordered schemas. This allows one to treat different subcomponents of stored information as an element organized according to the order in which it will be applied or used. Schema refers to a closely linked set of ideas (and concepts) related to a particular event or object (Ormrod 2011). Schema helps one reduce the workload on working memory as well as storing new knowledge in long-term memory. Based on this model, any increase in the cognitive processes of new information that is not directly linked to the acquisition of new schemas would result in a burden of working memory capacity and reduction of resources one uses for learning

Additionally, among different modes of communication, sketching found to be a predictor for idea selection X^2 (1, N=37) = 12.23, $p<0.01$. Therefore, textual, or digital images had no association with idea selection. This is somewhat consistent with the results of experiment by Sundar (2000), where he suggests that multimedia content can be a 'double-edged sword' – it can hinder user's memory in some content, or it can positively influence.

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Multidisciplinary design collaboration through the lenses of CSCW

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1. Poster abstract

We aim to define the team dynamics aspects in multidisciplinary design collaboration in reference to the CSCW (Computer-Supported Cooperative Work) discourse. Presenting a comparative analysis and co-occurrence analysis with emerged themes from the literature of design collaboration studies, we juxtapose the findings with technology-enabled tools suggested for CSCW. To illustrate our recommendation for future research, we discuss and suggest a matrix evaluating communication systems based on the identified themes. The results allow us to define the gap in the design research in reference to the real-world context, future of work and technology enablement.

Impact of a Sketch-Based Tutoring System at Five Universities

Changing Homework Achievement with Mechanix Pedagogy

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1. Abstract

Introductory engineering courses at large universities often have large enrollment numbers, making more detailed feedback to students; classwork and homework difficult. Often times these classes evaluate students' understanding of material using online text-only systems, or through simple multiple choice questions, neither of which provides optimal feedback. Often times these homework systems provide binary correct or incorrect responses. This format of grading gives little to no additional information to assist in students understanding of the material, while doing little to facilitate understanding of missed portions of the content. Additionally, these systems often fail to encourage students to sketch physical systems as simplified representations in the form of free-body diagrams (FBDs). These concerns have some engineering educators believing that students may have limited ability to idealize real-world systems, and have created an opportunity for interactive sketch tools for use in engineering education.

Sketch Mechanix is an online sketch recognition tool built at Texas A&M, Sketch Mechanix is an online sketch Recognition tool built at Texas A&M, which is used to provide introductory engineering students feedback and additional tutoring in the process of drawing free-body diagrams to solve a variety of statics and dynamics problems. The application allows students to virtually draw the FBD and using Artificial intelligence algorithms to give students instant feedback as to whether or not the diagram is missing any components, while also reporting if the proposed solutions to the force values found within the problem are correct. Automated sketch recognition using these AI systems gives iterative real time feedback to students. This feedback is more substantial that other online homework applications, while also being quicker than feedback given by paper submissions graded by the instructor of the class. Additionally, Sketch Mechanix provides a sketch interface that allows for students to draw the FBDs of more complex open ended problem, and through a creative design problem allows for the iterative development of complex truss systems, that would be difficult to provide constructive feedback if a traditional homework method was used.

The application is being used as an educational tool at 5 different universities, with it being deployed in introductory classes in Statics, Aerospace engineering, Dynamics, and mechanics of materials. The classes that deploy Sketch Mechanix as part of the class curriculum randomly separates the class or classes at the university into two separate groups, having once group use traditional homework methods while the other group uses Sketch Mechanix to complete identical problem sets. Students' knowledge is measured using

a comparison of Physics, Statics, and Dynamics Concept Inventories taken both at the start and conclusion of the class. Specifically chosen exam questions are also used to compare students understanding of the material, as well as their ability to free-hand sketch FBD representation of complex problems.

Past data and Preliminary results show that Sketch Mechanix performs just as well as traditional homework methods in improving introductory student's understanding of the material, while also significantly improving at risk student's understanding of difficult concepts and reinforcing all students understanding of the overarching concepts of these introductory courses. The application shows signs of reshaping engineering education, allowing for increased understanding and feedback than what is offered by traditional online homework methods. The intent is to assist in the growth of the modern twenty first century engineering classroom, as the application is poised to assist instruction in classroom environments that are entirely virtual, while also providing more feedback in today's ever modernizing classroom setting and shows signs of being a powerful tool in strengthening a students' ability to conceptualize complex engineering problems.

POSTER ABSTRACT

« Let the Avatar Brighten Your Mind »: A preliminary study towards using avatars and virtual environments to foster creativity in design activities.

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Abstract

In a context where the world is changing faster than ever and where being creative and innovating has become an asset to face competition, it is a real challenge for companies and designers to come up with products that are both new and adapted to future users (Bonnardel & Pichot, 2020). For this reason, providing effective means to collaborate with geographically distant people while optimizing their creative activities is a real need.

With the progression towards Web 4.0, we are witnessing the democratization of virtual spaces and particularly those from multiplayer games. A technology that does not only redesign the way companies work, but also optimizes the creativity of employees. In line with recent research on the Proteus Effect (Yee and Bailenson 2007) which suggests that people "conform in behavior and attitudes to their avatars' characteristics" (Ratan ,Beyea, Li, Graciano 2020), we investigate how embodying these avatars (the virtual representations of the user) can be a way to stimulate creativity and help to reduce the difficulties inherent to creative design activities.

However, when it comes to supporting creative ideas generation (Guegan Lubart and Collange 2019), the Proteus effect is generally observed when participants are able to identify with their avatar (De Rooij, van der Land and van Erp 2017; Marinussen and De Rooij 2019). Knowing that individuals most often identify with media characters of the same sex, that are popular, successful, and intelligent (Hoffner and Buchanan 2005), we suggest that embodying a famous inventor who is perceived as creative, would improve the creativity of the participants.

With a view to contributing to enhance creative design activities we conducted a preliminary study with a population of psychology students. More precisely, the objective of this study was to identify what a creative avatar may look like. Towards this end, we asked participants to respond to

an online survey inspired from the scale of Guegan et al. (2016).

Results of this survey enabled us to select Steve Jobs as an avatar representing a famous inventor that is perceived as creative by our target population.

The data from this study also enabled us to determine the visual features of the avatar that will be used in a further research that aims to improve creativity in design.

This preliminary study is the first step towards a research work, in which designers (students or professionals) will have to embody this inventor avatar while performing a creative design task. By comparison with control conditions, we will determine the influence of the use of this kind of avatar in a virtual environment to favor creativity in design.

Therefore, this research will contribute to reach a double objective: (1) enabling a better understanding of the conditions that promote creativity in design, (2) participating in the deployment of virtual environments that promote collective intelligence, in order to design products adapted to the user's needs and to the context of use.

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