Poster Abstracts
Design Computing and Cognition'14

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CITY-TO-CITY LEARNING

A Supervised Machine Learning Approach for Urban Design

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1. Abstract

With the increase in urban complexity, knowledge-based design models became highly valued as the way to decode and reconstruct the organisation that makes urban systems. What they lacked is a mechanism by which an analytical description of urban complexity could be translated into a synthetic description. In an attempt to find such mechanism, an analytical description of Barcelona's urban form and function is encoded in a nonparametric Neural Network model. After calibrating the model using data from Manhattan, the functioning description of the model is devised to forecast urban features for a given street network. With this approach, a quantitative description of urban structures is retrieved from empirical data and reconstructed in a design experiment. This process serves as to support design decisions when tackling the complexity of large scale urban design problems.

2. From analytical descriptions of cities to design models

In recent times, studies that explored urban design were witnessing a divide between the analytical sciences and the applied sciences of cities. Space Syntax; a branch of analytical sciences; was focused on decoding the language of architectural and urban space, form and function (Hillier, 1996a). In the meanwhile, the applied sciences of cities were predominantly occupied by assumption-based simulation models (Wu and Silva, 2009). These approaches remained divergent in essence, making it difficult to adapt them in the urban design process. To bridge the analysis-synthesis gap, there needed to be some intuition into the type of mechanism required to convert an explanatory reading of architectural phenomena into a synthetic design approach. Therefore, a framework needed to be developed to decode, encode and reconstruct the complex composition that makes cities as problems of organised complexity (Jacobs, 1964). A simple description for such organisation was made in Space Syntax, illuminating the relationship between a physical network representation of urban spaces and other socioeconomic variables (Hillier, 1996b). Along with disputes on the validity of the Syntactic representations and the missing third dimension (Ratti, 2004), the theoretical propositions made in Space Syntax were debated in the context of complexity science, often questioning their overreliance on linear models, suggesting that such relationships could be better represented in nonlinear and elaborative models (Batty, 2010). This is in view of the argument that deterministic models that relied on simple causal relationships between two variables or more were not immune to erroneous assumptions. In response to this argument, there needed to be some intuition into the type of mechanism needed to minimise assumptions and to devise analytical knowledge on cities into forecasting design models (Al_Sayed, 2014).

In an attempt to define this mechanism, we propose here an artificial Neural Network (ANNs) model to forecast urban features based on empirical data taken from Barcelona. The model was tested and calibrated using data from Manhattan. This includes the configurational properties of the street network, street width, building height, block density and land uses. The ANNs model was encoded to outline the relationship between street configurations on one side and the rest of these variables on the other side, suggesting that it is street accessibility that defines the demand for wider streets, block subdivisions, high-rise development and the clustering of retail and commercial land uses. Building on this hypothesis, the ANNs model was devised to automate two dimensional forecasts for formal and functional attributes of a hypothetical grid structure. For the input layer, measures of street accessibility were used as factors. When applied to Barcelona's case study, the spatial accessibility measures were found good predictors of formal and functional variables. The results for Barcelona's case were tested on Manhattan's data. The testing was returned positive for the applicability of the ANNs on other cities, hence as a tool for urban design and forecasting.

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IMPACT OF INDIVIDUAL COGNITION ON PRODUCT LIFECYCLE MANAGEMENT SYSTEMS

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1. Introduction

Product Lifecycle Management (PLM) aims at an integrated management of all product-related information and processes through the entire lifecycle for Terzi et al. (2010). Within an extended enterprise, systems interact in order to share data and information throughout a product lifecycle. Beyond this computing point of view, individuals may be spread throughout the world and that is the reason why the same information on the same product shared through the same PLM system within the same extended enterprise may lead to different interpretations. Individual cognition, knowledge and particularly tacit knowledge as introduced by Polanyi (1958) have to be considered during the design of such computing systems.

The aim of this work is to outline a semantic interoperability between a collaborative platform and a PLM system. Such interoperability allows individuals to construct a shared understanding, supporting tacit knowledge sharing, i.e. knowledge that cannot be made explicit. Our approach leads then to focus on the impact of individual cognition on PLM systems.

2. Research Background

Information is continuously interpreted through individual cognition during sense-reading processes according to Polanyi (1967). Within extended enterprises, information can be transmitted by speaking, writing or acting, and more generally, by information systems such as PLM systems. Knowledge can then be:

- *explicited*, i.e. it has been made explicit by someone within a certain context and it can be supported by information technologies. Individuals, as well as computers are "information processing systems" as said by Hornung (2009, p. 9),
- *tacit*, it cannot always be articulated, relying on Polanyi (1958) notably:

"we can know more than we can tell". However, it can be managed as explained by Arduin et al. (2013).

Le Duigou et al. (2012) proposed a PLM model supported by the French Technical Institute of Mechanical Industries (CETIM). Such model should interoperate with a collaborative system in order to give individuals the means to elaborate a shared understanding. Through such interoperability, our approach focuses on the impact of individual cognition on PLM systems.

3. Research outlines

In Abel (2008) the MEMORAe approach is presented as aiming to offer an alternative to the loss of competencies and knowledge in an organization. Such approach offers an ontology-based learning organizational memory. Its use leads to collaboratively elaborate a shared understanding by focusing on individual cognition, so that tacit knowledge may be shared.

Our work aims at linking the PLM model of Le Duigou et al. (2012) and MEMORAe. The proposed methodology is to use a model driven engineering approach to create a transformation from a model to the other. The model transformation allows creating a target model from a source model and is constituted of two steps: the specification of the transformation rules and the application of these rules to generate the target model. We are currently realizing such transformation and we are planning to study its implications and limits within industrial fields.

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A Game-with-a-Purpose Framework to Facilitate Biologically Inspired Design

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1. Introduction

Nature often has solutions to design problems, but providing designers with biological inspiration remains challenging. Current computer-assisted bio-inspired design tools require human-in-the-loop synthesis of biology knowledge. Either a biology expert must synthesize information into a standard design-compatible form, or a designer must interpret and assess biological strategies. These approaches limit knowledge breadth and tool usability respectively. Bio-inspired design database approaches in particular share a key drawback: they rely on a curator to synthesize biology knowledge into a useful format. This severely constrains the breadth of information that they can contain, ultimately limiting their value as analogy search tools.

The work presented here aims to address this problem by applying the human computation approach from computer science. The Biology Phenomenon Categorizer (BioP-C) is a game-with-a-purpose that collects biology knowledge to computationally support analogizing between biology and engineering domains. This work aims to (1) distribute the synthesis step to a large number of non-expert humans, and (2) capture that synthesized knowledge in a format that supports analogical reasoning between designed systems and biological systems. Several validation activities are conducted on data from a small trial of the BioP-C game. The results of these activities indicate that BioP-C collects generally true assertions about biological phenomena, suggesting that games-with-a-purpose represent a feasible approach for addressing the breadth problem faced by biologically inspired design databases.

2. Related Work

Human computation involves splitting a computationally challenging problem into sub-tasks that can be performed by many humans, thereby addressing the initial problem. Games-with-a-purpose entice participation in human computation tasks by offering entertainment value for users as they provide information. A key attribute of such games is that they address computationally challenging tasks that are easy for humans.

Information from such games has been gathered into ConceptNet (Liu and Singh, 2004b), a semantic network that provides a means to computationally organize and reason about this information. As it relates to analogy, ConceptNet can support multiple styles of analogy formation (Liu and Singh, 2004a). Frequency weightings on ConceptNet's graph edges provide data for purely connectionist search, while the typed nature of graph edges provides some support for content theories of analogy.

3. The Biology Phenomenon Categorizer

BioP-C is an asymmetric cooperative 2-player word game. Players are paired anonymously, and then randomly assigned to the role of either *Keymaster* or *Codebreaker*. This player pair is presented with a single text passage describing a biology concept. To maximize interpretability, the passages themselves are selected for length and word commonness in contemporary English. To begin the game, the Keymaster selects a secret word or phrase from the passage. The Codebreaker tries to guess that word, and both players are rewarded when the word is guessed correctly. For every wrong guess, the Keymaster can form a template-style hint relating the guess to the actual keyword.

For example, "[secret word] *is* cell division" and "[secret word] *causes* daughter cells" might be given as hints for "cytokinesis," the process of cell division. The shared goal of the game naturally incentivizes players to produce valid assertions from the text.

These player-made assertions ("cytokinesis causes daughter cells" and "cytokinesis is cell division") are entered into a database. Confidence in assertion truth can be inferred from (1) assertion frequency across all players and (2) session data such as time and number of hints. These assertions can be merged into a semantic network format that closely mimics that of ConceptNet, such that similar types of reasoning should be possible.

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Multidimensional Lattice Structure for Parametric Models

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1. Background

Computers and computational procedures allow designers to create numerous solutions to a problem in short time. In design this is of particular importance in the early stages of the design process or exploratory design phases. An important question to bear in mind is how to effectively navigate through the universe of possible solutions generated by a computational design procedure. In particular when the number of solution candidates is very large.

An optimum navigation through the solution space is often an overlooked matter in parametric modeling and design. Due in part because designers are in control of parameters and they usually limit the possible number of iterations that a parametric model can generate, but also because designers rely on their experience to discard some solutions. This poster presents an example towards finding a solution to the proper visualization and optimum navigation problems.

2. Formalistic Model

The multidirectional lattice structure allows the visual display and logical arrangement of all design solutions from a parametric model.

The Multidimensional Lattice is presented as a hyper-dimensional structure conceptually built on the following premises:

- Parametric variations are based on a single parametric model only, thus each lattice may contain only one parametric model.
- In the lattice each axis or direction represents a parameter or variable attribute of the geometrical model. The number of parameters will determine the number of axes, which can grow as needed.
- Each node in the lattice is a placeholder for a single parametric instance. Each node shows the actual values of the parameters that are varied at that particular point, or the result of the interactions

when multiple parameters are simultaneously varied.

- When new parameters are introduced a new axis will be introduced. New axes can be traced back to any previous node in the lattice at the designer's will.

3. Discussion

There is virtually no end to the lattice growth in the lattice, but the designer can restrict it as deem necessary.

The structure is based on the model of "Periodic arrangements in hyper-structures" developed by H. Lalvani.However it differs from it in three important points:

1. Incorporates growth in the lattice in multiple directions on the hyper-dimension spaces allowing subsequent transformations for the same parameter
2. The facility to add new parameters on demand and impromptu basis that is characteristic in the design process
3. Eliminates the periodicity of the original hyper-structure model

Furthermore, ideas of recursive application of design rules and parameters are carried from parametric computation that allows a continuum of design transformations.

In some cases small local parametric variations may be allowed but this will require nesting of lattices inside the nodes and the possibility that one node can contain more than one parametric instance. This will be the subject of future studies and development.

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RE-INVENTING PORTUGUESE CERAMIC TILES:

Shape grammars as a generative method and its impact on design methodology

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This poster focuses on the results of the workshop 'Re-inventing Portuguese ceramic tiles: Using Shape Grammars (SG) as generative method' that took place in Porto University School of Architecture, Portugal, in April 2013. The main goal was to use SG as a design methodology for the creation of bi-dimensional ceramic tile patterns. SG were also used to analyze and describe the designs and produce new solutions.

The workshop was carried out in one day, and it was divided into 4 mains stages: 1) Introduction to SG, 2) Creation of a new SG to generate ceramic tiles patterns. 3) Rule extraction and SG inference. 4) Creation of shape rules to convert the bi-dimensional SG inferred to a three-dimensional one.

In Stage 2 amongst the different groups diverse solutions and grammars were originated despite the initial limitations and the pre-set lexicon of shapes that did not inhibit design and creativity. Most rules developed by the participants were clearly segregated between design rules and tiling rules. Figure 1 and 2 show the work of two teams which started with the same method of experimenting different spatial relationships but developed differently – Team A to an addition strategy followed by subdivision rules, Team B used both addition and subdivision rules and add deletion rules.

In Stage 3 participants were presented with pre-existing patterns, invited to infer a grammar by extracting shape rules observed through design patterns – for comparison purposes the same image was provides to two teams (Figure 3 and 4). This task was important to test how different participants would propose rules to describe the same body of work. Team A showed a deep concern by the shapes and patterns to be illustrated and had more difficulties exploring the shape grammar methodology resulting into a more extensive set of rules. Team B embraced shape grammars formulae and experimented with labels which resulted into an elegant, concise and descriptive grammar.

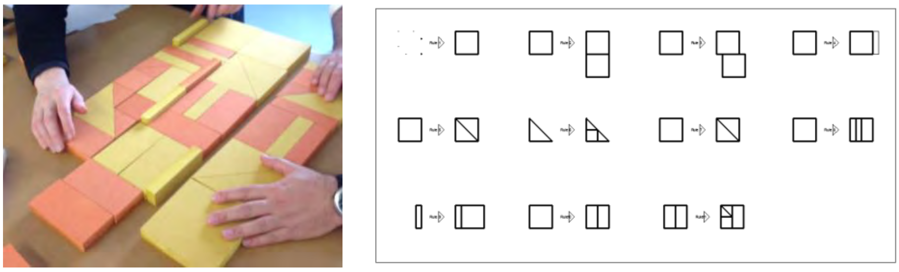

Figure 1: Team A, stage 2 - (left) pattern, (right) shape grammar

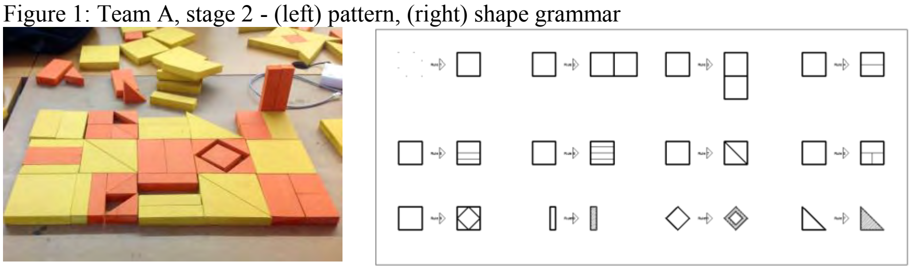

Figure 2: Team B, stage 2 - (left) pattern, (right) shape grammar

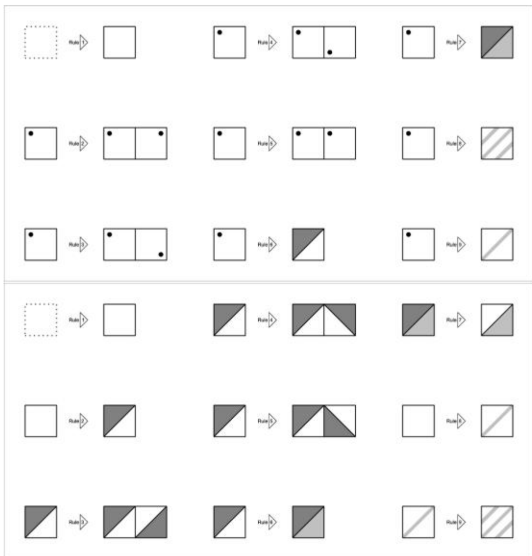

Figure 3: Ceramic tiles pattern as provided to Team A and B from which they had to infer the grammar, stage 3.
Figure 4: Inferred shape rules, stage 3 – (top right) Team A, (bottom right) Team B

The results achieved by both teams revealed important issues: i) SG methodology allows for more than one grammar to describe the same body of results or design languages; ii) restrictive and descriptive grammars allow for a level of precision useful to replicate an existing body of work; iii) unrestrictive grammars allow for useful design exploration by setting specific design principles but not over restricting outcomes; iv) descriptive SG result into an extensive set of rules; v) the use of labels can aid in the optimization of SG and result in an elegant, concise and intelligent grammar; vi) more than one SG can prove feasible responding to the problem formulated.

COGNITIVE WALKTHROUGH OF MEDICAL USER INTERFACE OF VENTILATOR SYSTEM IN INTENSIVE CARE UNIT

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1. Introduction

A ventilator system is a high-risk therapeutic device, which provides a respiratory support to critically-ill patient (Gould and de Beer 2007). Its User Interface (UI) displays vital information such as numeric values, icons, options, messages, graphs or alerts (Bhutkar et al. 2008) as depicted in fig. 1(left). This research work is focused on usability evaluation of ventilator systems used in Intensive Care Unit (ICU). Its focus is on primary tasks such as setting up a ventilator system, changing parameter values, entering patient data and setting up alarms / alerts.

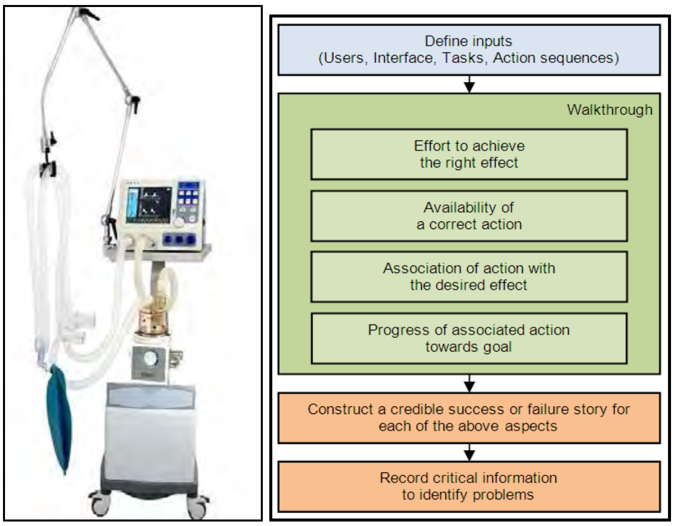

Fig. 1 Ventilator system (left) and related cognitive walkthrough (right)

For usability evaluation, a cognitive walkthrough method is selected as it helps in task evaluation providing correct paths for tasks and revealing reasons for errors. **Cognitive Walkthrough (CW) is a method, which**

focuses on usability evaluation of a system for ease of learning through exploration (Jadhav et al. 2013 and Wharton et al. 1994). It is performed by a team consisting of two usability experts along with a physician, who has a sound knowledge of ICU environment. The evaluators have specified a sequence of actions for tasks and then, stepped through that sequence to identify usability problems. This walkthrough is depicted in fig. 1(right).

2. Identified Usability Problems with Medical User Interface

Table 1 Identified vital usability problems using CW

Sr. No.	Problem identified	Related Ventilator Systems	Mean Problem Severity
1	Inappropriate data entry	V3	**Catastrophic (8.1)**
2	Missing valid ranges for values	V1, V2, V3 & V4	**Catastrophic (8.0)**
3	No or unreadable feedback	V1, V2, V3 & V4	**Critical (7.8)**
4	No onscreen help provided	V1, V2, V3 & V4	**Critical (7.7)**
5	High waiting time	V1 & V4	**Critical (7.6)**
6	No confirmation on important action	V1, V2, V3 & V4	**Critical (7.5)**
7	No provision of screen lock	V1, V2, V3 & V4	**Critical (7.5)**
8	No use check	V1, V2, V3 & V4	**Critical (7.4)**
9	No storage of multiple records	V1, V2, V3 & V4	**Critical (7.0)**
10	Unnoticed LEDs / Alerts	V1, V3 & V4	**Critical (7.0)**

The identified vital usability problems with medical UIs of ventilator systems as per mean problem severity are depicted in table 1. Mean problem severity is derived from survey of identified problems with 10 medical users. The **catastrophic and critical problems** (Wiklund et al. 2011) have mean problem severity greater than 8.0 and 6.0 respectively. In future, the identified usability problems should be resolved for improved patient care.

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POSTER: AN EXPERIMENTAL STUDY OF REASONING IN DESIGN

Testing the Pattern of Reasoning in Conceptual Design

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1. Background

Design is understood as an ill-defined process, hence no clear operators are defined. Therefore, understanding reasoning in design activity is fundamental for building AI or other design support tools. Design is intentional, purposive and goal-seeking and involves many forms of mental activity. These mental activities rely on reasoning processes both in the individual and in groups of people engaged in design. Therefore, studying the role that reasoning plays in design is critical to understand how design takes place (Rittel 1987).

Roozenburg (1993) presents a model for distinguishing the pattern of reasoning as a 'logic of design' involving plausible reasoning and the forming of hypotheses. In the model, Roozenburg proposes that *innovative abductive* reasoning, as opposed to (*explanatory) abduction*, is key in design and required to develop innovative solutions. Innovative abductive reasoning differs from abduction in that a surprising fact (a concept) is proposed as the premise to conclude both a rule and a cause for the fact, while abductive reasoning concludes a cause from an effect and a rule; a causal explanation (Habermas 1972).

2. Aim

A study was conducted investigating patterns of reasoning in design and the effect reasoning has on the resulting solutions in a context of creative group problem solving. Hence, the study empirically tests the model of reasoning proposed by Roozenburg (1993), to establish the correlation between different patterns of reasoning in design and the originality and usefulness of the resulting solutions. The hypothesis was that a pattern of innovative abductive reasoning would be observed prior to solutions emerging that will be assessed as highly innovative.

3. Methodology

A protocol analysis of five groups consisting of three professionals was conducted. The groups were presented an industrial case and received three different design methods for idea generation. They were given 20 minutes to brainstorm freely, followed by 20 minutes each with the two different methods – random images, and bio-inspired cards. Each group was facilitated and recorded with video cameras.

4. Findings

Results are expected to show that a higher presence of innovative abductive reasoning in problem solving activity leads to solutions evaluated as being more innovative than problem solving activity not represented by innovative abductive reasoning. The bio-inspired cards are expected to create more innovative solutions as they are far analogies (Dunbar 1996), from the biological domain, hence a greater amount of innovative abductive reasoning is expected.

The study contributes to empirically understanding patterns of reasoning in design and the effect on problem solving activity. The understanding of reasoning processes support the building of theory to underlie the foundations of design support tools and selection of methods to facilitate idea generation.

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THE IMPACT OF ARCHITECTURAL REPRESENTATIONS ON CONVEYING AN INTENT – AN EXPLORATORY STUDY

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1. Context and Objective

Architects have to express themselves graphically in order to communicate ideas both to clients they need to convince and to themselves. To do that, they appeal to a variety of representations (free-hand drawings, 3D computer rendered images, photomontages, …) supposedly faithfully carrying their initial intent. Research to date has demonstrated how "*experts*" designers and "*non-expert*" public differently perceive, or on the other hand share, visual understanding (Alcantara et al., 2005; Bates-Brkljac, 2007). It is yet unclear how architects *themselves* use different types of representations to express different intentions, and how their expected audience more or less successfully captures those intentions. The purpose of this on-going research is consequently to refine understanding of how differently a non-expert public captures the initial message of an architect, and what role representations (in different formats) do play in this understanding process.

2. Methodology

We design a 5 steps methodology to build a survey that will help us research this question.

<u>The first step</u> is to research projects with easy access to the initial architectural intent (the "*Study Space*"). Sixteen architects, from various backgrounds and expertise, provide us each with 3 representations of one of their architectural projects (a free-hand drawing, a 3D computer rendered image and a photomontage, with similar viewpoints), together with a description of their initial intent, either written or verbal when possible. A quick scan reveals that intentions extensively rely on adjectives, such as "*verticality*", "*enclosed*" or "*elegant*", that we consequently gather in a database of 90 adjectives in total. The question of representativeness of these adjectives – and more fundamentally representativeness of these 16 available projects – is naturally also raised.

<u>Second step</u> of our methodology is consequently to search for more examples, even without personal contact with the architects. Magazines and

available portfolios provide us with 460 more projects totalizing 287 adjectives, building the "*Reference Space*". The third step is then to submit both study and reference spaces to a "*Semantic Filter*", designed to classify them and to refine the choice of adjectives to finally introduce in our survey (Artacho-Ramirez et al., 2008). Several custom-made criteria are used to refine the list: adjectives conveying architectural intents similar to previous ones are grouped, as well as redundant antonyms, irrelevant value judgments, or description of qualities that are visually absent of available representations. This semantic filter reduces the list to 28 groups for the "*Study Space*", and to 51 for the "*Reference Space*".

The fourth step consists in a simple co-existence test: each adjective of the reduced "*Study Space*" also existing in the reduced "*Reference Space*" is considered as sufficiently representative of a shared architectural vocabulary and goes directly into the "*Final Space*". The 20 groups of adjectives is eventually used to create our fifth step, a survey that will be sent out to architects (the images' producers, as reference point) and to lay people.

3. Next Steps and Expected Outcomes

The survey will soon be sent out to the architects and hundreds of Mechanical Turk© workers who will be randomly presented with three representations, different in style and issued from different projects to avoid any adaptation phenomenon or unconscious comparison. To each representation will be associated a list of randomly picked "final" adjectives, confronted to their linguistic antonym (the "light/dark" pair being this way unmistakable from the "light/heavy" pair), separated by a 5 points rating scale such as the semantic differential scale defined by Osgood et al. (1957).

The results will then be presented in graphs for each representation and project and will help us better understand how architects and lay people respectively generate and capture different architectural intentions when confronted to different types of representations.

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CHARACTERISING PLACE BY SCENE DEPTH

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1. Aims

Comparative study is a common technique for quickly assessing the similarities and differences of a design proposal to a known type. For instance, Nolli plans are typically used as comparative devices to judge urban scale and density in a plan configuration. Similarly, street sections of known urban conditions are often used to predict what the public realm of a proposed design may feel like.

This research proposes that characteristics of different places can be distinguished based on views sampled therein.

2. Method

Depth views similar to three-dimensional isovists were sampled from thousands of points in two cities with differing spatial characteristics. Principal component analysis was employed to determine the most significant characteristics of images from both cities. Plots of each sample against the first three principal components demonstrates that this low-dimensional representation is sufficient to infer distinctions about the spatial quality of each city.

3. Conclusions

The method provides an effective classification system. Views of like places (defined by similar spatial structure, as reflected through depth) displayed similar morphology and/or regional clustering when organized by their principal components. Low-dimensional differentiation was in evidence between cities, and between different places within each of those cities. The most significant shortcoming of the method is that it fails to characterize reflected images or images taken from a rotated viewpoint as referring to identical places. The method is computationally efficient and has the benefit that the classifiers (eigenviews) have some degree of human legibility.

We suggest that this method is useful to design process because it is conceptually similar to established approaches in comparative analysis. This method augments existing approaches in that it makes use of three dimensional input data and can accommodate a much greater number of spaces to analyse. Despite this capacity to handle complex data, the method benefits from using comprehensible visual stimuli and from using a spatialised representation to demonstrate likeness and unlikeness

MIZZOU INTERNATIONAL SYMPOSIUM ON CREATIVITY AND NEW MEDIA

Studying Media Affordances and Design Creativity

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Even with rapid advancement of computational medium, we are still at a nascent stage in developing environments that facilitates the creative process (for e.g. environments for art, design and theatre studies). Unlike other routine cognitive tasks, creativity thrives on the model of 'learning by doing' and the digital version of this model in remote collaborative environments is unclear. The Creative Convergence Network (CCN) at the University of Missouri (MU) is an interdisciplinary team of scholars interested in the impact of new media on creative design process. CCN is led by Architectural Studies faculty and involve experts from different disciplines such as art education, textile design, theatre, film studies, instruction technology, museum, and graphic design. Our goal is to evaluate the impact of new media on creativity and facilitate creative convergences between tools, processes and disciplines. Funded by the Media of the Future strategic initiative of MU, the CCN team conducted a week-long design research project in collaboration with Hallmark Cards Inc., a world leader in greeting cards. Design brief challenged an interdisciplinary team to envision birthday celebration for the digitally savvy, new age user going beyond the old model of "send a card." The team members played the dual role of consumers and designers. With a broad research question on assessing impact of media affordances on design creativity and collaboration, we documented the week-long process, and captured data in a variety of formats including video and audio recording, human-computer interaction and media use. Our work culminated in the Mizzou International Symposium on Creativity and New Media in April, 2013. The symposium and workshop attracted world-renowned scholars including Mihaly Czikzentmihalyi, Mary Lou Maher, Barbara Tversky, Peter Lloyd and Gabriella Goldschmidt. We are now in the process of analyzing this data into a publishable format. Several topics were identified at the symposium including creative team and interdisciplinary collaboration, design thinking, design education, the use of archives in the design process, and disruptive/transformative attributes of media.

Our current focus is on the issue on Media Affordances and Design Creativity, in which we will emphasize interdisciplinary team collaboration both in terms of our subject area, and in terms of differing expertise brought to bear for analyzing a common set of data with different methodologies and perspectives. While this first round of funding enabled us to focus on the impact of new media on creativity in *co-located collaborative* settings, we will further our investigation in *digitally-mediated remote collaborative* settings in the next round.

In the poster to be submitted at DCC we will describe the experimental set-up needed to conduct a week-long protocol study. This will include discussions on the Immersive Visualization Lab (iLab) in the Department of Architectural Studies at the University of Missouri, use of new media tools, and creative artifacts that resulted. We will also discuss the nature of mixed data collected in the experiment which includes, video (and audio) recording, on-screen interactions with digital tools through screen capture recordings, journals, thematic coding of observations of design process, and design artifacts resulting from the creative process

The following issues that came up during the symposium will also be addressed:

Topics on Creativity:
(i) Creativity as displayed in Product, Process or Person
(ii) Creative Team and Interdisciplinary
(iii) Creative expression and meaning
(iv) Gestures
(v) Surprise and metaphors
(vii) Basic human relations and behaviors
(ix) Small ‘c’ creativity
(x) Millennial generation as content creators and consumers

Topics on Media Affordances:
(i) Re-mediation between ‘Old’ and ‘new’ media
(ii) Tradition and new ways of communicating
(iii) Communication technologies and working relationships
(iv) Tangibles and intangibles
(v) Archiving and Retrieving
(vi) Enabling and inhibiting relationships between task and media
(vii) Disruption and transformation in task
(ix) Use of right tools at the right time

POSTER: THE DESIGN TEAM OPTIMIZER

Automating the Selection of Successful Design Teams Considering Personality Type and Project Preference

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1. Introduction

Oregon State University is home to one of the largest mechanical engineering design groups in the US, which has been a leader in undergraduate design education. The undergraduate design sequence includes a junior-level introductory course and a multi-term senior-level capstone course. In the junior course, students have been placed on design teams considering MBTI personality types for more than twenty years; however, the instructor has always performed this team selection process manually. Similarly, in the senior capstone course, students are introduced to a breadth of available research or industry-sponsored projects, and then are manually placed on teams depending on students' ranking of their interest in each project.

Optimal team selection in introductory and capstone mechanical design courses is vital to the success of the project, and as such, many studies have been conducted to determine the means of generating ideal design teams. This work seeks to employ multiple areas of design team theory, including the use of Myers-Briggs Type Indicators (MBTI) for personality assessment and the capability for students to be placed in teams with respect to their preference for certain available projects, in order to automate the optimization of design team selection. Various test cases are shown that indicate the weighted multi-objective Mixed-Integer Linear Programming approach shown can quickly select optimal design teams that consist of diverse personality types and assign students to preferred projects. This work serves as the first step toward a web-based automated design team selection tool that will be made freely available to design researchers and educators.

2. Method

The presented method automates and optimizes the selection of student design teams for an introductory or capstone mechanical design course, while accounting for both the MBTI personality types of individual students and the preference of design projects for each team. The algorithm maximizes the diversity of personality indicators given by the completion of an MBTI exam (a variation of the Keirsey Temperament Sorter (Wilde, 2007)) while allowing for constraints that may be seen in certain design team scenarios, such as assigning particular students to particular projects (Figure 1). Using the project selection algorithm developed by Kirkwood (Kirkwood, 2004) as a foundation, this work serves as the preliminary step in creating a freely accessible web-based application that instructors of design courses at other schools can use to automate team selection.

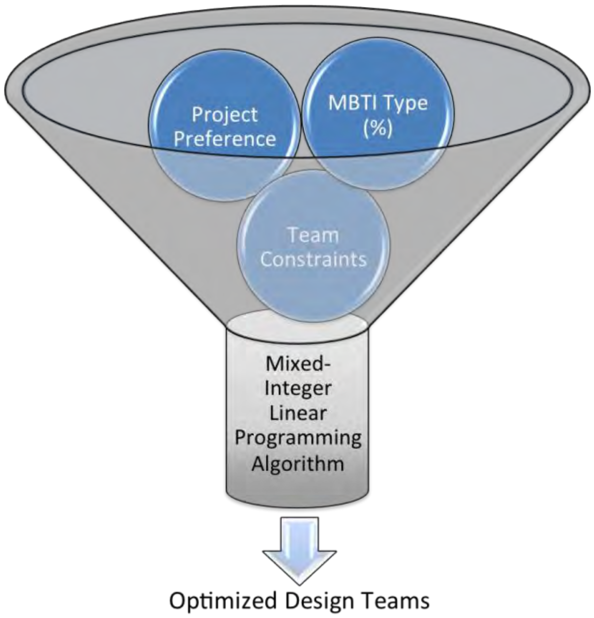

Figure 1: Design Team Optimization Method

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WHOSE DIGITAL PROPERTY

A Discussion in the Ethics of Open-Source Computational Design in Architecture

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1. Whose Digital Property

This essay questions the relationship between the legal, ethical, and economic challenges that are presented by new ways of utilizing digital and computational methods of production as opposed to traditional industrial manufacturing. While it does not attain a conclusive resolution—as this is a work in progress—the poster addresses the systemic changes in production that are implicit in new forms of more localized and distributed manufacturing practices. It is proposed that by understanding these relationships with respect to the prevalent global economic model, research may be able to identify ways of commercializing process-based and to reward all members contributing to the production system.

The aim of this research is to explore the growing concern within the design community—for both corporations and individuals—with intellectual property, focusing principally on the commoditization of labour and on production with digital and computational design tools.

As an amalgamation of Intellectual Property and digital communication in relation to labour (that is, low-cost versus high-end) and production (that is, rapid-prototyping and aggregate manufacturing versus unskilled workforces), the crux of this body of work aims to explore and address the intersection of digital technology, law, and the rapid technological advances that are creating contradictions and areas of conflict between them. The focus lies here within the spectrum of computation and open-source information systems within the fields of design and architecture, as influenced by the contemporary age of reproduction and commoditization.

The topic is most relevant where discussions around production methods such as rapid-prototyping now encompass a larger (and more public) commercial audience—in debates about reducing the labour force and production lines to enable a greater diversity and dissemination of digital design technologies to individuals.

With the progressive state of architectural tooling, and technological advances within digital and computational design, potential conflicts between corporations and bottom-up developers have become more evident. The larger potential to utilize effortlessly disseminated rapid-prototyping technology—competitive due to its lower costs of production, widely available fabrication materials, and the ease of downloading models from open-source websites—has raised reservations as to how one could maintain appropriate ethical, legal and material uses for such creative resources.

Computational design on one hand has reached its argumentative state of algorithmic and/or parametric processes, and the debate will no doubt continue; however, digital and computational design promises not merely a new style, but a radically new approach to design. A revolutionized computational technique is embedded within both evolutionary and emergent systems, whereby the two approaches will continue to bring forth new strategies, and will therefore require to be tested out in real time, also in terms of ethical and legal accountability.

Widely distributed and open-sourced coding and rapid-prototyping emerged from bottom-up designers, who aspired to enable "everyone and their grandmothers," (also known as the general public) to code, generate, and produce relevant design. Open-source developments—for example, David Rutten's Grasshopper—allow digital and computational design to be disseminated and developed by its users. This type of active participation design-research within the computational architectural community has generated a larger ability, mobility, and resourcefulness in establishing a network, or a field of generators, who focus on more intelligent and logical design processes.

Although the computational design community has in the past two decades concentrated on "formal styles," from parametricism to algorithmic design, current discussions have moved beyond form. Form is largely irrelevant within this new horizon and generation of self-organized designers. Logic and the possibility of developing with a set of consequences in mind could potentially become the new "form."

There is a larger predicament within the new generation of open-sourced computational design, regarding the balance between corporate dealership and grassroots developers. From the standpoint of commercialization and commoditization, even in terms of the capitalization of resources, there is a serious impediment within the architectural and computational design community to the development of open-sourced digital designs.

The recent 2012 lawsuit between *3D Systems* and *FormLabs* (MIT Media Lab) is a solid example of the patent infringement discussions between technology and the proprietary state of creativity and ideas—between material and research, academic research and public resources, corporations and people.

FNS Diagram – A Model of Synthesis

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Designing a Model of Design Process - FNS Diagram

We are designing a model of constructive process - FNS diagram (Fig.1), to be utilized for practice, research, and learning of design. A constructive method of creating something is recurring of cycle composed of generation (C1), interaction (C1.5), analysis (C2), and scripting (C3). Each process has the recursive structure involving smaller cycles of generation, interaction, analysis, and scripting. We are designing FNS diagram by practicing the process modeled as FNS diagram. We are repeating the cycle of generating the current model on the basis of our intuition and theoretical or empirical understanding of design (C1), letting it interact with its environment by providing it to be utilized for design practice, research, and learning (C1.5), observing and analyzing the interaction to see how the model works (C2), scripting a scenario for the succeeding cycle of FNS diagram so as to improve and refine the current model.

Design Analogous to Scientific Inquiry

Scientific inquiry is constructive. We associate the philosophical model of scientific inquiry by Peirce (1887) with FNS diagram. The model is outlined as follows: (**Sc0**) Every inquiry is triggered by the observation of some surprising phenomena in which inquirer experiences some unexpected things. (**Sc1**) The inquirer ponders the phenomena in all their aspects, invents some hypotheses that shall resolve the surprising phenomena, and creates or selects the hypothesis that seems promising to the inquirer. (**Sc2**) The hypothesis is tested. The inquirer anticipates the conditional experiential consequences that would be logically or probably derived in accordance with certain inference rules if the hypothesis were assumed to be true. (**Sc3**) The inquirer estimates the proportion of truth of the hypothesis by verifying how far the anticipated consequences are consistent with the experiential observations and judges whether the hypothesis is sensibly correct, or requires some trivial modification to increase the consistency, or must be rejected. (**ScR**) Sc1, Sc2, and Sc3 are repeated until the inquirer makes the hypothesis plausible enough to explain the surprising phenomena.

Design is modeled by analogy to scientific inquiry. (**De0**) Every design activity is triggered by a feeling of wrongness about the current or coming situation and by an intention to device a course of actions to change the situations into preferred ones. (**De1**) The designer ponders, on the basis of the experiences of living and designing, how the situation can be changed if certain artifacts are built. The designer creates or selects some promising hypotheses to fulfill the intention. The artifact is designed in accordance with the hypothesis. This process is scripting (C3) in FNS diagram and corresponds to Sc1 in scientific inquiry. (**De2**) The designer tests the artifact to see if the expected situation is realized. She or he anticipates the conditional experiential consequences that would be derived in accordance with certain inference rules if the selected hypothesis were true and the artifact were actually built. This process corresponds to scripting (C3) in the sense that the test in executed in the conceptual layer. The artifact is generated as its representation (C1 in C3). The designer interacts with the representation through thought experiments or simulation (C1.5 in C3). If the artifact, or a part of it, is actually generated (C1), then they interact with other entities in the environment (C1.5). (**De3**) The designer verifies how far the anticipated consequences are consistent with the observations of the interaction and judges whether the artifact and the hypothesis is sensibly suitable to be adopted, requires some inessential modification to fulfill the intention, or must be rejected. This process corresponds to analysis (C2) if the interaction among the physical entities is the subject. It corresponds to analysis in scripting (C2 in C3) if the subject of the verification is the representation of the artifact. (**DeR**) De1, De2, and De3 are repeated until the designer makes the artifact that can realize the intended situation.

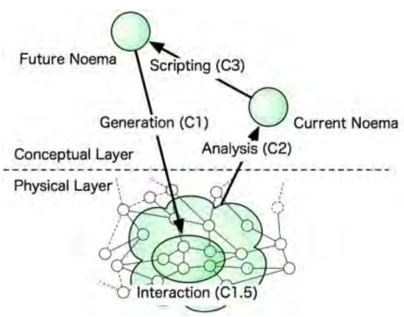

Fig. 1 FNS Diagram

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AN ANALYSIS OF VIEWPOINTS DURING PRODUCT EVALUATION

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1. Introduction

In this study, we consider that the subject's preference for a product is connected with the way the product is evaluated. To address this issue, we pay attention to how products are viewed during evaluation. In particular, we introduce the definition of a "**viewpoint**," or a specific time period during product evaluation. Our analysis is conducted based on the capture of subjects' "viewpoints" of the product. Our interest is in the characteristics of "viewpoints" involved in product evaluation.

2. Method

To capture subjects' viewpoints, we analyzed subjects' "**movement**" of a 3D model of a product using mouse operation (presented with a 3D model viewer on a computer screen). This allowed subjects to look at the product model from different sides (using the left mouse button). Then, the "viewpoint" was identified as the time period when the subject was not moving the model (with the left mouse button), and "movement" was identified as the time period when the subject moved the model (in order to change "viewpoints"). "Viewpoints"—the time between the subject stopped moving and started moving the model again—were determined using screen video recording (with a precision of one second). Furthermore, parameters quantitatively describing the "viewpoints" were defined as follows: "**Time of viewpoints**" was the total time of the identified "viewpoints" during the evaluation, while "**Number of viewpoints**" was the number of identified "viewpoints" during the evaluation. "Movement" parameter was defined as follows: "**Time of movements**" was the total time when "viewpoints" were not identified during the evaluation. We expect that this analysis method, along with verbal protocols, will provide insights into product preferences.

We conducted these product evaluation experiments with six subjects' examinations and evaluations of 3D models of five products—chairs—which were presented in random order. Subjects were asked to (a) examine the 3D product model and evaluate the product, and to (b) freely verbalize their impressions of the product. Written evaluations of the products were obtained using four Semantic Differential (SD) scales (e.g., a five-level “Dislike-Like” scale). As mentioned above, the conducted analysis registered viewpoints and calculated relevant parameters.

3. Results

Considering the subjects independently, we conducted rank correlation analysis (Spearman’s rho) between the “viewpoint”/“movement” parameters and SD evaluations. Significant correlations were found in cases of three subjects’ “Dislike-Like” evaluations. In particular, the “Time of viewpoints” and the “Number of viewpoints” (Fig. 1) in the case of Subject 1 exhibited significant positive correlations with evaluations on the “Dislike-Like” scale. Furthermore, the “Time of movements” in the cases of Subjects 4 and 6 exhibited significant negative correlations with “Dislike-Like” evaluations.

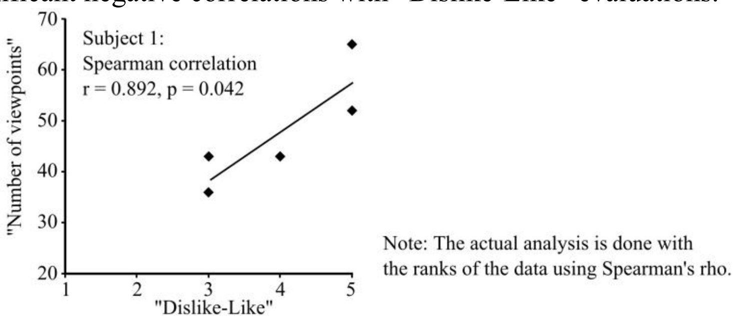

Fig 1. The relationship between “Dislike-Like” and “Number of viewpoints”

4. Discussion

The aforementioned correlations may point to two complementary aspects of the same process. The first is that longer “Time of viewpoints” and higher “Number of viewpoints” may be related to higher preference for the product (“Like”). On the other hand, longer “Time of movements” may be related to low preference for the product (“Dislike”). These findings provide insights into how people interact with products they prefer, potentially informing design of highly preferred products. The limitations of this study’s method include potential differences between the examination of 3D product models and actual products. Furthermore, correlations were only found for three subjects. Future work will focus on analysis of the collected verbal data.

Acknowledgements

This work was supported by JSPS KAKENHI Grant Number 25750001.

DESIGNS WITH MOVING PARTS

Rules for action and refection

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1. Generating designs through action and reflection

Design has been described as an iterative process of action and reflection, where designers identify and make series of changes to external representations of designs, whilst considering how various properties are affected. Conceived by Schon, this view of design was derived through studying designers' use of drawn two-dimensional visual representations (Schon and Wiggins 1992). Similarly, Stiny (2008) has shown how transformations which make changes to relationships between shapes within static visual descriptions can be formally described using shape rules. This approach affords the reinterpretation of unstructured shape descriptions to enable transformations to be applied to designs in new ways.

2. Designs with moving parts

Here we consider the types of actions and reflections that occur when examining and designing objects with moving parts. Many designed objects contain several inter-connected parts, which can move relative to one another in order to perform mechanical functions. Static representations are often not adequate when considering the motions of such designs, and functional physical models can play an important role. We are interested in how a formal computational approach might model the processes which bring these kind of designs about. We therefore consider how various aspects of this particular kind of design exploration might be usefully described using formal rules.

Motion itself is an objective property that can be evaluated using computational techniques. Yet how relationships between shapes of parts and the structure of the connections between them give rise to motions can be difficult to discover or understand, although various approaches to considering such relationships do exist (Faltings & Sun 1996; Sacks & Joskowicz 2010; Shapiro & Voelcker 1989). It can therefore be difficult to identify the extent to which a design's shape and structure can be altered without adversely affecting its motions. In some cases, systematic exploration can identify boundaries beyond which design changes have adverse effects. Here we begin to explore how relationships between shape, structure and motion might explored, described and explained using formal generative rules.

3. Experimental model-making

A practical enquiry was undertaken, employing physical model-making in a process of action and reflection to make changes to an existing object and examine their effects. The chosen object is a toy composed of interconnected hinged panels which when articulated exhibits an unusual sequence of motions, moving in a continuous cycle between four distinct static states. Subsequent to conducting this work, we discovered that the toy is described by a patent (Byrnes 2005). We described the toy's construction in terms of shape and structure, enabling us to make a working copy. Examining this description, we considered how it might be simplified to remove unnecessary details. Through model-making we sequentially tested changes to the initial description to examine their effects on the resulting object's motions. Successful new models justified revised descriptions, prompting ideas for further changes. We note that, when considering design models that exhibit motions, 'seeing', in the sense that is used by Schon, requires not only visual observation but also tactile interaction in order to examine spatial motions through physical manipulation.

Through systematic experimentation, for this particular design we were able to identify limits of changes to shape and structure beyond which the original sequence of motions is no longer preserved. This understanding allows us to describe this design and all viable variations in a more succinct way. We note that models embodying unsuccessful changes were most helpful for positively identifying these limits. Significantly, the revised description suggests that here shape features are of secondary importance to structural features. Since it clearly defines all possible design variations, it explains the scope for making design changes whilst still preserving motion, and contains all the information necessary to generate designs systematically using shape rules. We reflect that aspects of the process through which this description was discovered might also be formally described.

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TOWARDS COMPUTER-ASSISTED WAYFINDING DESIGN SUPPORT

Interview-based needs analysis across stakeholders

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1. Introduction and Motivation

The processes that lead to the final shape of a building consist of numerous sequential design alterations reconciling a variety of requirements, from energy efficiency parameters through to accessibility, capacity and costs. These processes are time consuming and involve the interaction of diverse stakeholders (e.g., architects, wayfinding designers, energy consultants).

For this poster, we explored the social aspects of this interaction during the design of the new building of the Faculty of Architecture of the University of Melbourne (designed by John Wardle Architects and NADAAA). An architectural faculty building has to accommodate a range of users and functions (e.g., offices, lecture rooms, library as well as exhibition and fabrication spaces). Tenbrink et *al.* (in press) highlight the fundamental communicative challenge between clients, building users and designers, each of these consisting of different sub-groups. Kamara et *al.* (2002) have pointed out how contradicting expectations and values can complicate and obfuscate decision-making in design. Our study focused on (a) the interaction of stakeholders across the architectural design process (e.g. how, when and why decisions that impact building users' orientation and wayfinding were made by various stakeholders), and (b) the evolution of floor plan changes potentially impacting wayfinding characteristics of the building (floor layout, signage design and placement). Our work aimed at untangling processes at the group level, complementing existing literature in design studies (e.g., Bertel et *al.*, 2004) concentrating on how an individual designer shifts focus between different design aspects (function, form, etc.).

In this contribution, we specifically explore the reasons why existing formal quantitative and qualitative approaches to wayfinding design are not systematically applied in practice and what technological tool improvements are necessary in order to promote wayfinding considerations from post-occupancy analysis and critique to the design stages.

2. Results and Conclusions

Through qualitative analysis of a series of interviews with stakeholders, we conclude that considerations for movement and orientation design are dominantly based on tacit knowledge contributed by the experience of the design team (architects, wayfinding consultants, landscape architects), and that analytic quantitative and qualitative optimization and evaluation tools are seldom used consistently throughout the process. Analytic tools (e.g., space syntax) can identify wayfinding problems in building layouts, and simulation tools like multi-agent pedestrian models can help validate architects' assumptions on visitor flows. Yet both are currently not closely integrated in the Computer Aided Architectural Design (CAAD) process and are primarily applied in late stages, usually in post-occupancy evaluation. Standardized, explicitly specified optimization parameters should be identified and exposed through interfaces informed by on-the-fly update during the modification of a design. This can be part of either generative design tools, or manual, interactive CAAD modes in the form-finding stages of the project. Earlier consideration of the quantitative parameters of designed spaces could increase actual wayfinding experience and support the deliberation of stakeholder groups.

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SUSTAINABLE DESIGN INFORMATICS

Managing Dynamic Knowledge Flows in Innovation Enterprises

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1. Introduction

Sustainable Design Informatics is defined as a design discipline combining design concepts and practices with information technology (IT)—or informatics—for achieving sustainable living (Ibrahim and Meor Razali 2013). It focuses on the arts and sciences of design relating to collection, creation, storage, retrieval, processing, display and dissemination of knowledge throughout the designed product's lifecycle impacted by information technology. It was founded on four multiple yet distinct characteristics to mitigate dynamic knowledge losses. They are having multiple concurrent and sequential phases, discontinuous memberships, tasks interdependencies and different dominating knowledge types for each lifecycle phases (Ibrahim and Paulson 2008; Shumate et al 2010; Ibrahim and Nissen 2007; Ibrahim et al 2005).

2. Managing Dynamic Knowledge Flows

Since complex enterprises will always maintain the discontinuous operational approach for maximising profitability, the author claims that the best recommended solution is to improve the knowledge flow management in situations where expected interdependencies would occur in those complex workflows. Design research investigations have advanced the understanding of a designed product's development lifecycle processes for successful IT/ICT integration (Pourzolfaghar et al 2013); understanding stakeholders' behaviour and cognition for successful collaborations (Pour Rahimian and Ibrahim 2011); and understanding and streamlining people and processes that utilise different knowledge types and sustainable resources for successful product innovations (Jaganathan et al 2013).

Most completed works so far have contributed new theories proven and validated either through enhanced proof-of-concept prototypes or product/process models. They are divided into three categories of knowledge contributions: enhanced processes, enhanced products and novel integrated systems. The successes of three systemic business innovations have further boosted the support for merging the fields of business management (people-process-product) and computer science merge to support profitable sustainable innovation processes.

3. Conclusion and Future Recommendations

Sustainable Design Informatics emphasises the trans-disciplinary nature in design approach which gives emphasises on the development lifecycle of innovative solutions using indigenous resources while addressing socio-cultural needs that meet economical aims. Among its research targets would include content, methods, technologies and systems besides development of tools, techniques and applications specific and practical for cradle-to-cradle product innovation in certain context.

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A Distributed Cognition Approach to Configuration

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The purpose of this paper is to (1) explore the distributed cognition of an organism in a spatial domain (i.e., a region in which an organism interacts with its environment at any given time), and (2) to propose how this conceptualisation may be extended to reapproach how architectural space is organised.

Concerned with the problem of spatial configuration in architecture we argue (from an evolutionary perspective) that 'human-space' may be comprehended by extending the problem downwards to the pattern recognition and control processes of simpler organisms, on the premise that the mechanisms we see at play in single celled organisms lead to higher and higher degrees of sign processing in humans. In this respect we claim a naturalised conception of space. The spatiality of an organism is affected through its capacity to sense, which underpins spatial intelligence and the capacity to engage with the world. This ability is ambient and distributed. Recognised as an approach to the study of all cognition the concept of distributed cognition is redefined on the basis of an ectoderm-centric perspective, which it is argued is the basis for distributed cognition. Understanding an organism to be coupled to its environment (brought about as a consequence of its abilities to 'read' and interpret its surroundings) the ectoderm-centric perspective is transferred to the subjective and objective characteristics of organisms to illustrate how ontogenetic development translates to social existence, and establish distributed cognition as embodied in, and part and parcel of, the human organism whose development is intimately tied to the environment in which it dwells. Distributed cognition is thus redefined as the ability of an organism to interact with its environment for the purpose of satisfying its most basic physiological (internal and external) and social needs in order to survive and sustain itself (Cárdenas-García 2013). An implication of this approach is that the sensory capabilities which drive the distributed cognition of the organism define its spatial domain. Our argument is based on the following principles:

1) 'The universe is perfused with signs', and that a sign is fundamentally a difference which holds some meaning for an interpreter perceiving said difference in some context (Peirce 1992).
2) Information is 'a difference that makes a difference', which an interpreter detects and acts on (Bateson 2000).
3) A system has identity, which its components share. A difference is therefore 'observed' by a component as something which is not an aspect of its identity, which it thus responds to. Signs are intrinsic to and underline the primacy of agency and how choice is based on value and meaning (Uexküll 1957).

The spatial salience of an organism is an effect of its distributed cognition, and this is constructive. On the basis that design is a constructive activity (Glanville 2006) we argue that the distributed cognition of an archetypal organism may be transferred to designing on the basis that to design is to configure; meaning to arrange elements or parts in a particular way so as to satisfy some need - and that this is akin the development and survival of an organism-in-its-environment. Inherently spatial, the manner in which the parts of some thing come together and the manifestation of this thing are determined by relations, which have meaning and are spatial. We therefore propose a distributed cognition approach to configuration. Focused on the subjective-objective qualities of inhabitation we explore the systemic manner in which one thing relates to another (effected through meaning), and that, being spatial, this effects configuration in accordance to pressures imposed on the system. An artificial life model demonstrates the argument and outlines a methodology for configuring architectural arrangements which takes into account that we as organisms interact with our ever present changing environment and redefine our spatial domain depending on our sensory interaction with said environment.

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THE EFFECT OF 3D CAD APPLICATIONS ON STUDENTS' 3D CAPABILITY IN DESIGN EDUCATION

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It has been argued that the understanding of 3D spaces is an essential ability for architectural designers, and thus 3D capability should be taught and enhanced through education curriculums. With the adoption of 3D CAD applications in design education, teachers have developed different views on the effect of those applications on students' capability for perceiving 3D space. Some people argue that students' 3D capability would be empowered by adopting 3D CAD applications in design education while others argue that 3D CAD applications would reduce students' 3D capability and thus traditional manual drawing skills would be more appropriate for supporting students' 3D capability. However, there is no empirical evidence either way. This research started from this question.

In order to explore the effect of 3D CAD applications on students' capability for perceiving 3D spaces, we developed an experiment design comparing undergraduate students' 3D capabilities in two different media conditions: a manual drawing vs. SketchUp. Firstly, we asked forty 1st year undergraduate students, who had never been trained in 3D capability before, to take an test evaluating their capability for perceiving 3D spaces, and then recruited ten students from this group with similar capabilities, based on the result of the test. For five weeks running, five of the students were given two hours' training in developing 3D designs using a conventional drawing method, while the other five students were trained to develop 3D designs using SketchUp.

After the training period, we plan to evaluate how capable the students are of understanding 3D spaces using a customized metric to investigate the effect of the two conditions on the students' 3D capability. We are not interested in the design process or outputs but rather the changes in the students' 3D capability in the two different conditions. If improvements are identified in students' 3D capability in a specific media condition, we could utilize and emphasize the potential of that media for supporting students' 3D capability in design education. If there is no difference in students' 3D capability in the two different conditions, we could argue that, at the very least, 3D CAD applications would not reduce students' 3D capability.

This research is a pilot study to be undertaken in order to develop and conduct an elaborate experiment that will provide an empirical evidence for the effect of 3D CAD applications and manual drawing methods on students' capability for perceiving 3D space in design education. By applying the result of the empirical studies in design education, especially for 1st year undergraduate students, we could provide more opportunity for training and developing their capability for implementing 3D spaces, and further, creativity in designing.

Acknowledgements

This work was supported by the National Research Foundation of Korea Grant funded by the Korean Government (NRF-2013R1A1A3A04008324)

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INFORMATION MODELING AND FACTOR ANALYSIS TO FIGURE OUT THE DIRECTION FOR GLOBAL BIO-MODEL SEARCH

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1. Introduction

The trend of biomimetic approach in engineering design is powered by the advantages that most designers might get through the process, specifically the design approach makes possible to reveal undiscovered or hidden ideas that nature incubates (Kindlein and Guanabara 2005). Through the efforts supporting the approach, the thing that was noticeably progressed is the data quantity of biological or ecological information investigable for ideation (Dikinson 1999). However, even though we are securing abundant studied or examined species by biological researches, the economical search method to figure out an unknown proper species in the nature has not yet progressed.

By the fundamental bias of biomimetic design, even designer could succeed to search a good bio-model (e.g. species) in the nature, the fundamental doubt that superior model would exist in the nature would not be solved, as long as designer cannot figure out the pros and cons of all species.

The following hypothesis is accompanied with this research.

The relational pattern between species and its functional traits would indicate the search directions for global optimization in a bio-model search process, if the mechanisms of evolutionary adaptations had been controlled by functional constraints and the functional traits of species are used to trace evolutionary diversifications.

To figure out the optimal bio-model among species, as a provision on the possibility that a superior bio-model exists in the out of the selected group of alternatives, the group of alternatives should be defined through a global search. In evolutionary biology, sub-organs and morphology of one species are perceived as evidences of functional adaptations and those are used as traits that researchers would use to explain the derivation from one primal species (Carroll et al. 2005; Ptacek and Hankinson 2009). Thus the derivational processes of evolution – usually the processes are represented in a tree structure – are dependent with functional attributes of species (Carroll et al. 2005). And, conclusively, from this special domain knowledge, we would insist a possibility to develop an optimized global search method by an analysis about the relational traits between derivation and functional attributes of the great successors. Technically, clustering for the bipartite network of species and functional attributes of each species will be a way to verify the hypothesis.

2. Methodology

The relation between function and taxonomic information is analyzed to find out similarity between functional traits of species. To do this, the bipartite network of '*Order*-function network' is represented as matrix and analyzed by cluster analysis. The design strategic information is gathered in the AskNature (*www.asknature.org*) web service operated by the *Biomimicry 3.8 project;* total 3,012 design strategies. The taxonomic information of creatures (bio-model) are searched from taxonomic information systems. The database of *ITIS* (*International Taxonomic Information Systems*) was used to link each species that is connected to functions to its parental categories; '*Order*' and '*Class*' (total 151 *Orders* and 34 *Classes*). The functional words are standardized to support systemic approach (McAdams et al. 1999). The bipartite network is analyzed by Singular Value Decomposition (SVD) method.

3. Conclusion

We expected that the result would imply three things. The relation between function and taxonomic information would be applicable in global search. But it might be complemented by more precise level network: e.g. '*Species*-function' network. And functional attributes of a bio-model and functional conditions of living environment may critical in cluster analysis and global bio-model search. Finally, the basic database should be enriched in terms of increasing the diversity of functions and species.

As a future research, the ecological information of species will be considered to qualitatively explain the clusters figured out in this pilot study. And to construct the result and findings on design support system, further technical supports are needed; case-based reasoning system or recommender system.

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USING GEO STATISTICAL ANALYSIS TO DETECT SIMILARITIES IN EMOTIONAL RESPONSES OF URBAN WALKERS TO URBAN SPACE

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1. Introduction

In the following we investigate the impact of urban form on emotional response. The presented examination is a preliminary-study aimed at developing a method which allows us to measure human emotions in various spatial configurations and to define the spatial statistical methods needed to analyze the collected data.

2. Data Collection

We start from the hypothesis that people have different emotional responses to different urban spaces. Resulting from this, the first question is how to measure human emotional responses in space. To answer this we use a sensor-wristband (Smartband), developed by Bodymonitor in combination with a GPS-tracker.

The model we use in this study for measuring emotions is based on the concept of cognitive appraisal that categorizes a relatively complex set of secondary emotions (Russell 1980). The company Bodymonitor processed the raw data collected by the Smartband and analyzed them with respect to four activations: Negative arousal, positive arousal, balanced, and retraction.

3. Statistical Analysis

The aim of the analysis is to answer following questions: What is the probability that the distribution of the emotion values occurs by chance? If the emotion values occur not by chance, where are the areas of clustering? Where is the clustering of high and low values?

Based on Geospatial analysis methods (Getis-Ord General G, and Getis-Ord hot-spot analysis Gi* (Getis 1991, Mitchell 2005) significant clustering of positive and negative arousal values at specific distances was proved and the null hypothesis rejected.

4. Conclusion and Outlook

The allocation of positive and negative arousal clusters could by characterized by areas with high density of both responses (positive, negative) standing close to each other and areas with predominately balanced emotional response. A possible explanation is that the emotional response is not caused primarily by a certain spatial situation but rather by a changing sequence of spaces. If there are no changes in the environment our emotions are more or less in a kind of balanced or retrieving mode.

Assuming that further studies validate our findings, we will then search for correlations between emotional response and spatial measures derived from computational spatial analysis like isovists (2D and 3D), visibility graphs (Hillier 1996), daylight and street-network analysis as well as combinations of these.

As the results of this pre-study suggest, changes in a sequence of spaces along a path may be a reason for positive or negative arousal. Consequently, it would be valuable not only to test static values for certain points of view but to investigate how the measured responses change along the path.

Acknowledgement

We are indebted to Dr. Georgios Papastefanou from Bodymonitor for his advice during our discussions and his technical assistance in the use of the Smartband and interpreting the data. This study was undertaken as prepa-ration for the research project [excluded for review] and was partially sup-ported by the Swiss Government Excellence Scholarships for Foreign Scholars and Artists.

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A LEXICAL SUBSTITUTION OF BIOLOGICAL TERMINOLOGY FOR BIOINSPIRED ENGINEERING DESIGN

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1. Motivation

Bioinspired engineering design is the process of adapting or principles from biology to engineering. While biology can provide ingenious solutions to engineering problems, the lexical difference between biology and engineering practically prevents the broad practice of analogical transfer of principles from biology to nature. To resolve this problem, this study aims to bridge the linguistic difference of the two domains using lexical substitution theories.

2. Algorithm

The developed algorithm is a full automatic text translation process on a monolingual biology domain document. The lexical substitution consists of two automatic steps (McCarthy and Navigli, 2007); 1) Identify the target word for translation, 2) Substitute a preferred word for the target word considering the meaning of a word in context.

For the first step, the algorithm selects the target word based on the English word frequency list (British National Corpus) based on the assumption that technical terms, not familiar to broad audiences, have low frequencies.

The second step uses several cases strategies for word substition. In the case of monosemy, the algorithm substitutes the targeted word with the most common synonym in the WordNet. For polysemy, the correct meaning of the word is determined based on usage context before the substitution by the Word Sense Disambiguation process. The scientific name is substituted with the commonly used name stored in the Integrated Taxonomy Information System (ITIS) database. A word that could not be substituted by previous steps is translated using Wikipedia. The algorithm collects a definition sentence that defines the desired entry and finds the expressions (noun phrase), which can substitute the target word in the definition sentence.

3. Result

The algorithm was tested on a selection of passages. The translated result was evaluated manually. The judge executed a simple "good translation" "bad translation" assessment. Of the 135 translations, 91 translations are evaluated successful with the remaining 44 translated incorrect, resulting in a success ratio of 67.4 %.

Following is the examples of translated result.

Before Translation	After Translation
Setae are subdivided into hundreds of tiny flattened tips called spatulae (Hill, 1977, Homann, 1957 and Roscoe and Walker, 1991), which hypothetically allow spiders to adhere to surfaces via dry van der Waals forces, similar to gecko (Autumn et al. … (Spagna and Peattie, 2012)	[hair]] are subdivided into hundreds of tiny flattened tips called [[nanometer-scale projections]] (Hill, 1977, [[Homann]], 1957 and [[Roscoe]] and Walker, 1991), which hypothetically allow spiders to adhere to surfaces via dry van der [[Waals]] forces, similar to [[lizard]] (Autumn et al. …

4. Conclusion

Using textual inspiration in bioinspired design process has its limitations, because of the terminology gap between two different study fields, biology and engineering. For providing effective biological textual inspiration to the engineers, the translation of a biotext is required. This study developed the lexical translation algorithm on the biological texts using WordNet, ITIS, and Wikipedia. The developed algorithm can contribute to the easier textual bioinspired design process, since engineers can get instant inspirations from the biological text without struggling to understand it.

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TANGIBLE INTERACTION DESIGN

Can we design tangibles to enhance creative cognition?

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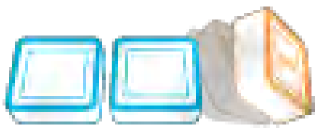
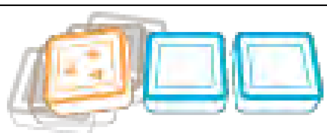
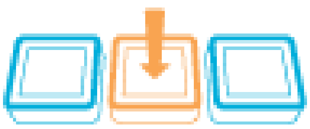
1. Tangible Interaction Design

There is an increasing interest in tangible interaction design comprising graspable object technologies as interaction devices and their associated applications. The Sifteo cubes are one of many new graspable interactive devices that are programmable for a wide range of games and learning applications. Table 1 illustrates the multiple affordances for moving and combining the cubes while receiving visual feedback on a screen on each cube (Hunter et al., 2010). These cubes are the technology platform for our studies on the impact of tangible interaction on creative cognition.

Table 1. Affordances of Sifteo Cubes

 Tilt	 Neighbor
 Flip	 Press
 Shake	

2. Impact on Creative Cognition

As a basis for developing design principles specifically for designing tangibles for creative cognition, we first explore hypotheses about tangible interaction and creative cognition. Our hypotheses are tangible interaction...

- facilitates epistemic gestures and actions.
- encourages thinking about non-spatial / abstract concepts.
- encourages greater bodily movement beyond that necessary to interact.
- encourages more spatial and metaphorical thinking.
- enhances creative cognition.
- serves to offload cognition as tactile, visual, and spatial representation of working memory, and as externalization of cognitive processes.

We have developed an experimental approach for studying the effect of tangible interaction on creativity using a protocol analysis methodology. Participants were asked to combine words from a given set of words then define meanings for the compound words. In the control condition, participants are given the set of words printed inside squares arranged on a piece of paper, and in the experimental condition the same participants were given the Sifteo cubes, each displayed one word. We coded the resulting data for both gesture and creativity of word combination meanings. Our gesture codes include actions on the cubes, as shown in Table 1, other actions on cubes that are not within the designed set of affordances, and gestures not related to the cubes. The participants' descriptions of the meaning of the word combinations were transcribed and evaluated using Amabile's (1982) consensual assessment technique.

Acknowledgements

This work was funded by NFS grant no. IIS-1218160 to M. Maher, T. Clausner, and A. Druin.

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DESIGN INFORMATION TRACEABILITY VISUALIZATION THROUGH NETWORK OF DIAGRAMS

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1. Diagrams as means of information recording

Information displayed in computer-drawn diagrams is stored within nodes and links, making them information containers. A wide range of data can be stored, including digital entities storage information, such as hyperlinks to computer-stored files or diagrams. Two or more linked diagrams form a diagram network. Links between diagram files allow users to cross boundaries of a single record and browse information spread through the network, by shifting from one diagram record to another. The purpose of building diagram networks is the ability to track every important piece of data or information back to its source. All networked diagrams serve as pathways for users to access requested information.

Presented research has been conducted in collaboration with one of the development departments of large company that produces equipment for power plants. Several types of diagrams were introduced throughout the methodology and diagramming tool implementation on an ongoing project. These diagrams cover communication visualization, product structure and specification, and design rationale. The capture of design information through linear text documents is a challenge because of the complex and fast-flowing nature of design activities (Aurisicchio and Bracewell 2013). Replacing text documents with diagrams proved that they are more convenient means of information recording such as meeting notes and design rationale. Issue Based Information System (IBIS) diagrams are used to record design rationale.

2. Diagram integration into design documentation

Links between diagram nodes and external files are unidirectional, meaning they only lead from diagram nodes to files, but not from files to diagram nodes. This is an issue which makes diagram network hard to integrate into project documentation. Difficulties of diagram integration have been solved with a newly developed explorer environment. Files that are displayed in explorer browsers can be associated with statuses and manually linked to other files, directories, diagrams or ontology. Modifying file representation properties allows users to enrich stored design files with additional information.

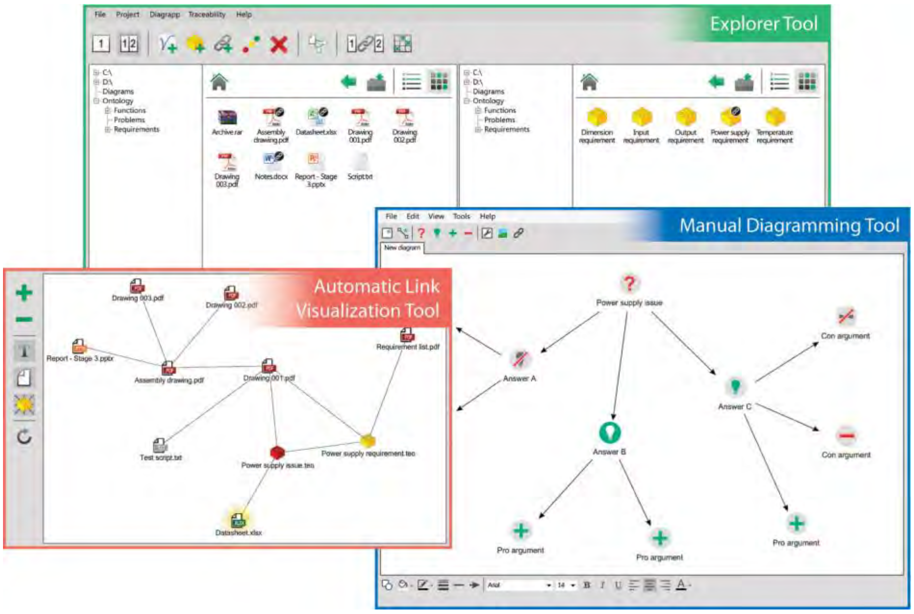

Figure 1. Design explorer environment with integrated visualization tools is used to create networks of diagrams

The developed tool visualizes information in two ways, on two different levels. The first is on browser content level, where file icons are automatically changed depending on whether the files are linked or associated with a status. Other way of information visualization is on diagram network level, by visualizing all established traceability links in form of a diagram. Each file, diagram or directory is represented as a diagram node with traceability links between them represented as diagram links. Prototype implementation showed that diagram network visualization facilitates requirement fulfilment verification, whereas only a quick diagram overview gives an insight of all requirements and the corresponding test documentation. This is particularly helpful when the verification is done by a third party.

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EXPERIMENTING WITH MONDRIAN

Comparing the Method of Production with the Method of Choice

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The Dutch painter Piet Mondrian (1872-1944) is the archetypal modernist, with the paintings of his uncompromisingly austere mature period, comprised of a white background, black vertical and horizontal lines and occasional, areas of red, yellow or blue, being icons of modern design. His paintings also represent a rare opportunity to experiment on aesthetic composition, the paintings being simulated relatively easily on a computer screen, with participants manipulating them interactively.

The founding father of experimental aesthetics, Gustav Theodor Fechner, described three research methods in his *Vorschule der Aesthetik* of 1876, the Method of Choice, the Method of Production and the Method of Use. Most empirical work has used the Method of Choice, whereby participants are shown two or more similar images and choose between them.

Our first studies of Mondrian used the Method of Choice. A set of 25 original ('O') Mondrian paintings were synthesised on a screen, as also were two pseudo-Mondrians, (P1 and P2). The pseudo-Mondrians were created by randomly moving all of the horizontal and vertical lines in the painting by a small amount (for P1) or by a slightly larger amount (for P2). P1 and P2 therefore had the same broad structure as O, containing the same 'words' (components), using the same 'deep structure' or 'syntax', but with the composition varied only by altering the relative positioning of the lines (equivalent in linguistic terms to a different pattern of stress or emphasis – prosodics). For each of the 25 paintings we created O, P1 and P2, and participants compared O with P1, O with P2, and P1 with P2, making 75 paired comparison judgements overall.

In five separate studies, totalling 277 participants, it was clear that original Mondrians could reliably be distinguished from pseudo-Mondrians, with some participants being more sensitive than others.

Fechner's Method of Production allows participants to manipulate the content of an aesthetic object, altering it until they feel that it is most satisfactory. We adapted this method so that participants were presented with a single Mondrian painting on a computer screen. By moving the computer mouse a vertical, a horizontal or both a vertical and a horizontal line in the Mondrian were moved up and down or sideways. The images were constrained so that the moving lines were yoked to other lines of the same directionality, so that several moved at the same time, and lines could never cross over each other (i.e. the syntax remained fixed, with only proportional arrangements being altered). The original Mondrian was always a possible outcome of moving the cursor.

The Production studies manipulated 39 original Mondrian paintings, none of which were included in the set of 25 used in the Choice experiments. All of the 84 participants could therefore carry out both the Method of Choice and the Method of Production, the order of the two Methods being chosen at Random (and order having no effect upon the results).

The most striking result was that although the 84 participants, as expected, had clear preferences in the Method of Choice for Mondrians over pseudo-Mondrians, using the Method of Production there was no evidence that participants produced images which showed any overall similarity to the original Mondrians.

A detailed study of what participants were doing when they were using the Method of Production suggested that the complexity of the task, despite its relative simplicity, was too great for them. Despite only manipulating in a two-dimensional space (or sometimes a one-dimensional space), participants seemed to find the task difficult. The program always started with the cursor at one of the four corners indicating the maximum dynamic range of the cursor, and in many cases participants ended up either on one of the edges of the space or even in a corner. In most cases only a small proportion of the possible design space was sampled before a decision was made.

Our paper will consider how people can and cannot make complex aesthetic choices across a range of possible stimuli. In particular we will suggest that much of the problem with the Method of Production is a problem of visual working memory, participants not being able to hold in their heads a range of previous images to compare with the current one which is shown on screen. The Method of Choice, in contrast, makes no demands at all upon visual working memory. Although computer design in principle allows an almost infinite space of possibilities to be explored, in practice the ability to do so usefully seems to be heavily constrained by the cognitive limits of human processing, meaning that design systems need careful ergonomic organisation to prevent such problems.

STRUCTURAL COMPLEXITY METRICS APPLIED AGAINST PRODUCT GRAPHS

Predicting Market Price and Assembly Time from Function and Assembly Models

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1. First Order Headings

The objective of this research is to understand and identify key complexity metrics of different product model graphs (assembly models and function structures) that can be used for surrogate modeling of product performance metrics (assembly time and market cost). Previous work has shown that complexity metrics applied against graph topologies can be used to create predictive models of assembly time given product assembly models (James L Mathieson, Wallace, & Summers, 2013; E. Namouz & Summers, 2013; E. Z. Namouz & Summers, 2013; E. Owensby et al., 2011; J. E. Owensby, Namouz, Shanthakumar, & Summers, 2012) and market cost given function structures (J L Mathieson et al., 2011). This previous work has shown that historical data in the form of product graphs reduced to a vector of twenty nine complexity metrics coupled with performance metrics can be used for performance prediction through artificial neural network surrogate modeling. Building on this preliminary work, we will try to understand why these surrogate models work. We hypothesize that some complexity metrics are significant predictors for both market price and assembly even when applied against disparate models such as the function structures and CAD assembly models. To begin to develop a fundamental understanding of how the structure within a graph contains hidden information such as cost and time, we first begin by constructing four different base prediction models: Function Structures to predict Market Price (FS-MP), Assembly Models to predict Assembly Time (AM-AT), Function Structures to predict Assembly Time (FS-AT), and Assembly Models to predict Market Price (AM-MP). These four prediction models will be created with a common database of products with the graphs, and their associated structural complexity vectors, and the performance values externally defined when possible to ensure objectivity in the research. These products will be consumer electro-mechanical products, such as power tools, kitchen appliances, and children's toys. Once the prediction models are created through the use of artificial neural networks (ANN), we will analyze the level of significant contribution of each metric to the prediction model. We will explore both principle component analysis and linear and nonlinear regression analysis to refine the complexity metric vector.

The hypotheses that we explore:

1. Topological Complexity can be used to predict performance metrics (new exploration with different inputs and outputs).
2. Different graph sources will yield different accuracy and precision of results (FS< AM)
3. Different performance metrics will be predicted with different accuracy and precision of results (MP < AT).
4. A collection of diverse complexity metrics is required to develop good predictive models.
5. A sub-set of complexity metrics will be found to be significant in all permutations of input-output predictive models.

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A DESCRIPTIVE MODEL OF KNOWLEDGE TRANSFER WITHIN COMMUNITIES

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1. Context

As engineering design is an highly cognitive activity, it involves logical reasoning in which knowledge has an important role. While some knowledge preexists to the design and is used as a support for the related activities, some new knowledge is also created by the design activities themselves. In addition, both the growing complexity of manufactured products and high competitive pressure lead to highly collaborative and distributed design activities, where knowledge flows play a key role.

Hence, it is not surprising that knowledge management is considered "as one of the key enabling technologies for distributed engineering enterprises in the 21st century" (Mcmahon et al 2004). Among different technical and managerial initiatives, the adoption of a KMS (Knowledge Management Systems) is one of the more popular one. A KMS can be defined as an information technology (IT)-based system developed to support and enhance the three processes of knowledge creation, knowledge codification, and knowledge application (Alavi & Tiwana 2002).

However only few organizations have implemented successful KMS (Atwood 2002) and some studies even describe major failures (i.e. Malhotra 2004). Some authors, as Grant, argue that KMS implementations fail because of a simplistic view of the tacit/explicit dimension of knowledge adopted by some knowledge transformation theories (Grant 2007). Furthermore Bernard suggests to focus on what is not captured by the KMS instead of what is captured (Bernard 2006).

In this context, our research work aims at improving the use and efficiency of KMS within engineering teams. As a first step, we present in this poster a descriptive model of knowledge flows within engineering teams or communities using a KMS.

2. A descriptive model of knowledge flows

To investigate in this study, we started by reviewing some key knowledge transformation models from the literature. We also adopted a participant observation approach in order to challenge the existing models with data from the real world. This lead us to propose a descriptive model. This model intends to explain the co-construction of "common knowledge" (Alterman 2013) and the transition of knowledge into a formalized object. A key element of this model is the "knowledge footprint", a tangible element (wording, gesture, action…) resulting from interaction between engineers, and that reflects the existence of a related knowledge. The model then describes how these "knowledge footprints" change as they become shared through the interactions, until becoming a "knowledge object" that we will be stored and distributed with the KMS.

The proposed model was used to describe different real situations of knowledge construction and sharing by engineers. The situations include communities of practice meeting and discussions in online technical forums. The model proved to be useful for understanding the way engineers use KMS, and to identify different types of KMS use.

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SERVICE AS VALUE CO-CREATION IN A DESIGN PROCESS

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1. Service and Design

We define "X service" as a provision and utilization of X (Nakashima et al 2013). We define design as construction of a new system that has preferred functions or features. Provision and utilization of the product may produce a value that the designer has never thought of (Vargo and Lusch 2004). The new value should be taken into account for the next cycle of design.

2. FNS Loop for Synthesis

Both service and design processes form never terminating loops. To formalize both loops and the relationship between them, we use FNS diagram (Fig. 1) (Nakashima et al. 2006). Generation (C1) plus interaction with the environment (C1.5) corresponds to service provision. C1.5 plays a very important role. The environment is out of control of the designer. Unpredictable events may occur. Artists often utilize somewhat unpredictable interaction with the environment (C1.5) intentionally in their creation.

Gero and Kennengiesser (2009) discussed value systems encapsulated in a situation, interacting with externally embodied value systems. Their three worlds, expected, interpreted and external, seem to correspond to our future noema, current noema and environment respectively. However, external world in their model is the conceptual one. In contrast, since our FNS model assumes the environment as extending beyond the reach of the designer, it can capture the unpredictable character of value creation.

Twin loops of a provider and a user (Fig. 2) must be considered in service. Note that the user is beyond the reach of the provider. The provider (designer) and the user interact each other through the use of provided system in the physical layer. PF (provider's future noema) represents the

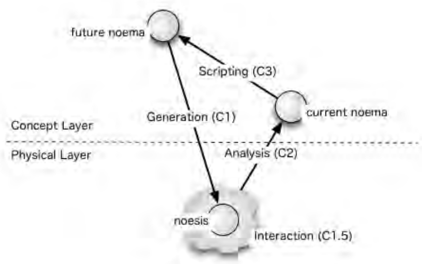

Fig. 1 FNS loop for Synthesis

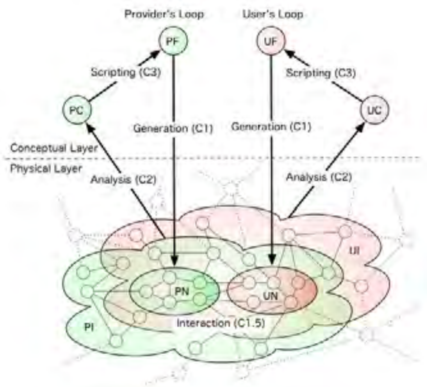

Fig. 2 Provision and Utilization Twin Loops

provider's concept (design or goal) of the system. The provider then generates the actual system PN (provider's noesis). PN is put to service and it interacts with the environment that includes the user.

The provider runs the provision loop only. From the provider's point of view, utilization loop is invisible and buried in C1.5 (PI). It is reciprocally the same for the users. Provision loop is buried in C1.5 (UI). The provider and the user only see their own loop as depicted in Fig. 1.

The result of the interaction sometimes widens the application area or the function of the system from PN to PI. The additional area, PI minus PN, is called the latent function of the system, which is not intended but is within the function of the system.

User's use of the system forms UN (user's noesis). Interaction of UN with the environment yields UI. We call UI minus PI as latent service. Latent service is not designed by the provider, but in a sense designed (or discovered) by the user. It is outside the scope of even latent function of the product. For example, when a good public transportation system is put into service, users (citizens) may stop owning their private cars and save money and parking spaces. This is not either a function of public transportation or its intended service. Therefore we call it latent service.

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VISUAL SEARCH IN URBAN ENVIRONMENT SIMULATED BY RANDOM WALKS

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1. Urban Activities, Pedestrian Movement and Vision

Visibility of urban environment affects human navigation, thus a comprehensive representation of visibility context is useful in understanding human activity patterns and associated urban dynamics. Current study focuses on the walking mode of urban travel. Any walk in the city comprises of multiple destination selections. In this study we address a question of pedestrian visual search for these destinations.

We implement random walk simulation imitating aggregated navigational search for urban activity location within a given built environment. The random walk model accurately describes visual accessibility of the urban setting linking the emergent functional structure to so-called "micro motives" of human cognitive behaviour.

There is a direct relationship between spatial configuration of the city and urban activities, thus simulation and analysis of human behaviour provides a powerful tool for designing, shaping, maintaining and altering built-up environments.

2. Modeling Urban Visual Search by Random Walks

Urban environment is represented by means of integrative visibility graph that incorporates structural and functional aspects of the city (Natapov et al, 2013). There are two types of nodes in the graph: the street network characteristic points, the decision points where a person makes a navigational choice, and the points of interest - locations of urban activities, i.e. possible navigation goals. The nodes of the graph are connected if visible from each other. Thus, a path in the graph is a hypothetical route of a traveler searching for a specific place, function or location in the city.

We propose an innovative use of random walk agent-based simulation to describe the cumulative navigational search and to estimate the distribution of visual scanning trajectories in the historical district of Tel Aviv-Yafo, Israel.

3. Visual Intelligibility of Urban Environment

The random walks represent natural stochastic process of diffusion on graphs. It provides efficient solutions of many practical problems requiring non-deterministic algorithms, which contain probabilistically branched outputs. We use the random walk model to examine local and global visibility properties of the city.

Global-local relationship of the spatial networks is known by the term intelligibility in the Space Syntax theory. Intelligibility is proved to be a key determinant in human navigational and wayfinding abilities (Hillier, 1999). This positive relation between the local and the global properties of nodes is a profound feature of complex networks and entails the underlying process of network self-organization (Blanchard and Volchenkov, 2008).

In our study the global property of a node is characterized by the first passage time (FPT). FPT is defined as the expected number of steps required for a random walker to reach the node for the first time starting from a location randomly chosen among all locations of the graph. We estimate the FPT by Monte Carlo simulation of a random walk on our graph. The examined local property of a node is its recurrence time (RT). RT of a node indicates how long a random walker is expected to wander before revisiting - the node (Blanchard and Volchenkov, 2008). We also compare FPT with deterministic local properties of a node, namely, its centrality measures.

The main result of our study exposes a strong positive relation between local visibility properties of a place and its global properties. Comparison between the global properties, which are outcomes of the stochastic process, with the local deterministic properties illuminates a part-whole relationship of urban space creating intelligible visual perception.

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Poster: DAPPS- Design Analogy Performance Parameter System: An Analogy Retrieval Tool

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1. Abstract

Analogical reasoning is not the only approach for achieving innovation, but it is a highly effective and noted method. It is often difficult to identify appropriate analogies for a given design problem. To avoid relying on chance identification of analogies through unique individual knowledge and experience, we consider the potential impact of a system where an engineer could begin with their existing design, specify to a computer a set of critical functions and desired design performance improvements, and be presented with a number of design analogies intended to inspire avenues for design improvements. This system, called Design Analogy Performance Parameter System (DAPPS), would implement performance metric matching to retrieve examples and stimulate analogical mapping, enabling revolutionary leaps in design that lead to innovation. DAPPS is envisioned as a unique alternative approach for analogy retrieval.

This poster presents current progress in creating a proof-of-concept DAPPS tool, organized into 3 major areas: 1) critical functions in analogy mapping, 2) theoretical frameworks for performance metrics, and 3) a case-driven approach to performance metric organization and mapping.

For a given design problem, critical functions, as defined by this research, are those which are most important for meeting the requirements and customer needs. A pilot study of analogy-inspired products identified 2 existing modes of critical function usage – *direct transfer* and *inverted transfer* – which can be considered for the implementation of DAPPS. Functions which are commonly used in a given design domain provide an optimal target for demonstrating DAPPS with a limited set of database examples which satisfy common functions. A study of function usage in the student design repositories of 3 universities was conducted which reveals the

high prevalence of a small set of functions for the domains represented in those repositories. The study results strongly agree with results in an earlier study by Caldwell, *et al.*, of a single design repository, and suggest building a demonstration database of examples which solve the functions “transfer”, “convert”, “store”, “actuate”, “separate”, and “guide”.

Organizing the many technical performance metrics in engineering design, such as measures of efficiency, is a major challenge for DAPPS. Studies were conducted to investigate and propose theoretical frameworks for organizing metrics and facilitating metrics-based design example retrieval. An initial effort pursued a hierarchical taxonomy of performance metrics akin to the functional basis vocabulary of function and flow terms. Derivations in this effort involved concepts from bond graphs, control theory, and Design for X guidelines. The approach yielded a taxonomy which is thought to be unsuitable for generalization across many products due to the inability to scale across products and domains. The project has thus transitioned into an ongoing effort to use dimensional analysis to organize performance metrics by their composite, generalized units of measure (e.g., mass, length, time), augmented by function and flow information to further refine the search scheme.

In a separate attempt to organize and map metrics across different domains, a case study was performed using metrics from an engineering domain and a biology domain. Engineering performance metrics were surveyed from: (1) academic literature on wind turbines, and (2) a design problem assignment to engineering students. Biology metrics were obtained from biomechanics publications concerning marine animal locomotion. A heuristically-derived framework similar to influence diagrams was used to organize metrics in each domain by their dependency relationships. Function and flow associations are added to each metric to permit mapping between domains. Applying the framework in 2 design scenarios, biology metrics and accompanying performance data were retrieved for specified wind turbine metrics. Although metrics-based retrieval was demonstrated with this approach, difficulty in creating metrics dependency diagrams presents a challenge for implementation with multiple example domains.

Ongoing work seeks to integrate these two mapping efforts into a single repository for the DAPPS database performance metrics for matching analogs. Once analog matching has been completed, a ranking system will convey how well the analogs meet the desired performance metrics of the original problem, enabling the user to expand their design problem abstraction and improve their understanding of the returned analogs.

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AN EMERGNT APPROACH FOR NEW URBAN MEDIA

Developing a Mobile Outdoor Media Platform in the Built Environments

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1. Introduction

Today, with the advancement of information and communication technologies, we face a world where "smart things explore their environments, communicate with other smart objects, and interact with humans" (Bohn et al. 2004). These technical developments allow us to create new methods of representing diverse arrays of information. Our ultimate goal in this research project is to find harmony with our urban landscape in two ways: first, by visualizing data generated from dynamic communications between mobile outdoor media, such buses or taxis, and second, by producing interactions between mobile outdoor media and buildings for the purposes of commercial application. For such data visualization experiments involving these interactions and communications, our platform, consisting of both hardware and software, is currently being developed as an agent system, which is the most suitable for an emergent approach that can generate complex patterns from simple, local dynamic interactions.

The purpose of this research is to propose a new approach to developing a mobile outdoor media platform *as* new urban media. To this end, we are currently developing this platform and performing different tests with basic mobile robots in order to verify our method.

2. Implementation

The urban media platform is composed of two applications: hardware and software. The hardware consists of mobile robots composed of an LCD, microcontroller, actuators, proximity sensor, and wireless communication module. The software is an application that can control various contents for an LCD, based on their location. Both hardware and software applications are interconnected and continually exchange data related to their position and contents.

This mobile outdoor media platform can be employed as a media device for external advertisements on buses and taxis. Mobile media can display specific content that varies according to their location. When a device enters a specific area, it can generate even more content through the communication and interaction between nearby mobile media devices, as shown in Figure 1.

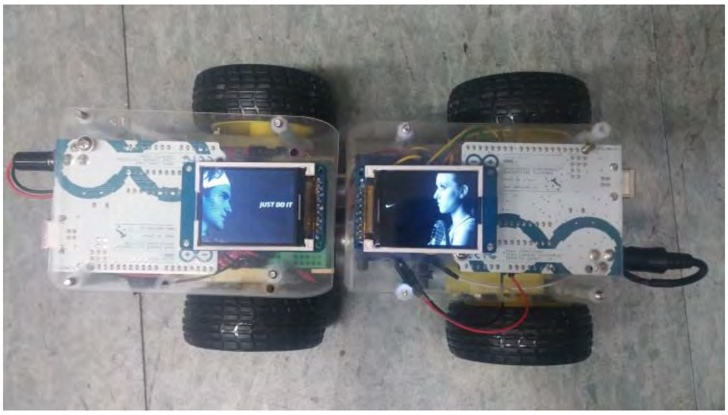

Figure 1. Working Prototype

3. Conclusions and Further Research

At present, we are developing this urban mobile platform as a prototype for commercial application. This research will furnish a new approach for researchers working to develop new urban media. Further research will unfold along the following lines: first, by developing algorithms for visualizing data based on other kinds of dynamic interactions with buildings or between the mobile media themselves; second, by evaluating this mobile media platform in real environments.

Acknowledgements

This research was supported by Basic Science Research Program through the National Research Foundation of Korea(NRF) funded by the Ministry of Science, ICT & Future Planning(NRF-2013R1A1A1061628)

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ENHANCING THE VISUAL TEMPERATURE COMFORT IN A SPACE USING A MENTAL IMAGE – *based on Regional Digital Colors*

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Residents' desires to live in a better interior space that satisfies their need for comfort and amenities while implementing a sustainable environment is a current architectural issue. Many designers are therefore interested in the vernacular environment in order to apply regional information to the sustainability aspect. In this study, we utilized regional color information to improve the visual temperature amenity because regional colors are familiar to regional residents and the properties of the colors reflect the temperature that humans perceive.

This paper's aim is to suggest a creative design process that improves the visual temperature comfort of an interior space using digital color information. The creative design process deals with the transformation of the regional digital color information into a mental image with CIS (Color Image Scale) developed by Japanese researcher, Shigenobu Kobayashi (1981). CIS presents a sensitive vocabulary around the colors humans feel. Towards this end, we firstly present a schema diagram related to the transformation of the physical information of a regional color into the mental information that humans perceive as a color. Fig.1 illustrates the schema of processing in this study.

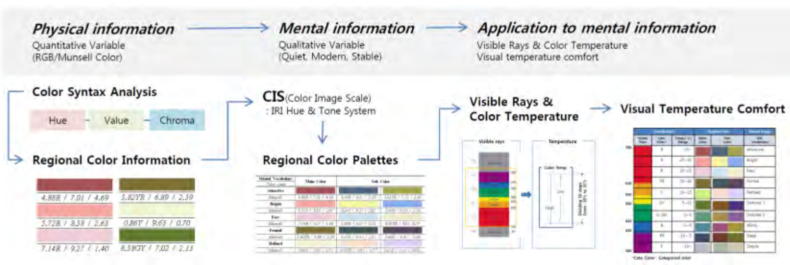

Fig. 1 The schema of processing in this study

Secondly, we collect and analyze regional color information using a color syntax program. In the course of analyzing the digital color information, the color palette is created by the physical information derived from the main regional colors and the mental information associated with CIS and color temperature. Finally, we simulate an interior space by applying the suggested color palette, and conduct a questionnaire survey on the simulated results in order to confirm the consistency of the color palette created by mental image. Fig. 2 shows the simulated results applying the suggested color palette.

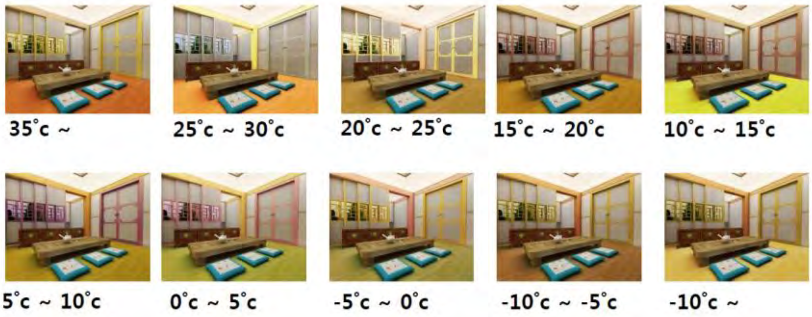

Fig. 2 The simulated results applying suggested color palette

This study has a significant in transforming physical information based on regional color to sensitive information as mental images, and to enlarge the application of regional color information by simulating an interior space to increase the visual temperature comfort. Thus, the results of this research would provide us with a novel opportunity for enhancing the visual temperature amenity in interior environments.

Acknowledgements

This work was supported by the National Research Foundation of Korea Grant funded by the Korean Government (NRF-2013R1A1A3A04008324)

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PATENTABILITY OF DESIGN STATE SPACES

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Design can be characterized as routine design, innovative design, and creative design (Gero, 1990). In computational terms, these design spaces can be defined by different ways of exploring variables and their respective value ranges. We first use design prototypes (Gero, 1990) to map routine design, innovative design, and creative design to the patentability criteria of novelty and nonobviousness. Second, we identify how function, behavior, and structure variable–from Gero's function-behavior-structure (FBS) framework (Gero and Kannengiesser, 2004)—may be patented. Specifically, the FBS framework details how a designer transitions iteratively through various processes in order to create a design solution from requirements (Gero and Kannengiesser, 2004). Our work enables designers to identify, throughout the design process, design elements which may be patentable.

With design prototypes, we define routine design as the space of designs where "all the variables and their applicable ranges as well as the knowledge to computer their values are all directly instantiable from existing prototypes" (Gero, 1990). There are two cases to consider. In the first case, if a designer uses variables and variable ranges taught by a single prior design prototype, then the resulting design is not novel. Lack of novelty implies obviousness. In the second case, if the designer combines two or more prototypes to derive the variables and variable ranges for a design, then the resulting design is novel. In both cases, the designs would be considered obvious since the designer is combining prototypes within known bounds to obtain predictable results.

In innovative design, the boundaries of design variables are allowed to go beyond practical and known "good practice" bounds. This manipulation generates values outside the ranges taught in prior art design prototypes, which results in novel designs. The exploration of variable values in innovative design also has the potential to generate unexpected results, which would result in potentially nonobvious designs. Therefore, the innovative design state space includes a first subspace with solutions that are novel and obvious, and a second subspace with solutions that are novel and nonobvious.

In creative design, one or more variables are added to prior art design prototypes, resulting in a new and disjoint state space. This results in designs that are novel, as these designs would include variables not taught by prior design prototypes. The addition of variables also changes the context in which the designer is working (Gero, 1990), introducing the potential to generate creative solutions, and consequently to generate nonobvious solutions.

Given a potentially novel and/or nonobvious design, how does a designer identify what to patent? We use the FBS framework (Gero and Kannengiesser, 2004), to identify how function, behavior, and structure variables may be used to patent a design or parts thereof. First, the structure of a design, a subset of the structure, and a method of manufacture of the structure, can all be patent protected. The function and actual behavior of the structure cannot be patented on their own. However, in combination with the structure, function or actual behavior can be used as functional limitations of the structure. A new function for a structure—that is not novel—may also be patented as a new method of use of the structure. Finally, expected behavior cannot be patent protected, even in combination with structure.

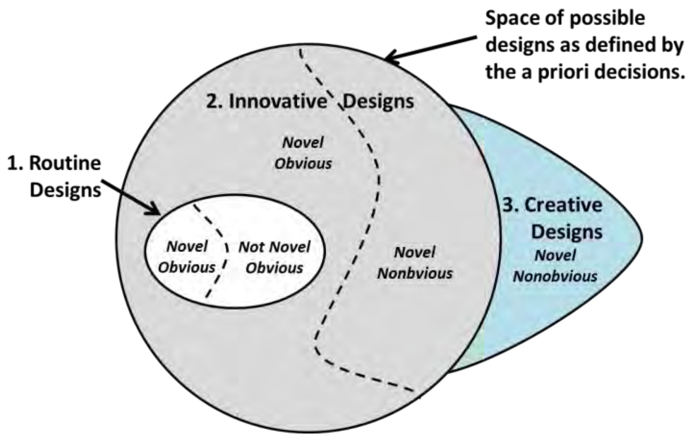

Fig. 1 Novelty and nonobviousness in routine, innovative, and creative design.

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ENGAGING COGNITION FOR IMPROVING WORKFORCE CAPABILITY THRU SERIOUS GAME TRAINING

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This study presents the development of a Serious Game tool that is expected to improve the cognitive engagement of low skilled labourers. The purpose of its development is for use in the capability training of industrialised construction projects in developing countries.

In recent years, there has been an increasing interest in information and communication technology in Architecture, Engineering and Construction (AEC) community due to greater push of globalisation amongst developing countries. In lieu of this, concerns have been raised in the developing countries for the need to expedite the learning and experience of skilled workers. Their shortages and low skill level among the workforce could affect performances when partnering with multinational contractors.

Therefore, we are proposing to engage the labourers' cognition by simulating their training on selected industrialised building system using an interactive Serious Game training environment. The success of this intervention is expected to improve their respective capabilities thus improving the productivity on the construction site.

We have developed a Serious Game proof-of-concept prototype which could evaluate the capability improvement of the trainee in real time. The Serious Game prototype was developed based on selected design principles synthesised from four major gamification design guidelines: Said (2004), Sherif and Mekkawi (2006), Moreno and Mayer (2007), and Annetta and Bronack (2011). The proposed selected principles are expected to create an effective educational game design and evaluation components for computer games learning. For the purpose of developing the prototype, we had utilised an industrialised building system and developed a curriculum based on its targeted learning outcomes.

This prototype is expected to extend the classroom learning into a fun and less risky environment. The significance of this study would illustrate the potential of learning new technology among low skilled labourers for the construction industry. Among the benefits is the potential for expediting the learning process of complex technology curriculum to low skilled labourers in order to enhance the work culture with higher performance and productivity.

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POSTER - BIOLOGICALLY INSPIRED DESIGN

Bio-inspired Fog-Harvesting Mechanism

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Abstract

Water is vital for the existence of all living organisms on Earth. Though approximately 70% of the Earth's surface is covered with water, potable and human-accessible fresh water accounts for only 0.5% of the total water available.

Plants and animals in arid deserts have evolved to extract the water needed for their existence from the highly humid nocturnal and early morning fog. For example, the Namibian Desert Beetle (*Stenocara gracilipes*) harvests water for its consumption from the fog by a process called fog-basking (Hamilton and Seely 1976; Norgaard and Dacke 2010). The Namib Beetle has forewings with alternating hydrophilic and hydrophobic areas, which aid in water-collection (Seely 1979; Parker and Lawrence 2001).

Man has always been fascinated by nature and looks up to it for ideas to solve evolving problems; this is called bio-inspiration (Arciszewski and Cornell 2006). Thus the Namibian beetle has inspired scientists to develop structures mimicking its fog-harvesting nature to provide a potential source of potable water in highly inaccessible areas (Furey 1998; Park, Chhatre, Srinivasan, Cohen and McKinley 2013). Researchers across the globe have come up with fog-harvesting structures Beaini 2012's work focused on enhancing the condensation on surfaces and the factors affecting it and concluded that ZnO coating on surfaces can be made to have both hydrophilic and hydrophobic areas on it.

In this work, I propose a double-layered fog-harvesting setup which has a hydrophilic mesh followed by a surface coated with ZnO to obtain alternating hydrophilic and (super)hydrophobic regions mimicking the forewing surface of the Naibian beetle. Double layered structures increase the water-collection efficiency and in this case, the mimicked surface significantly increases the amount of water harvested.

The forewing surface of the Namibian beetles and the water-repellant (self-cleaning), superhydrophobic surfaces of the wings of Cicadas,

leaves of Lotus and Rice (Gregory and Bhushan 2012; Nishimoto and Bhushan 2013) and the longitudinal grooves on Shark scales provided bio-inspiration for this design. This method would also prove to be a potential solution for tapping water in tropical and temperate regions.

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PARAMETRIC CHAIR GENERATOR

A tool for machine learning style

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1. Learning Styles

An on-going problem in design computing is determining the factors that are involved in our perception of style. Past research suggests that it is possible to learn the parameters that may define a style. Examples of objects such as door handles (Hsaio & Tsai 2005) and pens (Gorno & Colombo 2011) have been studied. This research aims to cover a much broader range of styles, including some that have not found a place in design history. It uses as its case study the chair – traditionally one of the key design challenges.

It was decided that a computer system to generate new models was required for two reasons; firstly it will allow the learning process to work over the generating parameters, rather than parameters read from existing models. Secondly, it would allow an active learning method to fill in gaps in the existing design space; this could extend the scope for original designs to be produced in the future.

2. The Chair Generator

The chair generator is designed to allow a wide range of chair designs while keeping the number of generating parameters to a minimum. The parameters fall into four main categories: form, proportion, texture and method.

The form parameters are discrete, selecting a shape from a set of cross-sections. Each of the set has 34 vertices to allow solid shapes to be created using lofting – joining the corresponding vertices of each cross-section with a spline curve. Two cross-sections can also be hybridised by averaging the corresponding vertex values. After selection the shapes are then positioned according to the proportion and method parameters.

The continuous proportion parameters specify two aspects of the form; firstly they control the size of the cross-sections and secondly the position. The position values will determine the placement of the cross-sections and therefore the proportions of the chair. The method parameters then determine how the cross-sections will be arranged and joined using the lofting method. For example these determine if the chair is made of a single piece or a separate seat and back. They also dictate tension values of the lofting curves. Finally the texture parameters set the finish of the piece.

The generator can create a wide variety of designs that are visually different and viable as chairs.

3. Next Steps

In our on-going work the chair generator is used with an active learning method, where significant regions of the design space are identified and representative designs produced and tested to provide new data as the learning progresses. The testing will be done over keywords (such as 'elegant') to represent the different styles. This is for two reasons; firstly it increases the number of people eligible to act as testers as they will not require expert knowledge to categorise the designs. Secondly it is likely that the chair generator will produce designs that do not fit any of our currently accepted style categories. Previous research (Hanna 2006; Jupp & Gero 2006; Lorensuhewa, Pham & Geva 2006) suggests that keywords provide a good definition of a style so it is expected that there will be a correlation between the words and parameters.

Providing the learning process is successful it is hoped that new designs could be developed to order, potentially using evolutionary methods. However care will have to be taken to ensure sufficient variation is maintained, as this can be a problem with evolutionary methods (Reed 2013).

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What Happens when Creativity is Exhausted? The Role of Design Tools

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1. The Limits of Idea Generation

Previous research has identified tools to help designers in the idea generation process (Scribner, 1962; Eberle, 1995; Zwicky, 1969; Gordon, 1961; Altshuller, 1997; Daly, et al., 2012; Singh, 2009). However, designers may prefer to generate their own solutions (Purcell & Gero, 1996) rather than seek assistance from these tools. It is important to demonstrate that creativity tools can stimulate new ideas even when designers have already exhausted their own ideas. In this study, an idea generation tool called *Design Heuristics* is employed. This method provides prompts to help designers generate alternatives that vary in nature (Yilmaz & Seifert, 2011; Yilmaz, Seifert, & Gonzalez, 2010). The 77 *Design Heuristics* are derived from empirical evidence of industrial and engineering designs.

2. An Empirical Study of Idea Generation With and Without Tools

An industrial design class at a major midwestern university (n=34) participated in a conceptual design session within the classroom. The design problem presented was stated as follows: "Please design a seating unit. Generate as many solutions as you can."

First, participants were told to use any method they wished to come up with creative solutions to the design problem. They were given 30 minutes for their work. Next, the participants were provided a ten minute instructional lesson on *Design Heuristics*. Each participant was given a randomized set of 10 *Design Heuristic* cards with a graphical depiction and description of a heuristic on one side, and two example products where the heuristic is evident on the other (see Figure 1). For example, one heuristic is, "Allow Use to Reorient," which suggests letting the user change the product's orientation to perform different functions. Then, participants were asked to continue working on the *same* design problem using the Design Heuristics cards in their concept creation. The participants had 30 minutes to continue working on their concepts using heuristics.

Working on their own, participants generated an average of 6 concepts each, with a total of 205 concepts across participants. Then, working with *Design Heuristics* on the same problem, participants generated an average of 2.74 more concepts, with 93 new concepts in total.

Two professional designers rated each of the concepts while blind to condition, with a correlation of 0.80. The ratings used a seven point scale for Novelty, Relevance, Feasibility, and Specificity. For Novelty, the average working on their own was 3.8, and using Design Heuristics, 4.6. Specificity was also higher with Design Heuristics concepts, 3.1 vs. 4.4. These differences were significant, $p < .05$. For Relevance and Feasibility ratings, no significant differences were observed (4.6 vs. 4.6; 5.1 vs. 4.8).

3. Design Heuristics Aid in Idea Generation after Exhaustion

When brainstorming ends, further ideas may be generated by using ideation tools such as *Design Heuristics*. This tool provides prompts to help the designer consider variations in their ideas to diversify their concepts. The present study showed that even when idea generation is successful, using *Design Heuristics* resulted in more novel and more specific design concepts. For designers in need of new ideas, tools like *Design Heuristics* can help to move beyond the ideas that initially come to mind.

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INNOVATION-RELATED NEEDS: STABLE AND EXCITED STATES!

Why do needs change when it is 'business as usual' and when not anymore?

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1. Purpose

This poster presents a behavioural perspective on innovation-related needs of actors and the implications for design and management of systemic innovations. There are three key objectives of the poster. First, a theoretical argument is presented to demonstrate congruence between Maslow's (Maslow 1943) hierarchy of needs and the behavioural attributes of actors in Rogers' (Roger 1962) innovation diffusion network. The second objective is to present the findings from an investigation into the innovation-related needs of actors in an innovation diffusion network, using the hierarchical ordering of needs as the underlying conceptual framework. And the third objective is to propose a theory of stable and excited state needs related to innovation and innovation diffusion, which seeks to provide the best plausible explanation of the behavioural patterns observed during this study.

2. Background

Innovators and designers are change agents. Besides being creative, they are also expected to be adept at identifying and creating needs. The needs perspective of innovation is critical, because the success or failure of an innovation is often explained in terms of misread needs or failure to meet user needs. Despite this coupling of innovation and needs, there are no established theories on innovation-related needs and their role in innovation diffusion. This gap is the primary motivation for this research.

3. Methodology

This research is conducted in multiple phases. The initial framework is based on a theoretical argument, which is then tested through empirical studies conducted in the Architecture Engineering and Construction (AEC) sector, especially on the diffusion of ICT enabled systemic innovations. The empirical studies, supported by secondary data from case surveys reported in the literature, are used to identify the patterns in innovation-related needs of the actors. Finally, the observed behavioural patterns of actors' are explained using abductive reasoning, based on the premise that we already know that actors have hierarchical needs such that there are distinct primary and secondary needs. Abductive reasoning allows the best possible inferences and explanation for the observed behavioural patterns, which are otherwise difficult to establish statistically using inductive reasoning.

4. Results

Based on the findings, it is shown that besides individuals, organizations also demonstrate a hierarchical ordering of innovation related needs. The hierarchical view of needs is found to be applicable to each of the three categories of innovation-related needs reported earlier (Singh 2014), which include: (1) 'need for the innovation', typically associated with users and clients; (2) 'need to innovate', typically associated with designers, innovators and researchers, and; (3) the 'need for the diffusion of innovation', typically associated with innovation champions and other beneficiaries. However, actors may move across the need categories and need levels (primary or secondary). For example, environmental conditions may convert a user into innovator or vice versa. While this structural change is well-known, the socio-cognitive mechanisms leading to the change in actors remain unclear. Consequently, it is proposed that the innovation-related needs of actors can be described in terms of stable and excited states. Stable state needs correspond to their needs in unperturbed environmental conditions. For creative actors the stable state needs correspond to secondary needs. For routine actors the stable state needs correspond to primary needs, as work for them could primarily be a means of livelihood. On the other hand, excited state needs correspond to altered needs of the actors under the influence of external perturbation, when it is no more 'business as usual'. For example, the change in environmental conditions may force creative actors to demonstrate conservative and non-creative behaviour, or routine actors to demonstrate creative behaviour, which are their excited state needs.

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PHYSICAL DESIGN COGNITION

Embodied Intelligence for Taming the Digitally Fabricated Singapore Horses

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1. Introduction: Designerly Ways of Unknowingly Using the Body

Much of how we learn in the design process is embodied through interactions with tools, materials, and other people in specific environments. Call it tacit knowledge (Polanyi 1966) or reflective conversation (Schon 1992), these actions are hard to understand in everyday life, let alone formalize in a complex design process. Design cognition and computation should reflect and support this embodied and situated nature of designing. This work explores and develops a *physical* design cognition so that a designer's embodied intelligence can be integrated into physical computation tools.

2. Background: Embodied Cognition

Theories of embodied cognition are often contrasted with information processing models of cognition. Wilson writes, "Human cognition, rather than being centralized, abstract, and sharply distinct from peripheral input and output modules, may instead have deep roots in sensorimotor processing" (2002, pg. 625). Epistemic action suggests that physical interaction eases mental processing (Kirsh and Maglio 1994). Research in the learning sciences demonstrates how bodily engagement facilitates learning of abstract concepts in mathematics (Broaders et al 2007; Alibali and Nathan 2012).

3. What is the body learning in digital design fabrication?

We explore embodied cognition in the context of digital fabrication. Our pilot project utilizes the production steps developed by Sass et al (Sass 2007; Cardoso and Sass 2008). Within this framework we identify examples of embodied knowledge generated through physical interaction during the assembly stage. We track the interactions of the designer's hands (http://youtu.be/P4oX_9bJm28) and categorize three bodily actions that begin to frame how the designer 'thinks with his hands'.

4. Future Work

We use video capture and frame-by-frame editing to track and annotate the movements of the designer interacting with the physical model. The designer retrospectively watched the video to correlate his thinking and actions. Future work should implement more automated motion tracking and sensor technologies. Additional methods of design making can be studied as well.

5. Conclusion

As robotics and other physical computing tools are integrated into design (see e.g., Braumann and Cokcan 2012) embodied theories of cognition are needed to explore how a designer uses his body for design advancement. Can physical computation enhance a designer's embodied intelligence? Are there embodied design skills that cannot be replicated or automated?

Acknowledgements

The authors would like to thank the SUTD-MIT International Design Center for funding this research and making possible its presentation at DCC '14.

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DESIGN SPACE EXPLORATION USING A SHAPE GRAMMAR IMPLEMENTATION

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1. Introduction

Design space exploration (Woodbury and Burrow, 2006) is the activity of discovering and evaluating design alternatives. While this is one of the long-standing motivating ideas underlying computer-aided design (CAD) research, it gains renewed interest in the current context of increased emphasis on building performance. In order to meet specific performance requirements, a designer has to create and evaluate possible design alternatives and their performance. Information systems that can support this task of generating design alternatives can be beneficial, because they allow the designer to quickly evaluate alternatives and freely proceed in an open-ended process of discovery.

A rule-based design exploration system founds on the collection and management of knowledge described in rules. Shape grammars represent a class of rule production systems that generate geometric shapes. They are used to capture design knowledge into shape rules. Using a finite set of rules, a grammar can represent an infinite range of design solutions that can be explored systematically. Moreover, shape grammars define a formalism to represent visual thinking and handle ambiguities that are characteristic of design. However, the computer implementation of shape grammars remains an open research question.

2. Graph-based representation of shapes

The mapping of shapes to graphs, and shape rules to graph rules is a common approach for the implementation of shape grammars. This approach has several advantages, including subshape detection and parametric shape support. An attributed topology graph is used to represent (geometric) objects as nodes, and relationships between these objects as directed arcs. Several node types are distinguished that represent different geometric and non-geometric objects (vertex, edge, face, wall, door, etc.). In addition, several attributes are associated with the graph nodes in order to store non-topological information.

Graph rules are described as transitions between two graphs, which are represented using a typical '*IF-THEN*'-statement. The left-hand side of a graph rule (the 'IF' part) describes the graph that needs to be matched to the host graph. The right-hand side (the 'THEN' part) describes the graph with which the match found in the host graph needs to be replaced. This graph transformation includes deleting or manipulating existing graph nodes, creating new nodes, or performing computations on the node attributes.

3. Design space navigation

An important aspect of design space exploration is the representation of the explicit design space, which is the record of visited design states. This functionality allows a designer to navigate a design space by going back and forth in the exploration process. Moreover, it allows a designer to compare and reflect on multiple design states at the same time, and enables him to recall prior design states or re-use previous paths traversed in the design space. Therefore, the record of visited design states is stored during the exploration process using a tree-like data structure. The tree root represents an initial design state, the branches represent possible rule applications and the nodes correspond to specific states in the design space. The a priori unknown design space is further explored by applying rules to a chosen design state. The set of all leaf nodes that are available for expansion is called the frontier.

4. Proof-of-concept tool

In order to investigate the feasibility of the proposed approach, we have developed a proof-of-concept tool. The interface is designed to provide an intuitive user experience that allows a designer to explore design alternatives using a set of rules. Design states that are on the frontier of the explicit design space are visualized in a separate window, next to a window displaying the current design state. Using the main navigation toolbar, a designer can navigate back and forth in the exploration process.

Finally, the feasibility and performance of the proposed approach is evaluated using two case studies. These two case studies discuss two types of common shape grammar subsets: two-dimensional polygon grammars and grammars that capture building style.

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THE INFLUENCE OF MEMBERS' CREATIVITY POTENTIALS AND CONCEPT EVOLUTION OF PROCESSES ON RESULTS OF COLLABORATIVE DESIGN

A Protocol Study using Torrance Test and Linkography

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1. Purpose & Objectives

It is a hot issue in design studies and practice to know how to encourage creative members of collaborative design to conduct a creative design process and in turn to have innovative results. The purpose of this study is to understand the relationship between results and collaborative groups with different creative potentials sum and the relationship between results and the design process with different concept evolution. The objectives are twofold. First, we used Torrance test to gain score of creative potentials of all participants (Runco & Chand, 1995). They were grouped by the score to form ten teams with different creativity potentials. The results were compared in terms of their design results. Second, we utilized Linkography (Goldschmidts, 1992) to encode the design process and represent the concept evolution process. The results were again compared in terms of their design results. The results of this study hopefully could provide some insights to the question: whether the personal creative potentials or the quality of the design concept evolution contributes more to the end products of collaborative design process.

2. Experiments & Analysis

The experiment was a typical protocol study conducted in lab. Two video-recorders were used in face-to-face collaborative design process for macroscopic and microscopic views. The procedure of the experiment was briefing for 1 minute, concept design process for 70 minutes, presentation for 5 minutes, and post-experiment questionnaires for 15 minutes. Twenty participants were year-four industrial design students from the same class. Ten groups were formed by their creativity potentials.

The design results were evaluated by six experts of both academic and practice. The grading was based on their drawings and the 3-minutes final presentation. Nine points Likert scale was used. Seven scoring criteria included design ideas, function, material, scenario, creativity, style, and completion. The sum of the seven scores represents the design result.

Two encoders were used to encode the design process according to Linkography. Linkography of each team was drawn and the corresponding horizontal concept number (HCN), vertical concept number (VCN), and critical move number (CMN) were calculated. HCN was the number of the main concept along the design process. VCN was the level of the concept being extended or developed from the main concept, being the number of total inks divided by total concept number. Critical move was defined by the sum of backlinks and forelinks. A move of link sum of more than 5 was marked as CM.

3. Results & Conclusions

Main results of this study are four. First, the correlation between creative potentials and score of design result was not statistically significant. Second, the Linkography of the ten teams reflected their scores of design results. The graphs would be shown in the poster for discussion. Third, HCN was of no statistically significant correlation with the score of design results. Four, VCN was of statistically significant correlation with the score of design results. Five, CMN was of statistically significant correlation with the score of design results.

The conclusions of this study are the followings. First, the creative potentials of members of collaborative design process is less important than the level of concept evolution in the process. Second, how much the concepts are developed is more important than how much concepts are produced in terms of the design results.

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COGNITIVE DISCOURSE ANALYSIS FOR DESIGN COGNITION

Addressing cognitive processes in design through systematic linguistic analysis

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Research in design cognition addresses empirical questions about concepts and cognitive processes involved in design procedures across various disciplines, for example to inform computational cognitive models. Unfortunately, phenomena of this kind are not directly accessible to observation, since they concern structures and processes in the mind. Instead, access to internal processes is only possible indirectly, through analysis of external representations and measures: performance data, behavioural strategies, brain imaging techniques, reaction times, and other approaches and methods used in cognitive science. Not all of these tools and methods are accessible to design cognition researchers, whose main focus and expertise lies elsewhere. Arguably, language is a more readily available external representation of cognition. However, simply interviewing people concerning their thoughts and how they went about their task may not be sufficient; this kind of information has often been criticised as being unreliable and unsystematic, and typically does not make its way into scientific reports.

Remedying these issues to some extent, Ericsson and Simon (1993) developed a more systematic way of addressing higher-level cognitive processes by eliciting and analysing verbal protocols produced along with cognitively complex tasks, such as problem solving or decision-making. Think-aloud protocols and retrospective reports provide procedural information that systematically complements other data, such as decision outcomes and behavioral performance results. However, as the analysis of verbal reports in this paradigm typically remains on the content level, in many cases the insights gained in this way still remain illustrative and anecdotal, rather than being treated as substantial evidence.

The methodology of Cognitive Discourse Analysis (CODA; Tenbrink, in press) extends Ericsson & Simon's (1993) approach by providing an operationalised way of capturing verbalised content using linguistic insights.

Cognitive linguistic theory highlights the relationship between language and thought (e.g., Talmy 2000, 2007; Evans and Green, 2006). In particular, lexicogrammatical structures in language appear to be systematically related to cognitive structures and processes. This structural fact carries over to principles of language in use: the way we think is related to the way we talk. This is true both generally in terms of what we can do with language, and specifically with respect to what we actually do – for example when verbalising thought along with design processes.

When asked to verbalise their thoughts, speakers draw in systematic ways from their general repertory of language to express currently relevant cognitive aspects. Their choices in relation to a cognitively demanding situation reveal crucial aspects of their underlying conceptualisations and thought patterns. For instance, the formulations architects used when verbalising architectural design processes systematically reflected various underlying perspectives and shifts between them. These varied between the current view on a design sketch of a complex public building, the envisioned target building, and the wayfinding perspective of a future user (Tenbrink, Brösamle, and Hölscher, 2012).

A systematic analysis of such phenomena provides a useful pathway to access cognition, drawing (where possible) on knowledge about relevant features of language supported by grammatical theory, cognitive linguistic semantics, and other linguistic findings. Although linguistic expertise thus provides useful background, the general approach is simple enough to be adopted by non-linguistic experts, with the most important feature being operationalisation and systematisation of language analysis. The crucial methodological steps of CODA as described in Tenbrink (in press) are straightforwardly accessible to researchers across disciplines. In design cognition research, one possible outcome is a validated account of systematic cognitive processes feeding directly into subsequent computational cognitive modelling.

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The role of difference in reflective design activity

An application of Schön's "see-move-see" account of designing within groups.

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1. Introduction

This research project investigates whether designers and other non-designing actors, working reflectively in heterogeneous groups, is effectively accounted for through Schön's (1984) account of design activity involving 'see-move-see' episodes. We discuss the implications of design activity involving multiple actors, engaged in different types of conversations about different things. Conversation is understood as a signifying practice involving a system of representations, and a key feature of such systems is difference. We discuss an account of the reflective design process within groups outlining how actors identify and manage difference, constructed from two perspectives. First, a series of observations with a postgraduate product design student engaged in a self-initiated, self-directed project over one semester of study highlights the types and degree of difference present during tutorial discussions across a series of design episodes. Second, using a sociological framing, we construct a framework of difference, suggesting it is a significant feature of thinking which directs design activity. Our framework is constructed using a grounded theory methodology, derived from transcripts of conversations from this product design case study. Analysis reveals difference across three types of inter-dependent design worlds (social, material and technical) and how it is managed by actors in order to progress the design trajectory, involving a past, present and future state. Figure 1 illustrates types of difference, evidenced by various combinations of worlds and states engaged by both designers, and non-designers, during one episode during the design trajectory.

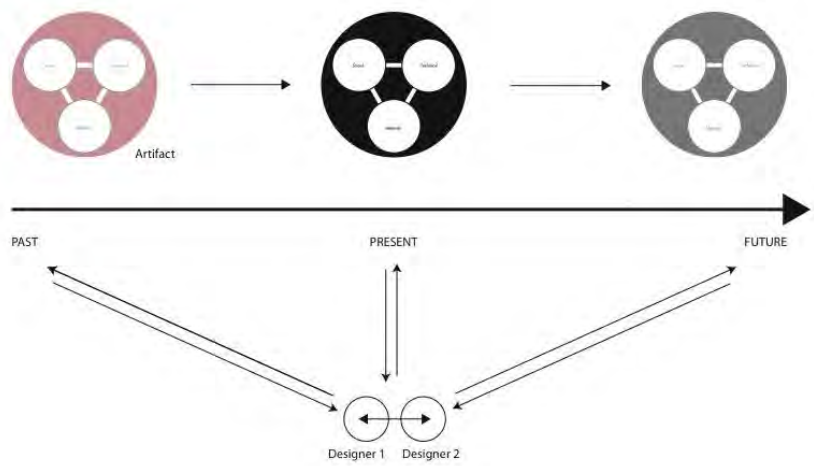

Fig1. Teleological model of a design trajectory, illustrating an artifact across three design worlds (material, technical, social), involving intention and interpretation of design worlds across past, present and future by two designers.

We highlight the importance of the intermediary object (Vinck and Jeantet, 1995, Eckert and Boujut, 2003), an artifact that is at once an inscription device (Latour and Woolgar, 1979) and a boundary object (Star et al., 1989) acting as a silent actor in the design episode, seen as central to the development of future artifacts which remain representative and abstract throughout the design process. We discuss ways in which difference enables the design process to proceed.

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THE RELATIONSHIP BETWEEN COGNITIVE STYLE AND USERS' OPERATIONAL BEHAVIOUR ON MOBILE PHONE INTERFACES

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Abstract

This study provides a detailed description of mobile phone users' operational behaviour based on cognitive style differences and points out the aspects of design that need to be considered from a psychological perspective. Previous studies regard with cognitive style mostly focused on the users' preferences of icons, categories and layouts rather than how the attributes of cognitive style reflect on individuals' operational behaviour. Six touch screen mobile phone interfaces were applied to this study to understand the paths that the individuals utilised to complete tasks. Eight attributes of holistic/serialistic style were described in detail in terms of the qualitative methods of observation and hierarchical task analysis (HTA). The process of individuals' operation with interfaces reveals that holists tend to functional-oriented whilst serialists are more likely goal-oriented. The HTA indicates that the difference of the individuals is highlighted by the strategy of checking unknown items randomly (holist) or one by one (serialist). A model was also established to present that serialists' operational behaviour tends to be more predictable than holists when seeking uncertain items. The phenomenon can be linked with the rigidity of mental set and the ability to deal with hierarchical structures in psychological aspect in future study for establishing a solid connection between design and psychology, to understand how users interact with interfaces from the root.

CONTINUING THE ‘CONTINUA’ II

Application of thin plywood in construction through biologically inspired approach

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1. Introduction

This paper investigates a possibility of application of thin (ca. 5 mm) plywood as structural material. It takes departure from the Erwin Hauer’s ‘Continua’ series (figure 1), and proposes how it could be developed with the contemporary digital tools and by following the biological paradigm. The objective is to minimise wastage as well as to test how the resulting structure would perform structurally and as a light-controlling device.

2. Biological paradigm

The re-design of the ‘Continua’ series takes inspiration from the biomimetic approach. Biological systems utilise information -- stored in the genetic code -- rather than energy in order to solve technical problems (Vincent et al., 2006) and self-assemble structures that unlike the engineered solutions are hierarchical. Energy is used sparingly, single material often serves both structural and protective purposes, the distinction between material and structure is blurred. Today’s environmental concerns and depleting resources invoke interest in the efficient and rational biological systems.

3. ‘Continua’ worth continuing

Erwin Hauer (b.1926) is an Austrian-American sculptor, known for repetitive screen-wall systems based on modular elements cast from moulds in concrete, gypsum or acrylic resin or later CNC-milled in MDF and limestone (Hauer, 2004). These are time and energy consuming and produce waste. ‘Design 3’ (1952) from the ‘Continua’ series would be applicable for external light-breaking building envelopes (Kłaczyńska, 2013).

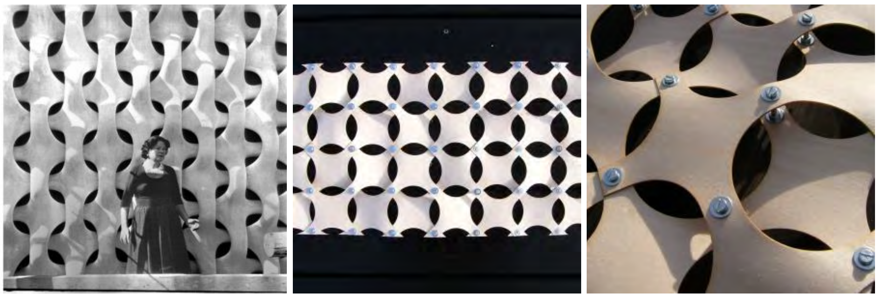

Figure 1 - Erwin Hauer’s ‘Design 3’. Figure 2 and 3 - proposed solution.

4. Proposed approach

The proposed solution (figure 2 and 3) is based on sheet material bent to form and thus achieving strength. Thin plywood is lightweight, durable, flexible and based on a renewable resource. Tension in bending is induced by threaded bars. The cross shape of the panels provides for achieving double curvature. The distribution of convex vs. concave panels regulates the overall stiffness. CNC laser cutter enables variation without extra production time. The system uses the method of parametric design, where sizes of the openings and amplitudes of the wave are variable. That allows for changing the geometry in response to the geometrical, structural and environmental factors. Hierarchically, global form is controlled locally at a level of a single unit, that being dependent on the combination of material properties and geometry. By doing so much less material, energy and time are used to produce a final piece. This solution required reconfiguration of the modules, but the geometrical features of the original ‘Design 3‘ are sustained. Further development of the system includes providing for self-support through the overall geometry, e.g. shells, as well as adding material criteria as a variable parameter by varying the number of plies in response to the curvature.

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ASSESSING USER PERFORMANCE OF DIGITAL INTERFACES THROUGH THE UTILISATION OF FACTOR GRAPHS

A novel method for the assessment of both simulated and empirical user performance data.

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1. Outline

This poster aims to introduce a novel approach in analysing timed user performance data of progressing through digital user interfaces (UIs). By employing a mathematical framework that assesses the complexity of reaching a given screen based on all actions that lead to that screen and segmenting the resultant timing data based on user type, meaningful insights aiding the design process can be derived. Furthermore, using this same method with simulated user timings allows behavioural simulation systems, such as cognitive architectures, to be more efficiently utilised in the design process of inclusive user interfaces. We outline the framework, its association with cognitive architectures and its development methodology. We also outline how the framework is deployed in the design process and how its impact can be assessed from a design perspective. We conclude with insights on the validity of this approach and the next steps in its development.

2. Method and Results

We introduce (i) the limitations of the output data from user testing and when employing cognitive architectures, (ii) a proposed extension based on the application of graph theory on the output data, and (iii) how this mathematical model can be embedded in a design process.

Whilst timing-based data is almost always available for usability assessment – whether through actual user tests or through user modelling applications – this information brings little value to improving the design of the related interface. Timings alone – whether segmented by task or workflow, individual user or distribution of a range of users – do not highlight the challenges actual users may have with the design. This underlines the statements made by Lewis and Rieman (1993) that "bottom line data" (which constitutes timing-based data) is an important aid, but rarely the sole source of usability assessment.

We propose to integrate the availability of rich data regarding the interconnectedness of individual screens and the aforementioned sparse timing-based data that is available in a factor graph representation. Vertices in this representation match individual screens within the context of the application; edges are the actions that the user may complete to move between these screens. The edges are re-weighted by each set of timing-based data, allowing – once a critical mass of user values has been acquired – a representation of both user progression and (timing-based) performance bottlenecks within.

Two distinct models are introduced: longitudinal and latitudinal user progression. The probabilistic interpretation that a user will experience difficulties when transitioning from one screen to another may be represented by the longitudinal user progression. The probabilistic interpretation of the relative difficulty of a specific screen action for a specific user type, based on the overall results across multiple user types, is defined as latitudinal user progression. These complexity models define a formulaic approach for assigning complexity values to the vertices between screens based on the weightings of the edges between them. Once they are propagated (Pearl, 1982) through the factor graph, a more complete representation of relative complexity is achieved and graphically interpreted for the designer.

3. Conclusion

This poster presents the mathematical foundation of a graph theoretical approach for assessing UI complexity, given the timing-based output of cognitive simulations.

The approach supports the design process of inclusive UIs through two key mechanisms: representation and adaptability. Representation is the process in which segmented numerical output data (i.e. timings from cognitive architectures) is collated in a visual representation which supports the designer in making better decisions based on data that gives insights on a broad range of users. Adaptability relates to the underlying capabilities of cognitive architectures, which allow specific impairments to be modelled, giving the designer the ability to investigate the usability of an interface for specific user types.

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TOPOGRAPHIC REPRESENTATION OF PEDESTRIAN COGNITION

Integrating the impacts of environmental qualities to plan walking paths

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1. Pedestrian Dynamic Models and Behavioral Studies in Architecture and Urban Design

Most path planning systems in pedestrian dynamics are based on the assumption that a walker selects paths that are either fastest or shortest (Hartmann, 2010). Research in architecture and urban design suggests that other factors in path planning include angular simplicity of paths (Dalton, 2003) and visibility accessibility based on isovist analysis (Peponis et al., 2004). Moreover, travelers are not ambivalent to many other features of their surrounding environment such as daylight, temperature, visual qualities, etc. Our study improves graph-based approaches in pedestrian dynamics to develop a model that considers the impact of environmental variables in capturing walking trails. It has been implemented as software that runs within a Building Information Model (BIM).

2. Representing the Desirability of Each Point in Space

Our algorithm represents the architectural setting with a 3D BIM, the pedestrians as software agents, each with idiosyncratic preferences for qualities of paths, and environmental qualities that determine desirability and undesirability of locations in space. The environmental qualities are represented as topographic surfaces aligned with the floor plan defining ranges of desirability or undesirability of locations in space.

3. Extracting the Most Comfortable Path vs. the Shortest Path

Hoogendoorn (2003) coined the notion of “cost” of walking to measure the unpredicted deviation from a planned path to avoid collision with mobile agents. We have extended the concept of cost of walking to include the desirability/undesirability of each point along a given path. Our software analyzes the BIM to produce a grid of points to define the walkable field. The points and their connections together define the floor graph. Typical pedestrian dynamics systems compute the Euclidian distance between two connected points and use the Dijkstra algorithm (1959) to extract the shortest path in a floor graph. Our software uses the desirability and undesirability of points to apply weighting factors to the Euclidean distance to find the most desirable path rather than merely the shortest path.

Our system allows for the consideration of an arbitrary number of environmental factors that affect desirability or undesirability. Factors can include daylight intensity, temperature, or isovist properties. The desirability of each point is determined by adding the desirability of different environmental variables after applying each agent's sensitivity factors. The cost of walking is determined by integrating the desirability/undesirability of each point of that path over its length.

Acknowledging the desirability and undesirability of paths opens the door to understanding whether a walking trip is affordable or not. Affordance, as defined by Gibson (1977), determines the possibility latent in a scenario defined in relation to the capabilities of an agent. We believe our algorithm can determine the affordance of a walking scenario for an agent in a more rich and complex way, producing more realistic paths. Our research is a way to incorporate individual's response to sensory aspects of architecture and urban settings into computational modelling and analysis. This subject can be very important to understanding the choices of people in elective walking scenarios related to walking for fitness, tourism, and shopping. Further research will attempt to calibrate our model to empirical evidence of the paths that people choose in these elective scenarios.

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