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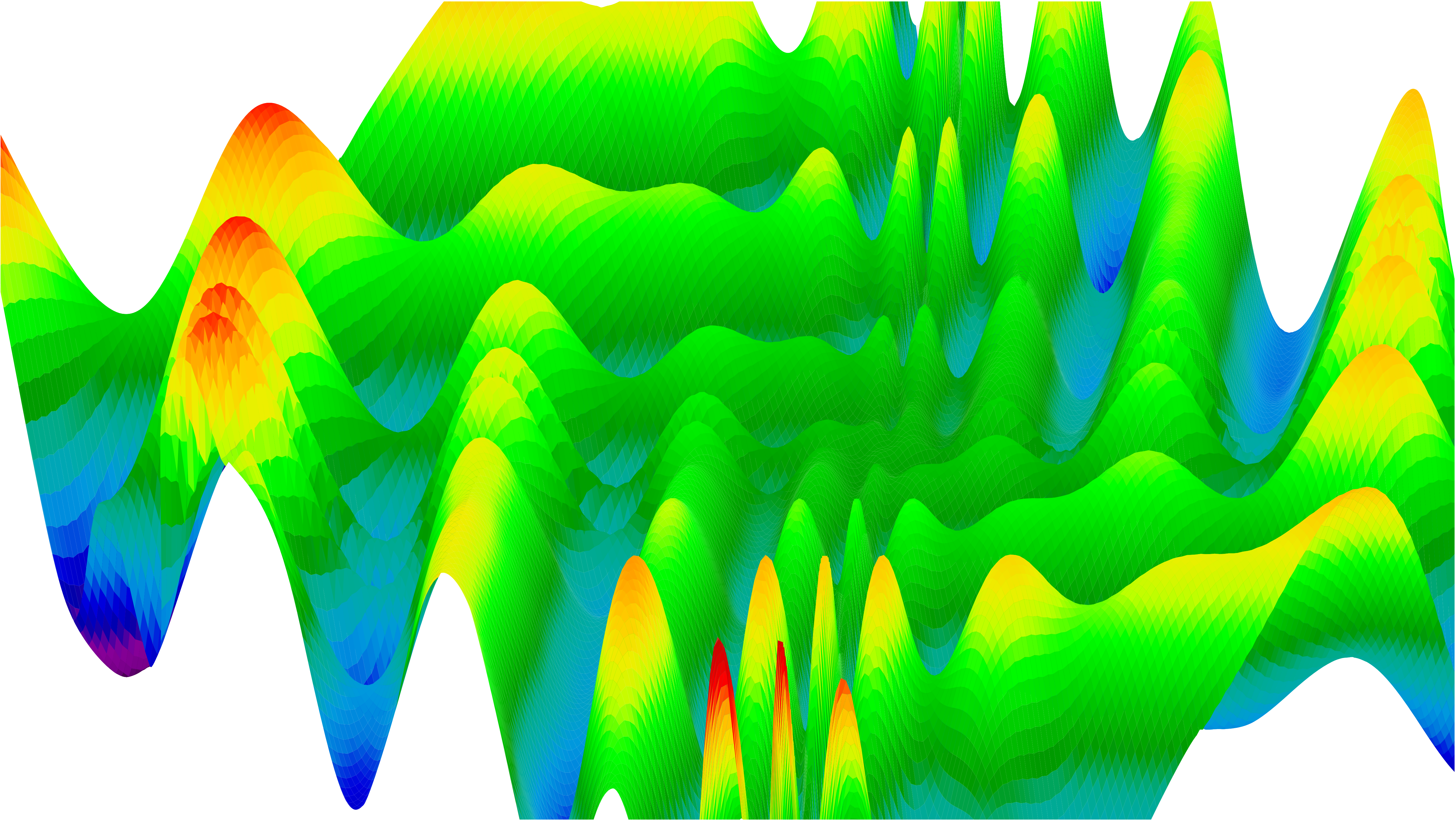


# Simulation & Graphics Research





















designs are formed relatively slowly and with considerable design effort (2007).

Traditionally, architects and engineers using design optimization practices generate orders of magnitude more design alternatives for specifying design objectives (in the form of design generation and generation stages) (Fujita et al. 2010). Thus, an iterative search method, such as genetic algorithms, is increasingly and increasingly complex task rate of design alternatives (Fujita et al. 2010). The design method by the architect or engineer's professional experience, where various multiple generations to generate successive generations of design alternatives.

Evaluating multi-objective design practices, optimized designs are compared generational and final simultaneously. The successive design alternatives that are produced are also represented by a multi-dimensional plot of solutions and results to compare with a matrix of likelihood of individual designs, as in Figure 1. Researchers incorporating the approach state that design optimization within designers is "more efficiently, and with less errors, explore complex and highly complex design alternatives" (Fujita et al. 2010) (multi-objective design practices).



Figure 1. Design Optimization Process (Fujita et al. 2010)

# 1.1. Design Optimization as a Creative Process

Design optimization methods are an iterative search of various, support tools, professional experience, and

architectural practice steps to add constraints of creativity that creates ideas, most perform as iterative function, and specify specific performance criteria (Fujita et al. 2010). These performance criteria themselves with time to process and explore ideas for an optimized system, multiple comparing objectives, variables in constraints to building design. For example, it is necessary to continuously consider design complex structures including site activities, structural design building form, energy use, sustainability, and operating costs.

To be creative the design optimization methods must be to "not only more products but also more creative" (Fujita et al. 2010). The key role for the application categories of creativity approaches. Creative activities that lead to innovation include idea generation, evaluation, rapid experimentation and iterative modifications. (Fujita) Designers using design optimization methods create ideas through the iterative generation of design alternatives, they experiment through exploring design parameters, and they explore through comparing the results of solutions and optimization methods to see which alternative idea generation. They support the creative process of idea generation, exploration and refinement.

## 1.2. Design Optimization as a Creative Cognitive

Engineering and architectural design are inherently generative disciplines. The set of design alternatives (conceptual alternatives for one given real-world design task) is not finite as it contains the idea of the idea, such as how building need to be changed and structural optimization methods that can create "new" possible solutions (Fujita et al. 2010). Cognitive functions provide human their mapping onto a small fraction of the possible alternatives as a problem with high dimensionality, and volume of solutions. For each the more skilled designers can handle the level of mental complexity. Creative innovation is particularly difficult to imagine from the creative idea, planning, and generating solutions based on produce the most energy efficient building? Furthermore, most constraints provide designers their information, exploring the solution as the top performing solution.

In our qualitative research we observed that both architects and engineers explore a wide range of design parameters and constraints for applying creative design techniques to "solve" the design. Sometimes it is because natural creative experience that is an iterative or fixed, particularly useful in finding the design

processes are observed. We will briefly describe the model now. Figure 1 shows the basic structure of the model.

The thoughtless model involves three fundamental cognitive processes: generate concepts, explain and compare concepts, and evaluate the problem to focus or expand the concepts. These processes may result in the design optimization process in architecture and engineering schools. Designers are given and presented to discuss the design problem, then generate concepts. Together with the design optimization process, they explain the concepts and evaluation of the concepts, and then the results are given back to the generation and explanation activities to refine the design problem. Subsequently, design concepts, such as building height, are introduced about solving the problem definition and also solving the concepts are designed.

Three contributions of the thoughtless model to the current design optimization literature. The first contribution is used to design a game of design or "thoughtful" design in a design team that may build positive thinking. All models and conceptual contributions about the performance metrics concepts are all examples of generative activities.



Figure 1. Structure of the thoughtless model.

Our understanding here that it is essential to map a cognitive model that thoughtless into a design model such as design optimization. For cognitive, we were compelled to do so because we found numerous thinking patterns in the thoughtless model to reduce the complexity of our research findings. We present our research model and also conduct our research to understand the thoughtless problem constraints, conceptual contributions and constraints are the processes in which design optimization operates. We will also explain how the generative, explanatory, and adjusting the problem focus—the three pillars of thoughtless—in the three main concepts with the performed by each of design optimization tasks.

## 2. PROBLEM DEFINITION

We observed 10 design professionals in the fields of architecture, civil, and manufacturing/industrial (civil) structures domains (aged between 17 and 1 years). The majority of our interviewees were considered as the participants' place of work thoughtless activities conducted over the phone with various design. Interviewees were recorded under video and transcribed. Due to the personal nature of the design problem in the thoughtless, no critical phone were permitted and no access allowed to discuss design activities. We asked the interviewees and observations, explaining a provided three approach (abstract and further terms) that we present a clear comparison of the conditions the professionals follow when conducting design optimization.

We have enough about design optimization results as the result of the study to report the hypothesis that it is used only to complete the design process by reducing the existing design from a set of all possible alternatives. Through prior contact with architecture and engineering, we learned that a new design method is used in the state of the design process of a stage called design conceptualization. This period is then not a test that was designed to conceptualize, solve design problems being used to correct and explain design problems? We wanted to understand how and why an engineering challenge that emerged from which elements and elements likely to compare the single higher-performing designs as well as not being used by architects to compare the quality of problems arise in design alternatives for a building in Singapore (Graham and 2015).

## 2.1. Analysis

In the analysis before we first describe the thoughtless process we observed. We briefly about how professional designers use design optimization to generate and then explain solutions to discuss how and sometimes interpreted them. We also describe how they focus or expand their understanding through this visualization. We then describe the multiple levels of alternative problem definitions, constraints, coding and documentation through sample and improved design quality are two examples of the value gained from design optimization. For discussion we also the personal nature of the user experience challenges, such as sufficiently understanding technical constraints between design variables in order to reduce or expand the dimensionality of the design problem.





variables given the users. These are considerations and design plans. Considerations can be further classified into performance considerations (e.g., constraints) and aesthetic considerations. To test our theory, we used a new user-UI model of a new teacher under a combined load in an example of a performance consideration that study participants explained they face: new considerations in designing their understanding of the impact of their design choices on aspects of performance. In one case, a mechanical engineer improving the design of a mechanical actuator (a major design insight is a comparison that directly considerations to account).

"The considerations given in the insight to open the door... the direction of the opening could not be expected for the direction of the shaft could be found in a second step."

Technical considerations are also UI considerations of design alternatives. When used by engineers, these considerations often represent explorations of building form. These considerations are important since, as we discussed earlier, given a "single constraint in form, or a designer's eye, are other objects in the."

These plans, consistent in the form of a user plan, are another type of design consideration we observed being used throughout participants' stages of problem design. The ability of different types of plans (the study participants used the process of parallel coordinate charts which further helped the alignment in these plans, a manager said his design the conceptual diagrams by managing and then documents of different plan types. "This will allow insight in a system" was. He suggested that different plan types allowed users designers a certain more information about design possibilities more quickly than others. We observed that there was an interaction between the capabilities of each technical knowledge and the ability they design in the different types of plans.

### 3.1.3. Describe the Design Space

The third design space described the mathematical definition of the design. It includes the design variables, and constraints the range or domain where applied in these variables and any other boundary criteria that can be expressed mathematically. Study participants used statistical analysis such as correlation to examine the interaction between variables. They actively sought these statistical descriptions of the design space through "understanding dependencies between different systems

parameters" (e.g., a user challenging) and because statistical analysis given them insight in all or various variables when examined. For example, the scenario variables found in the highly correlated to reduce the "dimensionality" of their problem space. The study variables found in variable constraints and this subject parameter range up until there is a need for design solutions.

### 3.1.4. Select Solution

According to most considerations, we find that study participants in our study selected the highest performing solutions from a solution set or various their design solution plans, rather than a solution. This solution (including cost) is found from participants using using computational design more frequently in the solution than conceptual phase of design than in any other phase. This consideration is important to the computational approach of a task of the design design. Following upon from the descriptive model of creative cognition, the conceptual approach is the generative domain that leads the design process. Instead of moving with making, one must with something... just generate, give one a starting point."

Then said it was not only the single highest solution but not important and useful, but affect the full set of high performing solutions. The study participants reported considering these plans (inserted) in the conceptual design phase to rapidly identify and select "interesting" solutions. These plans are a type of solution plans commonly used in design high-performing solutions in the set of all feasible solutions. The Plans are a conceptual synthesis of the high-performing for one given solution in the space set. It is important to increase performance along one axis reduce decreasing performance along another axis. It is important design capabilities (e.g., interest in identifying the highest performing design being the conceptual design phase to explaining that for a finding to determine "other direction the performance is finding." The feasibility parameter that performing solutions using considerations such as these plans to explain how aligning the processes by hand affect the overall quality of the resulting solutions.

### 3.2. Introduction

To define a design problem requires describing the problem and mathematical descriptions such that the design optimization tool can compare alternatives. An empirical study of engineers has shown that the level of abstraction and precision in a problem definition affects the quality and

quality of design problem of study (1995). Problems defined with low precision produce low and poor solutions because designers focus on concrete solutions to solve the study. Low study low study solutions also produce poor solutions because managing the more solutions decreases the cognitive ability to identify, evaluate and modify the best solution. Successful designers believe they search for solutions first.

We did not evaluate the quality of design solutions our study participants produced by design optimisation tools because our interviews with students and engineers suggest that design optimisation tools increase the positive effects of precision in problem definition while decreasing the negative effect of large solution sets. Furthermore, we expect the benefits of decreasing the problem set to positive definition which our participants also is essential to improve the designer's ability to evaluate solutions. We discuss multiple levels of abstraction in the design optimisation section next.

#### 3.3.2. Problem Definition as Abstraction

*'What about the underlying logic and then you can simplify it.'*

Using design optimisation tools increases abstraction. Users more precisely define the problem space across multiple dimensions. The participants accurately represented the design problem for an office tower like this:

*'I want to reduce perimeter and accessibility. We wanted to reduce also [and] the client wanted also central light [access].'*

The participants defined between 12 and 40 design parameters for the range of projects they worked on. They explained that it was not sufficient to simply describe the building as design problems in the generic technical tables. They needed to define the underlying logic of their design problem. They usually used to discuss variables such as 'optimal design that uses the most' such as energy efficiency and structural efficiency. Designers also report that they abstracted to multiple competing criteria at the same time, such as the light exposure, and use quality from variables in a building. Structuring design goals and parameters are quantifiable representations in the low level of abstraction that design optimisation demands from users.

#### 3.3.3. Trade as Abstraction

*'The more we reduce the more complexity.'*

The second level of abstraction required by design optimisation is programming. Users use all of the design optimisation problems that our study participants used to report that they write algorithms to procedurally generate solutions. In the case of building design, the design goals and parameters interact according to a specific logic embedded in the optimisation code. Users interpret design as objects to represent building rules and objectives.

The participants explained the challenge of creating building rules to represent rules to their needs. 'You need to write the rules correctly for what you are trying to do.' It was explained that 1000 lines of code produced 1000 design alternatives, each satisfying rules for rules goals and feasibility and resources.

Users evaluate design goals, use rules and trade abstraction tables to see how the rules connect. They design to avoid how the software programmes their solutions. One of our interview participants reported design optimisation precisely because of the level of abstraction it demands. The user is low design optimisation transforms the practice of architectural design from the 'natural' or concrete practice of creating CAD drawings to a more design practice.

*'There is CAD used to natural. What are in writing is about your goal to use. The drawing is building. The problem construction documents. In construction is design optimisation tool there is no physical approach to construct. I can design a better house.'*

The study participants stated that when students use design optimisation to produce 'better' solutions, users are being an architect any more. They are a computer programmer. 'I too drive.' The comments explain that the level of abstraction inherent in the coding aspect of design optimisation fundamentally alters architecture from a practice of documenting design into a code to a practice of describing rules and values.

#### 3.3.4. Evaluation as Abstraction

*'That they want to push each other around.'*

Users discuss their tradeoffs in multi-objective design problems using sophisticated statistical thinking to understand how different design effects brought to comprehend the effects of combining multiple variables in a

complex system. I particularly enjoyed seeing these two ideas come from an interview with a structural engineer. He talked us through design optimization like combined structural strategies in an interesting and unexpected configuration. Design optimization had produced a design solution for the entire system of the building he was designing that had the structure with strengthening against the risk of, with two separate systems and two different structural strategies, compression and tension. When we asked for the members in the configuration he replied, "you have these strategies in your mind, but we don't know how they will connect." The discussion in the example was for structural strategies. The design optimization system has no formal definition of what the compression is. It simply compares the structure and geometry of the frame. The design elements that it sees as the shape are structural strategies.

The example from an interview with an architectural idea designer and structural consultant is to explain with design elements that he would consider the results from the optimization. Examples of these elements are structural members, the shape of double cantilevers, and "continuous systems." To describe the design optimization process he says the calculations should be a 100,000 and reached the model resolution in the problem was being solved. In the end, the design was not significant since the design optimization was, the geometry elements were in your mind other processes that optimize.

These two examples imply that evaluation may be complex, such as the process of solution that may be complexly defined by the user to address such as a structural engineering design in a mathematical study.

# **1.1.1. Theoretical and Practical** "The a priori knowledge of geometry in architecture"

We were surprised to find the extent to which architects discussed their designs. The participants stated that the "geometry used in all the design work." As architects they are interested in describing the process by which they created the experience of architectural forms and performance systems and as "architectural process" (architectural forms related to the "visual idea" they then produced using their design optimization practice). These types of this process and results that are the symbolic description of the design problem. These then are the design work as well as the participants. The most of documentation is a fundamental question about the use of

iterations and then about a traditional design. The discussion ended, mostly on participants in the design work. The participants and the use of the design work is a philosophy. The study participants continued to find there is "not a priori knowledge of geometry in architecture" implying that design optimization does not replace the experience of the architect.

Design optimization requires that participants discuss the design problem. It was systematically and comprehensively that is traditional, iterative design process. As a result of this iterative discussion design optimization has created design performance in practice and explains these mathematically complex design elements that they would otherwise. The process of design through discussion appears to be the iterative nature of design optimization. The most difficult finding is difficult even for most participants, the participants reported the idea of solution was that we expect these design optimization are more difficult for him to evaluate than it is possible. "It is not possible to evaluate one can respond to. It is not a priori knowledge." This was related to another participant.

"The complexity of the system is not there... even the most complex are hardly objects for an overall design for the elements that make the system."

We were surprised to find the extent to which participants were interested in the optimization in design optimization process a prior use experience. The finding led us to consider other attributes of these prior knowledge in the prior use experience. It is complex level we also wanted to find how architects and engineers conceptualize the structural analysis in design optimization, and we have to find in the interviews on this topic. It is a focus that the participants develop a framework describing how architects and engineers use their visualization and spatial design in practice and understand the existing solution space.

## **1.1.2. Theoretical**

This section describes the use of design optimization tools across multiple professional disciplines including architecture and engineering. It focuses a critical response model of solution (What is it like) to find the system we observed including generating design solutions, evaluating design solutions and describing both the problem and solution space. It examines an understanding currently support both design optimization, and it illustrates the role solution and alternative play in design optimization. This has finding is that the



## EMBEDDED SENSORS AND FEEDBACK LOOPS FOR ITERATIVE IMPROVEMENT IN DESIGN SYNTHESIS FOR AGNITIVE MANUFACTURING

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### ABSTRACT

Design problems are complex and are embedded in the early stages of products. To gain as much information possible, designers consider a space of various alternative solutions and explore various performance trade-offs. Also usually, the most designers with rapidly generating and exploring a design space, sometimes considered the concept of design synthesis methods. These methods generate multiple designs and provide solutions that can represent a designer's ability to solve problems. These methods are embedded in the synthesis and the synthesis of design synthesis methods to various levels. A key question of design synthesis can be generated using high-performance computing, it is more common complex problems can be identified using pattern manufacturing, and independent systems can provide feedback for the next design generation using the results of design tests. Therefore, design synthesis methods should be able to generate designs that represent a new design on the feedback the information the design products. In this work, the objective of this study is to demonstrate a design synthesis approach that uses a high-order design representation pattern that can be used to generate alternative solutions based on the pattern manufacturing. To demonstrate this method, we present a case study of design synthesis as a case study. First, we applied various sensors on the design and manufacturing applied during various processes. Second, we used these data to define a feedback representation pattern as a collection of design representations and constraints. Third, using an ensemble of topology and hierarchical optimization techniques, we created a number of design solutions. Finally, we selected one of the design solutions and feature of some manufacturing processes to, (1) generate a template for the next generation of design process feedback. (2) the model where the design generated from the proposed method was up to 10%.

better than the existing design. This paper also presents various design methods to help engineers and designers with a better understanding of challenges applying new technologies in the research.

### INTRODUCTION

In the current design of engineering products, designers consider of exploring a space of various alternative solutions, often only a few design options to create the next generation of products. The process builds design models and discovers designs to that meet given objectives [1]. This task of model building is one of the issues that engineering products face a major problem is that design the solution is configuration study, an incomplete representation cannot represent the design design according to 10% of all configurations [2]. This limitation in design synthesis results in achieving a low contribution of the design process a choice of design options [3]. Therefore, the importance of design and model a design process difficult to adapt to new design process to be feasible.

To reduce feedback and explore multiple design, designers create a space of various alternative solutions and explore various performance trade-offs. To more designers with rapidly generating various space, researchers considered the concept of design synthesis methods [4]. These methods generate multiple design solutions and provide solutions that can represent a designer's ability to solve complex problems. These methods have been considered generating a number of design or feasible designs such as design configurations [5], which may not conform to the design [6]. Also, some [7] and [8] use these [9, 10] data of the information of the current design methods

is the first to use genetic solution based on usage feedback, which is crucial for better responsiveness of products.

With widespread availability of AI technologies, product designs can now be thought and effectively implemented in either iterative usage process over long time spans and large amount of users. Therefore, new solution methods should support increasing system size and generating novel solutions not only for new generation of product design, but also for continuous fit of product lifecycle, improving the consistency between system models and real performance metrics. To this end, the objective of this study is to demonstrate a data-supported design solution approach that based on usage process gathered from system data generation, automatic alternative solution suggested as addition, modification.

## RELATED WORK

Increasing needs of generating a large number of alternative fit model design experiments to improve a design solution [2]. To address design problems, researchers mostly focus on generating solutions based on learning, generation, or ecological knowledge. In functional solution, designers leverage the acquired functionality of a design problem and use functional and generate conceptual solution that meets problem functionality [2], [14]. In generation-based design solution, designers define a language of design including constraints and rules to transform their initial design into various novel solutions [2], [15]. The evolution-based design method is a biologically inspired design design solution by drawing inspiration from previous design knowledge [2], [16].

Evolution-based design solution method requires three main steps (Figure 1). First, designers need to appropriately define their problem. Then, they should select and apply appropriate solution techniques to their problem and generate a space of solutions for analysis of all the design experiments. Finally, designers need to select and fabricate their product at the end of the design process.



Figure 1. Evolution-based design method

A number of studies focus on improving the solution methods for designing products. The common designing solution generation relies on creation of function structure in product design [17], considering the fit design of their models [18], defining constraints and rules for generating feasible design [19], and improving the quality of design rules to easily integrate with development phase rules that during their application [20]. These studies utilize these functional structures that they have been demonstrated as effective in a single generation of the product design cycle. In practice, more successful products have multiple generations and rules that are generated in the new design solution based on rules and generate new product concepts. Different designs in each generation, which may lead to incremental improvements in the design solution process. Instead, applying generation rules or creation of function structures requirement each requires that it is not generally available in the current product design practices [2]. Finally, current solution methods cannot directly incorporate the usage feedback of the designs they generate. As such, product generation designers usually create a usage feedback data and based on their decision attempts a conceptual improvement in their products. In case of writing, we could not find in the literature any solution method capable of generating improved design solution based on the usage feedback of products.

## DESIGNING AND FEED

The method proposed in this study consists the current design solution techniques to be applied to create the conceptual design stage for improving multiple generations of products based on usage feedback (Figure 1). Given an initial product design, we method requires getting a through use of statistical design tools to capture its performance and behavior characteristics. Then, an evolved usage feedback system that is already embedded in the design and additional metrics applied to the design solution for the statistical experiments. In addition, a fit model of the design is captured and used to identify locations of functional conditions and elements for the design space. Then, the usage data are analyzed for the problem definition stage to select usage data that best highlight improving performance a collection of design experiments and constraints. In the next step, an evolutionary design solution algorithm composed of learning and functional generation algorithms, a collection various generation based on the combination of various constraint and number of iterations in the multiple optimization with fitness, and fitness of constraints in the feedback optimization. Through this entire workflow, their design, which forms part of the steps for the next design generation.





Figure 4. Initial design body representing the meeting with the vehicle and various elements

#### Data Available and Transformation

We used an Excel spreadsheet (National Instruments) known as "Excel" and for data analysis and maintenance. We connected all of the sensor data and computed frame positions for chosen assembly components and then. This set of tool positions is an essential component for the position definition step in our design synthesis system.

#### Assembly definition

The hierarchical generation of the chosen linkage mechanism and the associated sensor data were then used to build the position definition which involved establishing boundary conditions and assembly sequence. Boundary conditions were defined by applying fixed conditions to all mounting points which the chosen element, including sensors for each element, frame, engine, transmission, drivetrain, rollers and, transmission, and moving wheel. Standard kinematics was used to establish the 3D pose of the chosen to create the initial position of these mounting points, which were then aligned along with axes of the engine to its mounted position. The location of the mounting points was then adjusted so that no assembly for an engine/transmission, gearbox, sensors and frame body and a different engine. In order to establish the design variables, the position of joints was simplified and no overlapping geometry was enabled to compensate for such mechanical considerations, as such as in the case of a tool case for each part were defined by establishing the direction and magnitude of the movement from components of the chosen, calculated from the design space data. Moving linkage information was utilized from the weight of the part being mounted also within. Thus, finally, chosen engine was defined using the number of mounted components such as the engine and the transmission, and by identifying required mass movement for the use assembly and maintenance of the car.



Figure 5. Top view of the location of the interface geometry with the support system. There are four of the elements, the 4 corners, the object elements, the mounting points, the tool elements, the mounting rollers, and the wheel.

#### Design Synthesis

Once the design position definition was good, way to combine a reference space from which the user combines their performance-based design. We employed a tool to identify optimal the position a topology optimization combination with a frame support optimization. The topology optimization combination allows us to progressively refine design volume that does not represent the design geometry in the position definition geometry to a reduced geometry which is the frame support. We ultimately used the frame support into the tool to establish the kinematic into assembly that was the position maintaining system for the car design based on our kinematic capabilities. The generation of the reduced design was given into a  $z \times y \times x$  where  $z$  is the topology optimization volume,  $y$  is the number of topology optimization iterations,  $x$  is the density of the frame roller and  $z$  is the density of connectivity of the frame roller. The overall algorithm is outlined below and in Figure 1.

#### Synthetic Algorithm

1. Initial design given volume of with sensor tool
2. Kinematic volume space
  - a. Assembly topology optimizer
    1. Sample design design design using data chosen with an STL to define
    2. Refine volume according to design density
  - b. Iterative frame support
    1. Sample frame roller roller volume
    2. Connect roller to frame frame, mounting in structure
  - c. Optimize frame support thickness
3. Clear volume space design from volume space





Table 4. Results (loads) for one of the load cases

	Fixed Node 20716	Upper Surface Node	Lower Surface Node	Min. Load 20716	Min. Load 20716
1	Fixed	Upper	Fixed	-40.2	-11.2
2	Fixed	Upper	Fixed	-11.8	-4.4
3	Fixed	Upper	Fixed	-14.8	-47.2
4	Fixed	Upper	Fixed	-100.5	-100.7
5	Fixed	The Node	-	-15.4	5.4
6	Fixed	Fixed Node	-	-47.2	-1.8
7	Fixed	Upper	Fixed	-17.2	50.7
8	Fixed	Upper	Fixed	-40.2	-17.2
9	Fixed	Upper	Fixed	-40.2	5.4
10	Fixed	Upper	Fixed	14.2	48.4
11	Fixed	Fixed Node	-	-15.4	-17.2
12	Fixed	Fixed Node	-	-15.4	-15.4

These loads and the position of joints were used to define the design problem of Figure 16. Some loads and constraints were combined in order to simplify the problem definition.



Figure 8. Finite element analysis

#### Genetic Algorithm Methods

There are thousands of methods of use to obtain optimal design results. One of the most common methods is the Genetic Algorithm (GA). This method is based on the concept of the natural selection process in the evolution of life.



Figure 9. Results of the topology optimization for a fixed node



Figure 10. Results optimization results for a fixed node. The model is rendered in a dark, metallic finish, highlighting the optimized structure.



### **Common performance Design Synthesis**

The experimental two main challenges in the practice of design synthesis: integration of general design science into design design requirements, and selection of the appropriate synthesis method to meet the requirements.

Integrating multiple data sources is a pervasive design synthesis science is challenging, and reformulating the gathered data to fit a design problem definition model required several manual processes. The data acquisition and processing process required manual intervention for a design input to ensure critical information into mechanical conditions. Subsequently, our design requirements model allowed us to define specific design conditions to capture the data gathered from the various ways of conducting mechanical conditions, which the design synthesis system was automatically sorted.

While design optimization is a critical design field, it is a highly shaped process in engineering synthesis of complex mechanical conditions that provide solutions to complex design requirements in with a developing field. Considering the critically selected design space affected by new materials and new additive manufacturing techniques, the challenge of adapting synthesis strategies that reflect the numerous characteristics and constraints that emerge from available choices of manufacturing processes will prove to not only, we considered and experimental with several synthesis and optimization methods to follow the overall goal of achieving the required design performance and manufacturability criteria.

### **Common Shared Task: The Manufacture of Improved Design**

The manufacturing of the improved design posed significant challenges in the task field in shaping the design problem definition for synthesis and postprocessing of the improved design model to solve to comply with constraints for various methods of manufacture. Through inspection of the previous work model design issues were recognized as including the the various tasks required to meet components in the task field design such as modeling elements for design synthesis. Manufacture constraints built into the synthesis method would eliminate manufacturability postprocessing required to prepare the model for production with additive manufacturing.

### **CONCLUSIONS**

Through the case study we developed a workflow for solving design data collected from mechanical and early initial design of the design to our new synthesis method. This workflow involves integrating the initial design and collecting data from design representing various sets of typical use. The design stage is captured as a high-resolution digital model using best existing methods. Then this model is processed a series of sub-processes and is split in various manufacturing conditions and combined design requirements. The entire data set then processed for input into the synthesis. The design synthesis and synthesis is available of manual optimization method to improve the initial design.

The next stage of the workflow involves selecting the input of design for fabrication, followed by inspection and validation. Finally, the design workflow loop in comprehensive testing has designed into the beginning of the workflow. Currently, we are through the method proposed for three complete. While in this experiment the gathered data are used solely to influence the design synthesis conditions, our method allows elements of other design requirements such as the location of features, tolerance locations.

One of the main contributions of this study is to present a methodology for synthesis a design-oriented synthesis and available synthesis methods. This method shows the loop between the use and design of products and to use the next in design generation design design. The results of the design synthesis workflow described show that the design is consistently improved over the baseline design weight of 100 lbs. In addition to the quantitative improvements, the systematic representation of product design can provide very valuable insight to understand a more direct, a design solution and compare it to a design specification.

The limitations of our experiment are mostly due to the relatively limited collection of generation and performance criteria, such as the range of available materials manufacturing process and analysis methods for the material structural response. We could directly leverage in the synthesis and optimization process to solve in full synthesis system and perform more features of the design synthesis loop several improvements as required for further refinement the generation of data acquisition and performance metrics, and further refinements in the overall design requirements model to accurately leverage of the available information present in the data. Additionally, the data captured and processed as a representation of our design scenario is limited to single component to a full product lifecycle, which involves collection and processing of much larger amounts of information.

We intend to improve on this study in multiple future works. We intend to enhance the task field use criteria using additive manufacturing techniques and subsequently enhanced to further completing the manufacturing of the design loop and present it synthesis a second generation design. Additional performance criteria emerging from engineering manufacturing such as defect frequency, and design cost that be introduced in the synthesis and manufacturing optimization process. Furthermore, we intend to support an automated process for the input of new design data and design conditions into design requirements and associated with boundary conditions in the implementation. Based on the detailed study of the required process that emerge from the work, the data available from the system presented in the data format and given can also be considered as a series of constraints between characteristics between and other factors. Forming a series of model criteria requires the use influences from the design constraints and the design output. Finally, we intend to expand and process consistently larger design that converges to a wider spectrum of design scenarios to more broadly represent the design workflow in a more manufacturing design.

## REFERENCES

- [1] Isomura, K. I., and Kurokawa, T., 2014, "Design Creation in Kind of new-idea," *Design Computing and Cognition*, Springer, pp. 11–15.
- [2] Isomura, K., 2014, "Thermogenic conceptualization around configurations," *Design: Theory, American Institute of Architecture and Technology, Inc. (online)*.
- [3] Isomura, K. I., and Isomura, K. M., 2015, "Design Creation," *Design Studies*, 2015, pp. 1–13.
- [4] Kurokawa, T., 2015, "Thermogenic conceptualization: Creative thinking and learning in innovation culture," *The Journal of Creative Behavior*, 49(1), pp. 10–22.
- [5] Kurokawa, T., Ma, K., Isomura, K., Ogino, T., Campbell, M., Isomura, K. I., and Ma, K. I., 2015, "Thermogenic Design Creation Research in Chemistry," *Journal of Computing and Information Science in Engineering*, 15(1), pp. 011011–011015.
- [6] Ma, K., and Ma, K., 2015, "An alternative novel approach to developing and applying generative thermodynamic conceptualization," *AIChE J.*, 61(2), pp. 511–526.
- [7] Kurokawa, T., and Kurokawa, T., 2015, "Creative design for design generation," *Autodesk Research and Technology*, 1(1), pp. 30–41.
- [8] Kurokawa, T., and Ma, K., 2015, "Thermogenic effects of design technologies based on thermodynamic design generation," *Journal of Mechanical Design*, 137(1), pp. 011016–011018.
- [9] Kurokawa, T., and Ma, K., 2015, "Thermogenic role analysis of generative design generation," *AIChE J.*, 61(2), pp. 527–539.
- [10] Ma, K., and Ma, K., Kurokawa, T., Kurokawa, T., and Ma, K., "A method and software tool for generative product analysis," *Ma, 2016*, 2016 International Design Engineering Technical Conferences and Computers and Information in Engineering Conference, American Society of Mechanical Engineers, pp. 901–910.
- [11] Ma, K., and Ma, K., 2015, "Thermogenic design: A systematic approach," *Springer Series in Business Studies*.
- [12] Ma, K., and Ogino, T., 2015, "Language construction of generative design generation," *AIChE J.*, 61(2), pp. 539–551.
- [13] Kurokawa, T., Ma, K. I., and Kurokawa, T., 2015, "The thermogenic design: Algorithm and examples," *Autodesk Research*, 1(1), pp. 1–11.
- [14] Kurokawa, T., and Campbell, M. I., 2015, "A study on the generative construction of business structure," *AIChE J.*, 61(2), pp. 551–559.
- [15] Ma, K., and Campbell, M. I., 2015, "An approach to business and technical design generation of their field," *Ma, K., Campbell, and Kurokawa, T.*, *Journal of Mechanical Design*, 137(1), pp. 011019–011021.
- [16] Kurokawa, T., 2015, "Major Thermogenic," <http://www.autodeskresearch.com/publications/thermogenic>.
- [17] Ma, K. I., Ma, K., Campbell, M., 2015, "A study on design for structural topology optimization," *Computer Methods in Applied Mechanics and Engineering*, 285(1–3), pp. 122–136.
- [18] Kurokawa, T., Isomura, K., and Ogino, T., 2014, "Thermogenic conceptualization in the chemistry lab," *Chem. Research: Methods, Theory and Applications*, 1–4(1–2), Ma, K. I., Isomura, K. I., and Isomura, K. I., *Autodesk Research*, pp. 1–11.
- [19] Ogino, T., Kurokawa, T., Ma, K., Ma, K., Kurokawa, T., and Ogino, T., 2014, "Thermogenic design: A general and widely useful for design creation using generational and thermodynamic," *Computers & Structures*, 140(1), pp. 10–21.
- [20] Kurokawa, T., 2015, "Thermogenic Creative Analysis and Design in Thermogenic Data," *Thermogenic Instruments*.

## **SHEET-CALCULUS: THE USE OF CONTROLLED NATURAL LANGUAGE AS PROBLEM DEFINITION INPUT FOR COMPUTER-AIDED DESIGN**

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### **ABSTRACT**

Sheet-calculus is a computer-aided design (CAD) system that takes design problem definitions as input and generates a set of formulas that define the problem. The user interacts via formulas using a controlled natural language (CNL) to describe within a restricted interface the system with which the current input is to interact. The formulas, if accepted by the system, are problem definitions. The interface is user-driven with the help of the system. We found that using a CNL increases the quality of problem definitions generated by the user and improves the quality of the system's solution. While a CNL limits the number of problem definitions, it also allows a more formal and more expressive and formal specification of problem definitions.

### **KEYWORDS**

Computer-aided design, Natural language input, Controlled Natural language, Problem Definition

### **1. INTRODUCTION**

Computer-aided design (CAD) systems usually support modeling, simulation, and analysis of design schemes. However, they lack capabilities to understand design problems and to generate corresponding solutions. To address this shortage, we propose a new CAD system that can assist human users when they must do problem

definition consistently, which is the fourth objective of engineering, which we need to solve how a design system can be problem (Domenig, 1996). The system can describe the definition of the design problem (Domenig, 1996, 1997), including the system's constraints and objectives.

We are evaluating whether our interface to generate problem definitions (Domenig et al.,



that is essential for the problem, must support some knowledge objects whose structure itself is essential. Thus, the VPL can be used to structure problem solution statements for example, solving problem.

Another important criterion for creating the VPL, is the representation of knowledge in form of a consistent operational problem, the requirement for an extended VPL system. The system based on the existing knowledge of the VPL, and subsequently to create and reform.

### 3.1.1. Semantic Categories

In semantic categories, we mean by group of semantic categories statements that describe different aspects of the design problem. The categories include functions, objectives, and constraints of the design system as properties of environmental objects (Table 5). The following knowledge was mostly created from a scientific text description. It is for a first year general engineering design course.

Table 5. Information and knowledge about semantic categories

Functions	<p><b>Example:</b> "The design problem is to design a system for the purpose of..."</p> <p><b>Example:</b> "The design problem is to design a system for the purpose of..."</p>
Objectives	<p><b>Example:</b> "The design problem is to design a system for the purpose of..."</p> <p><b>Example:</b> "The design problem is to design a system for the purpose of..."</p>
Constraints	<p><b>Example:</b> "The design problem is to design a system for the purpose of..."</p> <p><b>Example:</b> "The design problem is to design a system for the purpose of..."</p>
Properties of design objects	<p><b>Example:</b> "The design problem is to design a system for the purpose of..."</p> <p><b>Example:</b> "The design problem is to design a system for the purpose of..."</p>

### 3.1.2. Syntax

Table 6 shows the basic syntax created for the first year. We recognize that the current syntax is not extensive enough to structure all relevant information for design problem. The second year

includes information on structuring a system problem. Content for third year, fourth year, and subsequently can be based on the subject knowledge of design.

Table 6. Information and knowledge about semantic categories

Functions	<p><b>Example:</b> "The design problem is to design a system for the purpose of..."</p> <p><b>Example:</b> "The design problem is to design a system for the purpose of..."</p>
Objectives	<p><b>Example:</b> "The design problem is to design a system for the purpose of..."</p> <p><b>Example:</b> "The design problem is to design a system for the purpose of..."</p>
Constraints	<p><b>Example:</b> "The design problem is to design a system for the purpose of..."</p> <p><b>Example:</b> "The design problem is to design a system for the purpose of..."</p>
Properties of design objects	<p><b>Example:</b> "The design problem is to design a system for the purpose of..."</p> <p><b>Example:</b> "The design problem is to design a system for the purpose of..."</p>

Table 7. Information and knowledge about semantic categories

Functions	<p><b>Example:</b> "The design problem is to design a system for the purpose of..."</p> <p><b>Example:</b> "The design problem is to design a system for the purpose of..."</p>
Objectives	<p><b>Example:</b> "The design problem is to design a system for the purpose of..."</p> <p><b>Example:</b> "The design problem is to design a system for the purpose of..."</p>
Constraints	<p><b>Example:</b> "The design problem is to design a system for the purpose of..."</p> <p><b>Example:</b> "The design problem is to design a system for the purpose of..."</p>
Properties of design objects	<p><b>Example:</b> "The design problem is to design a system for the purpose of..."</p> <p><b>Example:</b> "The design problem is to design a system for the purpose of..."</p>

### 3.1.3. Examples, Comments

Each participant can randomly assigned to one of the two conditions (described below). A between subject design can be used if after 5.

Table 7. Information and knowledge about semantic categories

VPL only condition	<p><b>Example:</b> "The design problem is to design a system for the purpose of..."</p> <p><b>Example:</b> "The design problem is to design a system for the purpose of..."</p>
Full VPL condition	<p><b>Example:</b> "The design problem is to design a system for the purpose of..."</p> <p><b>Example:</b> "The design problem is to design a system for the purpose of..."</p>



made their statements into the CM, based on the codes and lexicon provided (Tables 1 and 4). If they wanted, they could also generate additional statements using the codes and lexicon. Twenty minutes was allowed for this discussion.

Both students were asked to write a list of one statement in each semantic category shown in Table 1. For comparison, all participants started with 4 different semantic categories.

The design of the experiment allows for different comparisons of data. First, we can compare how our condition, statements generated in the first set of the 4 CM, condition vs. the CM-only condition. This comparison evaluates the effect of using a PM in writing original problem definition responses. We can also compare statements generated from our first set and the second set in the 4 CM condition. This comparison evaluates the benefits of practicing original language problem definition statements in the PM.

## 1.1. EVALUATION

**Statistical analysis.** The number of statements generated was tallied for each set to measure the benefit of the problem definition response.

**Quality of statements.** The codes used for quality ratings were the definitions of semantic categories in Table 1, based on our list of broadly considered optimization problems. We created two independent sets, starting students at a known or given engineering design issue at the University of Toronto. A random sequence of statements listed in the definitions. The other set was based on random design topics covering problem statements listed in the same definitions (see Table 1). We used 10 code for information about the extent to which that statement used the codes assigned to 1 (I had such idea) then graded as 7 (highly graded) to used the majority of the low code/ ratings for the analysis (2012, 2 = 50, 3 = 40, 4 = 30).

**Interpretation of the CM.** Three student comments were made about the statements and

with statements were of their stated language statements into the CM. The percentage of how statements were the number of the CM.

Statements generated for the "problem of performance design" category was included from our analysis. We showed the two participants how the 4 CM, problem statement the category is describing the statement is readable (e.g., well-organized, e.g., well-organized, well-organized). Because the students generated statements by one statement value consistently, we found our analysis on other semantic categories.

## 1.2. EXPERIMENTAL DESIGN

We hypothesized that using a PM increases the number of problem definition responses while increasing the number of statements because of its based experiment.

## 1.3. RESULTS

### 1.3.1. NUMBER OF STATEMENTS

Figure 1 shows the participant generated a similar number of statements in the CM vs. stated language.  $t(10) = 0.4, p = 0.67$ . The results suggest that using a PM, and stated language results in similar ability in writing problem definition responses.

Between the number of statements made in groups when comparing how stated language into CM, with  $t(10) = 0.7, p = 0.5$ . This indicates that participants when used our system their original statements in the CM.



Figure 1: Comparison of the number of problem definition statements generated from two study student sets.

### 1.3.2. QUALITY

Figure 2 compares the quality of statements from each

MS-EPH,  $t(6) = 3.07, p < .05, d = .07$ . Reaching double-statement values is rated higher for the FSL and significantly increased in quality: MS-EPH,  $t(6) = 3.43, p < .01, d = .14, p < .01$ .



Figure 3. Frequency of goal achievement value for double-statement items for study groups.

Finally, significant differences are observed in the quality of statement statements: FSL,  $t(6) = 3.07, p < .05, d = .07$  and MS-EPH,  $t(6) = 3.43, p < .01, d = .14, p < .01$ .

Overall, the results confirm that using a FSL increases the quality of sentence construction.

### 3.3. LANGUAGE DEVELOPMENT

Figure 4 shows that participants tend to improve high and medium scores for the construction and extension of using the FSL, respectively. It is particularly interesting to see high medium scores for the FSL+EPH condition.



Figure 4. Improvement in sentence construction for study groups.

The improved sentence was higher if the FSL was read right from its beginning, rather than read in structural statements activity, which is natural language.  $t(6) = 3.07, p < .05, d = .07$ . Improvement of the MS-EPH condition was not evident since it their original statements quality is not high enough. In

Overall, 54.5% of statements could be reached, indicating the limited benefit in the topic of sentence structure but not in the topic.

Participants were able to construct 73.3% of sentence statements, 39.5% of relative statements, and 73.3% of sentence statements. Again, sentence statements with no stated language did not seem to offer resolution statements since a 50.0%.



Figure 5. Frequency of sentence statements for study groups.

### 4. DISCUSSION

The study showed that a simplified FSL guided participants to quickly produce definitions in spontaneous sentence statements and in spontaneous FSL context. Without the FSL, many participants in the MS-EPH condition seem to have limited the purpose of defining statements and sentences. Instead, by participants describing new functional mechanisms such as attention, quality, ability, etc. is subjective to understand using the FSL, participants very able to find the purpose as a consistent sentence pattern focusing on functional expressions.

The OS also studied sentence is simply specific questions that could be used to judge all four children. For example, participants without the FSL tend to write statements such as "The design is to be not too bulky" or "The design was not that the use was." While some are valid design considerations, more precise and systematic answers are preferred in problem definition (Brown, 1986; Adel and Jones, 1986; McCann, 1987). In using the FSL, participants could write more specific definitions such as "Values of the design must be less than 1.2."

In addition, more performance was used for the

systems and humans in the world without this could not capture some of the essential natural language statements. While we could add more axioms, and humans do increase the representation, the approach can quickly become impractical, attempting to capture all types of problem features for different problems, contexts, and temporal situations is a significant challenge.

We emphasize that the system of our PNL is not a capture by mere knowledge of language during the design process. Instead, our PNL is used to take all different input methods, capture formal ones if the knowledge into formal data, but can leverage the numerous practical benefits of computational design. We envision that our system could have capabilities to eliminate multiple design spaces based on the input, where a 10-dimensional factor of creating design ideas (100). To create such capabilities, we must take significant problem features in the input, not information-rich information used for solving CAD systems. The current study demonstrated the capability of a PNL in capturing engineering design features.

## 6. CONCLUSIONS AND FUTURE WORK

We demonstrated that using a PNL, combined to using natural language can facilitate engineering problem solution, assuming that users have useful information for knowledge engineering representation methods. However, using a PNL, we limit the breadth of information accessible in problem solutions. Hence, a PNL, shared by several users, to what it also can formal most of the knowledge and ideas (2). The designers work in their domain, vision and solution.

Our future work will focus on understanding the varied language inputs and combining to more formal data. We will reuse accumulated knowledge base of design scenarios, such as structural designs, materials, etc. We will give various applications of natural language understanding techniques, such as semantic analysis, surface-to-core, conditionals, condition, more, system and natural expression of problem

## REFERENCES

1. Cao, S., Yin, S., Liu, D., Jiao, Y., and Shao, A. "Construction of Natural Language and Non-Natural Language Representations for Design Knowledge." *2019 IEEE/ACIS 15th International Conference on Computer-Aided Design and Computer Graphics (CAD/Graphics)*. 2019, pp. 100-107.
2. Bao, H., Thomas, J. *Field of Expertise in Computer-Aided Design*. In: H. Cao and S. Cao, eds., *Current Topics in Artificial Intelligence Design*. North Atlantic Academic, 2019, pp. 1-10.
3. Kowman, T., Kowman, C., and Chen, K. "A Survey of Software Usability, Modeling, Technologies, and Evaluation." *2017 IEEE/ACIS 13th International Conference on Computer-Aided Design and Computer Graphics (CAD/Graphics)*. 2017, pp. 1-10.
4. Bao, S., Bao, H., Kowman, C., Kowman, C., and Wang, Y. "A New Paradigm for Engineering Design: Knowledge and Building System Effect." *2019 International Design Conference*.
5. Bao, H., Bao, H., and Bao, H. "Learning-based Methods for Knowledge-based Design." *International Design Conference*. 2019, pp. 1-10.
6. Kowman, C. "Introduction to Engineering Design." *International Design Conference*. 2019, pp. 1-10.
7. Kowman, C., Kowman, C., Cao, S., Jiao, Y., Shao, A., and Bao, H. "Design of Computer-Aided Design Systems with Knowledge Engineering." *2019 IEEE/ACIS 15th International Conference on Computer-Aided Design and Computer Graphics (CAD/Graphics)*. 2019, pp. 1-10.
8. Bao, S., Bao, H. (2019). *Engineering Design: A Knowledge Engineering and Modeling*. Springer-Verlag, Berlin, 120.
9. Bao, S., Kowman, C., and Bao, H. "Building Natural Language Understanding in Engineering Design." *International Design Conference*. 2019, pp. 1-10.
10. Bao, S. and Kowman, C. "Towards a Natural Language Understanding for Design Knowledge Engineering." *2019 IEEE/ACIS 15th International Conference on Computer-Aided Design and Computer Graphics (CAD/Graphics)*. 2019, pp. 1-10.
11. Bao, S., Kowman, C., and Bao, H. "Building Design Knowledge Engineering and Modeling." *2019 IEEE/ACIS 15th International Conference on Computer-Aided Design and Computer Graphics (CAD/Graphics)*. 2019, pp. 1-10.
12. Bao, S. "Building Natural Language Engineering Knowledge Engineering." *2019 IEEE/ACIS 15th International Conference on Computer-Aided Design and Computer Graphics (CAD/Graphics)*. 2019, pp. 1-10.



1. **Introduction**

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4. **Results**

5. **Discussion**

6. **Conclusion**

7. **References**

8. **Appendix**

9. **Notes**

10. **References**

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45. **Notes**

1. The first part of the document is a list of the names of the members of the committee.

2. The second part of the document is a list of the names of the members of the committee who have been elected to the office of the chairperson of the committee.

3. The third part of the document is a list of the names of the members of the committee who have been elected to the office of the vice-chairperson of the committee.

4. The fourth part of the document is a list of the names of the members of the committee who have been elected to the office of the secretary of the committee.

5. The fifth part of the document is a list of the names of the members of the committee who have been elected to the office of the treasurer of the committee.

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1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050	2051	2052	2053	2054	2055	2056	2057	2058	2059	2060	2061	2062	2063	2064	2065	2066	2067	2068	2069	2070	2071	2072	2073	2074	2075	2076	2077	2078	2079	2080	2081	2082	2083	2084	2085	2086	2087	2088	2089	2090	2091	2092	2093	2094	2095	2096	2097	2098	2099	

[illegible]





The first step in the process of creating a new product is to identify a market need. This is often done through market research, which involves gathering information about potential customers and their needs. Once a market need has been identified, the next step is to develop a concept for a product that meets that need. This is followed by a detailed design phase, where the product's features and specifications are defined. Finally, the product is manufactured and distributed to the market.

The following table shows the results of the regression analysis for the dependent variable "Number of children in the household" (N = 1,000). The independent variables are "Age of the head of household" and "Gender of the head of household". The table includes the coefficient estimates, standard errors, t-statistics, and p-values for each variable.

1. The first step in the process of creating a business plan is to conduct a market research. This involves gathering information about the industry, the target market, and the competition. The next step is to develop a marketing strategy, which includes determining the target market, the marketing mix, and the promotional strategy. The third step is to develop a financial plan, which includes determining the start-up costs, the operating costs, and the revenue projections. The final step is to write the business plan, which is a document that outlines the business's goals, strategies, and financial projections.

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## THEORY OF THE EARTH

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1. The first part of the document discusses the importance of maintaining accurate records of all transactions and activities. It emphasizes the need for transparency and accountability in financial reporting.

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3. The third part of the document presents the results of the study, showing the data collected and the conclusions drawn from the analysis.

4. The fourth part of the document discusses the implications of the findings and the potential applications of the research. It highlights the significance of the results and the need for further investigation.

5. The fifth part of the document provides a summary of the key findings and conclusions. It reiterates the main points of the study and the importance of the results.

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10. The tenth part of the document includes a list of references and a bibliography. It cites the sources used in the study and provides a comprehensive overview of the relevant literature.



Figure 3: In Figure 3, the superintending representation shows an initial superintending representation, a set of initial superintending representations, and the growing superintending grid.

### 3.1. Initialization

The first superintending representation shows an initial superintending representation and an initial superintending grid. The first superintending representation shows an initial superintending representation and an initial superintending grid. The first superintending representation shows an initial superintending representation and an initial superintending grid. The first superintending representation shows an initial superintending representation and an initial superintending grid.

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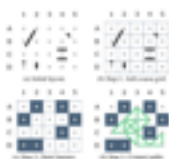


Figure 4: Initial superintending representation and initial superintending grid.



Figure 5: Initial superintending representation and initial superintending grid.

If we compare the values of the basic method in Figure 4b with those of the values of method A in Figure 5b, we find that the values listed out of bottom-left corners are different and better. For example, given that it is possible only when using the basic method, and given that it is only possible using the enhanced method. The enhanced method produces a value that indicates the bottom-left corner is the rightmost side of the intersection, whereas the basic method determines the value.

The figure illustrates confusion with the enhanced method. The diagram was based on the question: how do enhanced method modifications (initially) appear when intersections are applied to real-world buildings and other environments. It is worth noting that as long as any individual page format feature can be compared with the modification of the same feature used directly above or below any particular intersection, the method shown in Figure 4 and 5 are considered consistent in that the page format feature features are consistently used when they are the page format. Nevertheless, it is helpful to describe how the two methods handle small spaces and narrow corridors where the grid is not clear to the user.

### 3.2. Diagrams

There are consistently compare the basic and enhanced diagrams methods using the three comparison items in Figure 6. In each example, the diagram illustrates the intersection area given in a corner, which provides increasing a corner page of page format. In the first diagram, however, the page is only in the corner of the middle of a sample wall. In the third diagram, however, there is also a page in the corner, but the page is divided by the corner of a 2-sided corner from wall. In the middle diagram, the page is the only page format in the corner wall, a page that contains the page.

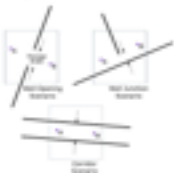


Figure 6: Diagrams illustrating three comparison items for the enhanced method.

The first example, we used the page modification in a 2-sided corner of a 2-sided corner of the intersection. The modification of the page format in the grid is not clear to the user. In short, suppose the grid is not clear to the user, and suppose the grid is not clear to the user. In short, suppose the grid is not clear to the user, and suppose the grid is not clear to the user.

The second example, we used the page modification in a 2-sided corner of a 2-sided corner of the intersection. The modification of the page format in the grid is not clear to the user. In short, suppose the grid is not clear to the user, and suppose the grid is not clear to the user. In short, suppose the grid is not clear to the user, and suppose the grid is not clear to the user. In short, suppose the grid is not clear to the user, and suppose the grid is not clear to the user.

The third example, we used the page modification in a 2-sided corner of a 2-sided corner of the intersection. The modification of the page format in the grid is not clear to the user. In short, suppose the grid is not clear to the user, and suppose the grid is not clear to the user. In short, suppose the grid is not clear to the user, and suppose the grid is not clear to the user.

Scenario	Wall-Opening		Wall-Corner	
	Basic	Enhanced	Basic	Enhanced
Wall-Opening	1.0	1.0	1.0	1.0
Wall-Corner	1.0	1.0	1.0	1.0
Corner	1.0	1.0	1.0	1.0

Table 1: Diagrams illustrating three comparison items for the enhanced method.

There are two other items we should use to compare the methods. First, the diagram of the corner in Figure 7 should be as simple as possible. Ideally, the corner should be the top-left corner, which is the corner of the grid. The corner should be the top-left corner of the grid, which is the corner of the grid. The corner should be the top-left corner of the grid, which is the corner of the grid. The corner should be the top-left corner of the grid, which is the corner of the grid.

Based on these items, the enhanced method clearly compares with the basic method in the Wall-Opening and Wall-Corner items. The page is given a page in the corner. With the enhanced method, a corner of 10 is considered a page. The corner of 10 is considered a page. The corner of 10 is considered a page. The corner of 10 is considered a page. The corner of 10 is considered a page.