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Paper: **Generic Product Feature Analyze and Reverse Application for Form Generation.**

Topic: Industrial Design

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References:
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Abstract:
The several similar operation model of generative design for product design was submitted for years, but need more practical cases to discover the detailed steps and relationship for suit for specific design problems for interested designers or learners to follow.
A generative system usually includes a generative model, but most methods have different aspects and ways to build this potential core. The way that how the generative designer build the generative model also influence the generative performance of the system.
Learn from the biological evolution, we can find the particular part, such as a bone or organ exists in different species' bodies but develop with different functions. We can regard the revolution as the god's idea development, and reverse this design process.
We build a generative model that can evolve into 5 different models, and each model presents a unique type or feature from each other. A multi-dimensional solution array can be extended by these models, and probably includes potential ideas inside. The method to build the generative design, multi-dimensional solution space and its potential to bring more ideas for a specific product will be demonstrated in this paper.

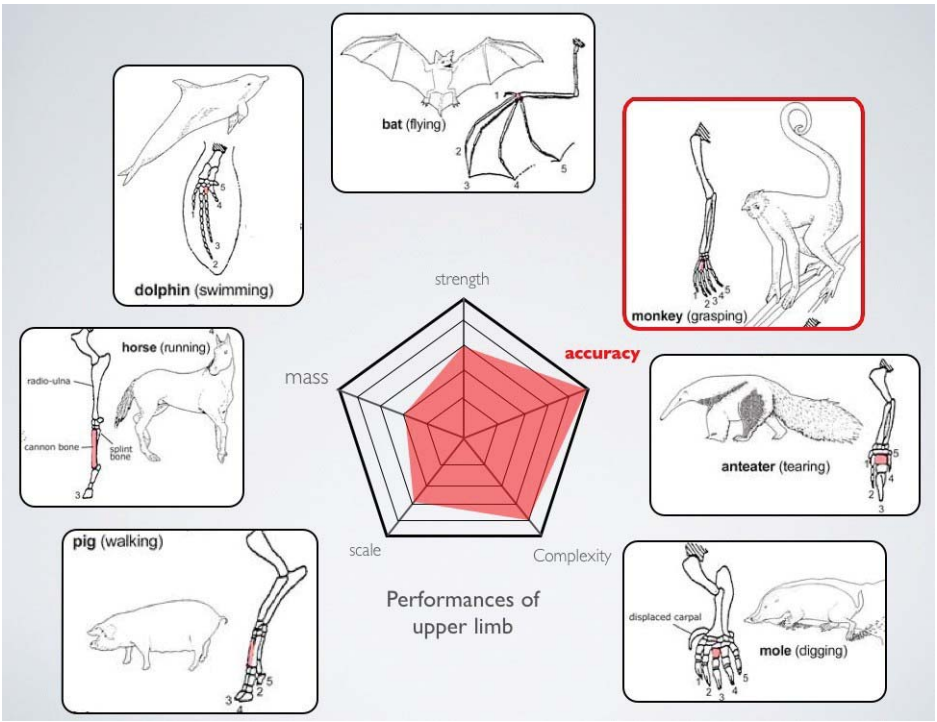

Image of Multi-Dimensional space of upper limb's evolution.

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Keywords:
product design, generative design, generative model.

Generic Product Feature Analyze, Multi-dimensional map and Topological Extraction

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The practical applications of generative design for product design have already been archived by few design studios, but most of them focus on the special features of the generative design, such as complex fabrication and irregular construction. However, the idea productivity is the major applying value of generative design for product investigation, but the application is still developed in the experimental stage so far. Although there are several operative models were submitted, but need more detailed description of procedure steps. In this paper, we discuss the state and barriers of generative design's application in the product design, and submit a method to build the generative model inspired from the concept stage of current design process.

1. Introduce-Comparing the Developments in Architecture and Product Design.

Since the generative design evolved from the generative arts to be a unique design tool, generally, the product design is regarded as one of the applied areas, but its development in product design is far behind to its situation in architecture obviously.

In the architecture, generative design gathers rapid development relatively, especially from the promotion of the free form and digital fabrication, the designers rely on the dynamic model that can reflects the conditional adjustment instantly to review and evaluate the mass complex results efficiently. The dynamic function is very similar the parametric design in the industrial design by an operative definition. The parametric design didn't drive a critical effect in the industrial design as in the architecture, because it has been integrated in the very early period of CAD history and didn't influence the design method.

Although the digital fabrication is also emerging on the few product design as a new trend element, but it was usually applied for its special aesthetic appearance and based on the recent technical improvement of RP manufacturing. Meanwhile, not only applied on the architecture, the irregular or bionics construction also appears on the furniture, lighting and interior design to archive the special balance by the algorithm's computation. But the application of digital fabrication and irregular construction doesn't suitable for the most regular manufacturing technology and means high cost, then become a few special cases.

However, the major value of generative design to be applied on the product design should be its potential of exploring possible ideas efficiently, but the operative process is still in the early development.

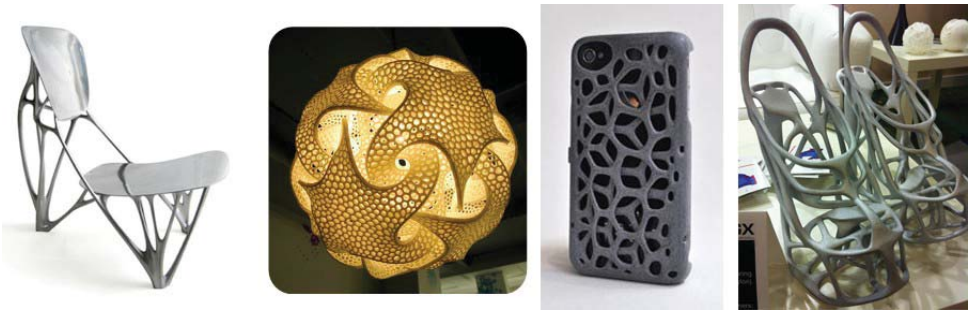

Fig 1: The wide applications of digital fabrication and irregular construction on the furniture, lighting even fashion design.

2. The Models for Generative Design

2.1 The barriers from the requirement about programming ability

The basic definitions of generative design were submitted in recent years, and the one of obvious features is that designer doesn't deal with the result of generative system directly, instead of changing the parametric input or the construction of algorithm to influence the final shapes or forms. The generative design is a design method that its output is generated by a set of rules or an algorithm [1]. Its interactive module that provides control and choices for the designer to guide the selection of desired solutions [2]. The models are shown as the Fig 2.

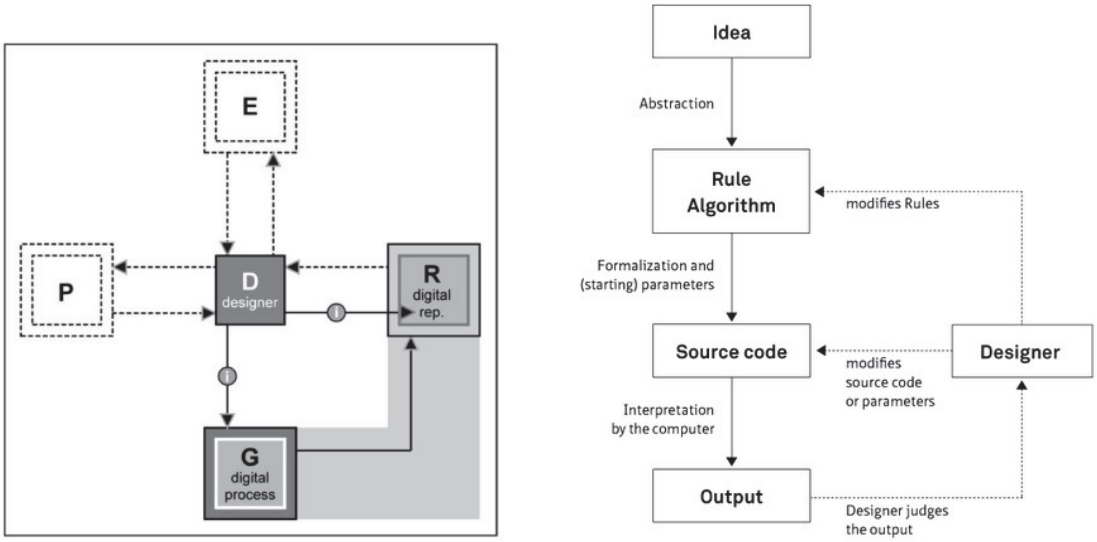

Fig 2: Left, the generative model, Rivka Oxman, Design Studies, 2006; Right, the process for creative generative design, Book, Generative Gestaltung, 2009.

The generative system's solutions probably include thousands, and every time an adjustment of algorithm or a new parametric input may cause a change to whole solutions. The new interaction of design method brings some barriers to designers. The designer can't operate the results directly in the method definition, and this against the traditional sense that designer can modify the result. If they want, the designer needs the programming ability to execute the control in the process, and most designers lack the related training in their background. The design method is based a basic condition of designer, the programming ability, and designer can't proceed designs by the original skill learned from their school. Although while defining the generative model, that need rich design experience about operating geometrical objects, such as fundamental data of curves and surfaces, but the knowledge still needs to be transited into the algorithm by programming.

This situation is very similar the web designer confront before. In the early period, the designing website needs aesthetic elements as most art jobs, and web designer's task is how to apply digital media and transit their creation to be the web materials. When the websites was developing toward to the better interactive service, the editing script provides the designers more power to improve the website's interactive performance. Therefore, the programming script became the priority for the web designers to learn, and now the training already been integrated into the interaction design course as other original art training.

The product design is confronting the same transition, too. Due to the visualized programming tools are emerging and got great progress, such as grasshopper, and make more architects and industrial designers able to apply the generative design technology. But the application and complexity of product design are not so simple. In the different phases of product design process, the performance and importance of generative design have not been verified yet, and several specific models about the product design process were submitted.

2.2 Further models for product design

More and more researches are focusing on the education and design method of product design, and this shows the development of generative design is growing in this field. These researches improved the general definition of general generative design model into a precise level for applying on the product design from other applied fields [3][4]. These models have similar steps about building the generative model, generating variants and selecting solutions, and the model construction for product design is almost stable.

Although these models gave a clearer procedure than before, but most designers or researchers still have problems to follow the steps and build their first generative model or system. Because detailed knowledge for applying the generative design need to be developed. For example, how to evaluate that the design target or what kind of product is suitable for applying this method, or how will the operation process change based on the different applied product.

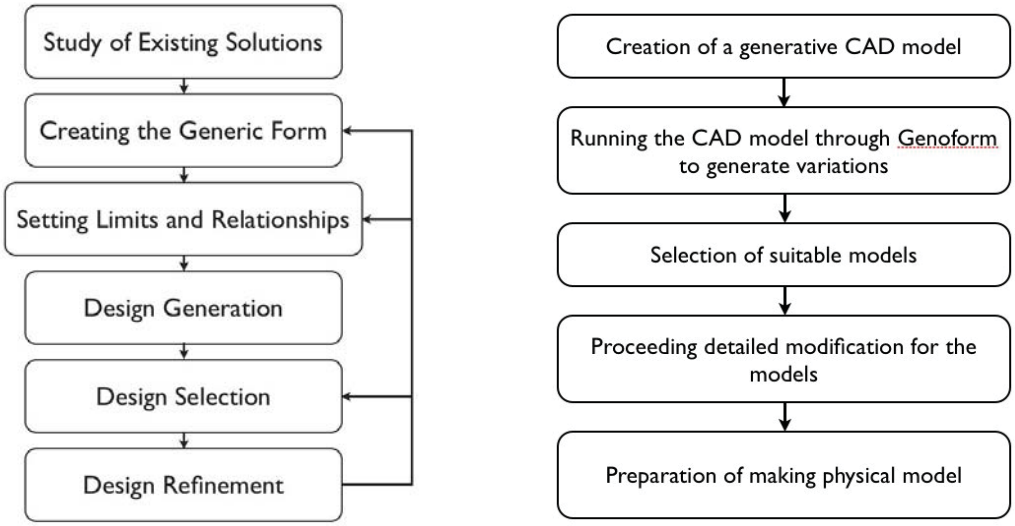

Fig 3: Left, the practical model of generative design for product design, Anandasivam and Bonllo, 2006; Right, the work process of course project, Teaching Generative Design Strategies for Industrial Design, Sivam Krish, 2010.

Besides, the barriers also come from the field and people. Many industrial designers noticed this emerging tool and design method, but most of them usually lack of correct knowledge about it than other people of architecture or graphic design. Even they have, not like the architects have highly interested in learning and using the new technology, they regard this trend as an invasion that is possible to replace their job by the system. Furthermore, even they have the patient to study how to build the generative system, despite of the reusability and productivity of generative design system, they like to compare it with the traditional design method, and query the benefit from the system results. Because building a generative system takes so much time to archive, repeat test and optimize the algorithm, and no mention they need to supplement enough programming ability firstly.

3. The Generative Model

In the model of left side of Fig 3, the first 3 steps descript how to build the generative system, included the study of existing solution, but what information or rules should be study from the existing solution is an indefinite notion. The detailed operation depends on the real situation. Several questions are necessary for designers to consider before they decide to engage in applying the method. For example, what kind of variant range I want my system can reach? Do I have enough knowledge to set the limit and relationships? The performance of generative system is decided by how the designer integrate their knowledge and experience, just like the expert and beginner have different performance in the sketch stage. If the designer didn't have clear cognition about the design object and their expected effect of the system, the building generative system will become an exhausting and frustrating task. A set of preparation should be considered by the designer and will help them to judge the possibility to continue building a generative system.

3.1 Evaluation

The products in different phase of Product Life Cycle get activated though product design, and different industry involves various market situation and strategies. Not every product is suitable for applying generative design, so how to evaluate the product is suitable for applying generative design?

(1) **Complexity of product architecture:** As the complex form fabrication applying on architecture and furniture, generative design has the advantage to execute computational procedure, but the complexity doesn't mean only the product has bionics appearance. The suitable product should include enough components or elements to consist the whole construction and provide enough permutation to establish a solution space that difficult to be developed by designer.

(2) **Unity of idea variants:** In the concept stage of product design, the designer usually develops different approach to satisfy the requirements of creativity, cost down or any design strategy, and few ideas may come out with a total new approach. For example, Dyson's vacuum cleaner used a different airflow principle to keep high suction, and its construction involved to many components that regular vacuum cleaners don't have. This highly creative idea is almost impossible generated by current generative system's capability and AI. The different framework of product usually generated by a new generative model or system, so such a system needs to include several generative models. Few optional features or components are acceptable for a single generative system, and could be archived by logic judgement of the algorithm.

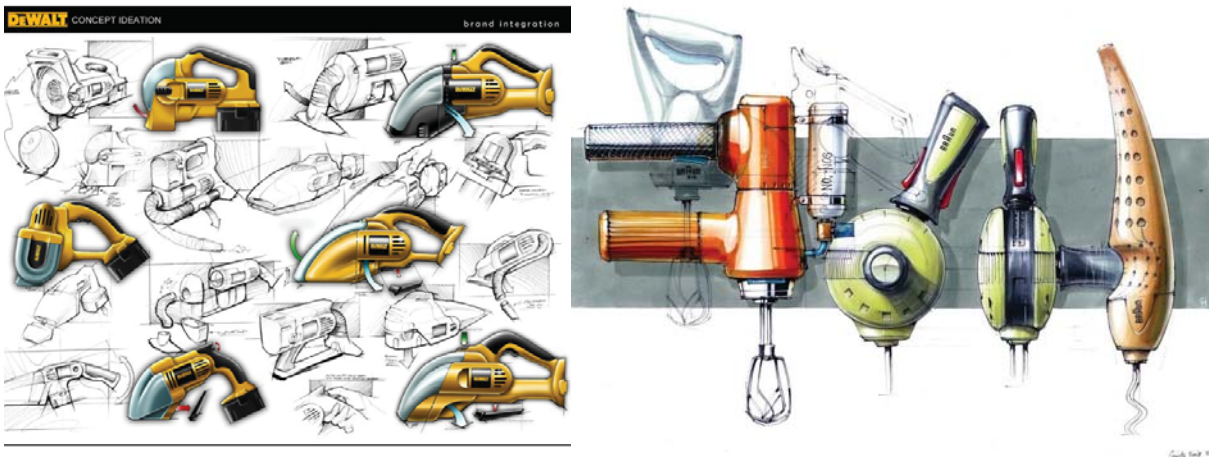

Fig 4: The different idea sketch with the same construction.

(3) **Cost and benefit:** Most experienced designers can generate enough idea variants of a simple product as the generative system, maybe the quantity of solutions from generative system would higher than human designers', but the valid ideas will be very limited by the product's simple framework. However, even building a system to generate a simple product still takes necessary time to define and program, and usually longer than idea

sketch stage. Unless elemental toolkit or package of generative design are developed and can be applied rapidly, or a simple, highly restricted and matured product has low benefit to apply the generative design.

(4) **Available Knowledge** for building the relationship and limits: A system' generative mechanism is consist of many defined relationships between parameters and procedure orders, so the mechanism can execute a set of process to keep the variants match the predefined rules. Enough relationships can maintain the system work well and generate feasible results, but a system lack of enough inner connections may crash often or generate invalid solutions, such as over simple or poor defined. These relationships are based on the various knowledge of ergonomics, manufacturing and materials, and designer need transit these knowledge into the algorithm or associative modelling. The product with rich knowledge resource has better opportunity to form a successful generative model.

After review these conditions, the possibility of product to be built its generative system should has a basic confirmation. Although these conditions probably cause the contradictions from each other, for example, sometimes the unity of idea variants or rich relationship resource means high restriction of idea development, but designer needs to balance these conditions while building the system to keep the system work as he expects.

3.2 The generative model

Several models mentioned about the generative model, the core of a generative system, and it is the most difficult part in the building process. The generative model can be expressed in different way depends on the programming tools, and usually presented as a parametric model. The visual programming tool provides more logic judgmental and computational function, and enables generative model to overcome a parametric model.

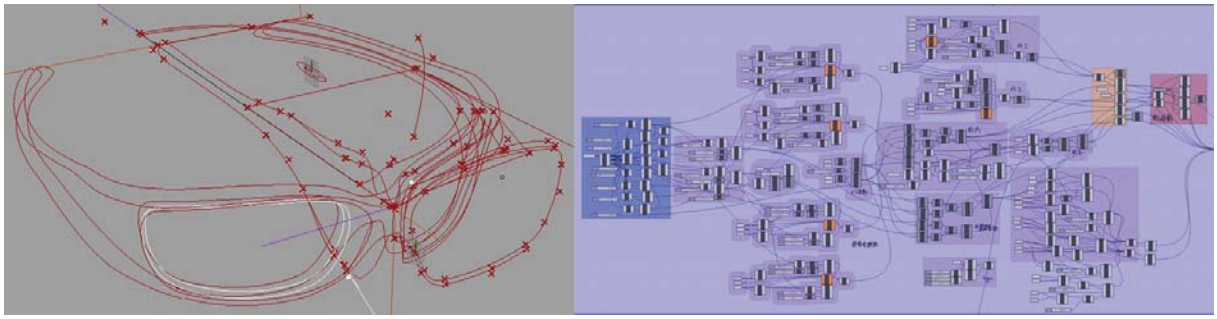

Fig 5: The generative model of sunglasses product and its visual program in Grasshopper.

The generative model is a prototype that has the potential to evolve into variants under the generative mechanism step by step. The steps to build the generative model are very similar to the most modelling process in product design, but every step is programmable and parameterized, and able to connect several optional steps. Therefore, when designer builds the model, he needs to consider about all

possibilities in every step, and every step must be very fundamental and necessary. That makes building generative model becomes a time-consuming task and requires an interdisciplinary background combines both design and programming ability.

The knowledge resource of a product should be analyzed, classified and organized before building generative model. The engineering information can help guild the connections rapidly at the same time.

(1) Ergonomic: Most product are involved with the human and using behaviour, and the dimensions of human body are the best materials to applied on setting the optimized feature size of generative model. The dimension usually indicates a direct geometric relationship between components. For example, the 3 points of a bicycle, the seat, handle and the lowest point of gear cycle decides the performance of riders, and their geometric relationship and range are easy to transit into the parameters and input range of generative model.

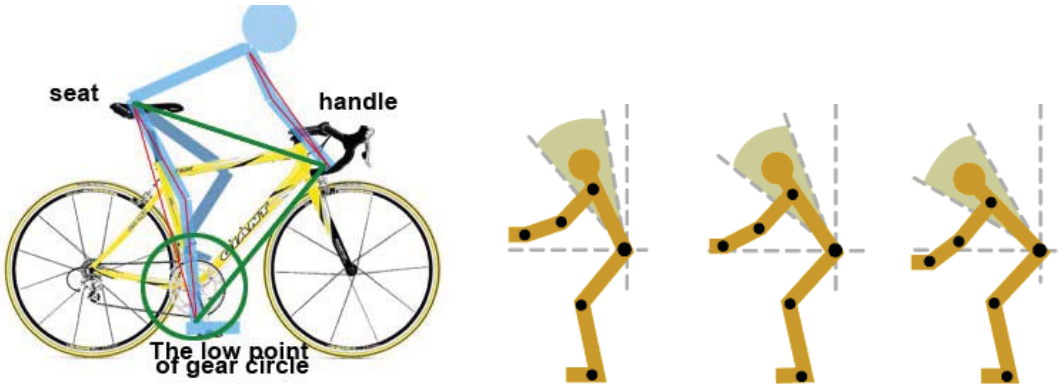

Fig 6: The 3 points of a bicycle riding ergonomics and 3 ideal poses.

(2) Manufacturing and materials: Many limitations and rules come from the manufacturing and materials, although the information probably won't be considered in the concept stage, but sometimes they can prevent the system generates the wrong results can't be made or cost high. The maximum casting size or the material thickness are available information to be integrated into the generative model and improve the feasibility of result.

(3) Component placement: In most product design cases, especially related to the electronic device or electric machinery, the placement of inner components is an important issue between engineer and designer. The engineering task is also easy to be defined into the generative model by algorithm and can be developed into a smart arranging AI to match different considerations. For example, the generative model can give several arrangements based on a tiny or comfortable-to-use placement.

(4) Frequent used preference: During designing product feature, designers usually has their unique method to sketch in their style, and they have their order and curve preference depends on the component placement or product language. The information of product requirements forms the input before designer's sketching and the output they react is their sketch. We can regard

the sketching behaviour and thinking as a sub generative system, and the sub system can be predefined as a macro instruction and can be applied in different generative system or design cases.

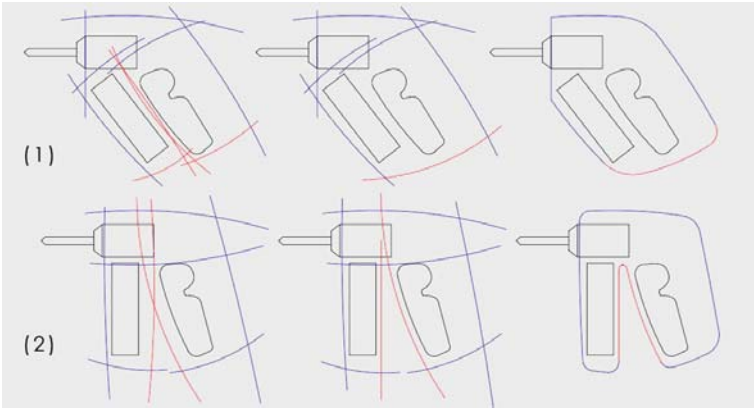

Fig 7: A programmed procedure to generate sketch for power tool design.

Many visual programming tools equip the modelling script functions, and can program above engineering knowledge or parametric preference into a packaged command or macro. The concept is very similar the program tool of Information Technology, and designers don't have to start a generative system from zero and save time to focus on the creative task of a design.

4. The Reversing Analyze from the Sketch

Although the above skills are provided, it's difficult to start building a generative system under a blur notion for most designers, because the way to build the system may very different for other purposes from the demonstration. The designers need a visual tool, and the idea inspired us to combine the traditional concept stage into the building system to help the early stage of setting generative model.

This method requires designer to develop at least 3 to 5 idea sketches in a case, and these sketches should qualify the requirements of product framework's complexity and unity in the 3.1. Every component, parameter and framework of product should be identified from the every sketch, and define their range and relationship. According the sketches, the designer can build a parametric model includes these factors and can transform into each one, then their difference in the parametric input range and feature setting can be recognized. We will use the 3 to 5 sketches to present different types in the designer's mind and construct a multi-dimensional solution map for topological controls. Then we can extract other solutions from the map for evaluation or improve the map structure.

4.1 Pilot sketch

The sketch is always the first choice for a designer to express ideas rapidly. Before the designer start the sketch, he already considered many details and express his concern in the drawing. If we could recognize and list all rules in the designer's mind, that would be dozens. Therefore, we extract the critical factors only from the sketch, and use them to be the reference of building generative model.

These sketches are required to be distinguished from each other and present a unique and classical type among ideas. But they should equip the same framework or product architecture. In this case, we use a set of sport sunglasses to present the designer's ideas, and the 5 types present the different functional consideration as the *Fig 8*.

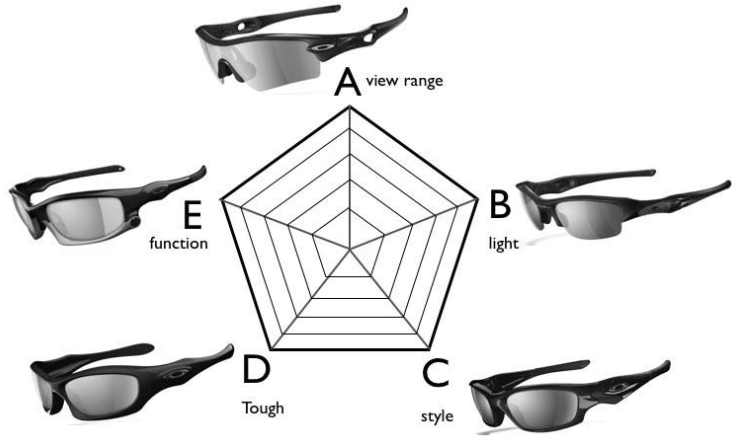

Fig 8: A multi-dimensional idea map that constructed by 5 different types of ideas.

4.2 Reversing analyze and definition

Then we analyzed the 5 types to figure out their difference of DNA, and evaluated the possibility to build the generative model for them. We listed every component and their property as *Fig 9*, and whole product includes almost 50 events. These ideas almost have the same framework and easy to build a model that can transform between them. But we found the Type A has a unique option between lens and frame, and we needs to create another model for it. We built the generative model in the grasshopper, and identified all property value range.

Fig 9: A multi-dimensional idea map that constructed by 5 different types of ideas.

4.3 Multi-dimensional solution map and topological extraction

We used the 5 types to be the corners of a pentagon and constructed a pentagonal multi-dimensional solution map with the generative model. Inside the solution map, every point has a coordinate that can be calculated by the algorithm. The coordinate will get a whole set of property data of product after decoding, and generate a new variant. An interface was designed as *Fig 10* to show the solution map and the solution image that is extracted from the map. The designer can move the extracting point on the map to search the solution efficiently, and the view window will display the 3D image of the extracted solution after decoding.

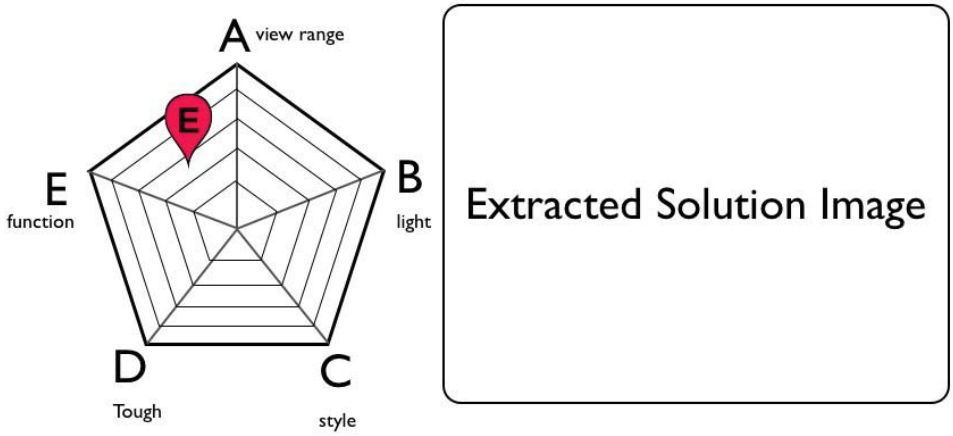

Fig 10: An interface of topological extraction on the multi-dimensional solution map.

Due to the map is 2D, every point is located at the area between 2 types and equips the feature combined the types only. Another 3D map was developed in our research for the extraction for multi-combination as the *Fig 11*, and the pentagon map become a square drill with the 5 corners.

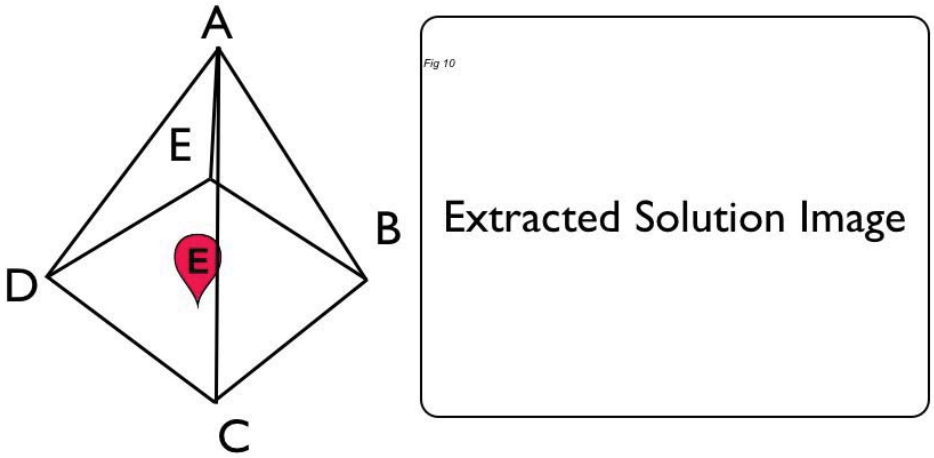

Fig 11: A 3D multi-dimensional solution map.

5. Discussion

The operation of multi-dimensional solution map and the topological extraction are still in our experimental stage to verify its function in the navigation of solution space. The extracted solutions are evaluated for their value and creativity to inspire the designer. The generative system is famous by its solution productivity, but the huge solution space becomes another issue about the navigation and designer is confused inside. The map can present easily the solution space by visual idea types and designer can search rapidly the solution that matches the condition in his mind.

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