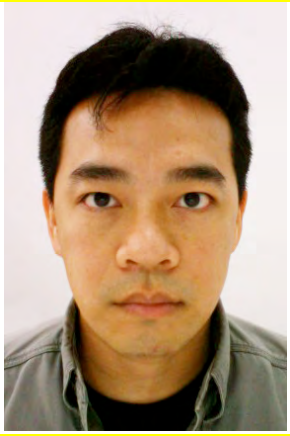
Jian You, Li

Paper: **The Parametric Sketch in the Conceptual Stage of Industrial Design**



Abstract:

Generative design has been applied and discussed comprehensively in architecture. There are also similar applications to generate structures or patterns for particular product in industrial design. However, due to the essential difference between architecture and industrial design, the developments of generative design in both are different. Most applications in industrial design were based on manipulating parameters of a completed 3D model, but not a conceptual idea. The power of generative design maybe restricted by the frame of existed model, therefore the generative function should be activated in an earlier stage. The sketch is an initial and necessary step in the design process, thus this paper leads to the possibility to apply the generative method on the sketch drawing.

For explain, a generative system will show the ability to generate various sketch outlines of product's side view by the drawing rules transited from the designer's experience. To archive above functions, a modelling software and a scripting plug-in language were used in the process. The system accepts the input data in a visualized way. The designer edits various placements of necessary components for the 2D input action, but not deals with the drawing directly. The system executes a series of drawing commands based on those placement figures and reacts with parameters and the editable order of commands. The command order maybe adjusted or developed by the designer after evaluating prior solutions.

In the final, we will discuss the step, rules of operating process, and limitation from the experiment, then review potential benefit, influences from generated results and the evolutional cycle of system under the designer's manipulation.

Topic:
Industrial Design.

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References:
[1] Thomas Fisher, "*Teaching Generative Design*", GA Conference 2001, Milano, 2001.
[2] Jon McCormack, "*Generative design: a paradigm for design research*", Design Research Society, Australia, 2004.
[3] Van der Zee, "Design by Computation", GA Conference 2008, Milano, 2008.

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A Sketch Approach of Generative System in the Conceptual Stage of Product Design

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In this paper, a set of general drawing actions mind activities are identified from a preliminary protocol of human sketch behaviour, and transited into a modular procedure of generative design system. The research object is developing an outline generating system of product's side view. The system takes an internal component placement that decided by users as an initial state, and this 2D input involves mass parameters in a visualized way. By comparing the original sketch thinking and the solutions generated in the system process, an autonomic sketch drawing procedure is rebuilt reversely. The sequence of system actions is updated from a default arrangement to a multi-path framework for dealing with more possible initial inputs. The each shape feature evolves in a main merging outline, and all shape evaluations and parametric decisions are took based on the considering integral composition repeatedly.

This experimentation explores the feasibility and integrity of this sketch transition, and reviews solutions generated in different time point on the sketch developing process.

1. Introduce

The generative design system has been applied for helping designers to systemically explore the solution space by computation, [1]. Designers modify the input, algorithm construction, and parameters of the system to instead of operating the solutions directly,[2]. A evolutionary concept also join in the generative design theory [3].

When review the human sketch behaviour, the form features are evolved and evaluated with the entirety together. A shape feature influenced by others around or the scale of whole body, then the relation makes a feature disappears, comes up and transforms. They are not generated separately and then assembled together.

Although CAD technology updates rapidly, the sketch is still an irreplaceable tool in the conceptual stage of current product design than other design fields. Thus undeniable, the flexibility and possibility make the sketch equips the essential to represent and develop human's creativity. In spite of human mental activities of sketching are difficult to perceived and realized well, the fragmental drawing actions and thinking still could be expressed and identified obviously by designers and on-lookers. These facts support the sketch approach evolve in a generative design context.

2. Definition

2.1 Theme

In this research, a product type is set to the theme for the experiment. The working principle of power tool is quite fixed, and most new designs on the market seek better conviction on the visual image. The design scope concentrates on the main shape, colour and integral composition, and towards a consumer trend. Thus, power tool is quite suitable to be the target.

2.2 Format of Results

In the product design process, the 3-view drawing is used to be a concrete representation for a long period. Due to the type of power tool, its side view expresses most features and details. Therefore, our format of generation in the experiment is a closed outline of power tool ‘s side view that covers a range of necessary components, as the right side of Figure 1. The placement of components decided by the designer in the initial.

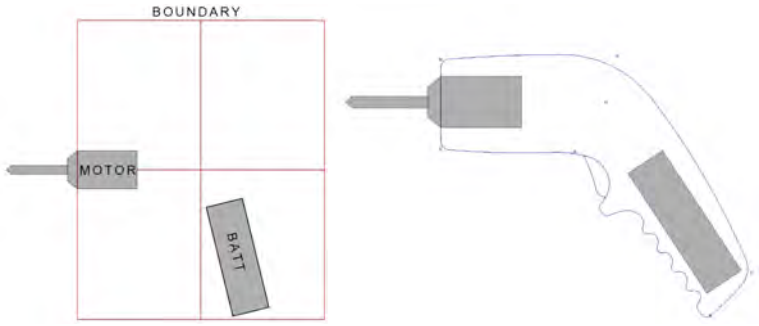

Figure 1.

2.3 Format of Inputs

For simplifying the prototype of system, the internal placement consists of only 2 basic components, includes a motor and a battery, as the left side of Figure 1. The components are presented by 2 rectangles with their rational size, and took as the 2D input in the next protocol and system procedure. The position and direction of motor are fixed, so interviewees just need to decide the battery’s placement. The range of placements has a rectangular boundary to limit the whole product size. The motor is fixed on the left middle of boundary and its working axis towards to the left side. This input contents mass parameters with a functional consideration in a visual way, includes the component’s relative position, size, and axis direction. The third or more components are possible to be added in the initial placement based on a maturer construction.

3. System Rebuilding

The process is divided into 4 phrases to collect the elements of sketch behaviour and transit them into a drawing procedure. The phrases include the protocol, action classification, prototype rebuilding and verification.

3.1 Protocol

The 5 interviewees are asked to draw 5 outlines of power tool's side view that based on various component placements. The detailed curves with the outline are allowed to draw on the paper, but the main result is focus on the outline. The first placement is the same one for all interviewees, and it's a normal gun type placement. The other placements depend on their various designs, but the last one is required to set a irrational placement by themselves. The basic requirements for their sketch are to cover the placement with a well shape to be hold, and express the style for better visual image. When processing each sketch, they need to write down all steps of both drawing and thinking as possible for a script. If those detail curves influence their thinking, they also should be recorded in the script. Their drawing records and sketches are analyzed in the next phrase to infer the types of fragmental action.

3.2 Action Classification

Only the obvious drawing actions and thinking that could be enumerated and explained by the interviewees in their sketching would be collected. Several basic types of actions and mental activities are classified as sketch drawing, visual perception, and evaluation. Then they are transited into several main categories based on modelling and programming commands. They are shown as table 1., such as geometry drawing, measurement, calculation and logical judgements.

Interviewee's action	Category	Execution
Drawing, adjustment, invisible drawing	Geometry drawing	Bezier curve, tangent line, rounding, etc.
	Curve editing	Trim, join, skew, divide, Boolean, etc.
	Parametric adjustment	Bezier curve editing, radius, angle, etc.
Visual perception	Measurement	Distance, angle, vector, scale, position, etc.
	Calculation	Mathematical operation with the value from the measurement.
Visual evaluation	Logic judgement	If, comparison, condition, etc.
Unexplainable preference	Radom function	Parametric input, action jump.

Table 1.

Some obscure actions in our inference are discussed with interviewees and then explained as below. (1) The drawing behaviour based on the interviewee's experience and preference, some actions are probably be skipped by skilful interviewees. Those skipped actions have to be reduced and back to a part of system drawing execution. (2) A short staring of designer on a partial sketch probably combine visual observations and evaluation, and this complex mental activity should be decomposed into continual but separated thinking. (3) Designers unexplainably take a new action that they have never do, or another action different from the one from the same context before. These judgements are inferred to a random under interviewee's agreement.

3.3 Prototype Rebuilding

Then, the interviewees were asked to arrange the commands to finish all sketch outlines as their work by hands in the protocol. If they feel difficult to finish a sketch by these commands, that means their records lose necessary steps. They can suggest new command or category after our necessity estimation in above situation.

The simple placements confirm their basic drawing logic, and the irrational placements test their solutions to complete the sketch in a bad situation. The other 3 scripts with different placements are compared to the first one for realizing the strategy and what fact effect them to make this decision. We found the 2 main facts, the relative position of battery and its direction, because they cause a different design strategy in the early steps. Therefore, the boundary of placement is divided into 4 quadrants after making their threshold clear, and this will applied to be the strategic parameter in the initial state.

In their results, several specific sequences consist of 2 or more actions are frequent and could be identified. For example, the measuring command usually follows the drawing action to detect the new change of outline, and the calculation or judgement usually follows the measuring command to deal with new measuring value. A few interviewees also use a command loop to express their repeated drawing or adjustment. When they could finish sketch by these commands, the Rhino and Grasshopper plug-in are used to rebuild these generative drawing procedures. Their sketching models are selected to be default system procedures in the following verification. In the rebuilding, our purpose isn't simulating the human behaviour only, but also inserting the parameters or options on the necessary points in the process as possible.

3.4 Verification

Based on each interviewee's scripts, similar constructions of drawing procedure are merged, and integrated into 3 prototypes. The original placements are inputted to these system prototypes, and compared the results to the hand sketches. If a difference happens, the procedure will be reviewed and adjusted for correspondence. This review helps interviewees to clear more potential mental activities, but due to the limitation of commands or interviewee's expression, few details of result can't be refined well as the hand sketch. The procedures with high correspondence are combined into the final prototype.

4. System Architecture

4.1 Operation

In our protocol, the sketch of interviewees can be divided to 2 stages generally, the integral drawing and then the detailed drawing. Therefore, the system procedure also contents these 2 stages. The below describes the shortest process to generate a basic outline, as the Figure 2 & 3.

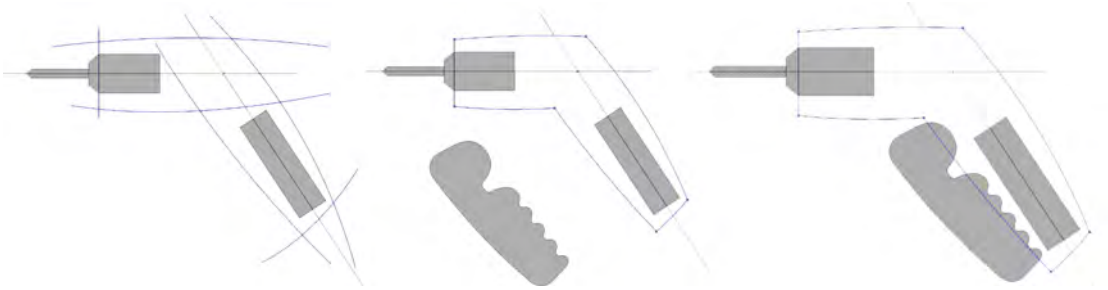

Figure 2.

When user decides the component placement, the system will extend the axes of 2 components to find the shortest path to connect each other. If the axes don't intersect in the boundary, the system will insert an empty component to fit the gap. All components will generate curves on the each side of the presenting rectangles with a distance, and the curvature and distance of curves are parametric. Then system will determine the intersection points from all curves, then trim and join all segmental curves to be a closed shape, the main body. These curves could be exploded and adjusted again by following drawing.

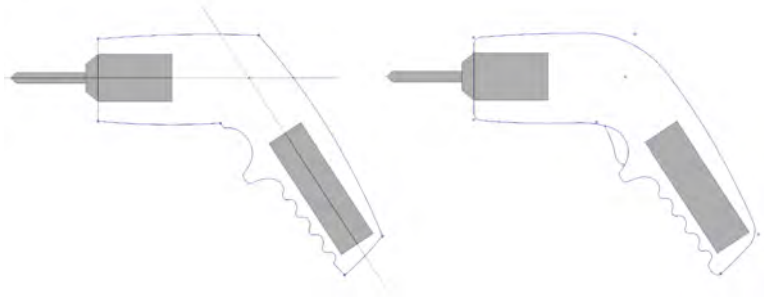

Figure 3.

The handle of power tool is an important detail in this side view and it's a closed shape generated by another drawing procedure for enhancing the hands-hold. The handle shape acquires parameters that recall from the curves of main body. The system will determine the distances between all intersection points for placing the handle shape. If more than one place allow put the handle shape, the procedure will divide to more paths and continue to evolve. If no place fit the hand shape, the system will adjust curves to generate a longest distance to fit the handle shape. When handle shape overlaps on the main outline, system will make a difference Boolean command to trim the curves inside the shape. The last step is deciding the rounding parameter in every corner.

4.2 Generation and Evaluation

There are many logic judgements in the procedure, and usually more than one option happens. Every option will create a new path to develop the sketch with other options in the same time. In a lateral aspect, one input will acquire various sketches in all branch ends of this development tree, as Figure 4.

In a vertical aspect, the system actually generates sketches at each step in a linear process. For example, a sketch takes 7 steps to finish a single process, and the sketches in the early steps usually don't mean any thing or over rough. The sketches in the last 2 steps may match the user's requirement, and later sketch doesn't mean better than its previous generation absolutely.

Summarize the both aspects, the system generate results in a concept of array. In other words, the users don't need to process be completed, they can take the results in any step if they are satisfied.

If a sketch accepted by the user, the related date which includes parameters and command sequences will be output and recorded for updating the parameter value and procedure architecture.

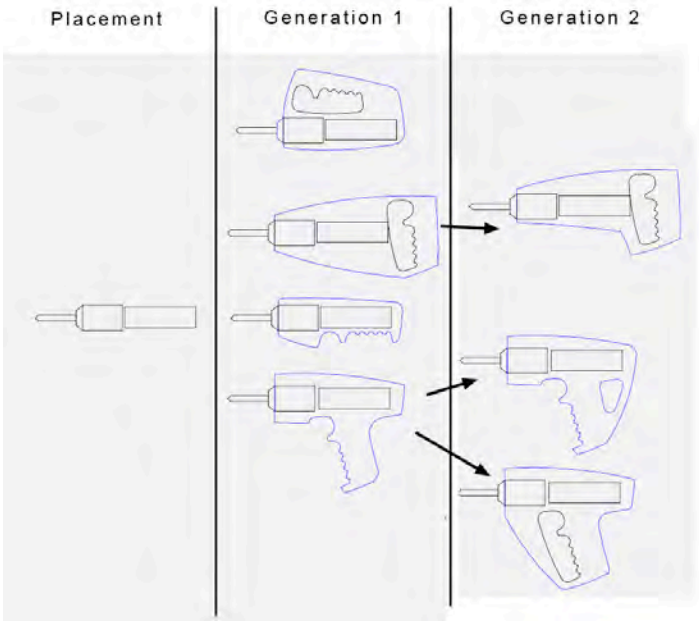

Figure 4.

4.3 Parameter's Construction

Besides the visual placement, the system includes many parameters unavoidably. These parameters appear in the process for the user to decide by evaluating the sketch's development, and the decisions will influence the next command provided by the system.

All parameters in the procedure are classified by functions and tracked, thus they can influence other same kinds by this connection. If a curvature parametric value

was used once, it will have higher rate to be referred by new curves. If a rounding parameter was modified, all rounding inherit the parameter from it will be modified in the same range. After accumulating enough sketches took by users, random or parametric values could be converged in a specific range, and the system will update with higher autonomy.

4.4 Sequence and modularity

In the prototype rebuilding, several command sequences already be identified so far, and integrated into modular sets. These sequences include: (1) drawing- measure- judgement, (2) parametric modification- measure, (3) measure- calculation- parametric modification. The integrations will help us to understand their applied frequency and context in the valid using.

5. Result

The system was provided to those interviewees only to do more inputs, and they tried to input the placements that they can't image, generated by random and add the handle as the third component in the placement. They found the system generated interesting sketches as figure 5 that different from their works, although the parameters are quite similar their style. In the following discussion, they admitted that these results inspired them in some way and encourage them to consider the possibility and innovation of those sketches. Some errors in the results were inferred to the mental activities are unable to explained or expected in the protocol, and that causes the necessary procedure connection lost in the system rebuilding.

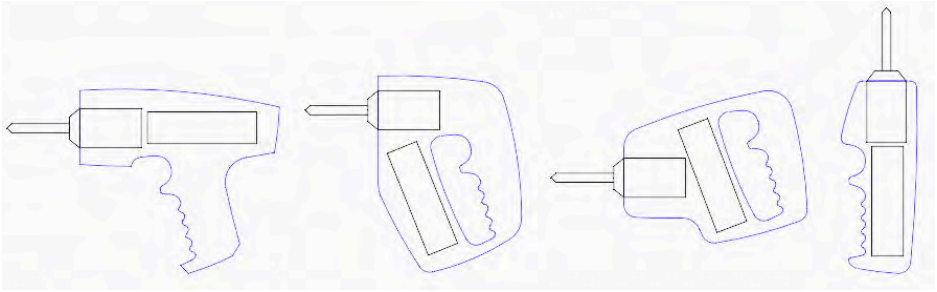

Figure 5.

6. Conclusion

This research focuses to explore the possibility and feasibility to transit sketch drawing into the generative design system and the appearance of the sketch results. This approach shows essential and importance of a sketch procedure. The feature elements should be developed in a completed framework and process.

The approach extends designs in a single view, thus the innovation exists in 3D space have difficult to express by this method. The method also fit for the product with obvious shape and functional expression.

Although our operation and generation base on the 2D curve drawing, but this format also bring the freedom and full support from current computer geometry drawing. The 2D outputs provide important indications and hints for the 3D generative system or modelling work.

7.Reference

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