CLEMSON MECHANICAL ENGINEERING

Fall 2016 ME Graduate Poster

Affordance-Based Product Evolution Using Customer Feedback

Ivan Mata
Department of Mechanical Engineering
Clemson University
imata@g.clemson.edu
Advisor: Dr. Georges Fadel

Fall/2011

Biography

Ivan Mata is a PhD student in mechanical engineering at Clemson University. He holds a BS in mechanical engineering from Central American University. Mr. Mata focuses on design theory (Affordance Based Design), more specifically on achieving affordance-based product improvements with the use of customer feedback. He is a member of ASME and the Design Society.

Overview:

Designers can benefit from involving the user in the product development process. Understanding how users perceive products can help designers make decisions that better accommodate user needs. The integration of ABD and genetic algorithms (GAs) is proposed as a way to capture the perceptions from users in the form of affordance quality evaluations. This research investigates how those user perceptions can be used to improve or evolve product variants.

Motivation

There is still no clear connection between user perceptions and the form of products. Understanding these relationships can enhance the way that designers define the shape of products based on direct customer feedback. Gaining this understanding can become more complicated when a product can be assessed on multiple criteria that can be conflicting. For example, how can the designer define a specific shape of a phone knowing that the size of the screen affects its portability? Moreover, those criteria could affect different aspects of the product differently, meaning that the portability of that phone might only be affected by its depth and not the combination of its height, width and depth dimensions. The challenge of solving this problem lies in successfully linking the form of products to the criteria that users evaluate. Such link can be found if the appropriate theoretical background that defines the criteria is used.

State of the Art

Researchers have created methods that involve the user in the product development process at different stages [1–6]. However, these methods take a long time to generate improvements and do not relate the form of products with the feedback obtained from the users (meaning the information gained cannot be reused). To mitigate this problem, efforts have been made that explore the connection between user perceptions with the overall product using optimization tools [7–15]. Though these methods solve the problem of achieving improvement faster, they still do not define how user feedback directly affects the shape of products. Nguyen et al. [16] proposed the integration of Affordance Based Design [17] and Genetic Algorithms to evolve product forms.

Though their experiments did not use real customers as evaluators, it offers a way to link user perceptions with the shape of products.

Intellectual Merit

The hypotheses tested in this research are:

- Product variants can be evolved using an affordance-genetic algorithm integration that uses real end-users to evaluate the quality of product affordances.
- Relationships between the affordances and the design parameters of the product can be extracted from the evaluations of end-users.

The theoretical background used in this research comes from Affordance Based Design. The affordances of products define the interactions between the users and the product itself. These hypotheses come from the fact that affordances are defined by their quality (how good a product offers a particular affordance, which could be assessed by users) and their form dependence (which suggests that there are relationships between affordance qualities and the shape of products). The previous hypotheses can be summarized in two main research questions:

1. Can design variants be evolved using an affordance-genetic algorithm integration that uses end-users' input?
2. Can relationships between affordances and design parameters be extracted from design evolution experiments results?
    a. Can affordance and design parameters relationships be used to predict user assessments?

Answering these questions would offer a way to predict how product form is perceived by crowds of users.

Broader Impact

This research can help designers gain a better understanding of how their products are perceived by end users. Designers would have better tools to design and improve products that better meet user needs. If used consistently on a large scale, products would be released with less design flaws.

Research Approach

The Affordance Based Design and Interactive Genetic Algorithm integration is proposed as the core mechanism to extract user evaluations. The Genetic Algorithm (GA) implementation basically looks at the evolution of products as an optimization problem, where the feedback from users is being maximized. The GA is in charge of generating solutions which have to be evaluated by the users. The integration requires the development of a design tool that captures user feedback; the tool's operation is explained in Figure 1.

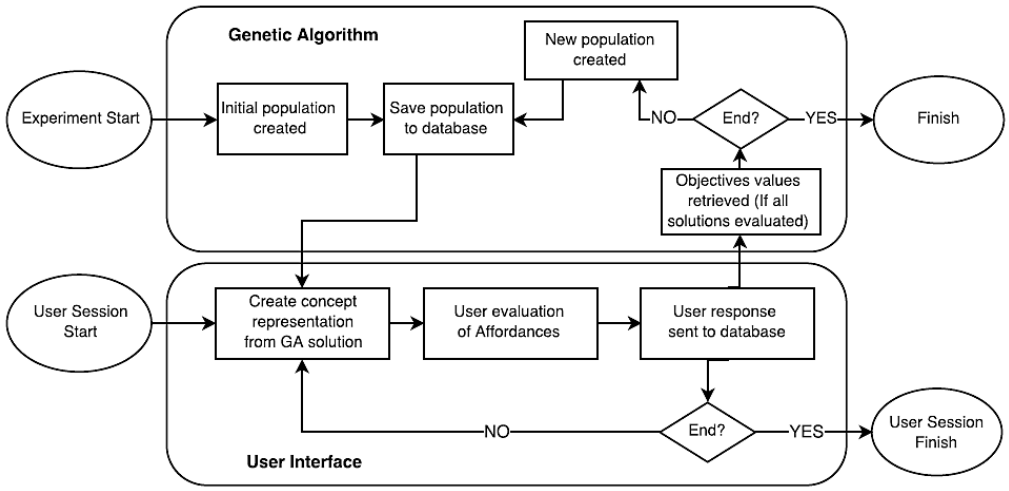

Figure 1 ABIGA operation

A steering wheel is used as a proof of concept to test if the ABD/IGA integration can evolve products through the quality evaluation of their affordances by end-users. Six experiments are performed. Three of these experiments are done with real users and three experiments are done with a random input that replaces real users (to discard the possibility that evolution can be achieved out of chance).

Findings to Date

The results from the experiments show that evolution can be achieved with the proposed integration. Relationships between the affordances and the design parameters of the steering wheel were found. Evolution was not observed with the random input, meaning product improvements are not likely to happen under this framework out of chance. The results confirm that the proposed integration can be used to process customer feedback to improve design variants.

Conclusions

The ABD/IGA integration has proven to be effective in evolving product shape, that is, the external characteristics of products. How the affordance quality assessments affect the internal aspects of products has not been explored in this research.

The quality assessments of affordances can be related to the design parameters of products. The fact that these relationships can be expressed mathematically means that the user assessments of the affordances can be predicted when applied to the redesign of the same product or similar products.

References

[1] Otto K. N., and Wood K. L., 1998, “Product Evolution: A Reverse Engineering and Redesign Methodology,” *Res. Eng. Des.*, **10**(4), pp. 226–243.

[2] Rosenblad-Wallin E., 1985, “User-oriented Product Development Applied to Functional Clothing Design,” *Appl. Ergon.*, **16**(4), pp. 279–287.

[3] Moore W. L., 1982, “Concept testing,” *J. Bus. Res.*, **10**, pp. 279–294.

[4] Dolan R. J., and Matthews J. M., 1993, "Maximizing the Utility of Customer Product Testing: Beta Test Design and Management," *J. Prod. Innov. Manag.*, **10**, pp. 318–330.

[5] Ciccantelli S., and Magidson J., 1993, "From Experience: Consumer Idealized Design: Involving Consumers in the Product Development Process," *J. Prod. Innov. Manag.*, **10**, pp. 341–347.

[6] Herstatt C., and Hippel E. von, 1992, "From Experience: Developing New Product Concepts Via the Lead User Method: A Case Study in an 'Low Tech' Field," *J. Prod. Innov. Manag.*, **9**, pp. 213–221.

[7] Reid T., Gonzalez R. D., and Papalambros P. Y., 2010, "Quantification of Perceived Environmental Friendliness for Vehicle Silhouette Design," *J. Mech. Des.*, **132**(10), p. 101010.

[8] Orsborn S., and Cagan J., 2009, "Multiagent Shape Grammar Implementation: Automatically Generating Form Concepts According to a Preference Function," *J. Mech. Des.*, **131**(12), p. 121007.

[9] Orsborn S., Cagan J., and Boatwright P., 2009, "Quantifying Aesthetic Form Preference in a Utility Function," *J. Mech. Des.*, **131**, p. 61001.

[10] Banerjee A., Quiroz J. C., and Louis S. J., 2008, "A Model of Creative Design Using Collaborative Interactive Genetic Algorithms," *Des. Comput. Cogn.*, pp. 397–416.

[11] Brintrup A. M., Takagi H., Tiwari A., and Ramsden J. J., 2006, "Evaluation of sequential , multi-objective , and parallel interactive genetic algorithms for multi-objective optimization problems †," *J. Biol. Phys. Chem.*, **6**(August), pp. 137–146.

[12] Brintrup A. M., Ramsden J., and Tiwari A., 2007, "An interactive genetic algorithm-based framework for handling qualitative criteria in design optimization," *Comput. Ind.*, **58**(3), pp. 279–291.

[13] Brintrup A. M., Ramsden J., Takagi H., and Tiwari A., 2008, "Ergonomic Chair Design by Fusing Qualitative and Quantitative Criteria Using Interactive Genetic Algorithms," *IEEE Trans. Evol. Comput.*, **12**(3), pp. 343–354.

[14] Hsu F. C., and Chen J.-S., 1999, "A study on multi criteria decision making model: interactive genetic algorithms approach," *IEEE SMC'99 Conference Proceedings. 1999 IEEE International Conference on Systems, Man, and Cybernetics (Cat. No.99CH37028)*, Ieee, pp. 634–639.

[15] Ren Y., and Papalambros P. Y., 2011, "A Design Preference Elicitation Query as an Optimization Process," *J. Mech. Des.*, **133**(11), p. 111004.

[16] Nguyen M. T., Guarneri P., Fadel G. M., and Mata I., 2012, "Genetic algorithms applied to affordance based design," *ASME IDETC/CIE 2012*, Chicago, IL, pp. 1–7.

[17] Maier J. R. A., and Fadel G. M., 2009, "Affordance based design: a relational theory for design," *Res. Eng. Des.*, **20**(1), pp. 13–27.