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INTERACTIVE EVOLUTIONARY DESIGN FOR RECOGNICING CUSTOMER NEEDS AND WISHES

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1. Introduction

In product design the aim is to modularize products for minimizing product variants and production expenses. Identifying customers' needs is one of the main issues. Mass customization has been tried as a solution to satisfy those customers' need, which means producing goods and services to meet an individual customer's needs with near mass production efficiency (Jiao & Tseng 2004). Mass customization is most often referred to as collaborative customization, which means that an enterprise has a dialogue with its customers to specify their needs in order to generate a customized offering that fulfils those needs (Gilmore & Pine 1997).

Mass customization may be carried out with various methods, which combine different options for customization while maintaining the cost option (Piller 2004). Modularization can be regarded as the central principle of mass customization: a product with a modular design provides a supply network with the flexibility that it requires to customize a product quickly and inexpensively (Feitzinger & Lee 1997).

In mass customization, identifying and understanding customer needs has become more important. The traditional methods – interviews, focus groups and observations of existing products (e.g., Ulrich & Eppinger 2003) – are not enough any more, instead, real dialogue between product designers and customers is needed. For sharing information about customer needs, they must discuss these issues in depth to ensure a common reference point and to reach a shared understanding (Miranda & Saunders 2003). Interactive evolutionary design could be a tool for improving collaborative discussions between a designer and customer.

The main way of using evolutionary design is to use it for optimization. In such case, the optimizing and evolution are performed with computer applications. When optimizing designs, great emphasis is placed upon finding a solution as close to the global optimal as possible. (Bentley 1999) In implementing an evolutionary design application, genetic algorithms are powerful: broadly applicable stochastic search and optimization techniques are based on principles from the evolution theory. Their use in addressing challenging optimization problems inherent in industrial engineering and manufacturing systems design has seen important advances in recent years. (Gen & Cheng 1997.) One reason to use genetic algorithms is that they are easy to connect to modular design; value levels of different genes expressing design of a product can be limited to modulated values, thus limiting the design space.

Interactive evolution for industrial design combines the types of Creative Evolutionary Design – for creating alternatives – and Evolutionary Art – for using a human being as the evaluator (Bentley 1999). Although the need for a human point of view is apparent, in many important studies the main focus has been elsewhere, for example; in Ujjin and Bentley's (2002) "human component" it is on the

optimization only and in Bezirtzis, Lewis, and Christeson (2007) the main focus is on computerized application development.
We will focus on interactive evolutionary design in which people are decision makers, not components of the system. We suggest that interactive evolutionary design can combine the benefits of modulated mass production and creativity; furthermore, it can bring in latent customer needs. We developed and implemented a test setting for studying whether evolutionary design could be used in helping to recognize customer needs and wishes. In product development process, designers should understand what customers need and want. In the case of personalized products, it is important that customers can describe what they want. Here we test if an evolutionary tool is of help in recognizing the needs and conducting negotiation about them.
In this paper we first describe a test case which is a table generation application. The section after that describes the process of user tests and the following section after that the results. Finally, the findings of the paper are discussed.

2. Table Generator

For evaluating an interactive evolutionary design concept, a piece of furniture, a table, was found useful for two reasons. First, a table is very suitable for user tests, since everyone is familiar with it; everyone has furniture at home and a piece of furniture is a common product to evaluate and purchase. A piece of furniture is a design-intensive product and it embodies many cultural, functional, visual, and esthetical meanings (Luomala & Lindman 2006). Therefore, consumers have different desires and expectations concerning this type of product.

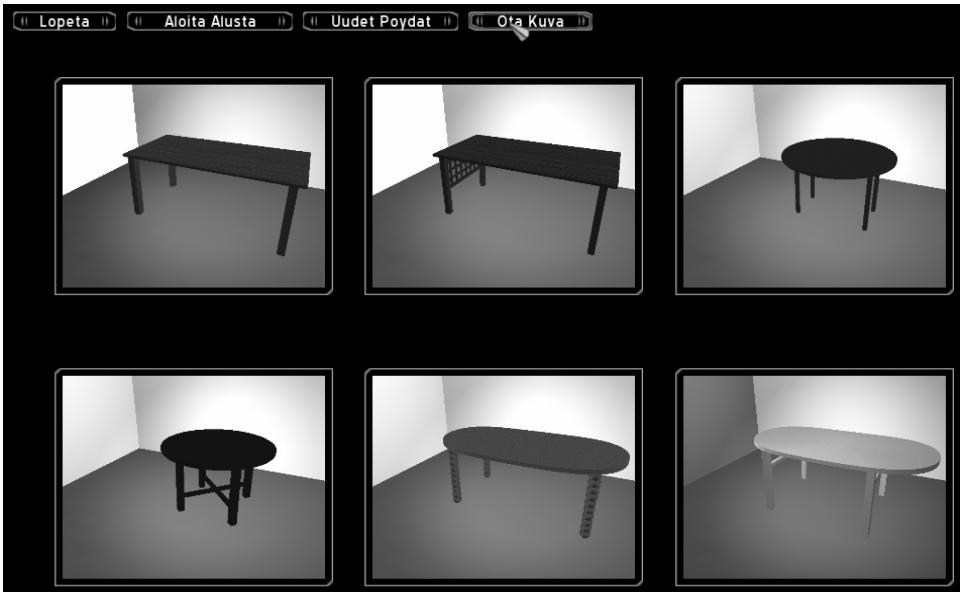

Figure 1. User interface of the Table Generator application

The second reason for choosing a table for test situation is technical. Products have both functional and visual properties. In the case of the table people are very familiar with tables' functional properties although their visual appearance varies a great deal. Images of a product are also easy to create with a parametric model whereas testing of functional properties of a virtual prototype is more demanding.
Genetic algorithms are usually accomplished with automatic decision making where optimization is based in large number of generations evaluated. When a human decision maker is used, it affects the

process: a human being can evaluate only a limited number of product variants at a time, and the evaluation process is slow. Therefore, it is not useful to use humans in evaluating many product generations. (Bentley 1999.)
At the beginning we wanted the test users to view several product variants prior to their individual selection starting to converge. Therefore we ended up with a solution where the user can view 18 different tables of one generation divided onto three different screens – an example of a screen is presented in Figure 1. In the first generation the parenting tables were pre-selected by the researchers to present the variety of shapes and materials in the best possible way. The user selects the most interesting tables and by that selection the next set of product variants is generated. This iteration is continued as long as the user wants. However, due to the limited design space users' product selection typically converges in few generations.
The Table Generator application used in this study was in-house software consisting of a user-interface, genetic algorithm and parametric product model as shown on Figure 2. A table consists of two parts (a board and legs, as Figure 3 illustrates) which are defined by four genes (the board's shape, its material, the legs' shape and their material). These values are presented in Table 1.
The user interface passes three sets of table parameters, selected by the user, to the genetic algorithm to create 18 new tables forming the next product generation. This information is forwarded to the parametric product model, which creates images of the products.

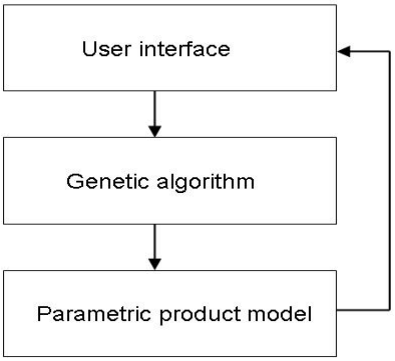

Figure 2. Table Generator application

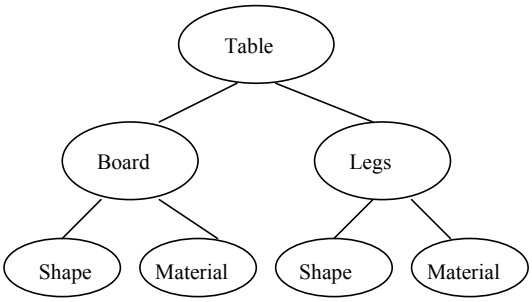

Figure 3. Structure of the product model

3. User Tests of Table Generator

We organized user tests to get users' feedback in order to find out whether the Table Generator can help in negotiation about desirable tables. The test itself was preceded by an introduction to the use of the Table Generator, its test use and answering a form. Besides of describing these, in this section, we explain the testing situation as it took place in a furniture fair, give an idea about the kind of test users that participated and describe the results of the test.
The test situation begun with a brief introduction to the Table Generator. Participants were told about the basic functions of the program and how to use it. The test users could choose whether they wanted to use the control device (mouse) themselves or whether the research assistant were to use it for them.

Table 1. Gene of the product model

Elements of a table	Genes	Values
Board	Shape	Rectangle (120 cm * 60 cm)
		Oval
		Circle (diameter 100 cm)
	Material	Wood-1 Brown
		Wood-2 Dark Brown
		Wood-7 Light
		Red
		Matt white
		Glossy black
		Glass
		Glossy white
		Chrome
		… Continues – all together 16 different varieties
Legs	Shape	4_legs_1 – Thin, square
		4_legs_2 – Fat, square
		4_legs_3 – Thin, round
		4_legs_4 – Fat, round
		4_legs_8 – Round, thickening in middle
		4_legs_9 – Round, cone
		4_legs_10 – Round, twisted
		Paired_legs_01 – Square, cone
		Paired_legs_02 – Square, supported dowm
		Paired_legs_03 – Square, grating
		Paired_legs_13 – Semicircle
		… Continues – all together 31 different varieties
	Material	Wood-1 Brown
		Wood-2 Dark Brown
		Wood-7 Light
		Red
		Matt white
		Glossy black
		Glass
		Glossy white
		Chrome
		Glossy black
		… Continues – all together 16 different varieties

In the test situation the users were first asked to pick six tables that they found most attractive among 18 tables. These tables were divided in three different screens for improving their visibility, each screen containing six tables from which the users chose two. The selection was done by clicking the picture. By double-clicking it one could see a full screen view of the table. Moving forward to the next set of tables or to the next generation could be done only after the required two tables per screen were chosen.

The selected six tables function as parents for the following generation process. On the following round the test users could again choose six most appealing tables from the new set of 18 generated ones. The generation rounds continued as long as the user wanted to use the program.

The second step was to respond to a set of statements in a form. The test user was asked to phrase her/his opinion about the application by focusing on three themes. Theme one concerned the usability of the Table Generator (statements 1 and 2); theme two focused on whether the Table Generator could

help the user to realize his/her latent needs and wishes (statements 3 and 4); and theme three dealt with the negotiation about the product that might be needed (statements 5 and 6). The statements were:

1. Assessing the table on computer screen was as easy as assessing a physical table.
2. There were some totally unexpected changes during the generation process.
3. Viewing the table options does not help me to define what kind of tables I prefer.
4. Viewing the table options brought up some useful ideas which I hadn't thought of before.
5. The table options make it easier to negotiate with my family about what kind of furniture I prefer.
6. The table options make it easier to tell about my wishes to, for example, an interior designer.

Statement 2 is about usability, since one of Nielsen's (1993) guidance to a usable system is that the user can predict how the system works and what will happen next. However, Statement 2 can also be connected to creativity; the Table Generator supports creativity if it gives new options to the user. The test users were asked to evaluate the statements on a scale of seven units (1 = total disagreement … 7 = total agreement).

The test use of the Table Generator was organized during the Habitare Fair in September 19-23, 2007 in Helsinki Fair Centre. Habitare is a furniture, interior decoration and design fair that is organized every second year in Finland. The first day of the exhibition was focused on professionals and the rest were open to all. Habitare 07 Fair had over 88 000 visitors (Habitare 2007). In the Fair, we had a stand in which we showed uses of information technology in presenting furniture models. We had there a virtual environment with a 3D furniture models application – the models had been made by students. There were also a copy of Table Generator on a laptop, but it was presented only to those who participated in the test use.

The participants to the test use consisted of visitors to the fair. Some of them were asked to participate in the test when walking by our stand and some when visiting our stand and showing interest in virtual furniture. Only few declined, most of them objecting to the time the test would take. Overall, the fair visitors seemed interested in participating in our research and testing the Table Generator. We managed to get 36 participants some of them furniture professionals, some students of the field, and the rest consumers. They were both men and women, and they belonged to different age groups – see Figure 4.

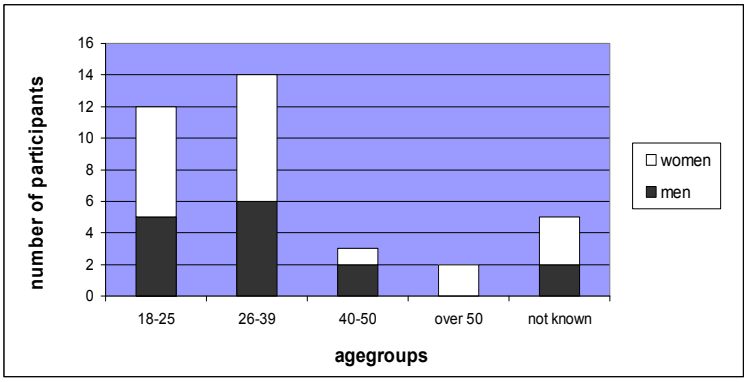

Figure 4. The age and sex distribution of Table Generator test users

As the test took place in a fair and the visitors there had also plenty of other things to see, the process was planned to be easy and short. The duration of each test situation depended on how long each participant wanted to use the Table Generator. The participants could stop the test program whenever they wanted. The average amount of rounds tested was 2.5; wanting to see two or three generations of tables meant watching 45 tables in seven or eight screens. The biggest number of rounds engaged was

5. The average estimated time used per test person was 2 minutes for the program and 4 minutes for the form filling.
The answered forms were analysed after the fair. In the analysis part, each statement were analysed separately by calculating the number of different answers. Also it was studied whether there would be some correlation between the answers and background information, but no correlation was found.

4. Results of testing Table Generator

The question form included six statements which focus on three themes. We describe the results individually by the themes.
The first theme was usability of Table Generator. The test users found that the evaluation tables on the screen were more difficult than the evaluation physical tables. Some test users answered that the Table Generator made totally or at least slightly unexpected changes, but others did not agree with that statement. In the theme of usability, the variation of answers was quite large and there were no surprising results.
The second theme was the recognition of latent needs and wishes. These concerns was deduced from the two related statements – a negative one and a positive one. Both of them were preset to the diversity of the views: about half of the test users answered that the Table Generator helped them to see new ideas, whereas the other half did not see such effect. Figure 5 presents the responses to Statement 4. In these responses, number 1 means that the responder completely disagrees with the statement and number 7 indicates total agreement.
The third theme was negotiation about the product. Statement 5 includes the whole negotiation about furniture at home, whereas Statement 6 focuses only on one part of it, i.e., describing one's personal wishes to a furniture professional. The most common answer to Statement 5 was 4 – no comments – although other responses were a bit more towards positive side. The responses to the statement 6 were clearly on the positive site, as Figure 6 shows. The test users found that the Table Generator is useful in describing their wishes to a professional designer.
Alhough the test users were participating in the test voluntarily, they still did not have unquestionably positive attitudes towards the Table Generator. This is seen in the variation of the answers to the different statements and in that some positive statements did not have support from most of the test users. However, we found two interesting results of the test use. First, Table Generator might be a useful tool in recognizing one's own needs and wishes, at least for some people. Second, Table Generator is a useful tool in facilitating discussion between customers and professional furniture designers.

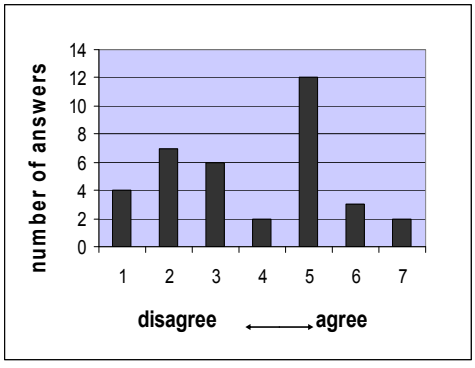

Figure 5. The answers to statement 4:
"Viewing the table options brought up some useful ideas which I hadn't thought of before."

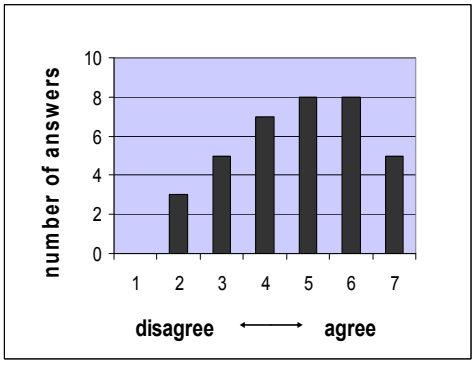

Figure 6. The answers to statement 6:
"The table options make it easier to tell about my wishes to, for example, to an interior designer."

5. Discussion

We made a Table Generator prototype for studying whether evolutionary design can be used for helping to assess customer needs and wishes. We organized related user tests in a furniture fair. The results of the user tests are promising. Most of the users thought that the Table Generator is a supporting tool in negotiation with furniture professionals, furthermore about half of the test users found that the Table Generator gave them new ideas about alternatives in table design.

The Table Generator helped the customer to understand his/her wishes better. This was due to presenting alternative shapes of tables, giving new ideas to the user. New ideas can mean increased creativity, i.e., finding something new, but they can also mean realizing something that has not been implemented earlier. The latter aspect can be connected to the discussion about tacit knowledge, which cannot be easily expressed (Polanyi 1967; Nonaka 1994).

Besides of understanding better one's own hopes, the Table Generator facilitates discussion between customers and interior professionals. In all cases, negotiation between professionals and non-professionals is problematic, since their underlying assumptions and conceptual worlds differ – that is that they have different meanings for the same words, for example (see, e.g., Tiainen 2004; Miranda and Saunders 2003). The Table Generator and other tools of its kind support the negotiation process by helping the participants to shape common reference points for their negotiation. In the case of the table, it means to have lots of different table images, which the professionals and consumers can point out when they describe their ideas about something they like or dislike. During the dialogue between a customer and a furniture professional the main point should be that the professional understands customer needs and wishes.

The Table Generator as a solution tool for supporting the identification of customer needs is very useful. This kind of solution proffered does not predetermine design alternatives, so it does not overemphasize the professionals' position in the negotiation process. This kind of solution nevertheless connects modular design – via modulated value levels of genes – and creativity – by creating new unplanned combinations by mutation.

Furthermore, the presented solution offers also solution for mass customization. If a gene's value levels are limited to the modular dimensions of the products, the genetic algorithm produces modular design. This approach combines the advances of mass customization by using personalized and modular design.

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