Designerly Ways of Customising

Abstract. This paper explores the customisation as a design problem-solving task for customers in mass customisation (MC). In a typical MC system, customers use provided tools to customise their chosen product. We applied Goel's cognitive method for assessing design problem solving tasks to compare the customisation with design and found a high degree of similarity. Customers who attempt to tackle these designerly tasks will typically have little or no design education. Consequently, we tend to consider the customer's lack of design experience a forgotten cause of confusion in customer-system interactions. Using the routine/non-routine design classification, we propose a taxonomic framework to classify different roles that a mass customisation system could assign to its customers. Further we use Gero's Function-Behaviour-Structure model to explain the proposed framework and analyse the processes inside each customisation session. We believe the proposed framework provides guiding principles to support proper design processes within customisation as an effective way of minimise confusion and improve customers' experience. This is the focus of our future research in designerly ways of customisation.

Keywords. Mass customisation, Design problem solving, Routine/non-routine design, FBS framework

Introduction

In recent years, researchers have explored a range of approaches to assist customers engaging with the co-design products using mass customisation systems (Karacapilidis and Leckner, 2004; Piller, Schubert et al., 2005; Chen and Tseng, 2007; Ma, Chen et al., 2007), the assumption being that customers are involved in a co-design process. Despite the interesting findings of these studies, the nature of customisation as co-design is unclear. Can we consider any customisation as a design problem-solving task for customers? If the answer is 'yes', then how can knowledge of the design domain be applied to improve the customers' experience?

Mention has been made of the designerly nature of mass customisation (MC) systems by early writers including Alvin Toffler (1980, p274) who, quoting Robert H. Anderson, stated: "The most effective thing a person will do twenty years from now is to be very creative... Namely, you will be sitting there doing things like designing a suit or making modifications to a standard design". While later studies acknowledge that design plays an important role in customisation (Franke and Piller, 2003; Ulrich, Anderson-Connell et al., 2003; Berger and Piller, 2004), little empirical work has been undertaken to facilitate an understanding of customisation as design by customers (Bee and Khalid, 2003).

Mass customisation is defined as 'a business strategy that promises the delivery of personalised products with near mass production efficiency' (Pine II, 1993). At first glance, this definition appears to demand customers' involvement in making decisions about the final product. This may be interpreted as designing by customers. Simon (1981) defines design as "changing existing situations into preferred ones". On this basis, anything we do in our everyday lives to change our extant situation is a design-like activity that requires us to make design decisions. At the same time, design, as a highly professional activity, demands considerable knowledge and competency. Lawson (2005) subscribes to a range of design-like activities, from selection and combination of predetermined items to professional design of artefacts for other people. This gives rise to research questions regarding the place of any customisation task on this spectrum of definitions of design.

To answer the above questions we apply different approaches drawn from design studies. Firstly, we draw on research from design studies and formulate our argument about the nature of design in mass customisation. We employ a cognitive method to explore the how the problem-solving tasks presented by typical mass customisation systems resemble design for customers. Secondly, we use formal models of routine and non-routine design and the process of designing in terms of function, behaviour and structure, to develop a framework within which to analyse different roles of customers in mass customisation systems.

Customisation as Design by Customers

We have employed Goel's (1995) cognitive method to determine whether customisation is a design task for customers or not. Goel proposed a comparative method to assess how different problem-solving tasks resemble design based on a list of twelve attributes of design tasks:
1. **Availability of information**: design problems lack information at every stage of the process.
2. **Size and complexity of problems**: design problems are often large and complex.
3. **Nature of constraints**: constraints are generally of two types, nomological and social/political. They are rarely, if ever, logical.
4. **Component parts**: design problems have many parts.

5. **Interconnectivity of parts**: the components of design problems are not logically interconnected.
6. **Right and wrong answers**: there are no right or wrong answers; only better and worse.
7. **Input/output**: input is information about users, the goals and behaviour of the artefact: output signifies artefact specifications.
8. **Feedback loop**: there is no genuine feedback from the real world during problem solving sessions.
9. **Costs of errors**: there are costs associated with every action in the world.
10. **Independent functioning of the artefact**: the artefact is required to function independently of the designer.
11. **Distinction between specification and delivery**: the specification of the artefact as distinct from its construction and delivery.
12. **Temporal separation between specification and delivery**: specification precedes delivery.

Goel uses these attributes to assess how different problem-solving tasks resemble design. The existence of these attributes will confirm the designerly nature of the given task and vice versa: any missing attribute will locate the task outside the boundaries of designing. Following Goel, we compared different types of customisation tasks (Gilmore and Pine II, 1997; Da Silveira, Borenstein et al., 2001; Blecker, Friedrich et al., 2005) with design and found a high degree of similarity between them. A selection of this comparative study is described below:

Availability of Information

Every design problem has three component parts; problematic situation, demanded goal, and transformation process from current to ideal situation (Reitman, 1964). Lack of information could exist in each of these three parts. In MC, the personal needs and preferences of customers (what they want) shape the problematic situation: the goal of customisation is to receive a product that corresponds to it. The transformation process also includes information about the behaviour of product features (aesthetics, functions, costs, etc.) and the behaviour of the company (quality, service, support, etc.).

Case studies in MC (Huffman and Kahn, 1998; Bee and Khalid, 2003; Piller, Schubert et al., 2005) have already shown customers' lack of knowledge of each of these three sections. At this level, the "customers often have no clear knowledge of what solution might correspond to their needs. At times, these needs are not apparent to the customers themselves. … The newer and more complex the individualization possibilities are, the more information gaps increase" (Piller and Tseng, 2003, p523).

Right and Wrong Answers

According to Rittel and Webber (1973), "design problems do not have right or wrong answers, only better and worse ones" (cited in Goel and Pirolli, 1992, p402) In fact, this is the essence of MC in which the final product is good because

it is designed to satisfy the individual. The astronomical size of the solution space in some MC systems supports this statement.

Feedback Loop

In MC, the customer has to await the delivery of her/his customised product in order to be able to test it in reality. One of the frequently occurring problems in mass customisation systems, it is known to be one of the important sources of mass confusion (Piller, Schubert et al., 2005).

Costs of Errors

From the customer's perspective, the penalty for failing to customize is paying all of the costs of customisation (product price, premium price, time) without receiving a favourable result from the venture. This is probably the strictest penalty that can be imposed for the commission of an error when performing a customisation task.

Customisation as Design

We found that the task of customers in some cases could not be considered as design because they lack some of the above fundamental attributes. For example, the temporal separation between specification and delivery, which is one of the listed attributes, requires that the decision making phase should always come before the delivery of the product. While the absence of this attribute in any MC system will eliminate it from being design, in some cases the final product comes before the actual customisation session. For example, adaptive MC systems, as specified by Gilmore and Pine (1997), belong to this group of non-design customisation tasks.

Even though we filtered out some customisations as non-design activities, comparing customisation against Goel's template showed a high degree of similarity between most of customisation tasks and design. However, as in MC, the complexity of these tasks differs in each system. This is not only effective vis-a-vis the technological properties of the system but also effective apropos of the customers' experience during customisation. Customers engage with different problem-solving tasks in accordance with their assigned roles in the system. The next step will be an attempt to classify these design-like customisations from the perspective of design. First, we will review two well-established models from design studies that have been used as the foundation of our classification of user roles.

Routine, innovative and creative design

In order to acquire a more detailed view of design-like customizations, we applied the notion of routine and non-routine design. According to Rosenman and Gero

(1993), any design activity is either routine or non-routine. From a knowledge availability perspective, they further divided non-routine design activities into innovative and creative.

In routine design (Gero, 1994), the range of possible values for variables is well-known: the solution space is limited to the predefined range of values. The consistency of variables during routine design implies the consistency of the generating rules. As a result, different concepts generated in routine design are instances of one general design structure. The problem solving task usually involves choosing the optimum value for existing variables. To facilitate the decision making process, the agent involved in routine design should be knowledgeable about the offered variables and values and/or the solution space. The routine designer usually gains this knowledge by searching inside the solution. Although the constraints and values are predefined, this does not necessarily mean that a routine design will not be hard or complex.
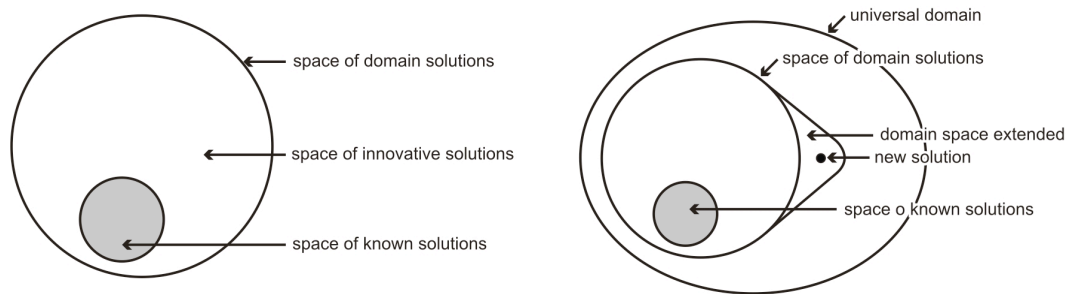

Figure 1. a) Innovative design solution space;   b) Creative design solution space

Innovative design, the second class of design, belongs to non-routine design activities. Generally speaking, non-routine design can be defined as that class of design activity when all the variables "are not known in advance, nor necessarily are all the processes needed to produce them" (Gero, 1994, p261). Innovative design involves the introduction of new values into the system, which will result in unexpected as well as unintended designs. In this class, the introduction of new values usually happens concomitant with the gaining of new knowledge, which describes the possibility of new values to the system. And while the results of innovative design activities broaden the solution space, their dependency upon past designs is observable (Figure 1a).

Creative design, the third class, belongs to non-routine designs as well. In creative design, a new variable is introduced into the system. The results of this particular design activity have little in common with the previous designs. In terms of solution space, creative design involves a transformation of the solution space (Figure 1b).

In other words, in non-routine design, the designer either modifies the solution space (innovative) or creates a new solution space (creative). Unlike routine design, which gains its knowledge about solution space by searching it, the non-routine designer uses exploration as the main process to find new solution spaces. In terms of processes, those are suitable for generating routine designs

should aim at deciding on the optimum value of each variable: the processes considered suitable for non-routine designs should be able to modify the structural rules or create new variables or values.

In the second round of our studies of the designerly nature of customisation, we compared the specifications of different mass customisation systems with the definitions of different classes of design. For the purposes of this comparison, we classified mass customisation systems based on the designerly roles of the customers submitted by the system. It is important to mention that this classification was done from the system point of view, i.e., while the system may assign an innovative design role to its customers, this does not guarantee that all of the products customised by the customers are innovative. Notwithstanding, such a system should afford the existence of innovative design activities and should support customers to perform in this way.

Function, Behaviour and Structure Model

The function, behaviour and structure (FBS) model, is a framework developed by Gero (1990) to represent design activity. It classifies all the variables of the design process into three categories: functional variables, behavioural variables and structural variables. Functional variables (F) describe the primary purpose of the artefact's existence. Behavioural variables (B) denote the attributes. They are further dividable into two groups: behaviours expected from the artefact (B_e) and the actual behaviour derived from the structure of it (B_s). Finally, structural variables describe the components of the object and their relations. According to the FBS model (Gero and Kannengiesser, 2000), there are eight fundamental processes involved in any design activity (Figure 2):
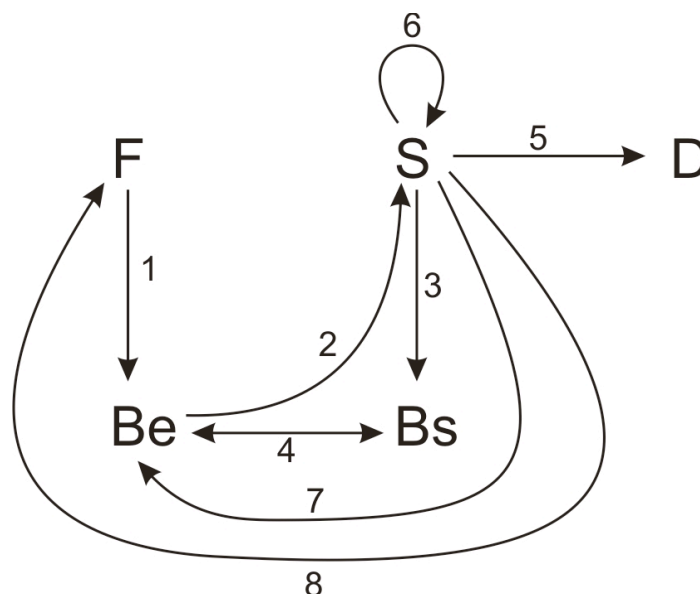

Figure 2. The eight processes involved in designing

1. **Formulation (F → B$_e$)** is the transformation of design requirements into expected behaviours
2. **Synthesis (B$_e$ → S via B$_s$)** transforms the expected behaviours (B$_e$) into structure (S)
3. **Analysis (S → B$_s$)** derives the actual behaviour of the proposed structure
4. **Evaluation (B$_s$ ↔ B$_e$)** the comparison between B$_e$ and B$_s$ which implies the acceptance or rejection of the synthesized structure.
5. **Documentation (S → D)** produces the description for manufacturing the artefact.
6. **Reformulation–1 (S → S')** involves changes in state space in terms of structural variables or their range of values in cases of unsatisfactory evaluation results.
7. **Reformulation–2 (S → B$_e$')** addresses the changes in state space in terms of behavioural variables or ranges of their values should the B$_s$ be evaluated as unsatisfactory.
8. **Reformulation–3 (S → F' via B$_e$)** changes the design state space vis-a-vis functional variables or range of values of them should the B$_s$ be evaluated as unsatisfactory.

The FBS model of design allows us to deconstruct the customisation session into its cognitive processes and use the terminology of design to describe them (Gero, 1990). We believe this expands our understanding of the design nature of customisation and inform us toward more designerly support for customers during customisation sessions.

Proposed Framework

As argued earlier, from a customer perspective, MC systems constitute a design environment that sets designerly problems. To shape an understanding of the different types of MC systems as design environments, we propose a taxonomical framework to classify the different roles of customers from a design point of view. This framework is based on the routine/non-routine classification of design and the FBS model of design processes. On this basis, any MC system can assign its customers one of these roles:

Requester

In some MC systems, the customer does nothing towards defining any customised product. It is up to the MC system to provide her/him with an individualised product, based on her/his needs and preferences (Gilmore and Pine II, 1997). Within mass customisation systems, a requester requires information about the problematic situation, i.e., the first component part of the design problem, and the system may need to provide this information. Although the customer has only a

limited role in the creative process of design, having personal preferences—and her/his ability to express them—is still an important factor in the MC experience.

Composer

A wide variety of MC systems allow their customers to configure their favourite products simply by choosing a series of options. While each option (stage) offers a variety of selections (states), the solution space is limited and known in advance (Tseng and Jiao, 2001). Depending upon the number of stages and states, the size of the solution space might be very big (Franke and Piller, 2003). This type of customisation matches the routine design described earlier. In routine design, the designer should be knowledgeable about the possibilities of the solution space. He/she gains this understanding by searching inside the boundaries of the offered solution space. In fact, some of the suggested features of configurators like randomisers are the metaphors of this search activity.

After acquiring adequate knowledge of the potential solutions (Karacapilidis and Leckner, 2004), the composer has to decide upon a favourite state at each stage of the design process. Even though these decisions are about the structure of the artefact, the actual cognitive process of design happens at both the behavioural and functional levels as well. In other words, the composer has to perform three different cognitive activities in order to decide on the final structure: Formulation ($F \rightarrow B_e$), Analysis ($S \rightarrow B_s$), and Evaluation ($B_s \leftrightarrow B_e$).

In terms of reformulation, the composer works on the structural level. This means that he/she can only manipulate the structural values, i.e., Reformulation–1 ($S \rightarrow S'$). In a pure composer system, all other processes have to be done outside the system, that is, by the customers. Because the range of values is constant here, the main cognitive challenge for the composer will likely occur in the Synthesis process, i.e., matching expected behaviours and structural behaviours ($B_e \rightarrow S$ via B_s) (Hippel and Katz, 2002). This has already been considered to be one of the sources of mass confusion (Piller, Schubert et al., 2005). A supportive MC system, that assigns the role of composer to its customers, will contain features essential to eliminating this major source of confusion and assist the composer through the customisation session, primarily by aiding the Synthesis process.

Co-designer

The term 'co-designer' has been loosely used by writers to describe all customers in MC systems (Berger and Piller, 2004; Piller, Schubert et al., 2005), however, as we have argued before, not all MC systems are design environments, consequently, not all MC systems assign the co-design role to their customers. Only a special type of customisation has the customer participate in the process of designing the requested product. It should be noted that this position is distinct from the perspective of customer involvement, where she/he has to deal with non-routine designerly problems and challenge constraints or limitations, set either by her/himself or the system, in order to design a personalised product.

We define the co-design role inside an innovative design space. This means that customisation is more than composing predefined items. A co-designer modifies the variables or the range of their values in line with his/her personal needs and preferences. However, for practical reasons, the introduction of new values is more frequent than the introduction of new variables.

In terms of an FBS framework, doing innovative design is related to behavioural variables as well as to structural variables. Consequently, in such systems, Reformulation–2 ($S \rightarrow B_e'$) becomes as important as Reformulation–1 ($S \rightarrow S'$). During the customisation process, the co-designer engages in a dialogue with the system: this includes the staff, consultants and an intelligent customisation tool. The systems side informs the co-designer about the design rules, to support Synthesis ($B_e \rightarrow S$ via B_s), and the behaviours of each structural item, to support Analysis ($S \rightarrow B_s$). Negotiation between the co-designer and the system primarily takes place at the behavioural level, i.e., through the process of Evaluation ($B_s \leftrightarrow B_e$) (Tseng, Kjellberg et al., 2003). The introduction of new variables or values happens when a negotiation ends with demands for new behaviours outside the bounds of the solution space. At this point, the system may decide to extend the range of values or variables to satisfy the needs of the co-designer. The dialogue between the MC system and the customer potentially expands the solution space and ability of the system to satisfy future demands, i.e., the customer collaborates in the design process of the mass customisation system.

Re-mixer

So far, discussion has centred on the composer and co-designer roles of customers in mass customisation systems. But there is a new role emerging in many mass customisation systems, which places the customers inside a social structure (Piller, Schubert et al., 2005). In these communities, the customers not only share their information about the products and companies but also collaborate in generating ideas. These online communities are either supported by the company or self-initiated by customers. In fact, this acts as a bridge to span the gap between the composer and co-designer roles: the customers collaborate in design but mainly via a third party—not the system but the community.

In terms of an FBS framework, this means that the system only need handle structural variables, leaving the behavioural variables to be handled by the community. Members of the community effectively add design knowledge to the MC system, by labelling structures with their behavioural properties (Analysis) and describing how to derive the structure out of the behaviour in hand (Synthesis). The customisable nature of the products allows the community to exchange information, collaborate with design, and disseminate ideas among members (Piller, Schubert et al., 2005).

We cannot specifically label the performance of this role as 'routine' or 'non-routine' design. Although the initial solution space is limited and predefined, the

community may force the system (a) to accept new variables, and (b) to extend the range of their values.

An MC system that assigns the role of re-mixer to its customers should allow the community members to share, transform and combine ideas with each other at the structural and behavioural level, even though the customisation system only supports structural variables.

Prosumer

Toffler (1980) devised the term 'prosumer' to describe the customer who is co-producer as well as co-designer. In this role, which is the most complex of all customer roles in mass customisation, they apply general production facilities provided by a company to produce designs of their own. The prosumer role is close to the role of a creative designer (Gero, 1990), engaging in a creative design activity and extending the boundaries of the design space.

In terms of an FBS model, the prosumer starts the design process from the functional level as the system doesn't limit what is to be made (F). However, this involves extensive effort on the part of the customers as they have to perform all the possible cognitive processes almost like a designer. Consequently, interaction between system and prosumer is facilitated by the prosumer, who gives manufacturing instructions to the system (Documentation). However, this does not necessarily mean that the system cannot be involved in other processes of design to support the prosumer through the customisation session. For example, designing by first principles is a method identified as increasing the chances of creative design (Rosenman and Gero, 1993). Implementation of this method in a mass customisation system may encourage the prosumer to come up with more creative concepts.

A well-known example of prosumer customisation systems is Ponoko[1], a customised laser cutting service available through a consumer friendly web site. In its early days, the system was designed to provide facilities for cutting 2D sheets for customers; eventually, customers started to use the 2D cut sheets to make 3D structures and, based upon this creative innovation, a whole new space of design possibilities opened up.

Benefits and Applications

The implementation of an FBS model allows us to gain a much more detailed understanding of the designerly processes central to the customisation session. This could be used to improve the customers' experience of design or to define the necessary features of the system.

For example, Dell is a well-known computer customisation system implemented as a website[2] offering a series of predefined options. This is a typical

[1] www.ponoko.com

[2] www.dell.com

mass customisation system, which according to our framework assigns the role of composer to its customers. As design is of routine type, customisation is focused on the structural variables of the product. This means that customising a computer with the Dell configurator involves deciding upon the structural specifications of the requested product.

A typical customisation scenario (Figure 3) might involve a customer using the Dell configurator to buy a notebook computer for business use on the road (F). He/she expects the customised product to satisfy a series of personal needs and preferences (B_e), e.g., extended battery life and light overall weight.
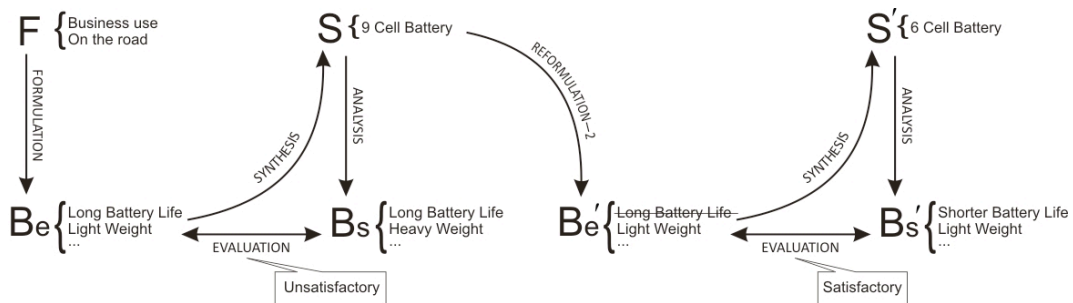

Figure 3. The processes involved in the example of notebook customisation task.

By searching the offered solution space, using either filtering, recommendations systems or randomisation, the customer forms an understanding of the system deliverables, including different types of batteries. Using the configurator, he/she can select structural items (S) that are likely to have same behaviours (B_s) as expected (B_e). However evaluation of B_e and B_s reveals that the selected structure (e.g. 9 cell battery) has some of expected behaviours (e.g. extended battery life) while missing the others (e.g. light weight). This evaluation pushes the customer into an iterative trade-off process, which culminates in the final product description. Though the possible solution space is limited, these trade-offs generally involve modifications in expected behaviours, that is the Reformulation–2 (Figure 3). Finally, the customised product (S') is assumed to have the same behaviours as the expected behaviours.

As we can see in this example, customising as a composer is mainly about selecting the structural items of the product. As the system deals with the structure, the interface between customer and system locates between structure and behaviours as illustrated in figure 3. In other word, all processes related to the behavioural and functional variables have to be done outside the system and only by the customer. This task load may cause confusion in customers experience with the system.

A positive way of supporting customers using the system would be embedding the behavioural variables into the system. This could be done by informing the customers about the actual behaviours of the structural items, e.g., capacity, weight or life time (Analysis). A possible way of improving such a system is to integrate the Synthesis process within the system by labelling the structural items with their behaviour, e.g., batteries with long life. It is also

important to inform customers about the relational behaviour of each item, i.e., how they behave together.

As seen in the given example, the proposed framework considers the customisation session in a detailed manner from the perspective of internal processes, by extension providing more insight into the designerly tasks of during customisation. Classifying the customisation task based on routine, innovative and creative design conveys a firm idea of the anatomy of the system, and its interaction model with customers. Application of the framework raises the following questions: what are the necessities of the customisation tool? How much information does the customer need to perform her/his task?

Conclusion

Despite the common notion of the role of customers as co-designers of their own products, we have started to question the designerly nature of mass customisation. We used Goel's (1995) cognitive method to compare the customisation task with design. Despite detecting some instances of non-design customisations, we found considerable similarity between design problem-solving and the customisation task from the customers' perspective. The diversity of these designerly customisation systems led us to develop a framework in which to classify them from a design point of view.

Employing the notion of routine/non-routine design as the foundation of our framework, we suggested four different design roles that a mass customisation system could assign to its customers. We used Gero's (1990) FBS model to explain the proposed framework and analyse the processes involved in customisation. Applying the FBS model confirmed our initial analysis of the designerly nature of customisation.

The proposed framework is applicable to existing mass customisation systems: it may be used to analyse the design processes explicated during customisation sessions and to improve a system's support for design by customers. It may also be useful in planning new mass customisation systems to find the necessary features of the configurators and predict the workflow of customers during customisation.

Future work will focus on using the proposed framework in real life examples in an attempt to discern its strengths and weaknesses. We believe that studying customisation systems from a design perspective will reveal the implicit processes of design by customers and improve the system in terms of customer experience during designerly customisation.

Acknowledgments

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