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An original design approach for stimulating the ideation of new product features

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ABSTRACT

The manuscript illustrates a method, implemented in a computer application, which supports the identification of new product features in the early phases of engineering design cycles. In the practice, such a task is commonly carried out through cognitive techniques that generate random and unstructured stimuli. These approaches and the computer-aided tools that implement them suffer from a scarce exploration of the design space. This criticality is faced by introducing an original classification of value drivers, thus organizing a large set of concepts consisting of stimuli for generating new product ideas. The proposed method combines the concepts belonging to different categories of the classification in order to identify scenarios in which the product can provide unprecedented benefits for customers and other stakeholders. Experiments in academia and industry show the capability of the developed method and prototype software to increase the number and the novelty of ideas, reveal previously overlooked drivers for customer satisfaction and enhance the definition of stimulated design requirements.
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1. Introduction

The paper illustrates a method and a computer application supporting the ideation of new product attributes. The contribution described in the present manuscript treasures a bundle of stimuli, which have affected the authors' background and visions. These hints arise from both the literature, with a particular reference to contributions within engineering design, and the interpretation of the needs that emerge by cooperating with industrial partners in various research projects. More precisely, the stimuli stand in grounded assumptions with reference to innovation in industrial contexts, which can be explained as follows:

- the declared relevance of innovation in the 21st century industry [1], which results in the increasing importance of design activities with a special emphasis on those initial New Product Development (NPD) tasks, such as Product Planning, that participate in the definition of the business opportunities to be exploited;
- the claimed need to fine-tune formal methods supporting the above design activities;
- the focus on individuals' creativity to achieve new products and services offering greater value for customers;
- the expected growing participation of computers in the creative phases of innovation activities;
- the need to build computer-based applications tailored to aid initial design phases.

The goal of product innovation gradually shifts from technologies for achieving superior performances to user-centred approaches aimed at including unprecedented sources of value for perspective customers. In this sense, the scope of engineering design is expanding towards the initial NPD phases, more focused on the definition of requirements to be fulfilled [2]. This trend is far from being surprising, if the claimed impact is considered of early design stages, the so-called Fuzzy Front End (FFE), in terms of the success chances of new artefacts and the determination of upcoming product development costs [3–5]. Consequently, the models used to describe design processes tend to encompass user needs and requirements, besides traditionally comprising functions, components, interactions and physical principles [6]. Within the FFE, a particular attention is paid to Product Planning, whose scope is, among the others, identifying and analysing users' needs and translating them into design objectives.

The need to aid systematically the early design phases has been frequently declared (e.g. [7]), but formal methods are considered

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still inadequate to the purpose [8,9]. The literature shows that big corporations have introduced best practices for an adequate management of the FFE, but they still require to introduce formal instruments for enhancing idea generation [10,11]. By insightfully surveying existing techniques devoted to support Product Planning, scholars claim that these tools face the dichotomy between, on the one hand, disruptiveness of generated ideas and, on the other hand, predictability of market results and feasibility of new products with the available company resources [12].

Similarly, it is possible to assess that strictly demand-pull approaches substantially limit the capability of exploration of designers, bringing to the development of poor-valued and scarcely innovative products [13]. The stimulation of creative thinking is conversely seen as a prerequisite for the generation of breakthrough ideas (e.g. [14]). Nevertheless, unconstrained stimuli can give rise to bizarre ideas, often characterized by noticeably limited utility for customers [15] and, therefore, not viable to correctly address NPD cycles. In this sense, the objective of this work is attempting to build a roadmap for systematically investigating the possible sources of value for customers and the circumstances in which they can emerge. The present proposal provides stimuli to conduct the exploration of said sources and circumstances. An original method has been fine-tuned, intended to leverage these guided stimuli to improve designers' ideation processes.

The following Sections (4.2 more in particular) will lay bare the large number of concepts potentially identifying new sources of customer value. In this perspective, the introduction of computerized tools results critical to support the management of a considerable quantity of stimuli. This aspect is consistent with the predicted increase of ICT involvement in NPD activities and innovation projects aiming at engendering major value for customers [16,17]. However, the role of computers in initial product development phases has been limited to a design partnership supporting communication between multiple parties and data management. This circumscribed contribution contrasts with the extensive development of CAD/CAE systems supporting the Back End of design cycles. To this regard, it is deemed that the goal of reducing new products' time-to-market has pushed the evolution of computer tools capable of shortening design processes by quickening those activities that could be easily faced through routine procedures. This has besides resulted in the disregard of design activities requiring a higher degree of creativity and innovativeness [18] and in the erection of inertial barriers in terms of exploring original solutions by hindering the representation of new concept models [19,20]. Therefore, on the one hand, it results desirable for commercial CAD systems to allow users to carry out initial design tasks proficiently [21]. On the other hand, new ICT instruments for the FFE (and tailored to Product Planning in particular) are viable to observe a shift towards computer coaches according to Lubart's [22] definitions about the forms of interaction between men and machines.

In this sense, the developed method and computer application work like a coach, since the latter suggests areas to be investigated for the identification of new product attributes, whose way of monitoring can be gradually subsumed in the thinking of perspective users. More specifically, the scrutiny of new features consists in mapping their so-called dimensions, i.e. what characterizes the benefits they provide, and finding unprecedented situations to offer value by asking some classical "*wh* question":

- *what* and *why*: the nature or the essence of the given benefit, the reasons behind its fulfilment (General Demand dimension, labelled as GD);
- *who*: the involved subject within the value chain (Stakeholder dimension, SH);
- *where*: the locus at which an useful interaction takes place (System hierarchy dimension, SYS);
- *when*: the time frame during the product lifecycle in which the benefit occurs (Lifecycle dimension, LC).

It is worth remarking that the *how* aspect has not been taken into account, since it concerns different NPD phases devoted to establish working principles and technologies through which to fulfil initial design specifications.

The article is organized as follows. Section 2 analyses the background of the present research and individuates the requirements and the evaluation metrics to be considered to the scope of fine-tuning an original idea generation tool. Section 3 investigates the attempts to address the ideation of new product characteristics, by surveying both scientific literature and existing software applications. Section 4 describes the proposed approach and its implementation into a prototype software. The verification of their effectiveness is illustrated in Section 5 through a testing campaign involving 24 Master Science (MS) students in Mechanical Engineering. Subsequently, Section 6 documents the outputs of the methodology employment in the industrial field. Eventually, Section 7 summarizes the main findings and draws final remarks and planned future activities.

2. Background

The quality of ideation processes is commonly linked with the capability to explore the design space, generally defined as the count for all possible options to address a posed problem [23]. To the scopes of the present paper, i.e. Product Planning and the definition of the objectives a NPD cycle should accomplish, the design space can be intended as the entirety of potential benefits to be offered by a new artefact.

Many literature contributions dealing with ideation issues in design substantially refer to generation of solutions for assigned technical problems or, more vaguely, to initial product development activities. Hence, this branch of literature predominantly focuses on Conceptual Design. However, we can extend the validity of the presented findings to Product Planning, since reference sources are committed to investigate the mechanisms underlying design phases requiring a great extent of individual creativity.

2.1. Analogies in creative design phases

Creativity contributes to the exploration of the design space and subsequently to limit design fixation, which is seen as the most harmful phenomenon at the beginning of NPD cycles. According to in-depth studies, design fixation leads to, among the others, repetitive ideas, small quantities of proposed solutions, imitation of provided examples [24,25]. In this sense, we could assume that examples or any kind of stimuli producing analogical thinking give rise to the drop of creativity.

On the contrary, design-by-analogy represents a fundamental process guiding idea generation and problem solving appropriately [26]. As a result, the research in engineering design witnesses several experiments related to the generation of ideas pushed by various kinds of stimuli, whose consequent manipulation of human memory is studied in [27]. Among the others, examples and descriptions from biology field claim to foster creative design solutions [28,29]. Different experiences consider the exploitation of stimuli pertaining to product domain [30] and to examples taken from firms' information repositories [31].

Ogot and Okudan show the growth of ideation effectiveness brought on by systematic procedures fostering analogical thinking, already for first-year Engineering Students [32]. More recent studies compare the outcomes of initial design activities

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