Title:
A CAD Tool to Support Idea Generation in the Product Planning Phase

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Introduction:
CAD tools provide an essential aid to designers in New Product Development (NPD) processes by accelerating and easing activities that required consistent time resources decades ago.

At the same time, the scientific community claims advantages with respect to the integration of all the phases of the design process [7]. More specifically, research efforts have been addressed to link the activities pertaining to the front end, i.e. Product Planning and Conceptual Design, and the back end, i.e. Embodiment Design and Detailed Design [16]. The diffusion of CAD instruments to support the latter represents a way with no turning back in the industrial world. Hence, any integration of all design phases cannot disregard the employment of computer platforms.

Unfortunately, the integration is slowed down by the difficulty of identifying repeatable patterns (translatable in algorithms) in front end phases. Indeed, it is widely acknowledged in the literature that these phases typically involve random process and “ad hoc” decisions based on intuition, observations, discussions or accidents [8, 15]. This is why the term “Fuzzy Front End” (FFE) [20] has been coined to describe the earlier phases of the design process. Besides, the lack of replicable actions to perform the FFE ranges among the causes of products’ commercial failure [9].

Some CAD tools have been proposed to support Conceptual Design [5, 6, 18], that is acknowledged as a fundamental step towards the definition of original, novel and sustainable technical solutions [1]. Conversely, the exploitation of Artificial Intelligence is so far marginal to ease the execution of Product Planning tasks. Product Planning consists in the identification of customer needs, the analysis of current lacks in the market and the definition of new product features capable to fulfil customer expectations [16]. Therefore, the main outcome of this phase is constituted by the product idea, expressed in terms of a requirement list. Insights from the literature show how even few acknowledged methods effectively support Product Planning [4]. Not surprisingly, a negligible set of software applications is tailored to aid the carrying out of Product Planning, as highlighted by an updated review of commercial computer-aided tools performed by the authors and other previous researches (e.g. [10]).

In such a context, the authors have attempted to extrapolate repeatable patterns within Product Planning and developed a computer-aided tool, namely iDea, to effectively support designers during idea generation processes. In order to assess the effectiveness of the developed tool, a test has been performed involving 24 MS students of Mechanical Engineering. In this experiment, the outcomes of iDea have been compared with those emerging from the employment of a more known tool, i.e. Six Paths Framework [12]. The latter supports the idea generation activity providing some hints to guide an individual “brainstorming” process. The choice of this instrument is motivated by the need of picking up a successful technique, besides diffused in industry, which however suffers from the lack of patterns allowing a useful computer implementation.

The next section will illustrate an overview of existing tools and approaches to support Product Planning, highlighting their main limits. Furthermore, the developed tool will be briefly described, the tests will be presented and the main obtained results will be discussed. Eventually, expected future developments of the proposed tool will presented in the final section.

Main Idea:

State of the Art

The weaknesses of Product Planning methods with respect to the scope of introducing idea generation capabilities into CAD environments have pushed the authors to investigate both literature sources and available commercial software.

Some scholars have surveyed the available computer applications that support the early stages of the design process (e.g. [10]). Nevertheless, most of the software tools described in said citations are no longer available and an updated review has been carried out by the authors. The investigation has confirmed that idea generation activity is poorly supported. On the other hand, several commercial tools support knowledge management, decision making and various NPD management activities, such as patent analysis, risk assessment, communication tasks.

Identified tools that support idea generation mainly concern platforms for collaborating in shaping new ideas (e.g. Sopheon, www.sopheon.com; HYPE Enterprise, www.hypeinnovation.com, etc.). These results comply with literature evidences in which the idea generation task is supported by digital Brainstorming and Crowdsourcing tools [10]. These instruments provide virtual environments in which designers and or/customers can share, improve and assess ideas generated through intuition and personal experience. Hence, the employment of Artificial Intelligence is devoted to ease the management of the information generated through the treated design activities rather than supporting the ideation process. However, this can hardly give rise to better product ideas with respect to the not-computerized methods that are basically implemented in the above software applications. In addition, these tools do not interplay with CAD systems; hence, they are conceived as creativity aids with no particular reference to design issues.

Some literature approaches provide guidelines to support individual [12] or collective [13] Brainstorming sessions. For instance, Six Paths Framework [12] is a set of strategic suggestions to explore new opportunities in a given industrial field. For the sake of completeness, the recommendations stand in the option to:

- look across alternative industries;
- look across strategic groups within industry;
- redefine the industry buyer group;
- look across to complementary product and service offerings;
- rethink the functional-emotional orientation of the product;
- participate in shaping external trends over time.

Although this approach offers only mere qualitative indications [3], it is observing, at the very least, a partial acceptability in industry [14]. This fact can be interpreted as a further confirmation of the need and interest in developing tools to support the Product Planning phase.

Overview of iDea tool

A preliminary research conducted by the authors [4] has allowed schematizing the design space to be explored during Product Planning. According to the obtained outcomes, four main directions, namely Value Dimensions, can be investigated in order to identify new product features or ideas that generate value for customers:

- General Demands (GDs): distinct tangible (e.g. quickness and speed in performing the functions, ergonomics, storability) or intangible (e.g. aesthetics, fun and adventure, ethics) customer needs;
- Life Cycle phases (LCs): circumstances that may occur along the different stages of product existence from its market launch to the end of its life;
- Stakeholders (SHs): all the actors that interact with the product during its lifecycle;
- Systems (SYSs): different hierarchical levels of the product, ranging from the environment in which the artefact is situated to its parts and inner components.

According to these Dimensions and their further articulation, the authors developed combination algorithms that allow designers to figure out possible scenarios or circumstances, capable to provide useful hints for the development of new products. For instance, a GD like "storability" combined with "product accessories" can suggest the possibility of integrating the functions of the accessories into the product or redesigning the shape of the product in order to better contain said accessories.

In other terms, the authors have individuated possible patterns that can stimulate the creativity of product planners. The claimed advantage with respect to existing procedures stands in the possibility to explore design opportunities systematically, by taking into account a comprehensive set of scenarios.

A computer implementation of the stimulation process was necessary to articulate the large quantity of proposed hints. Therefore, authors developed a software prototype based on a multi-screen GUI that allows selecting and customizing the above Dimensions (according to the specific NPD project) and automatically generates a set of questions that guide the designer during the idea generation task. The current version of the main mask of tool shows a first box that includes the list of generated questions and a second one that allows collecting a semantic description of new ideas (see Fig. 1). More details about the developed tool can be obtained from the link http://goo.gl/AwzZHF, through which the prototype software and the users' guide are downloadable.

Planning of the test to assess iDea performances

In order to measure the effectiveness of iDea tool, it was required to compare its performances with those of an acknowledged Product Planning method. The mentioned Six Path Framework was chosen as a reference due to its capability to stimulate new product ideas and intrinsic way of working that does not require a computer implementation.

The test has involved 24 MS Students at the faculty of Mechanical Engineering, University of Florence (Italy). They have been properly trained about the logic and the use of the two tools and then randomly divided in two groups (A and B). The test has been structured in two 3-hours sessions, in which the students had to work on their own, trying to identify as many ideas as possible in the field of cameras and domestic coffee makers. In the first session, all the students used the Six Paths Framework and group A dealt with cameras, while group B analysed the domestic coffee makers. In the second session, the students carried out the idea generation activity employing iDea and dealing with the theme that was not examined in the first session.

The two categories of product have been chosen because they represent everyday devices. Hence, the students could start the idea generation process from the very beginning, without requiring preliminary information gathering to understand products' as-is scenario.

Two widely acknowledged metrics in the literature have been used to assess the outcomes of the experiments [19]:

- quantity of ideas: it allows assessing the ability to generate as many ideas as possible in a predefined amount of time;
- variety of ideas: it assesses the ability to explore the design space as much as possible, identifying ideas that are very different from one another.

The first metric can be easily investigated by counting the number of generated ideas.

In order to assess the variety, the reference approach developed by Shah et al. [19] has been followed. Although this method has been originally developed to assess technical solutions, it can be easily adapted to Product Planning. The authors required to introduce an ad-hoc taxonomy. The obtained results have been analysed considering each case study independently.

A normal distribution of data has been hypothesized, calculating mean and standard deviation of the samples.

Main results: presentation and discussion

The main outcomes of the test are summarized in Tab. 1. The results show a considerable growth of quantity and variety of ideas for both industrial domains by using iDea. It is worth noticing that a quick overlook of the data is sufficient to individuate very similar variations for both the examples. The increase of quantity and variety is so conspicuous that no test has been conducted to reveal the significance of administering the developed software in order to perform idea generation. The

observed increment of standard deviations in sessions using iDea infers that this tool is likely capable to highlight the differences among the personal skills of users.

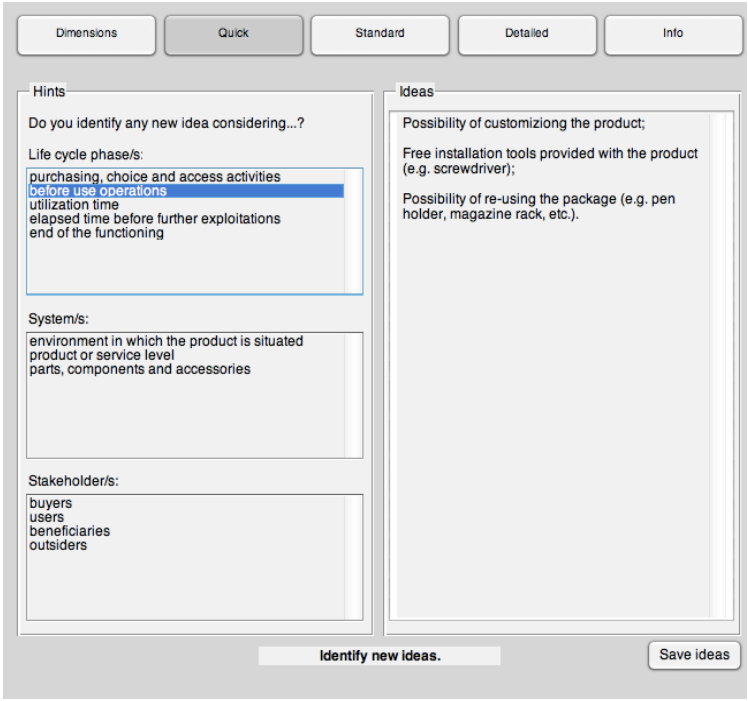

Fig. 1: Screenshot of iDea mask that the box of hints and the space for annotating ideas.

		Quantity		Variety	
Case studies	**Tools**	**μ**	**σ**	**μ**	**σ**
Camera	Six Paths Framework	4	2,2	15%	6%
	iDea	20,7	9,4	40%	7%
Domestic Coffee Maker	Six Paths Framework	5	2,1	16%	5%
	iDea	19,8	9,4	39%	10%

Tab. 1: Results of the idea generation tasks carried out with iDea and the Six Path Framework.

Future research activities

Despite the evidences arisen from the experiment, further research is required to fully validate the major inspiring capabilities of the developed framework and prototype software tool. Additional evaluation criteria should be introduced to estimate the suitability of iDea in real design tasks. Diffused evaluation procedures include other metrics that require the judgements provided by a representative sample of experts [11], such as:

- quality of ideas: it is related to the technical feasibility of proposed ideas [19] and allows to understand how many ideas could be actually implemented in new products;
- novelty/creativity of ideas: it allows to assess the originality [19] and creativity [2] of generated ideas.

Further tests will involve design teams, according to the current collaboration trend [17], in order to understand how the outputs change from individuals to groups. Eventually, the authors will focus on the integration of iDea with CAD tools supporting solid modelling, with the aim of accelerating the

whole NPD process. In this way, new identified product features might be quickly converted into 3D models and physical prototypes.

Conclusions:

Both the literature and the industry witness the lack of CAD tools capable to support the designer in the initial phase of the design process, i.e. Product Planning. In this work, the authors present a tool, namely iDea, which supports the main activity of Product Planning, i.e. idea generation. 24 MS students of Mechanical Engineering have tested this tool against a well-known approach, i.e. Six Paths Framework. The experiment gave rise to promising outcomes in terms of quantity and variety of generated ideas, as well as to hints worth of future investigation, as remarked in the previous Section.

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