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A CAD tool to support idea generation in the product planning phase

Daniele Bacciotti[1], Yuri Borgianni[2] and Federico Rotini[1]

[1]Università di Firenze, Italy; [2]Free University of Bolzano, Italy

ABSTRACT
The work described in the paper is motivated by the lack of computer-aided tools to support Product Planning and, more specifically ideation processes of New Product Development (NPD) initiatives. The domain is populated by software applications aimed at managing and organizing Product Planning activities, which thus poorly contribute to the definition of new product characteristics, and models to stimulate novel ideas. The latter face limitations in terms of overlooked implementation with CAD tools supporting the following NPD phases and poor exploration of the design space. The authors propose an original method and software prototype capable to provide a wide range of stimuli, whose testing demonstrated much better results than traditional approaches in terms of quantity and variety of generated ideas.

KEYWORDS
Product Planning; idea generation; product attributes; Value Dimensions; CAD; New Product Development

1. Introduction

CAD tools provide an essential aid to designers in New Product Development (NPD) processes by accelerating and easing activities, which required consistent time resources decades ago. Besides, the scientific community claims advantages with respect to the integration of all the phases of the design process [11]. 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, [24]. 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 and the lack of shared models among front end and back 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 [12, 23]. This is why the term "Fuzzy Front End" (FFE) [30] 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 (e.g. [15]) and determines the unpredictability of the costs occurring during the whole product development cycle [32].

Some CAD tools have been proposed to support Conceptual Design [9, 10, 28], which is acknowledged as a fundamental step towards the definition of original, novel and sustainable technical solutions [2]. In addition, the literature shows a growing trend in the proliferation of CAD software for Conceptual Design, as it results evident from the manuscripts published in a recent special issue devoted to outline next-generation of CAD platforms (e.g. [7], [13], [14], [19]). Conversely, the exploitation of Artificial Intelligence is so far marginal to ease the execution of Product Planning tasks. According to Pahl and Beitz [24] and several other scholars of the Engineering Design field, these tasks can be summarized as it follows:

- identification of customer needs to be fulfilled;
- analysis of current lacks in the products available in the market;
- ideation of new product functions, features and properties capable to fulfil customer expectations;
- selection of the most promising new product ideas.

Therefore, the main outcome of Product Planning is constituted by the product idea, expressed in terms of a requirements list. Since the information coming out from the considered phase represents the reference for the subsequent design activities, the undertaken decisions strongly impact on the success likelihood of the new product development initiative. Notwithstanding

CONTACT Daniele Bacciotti daniele.bacciotti@unifi.it

the strategic role played by Product Planning, insights from literature show how even few acknowledged methods effectively support the above recalled tasks [6, 31], as shown in Section 2. Moreover, whereas these methods have been implemented in computer frameworks, the scope was never considered of integrating the developed software with CAD tools supporting other design phases. As a result, a negligible set of software applications is tailored to aid the ideation process of Product Planning, by e.g. taking the review of computer-aided innovation tools described in [16] as a reference. Section 2 will elucidate too the scopes of diffused commercial software applications that ease the execution of Product Planning, remarking the little attention dedicated to the generation of new ideas.

The authors have attempted to extrapolate repeatable patterns within Product Planning and developed a computer-aided tool, namely iDea, to support designers during idea generation processes. Section 3 describes the software prototype and its underlying methodology. The aim of the proposal is overcoming the limitations of the most diffused methods for idea generation, by benefitting of Artificial Intelligence capabilities to offer designers a complete set of stimuli for generating original product attributes.

In order to assess the effectiveness of the developed tool, a test has involved 24 MS students of Mechanical Engineering (Section 4). In the experiment, the authors have compared the outcomes of iDea with those emerging from the employment of a more known tool, i.e. Six Paths Framework [18]. The latter supports the idea generation activity, providing some hints to guide an individual "Brainstorming" process. The choice of this instrument leant upon 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.

Eventually, Section 5 concludes the paper by introducing expected future developments of the proposed tool. In addition, it highlights the core findings of the present research, as well as its main limitations.

2. Background

A deep survey of procedures and techniques that support idea generation is out of the scope of the present paper. Readers can find detailed information about academic and industrial approaches to Product Planning in other sources, such as [1, 5]. With respect to the objectives of the manuscript, it is sufficient to point out how the most diffused approaches refer to stimuli or hints that proactively allow identifying new product ideas. As a result, the most appropriate software applications to support Product Planning consist in enhanced techniques that favour communication within design teams. Still with reference to [24], they include digital Brainstorming and Crowdsourcing tools. 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 treated design activities, but it can hardly give rise to better product ideas than the methods that are basically implemented in computer frameworks.

Some approaches provide guidelines to support individual [18] or collective [20] Brainstorming sessions. For instance, Six Paths Framework [18] is a set of strategic suggestions to explore new opportunities in a reference 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 [4], it is observing, at the very least, a partial acceptability in industry [21]. It is straightforward that a wide exploration of design opportunities is not well supported by procedures that entrust individual or collective intuition, or provide very few directions to reflect upon, as for the case of Six Path Framework. In addition, as already remarked in the Introduction, we can claim that the development of the recalled stimulation techniques has a weak relationship with CAD frameworks, especially from the viewpoint of integrating these tools in environments supporting the whole NPD cycle. Contributions discussing the link between Product Planning methods and CAD systems rather refer to software applications enhancing the sketching capabilities during brainstorming sessions, still without providing any functionality for stimulating the creativity of participants [27].

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 the opportunities provided by commercial software in addition to literature sources. In order to take into account the most diffused software supporting Product Planning, it was required to build a representative sample of tools to be further examined. To this scope, the authors picked up the computer applications emerging from the first 50 results by performing in February 2015 a Web Search through Google search engine with the following keywords:

- New Product Development software;
- Innovation software;
- Fuzzy Front End software;
- New Value Proposition software;
- Product Planning software.

The Web Search led to the identification of 41 computerized tools, which the authors classified according to four categories standing for the kind of supported activities in the initial phases of NPD tasks. Tab. 1 reports the computer applications in alphabetic order and associates them with the pertinent groups. Said categories, listed in the followings, merge the classifications provided by two different studies that used very similar taxonomies [22, 25]:

- Idea Generation: tools to stimulate new ideas, bundles of idea sources, brainstorming and creativity enhancement models;
- Knowledge Management (KM): tools devoted to the management of information regarding the product sphere and customer preferences;
- Decision Support Systems (DSS): tools for evaluation of products and projects, techniques for decisions undertaking;
- NPD Management: tools for managing innovation processes and patent policies, assessing risks, facilitating collaboration and communication activities.

At first, the investigation shows that Idea Generation activity is the least supported. Indeed, just 7 applications include capabilities to stimulate new ideas, whereas the

Table 1. Sample of innovation software applications classified according to the activities they support within Product Planning.

Software	Link	Idea Generation	KM	DSS	NPD Management
Accept360	www.accept360.com		•	•	•
Aha!	www.aha.io		•	•	
beCPG	www.becpg.net		•		•
Blueprinter 4.0	www.newproductblueprinting.com		•		
BoardPacks	www.whitecapcanada.com				•
Brightidea	www.brightidea.com		•	•	•
Business 360°	www.software-innovation.com		•		•
Changepoint Project Portfolio Management	www.changepoint.com		•	•	•
Daptiv	www.daptiv.com		•	•	•
DataStation	www.datastation.com		•	•	•
EXAGO	www.exago.com		•	•	
Genius Project	www.geniusproject.com		•		•
GenSight NPD PPM	www.gensight.com		•	•	•
GrowthCloud	www.growthcloud.com		•		
HYPE GO! & HYPE Enterprise	www.hypeinnovation.com	•	•	•	
Idea Spotlight	www.wazoku.com		•	•	•
Idearium	www.idearium.com			•	•
IdeaScale	www.ideascale.com		•	•	•
IHS Goldfire	www.ihs.com		•		•
Imaginatik	www.imaginatik.com	•	•	•	•
Induct	www.inductsoftware.com		•	•	•
Innovation Factory	www.innovationfactory.eu				•
Innovation framework	www.innovation-framework.com	•			•
Inova suite	www.inova-software.com		•		•
Kindling	www.kindlingapp.com			•	•
Mindjet SpigitEngage & MindManager	www.mindjet.com	•	•	•	•
Oracle Instantis	www.oracle.com	•		•	•
PD-Trak	www.elite-consulting.com				•
Planview Enterprise	www.planview.com		•	•	•
Powersteering	www.powersteeringsoftware.com				•
ProductPlan	www.productplan.com		•	•	•
ProductVision	www.asdsoftware.com		•		
PTC Windchill	www.ptc.com		•		
Qmarkets	www.qmarkets.net	•		•	
SAP	www.sap.com		•		•
Sciforma	www.sciforma.com		•	•	•
Sopheon Accolade	www.sopheon.com	•	•	•	•
Strategyzer	www.strategyzer.com		•		
Valkre Render	www.valkre.com		•	•	•
Wellspring Sophia	www.wellspring.com		•		
Windows SharePoint	www.microsoft.com				•

quantity of tools classified as KM, DSS and NPD Management is 31, 23 and 31, respectively. From this viewpoint, even though the performed search cannot be surely considered as a thorough survey, the obtained results suggest that the development is overlooked of computerized tools for individuating new ideas in engineering design tasks. Secondly, an insightful analysis of the 7 identified software applications shows that these tools are aimed at providing platforms for collaborating in shaping new ideas or offer strategies for enhancing the creative thinking. Moreover, none of them interplays with CAD systems; hence, they are conceived as creativity aids with no particular reference to design issues. In this sense, the investigated software instruments mirror the problems that were highlighted for the tools directly implementing Product Planning techniques, i.e. being constrained in the exploration of the design space and besides unsuitable to the scope of creating a CAD environment supporting users along the whole NPD cycle.

The objective of the paper is illustrating a preliminary proposal that aims at overcoming the above gap.

3. An original method and software prototype to support idea generation

This Section provides a deep description of iDea tool. More in particular, Subsection 3.1 summarizes the fundamentals on which the system is grounded with the aim of offering a brief overview of the adopted logic. Eventually, Subsection 3.2 describes an illustrative application aimed at showing software implementation, functioning and generated outputs.

3.1. Overview of iDea tool

A preliminary research conducted by the authors [6] 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. 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 systematically design opportunities 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.

The developed algorithm allows selecting and customizing the above Dimensions and automatically generating a set of questions that guide the designer during the idea generation task.

More in details, the user has to choose, from the default list of 20 elements shown in Tab. 2, those that are relevant for his/her NPD project.

Three idea stimulation logics have been introduced, in order to fulfil different project's needs:

- simple logic: it collects the selected elements of SHs, LCs and SYSs and asks the user to focus on all possible demands related to these elements, in order to identify new product ideas. This algorithm is useful when ideas have to be generated in little time. Indeed, it provides at most 12 questions like: *Do you identify any new idea*

Table 2. List of default GDs, SHs, LCs and SYSs available in iDea.

Value Dimensions			
GDs	SHs	LCs	SYSs
• Fulfilled needs • Versatility of use/ adaptability • Reliability/safety • Ease • Aesthetics/style/ethics • Quickness • Cheapness • Comfort/ergonomics	• Buyers • Users • Beneficiaries • Outsiders	• Purchasing, choice and access activities • Before use operations • Utilization time • Elapsed time before further exploitations • End of the functioning	• Environment in which the product is situated • Product or service level • Parts, components and accessories

considering the < *SH/LC/SYS* > *?*, whereas the term into the brackets is one of the elements chosen from the default list of SHs, LCs and SYSs.

- standard logic: it combines the selected elements of GDs with chosen elements of SHs, LCs and SYSs. In this case the user sequentially focus on each GD together with each SH, LC and SYS and tries to identify new product opportunities. In this case, the maximum number of generated questions is 96 and they have the following form: *Do you identify any new idea considering the combination of* < *GD* > *and* < *SH/LC/SYS* > *?*

Even if this logic can require more time to reflect upon the questions than the previous one, it provides more specific hints, which result likely useful to explore the design space.

- advanced logic: it allows customizing the chosen Value Dimensions in order to fit with the specific NPD project. Therefore, the user can provide suitable specifications and the algorithm combines them using the same procedure of the previous logic. In order to simplify the customization process, the authors identified a set of 114 specifications that represents cross-sectorial concrete examples of common characteristics linked with the list of elements of Tab. 2 (see an excerpt in Tab. 3). These specifications can be used as a starting point to customize the selected Dimensions. This algorithm allows focusing the ideation process on some specific directions that the user considers particularly relevant and interesting for the faced NPD project and the number of questions (and required time) can extremely vary according to the number of specifications provided by the user.

Therefore, as shown in Fig. 1, the exploration of ideas' space can be enlarged or narrowed according to users' needs. This opportunity provides a flexible approach to support the idea generation activity in various industrial contexts.

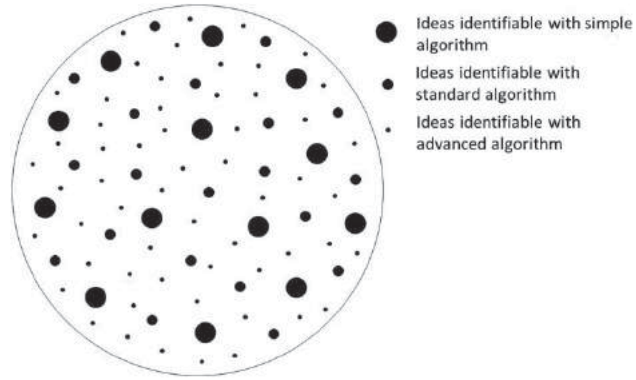

Figure 1. Representation of the design space that can be explored with the three suggested logics.

For instance, if the user selects the GD "comfort/ergonomics", specifying the need of storability, and the SYS "parts, components and accessories", by focusing on the latter, a possible question is:

Do you identify any new idea considering the storability of product accessories?

This hint can suggest the possibility of integrating the functions of the accessories or redesigning the shape of the product in order to contain said accessories, as shown in the example of Fig. 2.

Fig. 3 shows the implemented algorithm of iDea, while the next Subsection depicts the architecture of the software and provides an illustrative application to show how it actually works. For more details, the developed tool and a guide, reporting the main functions of iDea, can be downloaded from the link http://goo.gl/AwzZHF.

3.2. System implementation: an illustrative application

The developed software prototype is a multi-screen GUI that includes a first window (Fig. 4), in which the user has to select the Dimensions that are pertinent for its NPD project and further windows (Fig. 5–6–7–8) in which the above mentioned idea stimulation algorithms have been

Table 3. List of suggested specifications for customizing the default GDs, SHs, LCs and SYSs.

Specifications of Value Dimensions			
GDs	SHs	LCs	SYSs
Fulfilled needs:	Buyers:	Purchasing, choice and access activities:	Environment in which the product is situated:
- Quality of the expected outcomes;	- Manager, decision maker;	- Identifying the product on the web;	- Weather conditions;
- Quantity or extent of the expected outcomes;	- Parents or tutor;	- Identifying the product on leaflets, brochures;	- Tools or matched machinery
- Duration of the expected outcomes;	- Reseller;	- Comparing with similar products	- Matched or surrounding items
- Fun and adventure.	- Professional; - Agent.		
...	...	...	...

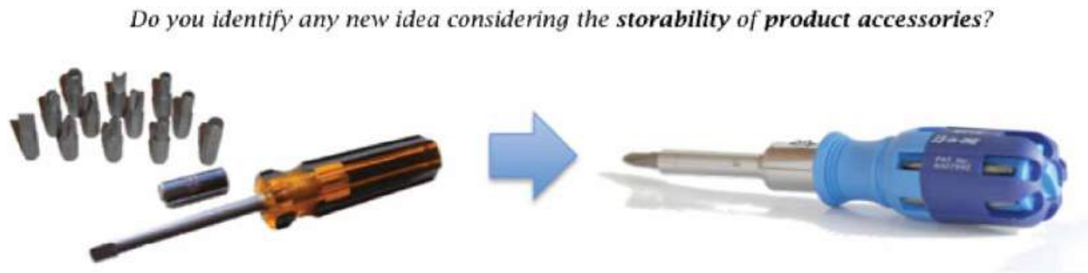

Figure 2. Example of a new idea identified considering the need of "storability" together with "product accessories": a screwdriver with a bit set integrated into the handle.

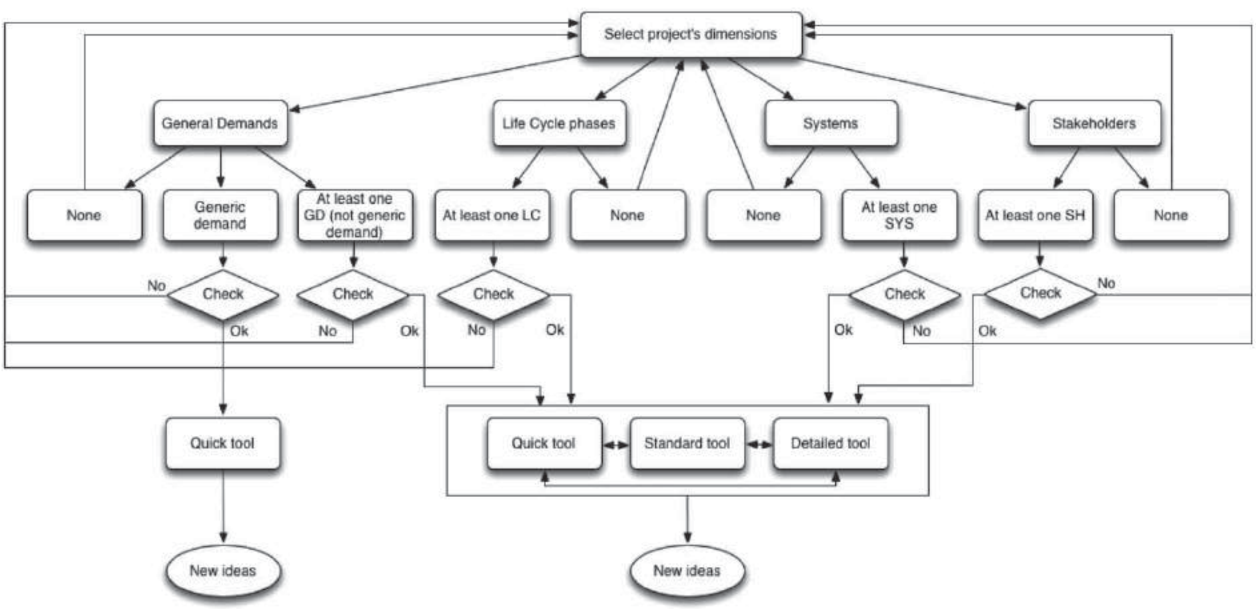

Figure 3. Main algorithm of iDea tool. GD, LC, SYS and SH stand for General Demands, Life Cycle phases, Systems and Stakeholders, respectively.

implemented. The three logics described in the previous Subsection, i.e. "simple", "standard" and "advanced", are implemented in different modules, named "quick", "standard" and "detailed", respectively.

With the aim of providing an illustrative example of the developed software, iDea has been used to generate new features for a common and simple product, i.e. a door handle.

In the first selection page, Dimensions can be chosen by ticking the related boxes. If "Generic demand" is selected, all the other GDs are automatically deselected and the unique module that can be used is the "quick" one. In the example, all the items concerning the four Value Dimensions were considered pertinent in the given industrial field and none of them has been consequently deselected, as shown in Fig. 4.

After the selection of Dimensions, idea stimulation tools can be used by clicking on the buttons activated on the top of the windows. They can be exploited separately and the user can switch from one to another whenever he/she wants.

The "quick" and "standard" windows are very similar (Fig. 5–6). They include the generated hints in a left box and allow collecting a semantic description of new ideas in a text field available on the right side of the window. For instance, in the "quick" module, the LC "before use operation" has led to the identification of three new ideas concerning the case study (Fig. 5), and the combination of the GD "Reliability/safety" and the SH "outsiders" in "standard" module led to the generation of three further ideas (Fig. 6).

Subsequently, the first window of the "detailed" module allows customizing the selected GDs. The default list of terms can be modified by adding or removing elements. By clicking on the "next" button, the same procedure can be repeated for the other three Value Dimensions. For instance, Fig. 7 shows a case in which the default SYS "parts, components and accessories" has been

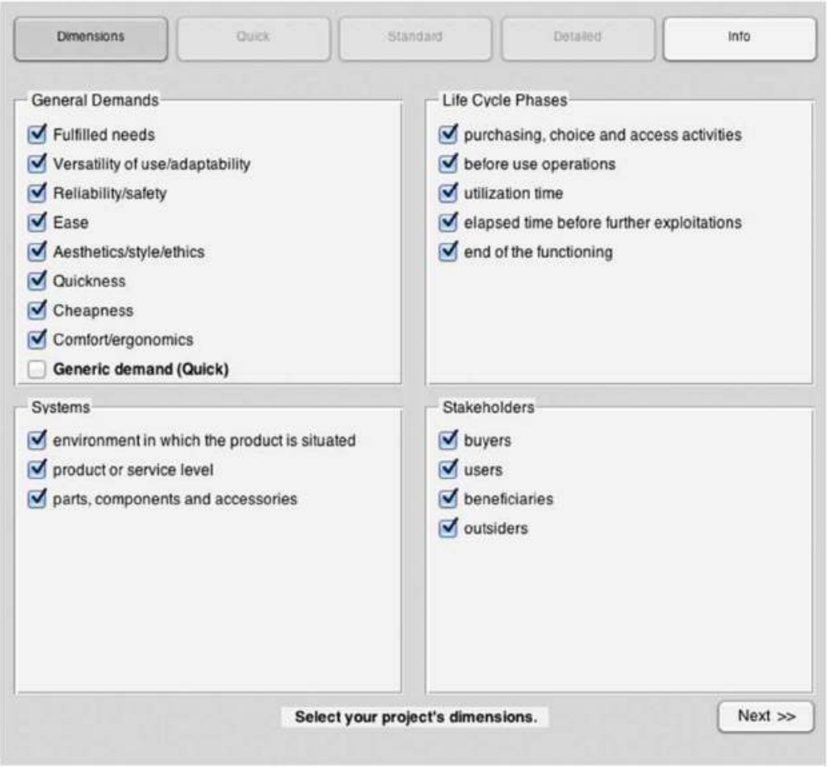

Figure 4. Screenshot of the Dimensions' selection page of iDea. All the terms have been selected for the case study.

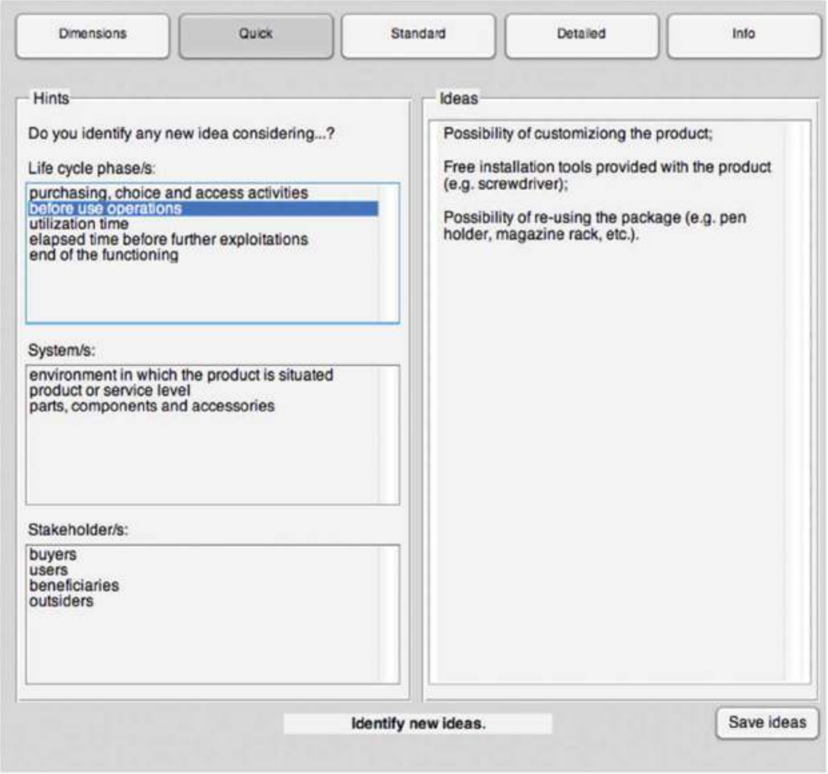

Figure 5. Screenshot of the quick module of iDea that shows the ideas stimulated in the case study by the LC "before use operations".

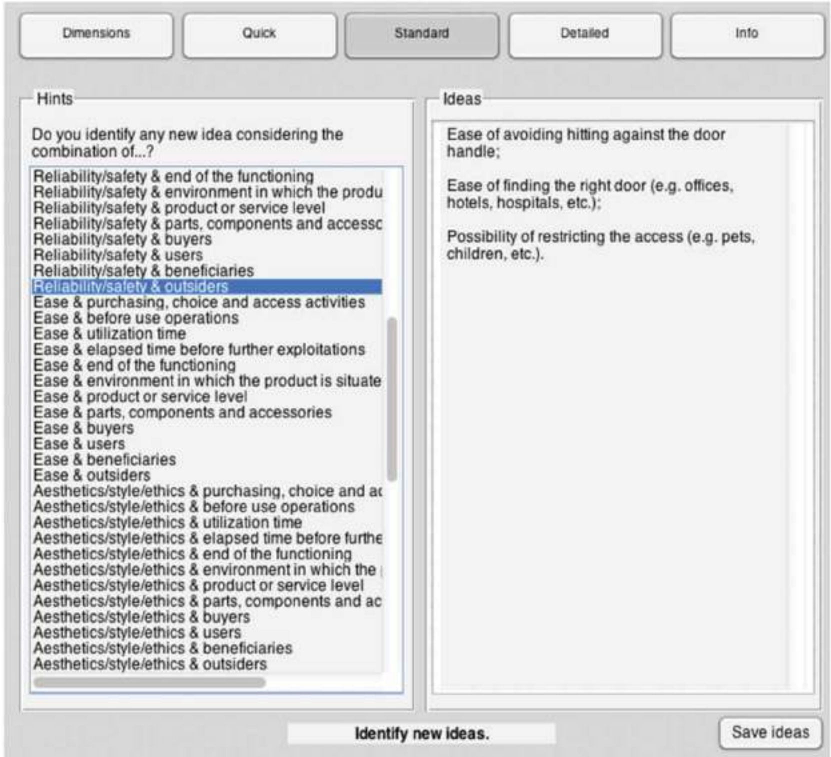

Figure 6. Screenshot of the standard module of iDea that shows the ideas stimulated in the case study by the combination of the GD "Reliability/safety" and the SH "outsiders".

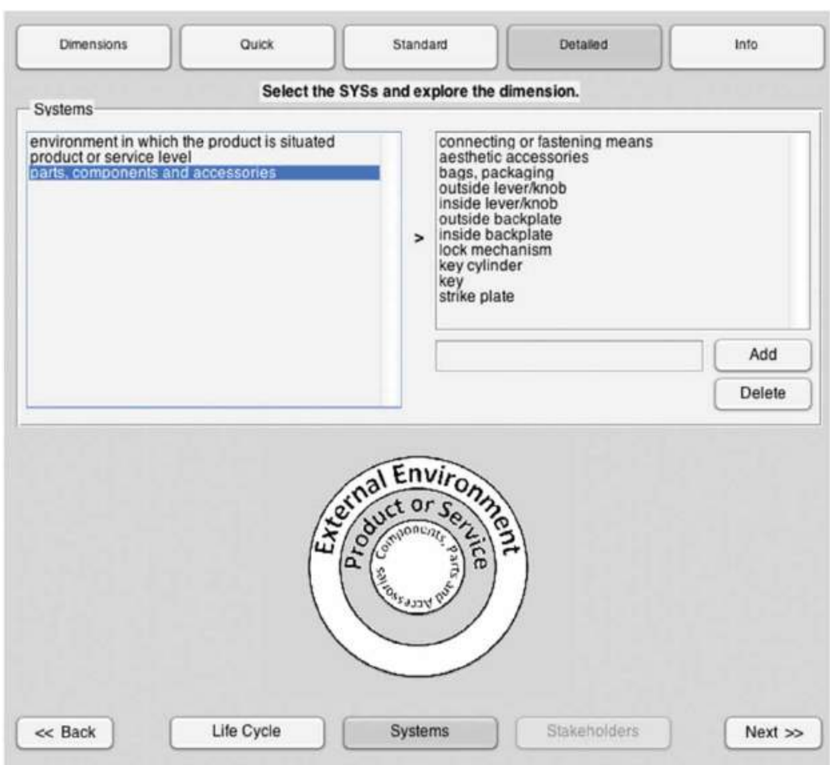

Figure 7. Screenshot of the detailed module of iDea. The default SYS "parts, components and accessories" have been customized according to the case study.

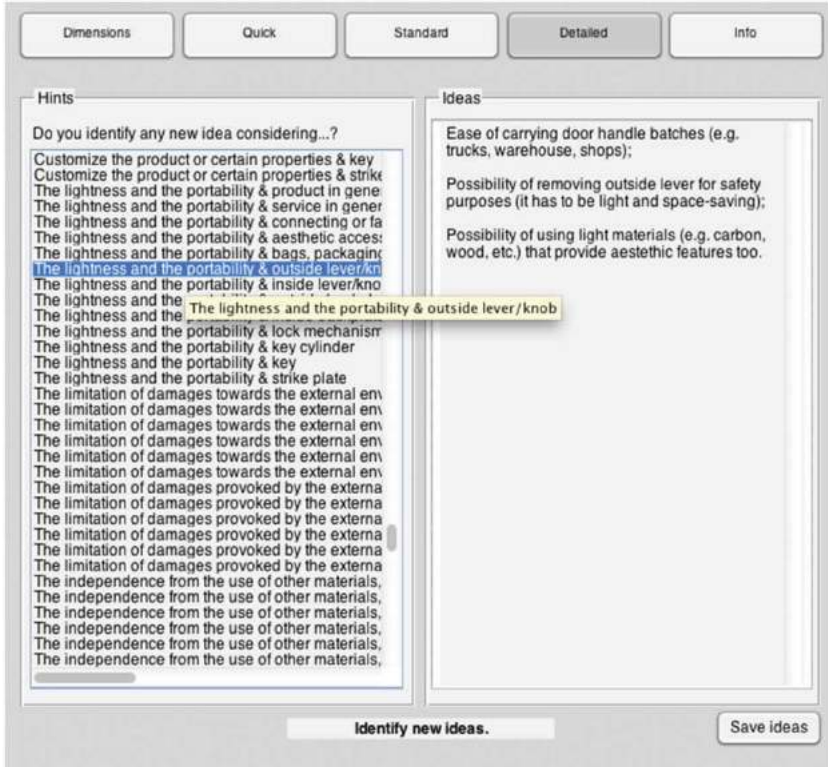

Figure 8. Screenshot of the detailed module of iDea that shows the ideas stimulated in the case study by the combination of the GD "The lightness and the portability" and the SYS "outside lever/knob"; long strings are currently highlighted through pointing procedures.

customized. Finally, the last click on the "next" button opens a window, which has the same layout of the other two modules (Fig. 8), i.e. it provides hints on the left side of the window and allows collecting new ideas in the right box. With respect to the case study, the combination of the GD "The lightness and the portability" with the SYS "outside lever/knob" has supported the identification of additional ideas (Fig. 8).

Projects and generated ideas can be saved and loaded in order to support both knowledge management and information sharing.

The use of the method and the prototype software has led to the identification of several new product ideas, among which a significant number was assessed as worthwhile of future development investments by an industrial partner working in the field. The most interesting ideas, still according to the cited firm, comprise:

- door handles that are visible or easily usable in the absence of light;
- door handles that target luxury markets and particular customer tastes;
- fully customizable door handles.

Other ideas are characterized by the matching of the studied product with systems and functions that characterize the environment that surrounds or is adjacent to the door handle. Illustrative examples range from anti-burglary measures to reminders, from detectors to conditioning systems. The systematic exploration of the design space has besides allowed identifying particular working conditions for the door handle, potentially leading to new product development opportunities. In this sense, it is worth remarking devised concepts such as foot-operated handles (useful in the common case hands are not free) or remote control systems that mirror analogous devices in the automotive field. The generated ideas can be plainly combined in order to give rise to superior benefits; for instance, remote controls can allow opening the door and enlightening the entrance area simultaneously, still with reference to what is common within the use of cars.

4. Test to assess the proposed software application

In order to measure the effectiveness of iDea, the authors organized a test campaign with the objective of comparing 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 three-hour sessions, in which 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 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 products 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 [29]:

- quantity of ideas: it allows assessing the ability of generating as many ideas as possible in a predefined amount of time;
- variety of ideas: it assesses the ability of exploring the design space, identifying ideas that are very different from one to 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. [29] 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 ad hoc categories to shape a "genealogy tree", which is suitable to characterize the design space of Product Planning instead of Conceptual Design. The authors used the above-mentioned four Value Dimensions to differentiate ideas at the highest hierarchy. Further detail levels refer to elements (Tab. 2) and specifications (see the excerpt of Tab. 3) that characterize the value provided by new product features with a decreasing degree of abstraction.

For instance, the set of ideas generated in the first session by the student identified as "id14" working with coffee machines (Tab. 4), has been structured through the "genealogy tree" of Fig. 9.

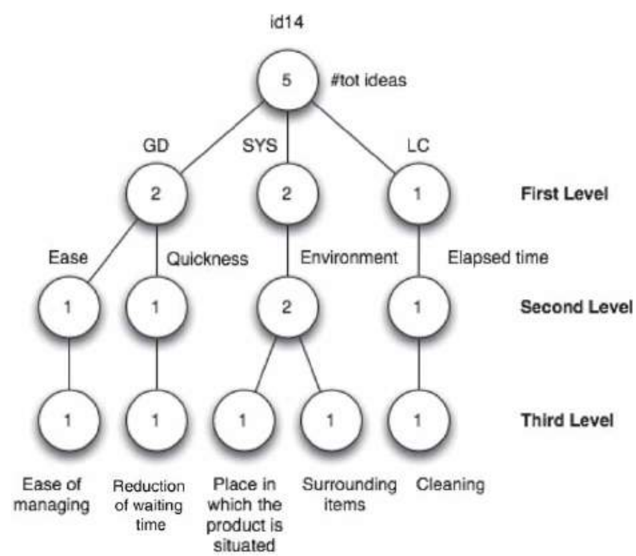

Figure 9. Tree diagram used to divide the ideas generated in the first session of the test by the student "id14". The reference topic was the ideation of new domestic coffee makers. GD, LC, SYS and SH stand for General Demands, Life Cycle phases, Systems and Stakeholders, respectively.

The reference formula proposed by Shah et al. [29] to assess variety is:

$$V_i = \sum_{j=1}^{3} S_j \times B_j / V_{max} \tag{1}$$

whereas V_i is the variety assessed for the ideas generated by the i-th tester; S_j is the score assigned for the level j (suggested scores are 9, 3, 1 for General Demands, elements and specifications, respectively); B_j is the number of branches at level j; V_{max} is the greatest possible variety score. This value is a constant, according to the

Table 4. List of ideas generated in the first session of the test by the students "id14", belonging to the group B. The reference topic was the ideation of new domestic coffee makers.

Student	Group	Test	List of ideas
id14	B	1	• Rollaway device, integrated into kitchen furniture; • Direct link to the water supply network; • Possibility of washing the cups directly into the device; • Easy management of the device through Wi-Fi connection; • Integration into the device of an alarm clock that wakes up in the morning and automatically prepares coffee.

Table 5. Main results of the test. The table shows mean and standard deviation of the quantity and the variety of ideas generated in the test. The two case studies, i.e. cameras and domestic coffee makers, have been analyzed separately.

Case studies	Tools	Quantity		Variety	
		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%

proposed classification of ideas. Indeed, it can be calculated using the numerator of formula (1) and considering the number of Dimensions (four), elements (twenty) and standard specifications (one hundred-fourteen) included in the model ($V_{max} = 210$). For instance, the following extent of variety, expressed in terms of the fraction of the maximum achievable value, is calculated for the above sample of ideas (Tab. 1):

$$V_{14} = \frac{9 \times 3 + 3 \times 4 + 1 \times 5}{210} = 0,\ 2 = 20\% \qquad (2)$$

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.

The main outcomes of the test are summarized in Tab. 5.

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 statistical 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.

5. Discussion and 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, supporting the main activity of Product Planning, i.e. idea generation. This tool has been tested against a well-known approach, i.e. Six Paths Framework, by 24 MS students of Mechanical Engineering and obtained promising outcomes in terms of quantity and variety of generated ideas. In addition, the test provided interesting outcomes, deemed worth of future research:

- the possible independence of the obtained outputs (in terms of quantity e variety) from the type of the product to be innovated;
- the fact that iDea can deeply highlight the differences among the personal skills of users.

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 [17], such as:

- quality of ideas: it is related to the technical feasibility of proposed ideas [29] and allows understanding how many ideas could be actually implemented in new products;
- novelty/creativity of ideas: it allows to assess the originality [29] and creativity [3] of generated ideas.

Further tests will involve design teams, according to the current collaboration trend [26], in order to understand how the outputs change from individuals to groups. Moreover, authors will focus on some implementation issues to improve software usability and efficacy. From this point of view, two main aspects should be addressed as further developments of the suggested approach, which concern improvement of creativity stimulation and reduction of boring effects on users. Both the recalled issues deal with the design of a GUI capable to ease the interaction with users. A possible solution that authors are assessing is the integration within the system of images that depict exemplary product features, which appear together with the queries the algorithm generates. In such a way, users can benefit of information that clarify questions' meaning, as well as get visual stimuli, which are supposed to make the creative process more fruitful.

Indeed, exemplary features can leverage the creative process by urging users thinking to analogous solutions in the specific context of the project. Of course, representations and images should avoid the onset on user of design fixation effects that might result deleterious for the ideation process in terms of quantity and variety of generated product ideas [8].

Eventually, authors are designing possible solutions for integrating iDea with CAD tools supporting 3D modelling and sketching, with the aim of accelerating the whole NPD process. As described in Section 3, the system prototype provides just the possibility of recording and storing the generated idea in the form of a semantic description. The authors are now thinking to include into the system an environment that can help users in translating ideas into sketches and models from which to start the subsequent design and developments phases. In other words, the system that the authors plan should not provide only a support for defining the objectives of the NPD activity but also functionalities capable to translate ideas into technical solutions. Currently, some preliminary studies focused on assessing feasibility have regarded the integration of virtual modelling environments of commercial software.

ORCID

Daniele Bacciotti http://orcid.org/0000-0003-0303-5957
Yuri Borgianni http://orcid.org/0000-0002-5284-4673
Federico Rotini http://orcid.org/0000-0002-1676-0835

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