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Editorial

Editorial for the Special Issue "Requirements in Design Processes: Open Issues, Relevance and Implications"

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1. Introduction

Requirements play a key role in the design process by affecting analysis, synthesis and evaluation activities at different levels and in different ways.

Markedly, during the analysis of the design problem, requirements are at the cornerstone of designers' reflection on processes such as the formulation and clarification of the objectives. Furthermore, requirements guide the process of solution finding; here, they affect designs both positively, by making designers focus on the solution, and negatively, by acting as potential triggers of psychological inertia and fixation. Eventually, during evaluation and selection activities, requirements constitute the reference criteria for the assessment of design outcomes in order to identify the solution that is supposedly the most compliant with design objectives.

Therefore, the designers' perspective on requirements and their use relentlessly changes during the design process due to the changes in the level of detail with respect to design representations and differences in terms of information needed to move forward. In most abstract phases, such as Product Planning and Conceptual Design, the designer tries to understand what should be designed and searches for the functions to be delivered and the modalities to implement them. During Embodiment and Detailed Design, the development of the solution progresses until a well-defined structure is identified, which is univocally represented by using CAD models and technical drawings. Moreover, due to the iterative nature of the design process, the definition and formulation of requirements are also affected by partial design outcomes, which depend on their respective requirements. Therefore, requirements orient the design process by taking into consideration the mutating nature of the design problem without introducing hindrances or leading to distortions of design objectives. This requires the implementation of strategies that continuously manage and update requirements. In addition, strategies targeting requirements might be tailored to design contexts, such as eco-design or Design for X, or conditions, such as co-design or open innovation.

The design community has made great efforts in investigating peculiar aspects related to evaluation and selection processes. Conversely, other important issues concerning the entire design process have received less attention—somehow, the big picture has been overlooked. Accordingly, the proposed Special Issue is aimed at investigating the impact requirements have on the quality and creativity of the design outcomes and the implications of requirements' handling in specific design activities, as well as across different phases. More specifically, it welcomed contributions with respect to the main issues summarized in the following list, which however should not be considered exhaustive:

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- Methods and tools for the definition, the understanding, the development, and the use and management of requirements in the design process. Case studies and comparative analyses in terms of performance of proposed approaches.
- Criteria and metrics to assess requirements.
- Planning R&D strategies through the anticipation of goals, objectives, and requirements.
- Emergence/elicitation and the management and evolution of requirements in co-design contexts. Knowledge externalization techniques and tools for problem analysis and goal/objective formalization.
- Role and importance of data and information sources to steer the design process and the definition of requirements (Big Data analysis, artificial intelligence, etc.).
- Handling sustainability-oriented requirements in engineering and product design.
- Handling affective, aesthetic, ethical, and emotional requirements in engineering design.
- Requirements in Design for X methods, such as designs for additive manufacturing.
- Prototyping requirements in product design and development processes.
- Tools and techniques for overcoming conflicts in requirements.
- Impact of requirements on design fixation and on creativity of design outcomes. Role of requirements in the assessment of creative design processes.
- Role and relevance of requirements in stakeholders' quality evaluation and acceptance of design outcomes.
- Engineering requirements in teaching and education contexts.

2. Requirements in Design Processes: Open Issues, Relevance and Implications

The Special Issue received 12 submissions, out of which 7 contributions passed the review process and have been published. The topics mainly refer to methodological approaches dealing with the analysis, assessment, and management of requirements and applications to case studies in several fields. In the following, a summary of the published papers is provided.

In [1], an approach based on living systems is presented, which is dedicated to the identification of gaps and potential improvements in the formulation of requirements. More specifically, the method provides support for product reengineering tasks that are specifically oriented towards the achievement of disruptive innovations. Beyond the description of the methodological approach, the paper presents an application to an illustrative case belonging to the cybersecurity field.

Contribution [2] presents a user-centered methodology to support product design, which primarily considers requirements in functional and aesthetic perspectives. The designer's role and responsibility are also taken into account. A case study shows how the proposed methodology can support the designer in selecting among design alternatives and in reducing potential biases and subjective decisions.

Contribution [3] describes a method for the systematic assessment of requirement change risks, which has been developed by using a multiple case-study approach. More specifically, the change risk was assessed by combining change likelihood and change impact, while propagation effects are considered by analyzing requirement interrelations. Furthermore, a software prototype was developed to enable the technology transfer to industrial applications.

The study described in [4] revisits some assumptions of the conventional prescriptive and descriptive models of design. Furthermore, it investigates whether conventional models can also be applied for representing problem–solution co-evolution patterns that appear during conceptual design activities and that affect requirements consequently. The findings demonstrate co-evolution patterns that cannot be described by the conventional models as well as some inconsistencies.

In [5], a new formulation of the design requirements in Natural Laminar Flow (NLF) optimization tasks is presented to make them less experience-based and much more grounded on quantitative criteria. The paper shows the impact of the proposed formulation on the result of NLF optimization in the design of transonic airfoils and aero-engine

compressor blades from two perspectives: Pareto front convergence and the improving effect of accessory performance.

Contribution [6] deals with the lack of structured processes to extract relevant information for benchmarking purposes in Product Planning. It presents an approach to identify and structure the relevant knowledge for innovating a product radically with respect to the definition of requirements. The proposed method is applied to the sector of agricultural machines, which is characterized by a high degree of maturity and, predominantly, incremental innovations.

Eventually, in [7], a structured tool was presented, which is capable of allocating different requirements to specific functions systematically and to discern between design wishes and demands. The tool can be integrated with different requirement checklists to enhance their performance in extracting useful information for product developments. Moreover, an experiment as described to assess the efficacy of the proposed approach.

Overall, the approaches presented in the accepted papers illustrate a variety of alternatives for handling requirements and how the alternatives considerably affect the design process as a whole. The contributions show how fields of application, designers' culture, and preferred methodologies play roles in requirement processing. A holistic and comprehensive model of design requirements' management and transformation during design phases is far from being developed. This can be interpreted as a fundamental paucity towards the development of a unified and universal understanding of the design process, which some design researchers aim towards, with clear repercussions on (engineering) design education. It is unquestionable how the authors of studies [1–7] have used different interpretations and nuances of the word "requirements" and none of them can be contrasted. For this reason, the Guest Editors deem that the subject requires further studies and investigation, as well as a significant and substantial amount of theoretical research. The Guest Editors expect and hope that the articles published in this Special Issue will contribute to forming the backbone of the systematic development of the field.

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