Guest Editorial

Computer-Aided creativity enhancement in engineering education

1. Introduction

Society values greatly the products of creative thinking. The question of how we may increase the likelihood that innovations will occur is at the core of this issue. We are looking for ways to enhance engineering education, which could enable engineers to think more creatively.

If we ask how engineers might be helped to deal with situations that demand creativity, perhaps the question if it is possible to study creative thinking has to be answered first. Creative thinking deals with bringing new ideas and inventions that positively change our world. Today, more than ever in the past, Computer Technology may be considered as an interface between engineers and the products they create, but we have to determine whether the use of computers effectively enhance engineers' creative activities.

Computers have gained more and more importance for product development, since the dissemination of the first prototype CAD systems in aerospace industry. Nowadays, they play a crucial role in any industry in detailed design tasks, as well as for planning production activities. Recently, Computer-Aided Innovation (CAI) systems [1] have extended the domain of computer application to the earliest stages of product development and to the support of the entire innovation pipeline.

Moreover, in the last decade, Information Technology systems have substantially fostered a shared vision of creative patterns among different disciplines, resulting in a consistently growing interest in creativity concept. This led towards the birth of a novel and fertile field of research, namely the interplay between creativity stimulation and computer systems. Among the different directions of research activities related to the role of computers to support innovation processes, an emerging role is played by software applications capable to develop human creativity by encouraging the perseverance of designer in the research of innovative solutions and by aiding the designer with a coaching activity, acting as an expert system that guides the user throughout cognitive processes.

Within this context, many open research issues still require to be investigated, from the theoretical models of the cognitive processes involved in inventive design, to the assessment of the potential of computers to reduce learning efforts and to enhance technical creativity.

The present special issue collects a number of contributions in this field, gathered through the initiative of the WG5.4 Computer-Aided Innovation working group of the TC-5 Committee (Computer Applications in Technology) of IFIP (International Federation for Information Processing).

Hereafter, first a quick overview of the relevant topics so far addressed in the literature is proposed, with the aim of positioning the research activities in this field. Then, the papers of this special issue are presented with respect to the proposed classification.

2. Research lines in the field of creativity enhancement by computers

As an editorial paper, the purpose of this section is not to provide a comprehensive survey of the on-going research activities, but just to build a bird's eye map of the main relevant topics of interest (Fig. 1).

The underlying theoretical framework is, of course, constituted by the huge literature on creativity, with a specific focus on those studies that can be useful for Computer-Aided Innovation (A). An updated and multi-faceted presentation on the relevant perspectives of research on design creativity can be found in [2].

Rooted in this science there is the wide branch of studies, both theoretical and application-oriented, dedicated to *computers for creativity enhancement* (B). The debate about how computers can be partners in the creative process is characterized by four main directions of investigation [3]: *(i)* computer applications aimed at facilitating the management of the working process, by encouraging the designer in the research of innovative solutions; *(ii)* the ease of communication between design team members, based on the assumption that circulation and integration of ideas play a relevant role in the creative process; *(iii)* computers that act as an expert system and guide the user's cognitive processes with a sort of coaching activity; *(iv)* Artificial Intelligence systems that contribute to ideas generation, thus cooperating in the creative process.

Among the others, two research streams appear as more significant within the scope of Computer-Aided Innovation, at least according to the topics discussed within the working group that launched the CAI

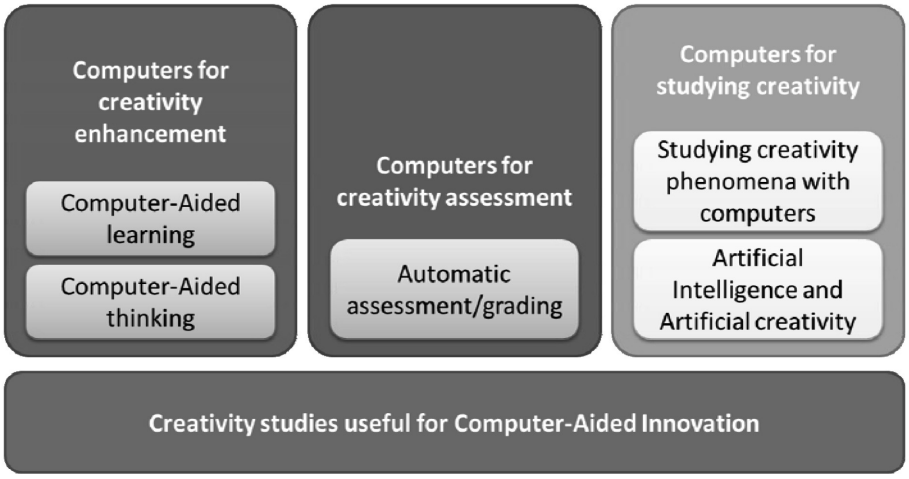

Fig. 1. Bird's eye map of the main relevant topics in the domain of creativity enhancement by computers

acronym: Computer-Aided learning (of creativity tools) and Computer-Aided thinking. The first is substantially connected with the objective of this special issue and will be further discussed in the next section. The latter is pursued by all those studies that aim at enhancing creativity in design through the use of software tools, e.g., by guiding the thinking process, by proposing stimuli for design-by-analogy, by providing visual support to problem mapping and problem solving, etc.

A second major branch of research is dedicated to *computers for creativity assessment* (C), which spans from the use of computers to support the execution of testing campaigns, to the automatic assessment/grading through the use of language technologies and machine-learning methods to automatically grade students' natural language responses.

Eventually, computers can be used as a *support for studying creativity* issues (D). This happens through direct and indirect approaches. The formers study creativity phenomena by building computational models based on theoretical assumptions about creative behaviors. Then, these models are used to inspect the phenomena associated to these assumptions and as a consequence to formulate conclusions about the nature and the effects of creativity. Besides, Artificial Intelligence and artificial creativity, despite essentially dedicated to the development of systems with a creative role, as a research-by-product, indirectly enable the investigation and a better comprehension of what's behind creativity.

3. The papers of the Special Issue

The papers proposed in this special issue reflect the variety of studies in the field with complementary research contributions dealing with educational models enhancing creativity (segment A of Fig. 1), or with computers for creativity enhancement (segment B).

More in detail, Harlim et al. investigate the features of what is perceived as "good problem solving" and can be used to improve educational strategies to develop problem solving skills, as well as to enable the implementation of computer-based tools for enhancing engineers' creativity.

The integration of the two traditional fields of product design and product engineering, namely Design & Engineering, is discussed in Carulli et al., where it is demonstrated, through an experimental validation, that thanks to the proposed framework both students and professional designers can improve the effectiveness of their overall design capabilities through the original use of even traditional Computer-Aided tools.

The use of Computer-Aided means to improve teaching effectiveness on transferring inventive design skills is addressed in Cavallucci et al. TRIZ, the Theory of Inventive Problem Solving, is the reference methodology for developing inventive design skills. Besides, it is well known that a major conflict exists between the time needed for effectively learning how to use its problems solving tools and the time generally allotted for teaching a new method in an academic course. Computers can both help overcoming this dichotomy and point out new pedagogic needs to be addressed.

Becattini et al., as well as Rizzi et al., propose original CAI tools aimed at improving and supporting engineering creativity, thus ranging from Computer-Aided learning to Computer-Aided thinking, but still

focused on the segment B of Fig. 1. The former presents a natural language dialogue-based framework, capable to coach designers in investigating non-routine technical problems through a TRIZ way of thinking. The latter, proposes an original computerized procedure to guide problem formulation tasks. Both CAI systems have been tested within engineering academic courses on problem solving and design creativity in different Italian universities.

An overall balance of TRIZ education at university is proposed by Belski et al., based on a five-year experience at the Royal Melbourne Institute of Technology (RMIT). The analysis is based on numerous surveys on students' problem skills and compares the impact on students' problem solving abilities of the TRIZ module with respect to a typical engineering course. The results suggest that the enrichment approach is superior to the infusion approach for teaching engineering problem solving. More in general, the paper constitutes a further reference contribution for the development of Computer-Aided Innovation systems (Fig. 1, segment A).

A broader perspective rather than technical problem solving is proposed in De Carvalho, where different tools for inventive and conceptual design are integrated for new product ideation. The proposed creativity enhancement system (Fig. 1, segment B), namely IDEATRIZ, has been tested also through industrial case studies, which have been briefly summarized in the paper.

In the final two papers, Lou et al. and Rivera-Solorio et al. propose example implementations of CAI-related courses with a focus on specific case studies. The first case study was dedicated to the development of a pneumatic propeller ship while applying STEM (science, technology, engineering, and mathematics) knowledge among Taiwanese female high school students. The second one was devoted to the design of a boat powered by solar energy at Tecnológico de Monterrey, Mexico.

Hopefully, this special issue provides interesting and promising insights on the potential of Computer-Aided systems for creativity enhancement in engineering education. The research domain is certainly of growing interest and largely unexplored, and will constitute a field of vivid scientific debate and industrial competition in the upcoming years.

References

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