Brain–computer interfaces (BCIs) are recent developments in alternative technologies of human-computer interaction. These interfaces aim to interpret the brain's activity as user intentions in active BCI systems or cognitive/emotional state in passive BCI systems. Emerging research in BCI covers many disciplines from psychology and computational neuroscience to engineering. Although this research promises a novel channel to engage human cognitive/emotional states in computer-aided systems, only recently have commercial BCI systems been widely available. BCI applications in CAD/E systems are in early stages and, thus further research and development are necessary to ensure that BCIs can meet the needs of specific user groups in the next generation of CAD/E systems.

Following the special issue on “Fundamentals of next generation CAD/E systems”, this is the second issue targeting the potential challenges and approaches in next generation of tools in computer-aided design and engineering systems that may be available to design community within next 5–10 years. In this special issue, we have sorted the various potential CAD/E applications of BCI into two main categories:

1—Novel implementation of BCI in CAD/E tools
2—Studies on the neurological basis of design cognition using BCI.

By emphasizing on these two directions this special issue aims to distribute recent insights and findings, to make the latest results of development known for the CAD/E community, and to stimulate further research in the multi-disciplinary research domain.

Studying the neurological basis of design cognition:
Understanding designer's cognitive process during design activity plays a significant role in developing design theory and methodology. The first study concerning the brain's activity during design process was conducted by Göker in 1997. He studied the effect of experience in design process. By analyzing the designer's EEG activity he showed that novice designers use deductive reasoning in design process, while experts prefer to apply their experience directly. Since then, most of the research in design cognition has been focused on other related concepts such as creative thinking.

Although design is a creative process, which is featured by flexibility, it also includes a set of well-structured steps for analyzing the problem, finding and expressing the solution and finally evaluating the final design. In the first paper of this special issue, Nguyen and Zeng have studied the cognitive efforts of designers during conceptual design. They showed an inverse U-curve relationship between designer's mental effort and his mental stress. In their experimental studies with seven subjects, power spectral density of brain activity (EEG signals) was used to estimate the mental effort while heart bit variability (measured via ECG) was used to calculate the mental stress. They showed that at high mental stress, designer's mental effort is the lowest compared to his/her mental effort at low and medium stress level. These findings would be crucial for next generation CAD systems in order to adaptively control the level of mental stress and mental effort. For instance, based on the inverse U-curve, the workflow and interfaces of CAD tools should be designed such that they do not add unnecessary mental stress while do not reduce mental effort.

In another paper, entitled “Fuzzy psycho-physiological approach to enable the understanding of an engineer’s affect status during CAD”, Liu et al. studied the contribution of the emotional state of CAD operators to the design process. They developed a fuzzy logic model to map combination of psycho-physical signals – EEG (brain activity), ECG (heart bits) and galvanic skin resistance – to a set of key emotional states (frustration, satisfaction, engagement, and challenge) for this purpose. The authors conducted two case studies where a log of CAD operation was recorded simultaneously alongside to psycho-physical signals. At different stages of the experiment, subjects were asked to fill a questionnaire regarding changes in feeling and emotion. Authors demonstrate significant correlations between the associated engineers’ CAD activities and their reported emotional states. Although this study has made the first steps only, its outcome is important to understand the role of affective computing in various domains of engineering design. The presented psychophysiological approach seems to be beneficial at investigating both individual and collaborative problem solving.

BCI as a novel CAD/E interface for product modeling and evaluation
BCI was primary designed for patients with severe neuromuscular disability and aimed to provide such patients with communication tools to interact with others and ultimately offer them a certain degree of independency. This was an inspiration for using BCI as a new modality in human-computer interactions. Over the last decade, the main efforts of BCI researcher have been focused on improving the robustness and accuracy of this newly adopted modality. However in most BCI applications, human competence and task-oriented demands (task with different level of complexity implies different level of workload) have been frequently overlooked. These are the two issues that Alonso-Valerdi and Sepulveda are addressing in a paper entitled “Development of a simulated
living-environment platform: Design of BCI assistive software and modeling of a virtual dwelling place”.

The authors developed a virtual living environment where BCI translates users' imaginary right/left hand movement into navigation command. They conducted three experimental sessions with eleven subjects. In the first session users learned how to control the BCI to navigate in the virtual environment. In the second session they were asked to maintain attention in their cognitive command for a period of time upon receiving a visual cue (cue-driven). In the third session the subjects were asked to do a sequence of planning and mental navigation at the same time (target-driven). Analyzing the user cognitive engagement and his adaptability through different levels of workload, the authors suggest that the progressive adaptation in BCI systems can enhance the performance, the persistence and the confidence of the users, even when they are immersed in simulated daily living situations.

In the last short paper entitled “Human factor study on usage of BCI headset for 3D CAD modeling” Shankar and Rai investigate the usability of BCI systems in developing CAD models. They mapped regular CAD commands to a set of motor imagery, eye movement and facial expressions. They asked five subjects to create 3D models with four different levels of difficulties. Despite variation in the thought patterns and facial expressions, they observed that performances of different subjects were not statistically different from each other.

Since the manuscripts submitted for this special issue covered only two major categories of application of BCI in the next generation CAD/E systems, some other research aspects such as integration of BCI with other modalities in a multi-modal natural interface have not been addressed explicitly by the accepted papers. We envision that effective integration of BCI communication with other modalities in design tools and systems would have the major impact on CAD systems in near future.

Another direction of research for BCI in CAD would be the implementation of concepts discovered in studying design cognition and utilizing them in collaborative environments. In such an environment an interactive multi-human–machine system can be used. This system could receive design information as well as cognitive data of designers, and then detect who in the design team is leading and should be given more attention.

Such applications can benefit from algorithms and methods in passive BCI systems such as detection of the workload or the emotional state of a user or the cognitive states involved in design collaboration. BCI has access to cognitive information which is not available through any other modalities and can serve best as the complimentary source for reducing the uncertainty in multimodal systems.

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