Editorial

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Biographical notes: Imre Horváth (1954) received his MSc titles from the Technical University of Budapest (TU Budapest), Hungary, in 1978 and 1980, respectively. He has held various faculty positions at the TU Budapest between 1985 and 1997. He earned a Dr. Univ. (1987) and a PhD (1994) from the TU Budapest, and a CDSc from the Hungarian Academy of Sciences (1993). Since 1997, he has been a Professor of Computer Aided Design Engineering at the Faculty of Industrial Design Engineering, TU Delft, the Netherlands. He is Co-Editor-in-Chief of *Journal CAD* and initiator of the *TMCE Symposia*. His research interests are in methodology of design research, ubiquitous design support and affordances-based innovation.

Wilhelm F. van der Vegte received an MSc (equivalent) in Mechanical Engineering at Twente University, the Netherlands in 1989, and a Master of Technological Design at Delft University of Technology, the Netherlands. For seven years, he has been a Project Manager and Industrial Designer at the Dutch TNO Institute of Industrial Technology. Since 1998 he has been an Assistant Professor of Industrial Design Engineering at Delft University of Technology. His research currently focuses on the integration of user interactions into engineering simulations. His educational activities include supervising graduation projects and teaching in design projects, engineering courses and computer support of product design.

Jože Duhovnik is a Professor in the Faculty of Mechanical Engineering, University of Ljubljana, Slovenia. He has been the Founder and Head of the Laboratory for Computer Aided Design (LECAD) in the Faculty of Mechanical Engineering from its founding in 1983. He founded the LEAD group in 2004. He graduated in 1972 and received an MSc in 1974 and a PhD in 1980. He continued his postdoctoral study in the Department of Precision Machinery Engineering at the University of Tokyo, Japan. His professional experience includes more than 14 years in leading positions in industry as Engineer, Head of project teams and Manager of an engineering company. He is a member of VDI, IFToMM, Eurographics, the New York Science Academy, The Design Society, SATENA, ZSiT and IZS.

Dr. Roman Žavbi received his university diploma and MSc and PhD degrees in Mechanical Engineering Design from the Faculty of Mechanical Engineering, University of Ljubljana, Slovenia in 1989, 1992 and 1998, respectively. His main research interests are conceptual design (*e.g.*, synthesis of elementary product concepts using chaining of natural laws with complementary basic schemata, function/structure sharing, prescriptive design models) and virtual product development teams (*e.g.*, formation and application of the teams in combined academic-industrial projects). He is involved in consultancy related to new product development and product upgrade, engineering design of drive units, and analysis of malfunctioning drive units. He is a member of The Design Society and the Slovenian Artificial Intelligence Society (SLAIS).

Some 40 years ago, design support was no more than using premature digital systems for two-dimensional drawings on vector graphics-based screens, and making numerical calculations on oversimplified models for physical and structural analyses. About 30 years ago, researchers brought up several new concepts and prototype tools for solid modelling, feature-based modelling, assembly modelling and manufacturing process planning. Roughly 20 years ago, new ideas were again placed in the limelight, such as web-based collaboration, multiphysics-based simulation, knowledge ontologies and virtual reality. In our time, designing for human experiences, ambient intelligence, ubiquitous computing and bio/nano Computer-Aided Design (CAD) are among the most important keywords of researchers working in this field. But people are already thinking about the digital design offices of the near future, which may support volumetric airborne visualisation, real-life simulation of the behaviour of artefacts, and testing of the interaction of users with artefacts in virtual environments.

The above developments give an indisputable indication that the boundaries of design support are continuously stretching and that this process will probably not cease in the near future. This can be explained as a consequence of the emerging technological opportunities and growing demands of designers and practical applications. Practically all developments in the field of design support have cast light on the importance of virtual product representations. Not only the variety, but also the quality of virtual models and processes is still increasing and, with various multisensational augmentations, they are increasingly approaching the 'look and feel' of their physical counterparts. In fact, physical model making is being pushed back to the very end of the product development processes, where it cannot be avoided. On the other hand, augmentation has become a critical issue in association with both virtual and physical artefact representations. Contrary to the impressive advancements, some key issues, such as handling semantics and complexity, managing heterogeneity and interoperability, human interfaces and experiences, and enabling creativity and systematisation, are still far from being solved and need further intense research.

This special issue presents a selection of articles that reflects the current efforts towards the development of advanced design support techniques, methods and processes. These articles are based on the papers that were originally presented at the *Sixth International Tools and Methods of Competitive Engineering Symposium* in Ljubljana, Slovenia. Many authors were asked to extensively extend their papers. Their revised manuscripts were put through a multistep reviewing and revising process, and finally seven articles were accepted for this special issue. Each of these articles offers some sort of scientific or technological novelty which stretches the boundaries of current design support. We arranged the articles according to the stages of the product development process they address, from conceptualisation and embodiment through engineering to manufacturing preparation and manufacturing.

The first contribution by Opiyo and Horváth, entitled 'Towards an interactive spatial product visualisation: a comparative analysis of prevailing 3D visualisation paradigms', gives an overview of the state of the art in 3D visualisation. They based their survey on a novel classification of visualisation technologies. They focused their investigation on technologies and systems that are capable of purveying the illusion of 3D volumes occupying space, namely, pseudovolumetric displays, aerial projection displays and truly volumetric displays. The authors assessed the strengths and weaknesses of each technology based on a set of desirable features (requirements) that they identified. It turned out that, for the intended target application in interactive product visualisation, the above three technologies could fulfil just a limited subset of the identified requirements, with truly volumetric displays showing the best prospects for future developments.

In their article 'A CAD system based on haptic modelling for conceptual design', Bordegoni and Cugini present an innovative system for the interactive generation of complex curved surfaces. The hardware of this system features 6-degrees-of-freedom hand tools with haptic feedback. The design of the tools has been adapted to resemble craftsmen's tools such as rakes, and thus provide designers with an intuitive means to sculpt 3D surfaces. The main functions of the software are to shape tessellations based on the designer's input, and to calculate the force feedback that is perceived as natural. Both are based on algorithms simulating the behaviour of clay being scraped. One of the main challenges for the researchers was dealing with the high frequencies at which feedback had to be calculated. A prototype system was built and positively evaluated by an expert designer. One of the recommendations for future work is to replace the 2D monitor, which gives feedback to the designer of the evolving shape, with a stereoscopic visualisation system.

Interactive Augmented Prototyping (IAP) of layout configurations is the topic of the third article by Colombo *et al.*, entitled 'Integration of virtual reality and haptics to carry out ergonomics tests on virtual control boards'. They present a system that allows designers and ergonomists to investigate the usability of control panels with different configurations of knobs, buttons and sliders. As specific IAP enablers, the authors combined a haptic interface, a head-mounted, see-through stereoscopic display combined with a wide-screen projection, and an optical tracking system. For this particular application, the haptic interface has been tailored to produce force feedback that is characteristic for the above controls, which is the novelty of the experimental system. The article also elaborates on the procedure to perform interactive simulations with human subjects. Their tests confirmed the feasibility of the proposed combination of enablers for the intended system, but they also revealed the shortcomings of the visualisation hardware/software and the tracking system, which have to be addressed in future work.

IAP represents a combination of physical and virtual prototyping technologies. It bridges the gap between these two and at the same time offers additional advantages such as better perceivable context, scale and proportions. In the fourth article, entitled 'The enablers for interactive augmented prototyping', Verlinden and Horváth started with an overview of 'IAP enablers', *i.e.*, technologies that could be combined to accomplish IAP: sensor technologies for input, physical model fabrication technologies and output display technologies. They found that current IAP systems mostly focus on visualisation and painting, neglecting application areas such as behavioural simulation and layout configuration. They analysed existing combinations that had been realised as IAP systems to power realistic design scenarios. In addition, they investigated the application potential of some suitable combinations of IAP enablers in different domains of design. The authors encountered difficulties in benchmarking the performance of IAP systems against other prototyping approaches. They suggest that this issue needs closer attention in future research.

The next contribution shifts the focus to engineering aspects. The article by Schnack *et al*., entitled 'Computational failure analysis, identification and optimisation in virtual design: accomplishments and research directions', offers insight into the state of the art in the virtual design and engineering of products featuring advanced composite materials. The authors endorse a hierarchical approach to modelling, finite elements-based simulation, and optimisation to identify, quantify and resolve mechanical problems concerning fatigue, fracture, elastic and plastic deformation, and natural frequencies of vibration. The proposed hierarchy runs from nano-level up to macro-level, addressing mechanical behaviour from the molecular arrangements and chemical composition during fabrication up to the level of a whole part and its geometry. The article also presents the mathematical fundamentals of the various theories. Practical application is demonstrated based on simple geometries and standard benchmarking problems. However, the performance of the proposed approaches in the case of complex parts and systems, such as the humanoid robot the authors are developing in a related project, remain for future studies.

The last two articles focus on the application of virtual engineering to product manufacturing, in particular to telemanufacturing and cellular manufacturing respectively. The first one is 'An implementation of resource-negotiating agents in telemanufacturing' by Van Zyl *et al*. The end users of telemanufacturing systems can send CAD files directly to a remote layered-manufacturing or rapid-prototyping machine, and order parts as specified in those files. These users can be designers in need of prototypes, maintenance firms ordering spare parts, or even consumers ordering complete products from catalogues. In the case of multiple suppliers (Distributed Manufacturing Resources or DMRs) from which the user has to select the one with the best offer, telemanufacturing involves e-commerce processes. The authors propose an automated agent-based system for negotiating with DMRs to replace the extensive human interactions currently needed for these e-commerce processes. An important issue in the realisation of such a system, one that exchanges information with mutually competing DMRs, is to keep negotiations in a secure environment. Though the authors showed the feasibility and applicability of their proposal in a test-bed environment, they also identified several issues, such as the standardisation of agent platforms, for further research.

The final contribution, by Harris and Fraser, is entitled 'Towards virtual manufacturing: an implementation framework from feasibility to product development'. Virtual manufacturing involves the modelling and careful consideration of manufacturing processes with the objective to predict potential problems and inefficiencies before real manufacturing occurs. This article concentrates on Cellular Manufacturing (CM). Despite the potential benefits of bringing manufacturing activities together into groups or cells to create units without mutual backflows or cross-flows, the introduction of CM is known to have been unsuccessful in many cases. The main reason is that the commonly applied recipes for CM implementation are not specific enough in terms of many human and technological aspects and different stages of implementation. Therefore, the authors have developed a six-phase implementation framework in which all the different aspects receive due attention. The article presents their framework and describes how the implementation was carried out. The validity is demonstrated qualitatively through interviews with the involved staff, as well as quantitatively through increased productivity results.

We would like to thank all of the authors for their involvement, cooperation and efforts that have led to this special issue. We would especially like to express our gratitude to the reviewers of the journal for their constructive appraisal and valuable comments.