Editorial

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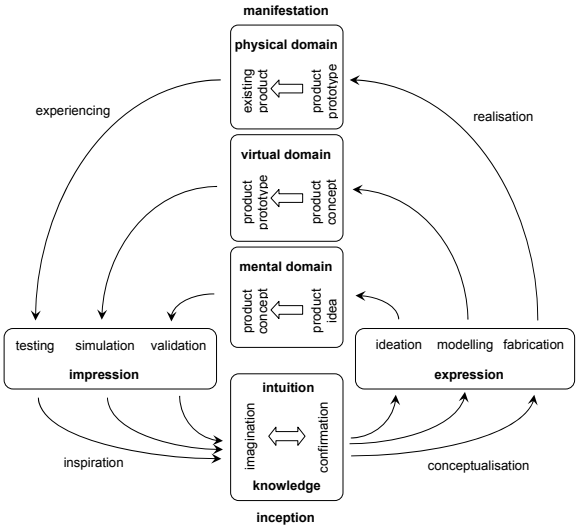
We are living in an age when man-made technologies and human life are getting intricately interwoven. It can be observed that more and more intelligence is built into traditional consumer products and design support tools and they, equipped with this capability, can increasingly adapt to human characteristics and behaviours. In addition, many innovative products are developed that facilitate new types of person-product interactions and that can support our daily activities in previously not expectable ways. Products are becoming able to communicate not only to humans, but also to other products and systems. Behind these advancements is a multi-disciplinary integration of extensive bodies of domain knowledge and a wide variety of advanced technologies that serve as true enablers of product development processes. Obviously, multidisciplinary integration of knowledge and technologies raises many challenges and there are no low hanging fruits out there, in particular when physical and cognitive ergonomics aspects are to be taken into consideration.

Figure 1 Domains and activities of creative work



Source: Horváth (2008)

Visualised in Figure 1, the complex process of product development connects various domains of knowledge and creative activities. Modern product development concurrently happens in the human mental domain, the computer-created virtual domain, and the physical (material) domain. Virtual reality technologies intend to connect the human mental domain with computational virtual domain, whereas augmented reality technologies pursue connecting physical domain with virtual domain (Horváth et al., 2008). Rapid prototyping technologies work in the physical domain towards tangible prototypes. While the mentioned knowledge domains and technologies act as enablers of multidisciplinary product development, human, implementation, business, and sustainability factors act as demands and objectives that imply various criteria and quality indices. In the current practice, consideration of various human factors has been facilitated by both virtual and augmented reality technologies, while using virtual and augmented reality-based tools and systems raises many perceptual, cognitive and motor issues that are to be addressed. This explains why we partly counter position and partly interconnect virtual reality and product ergonomics in this special issue. Our intention was to focus on the challenges of development of innovative tools based on virtual reality technologies with the consideration of ergonomics aspects. We believe that these tools will be able to make the daily practice of industrial engineering designers not only more effective, but also more adaptive to various contexts.

As explained above, due to the need of multidisciplinary integration, a change is needed in terms of looking at design support tools and in particular in their implementation. Development of computer-aided design support was in the past mainly based on commonly available hardware control devices, such as a mouse and a keypad. These technologies and devices were not developed with an optimal matching to human perception, cognition and action in mind. A consequence of this is that conceptualisation and elaboration of computer models of products go together with a significant cognitive load. In addition, mastering of these tools require long-lasting motor training. For instance, gaining adequate skills to control the drawing processes and to convert 2D on-screen information to 3D digital shapes cannot be done efficiently without practical experiences. Similarly, modification or further elaboration of a 3D computer model of a spatial object requires special vision and mental imagination. This is partly caused by the lack of the possibility of touching the boundaries of the object that is elaborated on, since traditional CAD systems do not offer any haptic experience. It has proven useful for the user to interact with the virtual object, as well as if the system could understand the meaning of the movements of the designer, that is, in other words, could comprehend the semantics of design gestures.

Already in the beginning of the 1990s, it has been broadly discussed in the literature that new design support tools and systems should be developed that possess the knowledge needed to understand and appreciate human factors, characteristics, behaviour, gestures, and variance. The new tools were supposed to be based on the affordances of virtual and augmented reality technologies and methodologies that can provide a higher level of immersion and more sophisticated and natural ways of interaction with products, stakeholders and the environment for designers. The need for new ways of data capturing and representation that are able to reflect the organic nature of the shape morphology and the biophysical behaviour of the human body, including the internal structures such as bones, muscles and other organs, was also formulated. Finally, it was also supposed that the different virtual reality tools and ergonomics enablers could

be blended and that this would facilitate both participatory and user-centric product design.

In line with the above mentioned trends, our intention by making a proposal for this special issue was to give an insight in the state of the art of multidisciplinary knowledge and technology integration in the field of ergonomics related virtual reality systems and methodologies. Our interests extended to:

1 elicitation and representation of knowledge about human capabilities, cognition and affordances

2 utilisation of the latest hardware and software technologies that allow consideration of natural human capabilities

3 the ways of expressing concepts by humans, and capturing and understanding human intentions.

In addition, we also wanted to learn what solutions are sought for to:

1 reduce cognitive load in various design and modelling activities

2 make shape and product modelling procedures more natural and effective

3 offer more efficient and appropriate materials selection approaches

4 organise product information generation and communication among designers.

Among the excellent papers that were submitted to the International Tools and Methods of Competitive Engineering (TMCE 2012) Symposium, we found papers that addressed the above mentioned issues. We also found other papers that presented novel research and results, amongst others, in the context of:

1 new techniques and methods for natural interfacing and interaction

2 representation of organic shapes using natural parameters

3 understanding human behaviour and emotions in user-product interaction

4 using different models (for instance, human, product and environment models) in a synergistic manner.

We selected some representative papers for this special issue, which were reviewed and revised more than one time before accepted for publication. In general, the objective of the reported research activities was to get a better understanding of the human capabilities and to design advanced ergonomics design enablers that consider the human factors and perspective as a starting point. Some of them were also complemented by the development of novel tools. We believe that the papers included in this special issue of the *International Journal of Computer Aided Engineering and Technology* provide a reasonable insight in the current challenges and status of research and development in this area.

The first paper, co-authored by Zoltán Rusák, Ismail Cimen, Imre Horváth and Aadjan van der Helm, is entitled ‘Affordances for designing natural user interfaces for 3D modelling’. The authors investigated the needs for natural interfacing for 3D modelling using persona’s and user scenarios. They studied the affordances of human gestures, as well as the opportunities offered by current monitoring and tracking systems, and used this knowledge to develop a new concept for a natural user interface. Their

objective was to support shape design with a natural gestural interface. They tested the applicability of a specific set of gestures to capture and transfer the intentions of designers in the context of using the Maya software. They used various metrics as quality indicators of the hand motion-based user interface. They found that the proposed gestural interface could be at least as effective as a conventional interface consisting of a mouse and a keyboard, while it was much more intuitive and expressive. Furthermore, the learning curve was much steeper in terms of accessing all available features of the software. Future research is expected to explore other affordances and application opportunities of natural user interfaces.

The paper of Prasad S. Onkar and Dibakar Sen, entitled 'Controlled direct 3D sketching with haptic and motion constraints', addressed the challenge of intuitive generation of spatial sketches for multi-component product conceptualisation. They studied the requirements for 3D sketching, and developed a system that enabled the constraint on the motion of the hand through haptics and through kinematics on the components. Furthermore, the proposed system provides view transformations and stereovision for visual feedback about the sketching process and visualisation of the product behaviour. For 3D sketching the authors used a desktop computer-based virtual reality environment. Groups of 3D lines were created using a 'pencil' connected to a haptic device, which exerted surface forces and field forces in order to guide the hand of the designer. The authors found that managing the haptic constraints was a central issue for 3D sketching. They applied specific computational models for calculation of surface forces and field forces. They concluded that motion constraints help understand the motion behaviour and part interactions in the early stages of design and help improve the quality of the concepts generated.

The next paper, co-authored by Michele Fiorentino, Antonio Emmanuele Uva, Giuseppe Monno and Rafael Radkowski, argues that the importance of designing maintenance tasks will increase in the coming era. By doing so, they recognise the ever changing properties of the parts of complex systems and the need to quickly and easily have access to the latest documentation during a simulated maintenance task. They developed a system that recognises the position and the gestures of the hands using cameras, tracking tools and software, and simultaneously provides information on a specific part when there is an indication of the need for its documentation. Entitled 'Natural interaction for online documentation in industrial maintenance', the paper provides an overview not only of the natural interaction for technical documentation in augmented reality, but also of its implementation in the proposed ARAMID system. The authors claim that their results proved that current gesture recognition technology is robust enough to be object of further investigations and research in industrial applications; however, some limitations still need to be sorted out and it needs further research to see whether the considered interaction techniques are scalable to large 3D models.

Seung-Yeob Baek and Kunwoo Lee investigated the possibility of representing the shape of human body parts, (in the presented case, of the foot) by a small number of natural parameters. Their paper provides a comprehensive overview on the related issues as well as on the completed work under the title 'Statistical foot-shape analysis for mass-customisation of footwear'. Although in the past several techniques for this have been developed (e.g., somatotyping), effective classification of organic shapes based on actual 3D measurement data is still is still somewhat premature. The authors measured and analysed the shape of a large number of feet using statistical data analysis, shape

clustering, and shape feature determination methods. They clustered the measured data with respect to geometric similarity, and produced shape clusters accordingly. They found that the shape of the human foot can be represented by a set of eight categories, based on natural foot dimensions. The guest editors think that the shape of the human body, but also the shape of, for instance, the internal organs and structures of the body can be captured and categorised in the same way, and parameterised shape models can be generated. Obviously, further research is needed in this direction.

Related to a promotion research project, Elizabeth Rendon-Velez, Imre Horváth and Wilhelm Frederik van der Vegte investigated the possibilities of reproducing the emotional state of being in haste of a car driver. In their paper, entitled 'Motivating subjects to drive in haste using time pressure in a simulated environment', they made an effort not only to reproduce the haste for the subjects taking part in a virtual reality enhanced car driving simulator-based experiments, but also to investigate the consequences of being in this state on driving behaviour, well-being, and traffic safety. In the driving simulator environment, they applied and investigated explicit time pressure as a surrogate of being in haste. In addition, they investigated various motivating effects, such as competition, rewarding, stimulation and contextualisation. It is interesting that they found that the various forms of motivation had insignificant influence of the feeling of driving in haste, while the shortage of time proved to be an influential factor. This finding explains their conclusion that they will impose time shortage on the subjects in their successive full-scale experimentation to produce distinctive symptoms of driving in haste. Further research can focus on the challenging issue of recognising being in haste in real-life driving situations and to develop an instrumentation in cars that can enable driver protecting and risk reduction.

In the next paper, Giorgio Colombo, Daniele Regazzoni and Caterina Rizzi combined digital human biomechanical models and digital product models in product evaluation. Their paper, entitled 'A methodology for virtual assessment of product ergonomics', focuses on ergonomic issues related to the use of devices and manipulating objects by workers. After a detailed analysis of the current situation and a wishful situation, they analysed the already proposed criteria and indexes for ergonomics assessment. They completed a case study, in which they used the ergonomics analysis tool Jack, and found it particularly suitable for simulation and post-processing product usage activities. They focused particularly on the fatigue of a worker in a specific set-up of filling the shelves in a supermarket. Based on a computational assessment they converted the 'as-is' situation to a 'to-be' situation in the studied case, considering alternative solutions. Although this type of research is not new, their work is worth attention due to the comprehensiveness of processing the related information, and for identifying some important issues of practical flavour for further study. From a different perspective, they provided practical evidence that combination of biomechanical models of humans and digital product models gives a robust platform for studying man-product interaction and for simulating the working conditions by the involvement of virtual humans. The authors point on the fact that further standardisation of domain dependent actions of humans is needed, considering human constraints.

Entitled 'Modelling tactual experience with product materials', the paper contributed by Georgi V. Georgiev, Yukari Nagai and Toshiharu Taura, addresses a number of research issues concerning tactility of product materials. Their work focused on the development of an explanatory model of tactile experience. They considered the associations behind explicit and implicit user impressions when interactions with various

materials happen. They seek to answer two specific research questions, namely what the basis of the formation of user impressions in tactile interaction is, and what method and tool can be developed for assessing tactile interaction on the basis of user impressions. To achieve their development objectives, they introduced a new model of the tactile interaction and creation of concept of material. They applied statistical classifications and an associative concept dictionary to analyse user impressions, and also proposed a four-step method for the assessment of the impressions, considering the typology characteristics of in-depth impressions. It is to be noted that the impressions concerning the tactile interaction were assessed only on the basis of user verbalisations, without experimental measurements. Nevertheless, the guest editors agree with the authors that their study contributes to improving the modelling of the process of the formation of users' impressions about product materials, which is an essential aspect of the human element for product innovation. Further research is needed to develop tools that can be used in material selection and product design.

An interesting paper, 'An augmented reality tool to validate the assembly sequence of a discrete product', was submitted by Gilberto Osorio-Gómez, Roberto Viganò and Juan Carlos Arbeláez. The presented work was stimulated by the recognition of the need for reduction of time and cost by more flexible augmented reality and virtual reality tools and environments in product design and development. The authors aggregated knowledge for and developed an augmented reality system, PoliArt, with the intent to support the visual creation and evaluation of assembly sequences of complex products at early stages of design. The proposed system also allows collaborative work between designers and manufacturing engineers from the very beginning of the product realisation process in order to consider assembly devices, operation times and resources, together with a shortening of the implementation time and reducing the incurred costs. It should be noted that, though the system proved to be a low-cost and flexible solution for quick evaluations at early stages of design, as the authors clarified, it cannot be compared to existing more complex and sophisticated, but of high costs and overheads, solutions. An obvious further development opportunity is to increase the knowledge-intensiveness and problem-solving smartness of the system, but it needs forerunning research.

The last paper included in this special issue is co-authored by Flip van Haaren and Niels C.C.M. Moes. As the title, 'Shareworks – a ubiquitous online learning platform for project-based learning and networking' indicates, the objective of the authors was to develop a knowledge sharing platform for academic students with creative projects. The proposed platform exploits recent results of Web 2.0 networking and ubiquitous technologies. One of the challenges addressed is sharing both formal and tacit design knowledge among interest groups of designers. Already being tested at several universities, the Shareworks system has been conceptualised based on the assumption that the closeness between the people participating in a design collaboration influences the degree of tacit knowledge transfer. Therefore, the system supports socialisation by means of tacit to tacit knowledge conversion. The efficiency of this conversion was tested by a survey involving a large number of design students and the final design of the Shareworks platform was adjusted according to the comments and evaluation. It has been concluded that it can be used as a creative networking hub, a personal learning environment, and a pre-incubation platform.

The above papers have shown that ergonomics knowledge-intensive, virtual reality-based design enablers can be developed for many important applications, such as shape generation, biomechanical analysis, natural interfacing, cognitive performance

enhancement, and engineering visualisation. Needless to say, the number of possible applications is infinite. When conceptualised properly, these enablers can be used not only in academic environments, but also in the daily practice in the industry. If we manage to stimulate more research and development in this direction, then we have achieved our primary objective. With this in mind, we would like take the opportunity to thank the publisher for offering us the chance to compile and to publish this special issue based on a selected set of papers presented at the TMCE 2012 Symposium. We appreciate the helpful work and useful advices of our reviewers, who indeed helped increase the quality of the accepted papers. Finally, we must recognise and appreciate the hard work and constructive cooperation of the authors, which was necessary to achieve the best possible quality of each paper and increase the coherence of the papers.

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