Editorial

Niels C.C.M. Moes* and Imre Horváth

Delft University of Technology,
Landbergstraat 15,
2628 CE Delft, the Netherlands
E-mail: c.c.m.moes@tudelft.nl
E-mail: i.horvath@tudelft.nl

Biographical notes: Niels Moes is an Associate Professor at the Faculty of Industrial Design Engineering, Delft University of Technology, the Netherlands. He received his MSc at the Eindhoven University of Technology in 1974. He earned his PhD from the Delft University of Technology in 2004. His primary research interests include the human factors aspects in human modelling and in applying ubiquitous technologies in design and design education.

Imre Horváth is a Full Professor of Computer Aided Design and Engineering at the Faculty of Industrial Design Engineering, Delft University of Technology, the Netherlands. He earned his Dr. Univ. title in 1987 and PhD in 1994 from TU Budapest in Hungary. He received his CDSc title from the Hungarian Academy of Sciences. His current research interests include design application of smart and ubiquitous technologies, systemisation of design research, affordance-based innovation, and teleconferencing-based active learning.

Since the appearance of computers in the second half of the 20th century, scientists and engineers have been working to use them for digital modelling of human beings. The goal of these efforts was to support the development and applications of digital human models (DHMs). The intended use of such models was to describe, analyse, optimise and predict the physical, emotional and psychological aspects of humans either as isolated individuals, or as parts of communities, or in relationship with the surrounding environment or with the specific artefacts used by them. Application of digital computers gave impetus to the development of the field of human factors (ergonomics). At the beginning, it was mainly used in the military sector, but later it has penetrated into other fields such as workplace design and ergonomic design of artefacts. The interplay of these two parallel developments lent itself to interesting new possibilities for the application of DHMs in the field of human-centred design (HCD) of products, processes and environments.

In the early times, DHM developers typically considered only one aspect of describing humans. For example, the early models described the morphological characteristics, the somato-graphical shape features, or some physical (kinematic/kinetic) aspects of the human body using a limited number of anthropometric parameters and/or a set of bony landmarks. Therefore, we refer to them as single aspect DHMs. Due to conceptual and computational constraints this first generation of DHMs had very limited means for describing any complex human behaviour, e.g., human perception or cognition, the functioning of the human mind, the human intelligence, or the tactile/haptic sensations. Nevertheless, the single-aspect DHMs proved to be useful means in many specific fields of applications and in a number of design and engineering problems.

However, the knowledge aggregated by research, the new modelling and simulation algorithms and means, and the computational and visualisation enhancement of computer systems drastically changed the situation back at the beginning of the 1990s. The objective of digital human modelling research and development has been to generate DHMs that are capable to capture and represent humans from multiple aspects in one single model. We call these multi-aspect DHMs. They have been widely used to describe complex physical, bio-physiological, cognitive and perceptive, and even affective behaviours of humans. The enhanced functionalities and the new investigation opportunities made the commercial digital human modelling systems indispensable and popular in practically all fields of industrial production and operation.

The knowledge platform of advanced multi-aspect DHMs is constructed from the knowledge originating in several scientific disciplines. Without being exhaustive, we mention the following disciplines:

- geometric (solid and surface) modelling and statistics offer mathematical means and techniques, as well as descriptive and simulation algorithms, for modelling the shape of human body
- continuum mechanics and biomechanics knowledge is utilised in modelling human kinematics (change of positions and movements), and computing human kinetics (force transmission through the body and dynamics) and stress/deformation of human tissues while interacting with physical objects
- psychology provides knowledge to model cognitive performance (e.g., taking decisions, creative performance of designers) and psychological states (e.g., mood) under varying circumstances
- physiology and psycho-physics knowledge enable us to model human perception (e.g., tactile perception, peripheral vision)
- kinesiology provides knowledge needed to interpret the intentions of human movements (e.g., modelling design intentions based on sketching, or tracking human actions using data gloves or a tablet)
- ergonomics and medicine provide knowledge that is necessary to model physical and informational (dis)comfort (e.g., comfort of physical actions, or comprehensibility of displayed information)
- descriptive statistics offer methods to represent large amounts of data (which are generated, for instance, by laser scanning of the shape of the human body) by using a few predictors (e.g., factor analysis or principal components analysis).

As early as in the 1980s, researchers began to systematically study the forms and effects of physical and cognitive interaction of humans with artefacts and environments. This gave stimulation to the development of both physical and cognitive ergonomics. The influences of the new research insights and the growing technological affordances were reflected by the articulation of the contents and by the increase of the complexity of DHMs. The second generation DHMs became more and more multi-parametric, multi-dimensional, and interactively usable. They made it possible to investigate human actions and behaviours from many individuals aspects, but also enabled integral investigations, i.e., studying multiple factors concurrently. Representative application examples include modelling of dynamic person-product interactions, studying the influence of the shape of a product on the stresses and deformations inside the human body, and application of cognitive architectures in virtual reality systems.

As a result of the amount of knowledge built into DHMs, the amount of input information used to specialise the generic models in various applications, and the sophisticated algorithms that process the information and knowledge, multi-aspect DHMs have become rather complex from an applicability point of view. Complexity implies the need for comprehensive verification and validation of DHMs both in general and in various application contexts. Verification tests are made to test the comprehensiveness, coherence and consistency of the modelling frameworks and algorithms, and the accuracy and robustness of the model as a whole, as well as to check whether a particular DHM complies with the objective for which the model was created. Validation tests are made to check how well the model is applicable to a particular application, if the results of a simulation are correct, and if the model can be conveniently adapted to varying requirements.

Currently, the third generation of digital human models are just around the corner. What differentiates this generation of DHMs from the previous one is the built-in intelligence. These DHMs are often referred to as smart agents or avatars. While the DHMs of the previous generation were knowledge intensive, but not inferential solutions, the new generation digital human models are able to show some level of individual or crowd (collective) intelligence, act somewhat autonomously to achieve certain objectives, provide some level of adaptability and learning, collect information and synthesise knowledge. To some extent they can replicate human perceptive and cognitive capabilities. Though the research and development in this direction is just at the beginning of the road, and digital human agents (DHA) are still in their infancy, due to the growing industrial need for these solutions, and the rapid progress of knowledge and technology, they will most probably revolutionise what is still called digital human modelling.

The need for more sophisticated and comprehensive models that are able to concurrently simulate multiple aspects of human activities, performance and behaviour is not, and will not be decreasing. Therefore, extensive and coordinated research is still needed to facilitate further understanding and developments, and to foster a wider applicability in the everyday practice. The trend of integrating different aspects, more knowledge and algorithms into advanced DHMs will continue. It is not too risky to claim that the research and development efforts in the field of DHMs will be even more intense and comprehensive in the forthcoming decades.

Having this in mind, we collected papers for this special issue with the intent to get information about the current status of knowledge and algorithm synthesis in advanced DHMs and to report on investigations in various issues of information synthesis in multi-aspect human modelling. We preferred considering a wide area of applications in order to cover a wide range of aspects, applied modelling techniques, and specific algorithm characteristics.

The papers included in this special issue were originally presented at the Eighth International Tools and Methods of Competitive Engineering Symposium (TMCE 2010), which was held in Ancona, Italy. All papers went through a severe review process, and after reworking, they were offered to the *IJCAET*. The individual contributions do cover a varying mix of the disciplines and technologies, e.g., cognitive psychology, physiology, medicine, biomechanics and anthropometry, using a wide range of applied modelling technologies and realisation procedures. What the papers inform us about is that the integration of knowledge and extension of algorithms are happening in an incremental manner, rather than based on completely new information technological resources and platforms, or on radically different methodological frameworks. Contrary to this, the results are impressive and influential, in particular if we consider the current practice of industrial applications.

In the paper contributed by Singh et al., entitled 'Human movement using a constraint-based software environment: gaining understanding during initial design phases', the disciplines of kinesiology, anthropometry, statistics and ergonomics were considered to create a type of DHM that can be used to predict human movements in relation to product use, and that applies practical constraints caused by joints, tendons, etc. Although their approach needs further extension and validation, it was shown that it can be applied to various spatial constraints, including the physical kinematic limitations of physically disabled persons. Probably, the inclusion of kinetics and cognition can further refine their model.

The influence of prior knowledge on cognitive performance modelling for finding requirements for design problems has been demonstrated by Morkos and Summers in the paper entitled 'A study of designer familiarity with product and user during requirement elicitation'. They combined knowledge of cognitive psychology, design methodology and statistical modelling to investigate the influence of prior cognitive conditions on the quality and the quantity of requirements considered in a design process. Although they proved the feasibility of their approach, many aspects need further research in order to better understand the underlying cognitive processes, to facilitate an effective description of the level of experience of the designer and their familiarity with the type of products, and to generate knowledge about professional designers. This latter is of paramount importance because only students were involved in the experimental work.

In the research reported in the paper '(Un)conventional engineering tests to predict fabrics sensorial properties', Salvia et al. applied materials science, tactile physiology, cognition and statistics knowledge to model tactile perception of artefacts. They focused on the testing of tactile properties of textiles. They compared subjective rankings based on the perception of experts with objective properties of textiles. In order to make the proposal appropriate for a general simulated tactile assessment, several aspects have to be refined and deepened such as the analytical observation of the panellists' gestures and their physiological reactions.

To interpret the movements of the hand of a designer showing the contour of an artefact, various pieces of knowledge and technologies, such as kinesiology, (fuzzy) statistics, geometry and spatial tracking, have been combined. Two papers which are specifically addressing the issues related to such applications have been included in this special issue. One of them, entitled 'Creative spatial interpretation of freehand sketches', submitted by Roth-Koch, deals with the extraction of 3D meaning from 2D sketches. Another paper, written by Liverani et al. under the title 'Tablet-based 3D sketching and curve reverse modelling', investigated the problem of deriving shape from the position and orientation of a hand-held device, according to the intention of designers. These contributions claim to overcome some of the limitations of traditional CAD systems. They have tried to capture the designers' intentions by interpreting lines in hand sketches, or based on the positions, orientations and movements of the hands that 'sketch' the shape of a product in the 3D space.

One of the most complex areas of ergonomics and HCD is the definition, measurement and prediction of comfort. In the paper submitted by Colombo et al. under the title 'Socket modelling assistant for prosthesis design', the set-up for a complete design tool for prostheses design is presented. They made an effort to synthesise knowledge from many fields (e.g., enabling technologies, ergonomics, experienced comfort, and physiology) in a knowledge intensive model. The tool includes knowledge and skills of medical staff, technicians, etc. The research work is orientated to relieving the emotional state of patients by reducing the number of embarrassing fitting trials. They computed the distribution of stresses inside the human body using finite element modelling. The paper pointed at difficulties concerning the assessment and interpretation of the levels of comfort, and called the attention to the fact that these are still subject for further investigation.

Baek and Lee presented their research in the paper entitled 'Parametric human body modelling system for virtual garment fitting'. They described the variations of the complex shape of the human body by means of a model that is based on a small number of meaningful predictors (principal components). Applying laser scanning techniques, human anatomy, and statistics they showed that the human body shape can be computed with an accuracy that is sufficient for application in garment fitting from an ergonomics point of view. They used only a few physical anthropometric measures. On the other hand, the proposed model has been built on one template (and, consequently, uses one topology). Therefore, it is not yet able to predict outside the tested population. Further development is needed to simulate the human shape based on a skeletal model – the authors also recommended this for future research.

As can be seen from the above concise analysis, the presented papers include a wide variety of sensing technologies, and data transmission, interpretation and reduction methods (geometry, statistics). The authors also considered different production technologies, measuring and modelling techniques, as well as model verification and validation testing techniques. The application areas covered in these papers include designing, optimisation, analysis and simulation in medical applications, clothing manufacturing, design creativity, and cognitive performance.

The papers exemplify that knowledge-intensive, multi-aspects DHMs can be developed for shape estimation, applying material properties, cognitive performance, biomechanical analysis, etc., through a dexterous combination of multi-disciplinary knowledge. This strengthens our conviction that product designers will have the opportunity of using generic DHMs to simulate humans and human behaviours from multiple aspects in the near future. The papers also show that there are no low hanging fruits out there, and both novel interdisciplinary insights and elaborate information/knowledge frameworks are needed for the implementation of effective and useful tools.

We would like to take the opportunity to thank the publisher for offering the chance for us to compile and to publish this special issue based on a selected set of papers presented at the TMCE 2010 Symposium. We appreciate the helpful work and useful advices of our reviewers, who indeed helped us to 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 the individual papers and increase the synergy among the papers.