Computational Anthropomorphic Anatomical Models

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History, latest advances, current challenges and future prospects for computer models of anatomy and physiological functions are addressed in this review.

Monte Carlo simulation techniques have become one of the most popular tools in different areas of medical physics in general and medical imaging in particular following the development and subsequent implementation of powerful computing systems for clinical use [1]. In particular, they have been extensively applied to simulate processes involving random behavior and to quantify physical parameters that are difficult or even impossible to calculate analytically or to determine by experimental measurements. The applications of the Monte Carlo method in medical physics cover almost all topics, including radiation protection, diagnostic radiology, radiotherapy, and nuclear medicine, with an increasing interest in exotic and new applications, such as intravascular radiation therapy, boron neutron capture therapy, and synovectomy. With the widespread availability and deployment of high performance computing platforms, Monte Carlo-based image reconstruction in emission tomography and treatment planning for radiation therapy are becoming practicable [2].

Object modeling is fundamental for performing radiation transport efficiently by means of a Monte Carlo method. It consists of a description of the geometry and material characteristics for an object [3]. The material characteristics of interest include density and energy-dependent cross-section data. Modeling of imaging and other medical applications is best done with anatomical and physiological models that match the gross parameters of an individual patient. Computerized anthropomorphic models can be defined by mathematical (analytical) functions, digital volume arrays, or a combination of both approaches (hybrid technique) [4]. The mathematical specifications for models that are available assume a specific age, height, and weight. People, however, exhibit a variety of shapes and sizes. In the first medical internal radiation dose (MIRD) pamphlets, several organs including the skeletal system were represented schematically using geometric forms (cylinders, cones, and ellipsoids) [5]. The representation of internal organs with this mathematical model is very crude since the simple equations can only capture the most general description of the organ's position and geometry [6]. A version of this model has been updated to include female organs [7]. The most studied model over the years is defined as "Reference Man," weighing 70 kg and measuring 170 cm in height (the height was later changed to be 174 cm) [8].

Since 1998, the ICRP's Task Group on Dose Calculations (DOCAL) and the MIRD committee of the Society of Nuclear Medicine have been assessing new dosimetry data from existing tomographic models. In particular,

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the DOCAL has been developing international guidelines and recommendations on the use of voxel-based models. In an annual report published in 2002 [9], the ICRP predicted a paradigm shift in the way the human body is modeled for radiation protection dosimetry:

> *An important issue for Committee 2 is the substitution of an anatomically realistic voxel phantom, obtained digitally in magnetic resonance tomography and/or computed tomography, for the MIRD phantom which is a mathematical representation of a human body [9].*

The ICRP has recently published its new guidelines, emphasizing a plea for a paradigm shift from conventional stylized models to tomographic models [10]. The new ICRP references for computational models representing the Reference Adult Male and Reference Adult Female are known as *RMCP* and *RFCP*, respectively. In addition, a number of new tissues and organs are now incorporated into the list for the purpose of effective dose calculation for radiation protection applications. The creation of the Consortium on Computational Human Phantoms[1] following the Monte Carlo 2005 Topical Meeting in Chattanooga, TN, will certainly help to facilitate interaction and research collaboration between active researchers and current key players in the field [11].

It is expected that over the next five to ten years, the majority of Monte Carlo radiation transport codes will be employing dynamic four-dimensional hybrid models to respond to the increasing demand for more realistic modeling. Therefore, it is essential that the medical imaging and radiation dosimetry communities make every effort to define the necessary requirements for simulation studies and identify those tasks where simple stylized models are still sufficient and those applications requiring sophisticated voxel or hybrid computational models to generate optimal results. This is a challenge that should be addressed soon so that the additional complexity and computational cost will not interfere with the widespread use of computational anatomical models in the day-to-day practice of medicine.

This is an exciting time for computerized modelling of the anatomy and physiological functions of the human body and laboratory animals. During the last few years, the number of published papers on this topic has been increasing steadily, which motivated us to assemble this Special Issue on computational anthropomorphic anatomical models as a snapshot of this dynamically changing field. The development of computational models has been very rapid and exciting, and there is every reason to believe the field will move forward more rapidly in the near future with the advent of novel molecular imaging technologies and high performance computing platforms and the unlimited imagination of researchers in the field. Despite the remarkable achievements summarized in this Special Issue and other peer-reviewed journals, there is still scope for further research. There is no shortage of challenges and opportunities for computational anthropomorphic anatomical models. We hope that in this limited space, we were able to give you a flavor of recent developments in the field and their potential applications in clinical and research settings. We found compilation of this Special Issue to be a rewarding and educational experience and hope that the reader is left with the same experience. ■

[1]www.virtualphantoms.org.

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ABOUT THE GUEST EDITORS

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