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Special Issue on Medical Simulation

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Special issue on medical simulation

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We would like to welcome you to this Special Issue on Medical Simulation, the first of its kind not only for *SIMULATION: Transactions of The Society for Modeling and Simulation International*, but for any technical journal. Our respective backgrounds are an indication of the technical and clinical breadth of medical simulation, as we approach the subject as primarily medical image analysis and biomechanics experts respectively, each with a variety of clinical interests spanning virtual reality (VR)–based neuro-, orthopedic and ear-nose-and-throat surgery. Moreover, we believe that the breadth of the papers that comprise this issue reflects an even broader perspective. After all, medical simulation can be seen as encompassing mannequin-based training, as well as nonsurgical areas such as pharmacological and physiological modeling, the latter of which is increasingly multi-scale and integrative.

One of the most compelling reasons for publishing an issue dedicated to medical simulation, and for emphasizing this area on a regular basis within the journal *SIMULATION*, is its inherently open-ended aspect. After all, if we view the current state of medical modeling and simulation (M&S), especially interactive M&S for training, in terms of the degree of its penetration in comparison with the amount of material that must be covered in medical school and in most residency programs, there is a large amount of research still left to be done.

Moreover, medical M&S is also characterized by conflicting requirements that will have to be resolved for it to make a serious dent in the requirements of these programs. For example, VR-based medical M&S will require therapy models (e.g., cutting and resection models) that reconcile real-time interactivity with realistic, nonlinear tissue response. It will also need a methodology for generating patient-specific anatomical models of sufficient descriptiveness to meet the exacting requirements of senior clinicians, which entails dealing with another set of conflicting requirements: The need to keep a ceiling on the element count in a simulation, which entails large elements, versus the need to account for critical tissues, which presupposes small elements.

New methodologies will have to be perfected for both specifying requirements and validation, in a manner that leads to meaningful simulation-based training that is predictive of future caseloads. From a requirements standpoint, we will have to exploit methods for specifying what goes on in a surgical intervention or medical process in a manner that leads to broadly usable top-down requirements analysis, which in turn may contrast with the artful aspect of clinical or surgical practice. From a validation standpoint, it may not be enough to merely distinguish between expert and novice clinicians, since the economy of movement of the expert in his or her surgical gestures immediately comes into play as soon as we integrate a haptic device into the simulation.

As described in the call for papers, the clinical need that justifies pursuing medical simulation with a strong predictive aspect lies in two marked tendencies in modern clinical practice: the compression of training schedules of residents and the constant influx of new therapeutic technologies. Recent compressions in training can adversely affect the development of clinical skill, particularly in the traditional framework whereby residents observe senior clinicians and gradually assume responsibility. Interactive medical simulation can provide a means for accelerating resident training, allowing junior clinicians to take a more active role than in the traditional framework, which can result in measurable improvements to both skill and patient outcome.

Increasingly however, if we are successful in reconciling difficult conflicts in requirements (such as interactivity and complex tissue response), we will find that the market for simulation is not merely medical schools looking to train students and residents, but all clinicians who are interested in a patient-specific dynamic exercise in surgical planning, in a manner that leads to finding the best among competing options, for example the surgical path that best spares eloquent and critical tissues to get to a tumor.

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This special issue reflects the diversity of applications, approaches and challenges described above. Each of the six manuscripts tackles a different medical issue, including cataract surgery, described in the invited paper by Dequidt et al., lumbar disc surgery, endoscopic third ventriculostomy, heart auscultation training, patient scheduling and planning of the Nuss procedure for correcting pectus excavatum, a congenital chest wall deformity. The types of simulation approaches used are varied, with three of the six manuscripts using software-based modeling of patient anatomy and physical response with user interaction implemented via haptic and movement tracking hardware interfaces. The other three manuscripts utilize physical models, augmented standardized patients and discrete-event modeling. The most common challenges amongst these varied papers appear to be realism of the simulation, validity of the results and clinical acceptability. Software-based surgical simulation faces the added challenge of real-time performance and realistic interfaces that mimic tools found in the operating room. We hope our readers will enjoy the diversity represented by these papers.

Guest editor profile

Michel Audette, PhD, did all of his university studies in Montreal, Canada: his Bachelor's in Electrical Engineering (1986) and PhD in Biomedical Engineering (2002) at McGill University, as well as his Master's in Electrical Engineering (1992) at Ecole Polytechnique. His distant past includes work in flight simulation (1986–88), range-sensing-based welding automation (1991–94) and surgical navigation (half-time, 1995–97). His PhD thesis research dealt with the application of range-sensing, which he introduced to the medical image community, to brain shift estimation for accurate neurosurgical navigation. His interest in medical simulation, particularly patient-specific anatomical modeling for neurosurgery simulation, dates back to postdoctoral research in Tsukuba, Japan from 2001–2005 and Leipzig, Germany from 2006–2008. He has continued this work through a phase I SBIR while at Kitware, Inc. (Chapel Hill, NC; Nov. 2008- June 2011), and through his current position as faculty member of the Modeling, Simulation and Visualization Engineering Department at Old Dominion University (July 2011–present). His main research areas are i) modeling of anatomy and therapy for surgery simulation, with a strong emphasis on neuro- and orthopedic surgery, ii) model-based surgical planning and intraoperative navigation, and iii) the application of areas i and ii for surgical robotics development. He is a strong proponent of the application of open-source software, such as ITK and SOFA, to medical simulation.

Hanif M Ladak, PhD, PEng, received his BASc degree from the University of Toronto in 1991 and his MEng degree from McGill University in 1994, both in Electrical Engineering. He received his PhD degree in Biomedical Engineering from McGill University in 1998. His doctoral research focused on measuring and modeling the mechanical behavior of the middle ear. From 1997–2000, he was a postdoctoral fellow in the Imaging Research Labs at the Robarts Research Institute working on the design and testing of computer algorithms for extracting patient-specific geometric models from medical images with applications to carotid artery modeling and prostate cancer treatment modeling. Since the year 2000, he has been a faculty member at Western University, focusing on medical image processing, finite-element modeling and parameter estimation.