KOÇ University
College of Engineering

January 14, 2013

Dear Sir/Madam:

This is a review of the habilitation dissertation of Dr. Christian Duriez and the technical contributions he has made so far. I am a faculty member in Mechanical Engineering and Computational Science programs at Koc University in Turkey. Previously, I worked as a senior member of the technical staff at the Jet Propulsion Laboratory of the California Institute of Technology for two years, as a research scientist at the Massachusetts Institute of Technology for four years, and as a research scientist with MusculoGraphics Inc. at the Northwestern University Research Park for two years. I received my Ph.D. degree in Mechanical Engineering from Southern Methodist University in 1994. My main research interests are in the areas of haptics, virtual environments, computer graphics, robotics, and mechatronics.

Christian Duriez is a research scientist at INRIA and conducts research and development in the areas of computer assisted medical simulation, training, and planning. He has published 2 book chapters, 10 technical articles in high quality journals, and presented his work in several conferences. He is currently involved in Shacra project and co-leading a team of researchers with S. Cotin. He is the co-supervisor of 4 PhD students and has been a member of the dissertation committees in 2 PhD thesis. Dr. Duriez regularly reviews papers for several top-rated journals and conferences in his areas of expertise and has also reviewed 3 project proposals for French Research Agency, ANR. He has involved as a researcher in one European-funded project and several national research projects funded by the ANR and by INRIA internally. In addition, he has 2 contracts with private companies in industry. He also teaches courses on finite element modeling and medical simulation at Institut Catholique d'Arts et M´etiers and University of Lille 1, respectively.

In my opinion, Dr. Duriez has contributed to the research and development in the following areas:

1. Fast finite element techniques for medical simulation and training

A core component of a medical simulation and training system is realistic organ-force models. Realistic organ-force models are virtual representations of soft tissues that display accurate displacement and force response. Unrealistic models may result in adverse training. However, modeling soft organ tissues is challenging since they exhibit complex, nonlinear, anisotropic, non homogeneous behavior. One of the most widely used methods for this purpose is the finite-element method. FEM solves the deformation problem by considering the organ as a continuous body that is trying to minimize its potential energy under the influence of external forces. A major advantage of FEM is that it uses continuum mechanics and has a solid mathematical foundation. It requires only a few material parameters to describe the model and its displacement response under the effect of external forces. However, FEM also has some drawbacks. It has a heavy computational load, and its computational complexity usually increases quadratically with the underlying mesh's quality. For example, running even a static (time-independent) nonlinear FE organ model in real- time is a highly challenging task because the resulting stiffness matrix (K) is not constant and varies with the depth of penetration into the model. Precomputation and condensation have been suggested as remedies to these problems. Dr. Duriez has developed techniques to deal with the non-linearities in the model based on the corotational approach used in computer graphics. Also, he and his colleagues has implemented implicit numerical integration schemes, which enables them to take large time steps solve the FE equations faster without jeopardizing the stability. Using these approaches, one can simulate nonlinear FEM models composed of several thousands of elements in real-time.

2. Constraint-based modeling for handling surgical tool-soft tissue interactions:

In addition to developing organ models, one must also simulate the interactions between the organs and the surgical tools. This is again a higly challenging task since the surgical instruments may deform, cut, or grasp an organ, the organs are linked to each other through connective tissues, and respiratory, cardiac, and patient motion may result in rigid body motion of the organs. Dr. Duriez has developed and implemented constraint based techniques to attack these problems. These techniques make it easier to implement friction, boundary conditions, tool-organ and organ-organ contacts. The earlier approaches have relied on a simple contact models for handling tool-tissue interactions and rarely accounted for friction. Again, proper implementation of boundary conditions has been often ignored or underestimated in the earlier work. However, there are important numerical issues related to this topic, which requires dedicated numerical schemes as developed by Dr. Duriez and his colleagues.

3. Haptic rendering of surgical tool - soft tissue contact interactions

This involves graphical rendering of computer- generated models of surgical instruments, detecting collisions between instruments and deformable organ models, and haptic rendering of the collision response in the procedure to be simulated. Again, executing these tasks in real-time is highly challenging. In this regard, Dr. Duriez and his colleagues have developed new algorithms based on the multi-rate simulation concept to fulfill the strong real-time constraints.

4. Applications:

Dr. Duriez and his colleagues have demonstrated the applications of the techniques and algorithms mentioned above in SOFA framework. SOFA (Simulation Open Framework Architecture) is an open-source C++ library targeted at interactive medical simulation.

SOFA is currently used by many researchers as a software platform to test their algorithms or as a basis for the development of complex, high-performance simulators.

in summary, to my opinion, Dr. Duriez has contributed significantly to the research literature in the areas of computer-aided medical simulation, training, and planning so far and I am sure that he will continue to contribute in the future as well (in fact, I have observed from his dissertation file that he has already moved onto new areas of research, which are all promising). According to Google Scholar, he has received 603 citations to his work so far and his h-index is 13, which is a good number. Also, it is obvious that he enjoys sharing his knowledge with the others by teaching classes and giving lectures to students in universities and by participating activities organized for children. He has also been successful in transferring his research and development experience to industry.

In short, I am favorable about the dissertation thesis and the research work done by Dr. Duriez. If you have any questions or concerns about this report, please do not hesitate to contact me.

Sincerely,

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