Meshless Methods in Computational Biomechanics for Medicine

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Abstract: The field of Biomechanics is in the most exiting state of transition from the theoretical subject of the 20th century to a practical discipline providing patient-specific solutions in the 21st century. Computational biomechanics is becoming instrumental in enabling a new era of personalized medicine based on patient-specific scientific computations. The Finite Element Method is used by almost all members of computational biomechanics community to analyze mathematical models described by sets of partial differential equations. FEM, however, has a number of fairly serious theoretical and practical deficiencies when applied to highly deformable objects of very complicated shapes, such as human soft organs (e.g., the brain) and vasculature. These include a practical difficulty of generating sufficient quality finite element meshes for a given patient as well as theoretical difficulties related to element distortion due to large deformations, topological changes to meshes due to introduction of discontinuities (e.g., cutting or needle insertion in surgical simulation) and obtaining reliable, converged results for derived quantities (such as e.g., wall shear stress in fluid mechanics).

For a number of years, at Intelligent Systems for Medicine Laboratory we have pursued alternative approaches based on weak and strong form meshless methods. In this lecture I will focus on considering pros and cons of meshless methods in solid and fluid mechanics. A special emphasis will be placed on practical methods with a prospect of being implemented in clinical workflows. My lecture will be illustrated by examples from the areas of vascular and neuro-surgery.