ID02:
Patient-Specific Physics-Based Virtual Twin for Neurosurgical Simulation Using FEM and Data-Driven Multi-Tissue Modeling

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Microsurgical dexterity is essential across multiple surgical disciplines, yet reduced training hours and limited operative exposure have created a critical gap in surgical education. While simulation-based training offers a safe alternative to operating room learning, most existing platforms lack haptic feedback, patient-specific anatomical accuracy, and realistic fluid dynamics.

This project proposes a cost- and time-efficient workflow for developing patient-specific augmented-reality surgical simulator that integrates haptic feedback and fluid dynamics, targeting both residency training and preoperative rehearsal of complex microneurosurgical procedures. The work will be conducted over three years in collaboration with the Department of Neurosurgery in Karlsruhe.

The methodology is structured into five sequential phases. First, tissue-specific biomechanical parameters (e.g. Young's modulus, Poisson's ratio, and viscoelastic coefficients) will be collected from the literature and refined through calibration against intraoperative observations. Second, patient-specific anatomical models, with high spatial fidelity, will be generated from CT/MRI data. Third, neurosurgical scenarios of increasing complexity, ranging from standard craniotomy procedures to intracranial aneurysm clipping, will be developed within a hybrid framework integrating physics-based and data driven modeling (to simulate brain tissue deformation and hemodynamic behavior) and real-time haptic rendering (to simulate touch sense). Fourth, Virtual and Augmented Reality environment will be implemented. Fifth, the platform will undergo systematic evaluation of face, content, and construct validity through structured studies involving neurosurgical residents and expert surgeons.

The final outcome will be a reproducible and scalable pipeline for generating patient-specific surgical digital twins, with direct applications in neurosurgical training, surgical rehearsal, and preoperative planning across multiple institutions.


Prof. Dr. Maria Francesca Spadea


Prof. Dr. Uwe Spetzger

Special requirements for applicants:

- Master studies in one of the following: Biomedical engineering, Electrical or Electronic Engineering, Mechatronic, Information Technology, Computer Science, Mechanical Engineering, Physics.