PerSiVal: Biomechanical Pervasive On-Body Visualization Using Mobile Devices

David Rosin[1], Johannes Kässinger[2], Xingyao Yu[3]

[1]) University of Stuttgart, Institute for Modelling and Simulation of Biomechanical Systems, Pfaffenwaldring 5a, 70569 Stuttgart, Germany
[2]) University of Stuttgart, Institute for Parallel and Distributed Systems, Universitätsstraße 38, 70569 Stuttgart, Germany
[3]) University of Stuttgart, Visualization Research Center, Universitätstraße 38, 70569 Stuttgart, Germany
{[1]rosin@imsb, [2]johannes.kaessinger@ipvs, [3]Xingyao.Yu@visus}.uni-stuttgart.de

Figure 1: This is a showcase of our demonstrator running on an iPad. For further info on the project also check `https://www.simtech.uni-stuttgart.de/exc/research/pn/pn7/pn7-1/`.

The goal of project PN7-1, better known as PerSiVal, is to develop a proof of concept for a real-time application of a complex, 3D, continuum-mechanical simulation of a human upper arm in an AR/VR-setting. This will enable pervasive simulation and visualization, making them available at any place and any time. With the goal to contribute to SimTech's digital human model vision, the project follows an interdisciplinary approach, integrating biomechanical models, interaction and visualization, and pervasive and distributed computing concepts.

This involves developing appropriate simulation models of different granularity, interfaces for human-machine-interaction, and visualization concepts, as well as methods for deploying and processing pervasive simulations on heterogeneous computing infrastructures. For this application, we are exploring novel augmented/virtual reality (AR/VR) visualization techniques and interaction methods for using and analyzing such simulation models. The final goal of the project is to develop methods for mapping the components of a simulation system (simulation, interaction, visualization, data repositories) to a heterogeneous infrastructure, with the careful concern of resource limitations (energy, network bandwidth, and compute power), time constraints and simulation quality.

Our use case for PerSiVal is based on a finite element simulation of an upper arm. This finite element simulation is too complex for real-time simulations, in particular on resource-poor mobile devices. Therefore, as one method, we use surrogate models to compute the muscle activation values, in particular, neural networks (NN). Furthermore, the model has been adapted for the use in a distributed system [1]. This involves the reduction of the muscle's geometry to as few as 30 crucial mesh nodes to significantly decrease the communication cost with a remote server. The reduced data can be interpolated back to the full resolution on the mobile device using a single-hidden-layer neural network, without significantly affecting the performance of the model in terms of accuracy or speed. This is mainly achieved by employing a genetic algorithm to pick the points for the reduced set.

Our mobile augmented reality demonstrator, as seen in Figure 1 combines our Tensorflow neural network models for the prediction of muscle surface deformation, with a Unity-based on-body visualization. The application can currently be run on an iPhone or iPad. When a person comes into view of the camera of the mobile device, their pose is estimated using tracker-less motion tracking. This in turn allows for the estimation of the muscle activation levels needed to reach the given pose, which then corresponds to a specific deformed state of our musculoskeletal upper arm model. With this system, we are able to reach an average positional error of under one millimeter in real-time. It has already proved itself as good showcase for SimTech research at events like the "Tag der Wissenschaft", "Inventing the Future - Universtiy of Stuttgart meets Bosch", or the detective-series "Sim&Tech".

References

[1] Kässinger, J., Rosin, D.,Dürr, F., Hornischer, N., Röhrle, O. and Rothermel, K. 2022. Persival: Simulating Complex 3D Meshes on Resource-Constrained Mobile AR Devices Using Interpolation. IEEE 42nd International Conference on Distributed Computing Systems (ICDCS)