Plenary Lecture

STATISTICAL BIOMECHANICAL MODELS: FROM INDIVIDUALS TO POPULATIONS

John Rasmussen
Aalborg University
jr@mp.aau.dk

Keywords: Biomechanics, Data Science, Running

Summary: Research into computational biomechanical models is influenced by two tendencies. On the one hand, much effort is devoted to subject-specific models, for instance a model of an orthopedic patient for the purpose of surgical planning. To this end, subject-specific data such as motion capture and medical imaging are included to improve the validity of the model. The model development process is typically laborious and can be too time-consuming for clinical use. On the other hand, computational biomechanics is inspired by rapid developments in data science, machine learning, artificial intelligence, etc., which require big data representing populations, and where the data analysis provides information about variability of parameters that separate individuals. Individualized models can then be perceived as specific parameter combinations in the population space, so the effort to make population models also serves the purpose of improving the ability to make individualized models, possibly with less laborious procedures. This presentation introduces a set of general procedures for population data processing and a versatile machine learning algorithm that produces subject-specific models based on the processed data and "little data*f*" of subject-specific information. In brief, motion capture data is subjected to an advanced kinematic processing, which extracts anatomical angle variations and detailed anthropometric information from them. The time-series data are then Fourier-transformed to derive signal features, which are subjected to principal component analysis. The approach is illustrated by examples of virtual runners generated from the big data set. This process reveals that a runner is described by roughly 1200 parameters with strong internal correlations that enable about 90% of the variance to be described by about 50 principal components. A conditional likelihood algorithm formulated as a quadratic programming problem produces estimates of all 1200 parameters given knowledge of a subset of them. For example, the algorithm will predict a running pattern characteristic for a person with given anthropometry. The relatively strong correlation between the model parameters means that it may be possible to reconstruct complex motion data based on simple and non-invasive measurements, for instance with inertial measurement units. Population-based models also have interesting perspectives for biomechanical science. Many biomechanical investigations begin with data collection from experiments with a cohort of unspecific test subjects, i.e., the statistical distribution of the cohort is important, but the individuals are not. In relation to such cases, population-based, big-data biomechanical models can work as a virtual lab from which populations with given properties or property variations can be sampled infinitely without conducting physical experiments.