Master Research Proposal

AIBE_Nr:

Topic: Smartphone-based Musculoskeletal Model Personalization

A musculoskeletal model is a computational representation of the human or other animal musculoskeletal system, constructed from data on bones, muscles, ligaments, and tendons, which is used to simulate and analyze movement, biomechanics, and physiological processes for applications in fields such as sports science, rehabilitation, and ergonomics [2]. The first musculoskeletal model was created through manual anatomical measurements and mathematical modeling techniques, in 1966 by Raoul M. Basmajian and Carl G. Blumenstein [1]. Currently, the state of the art uses scaling of anatomical parameter specifically segment length to generate musculoskeletal models [3]. However, despite this scaling, a notable deficiency persists in the personalization of biomechanical models [3]. This deficit arises due to inherent interindividual variations in body composition, which in turn affect the inertial parameters of individuals. Consequently, a substantial disparity exists, necessitating resolution [3].

Inertial parameters are crucial for accurate body-segment inertial parameters would be necessary to account for individual biomechanical analysis as they determine a person's response to forces and motion, impacting the precision of musculoskeletal simulations, movement predictions, and energy expenditure estimations [3]. Accurate and personalized anatomical variations, biomechanical characteristics, and movement patterns, enabling more accurate and patient-specific simulations, diagnostics, and treatment planning in the field of biomechanics [3]. Challenges in personalized musculoskeletal modeling research include limited person-specific data, expensive method of data acquisition and complex integration pipeline [3-4]. We expect our approach should solve the problem of acquisition of inertial parameters with a cheaper method and resulting in personalized model with lesser residual forces.

In this proposed thesis, a pipeline will be developed to automatically generate personalized musculoskeletal models from human body shapes [5-8]. Using smartphone, it is possible to derive point clouds, which can be used to fit a template surface model [5,8]. As Komaritzan et al. showed, fat and muscle composition can be estimated using the BeyondBMI dataset to infer a three-layer volumetric model [9]. Based on these three layers, which represent bone, muscle, and fat, body segment inertial parameters will be estimated by segments and integrated into a scaled musculoskeletal model [8]. A study will be conducted to test the hypothesis that smartphone-based musculoskeletal model personalization can reduce inverse dynamics residuals compared to the state-of-the-art scaling method [8]. Validation can be done with MRI data later with the hypothesis [8]. Initially the validation will be done by comparison with residual forces of the inverse dynamics of the current state of the art methods [8].

Objective: Extraction and Evaluation of Individualized Body Segment Inertial Parameters from Statistical Shape Models.

The proposed work consists of the following parts:

- Literature study on shortcomings of **generic musculoskeletal models**, **musculoskeletal model personalization**, and **statistical shape models**.
- Development of an extraction pipeline for inferring **body segment inertial parameters** from **statistical shape models.**

- Collecting data from various movements and body hulls
- Evaluation of the personalization method by comparison of **inverse dynamics residuals** between personalized and scaled musculoskeletal models
- Write thesis

The thesis must contain a detailed description of all developed and used algorithms as well as a profound result evaluation and discussion. The implemented code has to be documented and provided. Extended research on literature, existing patents, and related work in the corresponding areas must be performed.

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