A General Method for Scaling Musculoskeletal Models

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Computer models of pure technical systems are fully established in automotive engineering, but several comfort and safety issues are related to the human load situation which cannot be evaluated using kinematic tools. Musculoskeletal models are required and must possess the same scaling ability to be useful for product design.

Musculoskeletal modeling is much more challenging than mere kinematics, because scaling pertains not only to the visual geometry, but also to properties like muscle insertion points, muscle parameters and wrapping surfaces.

The purpose of AnyFamily is to provide a population representing some of the anthropometric variation of the population and thereby serves as a validation of the system's ability to scale models. Each member of the AnyFamily is represented by a set of anthropometric data generated by Ramsis, most prominently segment lengths and masses.

Scale factors

The definition of a segment in the human model requires mass properties and in addition a number of nodes defined in the segment's local coordinate system. The nodes are used for joint centers, muscle insertions, and such. The nodes of each segment are subjected to scaling, and such. The nodes are used for joint centers, muscle insertions, and such. The nodes of each segment are subjected to scaling, and such. The nodes are used for joint centers, muscle insertions, and such. The nodes of each segment are subjected to scaling, and such. The nodes are used for joint centers, muscle insertions, and such.

Scaling law:
uniform, non-uniform, mass-fat scaling
Musculoskeletal anthropometric parameters.

Scaled models

Examples

A typical application of scaling musculoskeletal models is the investigation of compatibility between human bodies of different sizes and car package dimensions. Traditional manikins cover the kinematic compatibility, but they do not predict the human ability to turn a steering wheel or pull a handbrake. In these pictures, three of the family members, Macy, Karl and John, who are respectively a 5th percentile female, a 50th percentile male and a 95th percentile male, have been inserted into a vehicle package environment adjusted to normally accepted comfort positions for these percentile family members.

Pedaling example

In addition to mere kinematics, the method also scales the muscle strength and is able to compute muscle forces and activities for different working tasks for differently sized subjects. So, for a similar task a small female will use more of her muscular strength than a large male. In the pedaling example below, the same three family members have been seated on bicycles adjusted to their respective dimensions. The three models are subsequently required to drive the pedals with a typical crank torque variation, all of them producing an average mechanical output of 170 W.

The AnyBody Modeling System computes the activity percentage for each muscle over the crank cycle, and the maximum activity over all muscles is a good measure of how many percent of the total body strength the model is using as the given time. These activity envelopes are shown for Macy, Karl and John below.

Method 1: Uniform Scaling

This method is a uniform scaling using a diagonal matrix with the same scaling factor on all diagonal positions and an assumed relationship between muscle strength and mass based on the idea that muscle strength depends on cross-sectional area while body mass depends on volume. In other words, it assumes that the scaled is in all directions as it is in the length direction.

Method 2: Non-uniform Scaling

This is a non-uniform scaling taking into account the fact that body segments tend to be organized with soft tissues arranged in layers around a longitudinal bone, here corresponding to the y-axis. This leads to a scaling in the perpendicular directions which is square rooted and dependent on the mass as well as the length.

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