

# A MATLAB TOOL TO SCALE ITERATIVELY AND AUTOMATICALLY GENERIC MUSCULOSKELETAL MODELS

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## Introduction

The scaling procedure of a generic musculoskeletal model is a crucial operation that can lead to inaccuracies for all the subsequent stages of the musculoskeletal analysis [1]. Changing marker locations is a fundamental part of the scaling procedure since it allows to estimate the scale factors that best match experimental data. It's a tricky operation manually executed so far, since it needs an iterative trial and error procedure. Thus, it is also time consuming and covers a large part of the whole musculoskeletal analysis. It may require from a half day to several weeks, according to the level of experience of the operator and to the desired level of accuracy. To diminish both time and efforts and to improve the accuracy of the scaled model, herein we present an innovative and automated procedure to scale generic MSK models in OpenSim environment.

## Methods

This tool consists of a MATLAB script that exploits OpenSim API functionalities. The code takes in input three files: the generic unscaled model file containing the generic set of markers, the static experimental trial file and the scaling setup file containing the measurement sets and the marker weights defined by the user. This script consists of an iterative algorithm that performs several times the scaling procedure until a given condition (e.g. RMS marker error less than a threshold) is fulfilled: in every cycle, the highest marker error is detected and its coordinates on the generic model are modified of a quantity proportional to the such error. Additionally, the routine performs a check on the resulting scale factors: if they become too low or too high it means that the scaled geometry is not reliable and then the manual repositioning of the initial markers on the generic model is suggested.

The tool has been tested on two datasets: a) experimental MoCap data collected at the Biomechanics Laboratory of the "Sport and Anatomy Centre" of the University of Pisa (where a Vicon motion analysis system with eight infrared cameras @100 Hz is installed) and b) public domain data of the Grand Knee Challenge Competitions [2].

A generic Rajagopal model has been adopted even though in future other typologies of models will be considered.

## Results

Preliminary results coming from the comparison of the scaled model of fifth edition of GKC subject with and without the tool show a net decrease of both RMS errors

and max error than the manual procedure. As a result, these differences also reflect on markers errors locations over walking trial, where the API method seems to keep both RMS and max errors lower than the manual procedure (Table 1). According to the level of accuracy desired, this script employs certain amount of computational time: for an RMS error of marker trajectories  $< 0.003$  m it may require up to 3 hours of simulation; instead for less strict criteria (RMS error  $< 0.01$  m), this script can lead the operation in less than half an hour.

| Scaling method | Static Error (m) |        | Gait Error (m) |        |
|----------------|------------------|--------|----------------|--------|
|                | RMS              | Max    | RMS            | Max    |
| API            | 0.0032           | 0.0064 | 0.0079         | 0.0175 |
| Manual         | 0.0063           | 0.013  | 0.0152         | 0.0289 |

Table 1: Markers mean error location (automated vs manual procedure) during static and walking trials of GKC 5<sup>th</sup> edition subject.

## Discussion

The herein presented tool can represent a useful mean to improve the scaling procedure, by iteratively modifying marker locations of a generic musculoskeletal model to reduce markers position errors.

This innovative tool has shown encouraging results, new tests in terms of experimental datasets and models adopted will be executed to further validate the algorithm, including the effect of marker weights.

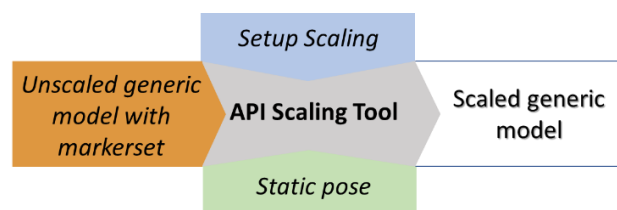


Figure 1: Tool operation flow. Inputs are: Unscaled model with markerset, scaling setup file and experimental static pose; The output is the scaled model.

## References

1. Tomasi M. et al, On the estimation of hip joint loads through musculoskeletal modelling, Biomech. Model. Mechan., (2022),
2. Fregly et al, Grand challenge competition to predict in vivo knee loads, J. Orthop. Res., (2012)

