# Automated Generation of Personalized Skeletal Models for Use in Musculoskeletal Applications

# 1 Introduction

Musculoskeletal models have been useful for a variaty of tasks, including ...

BUilding a musculoskeletal model requires availability of anatomical geometries from medical images or other source, to which apply techniques to build a skeletal kinematic and kinetic model adn finally,mostly through mapping technique, musculo-tendon actuators are mapped onto these skeletal models and used to run muscle-driven simulations.

However, despite the availability of specific tools (NMSBuilder) and codified procedures (Modenese) subject-specific models have not been used in any routine clinical scenario yet. Assemblying the models from the anatomical geometries is still a procedure requiring specialised operators, and requires a time that exceeds the 10h, making impossible to use this technology in a large cohorts.

There are methods to build models using statistical shape models. But these models are not shared, or not comprehensive (no feet) or not appropriate for certain population, e.g. juvenile.

Aim of this paper is presenting an approach to create skeletal models from bone geometries in a completely automated way. These models can than be used as baselines for kinematics and kinetics evaluation of patients or more further processing towards the construction of complete musculoskeletal models.

## 2 Methods

### 2.1 Anatomical datasets

X anatomical dataset were employed the study, aiming to represent a variaty of individual and variability of bones.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Dataset |  | MSK conditions |  |  | Geom Quality |
| In vivo | M | No | Adult male |  | Good |
| LHDL | F | No | Elderly | CT | Excellent |
| TLEM2 | M | No | Elderly | CT | Excellent |
|  |  |  |  | MRI | Good |
| JIA | ? | JIA | Juvenile | MRI | Scarse |
| CP | ? | JIA | Paediatric | MRI | Scarse |

For all models,

### 2.2 Manual models

Each of the datasets was employed to create a subject-specific model following the procedure of Modenese et al. (2018). For the published dataset,

### 2.3 Automated procedure

The proposed automateed procedure consists on building reference system employing the geometry of each bone of the lower limb and then use these reference system to:

1. Identify joint parameters to build the model
2. Identify bony landmarks for registration in the kinematics and kinetics simulations

Pelvis

The pelvis bones are processed accounting only for the iliac wings. The sacrum has been negletted because it si a challenging bone to segment from MRI scans, and that worsens the quality of the data. Given the triangular geometry of the pelvis, the inertial axes are calculated (REF) and used to define a provisional reference system centred at the centre of mass of the geometry. The most distal and proximal points are then identified as ASIS and PSIS, depending on their location and relative distance. The ISB reference system is then defined from these landmarks.

Femur

Several approaches are available in the literature for processing the femoral bone.

|  |  |  |
| --- | --- | --- |
| Bone | Approach | Description |
| Pelvis | Kai et al |  |
|  | This study |  |
| Femur | Kai et al |  |
|  | Miranda et al |  |
|  | Renault et al. | ellipsoid |
|  |  | cylinder |
|  |  | sphere |
|  |  | Artic surfaces |
| Tibia | Kai et al |  |
|  | Miranda |  |
|  | Renault et al | Cond centroids |
|  |  | Ellipse on AS layer (from prox art surf) |
|  |  | PIA on AS layer |
| Patella | Rainbow |  |
|  | Renault et al | Volume ridge |
|  |  | Ridge line |
|  |  | PIA of articular surfaces |
| Talus (talocrural) | Parr |  |
| Talus (subtalar) | Parr |  |
| Foot |  |  |

Equivalence of results with manual modelling

4 Result

Which methods failed in which dataser

5 Discussion

The presented methods become less reliable for anomalies in the geometries or bad quality meshes.

In particular, the algorithms fail if:

1. The femur has equal size condyles (medial should be larger) - femoral condyles
2. Mesh is irregular and produces multiple slices when it shouldn’t (femoral head)
3. Patella does not have a posterior ridge

This set of techniques will enable multiple applications at multiple joints.

With minor modification our approach could generate models for hip joint studies from CTs, applicable to falls and bone strength. Our algorithm automatically extract articular surfaces, that coud be used for fast setup of contact models (SMITH). Finally, our implementation of the ankle joint is particularly robust and would allow detailed studies of the foot and ankle behaviour.

NOT GENERIC? Same as statistica shape models.