OpenSim

Patient-Specific Model-building and Scaling with the Musculo-skeletal Atlas Project and Statistical Shape Modeling

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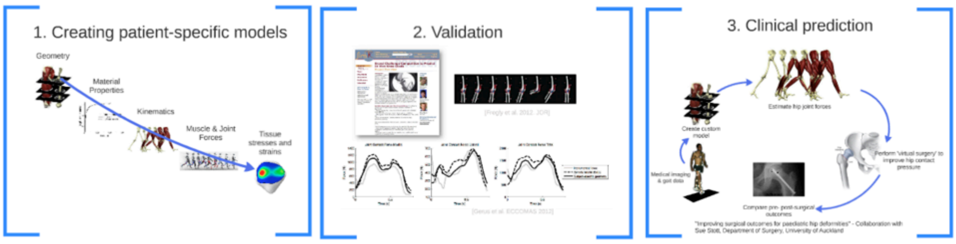
Subject-specific computational models of the musculoskeletal system have tremendous potential for clinical application

However, several challenges are limiting the uptake of musculoskeletal models in the clinic…

Challenges to clinical implementation



Generating subject-specific models is time-consuming and costly, and requires a high level of expertise

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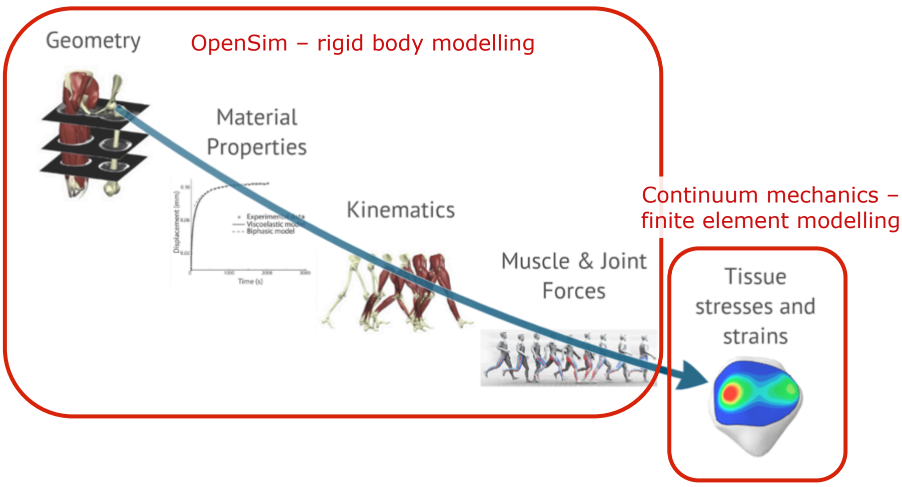
What do we mean when we say subject-specific?



This talk will focus on building subject-specific bone geometry to best-match *sparse* motion capture and imaging data

An example problem

What are the hip contact pressures during walking for this subject?

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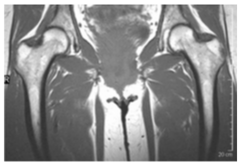
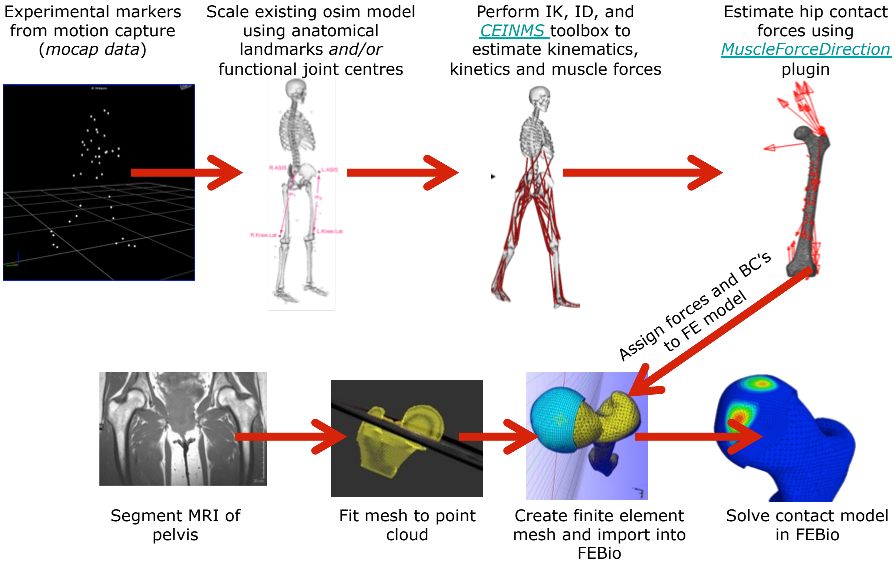


Motion capture data (mocap) MR images of the hip

We want to **scale** or **generate** an OpenSim model to best-match mocap and imaging data

Current approach to this problem



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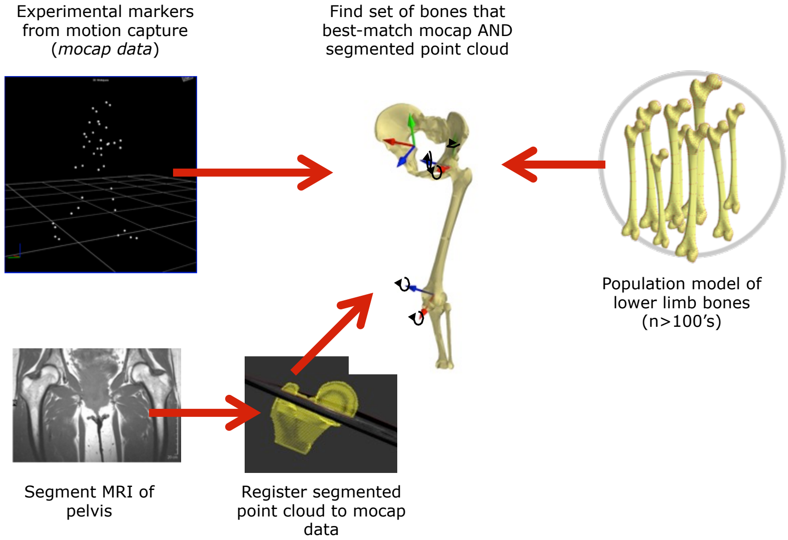
A different approach…



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Overview

- The MAP framework and the MAP Client
- Introduction to shape modelling
- Constrained scaling using shape modelling
  - Example 1 – scaling the hip joint with mocap
  - Example 2 – scaling lower limb with mocap and imaging data of femur
- Muscle and joint parameters
- Limitations and points for discussion
- Community engagement

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MAP
Musculoskeletal Atlas Project

Our aim is to provide the biomechanics community with a tool to rapidly generate subject-specific musculoskeletal models for computational modelling

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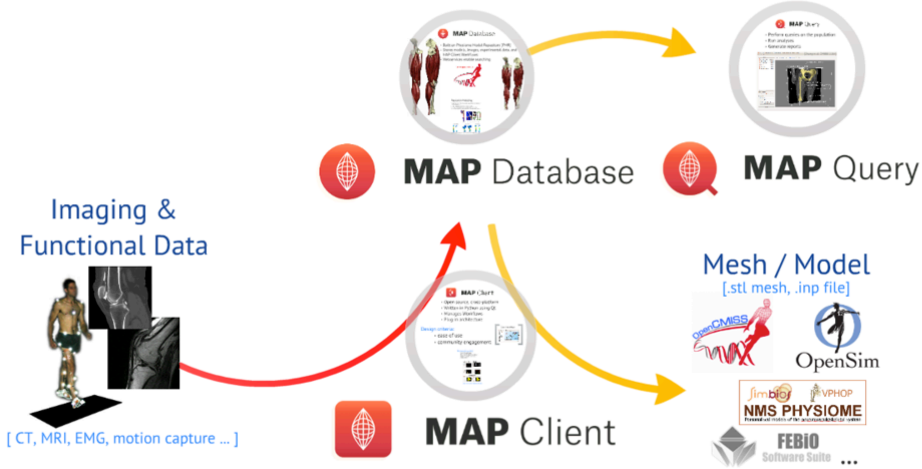
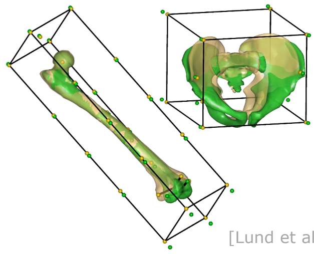
The Musculoskeletal Atlas Project

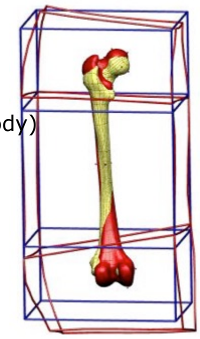


Current Scaling Methods

- Deform generic model to fit to landmarks
- Linear (OpenSim)
  - Reference geometry: Delp (1990)
- Linear + Nonlinear e.g. Radial Basis Functions (Anybody)
  - Reference geometry: Klein Horsman (2007)



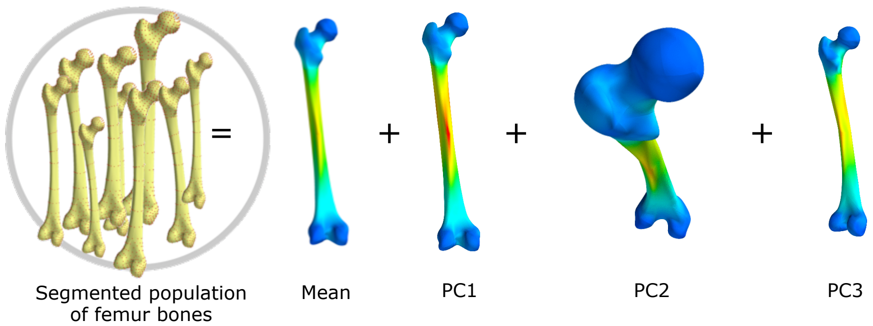
[Lund et al 2015]



[Fernandez et al. 2004]

Statistical shape models

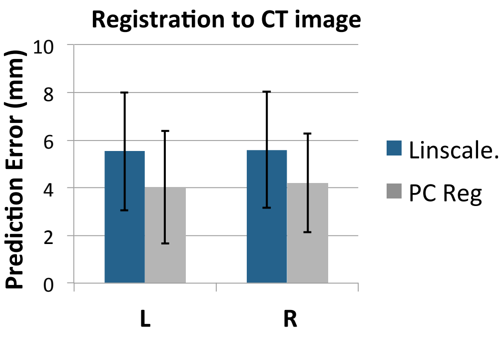
- Efficiently capture variation in shape across a population (n>100’s)



Demo 1 – scaling the hip joint using motion capture data

Results and summary of example 1

- Shape model constrains scaling to provide accurate estimate of **pelvis shape** and **hip joint centre**

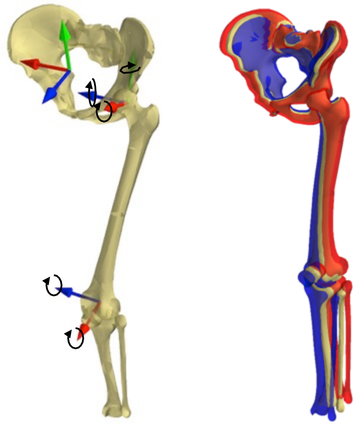


Example 2 – scaling the lower limb with mocap and imaging data

Articulated Shape Model

Degrees of freedom

- Pelvis Rigid: 6
- Hip rotations: 3
- Knee flexion & abduction: 2
- Shape model scores: n



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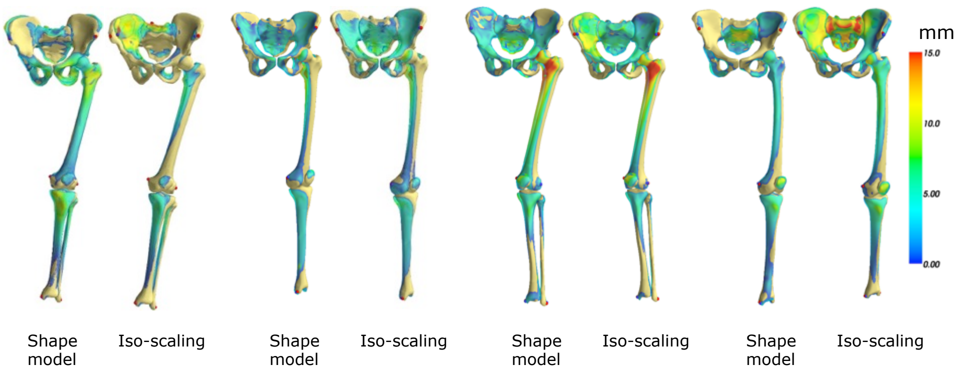
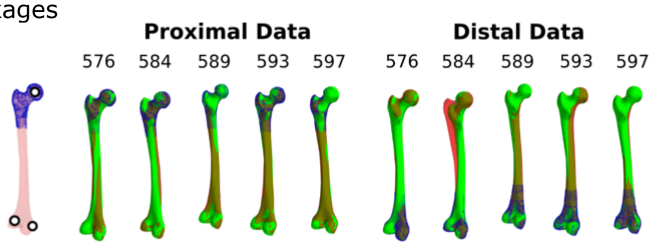
Results and summary of example 2

- Shape model constrains scaling of entire lower limb to ensure an anatomically feasible solution



Results and summary of example 2

- Combination of marker and imaging data improves the estimation of bone geometry
- Resulting bone geometry can be exported to OpenSim and/or FE packages



Error Metric	Proximal Partial Surface	Distal Partial Surface
Surface (mm)	1.75 ±0.31	4.95 ±3.09
X (deg.)	0.15 ±0.09	0.20 ±0.16
Y (deg.)	0.07 ±0.04	0.06 ±0.05
Z (deg.)	0.15 ±0.08	0.21 ±0.16

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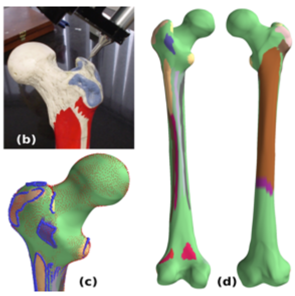
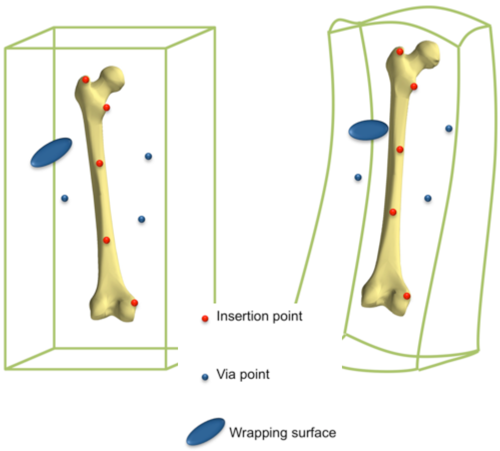
What about the muscles?

- Muscle attachment sites embedded onto bones, but via points and wrapping surfaces need to be adjusted





Points for discussion

- Complex joints (custom mobilizers)
- Scaling muscle-tendon parameters
- Body segment parameters (mass, CoM, moments of inertia)
- Where are the feet and other body parts?

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How can you contribute?

- Download the MAP Client and start developing your own plug-ins
  - Free and open source (GPL3 license)
  - Developed in Python
  - Cross platform

https://github.com/MusculoskeletalAtlasProject/mapclient

- Collaborate with us to grow our model repository (e.g. send us segmented data)
- Develop plug-ins
    - New joint models
    - …

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