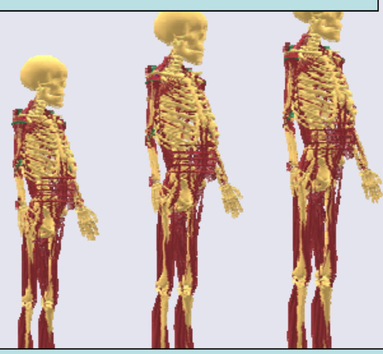
Scaling of musculoskeletal models

To fit your screen:
Sharing (upper right corner)->
View->Autofit

The web cast will start in a few minutes….



1. Review of scaling principles (~15 min)
2. New repository scaling methods (~15 min)
3. Demo (~15 min)
4. Q&A session (~10 min)

Please follow the instructions to set up the audio:
www.anybodytech.com/fileadmin/downloads/AudioInstructionsWebEx.pdf

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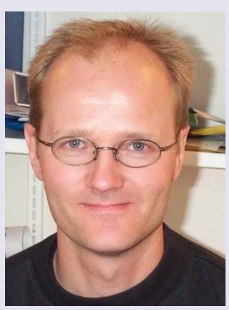
People



John Rasmussen
(Presenter)

Arne Kiis
(Host)

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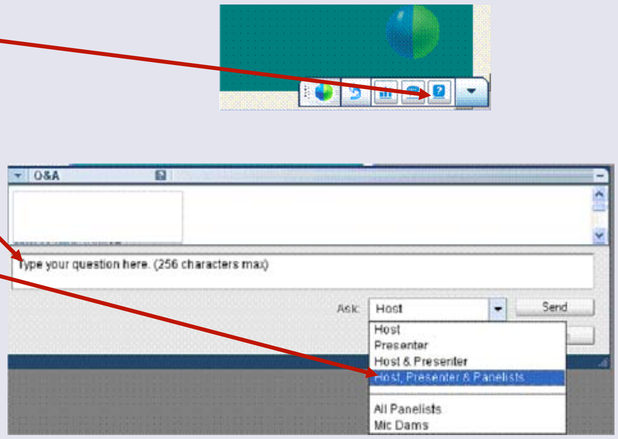
Q&A Panel

- Søren Tørholm
- Launch the Q&A panel here.
- Type your questions in the Q&A panel.
- Send the question to ”Host, Presenter & Panelists”
- Notice the answer displays next to the question in the Q&A box. You may have to scroll up to see it.



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1/3 Scaling Principles

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Scenarios

- Detailed level
  - Purpose-specific modeling based on scans, ultrasound data, and similar.
  - Detailed data for each model element.
- Individual level
  - Sports biomechanics for a particular athlete
  - Gait analysis of a particular individual
- Overall population level
  - Investigate ergonomic compatibility for a broad range of the population
  - Based on anthropometric databases

This has always been possible because AnyBody models are fully accessible.

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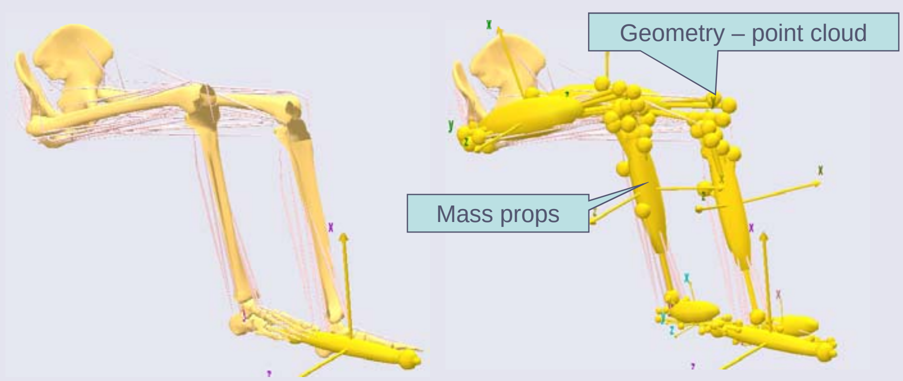
How a segment is defined



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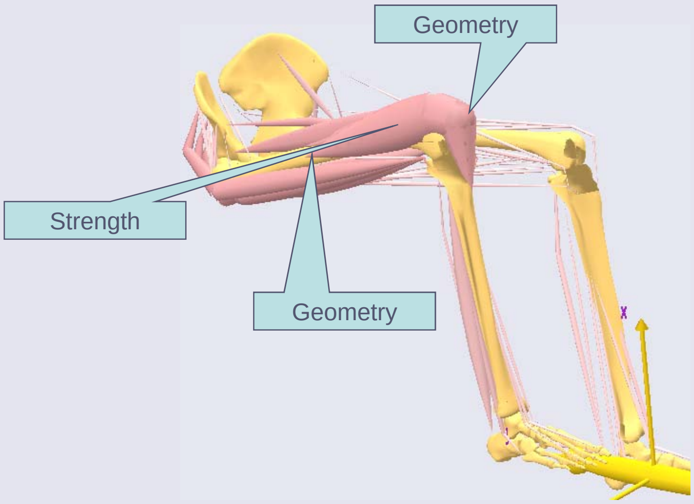
How a muscle is defined



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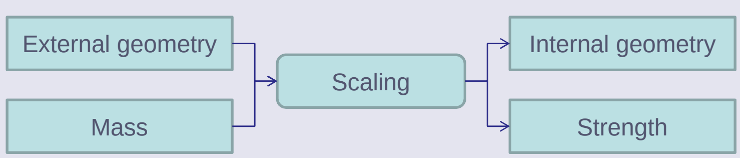
In summary...

- Geometry
- Mass properties
- Muscle strength



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Linear geometry scaling

$$\mathbf{s} = \mathbf{S}\mathbf{p} + \mathbf{t}$$

- $\mathbf{s}$: Scaled point
- $\mathbf{S}$: Scaling matrix
- $\mathbf{p}$: Original point
- $\mathbf{t}$: Translation

Different choices of $\mathbf{S}$ ant $\mathbf{t}$ lead to different scaling laws

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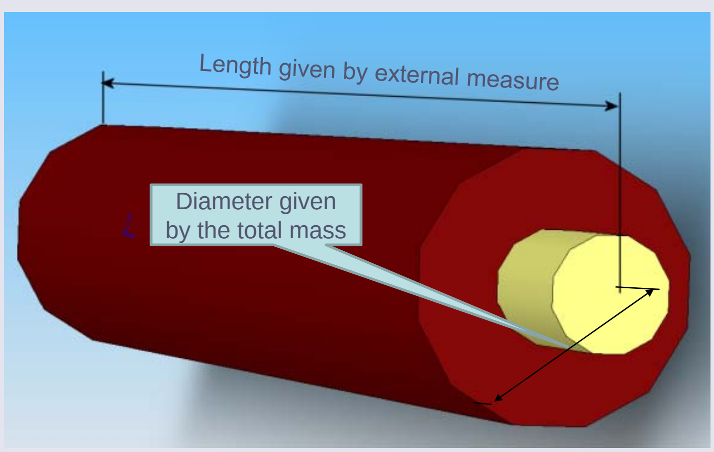
Basic idea: Segments are longitudinal an concentric structures.



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Length-mass-fat scaling

- Tissues:
  - Other (bone, cartilage, skin, blood, etc).
  - Fat
  - Muscle
- Fat percentage given or estimated from the BMI
- R_{other} = 50%

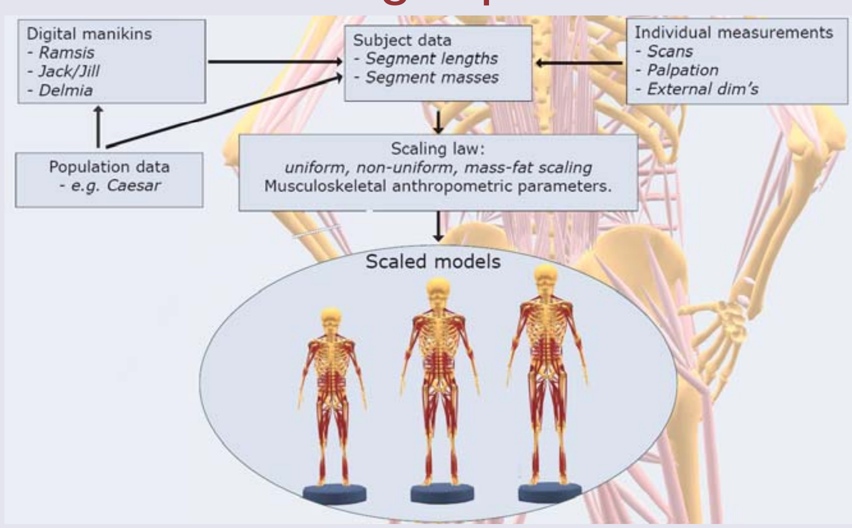
$$R_{muscle} = 1 - R_{fat} - R_{other}$$

$$F = F_0 \frac{k_m}{k_L} \frac{R_{muscle,1}}{R_{muscle,0}} = F_0 \frac{k_m}{k_L} \frac{1 - R_{other} - R_{fat,1}}{1 - R_{other} - R_{fat,0}}$$

Mass ratio

Length ratio

Scaling Pipeline

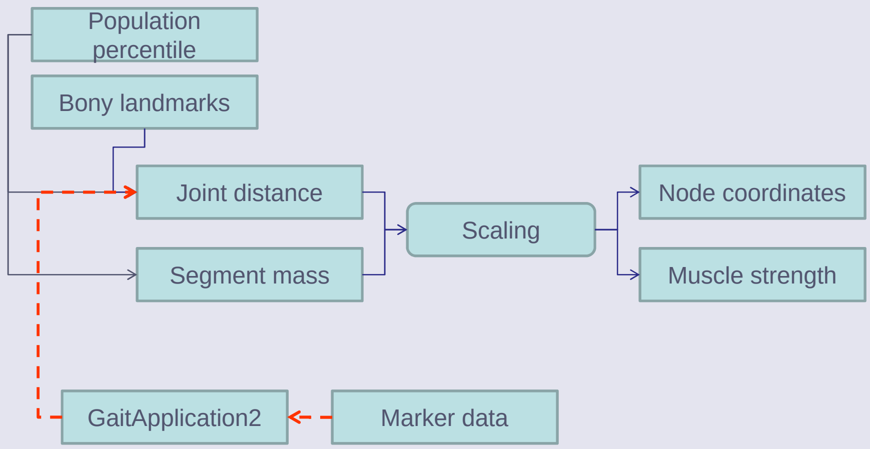


2/3: New repository scaling methods

Things to observe

- The repository models are written in AnyScript.
- AnyScript is a programming language.
- Scaling methods can be implemented in AnyScript.
- Scaling is a part of the repository – not the software.
  - Completely open for scrutiny and modification.
  - If you do not like the methods, make your own!

Extended scaling pipeline



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3/3: Implementation and demo

```
// This section below offers the choice between two scaling strategies for the
// human model.

// ScalingStandard means that all the body parts will have the standard size
// at which they were originally developed, i.e. with anthropometric
// data from the anatomical literature. This roughly corresponds to a 50th
// percentile European male.
// #include "..\..\..\Body\AAUHuman\Scaling\ScalingStandard.any"

// ScalingLengthMassFat will scale each segment of the body to ant… ata
// specified in the selected AnyFamily include file, attempting to take the
// fat percentage into account in the assessment of the muscle strength.
 #include "..\..\..\Body\AAUHuman\Scaling\ScalingLengthMassFat.any"
 Scaling = {
   #include "..\..\..\Body\AAUHuman\Scaling\AnyFamily\AnyMan.any"
 };
```

Method

Scaling file

- Old methods removed: ScalingUniform & ScalingLengthMass
- New Scaling files:
    - AnyManExternal
    - AnyManExtPercentile
    - AnyWomanExtPercentile

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AnyManExternal

```
// File of anthropometric data
// This file use external landmarks to measure each segment (see include file ***)
// You have to enter the legnth of each segment individualy

AnyVar BMI = AnthroData.Body_Mass/(AnthroData.body_height^2);
AnyVar FatPercent = (-0.09 + 0.0149*BMI - ...                                      ...d for men

AnyFolder AnthroData = {
  AnyVar Body_Mass = 75 ;
  AnyVar body_height = 180 /100;

  //Segment masses in kg from Winter ("Biomechanics and motor control of human movement." David A. Winter)
  AnyVar lumbar = 0.139*Body_Mass; // T12-L1 to L5-Sacrum
  AnyVar thorax = 0.1894*Body_Mass; // C7-T1 to T12-L1 (modified from 0.216 winter to separate scapula)
  AnyVar pelvis = 0.142*Body_Mass;
  AnyVar clavicle_r = 0.0133*Body_Mass;
  AnyVar upper_arm_r = 0.028*Body_Mass;
  AnyVar lower_arm_r = 0.016*Body_Mass;
  AnyVar hand_r = 0.006*Body_Mass;
  AnyVar clavicle_l = 0.0133*Body_Mass;
  AnyVar upper_arm_l = 0.028*Body_Mass;
  AnyVar lower_arm_l = 0.016*Body_Mass;
  AnyVar hand_l = 0.006*Body_Mass;
  AnyVar head = 0.081*Body_Mass; // head and cervical
  AnyVar thigh_r = 0.1*Body_Mass;
  AnyVar lower_leg_r = 0.0465*Body_Mass;
  AnyVar foot_r = 0.0145*Body_Mass;
  AnyVar ball_r = 0.000;
  AnyVar thigh_l = 0.1*Body_Mass;
  AnyVar lower_leg_l = 0.0465*Body_Mass;
  AnyVar foot_l = 0.0145*Body_Mass;
  AnyVar ball_l = 0.000;
};

AnyFolder AnthroSegmentLengths = {
  AnyVar ThighLength = 0.445; // from top of trochanter to epicondylus lateral along thigh
  AnyVar ShankLength = 0.420; // from condulus medial to malleolus medial along shank
  AnyVar FootLength = 0.243; // from back of heel to tip of longest toe along foot
  AnyVar PelvisWidth = 0.314; // between external bony tip of trochanter (horizontaly)
  AnyVar HeadHeight = 0.246; // from chin to top of head (verticaly)
  AnyVar TrunkHeight = 0.500; // From C7 to sacrum midle bony tip (verticaly)
  AnyVar UpperArmLength = 0.414; // From elbow bony tip to acromion bony tip along humerus (elbow flexed 90 deg)
  AnyVar LowerArmLength =0.268; // From elbow bony tip to ulna styloid bony tip along ulna (elbow flexed 90 deg)
  AnyVar HandLength = 0.182; // From the base of the palm to the tip of the middle finger
  AnyVar HandBreadth = 0.072; // From the external landmark of the CMP joint of the index to the external landmark of the CMP joint of the little finger
};
```

Definition of Body_Mass…

… becomes segment lengths

Bony landmark distances

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AnyWomanExtPercentile

```
// This file allows you to choose the percentile of the population you want to represent with the model.
// Valid only for women.
// Enter the percentile and select one of the three function for Z

AnyVar BMI = AnthroData.Body_Mass/(AnthroData.body_height^2);
AnyVar FatPercent = (-0.08 + 0.0203*BMI - 0.000156*BMI^2)*100; //Estimation from Frankenfield et al. (2001) valid for women

// Percentile
AnyVar Percentile = 50; //Percent of the population represented. Choose one of the Z linear regression below.

// Choose only one of the following linear regression depen...              ...percentile.
//AnyVar Z = (0.064*Percentile)-1.96; // This is valid for Percentile from ...
AnyVar Z = (0.0279*Percentile)-1.3971; // This is valid for Percentile from 16% to 84%.
//AnyVar Z = (0.064*Percentile)-4.44; // This is valid for Percentile from 85% to 95%.
AnyFolder AnthroData = {
  AnyVar Body_Mass = 58 + 7*.Z ;
  AnyVar body_height = 161 /100 + 0.063*.Z;

  //Segment masses in kg from Winter ("Biomechanics and motor control of human movement." ...
  AnyVar lumbar = 0.139*Body_Mass; // T12-L1 to L5-Sacrum
  AnyVar thorax = 0.1894*Body_Mass; // C7-T1 to T12-L1 (modified from 0.216 winter to separate scapula)
  AnyVar pelvis = 0.142*Body_Mass;
  AnyVar clavicle_r = 0.0133*Body_Mass;
  AnyVar upper_arm_r = 0.028*Body_Mass;
  AnyVar lower_arm_r = 0.016*Body_Mass;
  AnyVar hand_r = 0.006*Body_Mass;
  AnyVar clavicle_l = 0.0133*Body_Mass;
  AnyVar upper_arm_l = 0.028*Body_Mass;
  AnyVar lower_arm_l = 0.016*Body_Mass;
  AnyVar hand_l = 0.006*Body_Mass;
  AnyVar head = 0.081*Body_Mass; // head and cervical
  AnyVar thigh_r = 0.1*Body_Mass;
  AnyVar lower_leg_r = 0.0465*Body_Mass;
  AnyVar foot_r = 0.0145*Body_Mass;
  AnyVar ball_r = 0.000;
  AnyVar thigh_l = 0.1*Body_Mass;
  AnyVar lower_leg_l = 0.0465*Body_Mass;
  AnyVar foot_l = 0.0145*Body_Mass;
  AnyVar ball_l = 0.000;
};

AnyFolder AnthroSegmentLengths = {
  AnyVar ThighLength = 0.384 + 0.02*.Z; // from top of trochanter to epicondylus lateral along thigh
  AnyVar ShankLength = 0.354 + 0.021*.Z; // from condulus medial to malleolus medial along shank
  AnyVar FootLength = 0.239 + 0.012*.Z; // from back of heel to tip of longest toe along foot
  AnyVar PelvisWidth = 0.320 + 0.023*.Z; // between external biny tip of trochanter (horizontaly)
  AnyVar HeadHeight = 0.210 + 0.0115*.Z; // from chin to top of head (verticaly)
  AnyVar TrunkHeight = 0.466 + 0.014*.Z; // From C7 to sacrum midle bony tip (verticaly)
  AnyVar UpperArmLength = 0.335 + 0.0175*.Z; // From elbow bony tip to acromion bony tip along humerus (elbow flexed 90 deg)
  AnyVar LowerArmLength =0.253 + 0.013*.Z; // From elbow bony tip to ulna styloid bony tip along ulna (elbow flexed 90 deg)
  AnyVar HandLength = 0.175 + 0.009*.Z; // From the base of the palm to the tip of the middle finger
  AnyVar HandBreadth = 0.077 + 0.004*.Z; // From the external landmark of the CMP joint of the index to the external landmark c
};
```

Input

”Dependent” Input

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Demo:

Standing model with a shoulder bag

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Discussion

- Scaling has been implemented as simple formulas in directly in the models.
- The formulas are based on simple physical and physiological principles.
- Alternative scaling methods can be implemented by users.
- Future work might include age and gender.

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Online resources

- The AnyBody Modeling System
  - Free demo license www.anybodytech.com
  - Email: anybody@anybodytech.com
- The AnyBody Research Project www.anybody.aau.dk
  - Public domain library of body models and applications
  - Publications, for instance about scaling.

Thank you!
Q & A