The AnyBody model library: Content, model design strategy, and applications

If a part of my screen in missing from your View, please press View.

The web cast will begin in a few minutes....

Introduction (~5 min)
Body Parts (~ 25 min)
Applications (~15 min)
Q&A session (~10 min)

Please check that your audio settings correspond to the instructions in the email you have received from us.
Presenters

Søren Tørholm Christensen (Presenter)

Arne Kiis (Host)
Q&A Panel

- John Rasmussen
- 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.
Difference with normal approach

• Most research groups start with a problem and build a model to solve that particular problem

• We want to build **general models**, which can give information about a number of yet unknown problems

Our goal

• To develop general detailed models which:
  – can predict muscle, ligament and reaction forces for a given movement.
  – will facilitate sharing of the model.
  – will give the opportunity to scrutinize and improve the model by other groups
Repository structure BRep

A modular block building technique, which makes it easy to change and connect different body parts, has been developed. The philosophy is that when building for example a leg model, the model should be self-contained.

The BRep does not contain any motion drivers for the body parts. These are added in the application.
BodyModel collections

In addition to the individual body parts, the BRep now contains a BodyModel directory with popular collections of body parts:

• FullBodyModel
• SpineTwoArms
• SpineTwoLegs
• SpineRightArm
• TwoLegs

These even come in various combinations with and without muscles and with different muscle models.
BRep: Shoulder arm model

The arm block includes the shoulder region and comprises the following bones: clavicle, scapula, humerus, ulna, radius and a hand segment.

The model is mainly based on data collected by the Dutch Shoulder Group and made available on the World-Wide Web.

Example file: Brep/Aalborg/Arm3D/ShoulderArm.root.any
BRep: Shoulder arm model

The anthropometrical data originates from two different studies:
• VU study: data was collected for the shoulder region extending to the elbow.
• MAYO study: Data of the lower arm extending to the wrist was collected.

The model of the arm and shoulder has 118 muscle elements on each side.

Example file:
Brep/Aalborg/Arm3D/ShoulderArm.root.any
BRep : Shoulder arm model

**Kinematics**

- **AC**: Spherical joint
- **GH**: Spherical joint (kinematically only)
- **SC**: Spherical joint
- **TS**: Scapula thoracic gliding plane, ellipsoid
- **AI**: Scapula thoracic gliding plane, ellipsoid

This gives totally 7 dof. in the shoulder girdle

Eight very strong muscles which points from eight points uniformly distributed points around the cavitas edge on Scapula towards the GH rotation point, ensures that the resultant force in the joint falls inside the Cavitas glenoidalis
BRep : Shoulder arm model

Kinematics

FE  Flexion/extension, revolute joint
PS  Pronation/supination, combination of joints with one DOF
Wrist  Universal joint

Example file: Brep/Aalborg/Arm3D/Joint.any

BRep : Arm3D
Shoulder References


BRep : Arm3D
Spine model

The spine model comprises sacrum, all lumbar vertebrae, a rigid thoracic section, and a total of 158 muscles

Model developed by M. de Zee and L. Hansen

Example file: Brep/Aalborg/Spine/Spine.root.any
Segments and joints

- **7 rigid segments**
  - Pelvis
  - 5 lumbar vertebrae
  - Thoracic part

- **Joints between vertebrae**
  - 3 dof spherical joint
  - Centre of rotation based on Pearcy and Bogduk (1988)

Example file: Brep/Aalborg/Spine/JointsLumbar.any
Muscles: multifidi

- 19 fascicles on each side
- Based on information by the group of Bogduk

Example file: Brep/Aalborg/Spine/MultifidiRight.any

BRep : Spine
Muscles: erector spinae

- 29 fascicles on each side
- Based on information by the group of Bogduk

BRep : Spine

epars thoracis divisions
epars lumborum divisions

Example file: Brep/Aalborg/Spine/ErectorSpinae.any
Muscles: psoas major

- 11 fascicles on each side
- Insertion on the femur
- Via point on the pelvis (iliopubic eminence)

Example file: Brep/Aalborg/Spine/PsoasMajorRight.any
Muscles: quadratus lumborum

- 5 fascicles on each side
- Based on information by Stokes et al. (1999)

Example file: Brep/Aalborg/Spine/QuadatusLumborumRight.any
Muscles: abdominal

- Rectus abdominis
- Obliquus externus
- Obliquus internus
- Transversus

Example file: Brep/Aalborg/Spine/RectusAbdominisRight.any
The abdominal volume is idealized as a stack of five cylinders.

An artificial muscle is acting on the volume and generating forces on the vertebrae, thoax and pelvis. This muscle is part of the normal recruitment problem, it will only be active if it is of benefit for the model.
A Spine rhythm has been implemented. The rhythm calculates the joint rotations between the vertebrae as a function of the 3D angle between Pelvis and Thorax.

The rhythm removes the necessity for imposing the movement on each individual vertebra.

Only the rotations between Thorax and Pelvis have to be driven.

Example file: ARep/Aalborg/BikeModelFullbody/JointsAndDrivers.any

BRep: Spine / ARep: in most applications
Showcase

This video shows a standing model doing three different tasks:

1. Flexion/extension
2. Lateral bend
3. Axial twist

Please notice the motion of the five individual disks and the changes of the muscle tone.

BRep : Spine
Spine References


BRep : Spine

AnyBody Research Project
Spine References


The leg model comprises the following bones: pelvis, thigh, shank and foot.

The hip joint is modeled as a spherical joint, while the knee and ankle are modeled as hinge joints.

The leg model is equipped with 35 muscles elements.

Thanks to Mark Thompson, Lund University Hospital, for his help on developing the lower extremity model.
A couple of muscles with broad insertions (like the m. gluteus maximus) are divided into multiple individual muscle units to represent the real geometry and the mechanical actions of the muscle.

The parameters of these muscles are mainly based on the data published by Delp and Maganaris.
Leg References

S. Delp, Parameters for the lower limb, http://isb.ri.ccf.org/data/delp


Mandible model

The model is developed by
Mark de Zee
Department of Orthodontics
School of Dentistry
Faculty of Health Sciences
University of Aarhus
Denmark
Scaling
Introduction

The musculoskeletal models have been made scalable in size. This is no simple task since it involves changing literally thousand of parameters, properties like:

- mass and inertia
- geometry: muscle insertion points, joint centers etc.
- muscle parameters
- wrapping surfaces.

The scaling procedure is implemented in a generic manner and allows for user-defined scaling laws.
Scaling Scenarios

• Overall population level
  – Investigate ergonomic compatibility for a broad range of the population
  – Based on anthropometric databases

• Individual level
  – Sports biomechanics for a particular athlete
  – Gait analysis of a particular individual

• Detailed level
  – Purpose-specific modeling based on scans, ultrasound data, and similar
  – Detailed data for each model element

This has always been possible because AnyBody models are fully accessible.
How a segment is defined

- Geometry – point cloud
- Mass props
How a muscle is defined

Strength

Geometry

Geometry
Linear geometry scaling

\[ s = Sp + t \]

- Scaled point
- Scaling matrix
- Original point
- Translation

Different choices of \( S \) and \( t \) lead to different scaling laws
Scaling laws

Uniform scaling
- Same scaling factor in all directions.
- Does not seem to fit well with empirical data.

Length-mass scaling
- Scale the length to fit the longitudinal dimension and scale the width to maintain the specified mass.

Length-mass-fat scaling
- Idea: Take the fat percentage into account.
- The fat percentage can be estimated from the BMI.
- Or it can be measured directly.

This means that the scaling is implemented into the models and not into the system:
- Accessible to all users
- Can be modified by the user
- New scaling methods can be defined by users

\[
S = \begin{bmatrix}
  k_L \\
  k_L \\
  k_L 
\end{bmatrix}
\]
Friction is very important in order to obtain the correct boundary conditions between human models and environment elements such as seats, floors and handles.

A true Coulomb friction element have been added to the models. It is a combination of general muscles and linear combination measures.

The arrangement exploits the muscle recruitment to link normal and friction forces in such a way that friction is limited by the normal force but friction can be smaller than the maximally available value.

The friction element can be used very easily by using an include file, which are a part of the Repository.
BRep/Aalborg/Toolbox: Conditional contact

The new version 2.0 of AnyBody allows for user defined muscle strength definitions and it is possible to have dependency on kinematic measures such as distances.

This makes it easy to define contact which are conditional and dependent on distances.

Conditional muscle creates the contact force between foot and pedal.
ARep stands for "Application Repository", and it contains a collection of applications which are all based on BRep body parts. This slide shows a typical structure of an application model.
This slides gives an overview of the applications in the ARep Aalborg directory branch.

New applications are constantly being added.

The repository contains a wide variety of models, if you are trying to model a specific case, it is normally a good idea to start with one of the applications as a basis for your model.
## Application Categories

This table tries to categorize some of the features of the models

<table>
<thead>
<tr>
<th>Model</th>
<th>FullBody Model</th>
<th>Friction</th>
<th>Conditional contact</th>
<th>Marker driven</th>
<th>Center of mass drivers</th>
<th>Mannequin driven</th>
<th>Driven by environment and mannequin</th>
<th>Initial pos. from mannequin</th>
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<tbody>
<tr>
<td>GearStick</td>
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</table>
FreePosture

This is a full body model, the pelvis is locked to the environment.

The main file of the model is:
Arep/Aalborg/FreePosture/FreePosture.main.any

This model can be used for driving a fullbody model into any static posture, simply by setting the joints angles on the human model. These are all controlled from a the file "Mannequin.any"

Example from the file "Mannequin.any"

```
AnyVar HipFlexion = 0.0;
AnyVar HipAbduction = 50.0;
AnyVar HipExternalRotation = 0.0;
```

ARep :FreePosture
FreePostureMove

This is a full body, the pelvis is locked to the environment.

The main file of the model is:
Arep/Aalborg/FreePostureMove/FreePostureMove.main.any

This example can be used for driving the motion of a fullbody model. All joints are equipped with interpolation drivers. In the mannequin file it is possible to give vectors for each joint that will be used for interpolation it’s motion. These are all controlled from a the file ”Mannequin.any”

Example from the file ”Mannequin.any

```
AnyVector  HipTime = .TimeSerie3;
AnyVector  HipFlexion = { 0,0,0};
AnyVector  HipAbduction = { 0,90,0,0};
AnyVector  HipExternalRotation = { 0,0,0};
```

ARep :FreePosture
Standing model

The human model is made using the body collection directory

"BRep/BodyModels/FullBodyModel"

The main file of the model is:

ARep/Aalborg/StandingModel/StandingModel.main .any

What can the model be used for?
• This is a good starting point for applications using full body models, since the posture of the model is controlled through a mannequin file.

ARep : StandingModel
Gait modeling

The human model is made using the body collection directory
Brep/BodyModels/TwoLegs

The main file of the model is:
Arep/Aalborg/Gait3D/AnyGait.main.any
Gait data set

To have something fairly standardized and accessible, we grabbed the motion data and ground reaction force measurements from the book by Vaughan et al: Dynamics of Human Gait.

These data sets are available to the public domain from http://isbweb.org/o/content/view/66/73/. We used the "Man" dataset.
Driving the model with markers

All markers from the dataset are present in the model. They can be seen as the grey spheres. The position of these markers are controlled from the dataset.

Corresponding markers are defined on the bones. They can be seen as the blue spheres.
18 Drivers

The model is driven by requiring coincidence between the free floating markers (grey) and the markers on the bones (blue) for selected DOFs.
Seated human model

The human model is made using the body collection directory
"BRep/BodyModels/FullBodyModel"

The main file of the model is:
ARep/Aalborg/SeatedHuman/SeatedHuman.main.any

This is a model comprising the full body model, a chair and an interface between them. The interface is made such that the posture of the body is dependent of the settings if the chair.
BikeFullBody

This is a full body model of a bicycle rider

The main file of the model is:
Arep/Aalborg/BikeFullBody/BikeModel.main.any

Various parameters such as saddle position, cadence etc can be controlled from this file.

Since the model has 501 muscles it runs fairly slowly!
Bike3D

This is a bike model which utilizes the Leg3D model and the spine model with no muscles on.

The human model is made using the body collection directory

"Brep/BodyModels/SpineNoMusclesTwoLegs"

The main file of the model is:
Arep/Aalborg/Bike3D/BikeModel.main.any

Various parameters such as saddle position, cadence etc. can be controlled from this file.

ARep : Bike3D
Egress

The human model is made using the body collection directory
"Brep/BodyModels/FullBodyModel

The main file of the model is:
Arep/Aalborg/Egress/Egress.main.any

What can the model be used for?

This egress model demonstrates how the position of an assistive handle on the window frame influences the knee joint forces as well as the muscular effort of egress.
Pushup

The human model imported from the body collection directory

"BRep/BodyModels/FullBodyModel"

The main file of the model is:

ARep/Aalborg/StandingModel/Pushup.main.any

What can the model be used for?

• This is a good starting point for applications using full body models.
• The model has been used for adjusting the strength between the different muscle groups
ArmCurl

This is a full body model of a person doing an arm curl.

The main file of the model is:
Arep/Aalborg/ArmCurl/ArmCurl.main.any

In this example we have optimized the eccentricity of the wheel that the cable winds about to obtain an almost constant muscle effort throughout the arm curl.

Since the model has 501 muscles it runs fairly slowly!

ARep : ArmCurl
WheelChair

The human model is made using the body collection directory
"BRep/BodyModels/SpineTwoArms"

The main file of the model is:
ARep/Aalborg/WheelChair/WheelChair.main.any

This is a model of a person sitting in a wheelchair. The model only comprises the upper body including the pelvis.

Purpose: Investigation of wheelchair ergonomics.
We hope that the models will be

- downloaded
- improved
- validated for particular purposes
- used for solving development and research questions

The models require the AnyBody Modeling System v.2.0
Online resources

• The AnyBody Modeling System
  – Free demo license
    www.anybodytech.com
  – Email: anybody@anybodytech.com

• The AnyBody Research Project
  anybody.auc.dk
  – Public domain library of body models and applications
Thank you!
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