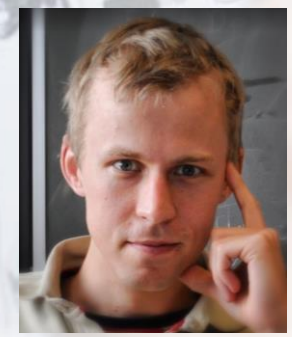
The new AnyBody Modeling System & Musculoskeletal Model Repository

TOUR AND OVERVIEW OF THE NEW 7.3 VERSION

Outline

- New features in the Modeling System 7.3
  - Core features
  - User interface features
  - New Reference manual and documentation
- New Model Repository (AMMR 2.3)
- Questions and answers



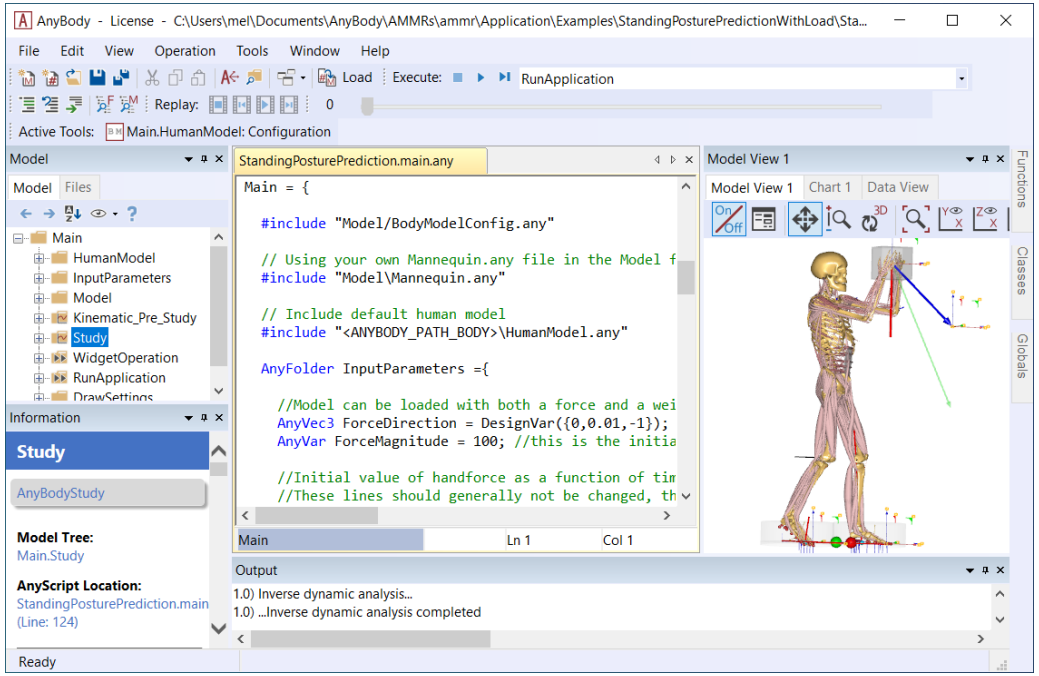
Morten Enemark Lund
Sr. Consultant
R&D Engineer
AnyBody Technology

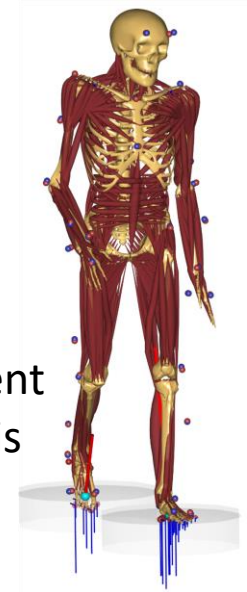
Musculoskeletal Simulation

Motion Data
Kinematics and Forces

ANYBODY
Modeling System

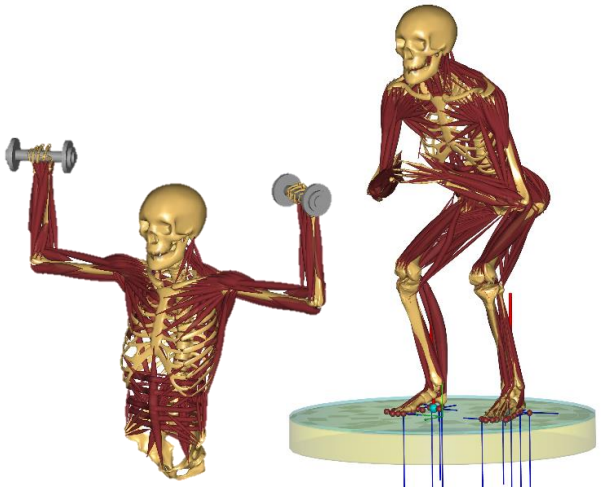
Body Loads
- Joint moments
- Muscle forces
- Joint reaction forces





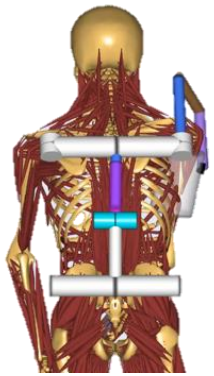
Movement Analysis

Product optimization design

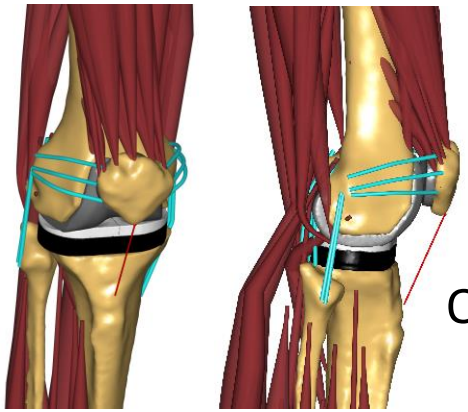


Sports

ANYBODY Modeling System



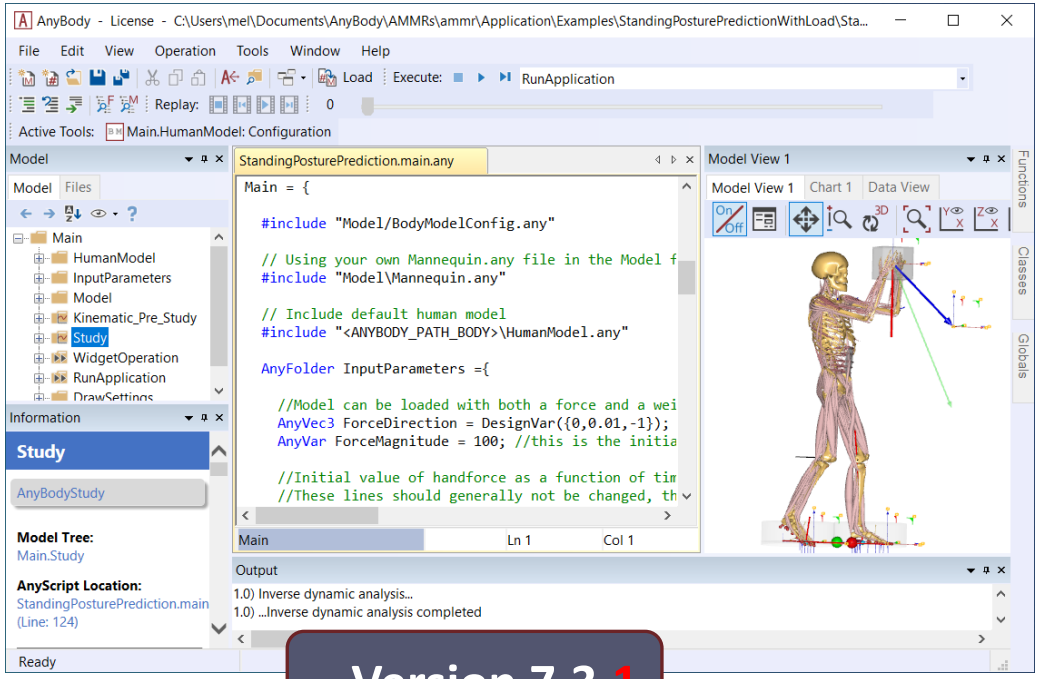
Assistive Devices



Orthopedics and rehab

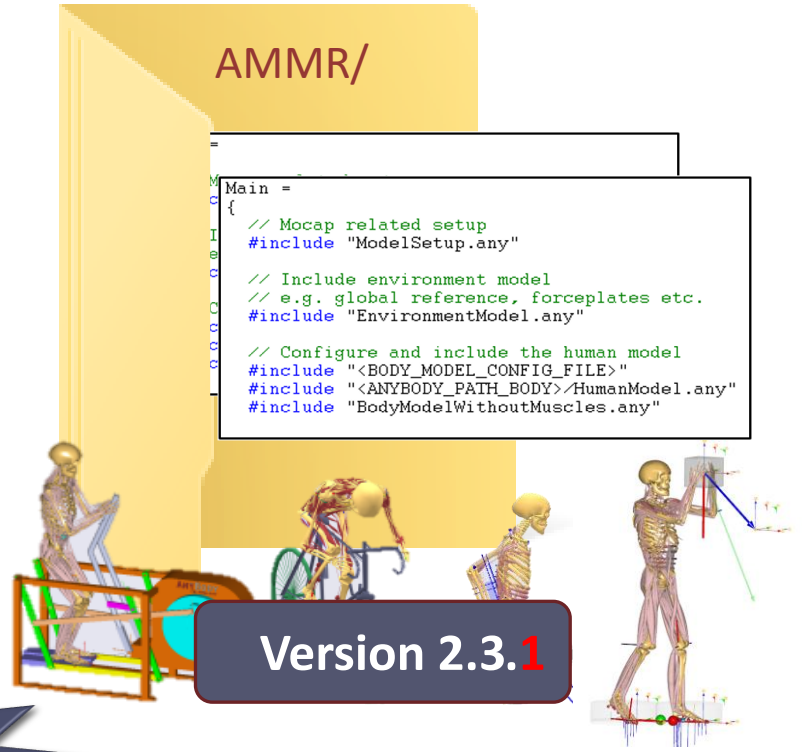
New AnyBody release

AnyBody Modeling System



Version 7.3.1

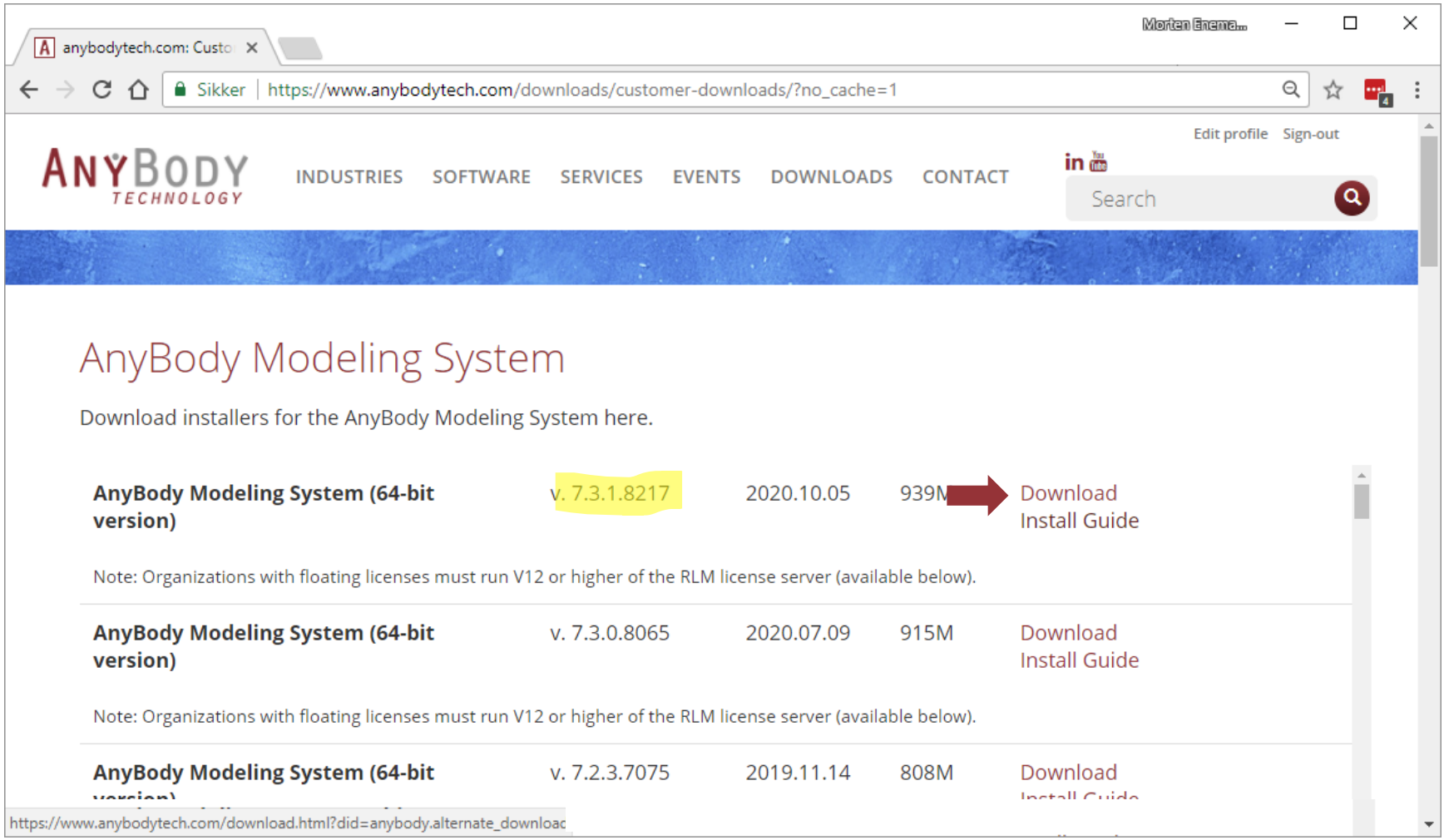
Model Repository

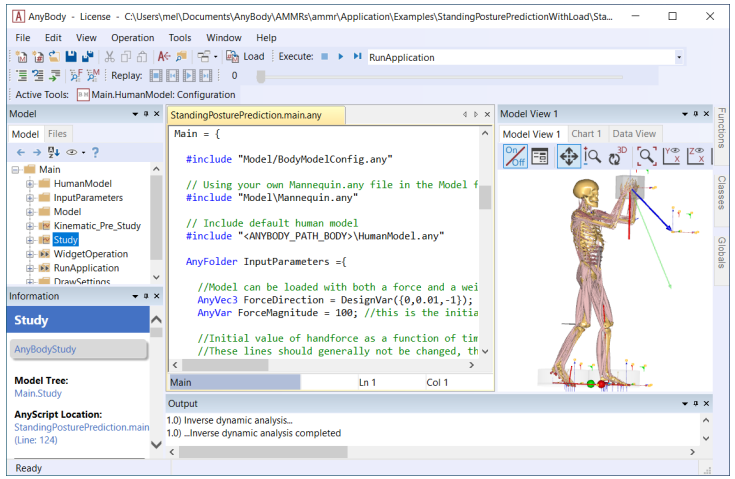


Version 2.3.1

Just released!

How to get the new version?





New features

IN THE ANYBODY MODELING SYSTEM 7.3

Core system improvements

25 % Faster load times

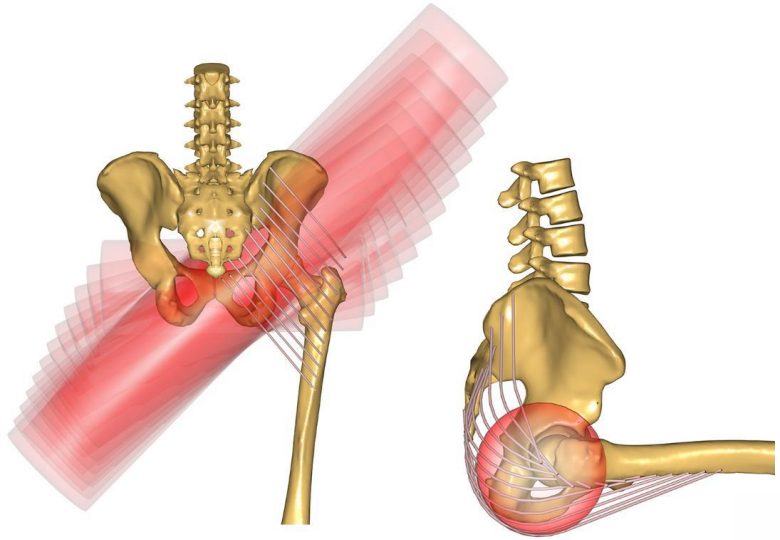
Faster simulation times

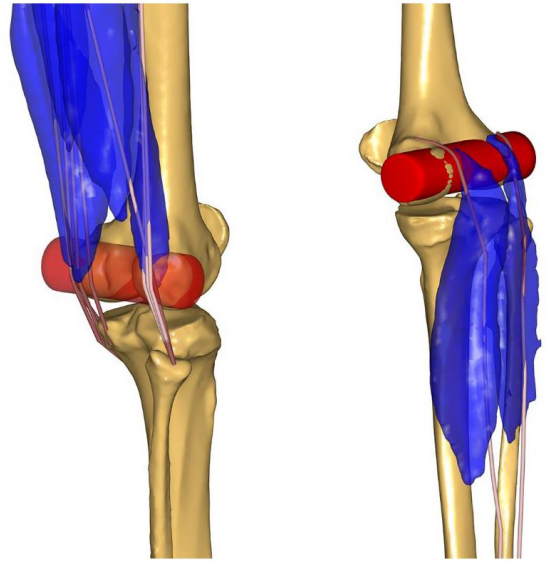
New wrapping algorithm

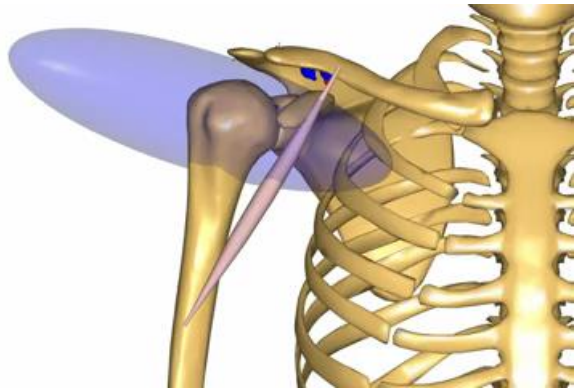
More robust muscle wrapping

What is muscle wrapping

Idealized objects guides the muscle paths.

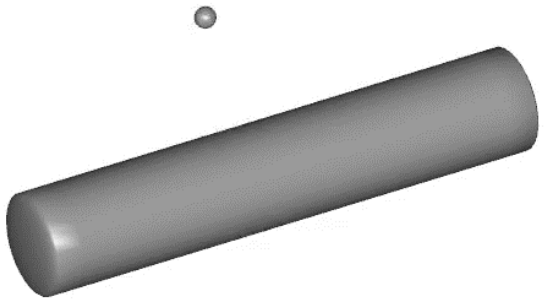






New wrapping algorithm

Old

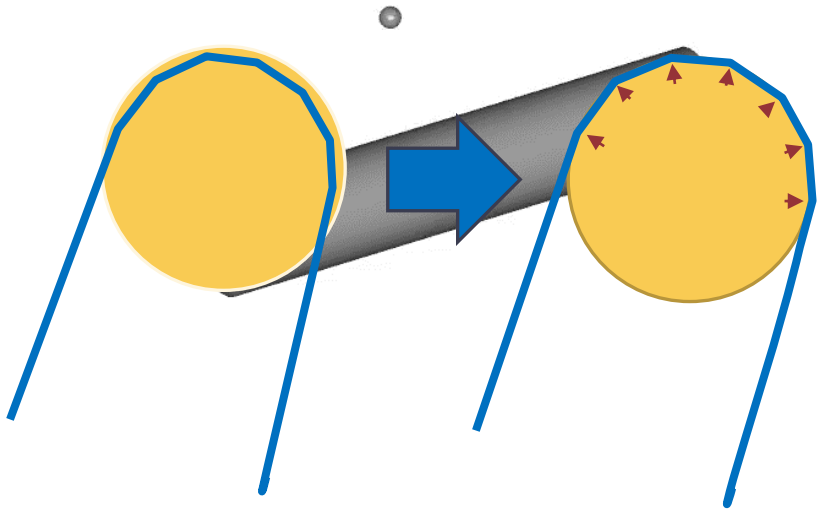


Default algorithm in 7.2

New

30x faster

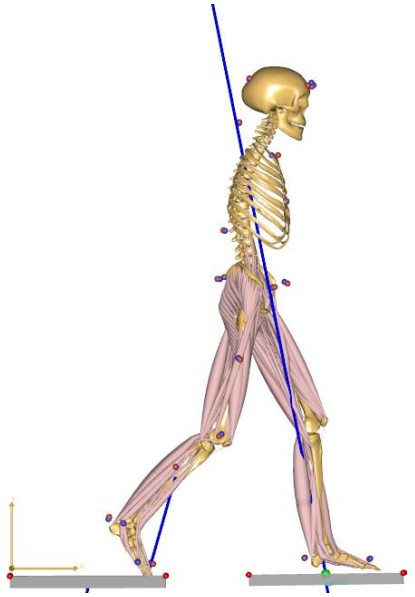
- New two step algorithm:
  1. Initial solve with penetration
  2. Final pushout onto the surface

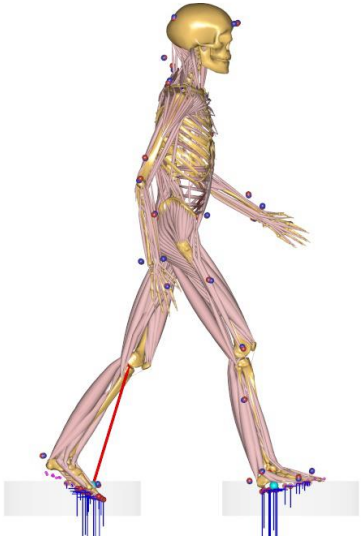


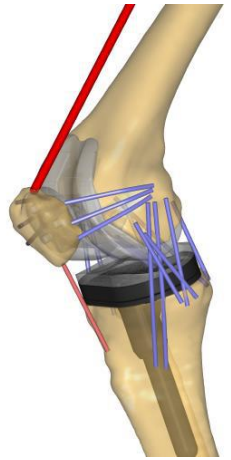
Experimental in 7.3

Default in 7.3.1

Speed improvements

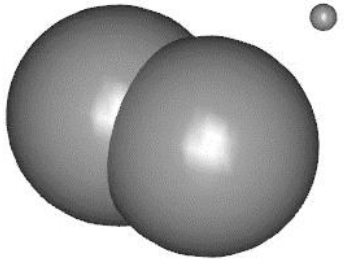


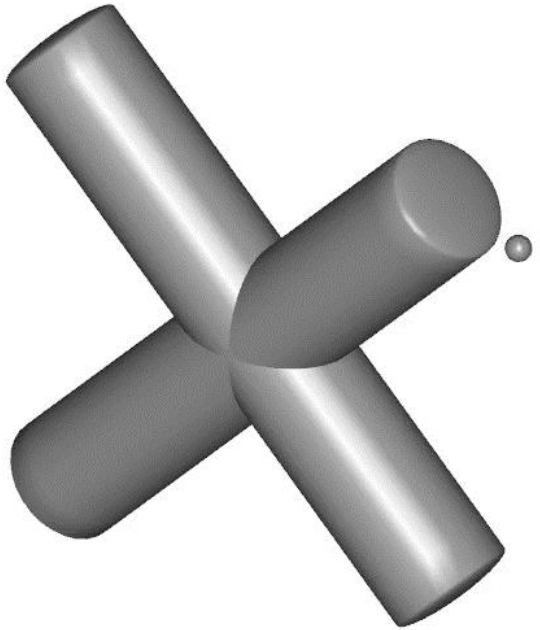




Model	Analysis	Old	New	Speed up
Lower extremity MoCap	Inverse Dynamics			

Multiple surfaces gives more options





Acknolegements

Ideas from:

- Lloyd, J., Roewer-Despres, F. & Stavness, I. Muscle Path Wrapping on Arbitrary Surfaces. IEEE Trans. Biomed. Eng. PP, (2020)

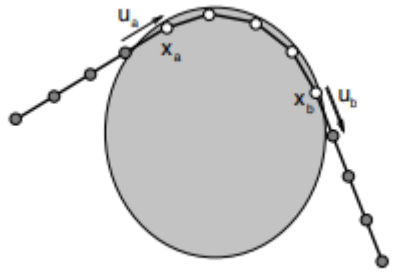
Conveniently, from (3), we see that $\mathbf{K}$ is block tridiagonal:

$$\mathbf{K} = K \begin{pmatrix} -2\mathbf{I} & \mathbf{I} & & & \\ \mathbf{I} & -2\mathbf{I} & \mathbf{I} & & \\ & \mathbf{I} & \ddots & \ddots & \\ & & \ddots & \ddots & \mathbf{I} \\ & & & \mathbf{I} & -2\mathbf{I} \end{pmatrix} + \nabla \mathbf{f}_c \qquad (5)$$

where $\nabla \mathbf{f}_c$ is a block diagonal matrix consisting of 3×3 blocks which are 0 for knots not in contact and $\nabla \mathbf{f}_{c,k}$ for knots that are. From (1) and (2), we have that

$$\begin{aligned} \nabla \mathbf{f}_{c,k} &= -K_c \mathbf{n}_k \nabla \phi(\mathbf{x}_k) - K_c d_k \nabla^2 \phi(\mathbf{x}_k) \\ &= -K_c \mathbf{n}_k \mathbf{n}_k^T - K_c d_k \nabla^2 \phi(\mathbf{x}_k). \end{aligned}$$

The last term, $-K_c d_k \nabla^2 \phi(\mathbf{x}_k)$, while small, is important to help achieve quadratic convergence in Newton's method.



This article has been accepted for publication in a future issue of this journal, but has not been fully edited. Content may change prior to final publication. Citation information: DOI 10.1109/TBME.2020.3009922, IEEE Transactions on Biomedical Engineering

Muscle Path Wrapping on Arbitrary Surfaces

John E. Lloyd, François Roewer-Després, and Ian Stavness*, *Member, IEEE*

Abstract*— *Objective: **Musculoskeletal models play an important role in surgical planning and clinical assessment of gait and movement. Faster and more accurate simulation of muscle paths in such models can result in better predictions of forces and facilitate real-time clinical applications, such as rehabilitation with real-time feedback. We propose a novel and efficient method for computing wrapping paths across arbitrary surfaces, such as those defined by bone geometry. *Methods:* A muscle path is modeled as a massless, frictionless elastic strand that uses artificial forces, applied independently of the dynamic simulation, to wrap tightly around intervening obstacles. Contact with arbitrary surfaces is computed quickly using a distance grid, which is interpolated quadratically to provide smoother results. *Results:* Evaluation of the method demonstrates good accuracy, with mean relative errors of 0.002 or better when compared against simple cases with exact solutions. The method is also fast, with strand update times of around 0.5 msec for a variety of bone shaped obstacles. *Conclusion:* Our method has been implemented in the open source simulation system ArtiSynth (www.artisynth.org) and helps solve the problem of muscle wrapping around bones and other structures. *Significance:* Muscle wrapping on arbitrary surfaces opens up new possibilities for patient-specific musculoskeletal models where muscle paths can directly conform to shapes extracted from medical image data.**

***Index Terms*—Biomechanics, musculoskeletal modeling, muscle wrapping, real-time simulation, signed distance field, geodesic.**

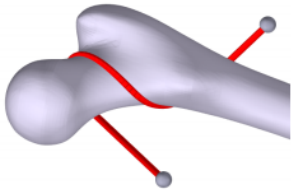


Fig. 1. Muscle strand wrapped around an arbitrary surface.

I. Introduction

MUSCULOSKELETAL simulations are increasingly being used to quantify the neuromuscular activity in a range of clinical applications including analysis of ankle [1] and shoulder [2] injuries and real-time control of prostheses [3], [4]. Line-based muscle models, represented as mass-

Simulation of thin strands and cables has been proposed in computer graphics studies for simulating cable-driven machines. These include adapted via point techniques [6], efficient cable-pulley mechanisms [7], frictional contact between wires and surfaces [8], and highly constrained cables that include both contact and routing through tunnels [9]. While primarily used for abstract mechanical systems, some of these approaches have been transferred to modeling musculoskeletal systems, notably for the musculotendon units in the hand [10].

The majority of muscle wrapping approaches in musculoskeletal models, however, have been limited to obstacles described by simple analytic shapes (e.g., cylinders, spheres, tori) or smooth parametric surfaces. The use of smooth shapes makes it simpler to compute shortest-distance paths and ensures smooth path evolution [11]. However, such approximations may have low fidelity with respect to the true obstacle surface, e.g. the humeral head and shaft are usually

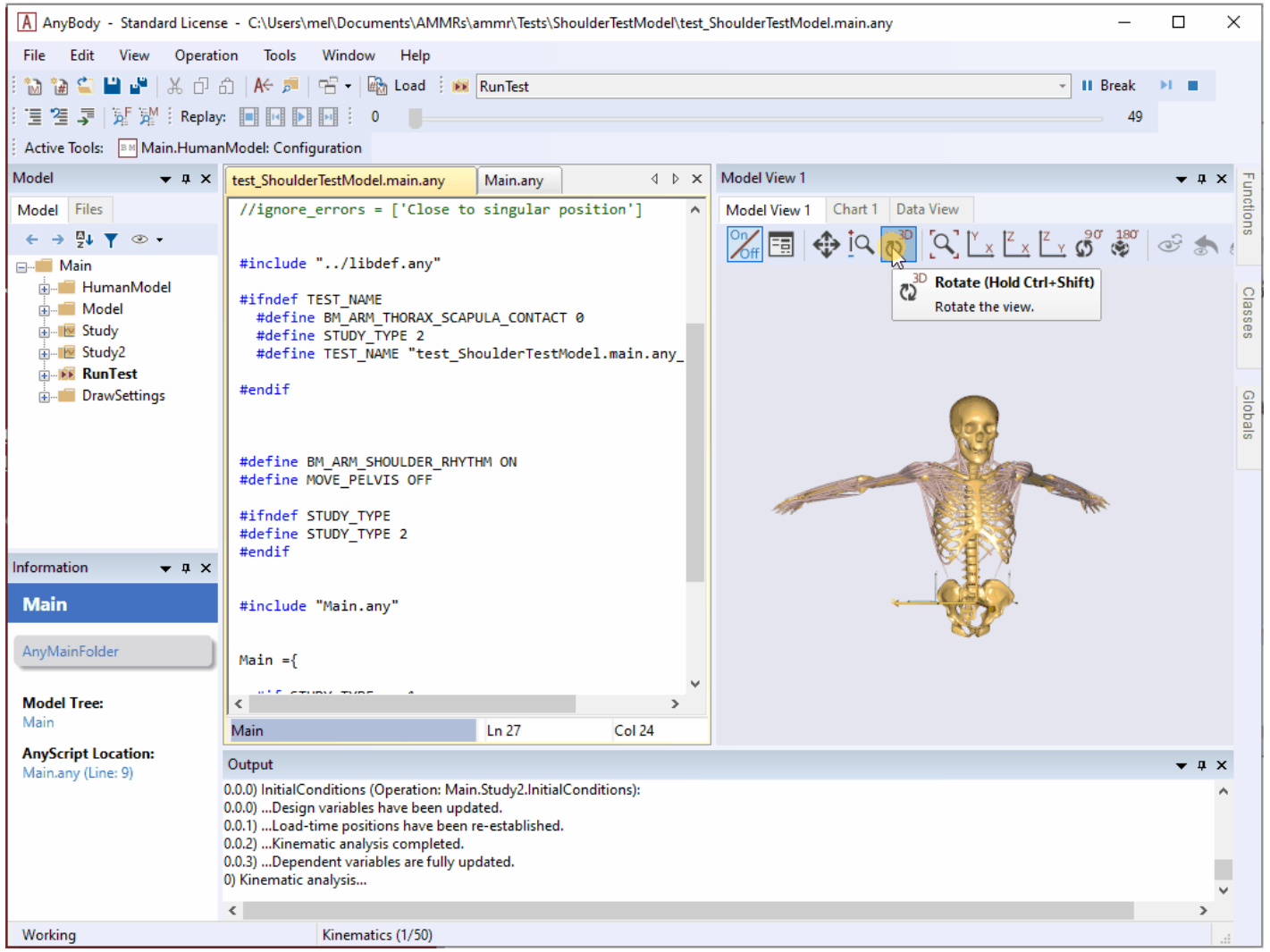
Improvements to user interface

Smoother model view when running simulations

Model view persists across reloads

New hierarchical model view

New reference manual



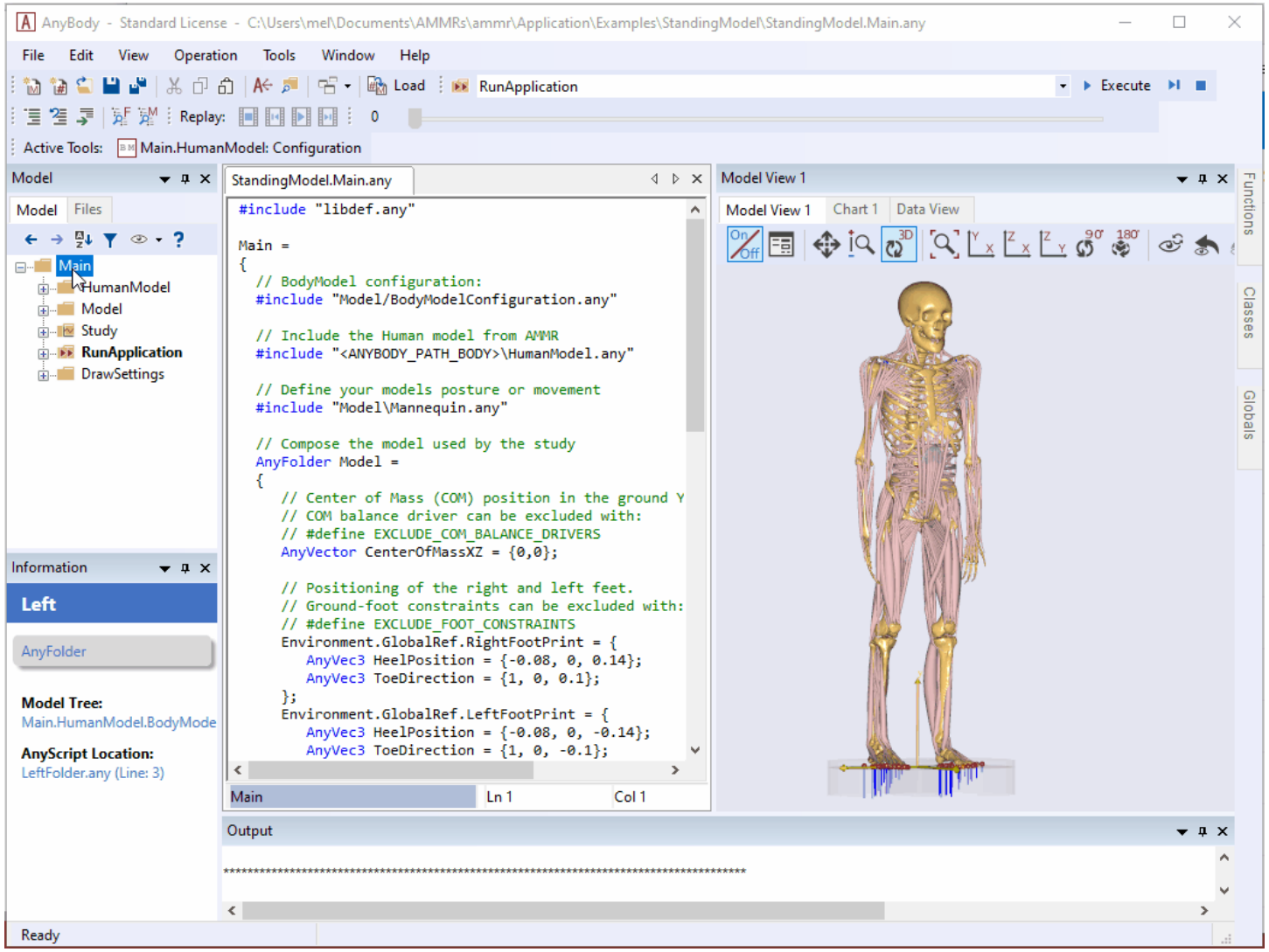
Improvements to user interface

Smoother model view when running simulations

Model view undo/redo/persistence

New hierarchical model view

New reference manual



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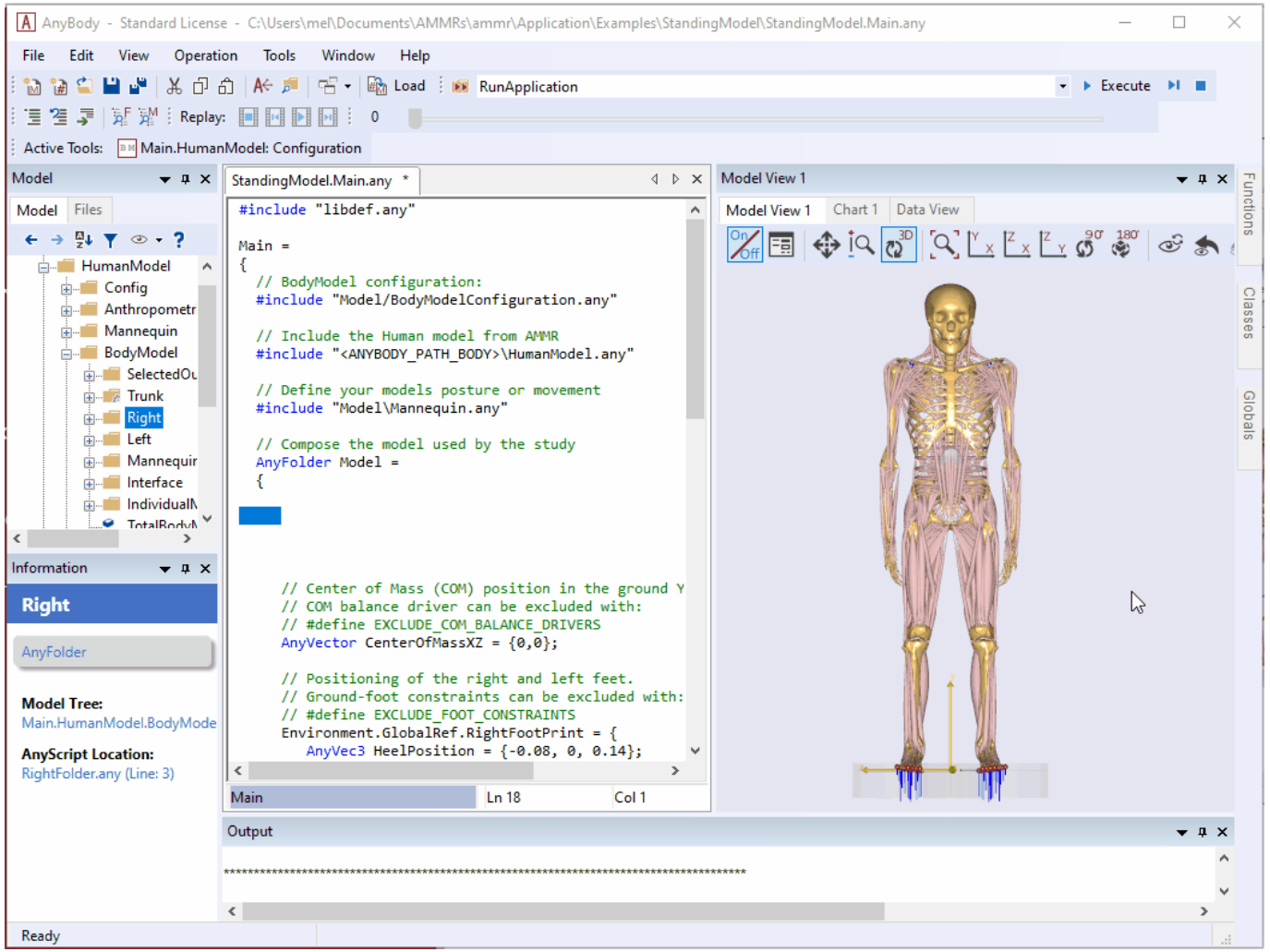

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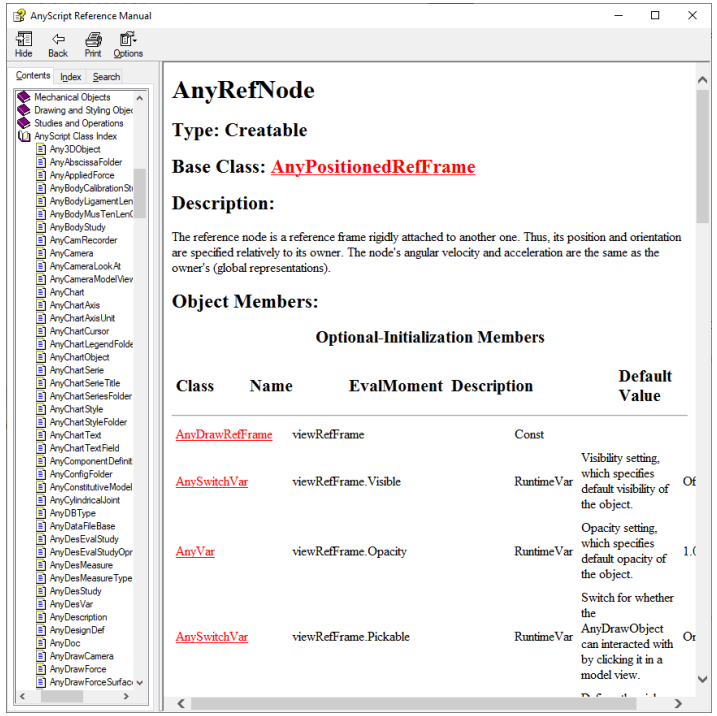
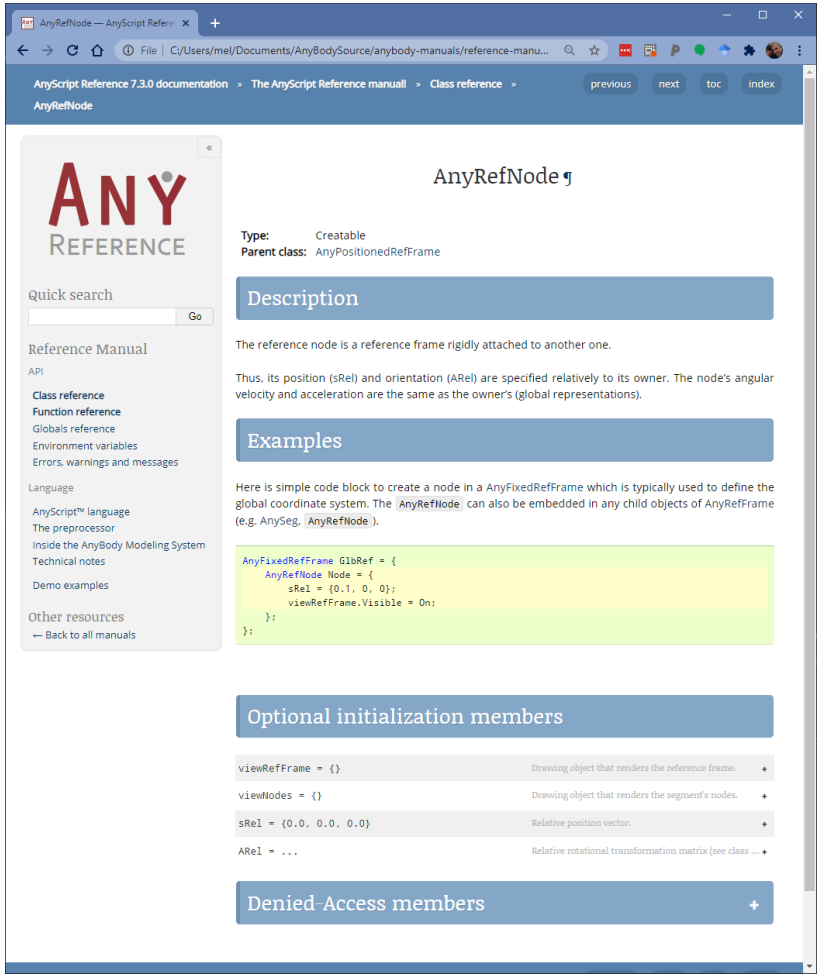
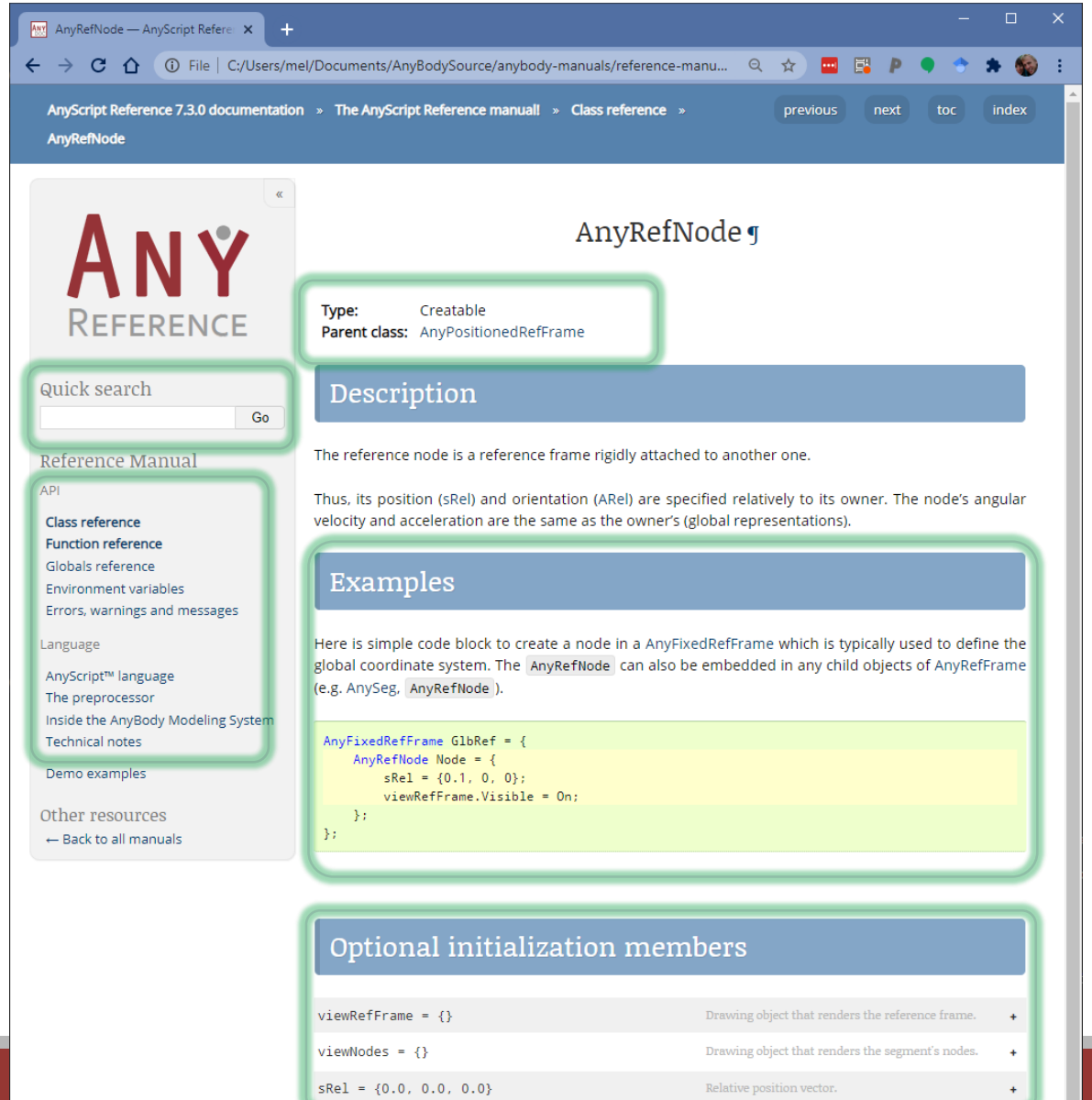


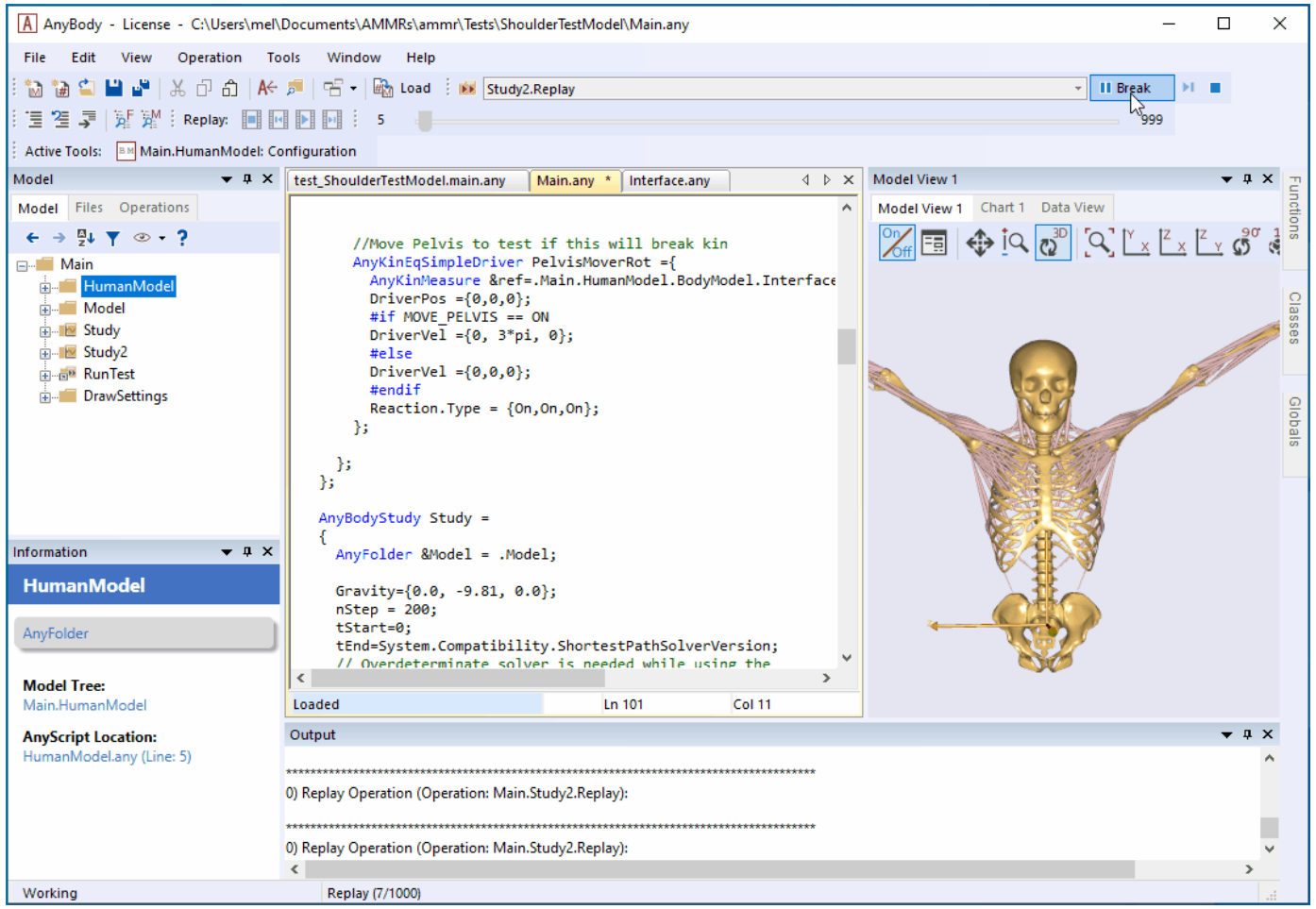


Documentation: Reference Manual

- Quick search
- Type/parent/child links
- Examples/snippets for some classes
- Class member descriptions
- More info on Classes/functions



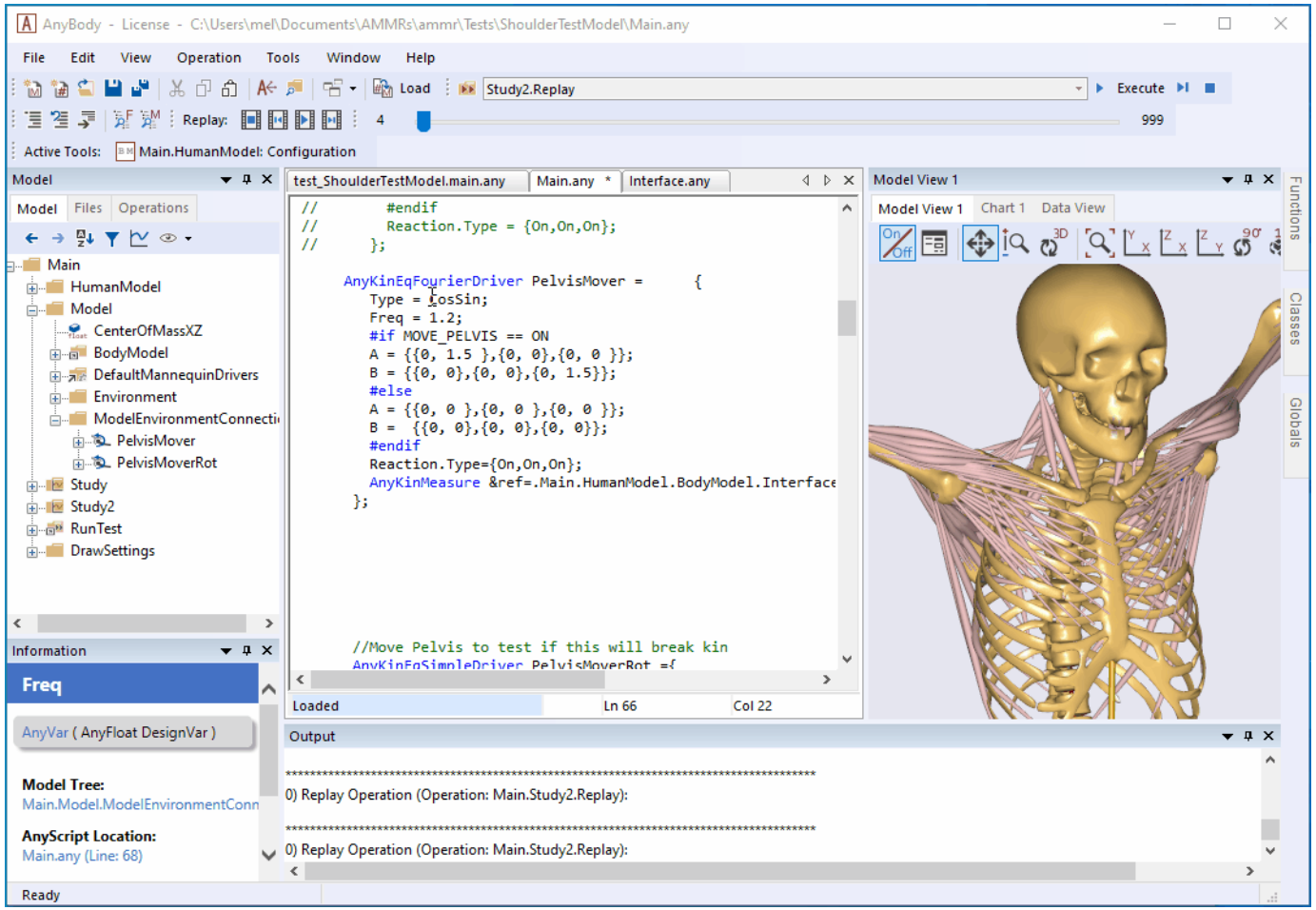
New reference manual



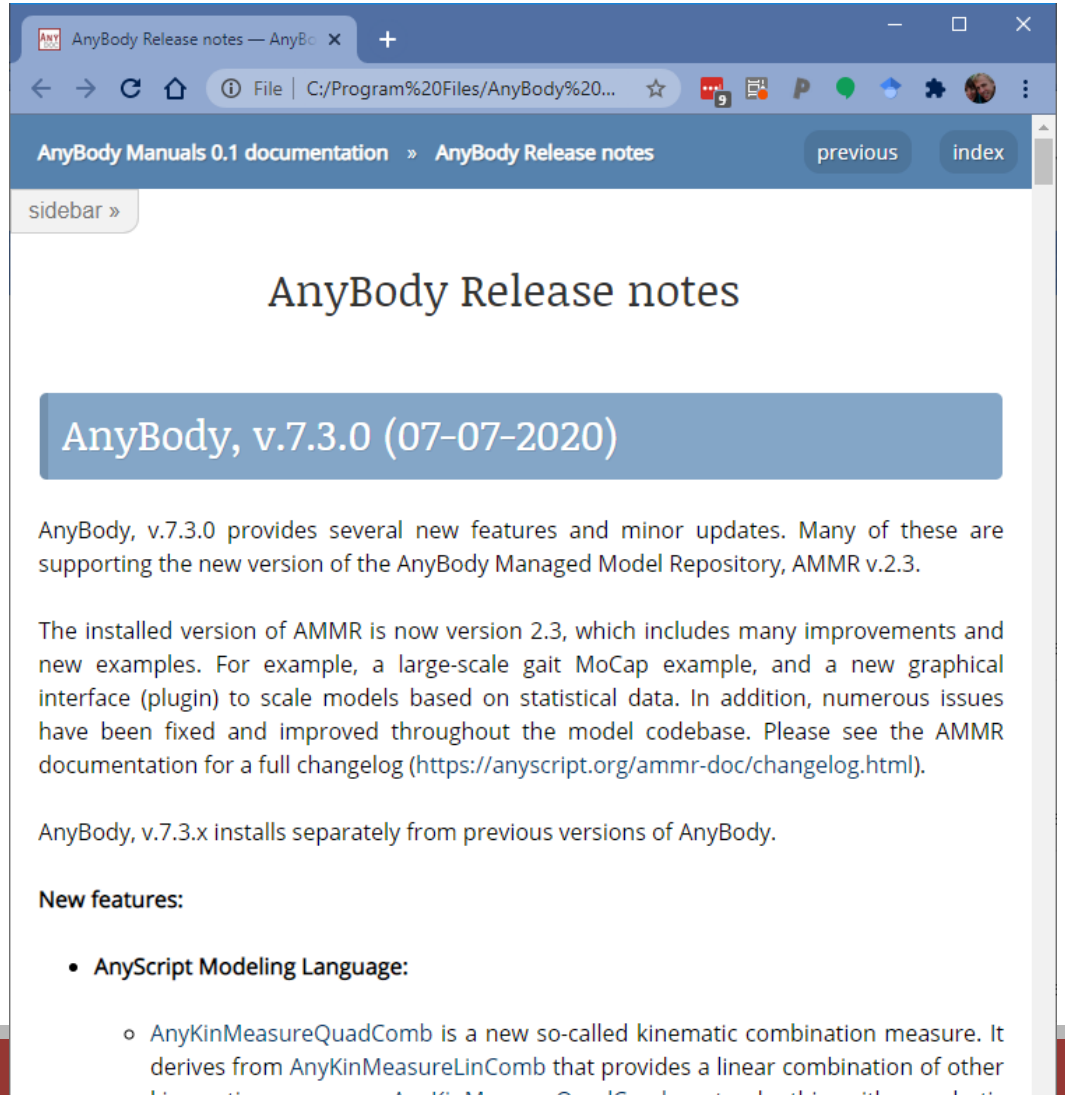
- In the help menu:
  - Help->Reference Manual

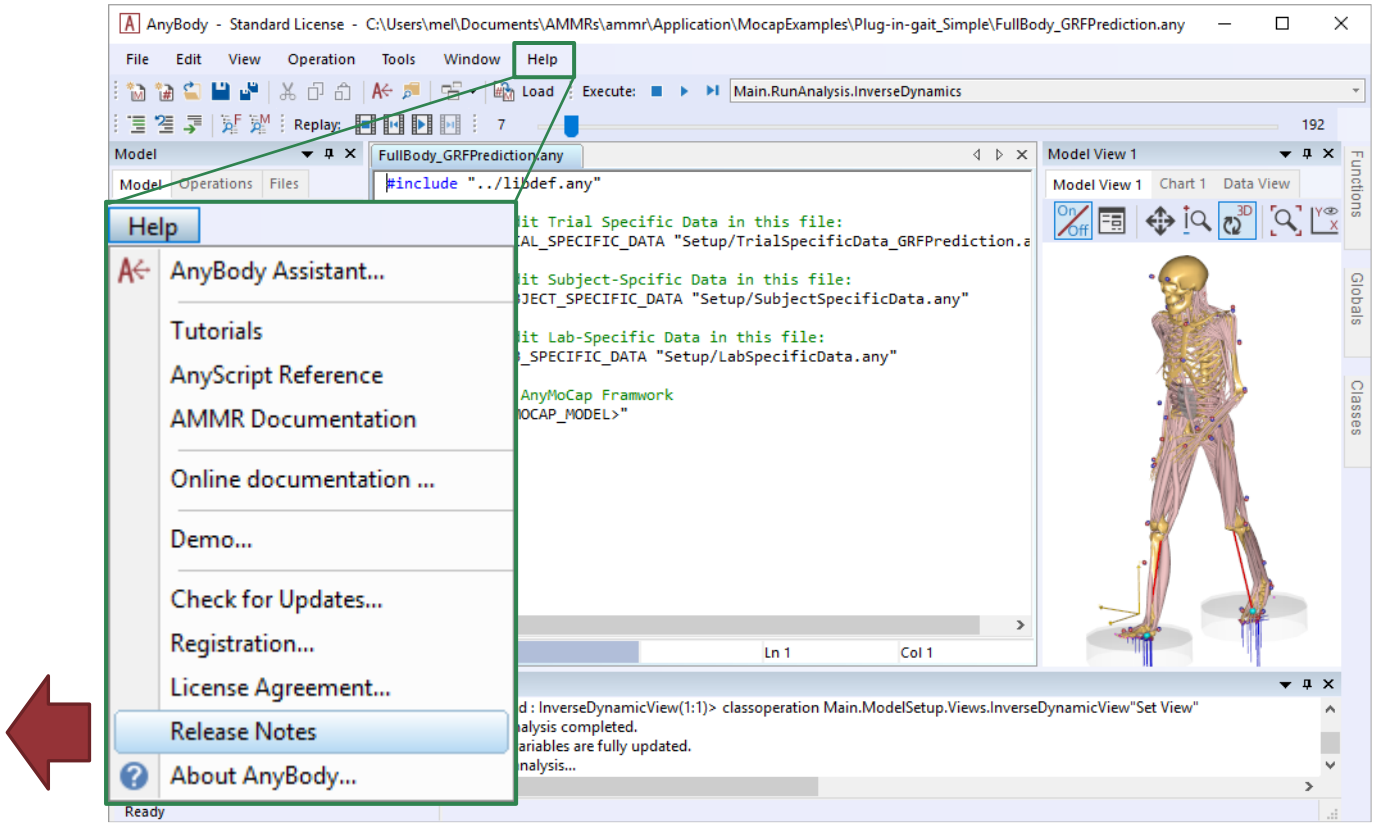
New reference manual

- By pressing F1:
  - In the model tree: selected objects
  - In the editor: cursor on class or functions.



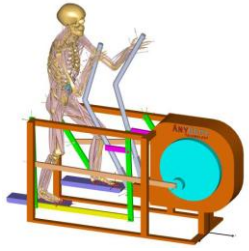
What else has changed in AnyBody?

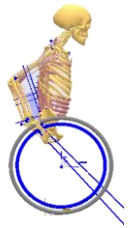
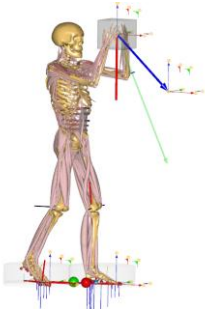




Model repository

WHAT IS NEW IN AMMR 2.3.0/2.3.1



Model Repository (version 2.3.1)

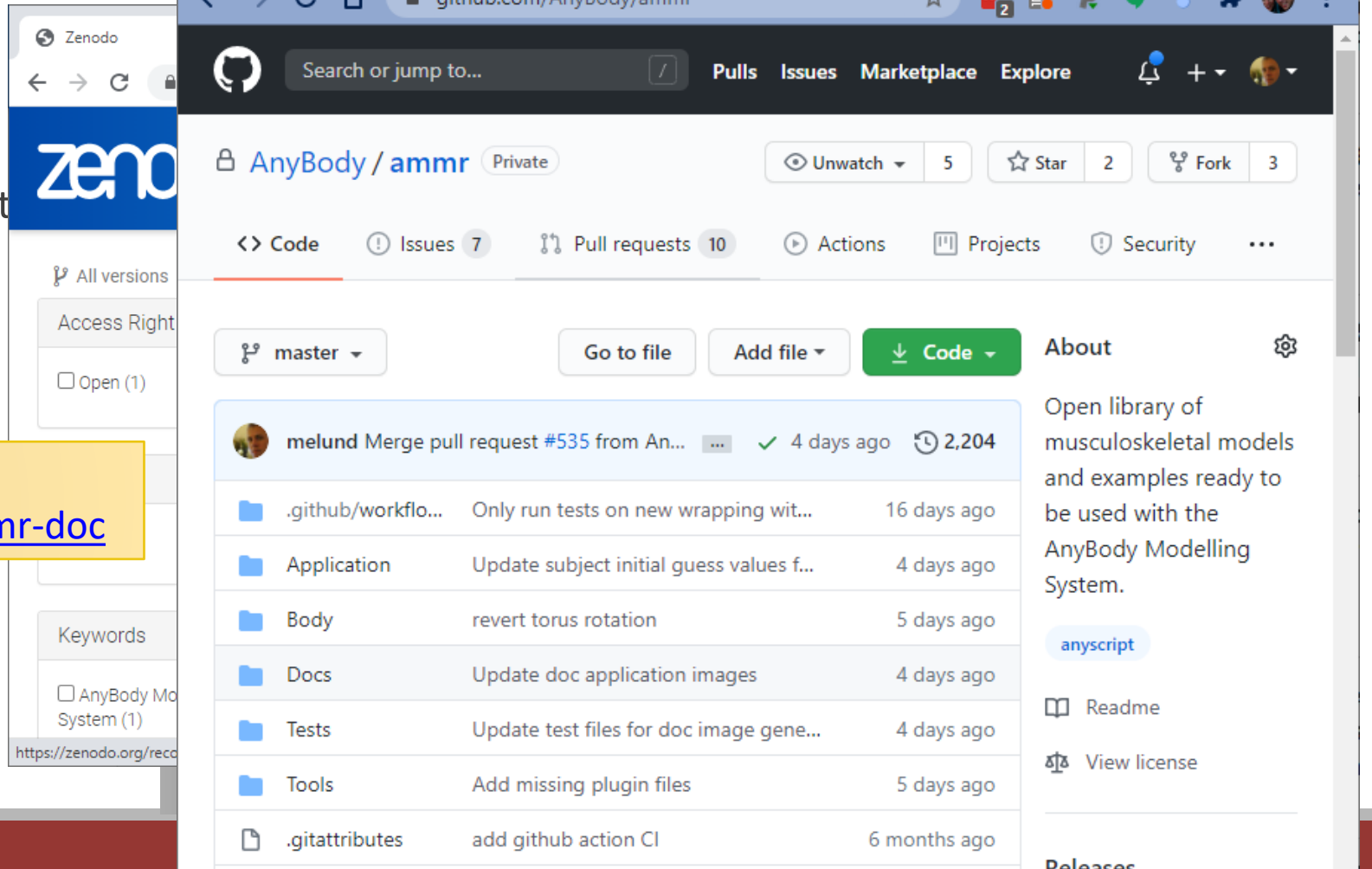
- Development since 2.2 (last December)
  - 90+ pull requests / 350 commits
  - Many contributions from users on GitHub.
- New model examples and improved body models
- Many fixes and tweaks to performance and robustness

AnyBody **M**anaged **M**odel **R**epository

How to get the model repository…

- Bundled with AnyBody
  - Unpack a version from the AnyBody Assistant
- Archived on Zendo
- From our internal development repository on GitHub

Apply for access here:
https://github.com/AnyBody/ammr-doc



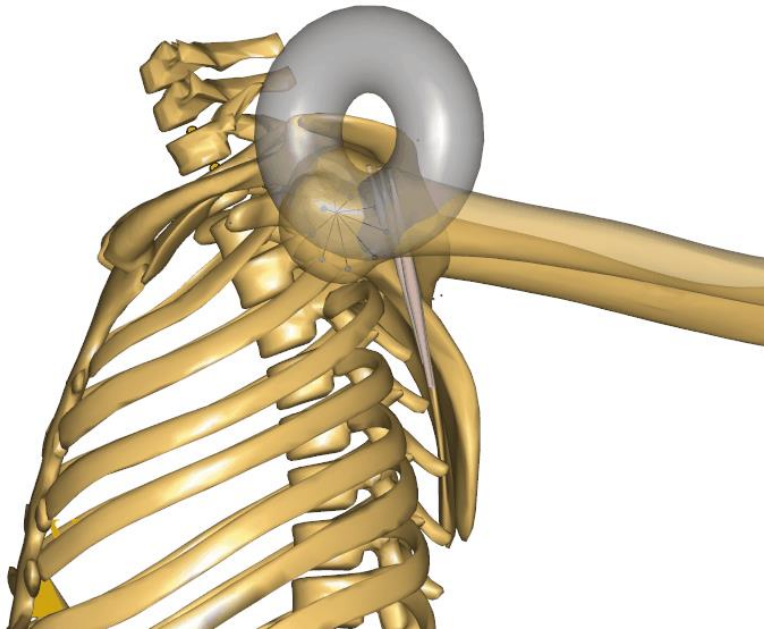
What is new?

Highlights:

1. Improved shoulder rhythm and shoulder wrapping
2. New full body Gait MoCap model
3. New statistical scaling plugin.

Shoulder improvements

- Updated shoulder rhythm
  - De Groot, J. H. *The shoulder: a kinematic and dynamic analysis of motion and loading.* (1998)



- Wrapping improvements many shoulder muscles.
  - Example: Teres minor and torus wrapping

Note: Still room for improvements to shoulder rhythms

Non-linear relationships can be implemented with the class: AnyKinMeasureQuadComb

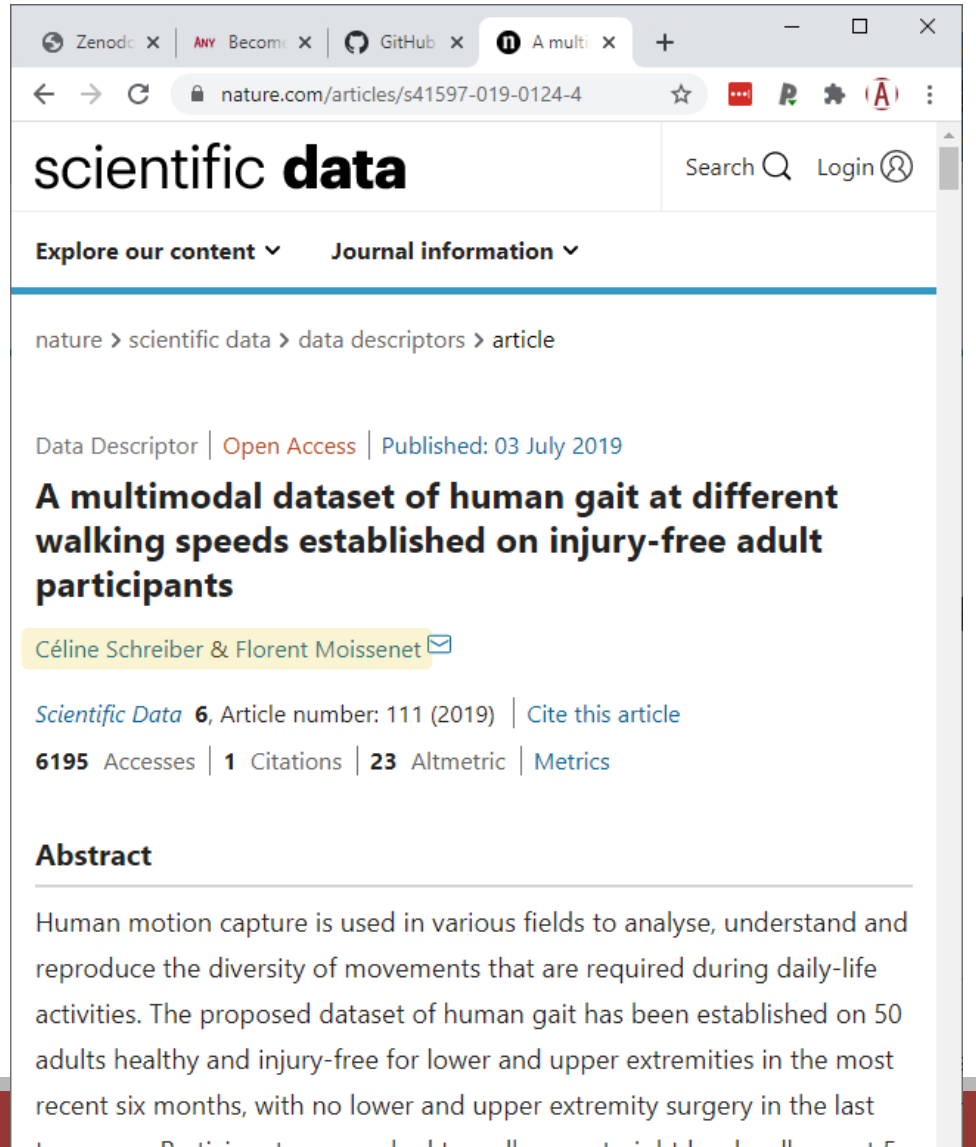
New full body “ADL” gait mocap model

Large pre-configured full body MoCap example

- 50 subjects/1193 trials
- 5 walking speeds

“Rehazenter adult walking dataset”

- Open license - creative commons **(CC BY 4.0)**
  https://doi.org/10.1038/s41597-019-0124-4



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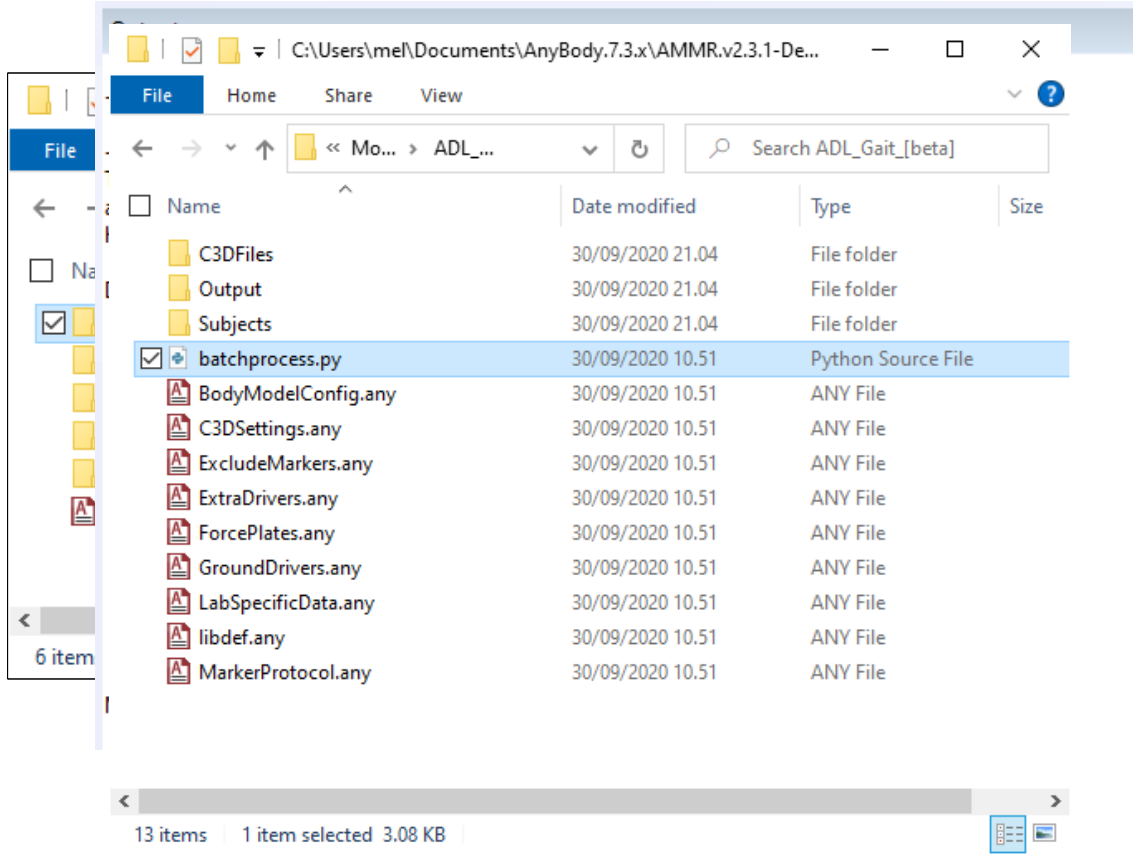
Dataset must be downloaded separately

Scripts for batch processing everything

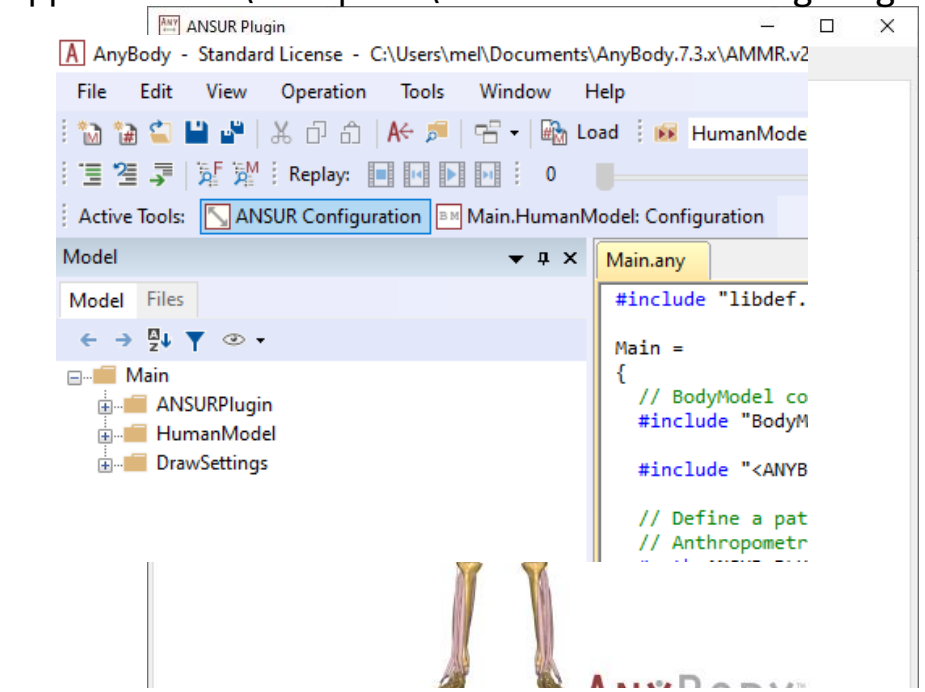


Statistical scaling plugin

- Small tool to create realistic model anthropometry/scaling

- Based on ANSUR anthropometric database
  - 1700 men / 2200 women

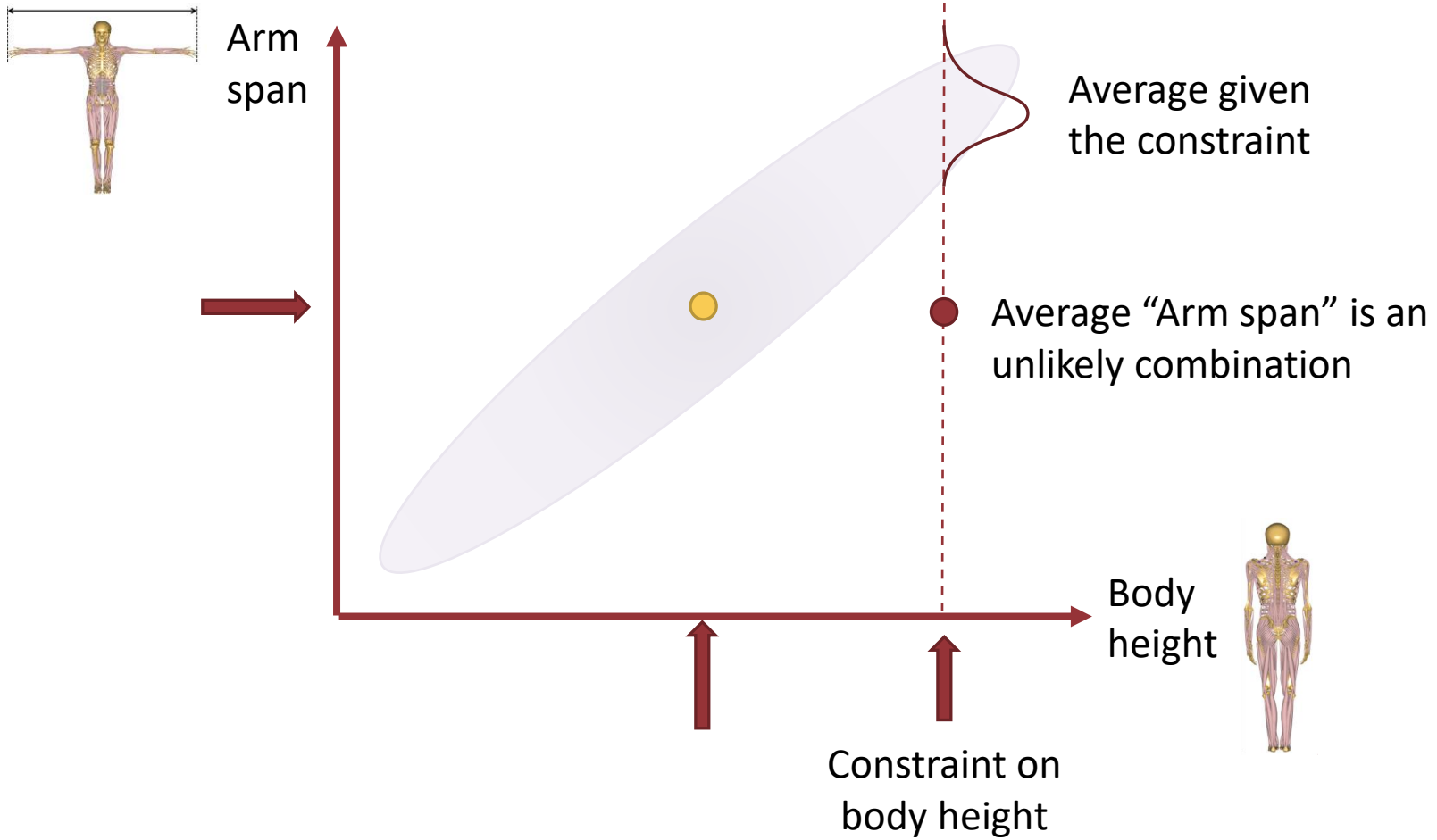
`Application\Examples\StatisticalScalingPlugin`




```
#include "<ANYBODY_PATH_AMMR>/Tools/Plugins/ANSUR_Plugin.any"

// Define a path variable so the plugin knows where to write
// Anthropometric information.
#path ANSUR_PLUGIN_ANYMAN_FILE "AnyMan_ANSUR.any"
#include "<ANSUR_PLUGIN_ANYMAN_FILE>"
```

Anthropometry is correlated



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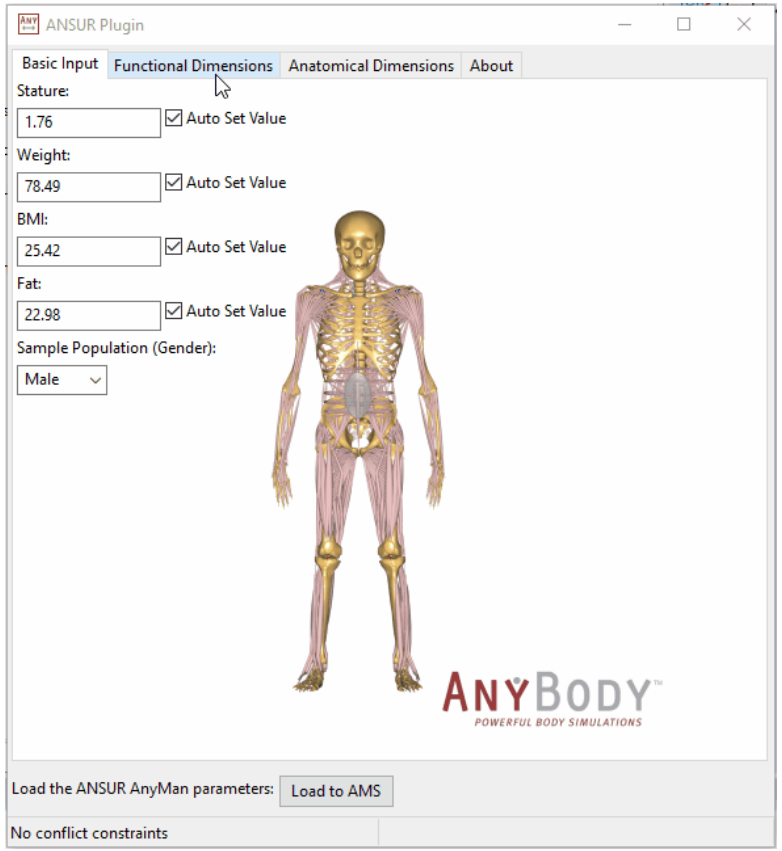
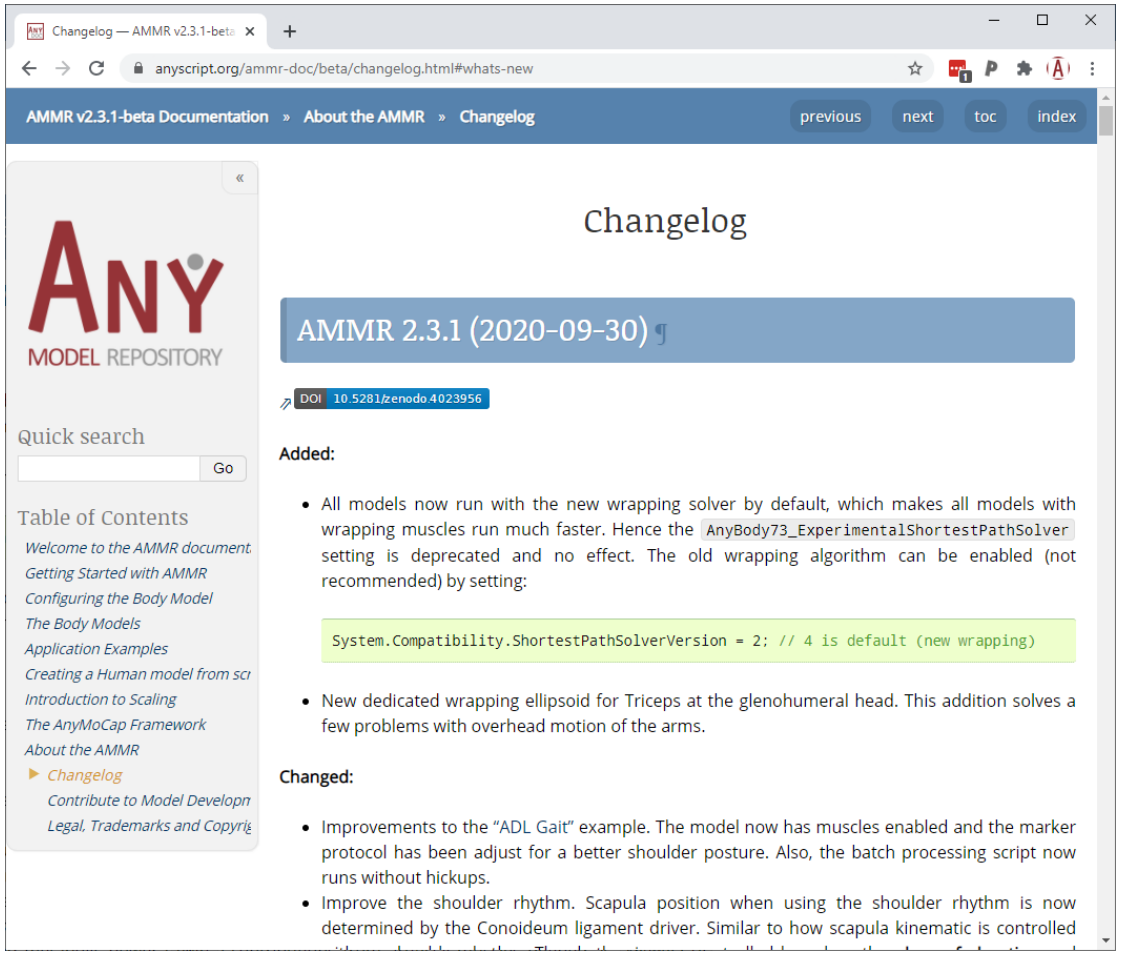


What else has changed?

- Improvements/bugfixes….
  - BVH marker protocol improvements -> triggers warning when using old models
  - Improvements to muscles/wrapping surfaces in many places
  - Stability improvements for MoCap models.

+40 different improvements/bug fixes

anyscript.org/ammr-doc



www.anybodytech.com

- Events, dates, publication list, ...

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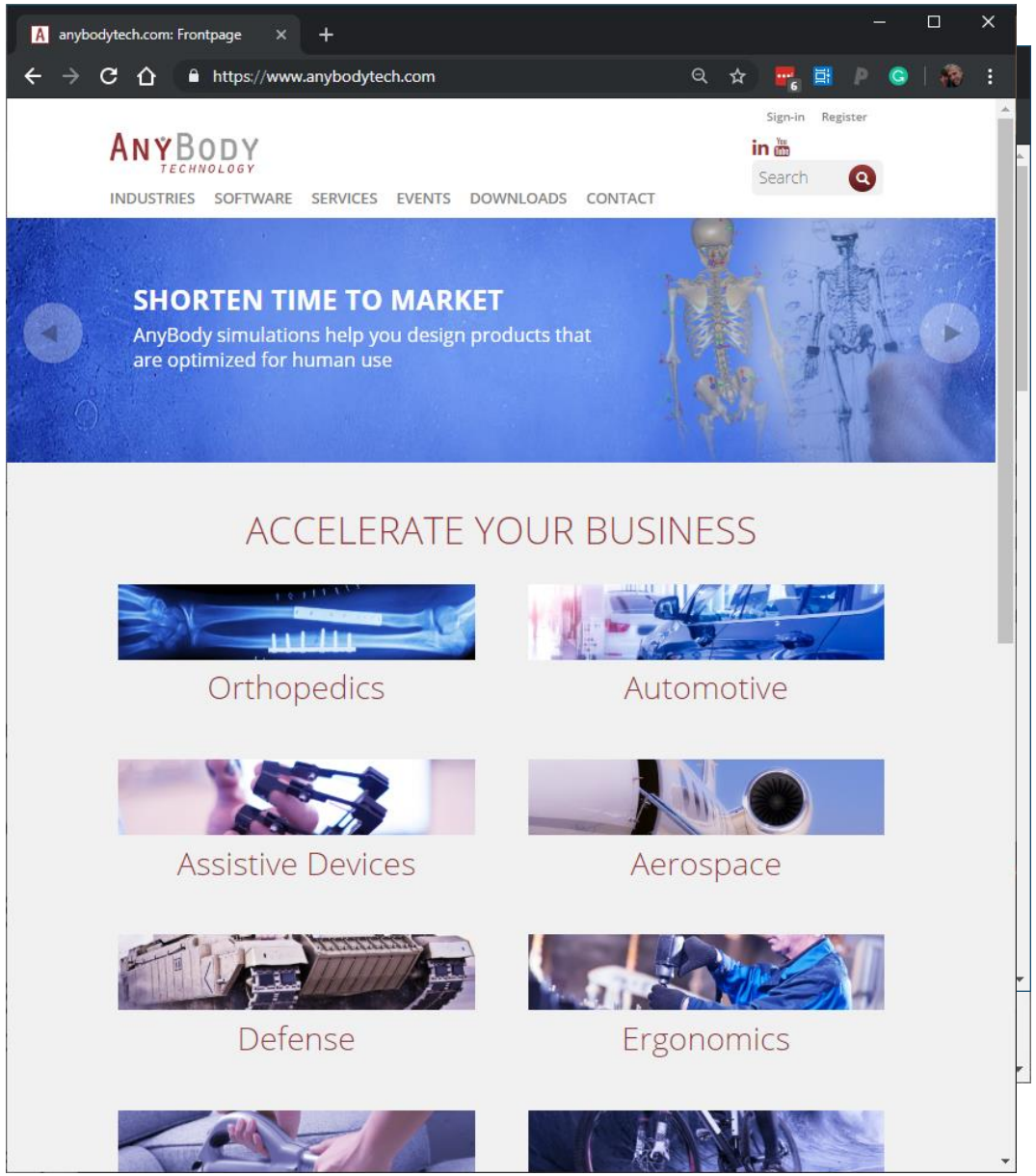
- Wiki, Forum, Repositories

Get in touch? sales@anybodytech.com



Time for questions: