ANYBODY™

POWERFUL BODY SIMULATIONS

Computational Biomechanics

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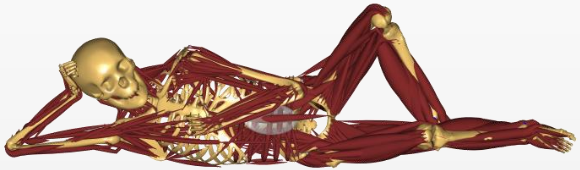
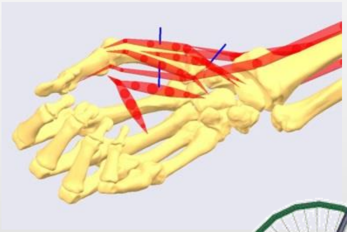
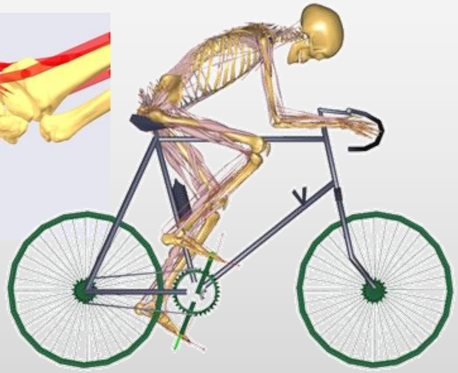
Summer Term 2017

General





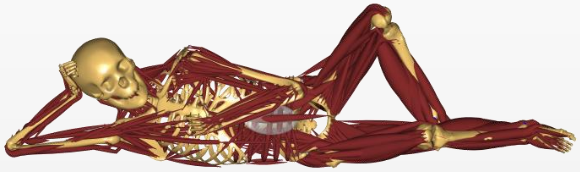


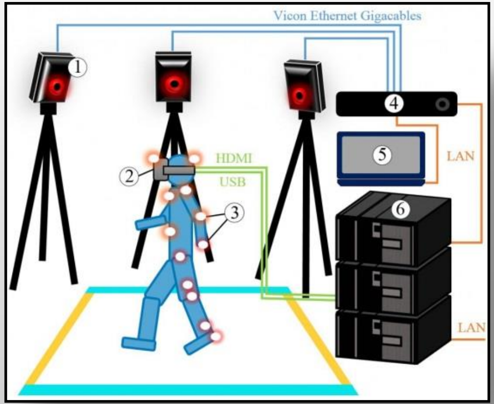
- The AnyBody Modeling System is..
  - **MusculoSkeletal Modeling System**
    - analyzing reactions in the human body
    - between the human body and an environment.

- Environment can be
  - something within (implant, e.g. knee or hip device),
  - something attached to (exoskeleton, e.g. knee brace or space-suit) or
  - something interacting (e.g. automotive seat, wheelchair, ...)

Picture Sources:
https://www.zhaw.ch/storage/_processed_/e/7/csm_Hand_Anybody_01_800x536_300dpi_b9a4bc8b48.jpg
https://www.anybodytech.com/fileadmin/_processed_/a/c/csm_Bike-Lat-View_7e98d15af6.png

Inverse Dynamics of Muscle Systems





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F_{ex}

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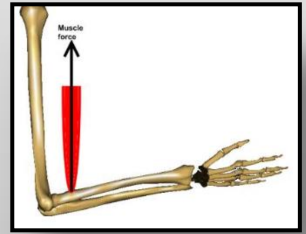
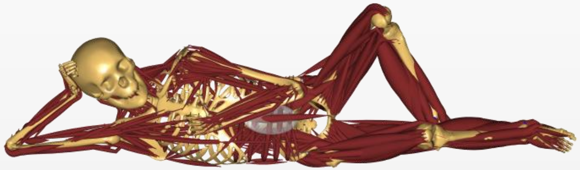
POWERFUL BODY SIMULATIONS

F_{int}



Picture Sources:
http://www.lfe.mw.tum.de/en/research/methods-and-lab-equipment/pedestrian-simulator/
http://www.ebay.com/itm/Dynamometer-130kg-Measure-Hand-Grip-Gym-Measurement-Power-Strength-Dynamometre-/152408324194?hash=item237c3e7862:g:K30AAOxyP4dTcdFS
Anybody technology

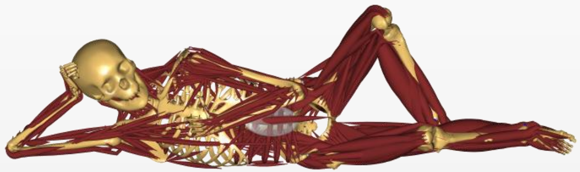
How?



- $C\,f = r$
  - f muscle or joint forces
  - r known forces (internal & external)
  - C matrix of equation coefficients

- Muscle forces $f \geq 0$
- Muscle redundancy

Optimization

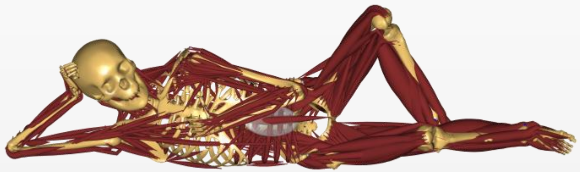


$$Min \qquad G(f^M)$$

$$s.t. \qquad C\,f = r$$

$$0 \le f^M \le N_i$$

Linear Muscle Recruitment

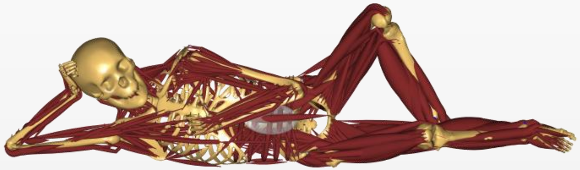


$$G = \frac{f_1}{N_1} + \frac{f_2}{N_2}$$

- With N as normalization factor (muscle activity)

$$\begin{aligned} &Min \quad && G(f^M) \\ &s.t. \quad && C\,f = r \\ & && f^M \geq 0 \end{aligned}$$

Quadratic Muscle Recruitment

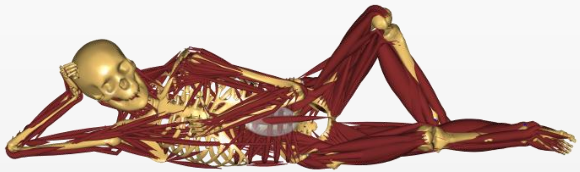


$$G = \sum_{i} \left(\frac{f_{\mathrm{i}}}{N_{\mathrm{i}}} \right)^2$$

$$Min \qquad G(f^M)$$

$$s.t. \qquad C\,f = r$$
$$f^M \geq 0$$

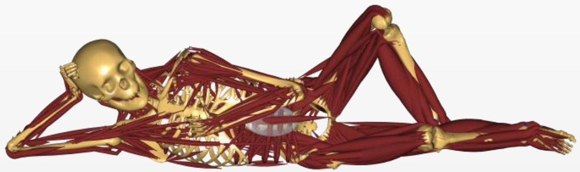
Polynomial Muscle Recruitment



$$G = \sum_{i} \left(\frac{f_{\mathrm{i}}}{N_{\mathrm{i}}} \right)^{p}$$

$$\begin{aligned} &Min \quad && G(f^M) \\ &s.t. \quad && C\,f = r \\ & && f^M \geq 0 \end{aligned}$$

Min/Max muscle recruitment



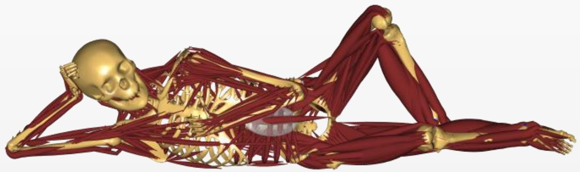
$$G = \max\left(\frac{f_\mathrm{i}}{N_\mathrm{i}}\right)$$

→linear problem

→nummerically efficient

→physiologically reasonable

Mechanical model



- Remind: $C\ f = r$
- Segment i

$$q_i = \begin{bmatrix} r_i \\ p_i \end{bmatrix}$$

Position

4 Euler parameters

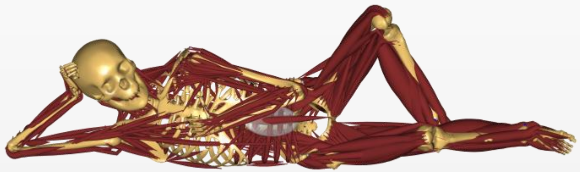
$$v_i = \begin{bmatrix} \dot{r}_i \\ \omega_i \end{bmatrix}$$

Translation velocities

Rotation velocities

- $\rightarrow \phi(q,t) = 0$
- Kinematic equations → obtain q, v, $\dot{v}$

Dynamic equilibrium



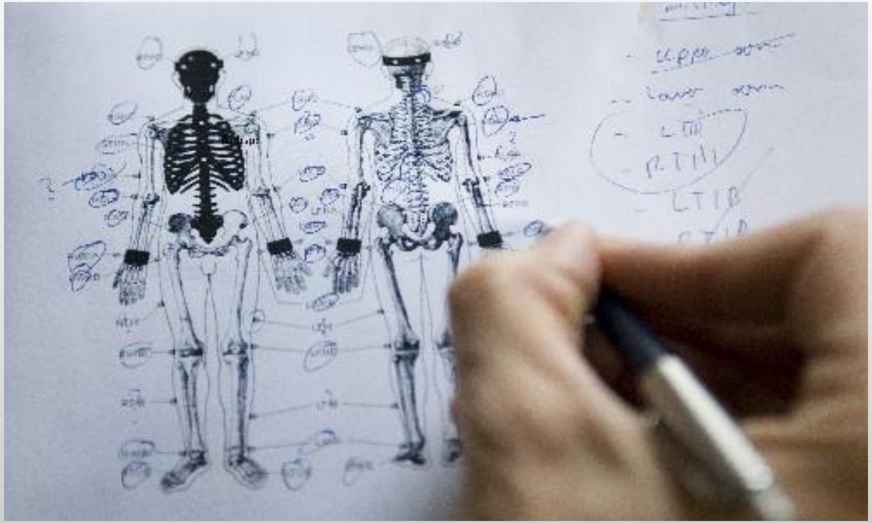
$$\begin{bmatrix} m_i I & 0 \\ 0 & J_i \end{bmatrix} \dot{v}_i + \begin{bmatrix} 0 \\ \breve{\omega}_i' J_i' \omega_i' \end{bmatrix} = f_i$$

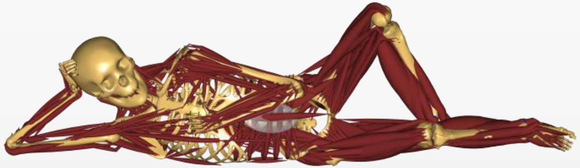
- f:

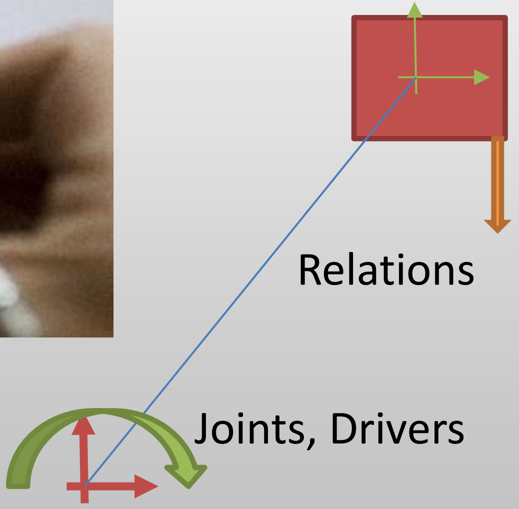
$$\left.\begin{array}{l} \text{– Muscle} \\ \text{– Reaction} \end{array}\right\} f \qquad\qquad C\,f = r$$

$$\left.\begin{array}{l} \text{– Applied} \end{array}\right\} r$$

Structure







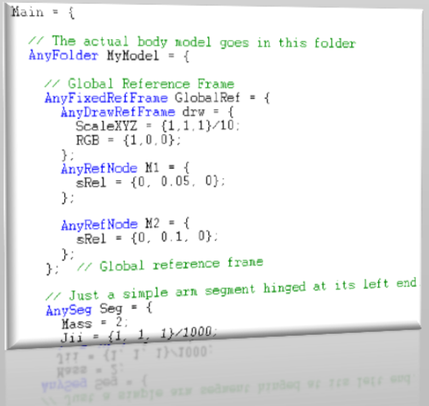
Propeties:
Mass, reference node…

Loads

Relations

Joints, Drivers

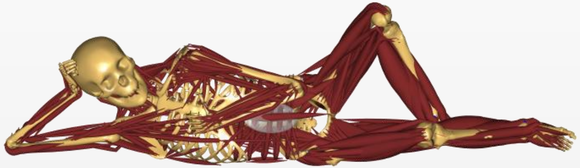
- ANYSCRIPT



```
Main = {

  // The actual body model goes in this folder
  AnyFolder MyModel = {

    // Global Reference Frame
    AnyFixedRefFrame GlobalRef = {
      AnyDrawRefFrame drw = {
        ScaleXYZ = {1,1,1}/10;
        RGB = {1,0,0};
      };
      AnyRefNode M1 = {
        sRel = {0, 0.05, 0};
      };

      AnyRefNode M2 = {
        sRel = {0, 0.1, 0};
      };
    };  // Global reference frame

    // Just a simple arm segment hinged at its left end
    AnySeg Seg = {
      Mass = 2;
      Jii = {1, 1, 1}/1000;
```

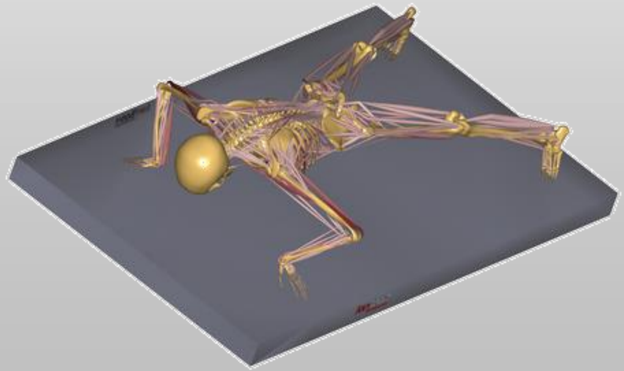
Picture Sources:
https://anyscript.org/assets/images/teaser.jpg

AMMR

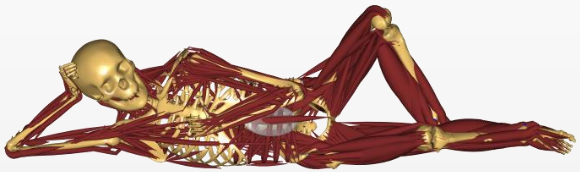


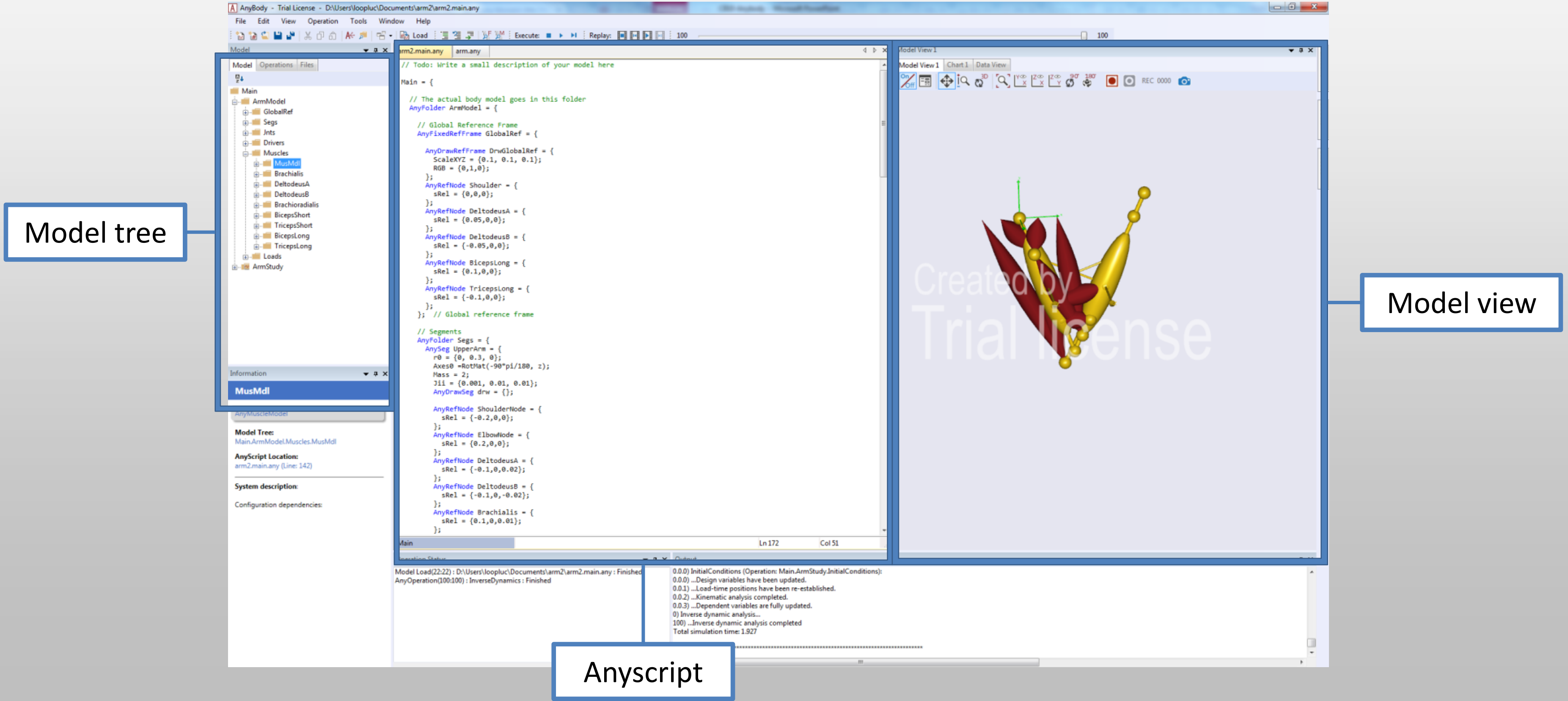
- repository of musculoskeletal models

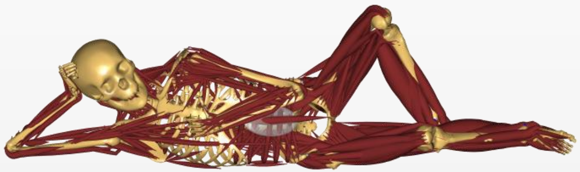
→ Fast use



Anybody







- Demo