Muscle Wrapping

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Overview

- Introduction
- Application area
- Difficulty of simulating muscle path
- Four types of modeling method:

  Straight line model

  Centroid line model

  Obstacle-set model (simple program provided)

  3D model based on finite elements (simple program provided)

  Comparison of the latter two methods
- Conclusion

Muscle Wrapping

What is Muscle Wrapping?

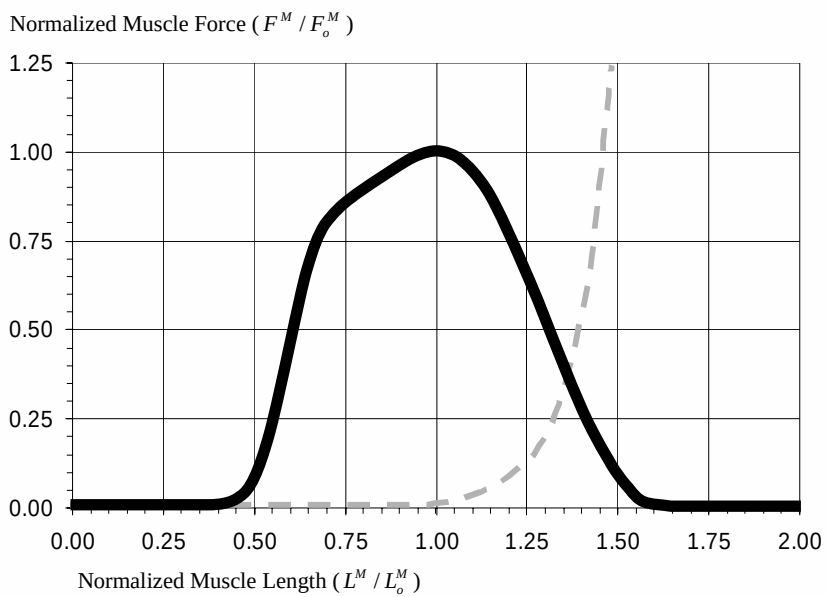
- Studied through the path the muscles take around joints and its connection to the bone
- Can be represented through mathematical models

Why Use Computer Simulation ?

- Can provide insight into how the nervous system and muscles interact to produce coordinated motion of the body parts

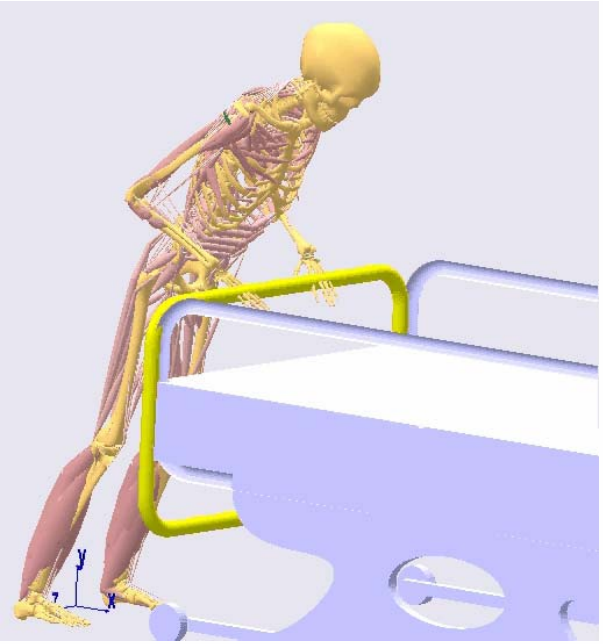
Why Muscle Wrapping Important ?

- Point of force application
- Direction of force application
- Muscle length and velocity



Application Areas of Muscle Wrapping

- Biomechanics
  www.anybodytech.com
- Biomedical engineering
- Computer graphics



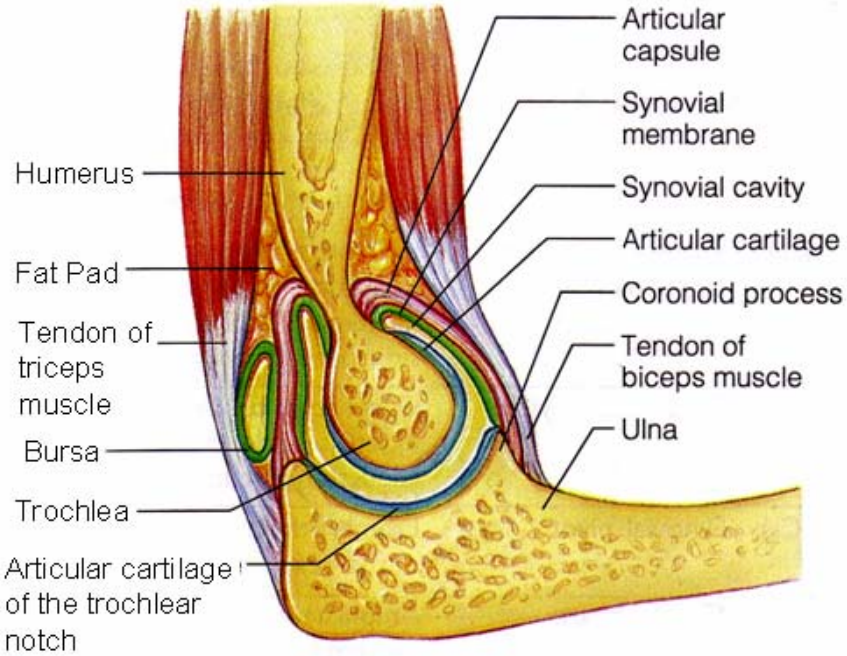
[1] Patria A. Hume, Justin Keogh and Duncan Reid, The Role of Biomechanics in **Maximizing Distance and Accuracy of Golf Shots**. Sports Med 2005 35 5 : 429-449.

[2] Arpad Illyes, Rita M. Kiss, **Shoulder Muscle Activity During Pushing, Pulling, Elevation and Overhead Throw**. Journal of Electromyography and Kinesiology 15(2005) 282-289.

[3] Marcus G. Pandy, **Computer Modeling and Simulation of Human Movement**. Annual Reviews of Biomedical Engineering, 2001. 3:245-73.

Difficulty of Simulating the Muscle Path

- Complex structures of human joint, take the elbow joint as an example



Studied Models of Muscle Wrapping

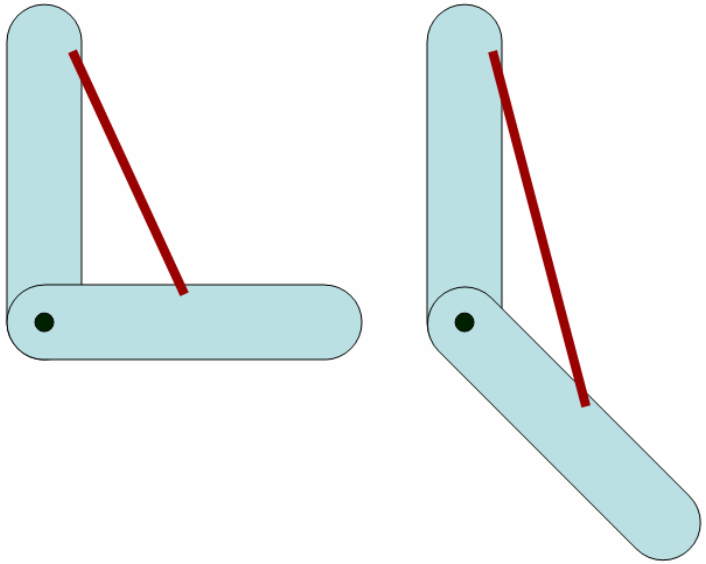
Straight-line model ……...Part I

Centroid-line model……Part II

Obstacle-set model ……Part III

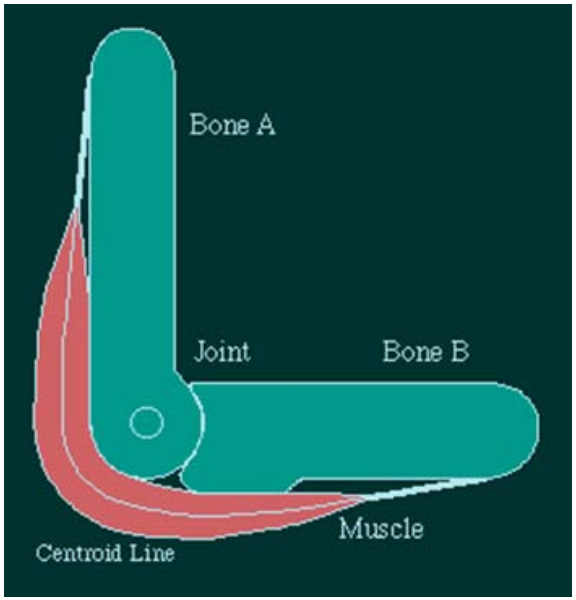
3D model ……Part IV

Part I
Straight-line Model



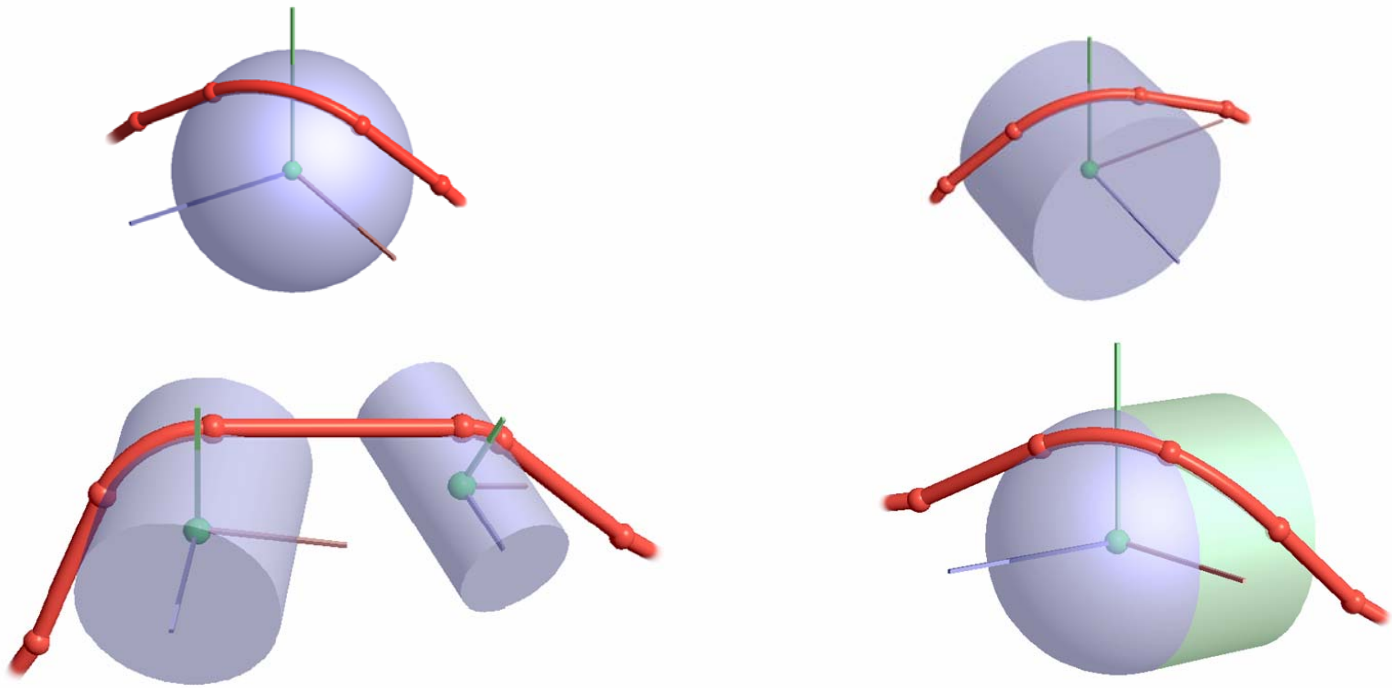
- Easy to implement.
- Represented by a straight line joining centroids of the muscle attachment areas.
- Does not yield meaningful results in the complex cases.

Part II
Centroid-line Model



- Represented by a line that passes through the locus of the cross sectional centroids of the muscle.
- More realistic description of the muscle action.
- Cross-sectional centroids are difficult to obtain.
- Applications limited with approximations.

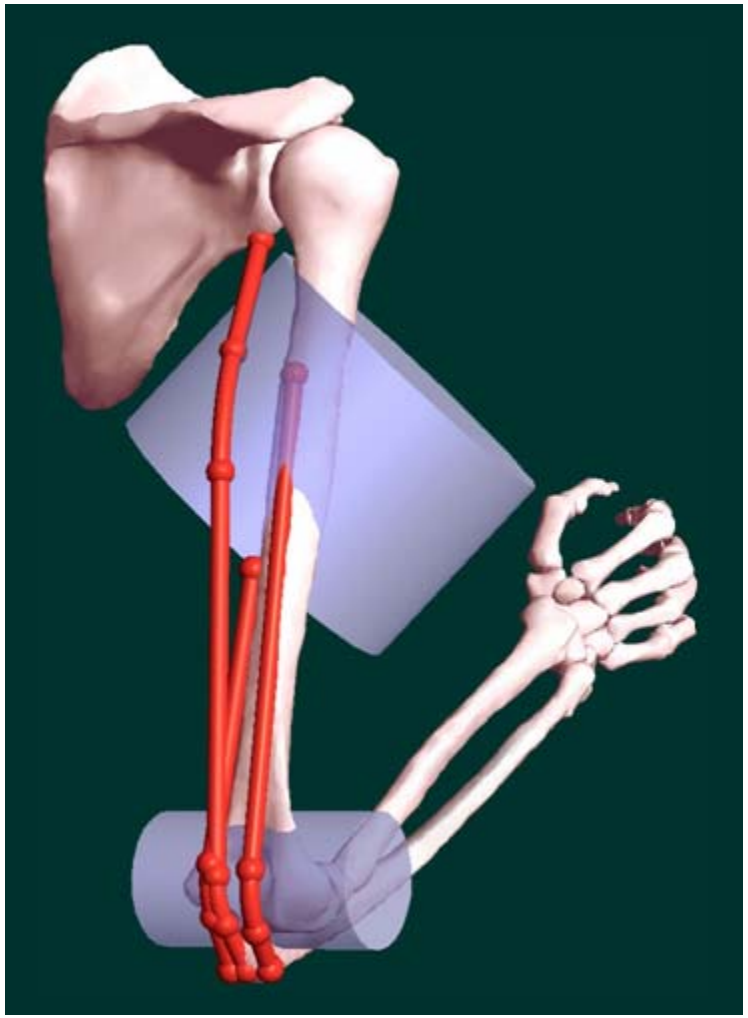
Part III
Obstacle-set Model



The muscle path in this method is formed by several segments of straight lines and curved lines joined together by via points. And the anatomical constrains are modeled by cylinder, sphere, stub, or any other combinations of those geometries.

Part III
Obstacle-set Model

Application: Model of paths of the three-heads of triceps brachii.



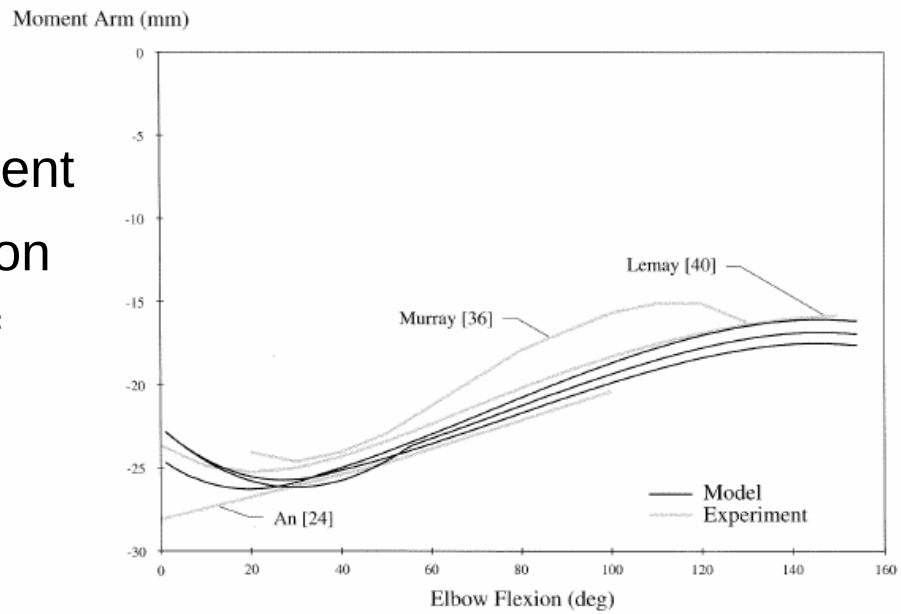
Reference:

Garner B.A., Pandy M.G., **The Obstacle-Set Method for Representing Muscle Paths in Musculoskeletal Models**. Computer Methods in Biomechanics and Biomedical Engineering, Vol. 3, pp. 1-30.

Part III
Obstacle-set Model

Model Analysis:

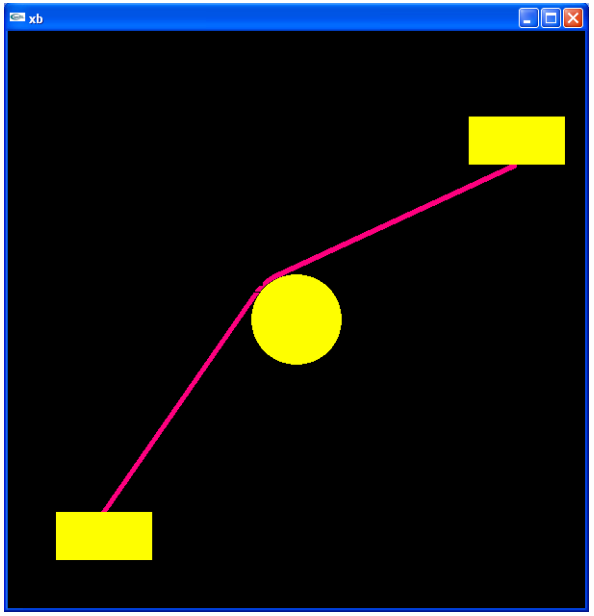
A good agreement can be found between the model and experiment over the full range of elbow flexion which indicates that the paths of these muscles are represented accurately in the model.

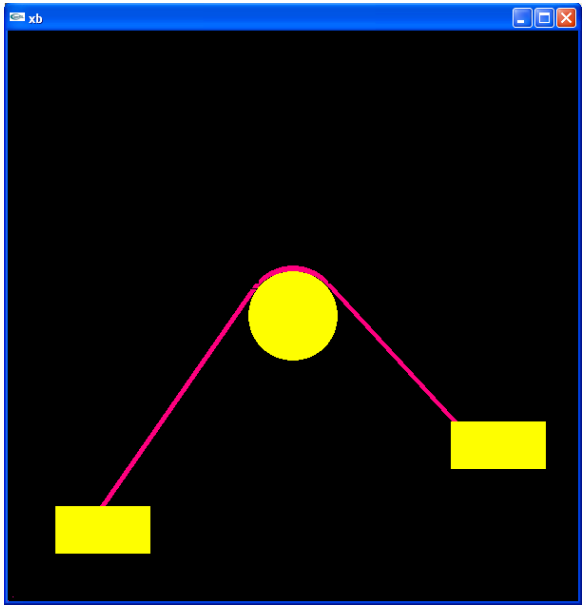


A Simple Program According to the Obstacle-set Model

via C++ & openGL

Obstacle-set Muscle Path:

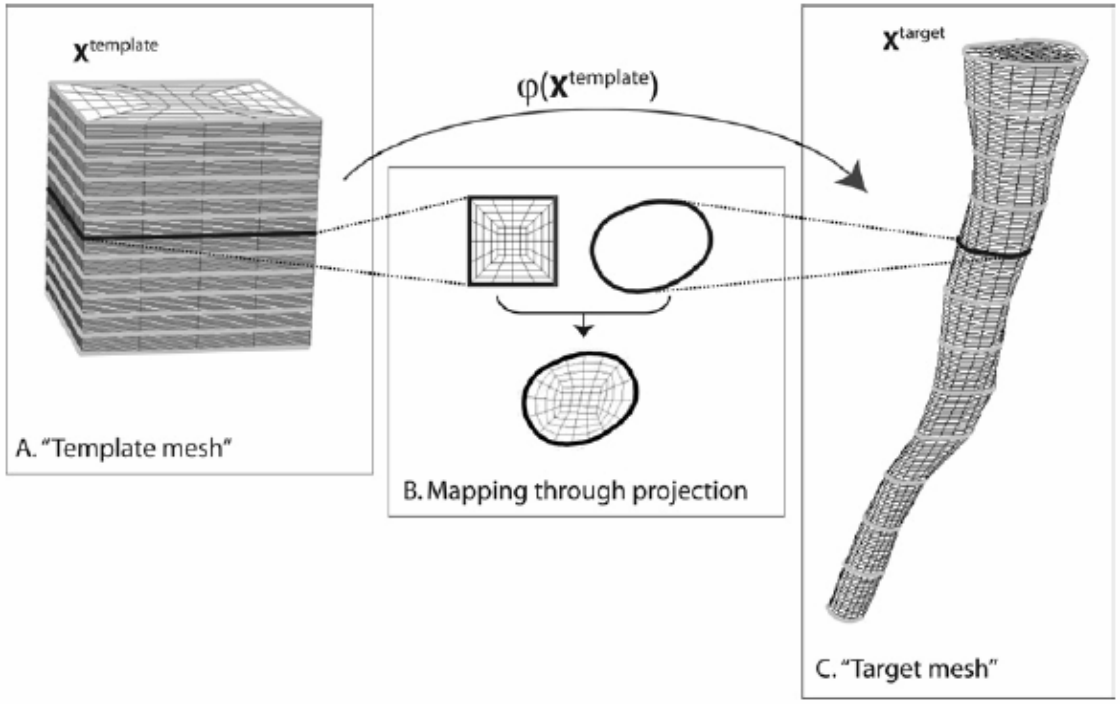




The muscle fiber wrapping around the elbow is modeled as three segments of lines going around a cylinder shaped elbow.

Part IV 3D Model

based on finite elements

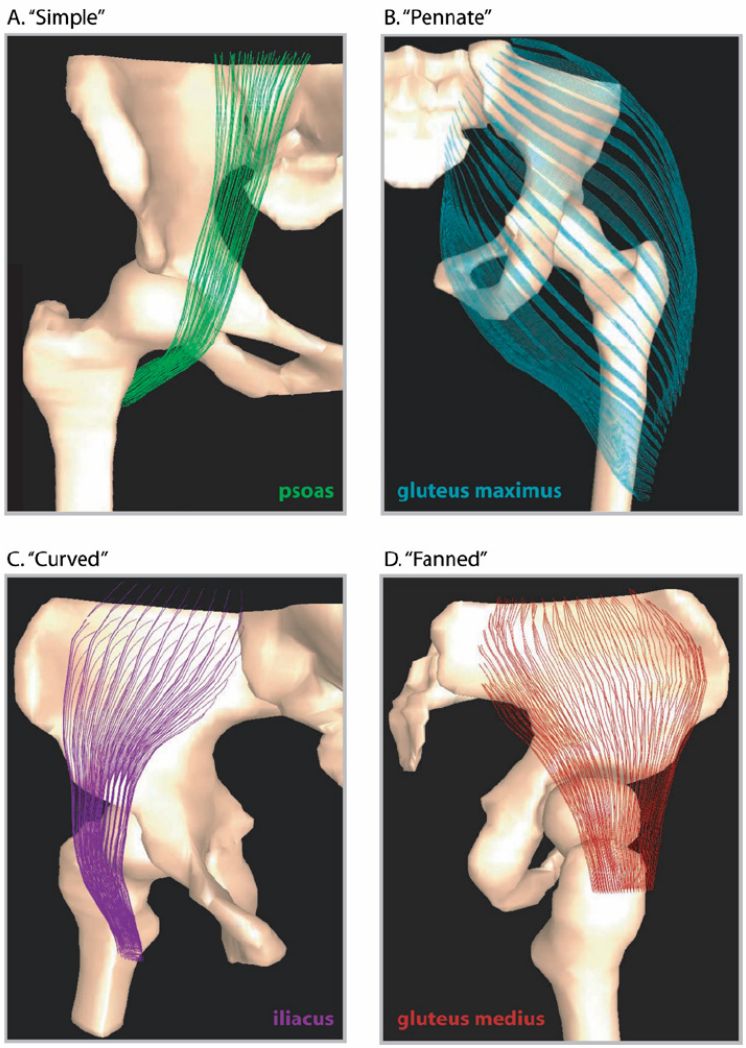


Finite element meshes and geometric descriptions of the fibers are created for each muscle.

Part IV 3D Model

based on finite elements

Application: Fiber geometries mapped to the psoas, gluteus maximus, iliacus and gluteus medius.



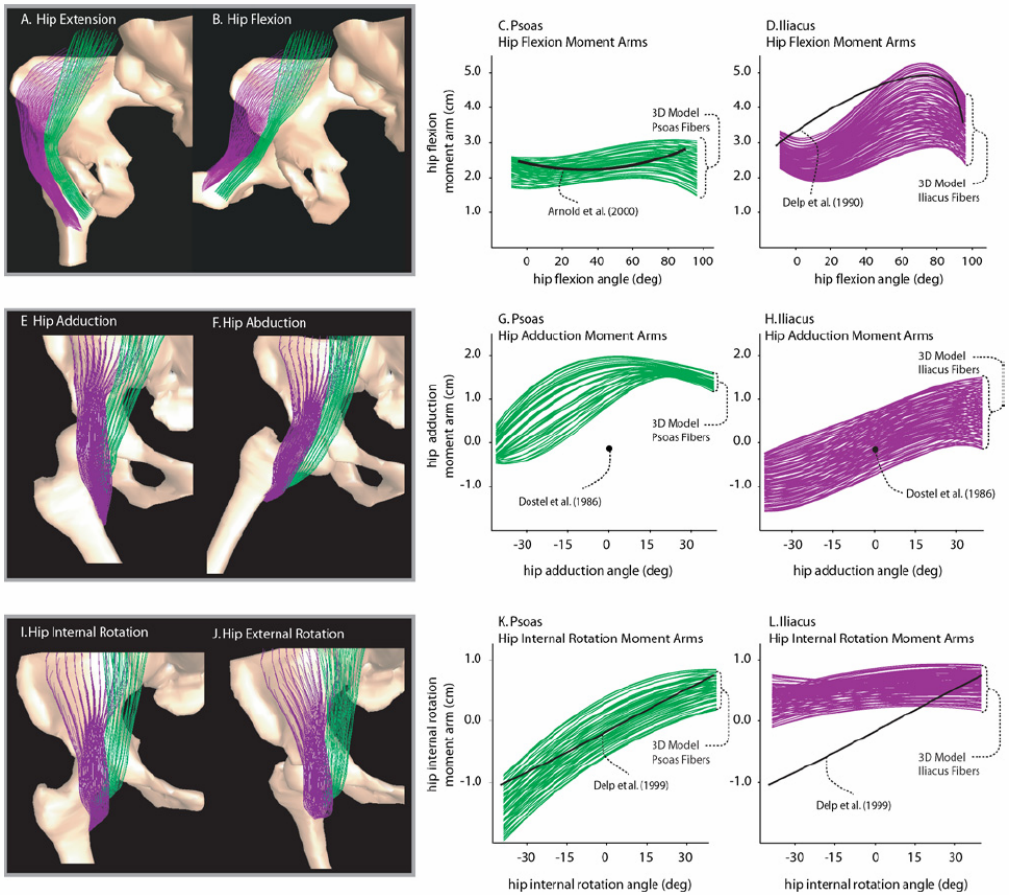
Reference:
Silva S. Blemker and Scott L. Delp, **Three -Dimensional Representation of Complex Muscle Architectures and Geometries**. Annals of Biomedical Engineering, Vol. 33, No. 5, May 2005 pp.661-673

Part IV 3D Model

based on finite elements

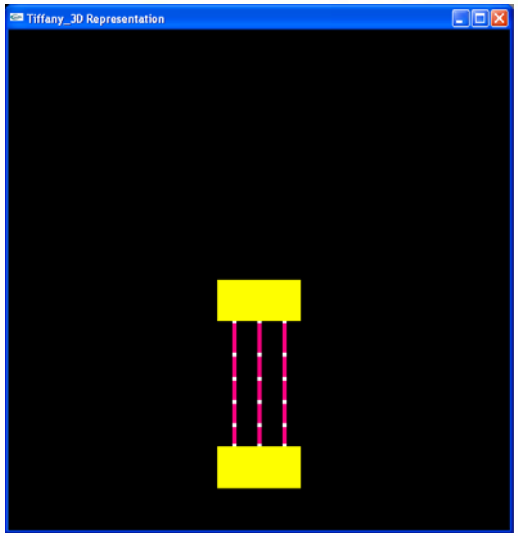
Model Analysis:

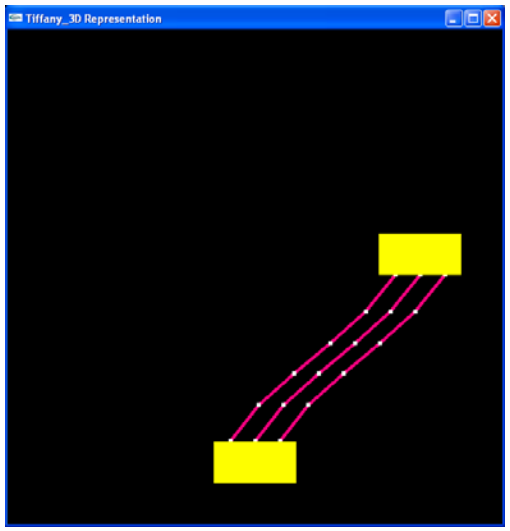
It turns out that there are generally good agreement between the muscle paths predicted by the models and the MRI data .



A Simple Program According to the 3D Model

via C++ & openGL





3D Muscle Path :

Based on the idea of the 3D model, the energy of a muscle fiber is calculated according to the following equation:

$$G_{Muscle} := 5.0 \cdot 10^{2} \cdot Pa$$

$$K_{Muscle} := 1.0 \cdot 10^{7} \cdot Pa$$

$$\psi = G_1 B_1^{\,2} + G_2 B_2^{\,2} + W_3(\lambda, \alpha) + \frac{k}{2} \ln(J)^2$$

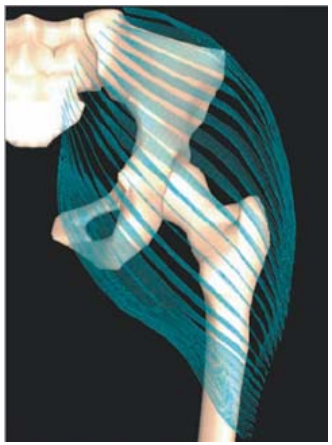
Smallest energy is reserved each time one end of the muscle fiber is moved.

Comparisons of Two Models

- Obstacle-set Model (Garner method)

  Does not account for fact that muscle tissue connects each other

  -- not accurate in some cases



- 3D Model (Blemker method)

  More data, complex math calculation

  -- not efficient

Further Research ?

- Tension between desire to have model accuracy, and desire to have simplicity and computational efficiency

- What's the future plan?

Seek some compromise approach that is both accurate and efficient??

Thank You!

Questions?

References:
[1] Patria A. Hume, Justin Keogh and Duncan Reid, The Role of Biomechanics in Maximizing Distance and Accuracy of Golf Shots. Sports Med 2005 35 5 : 429-449.
[2] Arpad Illyes, Rita M. Kiss, Shoulder Muscle Activity During Pushing, Pulling, Elevation and Overhead Throw. Journal of Electromyography and Kinesiology 15(2005) 282-289.
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[6] Paul, J.P. (1965).Bioengineering studies of the forces transmitted by joints: II. Engineering analysis. In Kenedi, R.M. (ed.): Biomechanics and Related Bioengineering Topics, Pergamon Press, Oxford.
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[8] Garner, B. A. and Pandy, M.G., A kinematic model of the upper limb based on the visible Human Project dataset. Computer Methods in Biomechanics and Biomedical Engineering.
[9] Brian A. Garner and Marcus G. Pandy, Musculoskeletal Model of the Upper Limb Based on the Visible Human Male Dataset. Computer Methods in Biomechanics and Biomedical Engineering, Vol. 4, pp.93-126.