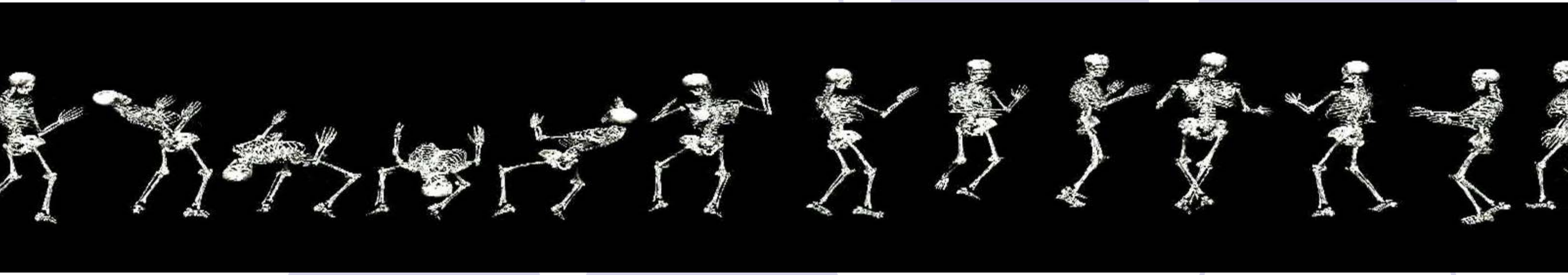
Human Skeletal and Muscle Deformation Animation Using Motion Capture Data



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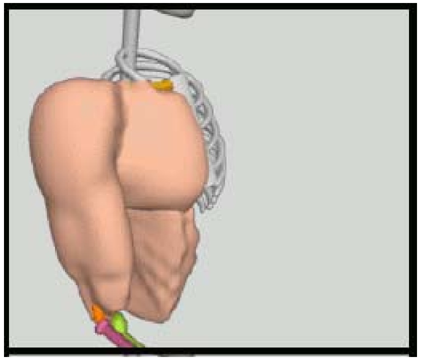
Motivation

- Realistic human character animation
- Using motion capture to generate realistic motion.
- Modeling skin deformations for realistic look.

Background – Layered Approach

- First proposed by [1] for construction of deformable animated characters.
- Applied to human figures by [5].



Taken from [5]

- Currently real anatomical data obtained from CAT scans are used [3].

Motion Capture Data

- CMU Motion Capture Database http://mocap.cs.cmu.edu/ [2]
  - The skeleton file is the ASF file (Acclaim Skeleton File).
  - The motion file is the AMC file (Acclaim Motion Capture data).
    - The AMC file contains the motion data for a skeleton defined by an ASF file.
    - The motion data is given a sample at a time.

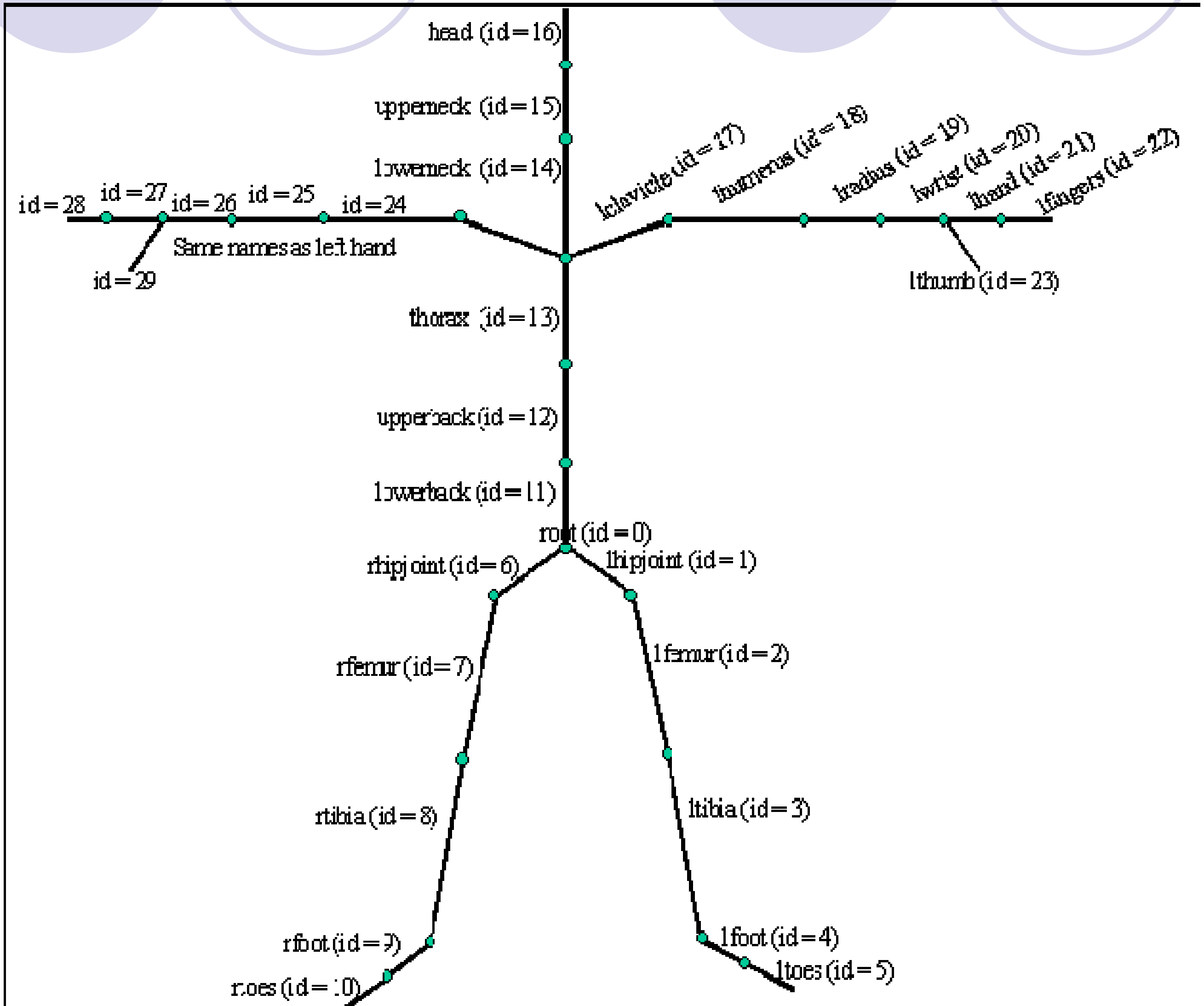
ASF/AMC Samples

```
:root
    order TX TY TZ RX RY RZ
    axis XYZ
    position 0 0 0
    orientation 0 0 0
:bonedata
    begin
        id 1
        name lhipjoint
        direction 0.655637 -0.713449 0.247245
        length 2.52691
        axis 0 0 0 XYZ
    end
    begin
        id 2
        name lfemur
        direction 0.34202 -0.939693 0
        length 7.59371
        axis 0 0 20 XYZ
        dof rx ry rz
        limits(-160.0 20.0)
              (-70.0 70.0)
              (-60.0 70.0)
    end
    ...
:hierarchy
    begin
        root lhipjoint rhipjoint lowerback
        lhipjoint lfemur
        ...
    end
```

```
1
root 0.0153558 18.0056 -30.6689 4.50125 -1.52943 -5.29441
lowerback 16.6573 0.623915 2.31726
upperback 1.63997 1.27324 0.345768
thorax -7.54311 0.547018 -1.23472
lowerneck -1.8004 0.193585 -0.370682
upperneck -11.6206 0.265701 0.0867618
head -3.4216 0.146142 0.0856841
rclavicle 3.47873e-015 -5.56597e-015
...
2
root 0.0242465 17.8811 -30.1748 4.07177 -0.793788 -4.88041
lowerback 17.0795 0.282084 1.9242
upperback 1.75822 0.752955 0.268076
thorax -7.67094 0.30618 -0.980861
lowerneck -1.92248 0.206817 -0.467365
upperneck -11.469 0.293671 0.211124
head -3.34657 0.159302 0.142233
rclavicle 3.67752e-015 -7.95139e-016
...
3
root 0.0522549 17.7574 -29.6766 3.55381 0.143059 -4.40369
lowerback 17.1766 -0.260743 1.88678
upperback 2.18061 0.00982433 0.0343028
thorax -7.28958 -0.0479967 -1.03734
lowerneck -2.21714 0.285124 -0.460451
upperneck -11.5577 0.416179 0.38525
head -3.32363 0.21388 0.195091
rclavicle 3.77691e-015 4.37326e-015
...
```

Taken from [2]

Skeleton Hierarchy – Rest Pose



Taken From [4]

Generating Motion

- Each frame is generated by traversing the hierarchy in a breadth first manner.
- The transformations are given in joint's local coordinate system.
- The order of operations applied are:
  - Translation is performed using the direction vector and the length of the joint.
  - The rotation that maps the global coordinate system to local coordinate system is applied.
  - The rotations of the joint are applied.
  - The rotation that maps the local coordinate system to global coordinate system is applied.
  - The transformation of the parent joint is applied.

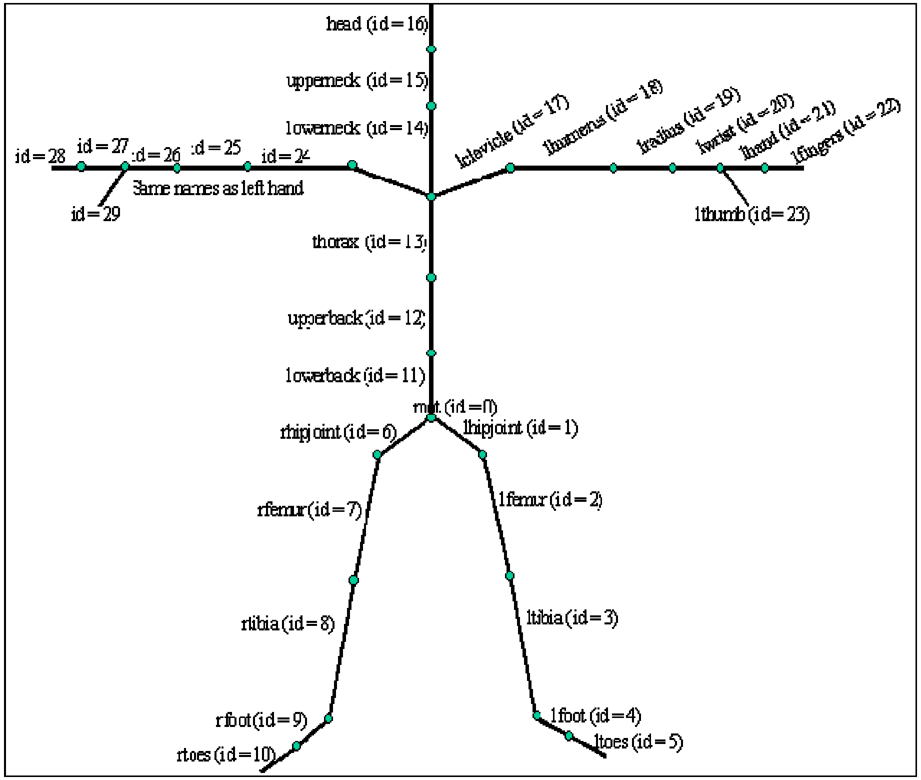
Skeleton Module

- The purpose of skeleton is to support the muscles.
- The global coordinates of attachment points of muscles are determined using the skeleton.

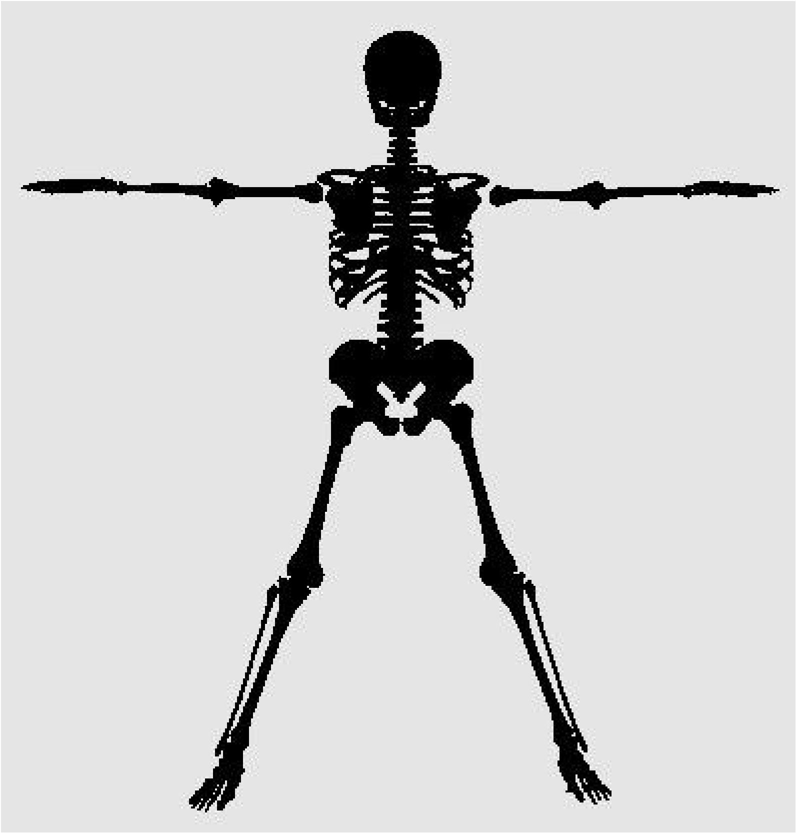
Related Problems

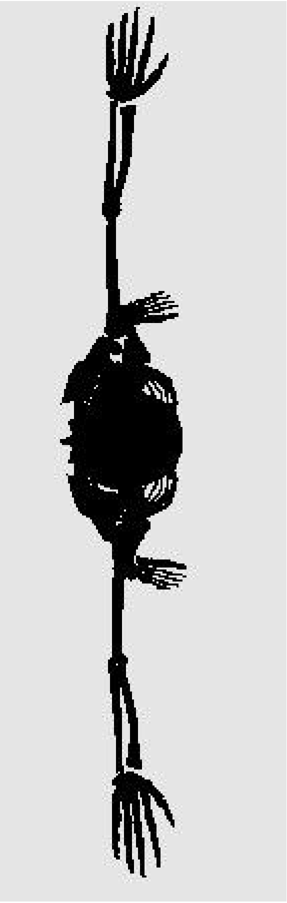
- The rest pose of motion capture data and skeleton differs.
- The markers actually show the positions on the subjects' skin not their skeleton.
- Transformation of spine needs extra attention.
- Resolution for hands is not sufficient.

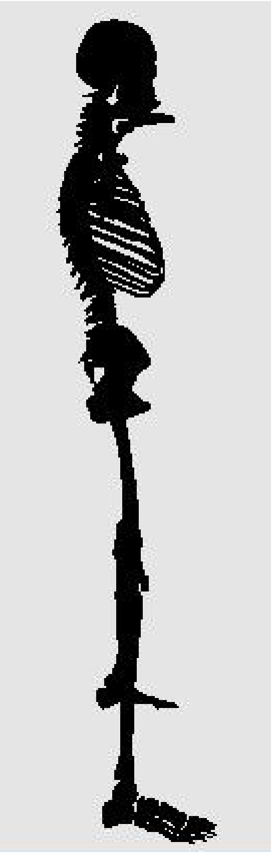
Calibrating the Skeleton



Calibrating the Skeleton





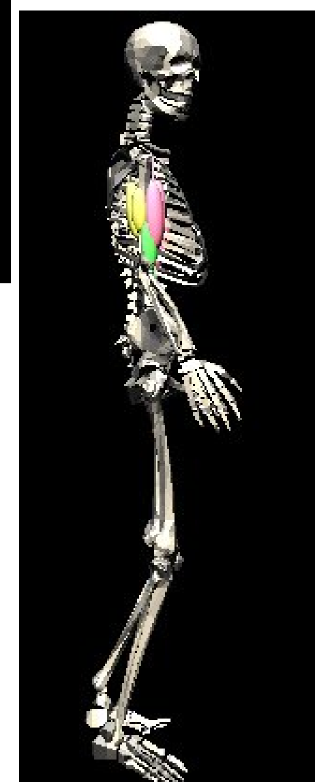


Modeling the Muscles

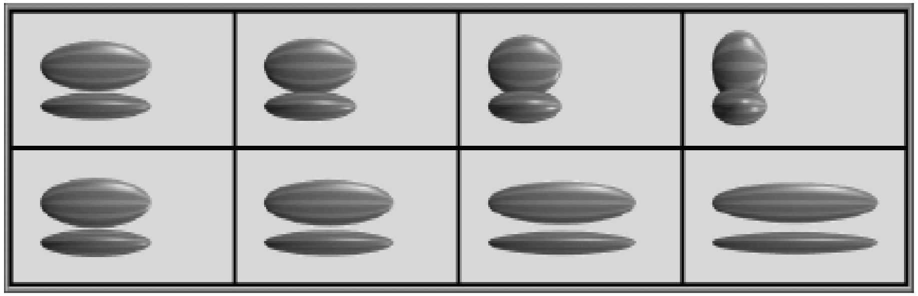
- Muscles are modeled using geometric primitives.
- Deformations due to isotonic contractions are implemented.
- Muscle models are inspired from [5].
- Brachialis muscle, biceps brachii muscle, triceps brachii muscle, deltoid muscle, and pectoralis muscle are modeled.
- Three different models are used.
  - Fusiform muscles.
  - Multi-Belly muscles.
  - Multi-Attachment muscles.

Fusiform Muscles

- Fusiform muscles are modeled using ellipsoids [5].
- Brachialis muscle, biceps brachii muscle, triceps brachii muscles are modelled using this scheme.
- Tendons are included.
- Tendons for triceps brachii muscle needs extra attention.



Fusiform Muscle Deformation



Taken from [5]

$$a = \frac{height}{2}$$

$$b = \frac{width}{2}$$

$$c = \frac{length}{2}$$

$$v = \frac{4\pi abc}{3}$$

$$r = \frac{a}{b}$$

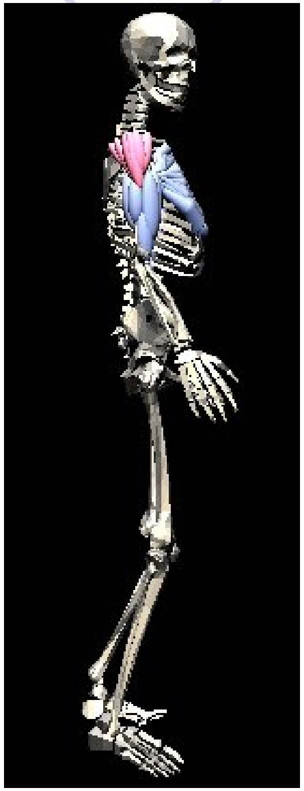
$$c' = \frac{length'}{2}$$

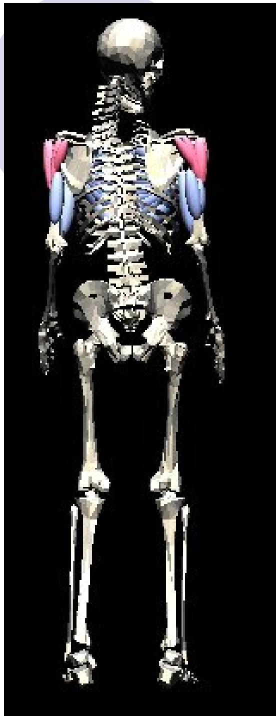
$$b' = \sqrt{\frac{3v}{4\pi rc}}$$

$$a' = b' r$$

Multi-Belly Muscles

- Used to model the deltoid muscle.
- These muscles consist of several segments and attachment points for each segment are given separately.
- Each segment is a fusiform muscle.
- Make use of the attachment points of the neighboring segments to find the orientation of the each segment.
- The local z-axis of each segment is the vector from the first attachment point to the second.
- The y-axis is the cross-product of two vectors from the first points of the neighboring segments to the second point of the current segment. If the current one is a boundary point one of the vectors is the current z-axis.
- The x-axis can be found by the cross product of the z-axis and the y-axis.



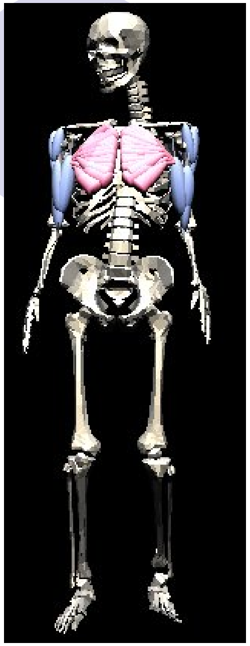


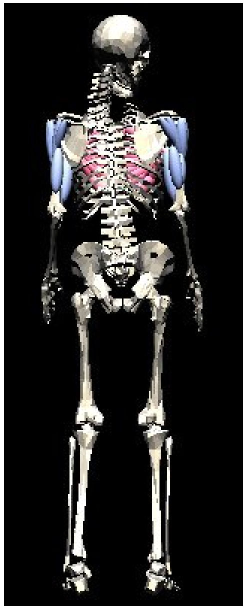
Multi-attachment Muscle

- Used to model pectoralis muscle.
- The cross-section area of the muscle gets smaller as moved from sternum to humerus. Thus, we have used cones.

$$r = \sqrt{\frac{3v}{l\pi}}$$

,where r is the base radius of the cone with volume v and length l.

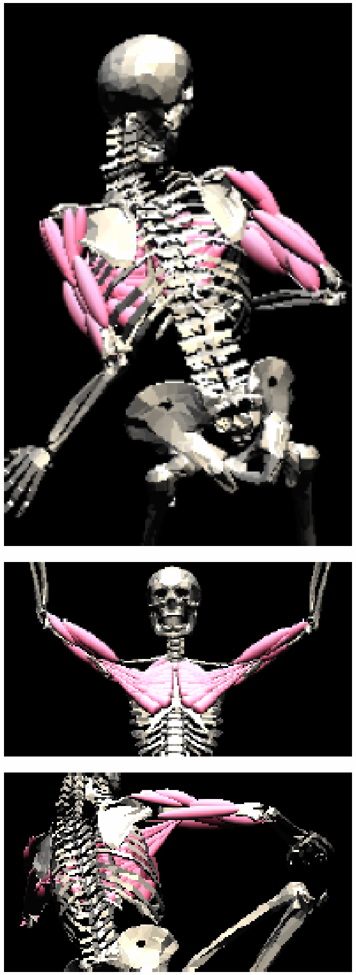


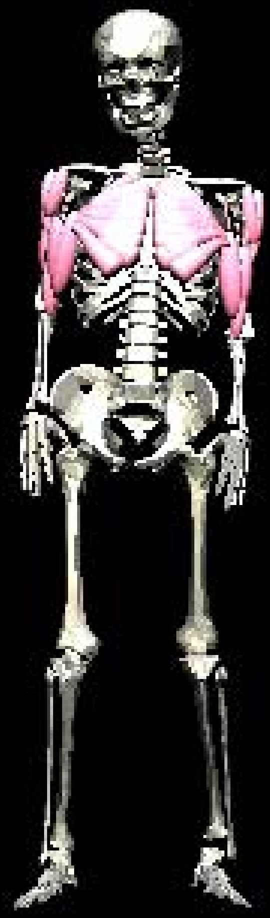


- Length is the sum of the Euclidean distances between the consecutive control points and the attachment points.
- The orientation of each segment is found separately.
  - The z-axis of each segment is found using two attachment points
  - The x-axis is found by the cross product of the z-axis with the vector from the point of the joint that the muscle connects and its parent joint.
  - The y-axis is similarly determined as the cross product of x and z axes.

Conclusions and Future Work

- We have constructed some of the human upper body muscles using some **geometric primitives** and a skeleton model which supports the muscles.
- One of the problems is the segmented rotation of the spine. We have solved that problem by applying rotation proportional to the y-coordinate of the bone and made the rotations smoother.
- The produced deformations of the muscles can be used to find the skin surface deformations by attaching a skin over the volume that is formed by the skeleton and the muscles.





Acknowledgments

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References

[1] J. E. Chadwick, D. R. Haumann, and R. E. Parent. Layered construction for deformable animated characters. In *SIGGRAPH'89: Proceedings of the 16th annual conference on Computer graphics and interactive techniques*, pages 243–252, New York, NY, USA, 1989. ACM Press.

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[3] F. Dong, G. J. Clapworthy, M. A. Krokos, and J. Yao. An anatomy-based approach to human muscle modeling and deformation. *IEEE Transactions on Visualization and Computer Graphics*, 8(2):154–170, 2002.

[4] Nancy Pollard. Description of motion capture file format. http://graphics.cs.cmu.edu/nsp/course/15464/Fall05/assignments/StartupCodeDescription.html, 2005.

[5] Coenraad Frederik Scheepers. *Anatomy-base Surface Generation For Artivulated Models of Human Figures*. PhD thesis, The Ohio State University, 1996.

Thank You

Any Questions?