Animation Basics
Lab 4: Modeling & Rigging in Maya

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KSOL course pages: **http://bit.ly/hGvXlH** / **http://bit.ly/eVizrE**
Public mirror web site: **http://www.kddresearch.org/Courses/CIS636**
Instructor home page: **http://www.cis.ksu.edu/~bhsu**

Readings:

Today: **Flash animation handout**
Next class: Chapter 17, esp. §17.1 – 17.2, Eberly *2e* – see **http://bit.ly/ieUq45**
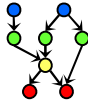Reference: **http://www.learning-maya.com**
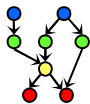
Lecture Outline

- **Reading for Last Class: §10.4, 12.7, Eberly *2e*, Mesh handout**
- **Reading for Today: §11.1 – 11.6 Eberly *2e* (736), Flash handout**
- **Reading for Next Class: §17.1 – 17.2, Eberly *2e***
- **Last Time: Curves & Surfaces**
  - **Piecewise polynomial curves (*aka* splines) and their properties**
  - **Hermite *vs.* Bézier curves: manipulation *vs.* display (rendering)**
  - **DeCasteljau's algorithm: recursive linear interpolation**
  - **Other representations: Bernstein basis functions, matrix form**
  - **Bicubic surfaces**
  - **Bilinear interpolation**
- **Today: *Maya* & Animation Preliminaries – Ross Tutorials**
  - ***Maya* interface: navigation, menus, tools, primitives**
  - **Ross tutorials (http://bit.ly/dFpTwq)**
  - **Preview of character models: PolyFacecom (http://bit.ly/h6tzrd)**
- **Next Class: Animations 2 – Rotations, Dynamics & Kinematics**

Where We Are

Lightly-shaded entries denote the due date of a written problem set; heavily-shaded entries, that of a machine problem (programming assignment); blue-shaded entries, that of a paper review; and the green-shaded entry, that of the term project.

Green, blue and red letters denote exam review, exam, and exam solution review dates.
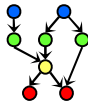
Acknowledgements:
Curves & Surfaces

Steve Rotenberg
Visiting Lecturer
Graphics Lab
University of California – San Diego
CEO/Chief Scientist, PixelActive
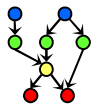**http://graphics.ucsd.edu**

UCSD

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http://www.computing.dcu.ie/~bmccaul/

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Massey University – Albany
http://www.massey.ac.nz/~kahawick/

MASSEY UNIVERSITY
TE KUNENGA KI PŪREHUROA

Acknowledgements: Splines

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Georgia Institute of Technology

James D. Foley
Georgia Tech
http://bit.ly/ajYf2Q

Andy van Dam
T. J. Watson University Professor of Technology and Education & Professor of Computer Science
**Brown University**

Andries van Dam
Brown University
http://www.cs.brown.edu/~avd/

Steve Feiner
Professor of Computer Science & Director, Computer Graphics and User Interfaces Laboratory
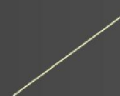**Columbia University**

Steven K. Feiner
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http://www.cs.columbia.edu/~feiner/

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John F. Hughes
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http://www.cs.brown.edu/~jfh/
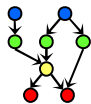
Review [1]: Vector Polynomials (Curves)

- Linear: $\mathbf{f}(t) = \mathbf{a}t + \mathbf{b}$

- Quadratic: $\mathbf{f}(t) = \mathbf{a}t^2 + \mathbf{b}t + \mathbf{c}$

- Cubic: $\mathbf{f}(t) = \mathbf{a}t^3 + \mathbf{b}t^2 + \mathbf{c}t + \mathbf{d}$

We usually define the curve for $0 \leq t \leq 1$

Adapted from slides ♥ 2003 – 2006 S. Rotenberg, UCSD
**CSE167: Computer Graphics, Fall 2006, http://bit.ly/hXxAIP**
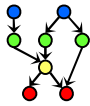
Review [2]:
Linear Interpolation

- Linear interpolation (Lerp) is a common technique for generating a new value that is somewhere in between two other values
- A 'value' could be a number, vector, color, or even something more complex like an entire 3D object…
- Consider interpolating between two points **a** and **b** by some parameter t
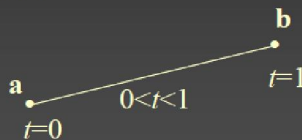
b
$t=1$

a
$0<t<1$
$t=0$

$$Lerp(t, \mathbf{a}, \mathbf{b}) = (1-t)\mathbf{a} + t\mathbf{b}$$

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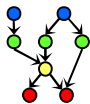
Review [3]:
Hermite Curves

- Polylines are linear (1st order polynomial) interpolations between points
  - Given points P and Q, line between the two is given by the parametric equation:
    $$x(t) = (1-t)P + tQ, \qquad 0 \le t \le 1$$
  - $(1-t)$ and t are called *weighting functions* of P and Q
- Splines are higher order polynomial interpolations between points
  - Like linear interpolation but with higher order weighting functions allowing better approximations/smoother curves
- One representation - Hermite curves (interpolating spline):
  - Determined by two control points P and Q, an initial tangent vector v and a final tangent vector w.
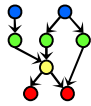
$$\gamma(t) = (2t^3 - 3t^2 + 1)P + (-2t^3 + 3t^2)Q + (t^3 - 2t^2 + t)v + (t^3 - t^2)w$$

- Satisfies:
  - $\gamma(0) = P$
  - $\gamma(1) = Q$
  - $\gamma'(0) = v$
 - $\gamma'(1) = w$

$Q: t = 1$
w

$P: t = 0$
γ

v

Review [4]:
Bézier Curves

▸ Bezier representation is similar to Hermite

  ▸ 4 points instead of 2 points and 2 vectors ($P_1 \dots P_4$)

  ▸ Initial position P_1, tangent vector is $P_2 - P_1$

  ▸ Final position P_4 tangent vector is $P_4 - P_3$

  ▸ This representation allows a spline to be stored as a list of vertices with some global parameters that describe the smoothness and continuity

▸ Bezier splines are widely used (Adobe, Microsoft) for font definition

Brown Exploratory (Spalter & Bielawa): http://bit.ly/fva1il

Adapted from slides © 2010 van Dam *et al.*, Brown University
http://bit.ly/hiSt0f   Reused with permission.
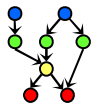
Review [5]:
De Casteljau's Algorithm

$$\mathbf{x} = Lerp(t, \mathbf{r}_0, \mathbf{r}_1) \quad \begin{array}{l} \mathbf{r}_0 = Lerp(t, \mathbf{q}_0, \mathbf{q}_1) \\ \mathbf{r}_1 = Lerp(t, \mathbf{q}_1, \mathbf{q}_2) \end{array} \quad \begin{array}{l} \mathbf{q}_0 = Lerp(t, \mathbf{p}_0, \mathbf{p}_1) \\ \mathbf{q}_1 = Lerp(t, \mathbf{p}_1, \mathbf{p}_2) \\ \mathbf{q}_2 = Lerp(t, \mathbf{p}_2, \mathbf{p}_3) \end{array} \quad \begin{array}{l} \mathbf{p}_0 \\ \mathbf{p}_1 \\ \mathbf{p}_2 \\ \mathbf{p}_3 \end{array}$$

Adapted from slides ♥ 2003 – 2006 S. Rotenberg, UCSD
CSE167: Computer Graphics, Fall 2006, http://bit.ly/hXxAIP
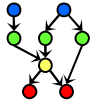
Review [6]:
Bernstein Polynomials – Matrix Form

$$\mathbf{a} = (-\mathbf{p}_0 + 3\mathbf{p}_1 - 3\mathbf{p}_2 + \mathbf{p}_3)$$
$$\mathbf{b} = (3\mathbf{p}_0 - 6\mathbf{p}_1 + 3\mathbf{p}_2)$$
$$\mathbf{x} = \mathbf{a}t^3 + \mathbf{b}t^2 + \mathbf{c}t + \mathbf{d}$$
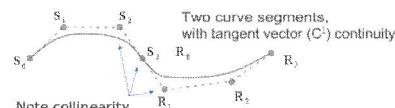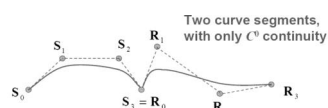$$\mathbf{c} = (-3\mathbf{p}_0 + 3\mathbf{p}_1)$$
$$\mathbf{d} = (\mathbf{p}_0)$$

$$\mathbf{x} = \begin{bmatrix} t^3 & t^2 & t & 1 \end{bmatrix} \cdot \begin{bmatrix} \mathbf{a} \\ \mathbf{b} \\ \mathbf{c} \\ \mathbf{d} \end{bmatrix} \qquad \begin{bmatrix} \mathbf{a} \\ \mathbf{b} \\ \mathbf{c} \\ \mathbf{d} \end{bmatrix} = \begin{bmatrix} -1 & 3 & -3 & 1 \\ 3 & -6 & 3 & 0 \\ -3 & 3 & 0 & 0 \\ 1 & 0 & 0 & 0 \end{bmatrix} \cdot \begin{bmatrix} \mathbf{p}_0 \\ \mathbf{p}_1 \\ \mathbf{p}_2 \\ \mathbf{p}_3 \end{bmatrix}$$

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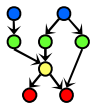
Review [7]:
G^i vs. C^i Continuity

- **Geometric Continuity**: G^i
  - **Guarantees that direction of ith derivative equal**
  - **G^0: curves touch at join point**
  - **G^1: curves also share common tangent direction at join point**
  - **G^2: curves also share common center of curvature at join point**
- **Mathematical Continuity**: C^i
  - **Guarantees that direction, magnitude of ith derivative equal**
  - **$C^0 \equiv G^0$: curves touch at join point**
  - **C^1: curves share common tangent direction / magnitude at join point**
  - **C^2: curves share common second derivative at join point**

Two curve segments, with only C^0 continuity

S_0 S_1 S_2 R_1 $S_3 = R_0$ R_2 R_3

Two curve segments, with tangent vector (C^1) continuity

S_1 S_2 S_4 S_3 R_0 R_1 R_2 R_3 Note collinearity
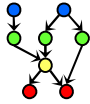
Review [8]:
Parametric Bicubic Surfaces

- **Parametric Bicubic Surface: Generalization of Parametric Cubic Curve**

$$P(u, v) = [x(u, v), y(u, v), z(u, v)] \quad 0 \le u \le 1 \quad 0 \le v \le 1$$

- **From Curves to Surfaces**
  - ✷ Let one parameter (say *v*) be held at constant value
  - ✷ Above will represent a curve
  - ✷ Surface generated by sweeping all points on boundary curve, *e.g.*, *P(u, 0)*, through cubic trajectories, defined using *v*, to boundary curve *P(u,1)*
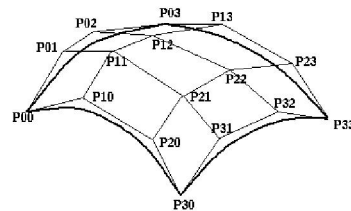

Parameter Space   Object Space
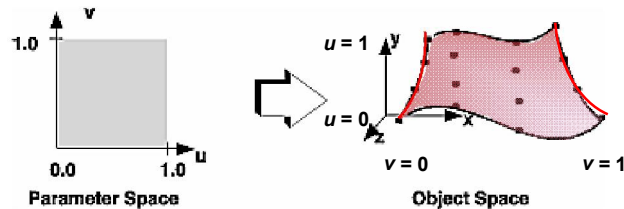
Adapted from slides ♥ 2006 B. McCaul, Dublin City University
CA433 Computer Graphics I, http://bit.ly/ghw08y
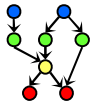
Review [9]:
Curves & Surfaces

- **Curves**
  - ✷ **Bézier: easier to scan convert (DeCasteljau)**
  - ✷ **Hermite: easier to control via GUI (tangent)**
- **Bicubic patches**
  - ✷ **Bilinear interpolation**
  - ✷ **Control patch *aka* Coons patch**

- **Acknowledgments - thanks to Eric McKenzie, Edinburgh, from whose Graphics Course some of these slides were adapted.**
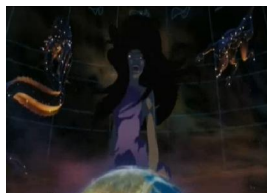
Sinbad: Legend of the Seven Seas
♥ 2003 Dreamworks SKG
Trailer: http://youtu.be/1KCX0pFPRwk
Eris scene: http://youtu.be/w1r8_vByXW4
2003 *Wired* article: http://bit.ly/gm85UU

Adapted from slide ♥ 2007 - 2008 K. Hawick, Massey University
159-235 Graphics and Graphical Programming, http://bit.ly/gmY8R8

Acknowledgements:
Maya Character Rigging

Aaron Ross
Founder, Digital Arts Guild
http://dr-yo.com
http://bit.ly/fzxN74
http://www.youtube.com/user/DigitalArtsGuild

Jim Lammers
President
Trinity Animation
http://www.trinity3d.com
http://bit.ly/i6yfyV

Larry Neuberger
Associate Professor, Alfred State SUNY College of Technology
Online Instructor, Art Institute of Pittsburgh
http://poorhousefx.com
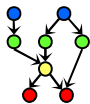
Resources [1]:
Basic Maya Tutorials – Ross

Maya Tutorial: Basics © 2011 A. F. Ross
Playlist: **http://bit.ly/dFpTwq**
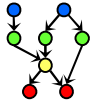
Resources [2]:
Animation Tutorials – Lammers
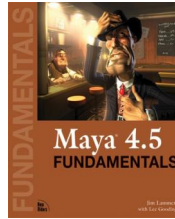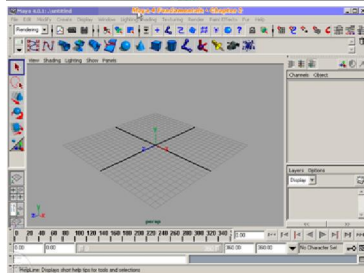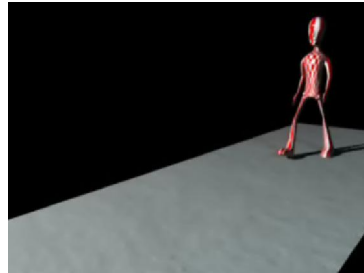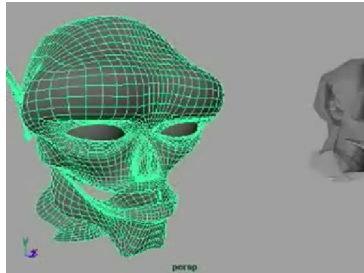
Maya 4 Fundamentals © 2001 J. Lammers & L. Gooding, **http://amzn.to/eWvrkn**
Maya 4.5 Fundamentals © 2003 J. Lammers & L. Gooding, **http://bit.ly/hxTpl1**
Maya 5 Fundamentals © 2006 G. Lewis & J. Lammers, **http://amzn.to/g021Ct**
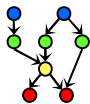
Resources [3]:
Examples Online

"Maya Animation" at **Animation Arena** © 2004 – 2011 G. Nakpil, Toronto, CANADA
http://bit.ly/gXXQTG
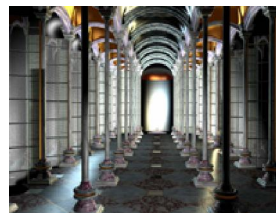
© 2001 J. Wilson, **http://bit.ly/hxTpl1**
Student art gallery for **Maya 4 Fundamentals** (**http://amzn.to/eOld3Q**)

Lab 4 [1]:
Rigging "Tin Can Man", Unreal Wiki
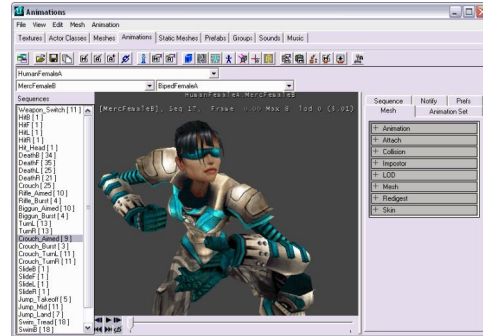
© 2003 – 2008 Unreal Wiki
http://bit.ly/dLRkXN
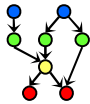
Lab 4 [2]:
Part A – Modeling
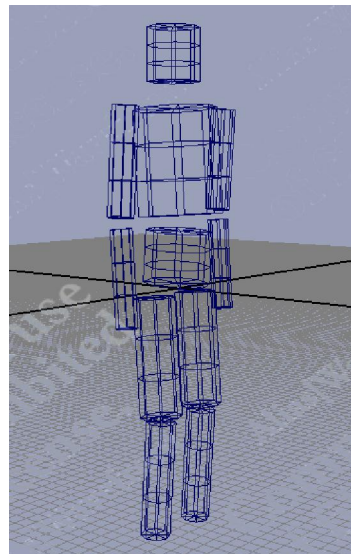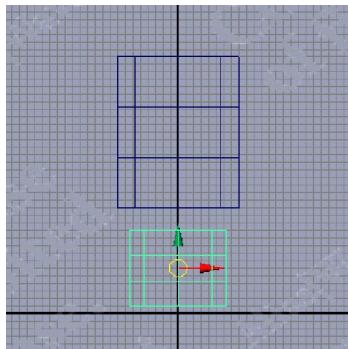
Maya Tutorial Part 1: Modeling, © 2003 – 2008 Unreal Wiki
http://bit.ly/h9lRmT
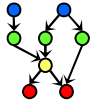
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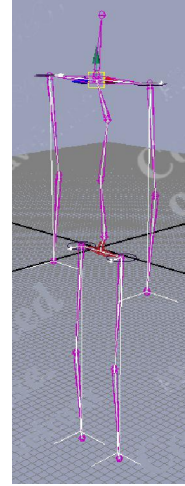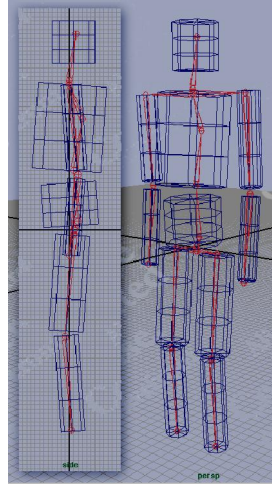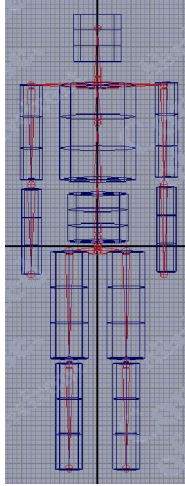
Maya Tutorial Part 2: Rigging, © 2003 – 2008 Unreal Wiki
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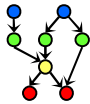
Character Modeling in Maya [1]:
Muscle Models & Deformations

Fig. 1.
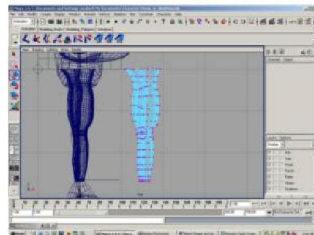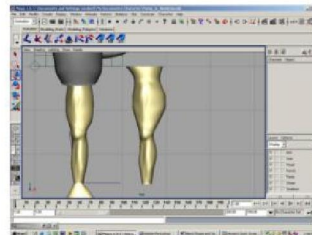
Fig. 2.   Fig. 3.

Adapted from material © 2003 L. Neuberger, http://bit.ly/gqBZ0d
Alfred State College, State University of New York

Alfred State College
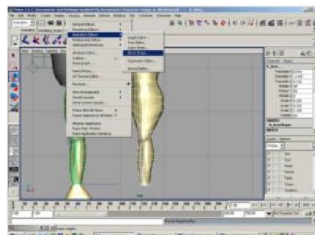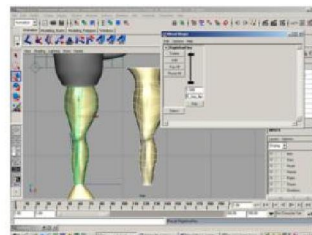SUNY College of Technology
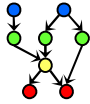
Character Modeling in Maya [2]:
Deform ✹ Blend Shape

Fig. 4.

Fig. 5.

Fig. 6.
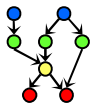
Character Modeling in Maya [3]:
Animate ✹ Set Driven Key ✹ Set
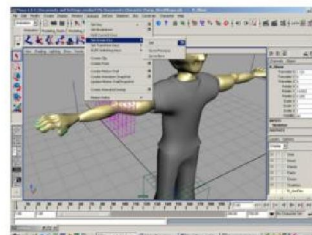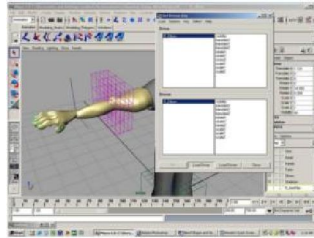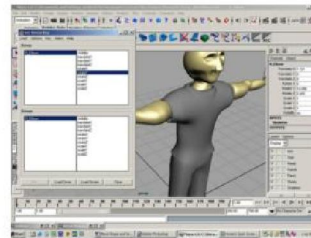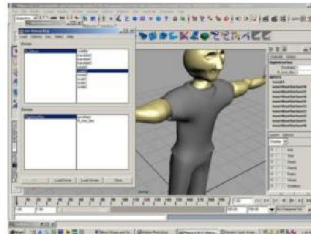

Fig. 7.

Fig. 8.

Fig. 9.

Fig. 10.
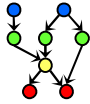
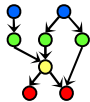# Character Modeling in Maya [4]: Driver

Fig. 11.

Fig. 12.

Fig. 13.

Fig. 14.

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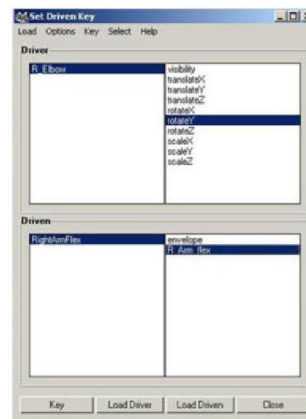# Character Modeling in Maya [5]: Blend Shape Deformation Setup

Fig. 15.

The driver is the elbow. This is saying that whenever the elbow joint rotates around the Y-axis, the arm deformation will take place.

The driven is the blend shape. This is what will be deformed when the driver.

We have the window to the left set up saying that when the elbow joint rotates around the Y-axis, the rightArmFlex blend shape will deform to my specifications.
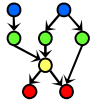
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Character Modeling in Maya [6]:
Inverse Kinematics (IK)

Fig. 16.

Fig. 17.

Fig. 18.
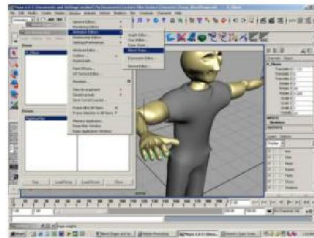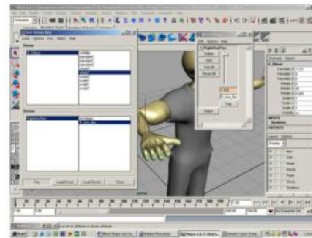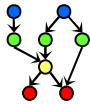
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Character Modeling in Maya [7]:
Controlling Deformation & Rotation

Fig. 19.

Fig. 20.
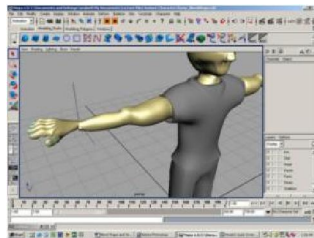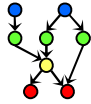

Fig. 21.

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Cloth Modeling in Maya [1]:
More Driven Keys & *Blend Shape*
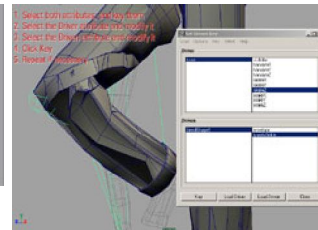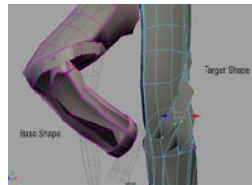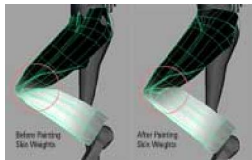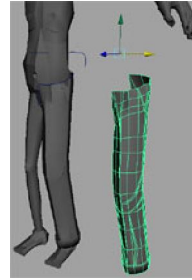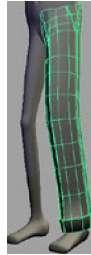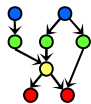
Cloth Modeling in Maya [2]:
Output

That's it! Now you just have to repeat steps 6 - 8 for all joints that will cause wrinkles in the clothing. Finally, the finished effect (Quicktime, double-click to play):

You can see how driven keys and BlendShape nodes can really enhance your character setup. You could also use this technique to create other effects like bulging muscles. The possibilities are endless!

Summary

- **Reading for Next Class: §17.1 – 17.2, Eberly *2ᵉ***
- **Last Time: Curves & Surfaces**
  - ❋ Piecewise linear, quadratic, cubic curves and their properties
  - ❋ Interpolation: subdivision (DeCasteljau's algorithm)
  - ❋ Bicubic surfaces & bilinear interpolation
- **Today: Maya & CGA Preliminaries – Ross Tutorials (http://bit.ly/dFpTwq)**
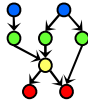 - ❋ Maya interface: navigation, menus, tools, primitives
  - ❋ GUI & objects (Ross 1); viewports, transforms, & hotkeys (Ross 2)
  - ❋ Nodes & attributes (Ross 3); UI, channel box & deformers (Ross 4)
  - ❋ Modeling, scene creation, materials (Ross 5)
  - ❋ Character models: PolyFacecom (http://bit.ly/h6tzrd)
- **Previous Videos (#3): Morphing & Other Special Effects (SFX)**
- **Next Set of Videos (#4): Modeling & Simulation**
- **Next Class: Animations 2 – Rotations, Dynamics & Kinematics**
- **Lab 4: Unreal Wiki Tutorial, Modeling/Rigging (http://bit.ly/dLRkXN)**
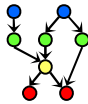
Terminology

- **Piecewise Polynomial Curves** *aka* **Splines**
- **Continuity: Geometric (G^i), Mathematical (C^i)**
- **Bicubic Surfaces including NURBS Surfaces**
- **Maya Software for 3-D Modeling & Animation**
  - ❋ **Shelves** – groups of tools & action icons; compare palettes, toolbars
  - ❋ **Hotkeys** – key combos for common functions; compare macros
  - ❋ **Viewports** – scene views for editing: orthographic, persspective
  - ❋ **Channel box** – GUI for accessing position, rotation, scale, history
  - ❋ **Deformers** – tools for controlling complex vertex meshes
- **Rigging Character Models: Defining Components of Articulated Figure**
  - ❋ **Joints** – axis of rotation, angular degree(s) of freedom (DOFs)
  - ❋ **Bones** – attached to joints, rotate about joint axis