Animation by Adaptation
Tutorial 1: Animation Basics

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Outline

Talk #1: Basics
- What is character animation?
- How do we represent motion?
- Where does motion come from?
- What is Motion Adaptation about?

Talk #2: Problems in Motion Adaptation
- Constraint-based Motion Adaptation
- Spacetime and PFIK+F approaches
- Lurking Issues
- Online problems
Objectives

Where’s the math?

- Slides/presentation light on math details
- My goal is to give you a feeling for the problems we are trying to address.
- Get you interested/intrigued enough to follow up (discussion, read papers)
- Enough back

- Besides, too hard to make slide with equations
What is Animation?

- Bringing something to life
  - Making something move

- A uniquely expressive art form
  - Independent control over form and movement – both are expressive!
  - A young, but well evolved, art form (approximately 100 years)
What is Animation? (2)

- Traditionally “film”
  - Cartoons, watched passively

- Beginning to mean new things
  - Interactive (games, help systems, virtual environments)
  - Mix into live action
  - Means of production in more people’s hands
Why Motion?

- Most unique aspect of animation
- Heart of animation
- People have least experience with
- Hardest to do (art & math)
- My personal favorite problem
- High quality standards
Animation Appreciation 101

Luxo Jr.
Pixar, 1986
J. Lasseter (dir)

- First computer animation nominated for an Academy Award
- Notable character animation
  It’s the motion! (well, it looks good too)
Why is this so hard?

- We are good at looking at motion!
- Motion is very expressive
  - Mood, activity, personality, ...
- But those attributes are subtle
  - What makes a motion sad? Realistic?
- We lack vocabulary
  - Talk about motion with metaphor
The Dream: Animation Everywhere!

- Animation is great
  - Expressive, appealing, ...
  - Flexibility and control
- But it is still the realm of experts
  - Non-experts need different tools
  - Not the same as making it easier for experts
  - Need to generate dynamically in response to interaction
What Motion Are we Talking About?

What is a Character?

- Roughly: Human-like forms
  - Or animal-like

- Fixed set of parameters
  - Current pose defined by a vector $\mathbf{p}$
  - Not continuum (water), large number of parameters (cloth), ...

What are those parameters?
How do we model a human?

Humans are quite complex...
Fortunately, we don’t care about details

“Gross Body Motion”
- Overall movement
- Small details hidden
  - Under clothing
  - Under simplified drawing models
  - View from far enough away
- Chains of rigid segments
Animation Appreciation 101

- Brilliance (Sexy Robot)
  - Robert Abel and Associates, 1985
  - Early motion capture
  - Early computer graphics look (chrome)

- Final Fantasy
  - Square Studios, 2001
  - Realistic, animated, human characters

- Hollowman
  - Sony Imageworks (effects), 2000
  - Complex human models, terrible dialog
Abstractions

206 bones, muscles, fat, organs, clothing, ...

206 bones, complex joints

53 bones Kinematic joints
Abstractions vs. Reality (skeletons vs. humans)

Representation of complex human structure with varying degrees of simplification

Simple Pin Joint

Complex tendon and bone system
Even the Elbow is complex!

Copyrighted image deleted

Image “3 joints of the elbow”
From the Anatomy Coloring Book
Standard simplified models of humans

- Small numbers of degrees of freedom for *gross* motion
- Articulated figures
- Kinematic joints
- Why this?
Abstraction of Human Motion

- Question of Approximating DOF’s
- Some number of connected, rigid pieces
  - (usually)
- Kinematic joints
Representations of Pose

- Angle vs. positional data
- Choices in rotations
- Global vs. relative
- Hierarchical vs. non-hierarchical
- Skeletal vs. Non-Skeletal
Rotations...

*The animation hacker’s nemesis*

- 3D rotations are a pain to represent
  - Have a unique topological structure
  - Cannot be embedded in $\mathbb{R}^n$ without singularity
- Several methods used for in animation, all have pros and cons
  - Matrices
  - Quaternions
  - Euler Angles
  - Exponential Coordinates
Hierarchical Representation

Common way to represent articulated figures

Root = pos, angle

Joint angles relative to parent’s coordinate system
Good Points of Hierarchical Skeletons

- Enforce key constraints
  - Connected segments
  - Rigid limbs
- Fewer DoF’s
  - Only store angles between segments
- Easy for skinning
  - Local coordinate systems defined
Bad Points of Hierarchical

- Need 3D rotations
- Coupled parameters
- End effector controls require IK
- Forces rigidity
- Problems with reference
  - Different ways of defining things
How to Maximize Good / Minimize Bad

- Custom character setup (have right DOFs)
- Well chosen joint sets (placement and type) and controls (IK / FK)

Good:
- make characters that animator can control

Bad: no uniformity/standardization
- important if motion from outside source
- important if want to build libraries / reuse motions
- Everybody has a different skeleton
How do skeletons differ?

- Obvious ways?
  - Topology
    - number of bones
    - Connectivity of bones
  - Joint Types
  - Bone lengths
  - Anatomical / skin relations
    - Is spine in middle of body, or up the back?
What is a motion (2)

- A motion maps times to configurations

\[ \mathbf{m}(t) \in \mathbb{R}^n \]

- Vector-valued, time-varying signal

- But... remember that we have angles! May not be \( \mathbb{R}^n \)
How to represent these functions?

- Dense samples
- Key poses and interpolation
  - How traditional animators do it
  - Smart interpolation
- Procedures / Computational methods
- ???
Many ways to represent a motion
Different creation methods yield different representations
Equivalent (in terms of output)
Different representations respond differently to change.

Different changes are convenient with different representations.

\[ h-(t-x)^2 \]
Three main ways to make motion

- Create it by hand
- Compute it
- Capture it from a performer

And increasingly...
- Re-use an existing motion
  (don’t make it at all)
Creating Motion by Hand: Keyframing

- Skilled animators place “key” poses
- Computer “in-betweens”
- Requires incredible amounts of talent
- But can be done extremely well

**Verdict:** Produces the highest quality results, at a very high cost
Computing Motion: Procedural and Simulation

- Define algorithms to create motions
- Ad-hoc rules, or simulate physics
- Physics provides realism
- But how do you control it?

**Verdict:** Good for secondary effects, not for characters (yet)
Motion Capture and Performance Animation

- Use sensors to record a real person
- Get high-degree of realism
- Which may not be what you want...
- Possibility for real-time performance

**Verdict:** Good for realistic human motions. Scary to animators.
Animation from Observation

Not (just) Motion Capture

- Capturing the motion is only one part of the process
- There are other reasons to capture motions
  - Medical
  - Surveillance
  - Sports performance
- Don’t look at capture as a silver bullet
Motion Capture Technology: Optical Tracking

- User markers and special cameras
- Tracking + Math
Animation Appreciation 101

- Michael Jackson’s Ghost
  - Digital Domain, 1997 (?)
  - Detailed Motion Capture
  - Recognizable motion
  - Skeleton is OK
Motion Capture Technology: Video

- An interesting and open problem...
- Limited information
  - But seemingly enough
- Problem can be arbitrarily hard
  - Or easy – if you make assumptions
- Video is surprisingly bad
Motion is tough

And it’s not just motion capture’s problem

Motion Capture
Sample every frame
- No structure.
- No intent.
- Lots of data!

Dense samples can represent rich frequency content

Noise, sensor errors

Hand Animation
Data at Keyframes
- Structured?
- Remember why?
- Maybe lots of data.

Good animators create complex frequency content

Quality takes work

Hard for academics to obtain quality hand animation
Mocap Pipeline

- Motion Capture is a misunderstood technology
- Good for what it's good for
- Not necessarily easy or cheap
- Must be done with great care
Processing Pipeline

1. Define Character
2. Define Character Controls
3. Define Skeleton
4. Retargeting & Control Mapping
5. Clean Skeletal Data
6. Animation Data
7. Application
What is performed is almost never what we want

- Animation: bring something to life
  - means we want to change *something* about the performance
- Actor vs. character
- Restrictions of realism
- Performers aren't perfect
- Need for usable data (loops, reference poses, ...)
- Studio is not virtual world
- Motion re-use
  - sometimes we are stuck with what we have
A Teaser...

Coming Attractions