Computer Animation:
It's Past, It's Present And its Future at UW

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Outline

- A brief history of computer animation
  - (animation appreciation) – Video!
- Overview of the Production Process
  - Where motion comes from – Video!
- Animation at UW CS
  - (what we do) – Video!
- Graphics and Animation Classes
  - (what you can do) – Video!

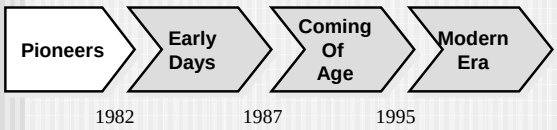
Goals

- Give you some idea of what Computer Animation is about
- Give you some idea of where (some of) the hard problems are
- Give you an idea of we do
- Try to get you excited about doing it
- **Show some fun video**

Caveats

- This talk is skewed toward 3D Animation for film and video
- That ignores lots of interesting stuff
  - 2D and image effects
  - Games, Visualization, Simulation, …
- Focus on character animation
  - Over-emphasize my heroes
- This is a rehash of some old stuff
- Little (or no) technical content

Timeline



- Phases of the history of animation

Pioneer Days (pre-1980s)

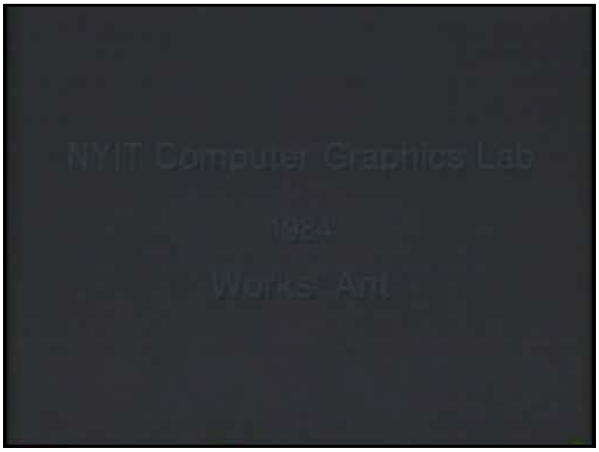
- What was happening:
  - Early pioneers (in research labs) started making movies with computers
- General Story:
  - It was hard to make pictures with computers, but people did it anyway
- Why it ended:
  - Computer Animation becomes feasible

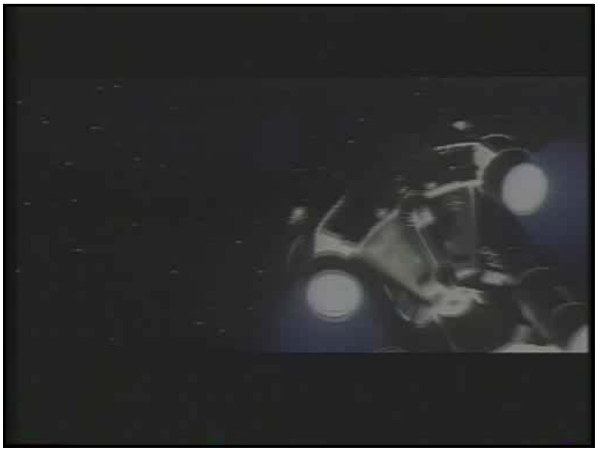
Early Days (early to mid-1980s)

- What was happening:
  - Computer animation in film and video
- What it looked like:
  - Computer graphics
  - Things computers could draw well
  - Chrome! Flying Logos!

Early Days (early to mid-1980s)

- Notable examples:
  - TRON ('82), The Last Starfighter ('84)
  - Many TV spots and commercials
- What it looks like today:
  - Quaint
- Why it ended
  - AUDIENCES grew more savvy





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A critical moment in history…

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)

Computer Animation Comes of Age (late 80s – mid 90s)

- Computer Animation not just for computer animation's sake

Beauty and the Beast, 1991

Jurassic Park, 1993

Glory Days of Computer Animation

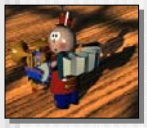
- What will they do next?
- Notable examples
  - Tin Toy '88 (and other Pixar Shorts)
  - Terminator 2 '91
  - Beauty and the Beast '91
  - Jurrassic Park '93
  - … more and more and more …

Another important film…

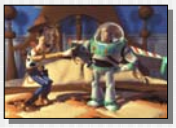
Toy Story
Pixar, 1995
J. Lasseter (dir)

- Feature length, 3D animated film
- Financially and artistically successful
- Everybody wants to copy

Why is Toy Story Different?



Tin Toy
1988



Toy Story
1995

- Same basic technology as shorts
- Different magnitude of problems
  - How to deal with all the bits!
- Must hold attention for 90 minutes

End of the Glory Days?

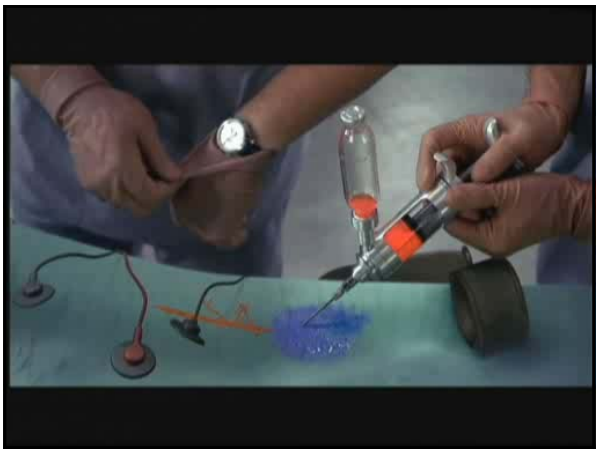
- No more firsts?
- Glory is for good films, not cool effects
  - Not just animation for animation's sake
  - Hackers are not the heroes anymore
- Technology is generally available.
  - (Kindof)
- Artistic factors drive

Toy Story++

- More and more animated films
- Greater levels of complexity
  - Antz, Bugs Life, Toy Story 2, …
- New artistic styles and possibilities
  - Tarzan, Prince of Egypt
  - Final Fantasy,…
- Current state of the art

The Modern Era ('95 - …)

- No more firsts?
- Don't believe your eyes!
  - Anything is possible!
  - Seamless integration of CG and real
- Some landmarks
  - Titanic '97
  - What Dreams May Come '98
  - The Mummy, Episode 1, The Matrix '99
  - Hollowman, Perfect Storm '00
  - Pearl Harbor '01



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How do you do it?

Design → Modeling → Animation → Lighting → Rendering → Post-Production

- "Typical" or Traditional pipeline
- Divides tasks
- Variants exist

Design

Design → Modeling → Animation → Lighting → Rendering → Post-Production

- One of the most important pieces
- Deciding what animation is to be made

Modeling

Design → Modeling → Animation → Lighting → Rendering → Post-Production

- What are the objects?
- What do they look like?
- How do they move?

Animation

Design → Modeling → Animation → Lighting → Rendering → Post-Production

- Animate: to bring to life
- Making things move

Lighting

Design → Modeling → Animation → **Lighting** → Rendering → Post-Production

- Making choices in how things look
  - Term is a "Pixarism"
- Catch-all for lots of appearance design

Rendering

Design → Modeling → Animation → Lighting → **Rendering** → Post-Production

- Let the computers color the pixels
- The compute intensive part

Post-Production

Design → Modeling → Animation → Lighting → Rendering → **Post-Production**

- Put the pictures into final form

Why focus on motion?

- It is the heart of animation
- It's the most unique aspect of animation
- It's the thing we have the least experience with
- It's the thing I am most interested in

What is a character? (for the purposes of motion)

- Some "object" (geometry)
- *Configuration* or *Pose* given by a set of numbers
  - Parameters
  - Control knobs
- Process to (or draw) geometry given parameters
- *Articulation*: define how parameters drive geometry

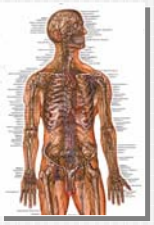
What parameters?

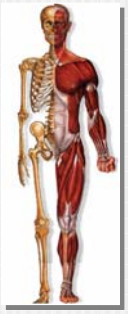
- It depends!
- Enough controls to be expressive
- Few enough to be easy
- Standard methods for gross motion
- Anything goes for details

What are those parameters?

How do we model a human?

- Humans are quite complex…





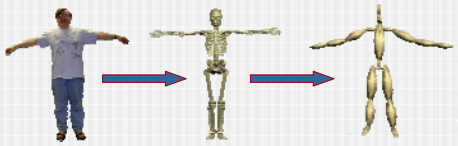
Fortunately, we don't care about details

- "Gross Body Motion"
  - Overall movement
- Small details hidden
  - Under clothing
  - Under simplified drawing models
  - View from far enough away
- Chains of rigid segments

Animation Apreciation 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



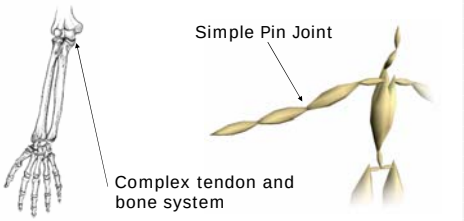
206 bones, muscles, fat, organs, clothing, …

206 bones, complex joints

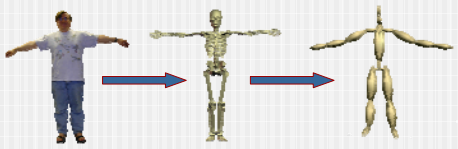
53 bones Kinematic joints

Abstractions vs. Reality (skeletons vs. humans)

Representation of complex human structure with varying degrees of simplification



Abstraction of Human Motion



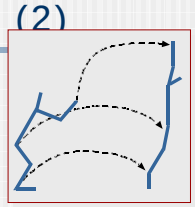
- Question of Approximating DOF's
- Some number of connected, rigid pieces
  - (usually)
  - Kinematic joints

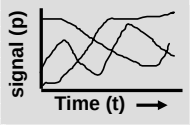
What is a motion (2)

- A motion maps times to configurations

$$\mathbf{m}(t) \in \Re \Rightarrow \Re^n$$

- Vector-valued, time-varying signal
- Representation comes from creation
  - typically interpolation
  - may not be convenient for editing





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

Three main ways to make motion

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

- 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)

All motion in this animation was generated using dynamic simulation.

Dynamics

David Baraff

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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.

Michael Jackson

"Ghosts"

Director: Stan Winston

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Motion Capture Technology: Optical Tracking

- User markers and special cameras
- Tracking + Math

Motion Capture Technology: Video

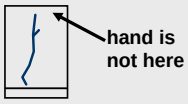
- An interesting and open problem…
- Limited information
  - But seemingly enough
- Problem can be arbitrarily hard
  - Or easy – if you make assumptions
- Video is surprisingly bad

So now you have motion…

- Transform Motion to new uses

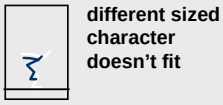
Problem: Motion is Specific

Specific Action



Edit **motion to meet new needs**

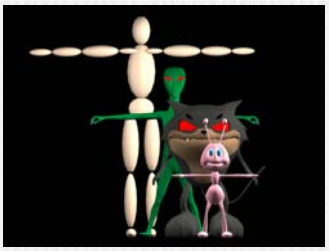
Specific Character



Retarget **motion to new character**

Retargetting Motion to New Characters

- Goal: one motion, a cast of characters
- Similar structure



Transformation Basics

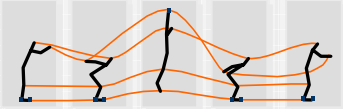
Change what isn't important, retain what is

- Hard to define what is important
  - high-level properties
  - motion specific
- Stick to what's easy to define
  - geometric constraints
  - signal characteristics
  - framework for better metrics later

Transformation as Constrained Optimization

- Find a motion that…
  1. Meets any specific requests
  2. Keeps any specific characteristics of the original
  3. Is as similar as possible to the original
- Naturally posed as constrained optimization
  - subject to meeting the constraints (1 and 2) minimize some objective (3)

Spacetime Constraints

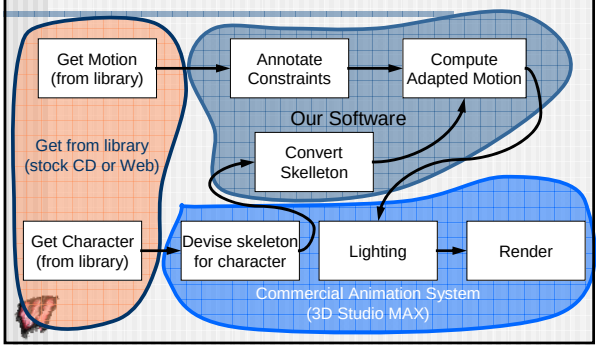


- Consider all constraints simultaneously
  - NOT frame at a time
- Solve for motions
  - "best" motion that meets constraints

What does it take to do this?

- Setup and Solve a BIG math problem
  - Non-linear, variational, constrained optimization
- Thousands of simultaneous equations
- Yes, you can do it in real time
  - with some caveats…

How did we do that?



Where did we do that?

- The UW CS Graphics Group!
  - The initial retargeting work was done before I came here
- There's a graphics group here?
  - I thought we only do stuff like Databases and Architecture?

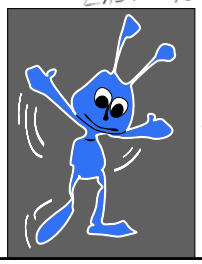
Graphics at UW CS

- Target for growth in the department
- New courses:
  - Introduction to Graphics
    - now taught as CS638, will get new number soon
  - Computer Animation
    - now taught as CS838, will get new number soon
  - Other courses elsewhere
    - Art (comp. anim), ECE (image proc), …

STYLIZED LOGO

University of Wisconsin, Madison
Computer Graphics
http://www.cs.wisc.edu/graphics

EASY TO REMEMBER URL



TOON MASCOT

University of Wisconsin, Madison
Computer Graphics
http://www.cs.wisc.edu/graphics

- History
  - Early 80s – grad students try to do
  - Mid 90s – identified as "important new area"
  - 1998 – Perry Kivolowicz teaches first course
  - 1998 – Gleicher is hired to form group
  - 1999 – First animation course (838)
    - (survivors still exist)
  - 1999 – Regular undergrad graphics course
  - 2000 – Chenney hired, first graphics students
  - 2001 – Graphics qualifying exam, …

University of Wisconsin, Madison
Computer Graphics
http://www.cs.wisc.edu/graphics

- Faculty
  - Mike
  - Stephen
  - Friends (Chuck, Vadim, Nicola, …)
- 7 graduate students (5 mike, 2 Stephen)
  - The only RAs in the department without offices
- 4-5 undergrads
- Lab shared with Computer Vision group
  - 1347 CS&S

University of Wisconsin, Madison
Computer Graphics
http://www.cs.wisc.edu/graphics

Mike's Research

Authoring by Adaptation

- Motion Editing
- Automatic Stylization
- Virtual Videography
- Human motion reconstruction
- Crowd Simulation

Stephen's Research

Scalability and Control of Physical Systems

- Control of Physics
- Scaling Physics
- Terrain Synthesis
- Cartoon Physics
- Crowd Simulation

CS Graphics Courses

Undergraduate & Graduate

- CS559 – Computer Graphics
  - General intro of field
  - Required for everything else
  - The "Extra Session" experiment
- CS679 – Computer Games Technology

Graduate

- CS777 – Computer Animation
- CS779 – Rendering

Elsewhere on campus…

Answers to Frequently Asked Questions

- It depends.
- Yes, 559 is a lot of work, requiring both hacking and math.
- Maybe.
- Yes, we do get undergrads involved in our research projects.
- 42
- Stephen is in Peru this week.
- No, the software is not available for you to try yourself.
- It depends.
- C++ is the programming language of choice for 559, just as English is the lecture language of choice. It's mainly a matter of what is most convenient. Many students pick it up as they go.
- Yes, there is one more distinguished lecture this week.