The Principles Of Animation
• History Of Animation

• The Animation Pipeline

• 12 Principles Of Animation
Increasing Complexity

So far in this course, we’ve explored:

- [ transformations ] (A1)
- [ geometry ] (A2)
- [ rendering ] (A3)

What about motion?
First Ever Animation

Shahr-e Sukhteh (3200 BCE) Iran
Early Animation

Tomb of Khnumhotep (2400 BCE) Egypt
Early Animation

Leonardo da Vinci (1510)
The Phenakistoscope (1831)
The Zoetrope
The Zoetrope

Blooms (2017) John Edmark
First Film

- Originally used as scientific tool
  - Horses thought to always have one foot in contact with the ground
  - Filming horse run cycle disproved it

- Critical technology that accelerated development of animation
  - Key usage: rotoscoping

Sallie Gardner (1878) Eadweard Muybridge
First Animation On Film

Fantasmagorie (1908) Emile Cohl
First Hand-Drawn Feature-Length Animation

- 83 minutes
- 3 years of production
- $1.5 million to produce
- 750 artists
- 250,000 drawings

Snow White and the Seven Dwarfs (1937) Disney
Modern-Day Hand-Drawn Animation

- 103 minutes
- >3 years of production
- $34 million to produce
- 60 artists
- 180,000 drawings
  - Each minute of animation takes a month to produce

Ponyo (2008) Studio Ghibli
First Computer-Generated Animation

Catalog (1961) John Whitney
First Digital Computer-Generated Animation

Sketchpad (1963) Ivan Sutherland
First 3D Computer Animation

Boeing Man (1964) William Fetter
Early Computer Animation

Kitty (1968) Nikolay Konstantinov
Early Computer Animation

Computer Animated Faces (1972) Ed Catmull & Fred Park
Early Computer Animation

Toy Story (1995) Pixar
Cloudy With a Chance of Meatballs (2009) Sony Pictures Animation
• History Of Animation

• The Animation Pipeline

• 12 Principles Of Animation
Hand-Drawn Animation

- Draw out every frame
  - Yes, you heard me correctly
  - Any questions?

- Before computers, animations would be drawn on thin cel-sheet papers
  - Translucent papers that were useful at seeing previous and future drawings
  - Idea would later be adapted into onion-skinning

public domain now
Vector-Based Animation

- Use vectors to drive the animation
  - Done on the computer. Vectors then rasterized to pixels
  - Allowed assets to be infinitely scaled

- Create 2D puppets as assets that are rigged for animation
  - Keyframe transformation properties of vectors to make puppets move
  - Requires a lot of vectoring and assets

- “Don’t ever let your audience realize you’re animating a puppet.”
• Using meshes, materials, and rendering to produce 3D animated sequences

• Use a photorealistic renderer to make results photorealistic

• No need to draw anything, computer takes care of everything
  • Model movements end up being more consistent compared to hand drawn
  • Lacks the hand drawn ‘charm’
Stylized Animation

- A hybrid of 2D and 3D animation elements
  - Best of both worlds

- Keep the ease of consistency with 3D animation
  - Add the ‘charm’ of 2D animation

- Uses very stylized render engines
  - Breaks many of the physical aspects of light
  - Can still be unbiased & consistent

- Render 3D content first
  - Composite the resulting content in 2D with 2D special effects
What are the stages of making an animation?
Script Writing

• People sit down and ponder over a script

• Scripts will encode:
  • Character dialogue
  • Character actions
  • Camera movements
  • Background information
  • Timing

• Script is pitched to executives
  • Whoever can make the most executives happy get their scripts made into a movie!

Exec Board Meeting (2023) Disney Animation
Storyboarding

• Scripts are converted to index-card sized drawings for key scenes in the film
  • Helped convey posing & staging of characters

• Would go back and forth between script and storyboard until a story was agreed on

Aladdin (1992) Disney Animation

Pinocchio (1940) Disney Animation
Storyboarding

• Storyboard cards pinned to walls
  • Made it easy to move around shots and get a quick sense of how flow would change

• Short description or dialogue often accompanied cards

Jungle Book (1967) Disney Animation
Animatics

• Animatics are digital scans of the storyboard that are played back as video
  • Gives a better sense of timing
  • Lowered ambiguities caused by storyboards

• Edited using a video editing program
  • Can pull of tricks like panning, scaling, and other camera movements

• Animatics sometimes accompanied with voice acting and soundtracks

Modeling

- Character models are created and rigged
  - **Created:** editing meshes to look like characters
  - **Rigged:** add bones to make a character moveable
    - Can be done for both for 2D (vectors) and 3D (meshes)

- Backgrounds modeled in 3D or hand-drawn in 2D
  - Stylized animations will composite 3D characters with 2D animations
Key Animation

- **Senior animators** work on keyframes of an animation
  - Requires higher degree of drawing/posing experience
  - Also referred to as **keyframing**

- Gives a quick impression of what the animation will be like before investing too much time into it

Attack on Titan (2013) WIT Studio
In-between Animation

• Animators revisit the frames and draw in-betweens
  • Junior animators will work on in-betweens

• With advancing technologies, in-betweens will be created by the computer

Lilo & Stich (2002) Disney Animation
Visual Effects

- Visual effects can be done after the character animation, or even in parallel

- For 3D animations, VFX will be done in 3D
  - Stylized animations will do VFX in 2D

- For 2D animations VFX will be done in 2D
  - Complex simulations (water, fog, etc) will be done in 3D
    - Known as CGI effects

Nimona (2023) DNEG Animation
Compositing

- Character animation, background, and VFX are combined into one video stream

- Final round for any changes
  - Lighting, staging, camera movements, etc.

- **Color correction** (also known as color grading) is the very last adjustment made
  - Allow frames between shots to look more consistent

Monster’s University (2013) Pixar
What techniques can help us make animations?
Onion Skinning

• **Onion skinning** lets you see previous and future frames at a lower opacity
  • Helps when you have two keyframes and want to add an in-between frame
    • Based off translucency of cel paper

• Good debugging tool debug **spatial trajectory** of objects
Easing

- **Easing** allows objects to **accelerate** into and out of their motion
  - Derived from physics
  - Objects with **inertia** feel a force before accelerating

- Visualized by 1D chart with tick marks with equal time separation but varying spatial separation
  - The closer the tick marks, the smaller the spatial separation, and the slower the motion

- Easy strategy to guarantee easing: **subdivision**
  - Draw a frame between frames 1 and 9 (call it 5)
  - Draw a frame between frames 1 and 5 (call it 4)
  - Draw a frame between frames 1 and 4 (call it 3)
  - Draw a frame between frames 1 and 3 (call it 2)

Illustration of Life (1999) O. Johnston, F. Thomas
• **Layers** used to separate different animation components and edit/transform them independently

• Generally have layers for:
  • Sketch
  • Linework
  • Color
  • Shading
  • Lighting

• Sketch layer only for reference and hidden in the end
  • Remaining layers merged back down into one
Problem With Animation

- Hand-drawn animation was very **rigid** and **robotic**
  - Animators only moved body parts that needed to be moved
    - **Example**: reaching for your hat means only lifting your right arm
    - **In reality**: Your head will also move towards your hand so that your hand doesn’t have to travel the entire distance

- **Key idea**: when one part of the body moves, the entire body should move

Humorous Phases of Funny Faces (1906) James Blackton
The Rotoscoping Machine

- Max Fleischer wanted to merge human-like movements with cartoon-like exaggerations
  - **Key idea:** real-life is your **best reference**

- Fleischer was from a family of tinkerers and worked with his brother to create the first ever *rotoscoping machine* in 1915
  - Projector on top would shine an image from film into the middle box which would be amplified using a headlight onto glass
  - The artist could the the frame and add any details **trace over** they want
  - The crank on the side moved onto the next frame

- Tracing over real life became known as **rotoscoping**
• Fleischer’s animated series “Out of the Inkwell” received high praise for its technical advancements at lifelike character movements

• The character Koko the Clown was acted out by Fleischer’s brother in a clown costume

• Disney invested in this technology with “Snow White & the Seven Dwarfs” in 1937
Rotoscoping The Rotoscoped

- Animation studios rotoscoped over older animations
  - No need to re-act out old sequences
  - Referred to as **recycling animation**

- Often takes longer to recycle animation, so why bother?
  - A directing move to **play it safe** by using old cycles that they knew would sell the ideas better

Robin Hood (1973) & Snow White (1937) Disney Animation
Modern-Day Rotoscoping

• Can use any recording from your phone camera and trace results in software
  • Premise is still the same: draw out every frame, adding additional details
  • Gives hand-drawn animations natural motions

• Commonly used for more complex animations such as dance and fight cycles
• History Of Animation

• The Animation Pipeline

• 12 Principles Of Animation
The 12 principles of animation were released by Disney animators Ollie Johnston & Frank Thomas in 1981. They are key properties widely referenced in the animation industry today:

- Squash & Stretch
- Anticipation
- Staging
- Straight Ahead vs. Pose to Pose
- Follow Through
- Easing

- Arc Motions
- Secondary Actions
- Timing
- Exaggeration
- Solid Drawing
- Appeal
Squash & Stretch

- **Squash & Stretch** is the deformation when an object hits something else.

- Common in rubber-hose animations where characters take a more rubber-based material form.
  - Characters feel freer and more energetic.

---

Aladdin (1992) Walt Disney Pictures

Squash & Stretch (2019) Josh Smithness
Anticipation

- **Anticipation** waits for an action to occur
  - Adds delays between actions so that viewers can get ready to focus on the action before it occurs

- **Examples:**
  - A jumper bends his legs before jumping
  - A bowler swings his arm back before throwing a bowling ball
Staging

- **Staging** is setting the scene such that no important actions or characters are obstructed.

- Camera angle, character placement, and lighting are all contributing factors.
  - Background scene should not obstruct from the main scene.

[Image of correct and incorrect staging examples with a scene from Ratatouille (2007) by Pixar.]
Straight Ahead vs. Pose To Pose

• **Straight Ahead** is drawing every frame sequentially
  • Easier to create more realistic movements,
  • Harder to keep proportions constant
    • Characters end up less dynamic and exaggerated

• **Pose to Pose** is drawing keyframes first before in-betweens
  • Easier to control posing
  • Easier to delegate tasks to senior and juniors

The Animator's Survival Kit (2001) Richard Williams
Follow Through

- **Follow Through** continues the motions of an action after the motion ends
  - An object in motion stays in motion

- Different body parts follow through at different rates
  - Long hair follows through more than clothes

*Tangled (2010) Disney Animation Studios

Illusion of Life (1999) O. Johnston, F. Thomas

The Animator’s Survival Kit (2001) Richard Williams
Easing

- **Easing** is how an object accelerates/decelerates
  - Characters don’t start at a constant velocity
- **Ease-in**: Start fast, end slow
- **Ease-out**: Start slow, end fast
- **Ease-in-out**: Start slow, end slow
- Represented by easing graphs in computer animation
Arc Motions

- **Arc Motions** guarantee that spatial trajectories are arc-like
  - Helps to build fluidity in the motion

- Walk cycles combine many arc movements
  - Joints rotate instead of translating

Mulan (1998) Disney Animation Studios

Illusion of Life (1999) O. Johnston, F. Thomas
Secondary Action

• **Secondary Actions** are the additional motions incorporated with the motions of a system
  • Illustrates a sub-animation cycle that we usually see accompany the main action

• **Example:** Hair simulation
  • Dog wagging its tail

Lady and the Tramp (1955) Walt Disney Pictures
• **Timing** is how the motions play out
  • How fast an object should be moving
  • How many frames should be used for the motion
    • The more frames, the slower

Exaggeration

- **Exaggeration** carries the motion faster and farther
  - Adds more energy to the characters

- Similar to **Squash & Stretch**, but for character actions
  - Gives the illusion that the object is rubbery

Tom & Jerry (1985) MGM Studio
Solid Draw

- **Solid Draw** adds depth to a character
  - Use bold lines close to camera
  - Construct characters from easy-to-recognize shapes

- Experience comes from practicing a lot of drawing and sketches from real-life

Simpsons (1989) Fox Interactive
• **Appeal** is the character’s charisma
  • How a character talks
  • How a character looks and acts

• Symmetric faces are likeable. Unbalanced or hard-to-read faces are not

• Your audience will spend a lot of time with your main characters. **Make sure they’re charismatic!**

Shrek (2001) Dreamworks Animation
The 12 Principles

- If an animation seems rough, sudden, or just off, refer to these principles
  - Rejection of these principles can lead to jerky, unpolished movements and scenes
  - The earlier in the pipeline you fix your animation, the better

Squash & Stretch
Anticipation
Staging
Straight Ahead vs. Pose to Pose
Follow Through
Easing

Arc Motions
Secondary Actions
Timing
Exaggeration
Solid Drawing
Appeal

The Illusion of Life
Disney Animation
Frank Thomas and Ollie Johnston