Topic 13: Animation Principles

Animation Timeline

- 1908: Emile Cohl (1857-1938) France, makes his first film, FANTASMAGORIE, arguably the first animated film (running time ~1min 20sec)

EMILE COHL

Fantasmagorie

—1908—

Animation Timeline

- 1911: Winsor McCay (1867-1934) makes his first film, LITTLE NEMO. McCay, already famous for comic strips, used the film in his vaudeville act. Pioneered keyframe animation, open about it and refused to patent his technique saying:

Any idiot that wants to make a couple of thousand drawings for a hundred feet of film is welcome to join the club.

Animation Timeline

- 1928: Walter Disney (1901-1966) working at the Kansas City Slide Company creates Mickey Mouse.
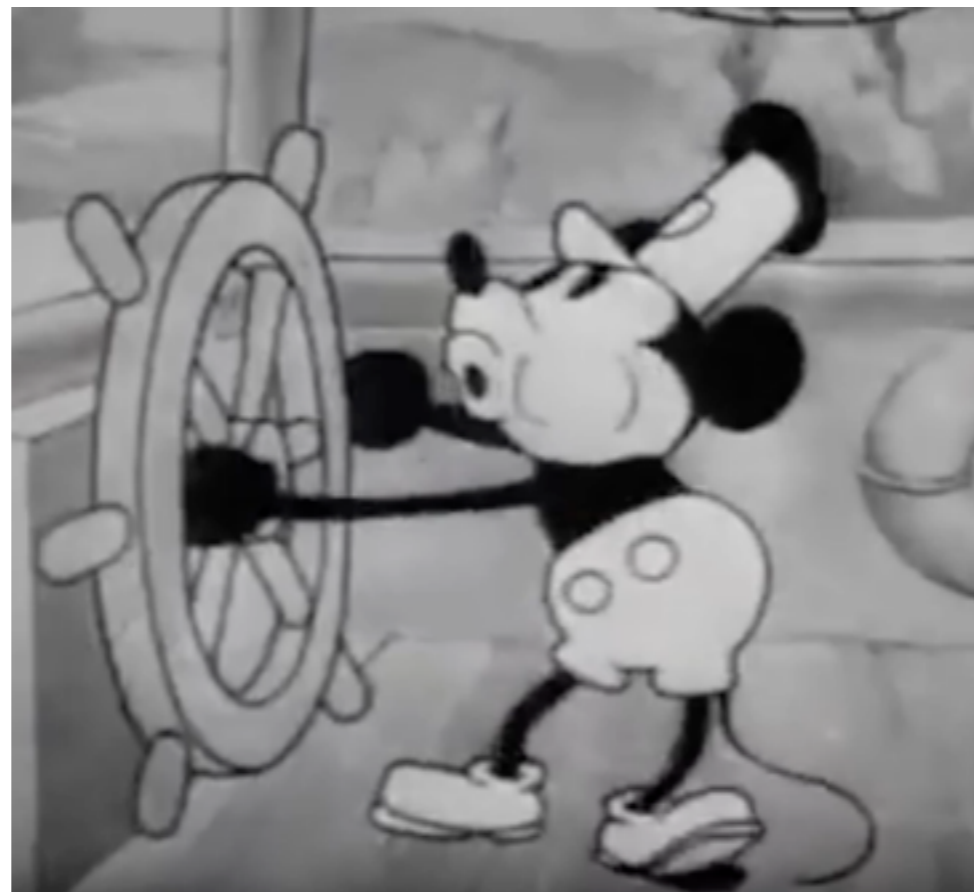
Animation Timeline

- 1974: First Computer animated film "Faim" from NFB nominated for an Oscar.

Animation Principles

- 12 basic principles of animation

- Deals with emotional timing and laws of physics

- Disney book "The Illusion of Life: Disney Animation"

Squash and Stretch

- Rigid objects look robotic: *deformations* make motion natural
- Accounts for physics of deformation
  - Think squishy ball...
  - Communicates to viewer object's composition, its weight,…
  - Usually large deformations conserve volume:
    Squash in one dimension, stretch in another to keep mass constant
- Also accounts for persistence of vision
  - Fast moving objects leave an elongated streak on our retinas

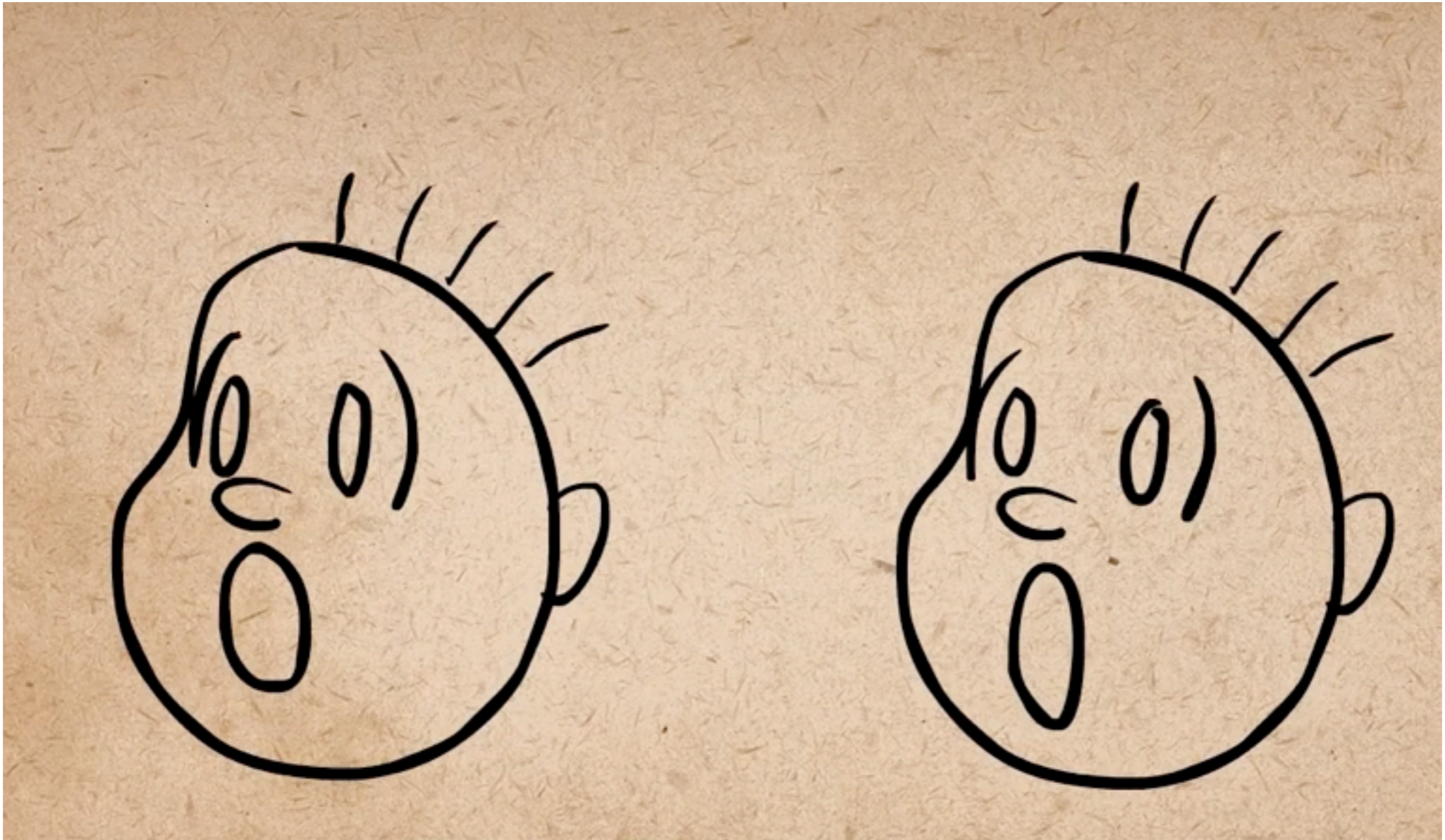FIGURE 2. Squash & stretch in bouncing ball.
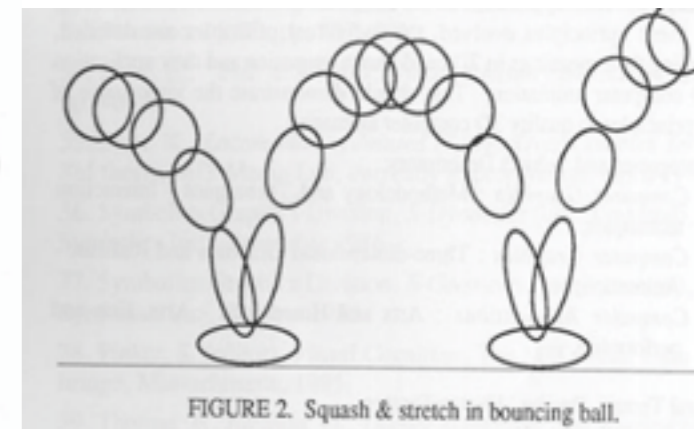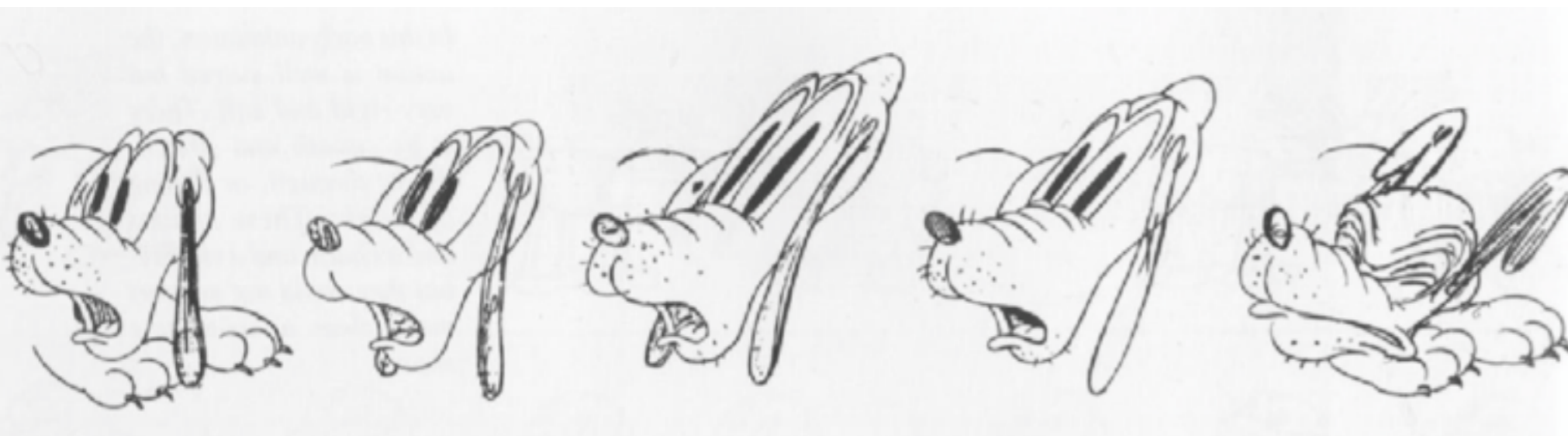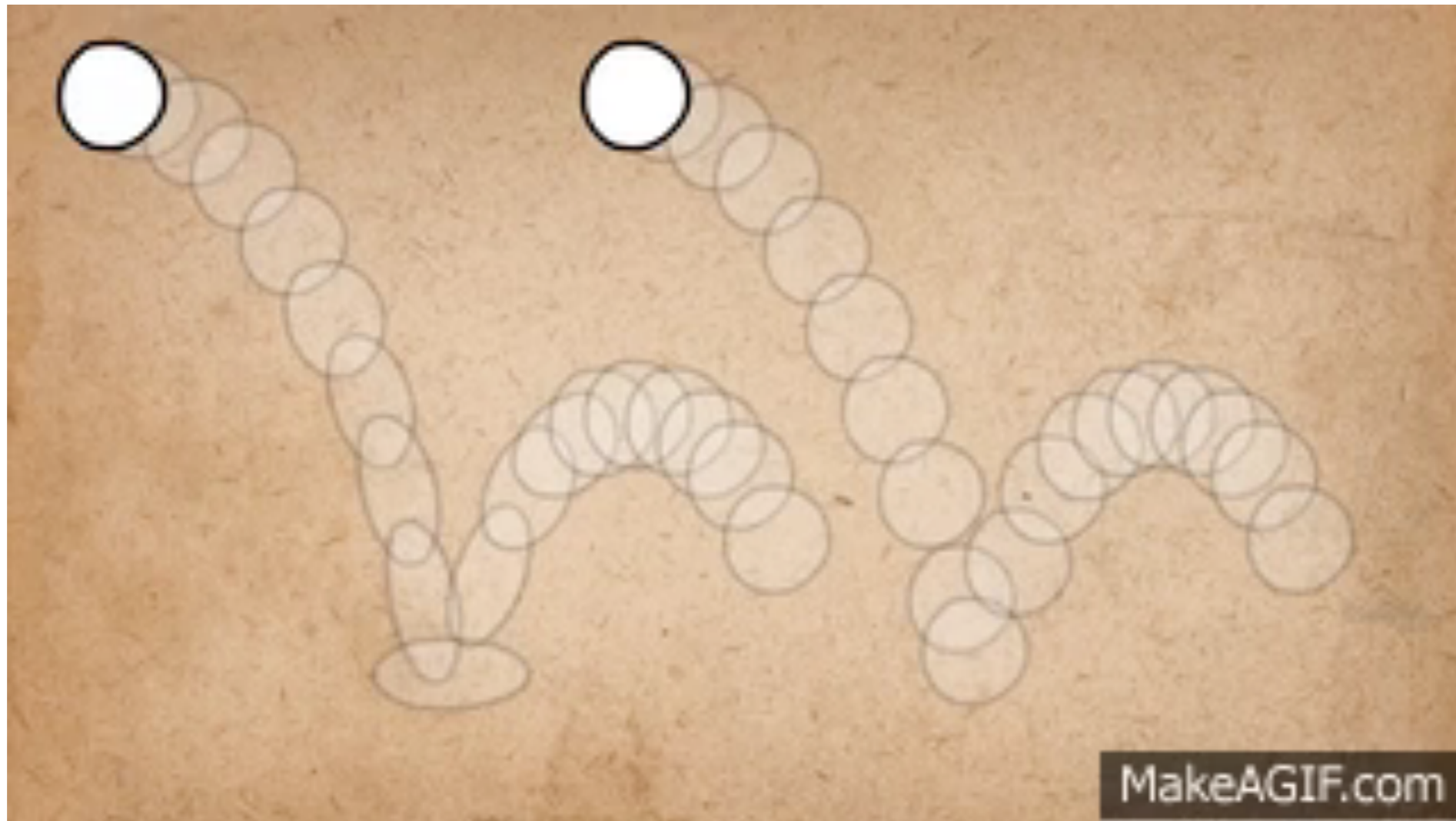
Squash and Stretch

Squash and Stretch

Anticipation

- The preparation before a motion
  - e.g. crouching before jumping, pitcher winding up to throw a ball
- Often physically necessary, and indicates how much effort a character is making
- Also essential for controlling the audience's attention, to make sure they don't miss the action
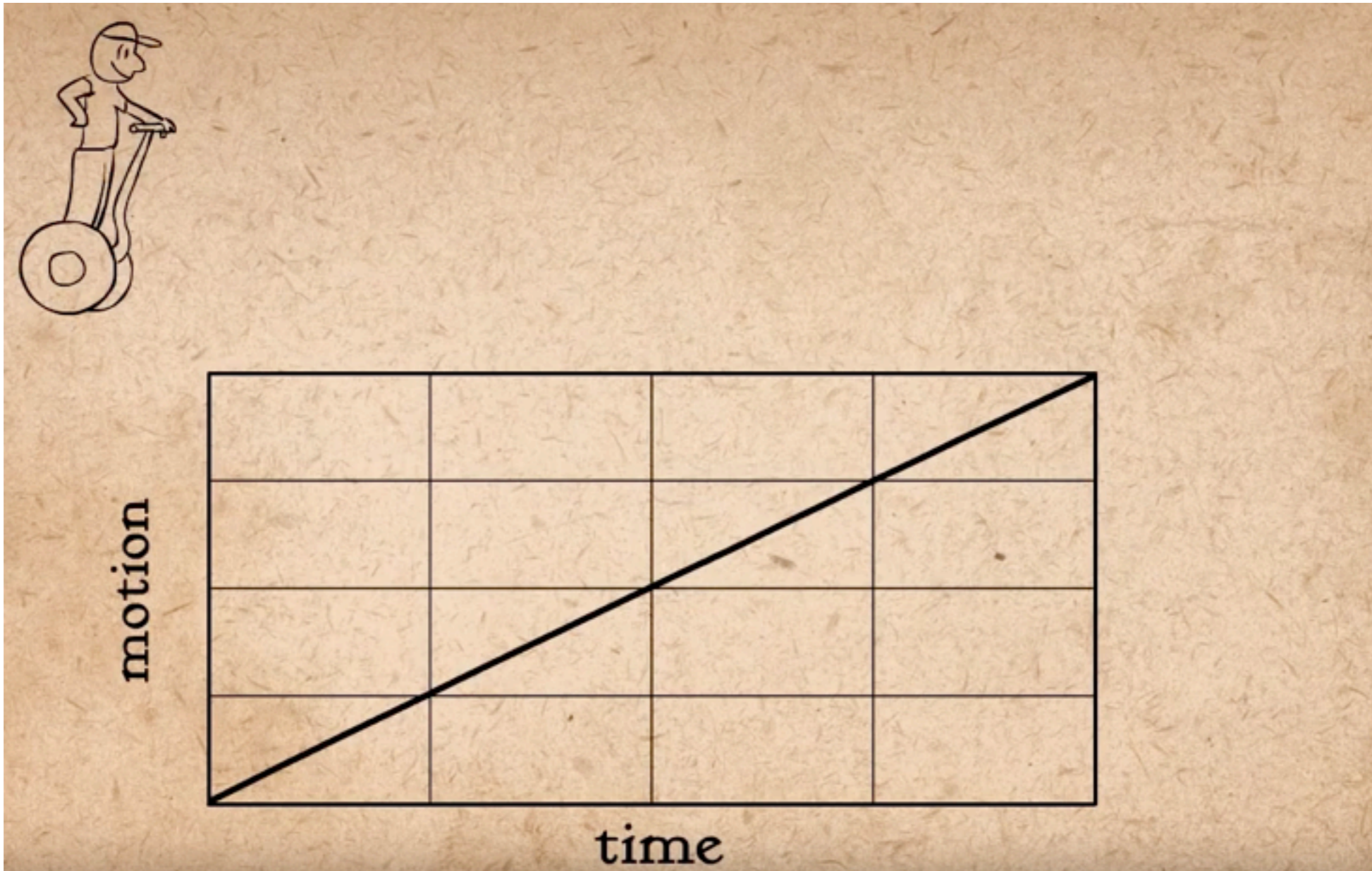 - Signals something is about to happen, and where it is going to happen.
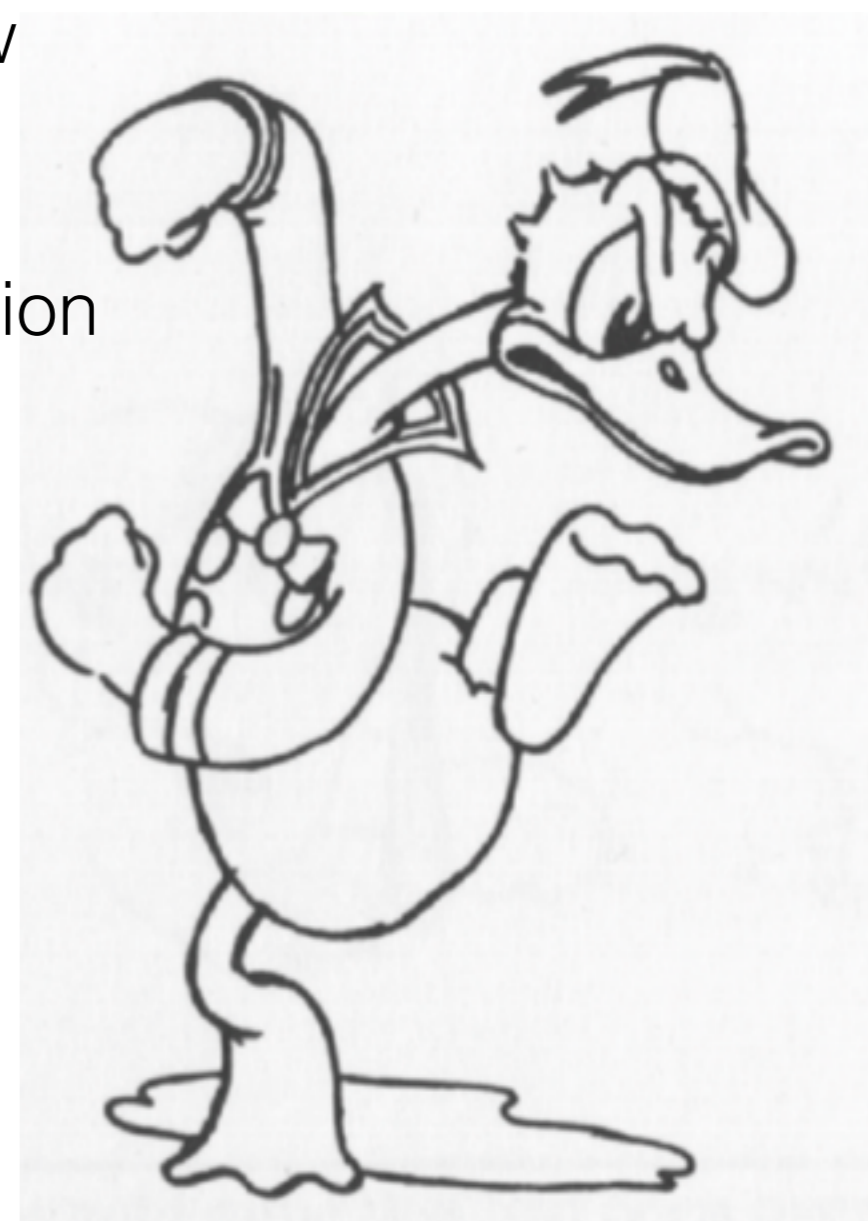
Anticipation

Ease-In & Ease-Out

- Objects don't have immediate speed and don't stop immediately
- Objects accelerate and decelerate, even if quickly
- Add more drawings near the beginning and end
- Emphasize extreme poses
- Can be controlled with spline interpolation

Ease-In & Ease-Out

Staging

- Similar concept in film and theatre
- Direct attention to most important point
- Remove ambiguity

Straight Ahead and Pose to Pose

- Straight ahead is to draw the scene frame by frame from beginning to end in a linear fashion
- Pose to pose draws important key moments (key frames) and fills in between the frames (inbetweening), to give the illusion of motion.

(more later)

Follow-through and Overlapping Action

- Uses the principle of inertia and laws of physics
- Follow-through: adds realism to animation through continued motion of loosely held parts on the body (hair, tail, clothes, fatty tissue, etc…)
- Overlapping action: different parts of body move at different rates
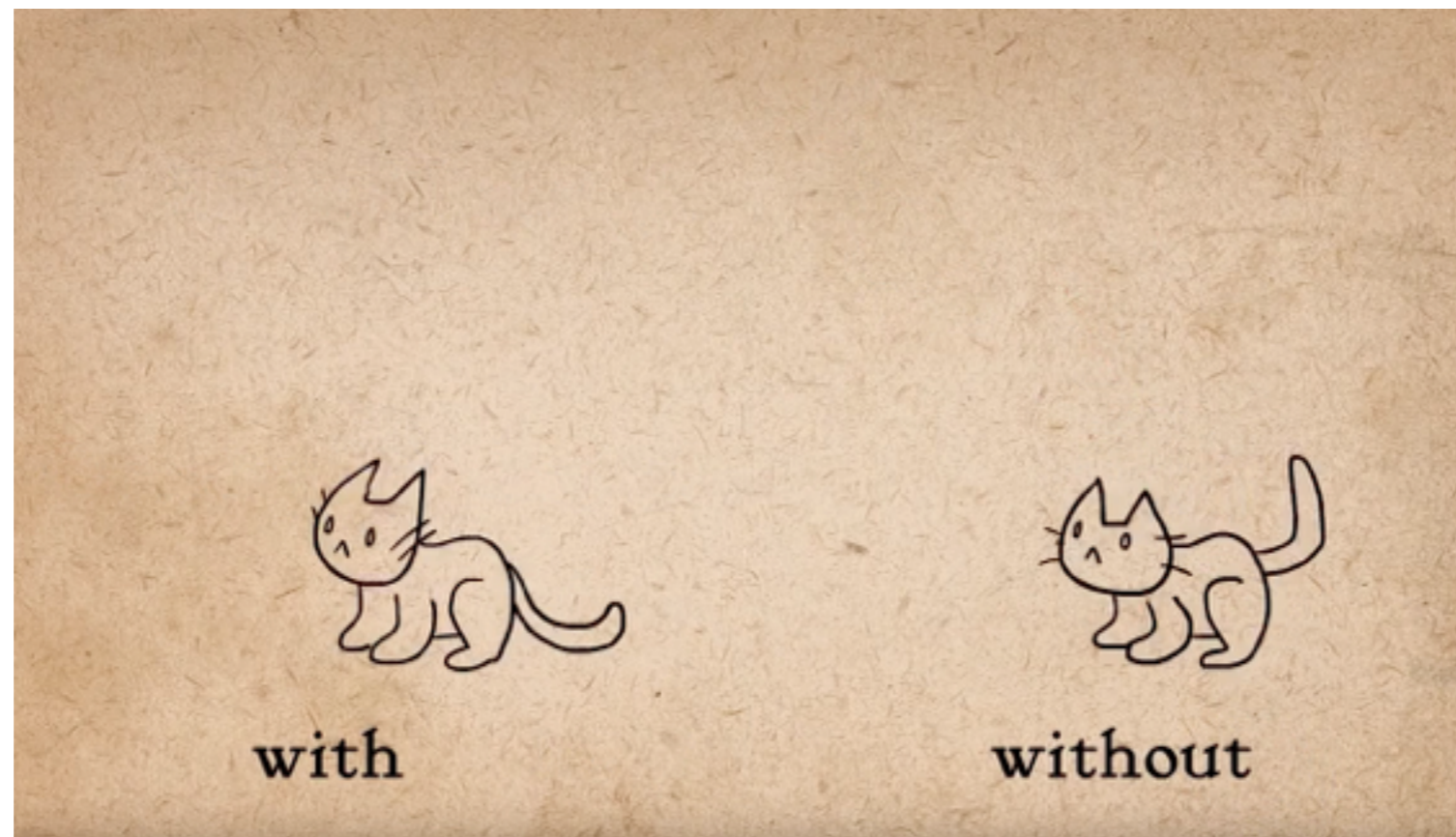
Arcs

- Things naturally move in arcs (baseball pitchers arms motion, swinging of a sword, etc…)
- Balls and objects follow a parabolic trajectory
- Follow the arc when inbetweening

Secondary Action

- Coupling a primary action with natural secondary actions
- e.g. Person walking swinging their arms, wiping a tear while crying, facial expression while eating

Timing

- The number of drawings for a given action.
- More drawings equates to slower motion
- Less drawings equates to faster motion
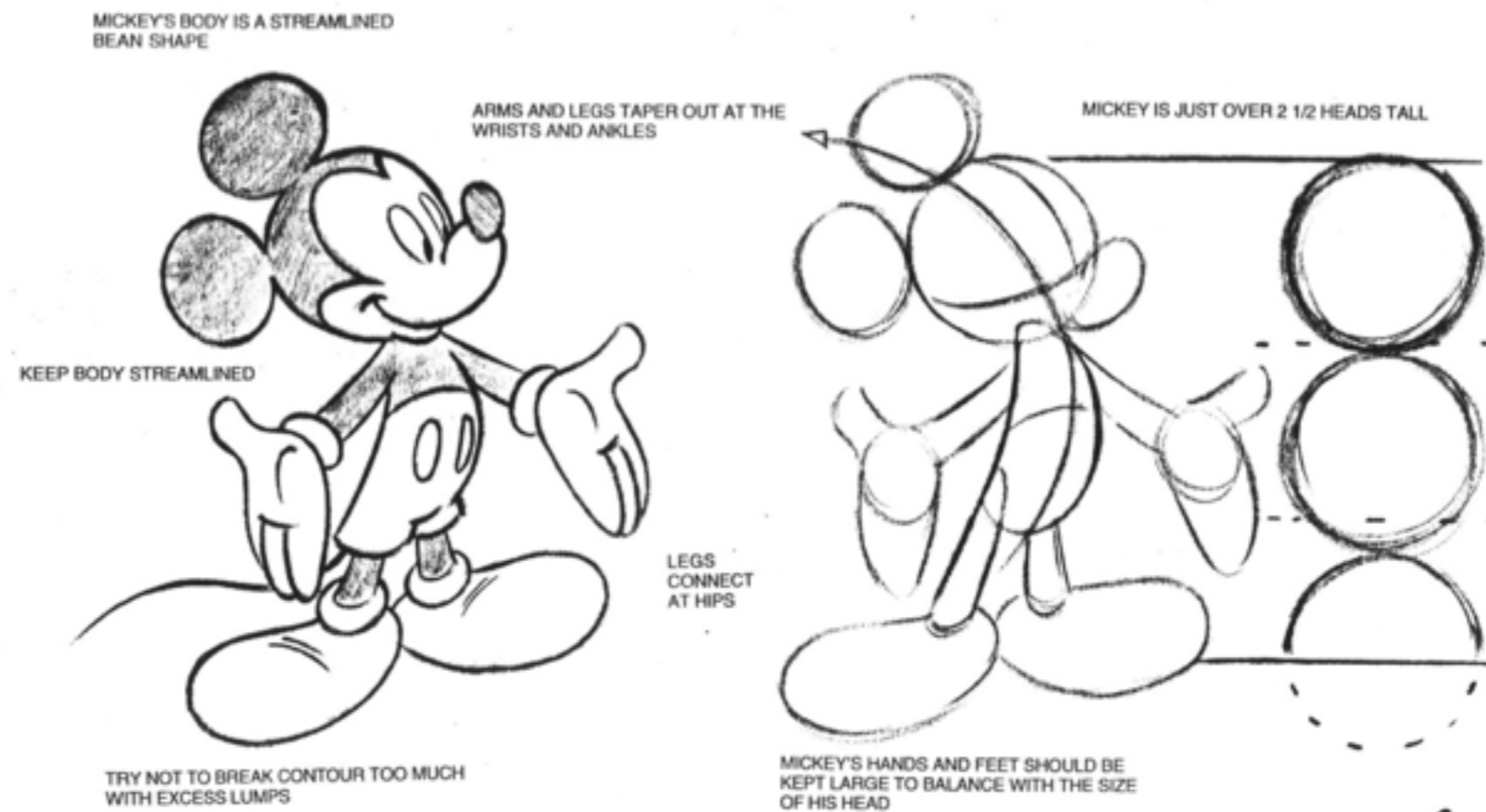- Can convey significantly different messages
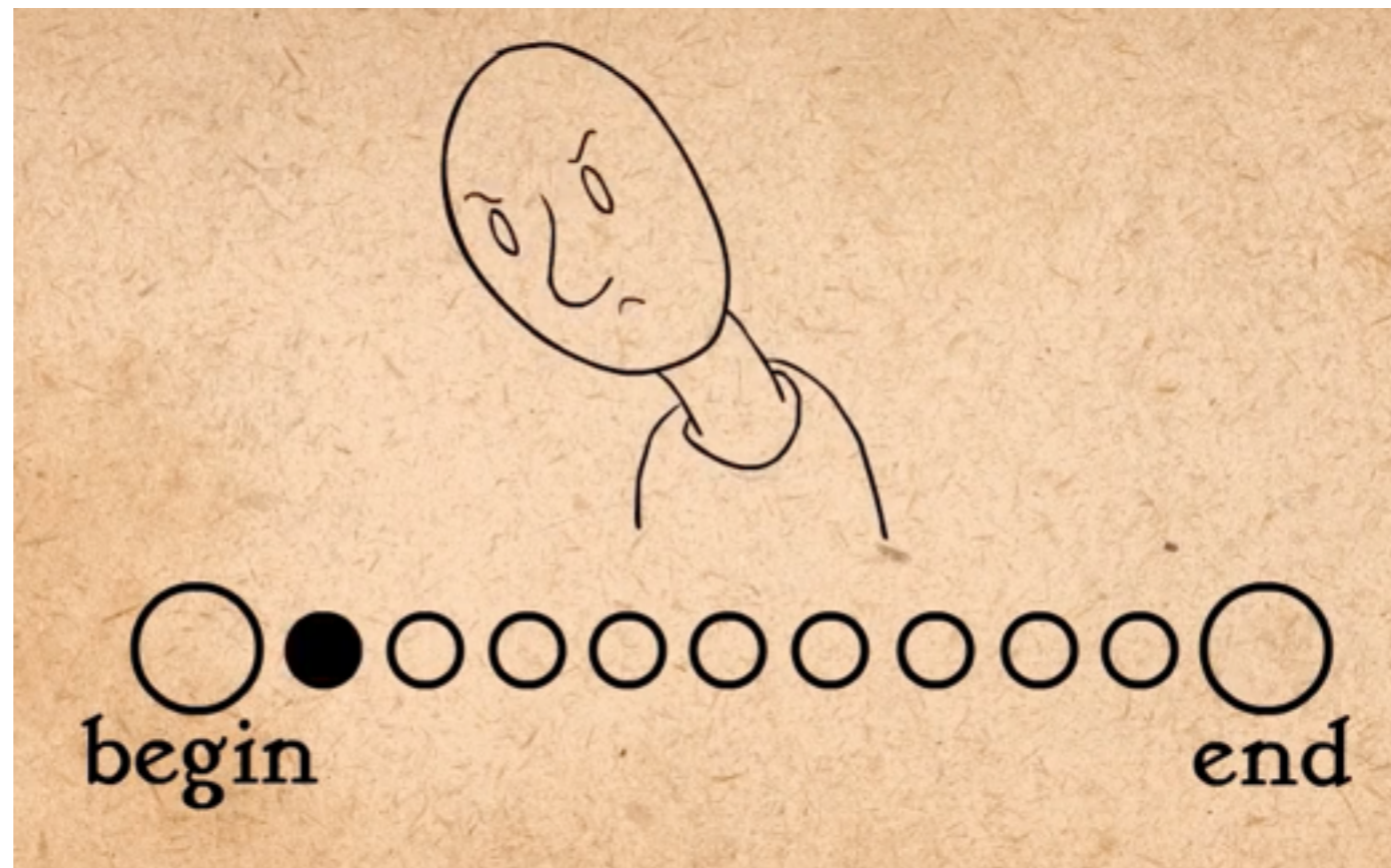
Exaggeration

- Can accentuate certain features
- Adds a degree of style
- Things that are "perfectly" real can come off as dull

Solid Drawing

- Able to draw things that are 3D
- Follow the contours of an object (e.g. sphere)
- Draw in perspective toward vanishing points
- Use solid shapes like cubes and circles to give dimension

Appeal

- Make the character real and interesting
- Pleasing to look at
- Charismatic aspect
- Interesting to look at, not necessarily "good-looking"
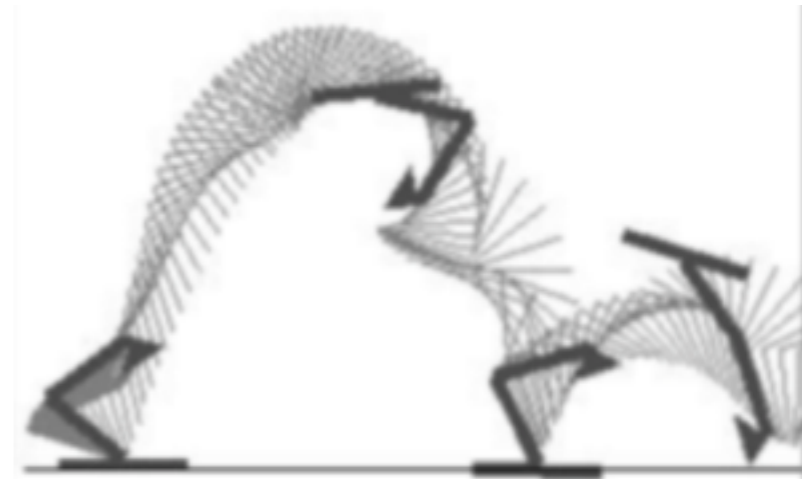- Avoid symmetry

Animation Principles

- **Squash and Stretch**

- **Anticipation**

- **Ease-In & Ease-Out**

- Staging

- Straight Ahead and Pose to Pose

- Follow-through and Overlapping Action

- Arcs

- Secondary Action

- Timing

- Exaggeration

- Solid Drawing

- Appeal

Elements of CG (animation)

- How does one make digital models move?

  - Keyframing

  - Motion capture

  - Physical simulation


  - Behaviour rules

Keyframes

Keyframes, also called extremes, define important poses of a character:
Jump example:
- the start
- the lowest crouch
- the lift-off
- the highest part
- the touch-down
- the lowest follow-through
- Frames in between ("inbetweens") introduce nothing new to the motion.
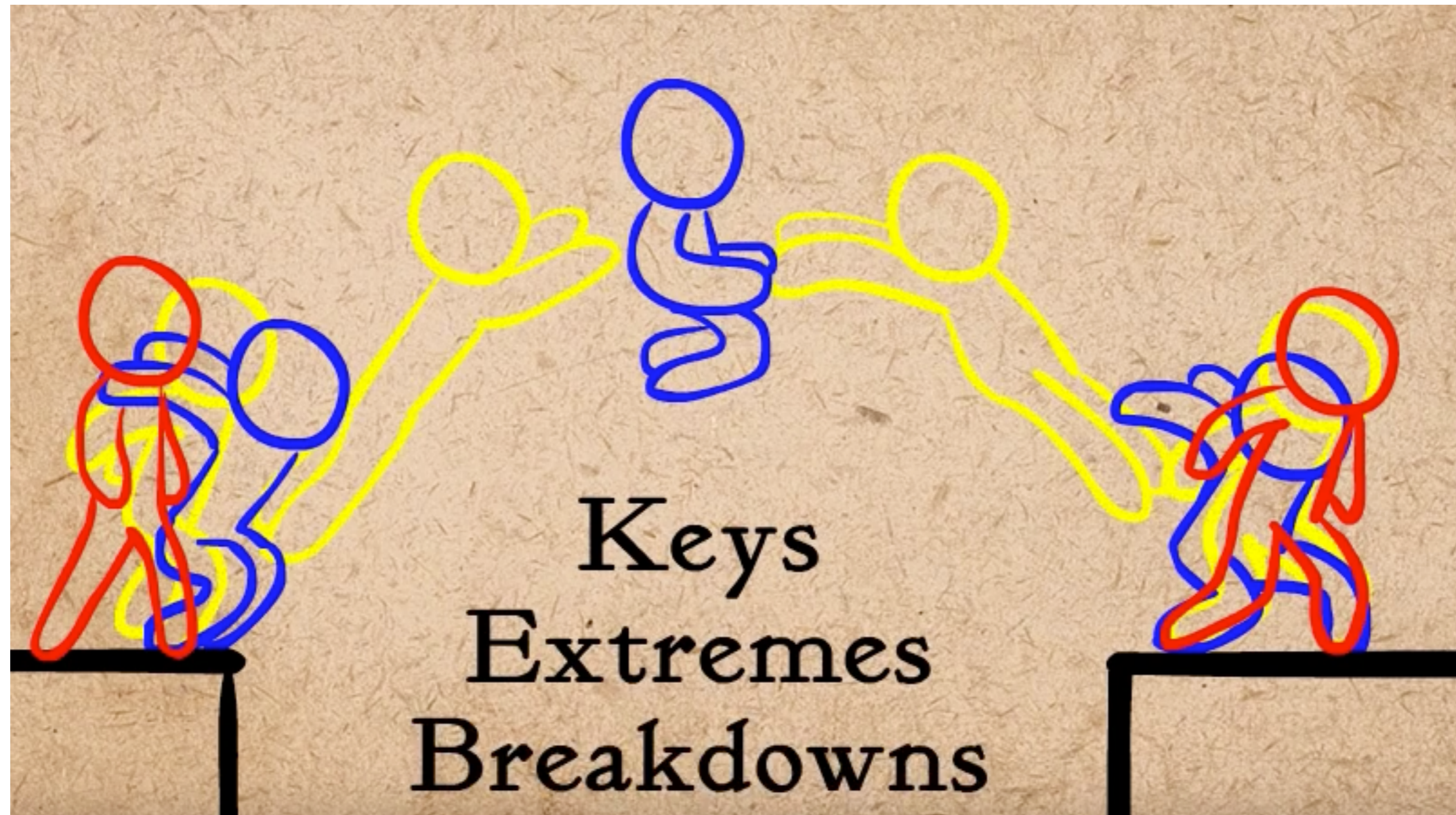- May add additional keyframes to add some interest, better control the interpolated motion.

Keyframes

Keyframes
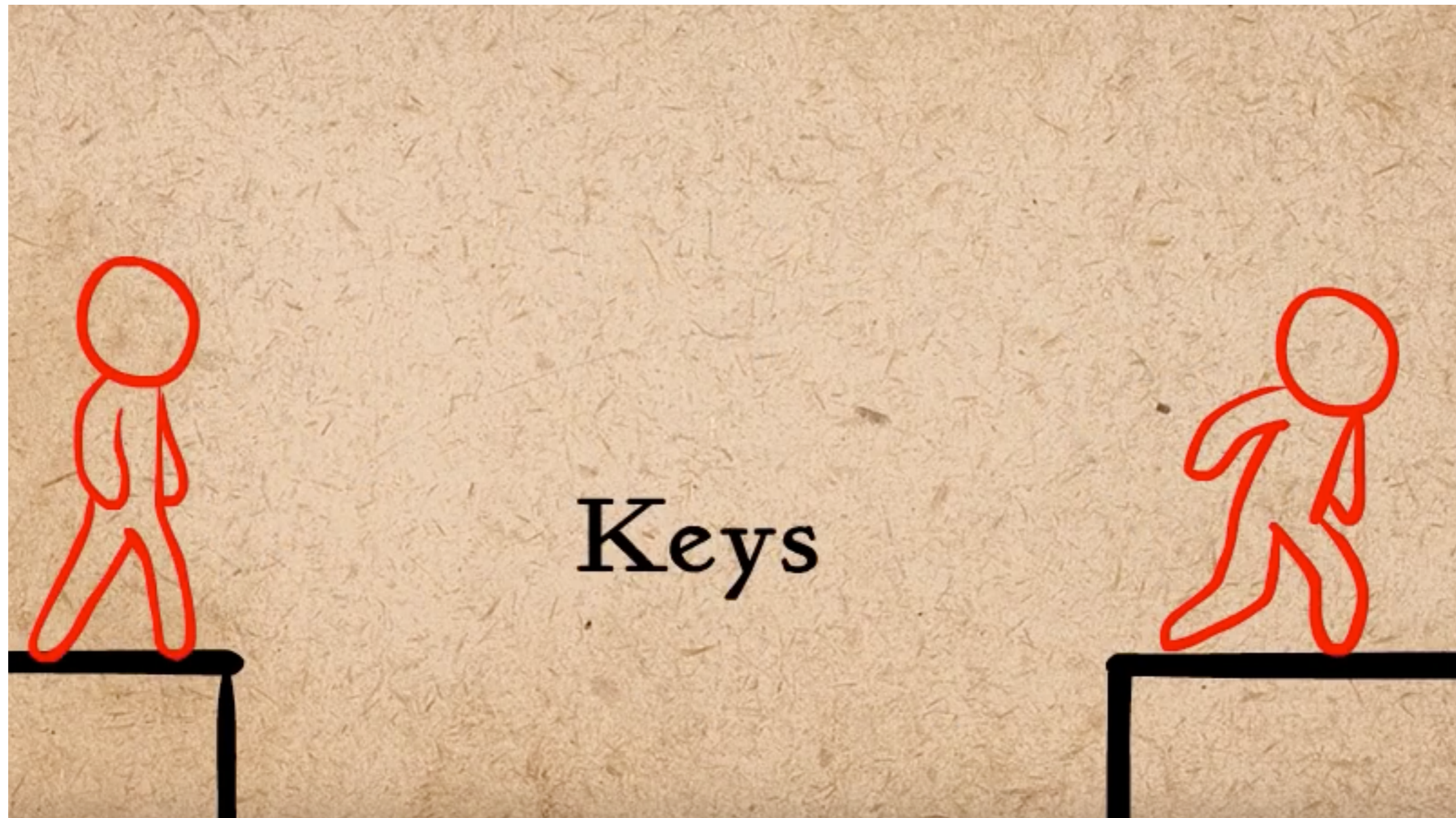
Keyframes
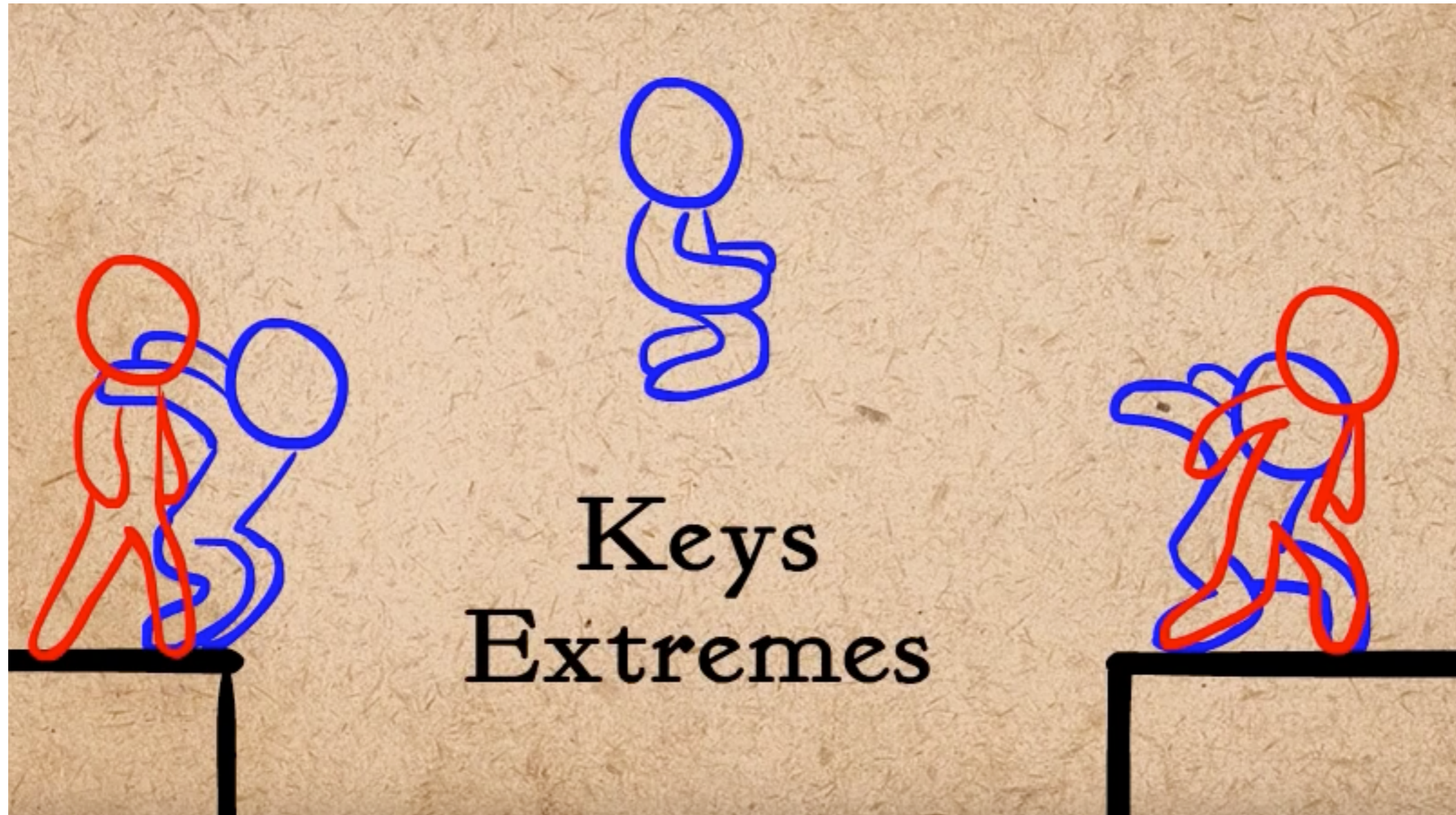
Keys
Extremes
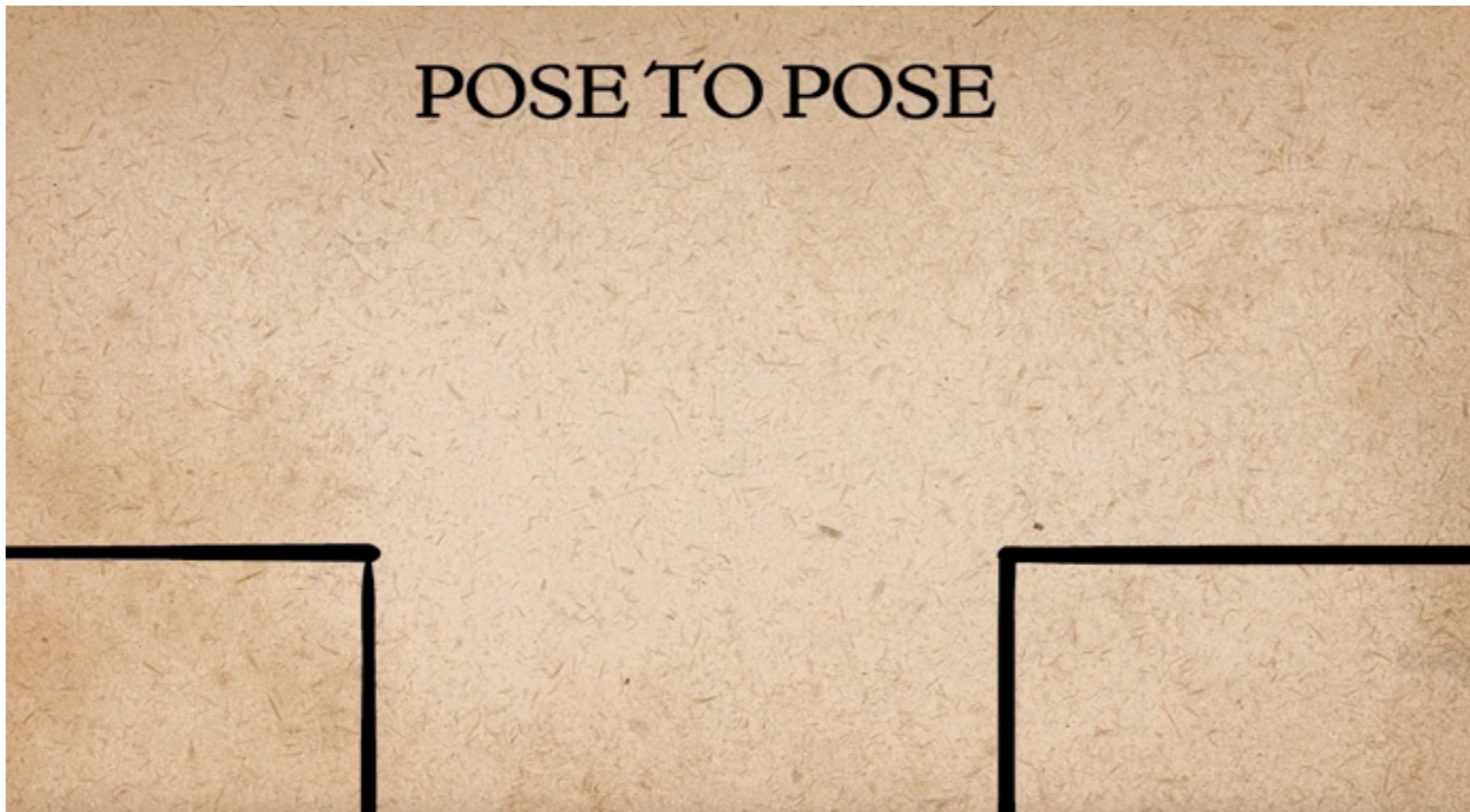Breakdowns

Keyframe Animation

The task boils down to setting animated variables (e.g. positions, angles, sizes, ...) at each frame.

Straight-ahead: set variables in frame 0, then frame 1, frame 2, ... forward in time.

Pose-to-pose: set the variables at keyframes, let the computer smoothly interpolate values for frames in between.

Keyframe Animation

Pose to pose

Keyframe Animation

Straight ahead

Keyframe Animation

Pros:
- Very expressive
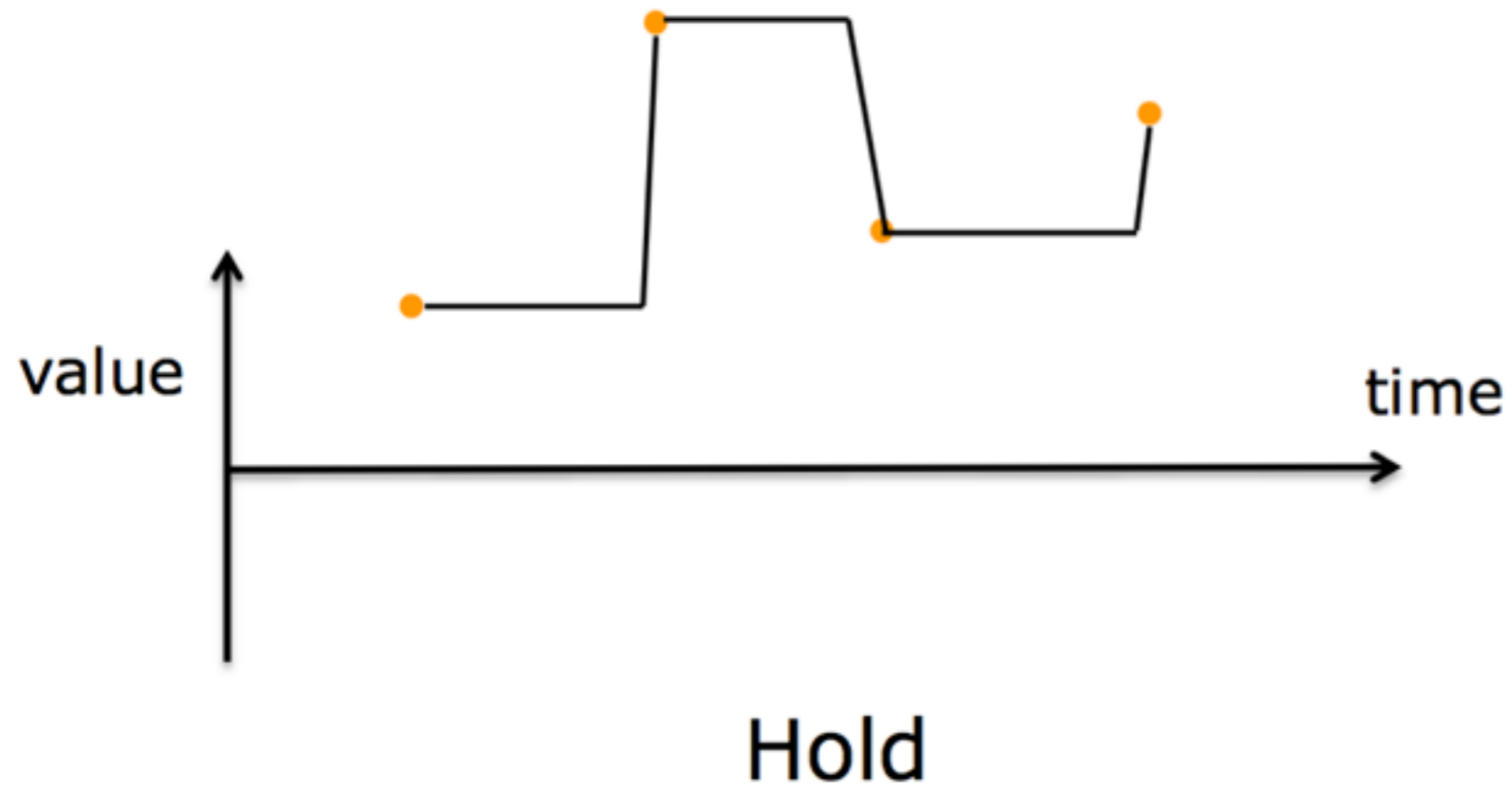- Animator has full control of animation

Cons
- Very labour intensive
- Difficult to create convincing physical realism (if that is a goal)

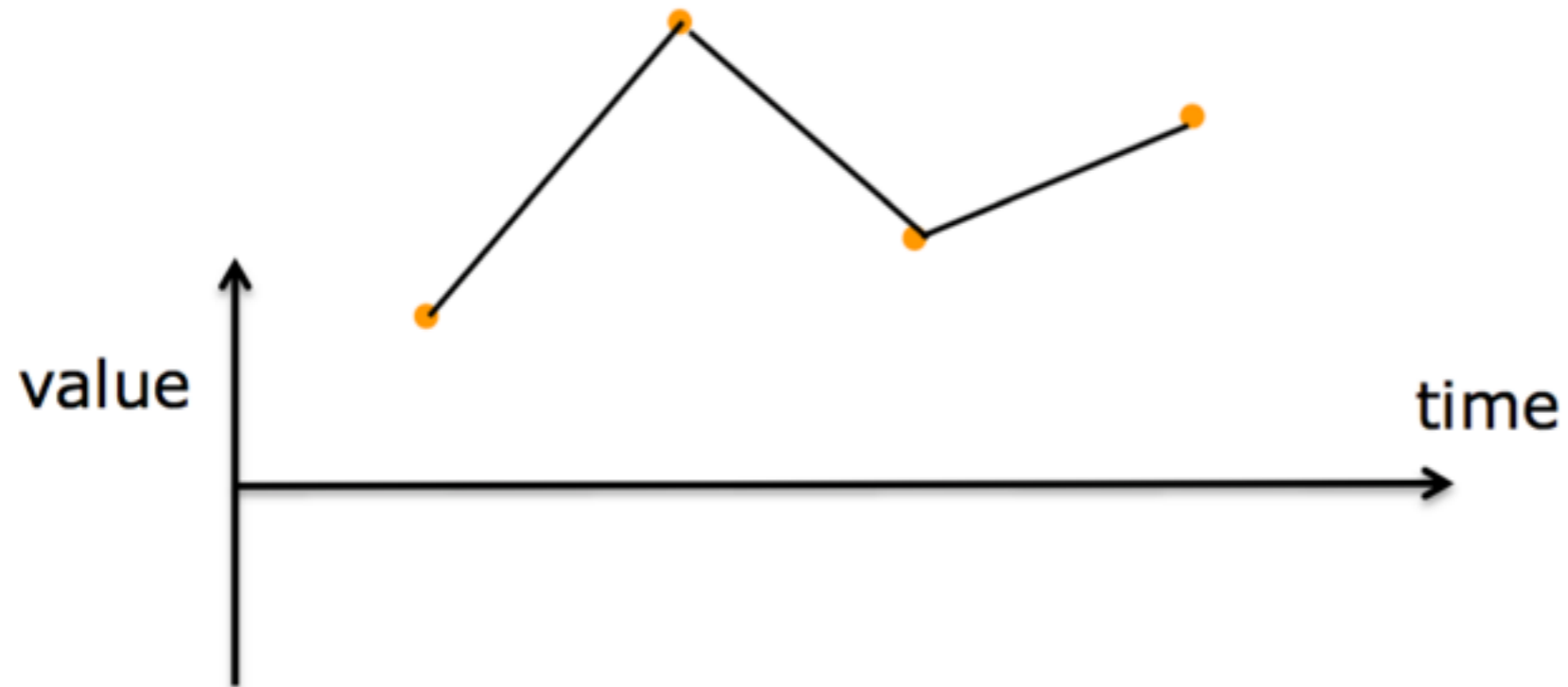Used for practically anything except complex physical simulations (smoke, water, etc)

Interpolation

How do we interpolate between two values?

Hold

Interpolation

How do we interpolate between two values?
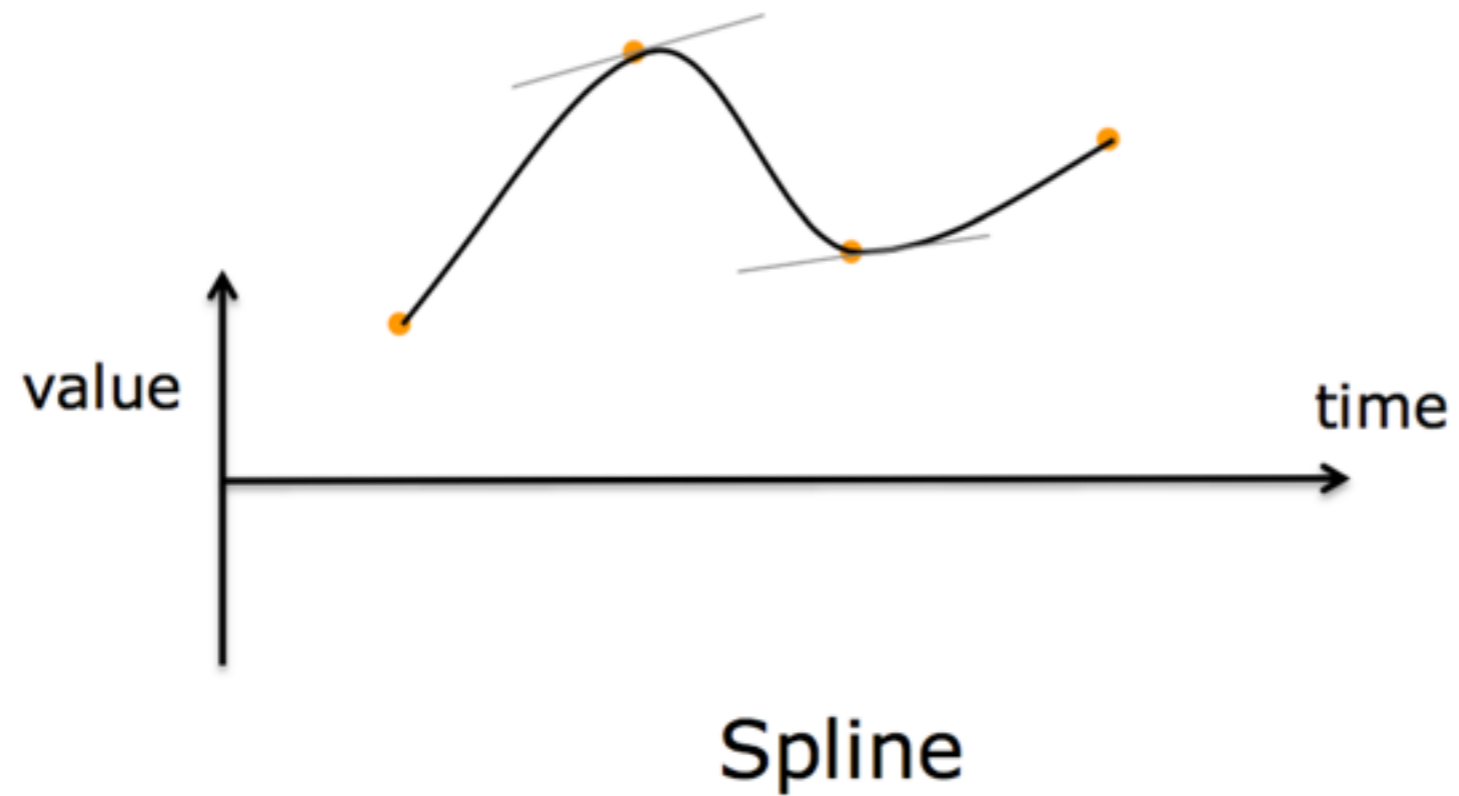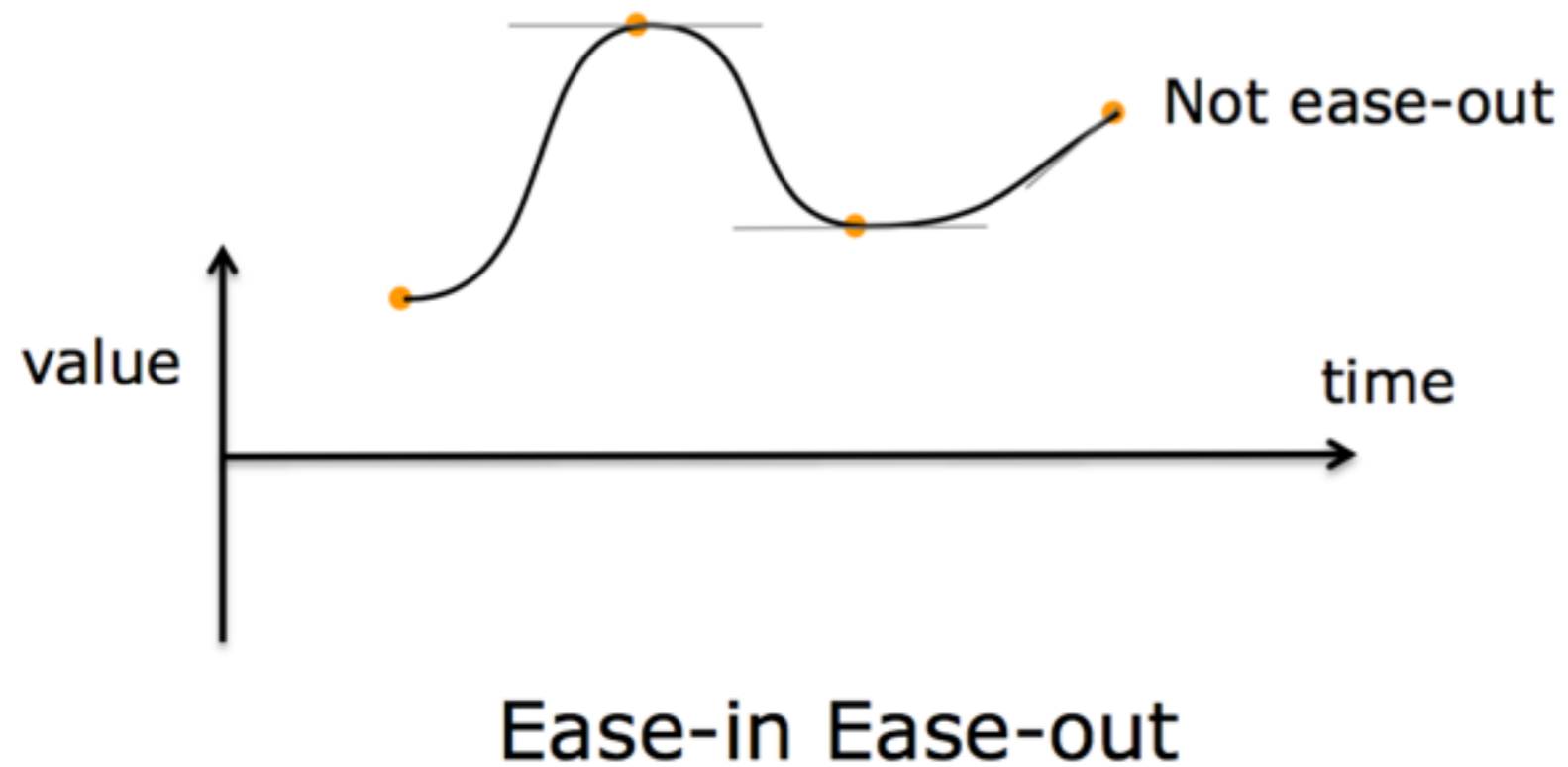

Linear

Interpolation

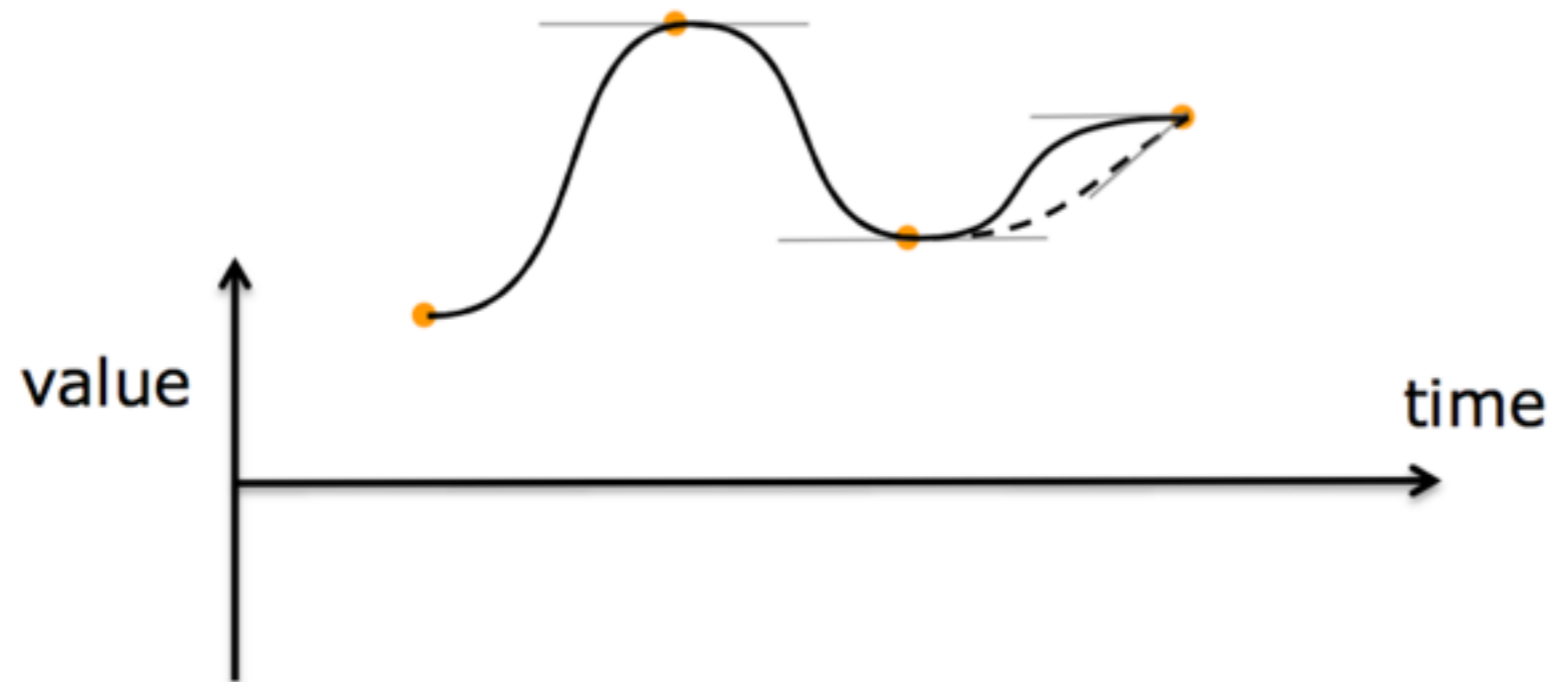How do we interpolate between two values?

Spline

Interpolation

How do we interpolate between two values?

Interpolation

How do we interpolate between two values?

Ease-in Ease-out
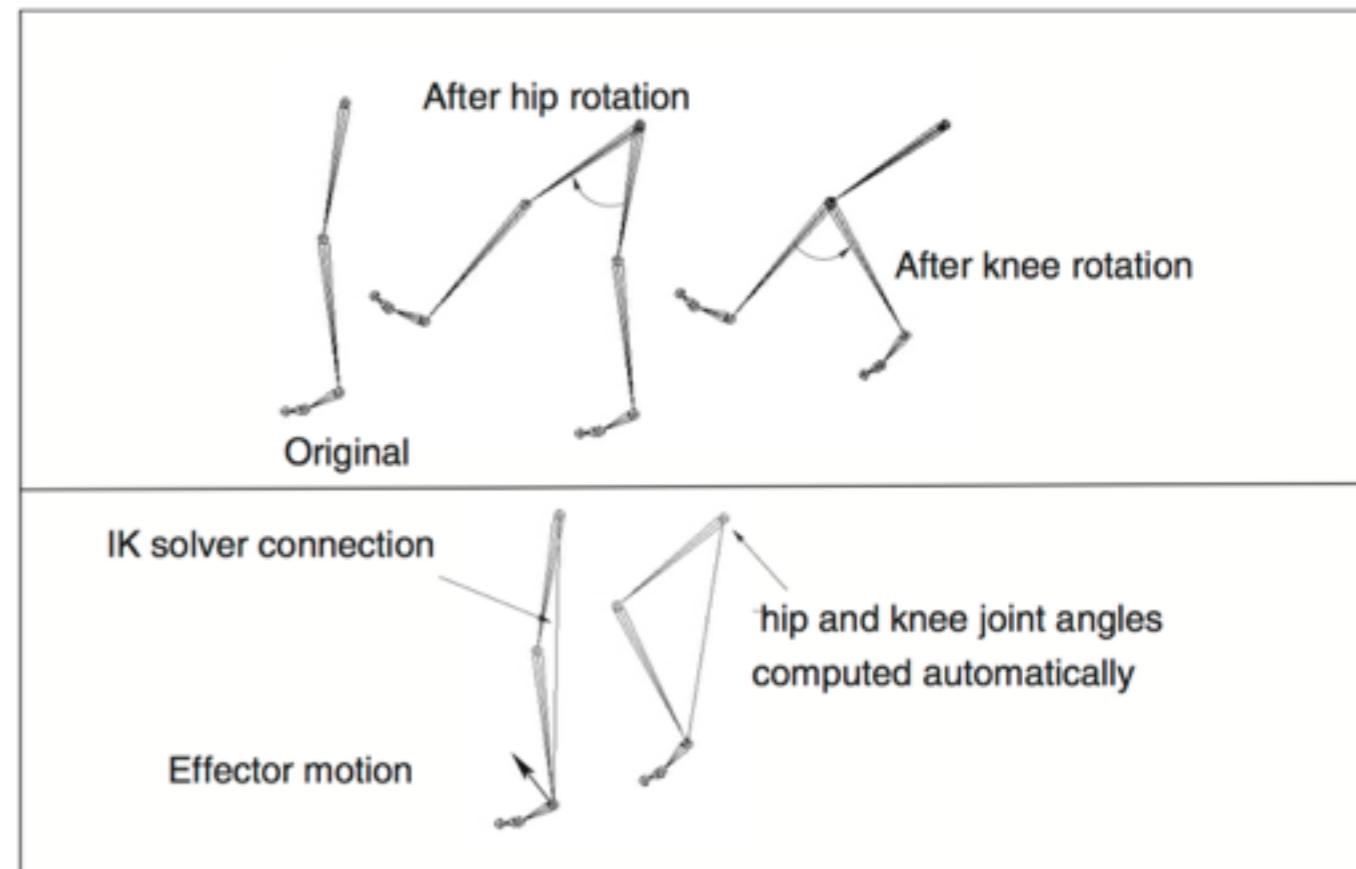
Forward Kinematics

- Specify how joints should move
- Determine the space of possible motion
- Parametrize it
- Establish a mapping from joint angles to positions

Pros:
- Very easy to specify and implement

Cons:
- Often we care about <u>where</u> the character should go, not <u>how</u> to get there
- Very hard to know how to move joints of a complicated figure in order to get the desired pose (esp. in presence of obstacles)

After hip rotation

After knee rotation

Original

IK solver connection

hip and knee joint angles computed automatically

Effector motion

Inverse Kinematics

- Specify where character should go, then deduce join motion
- Position of the end effector is set by the animator.
- Automatically solve for joint angles that will result in that effector position.
- Solution is not usually "closed form", iteratively solved by optimizer.
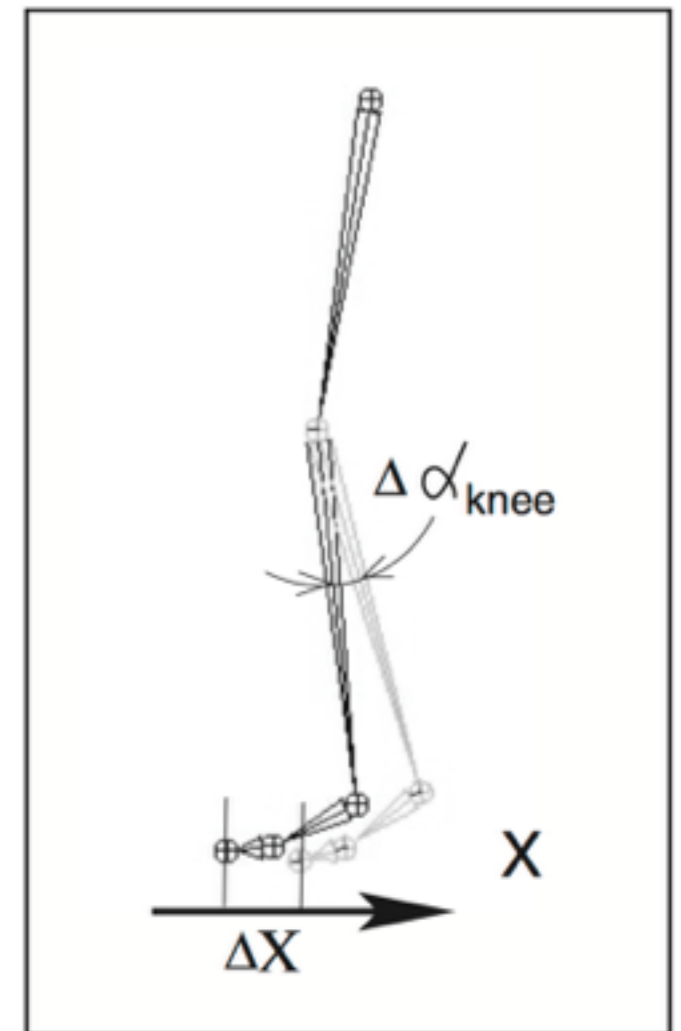
Inverse Kinematics

- Typically underconstrained: Multiple configurations of internal joints can result in the same effector position
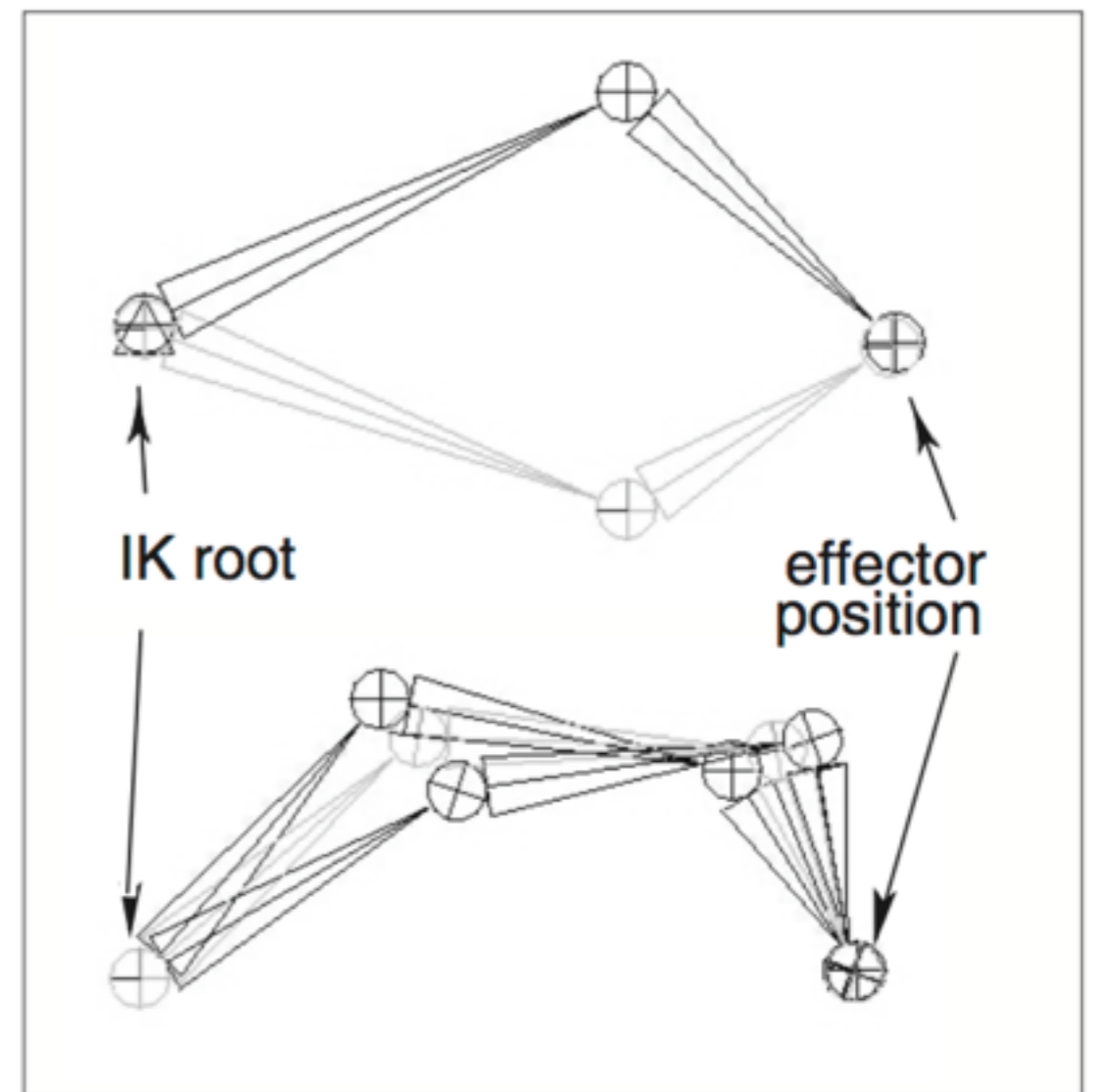
Physical Simulation

- Mathematically model real-world motion
- Animate via simulation
- Smoke, fire, clouds, fluids, cloth, rigid bodies, elastic objects.

Pros:
- Once implemented, easy to specify the state of the system at a particular time.
- Model can be easily changed via parameter settings
- High degree of physical realism

Cons:
- Complex systems used to model natural phenomena
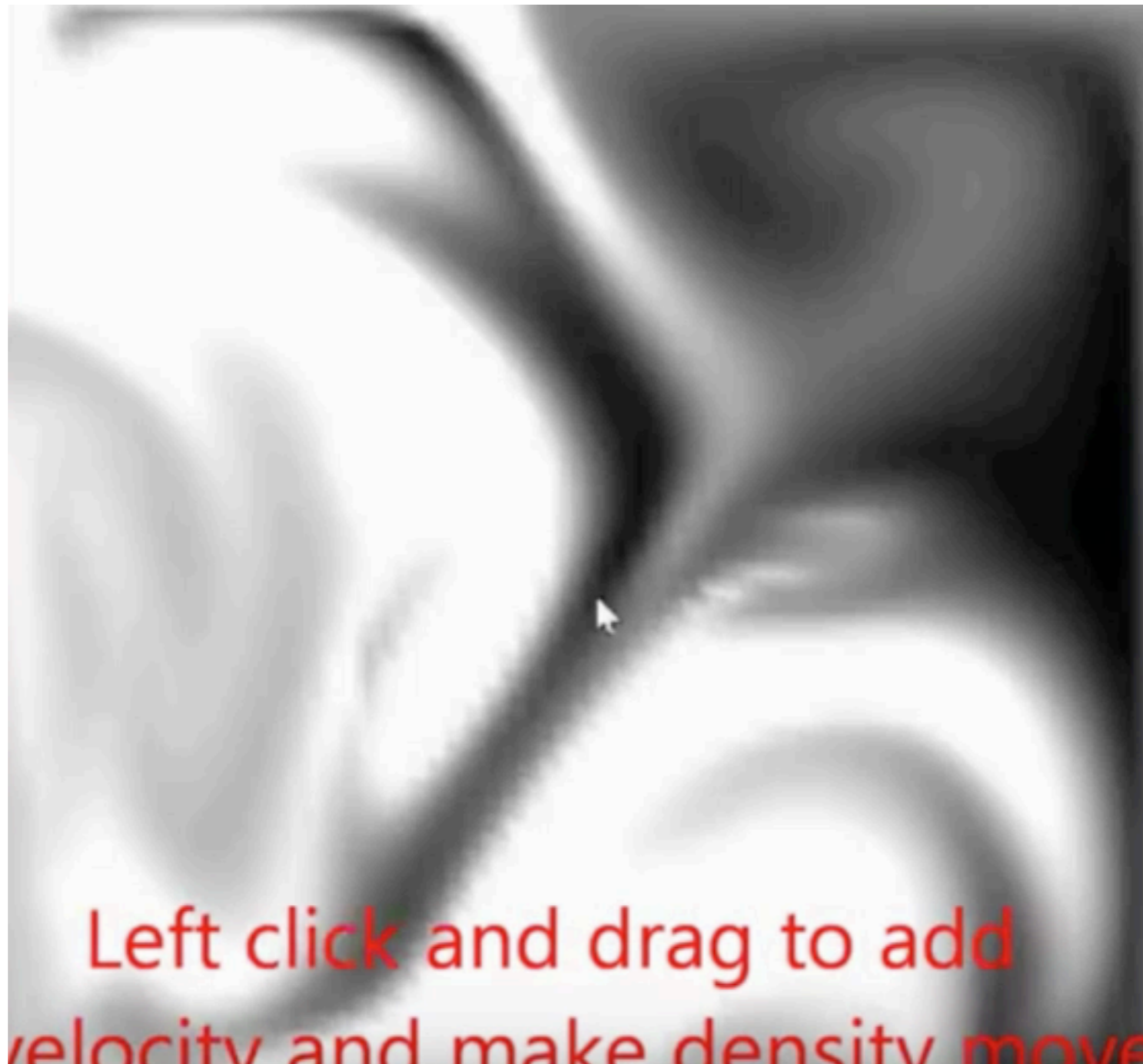- Computationally intensive

Physical Simulation

Particles

Position   x
Velocity $v = dx/dt$
Acceleration $a = dv/dt = d^2x/dt^2$

Forces

Gravity $f=mg$
Spring-damper $f=-kx-cv$
…

Simulation: x,v,a used to compute forces yielding total force F, F=ma used to update a, a used to update v,x…

Physical Simulation: Fluids

Motion Capture

- Record motions or real people/objects then transfer to digital characters.
- Markers can be occluded. Use multiple cameras and interpolate where needed.
- Noise can cause limbs to loose contact with ground or other objects. Use redundant markers to reduce noise. Correct with Inverse Kinematics.
- Retargeting: applying recorded motion to different characters.

Motion Capture
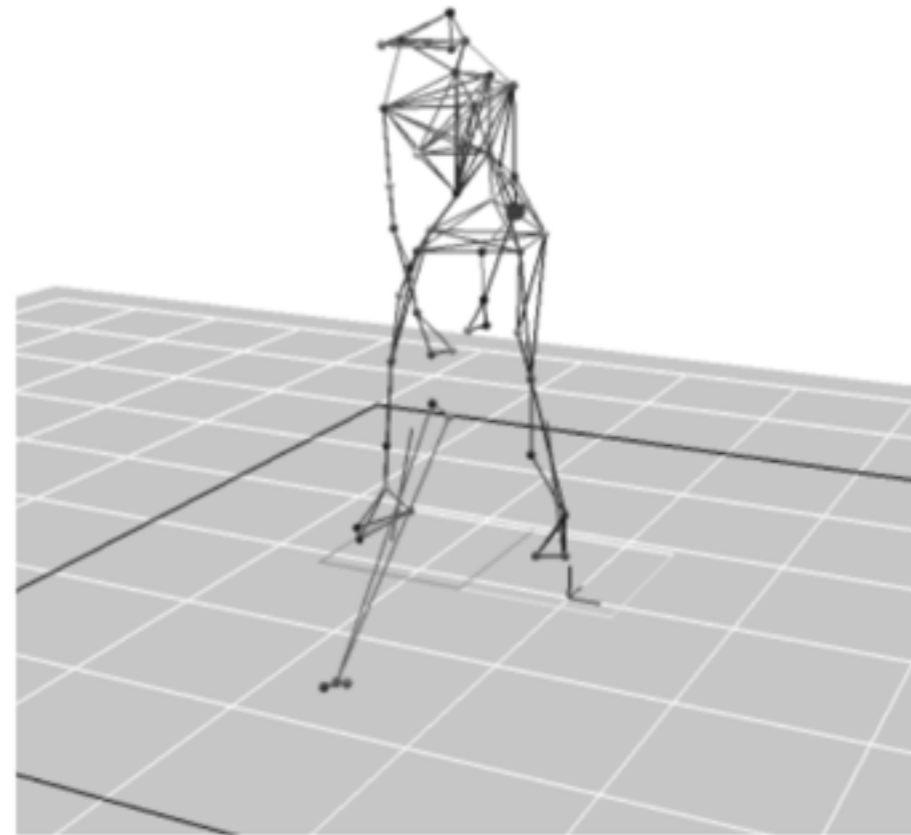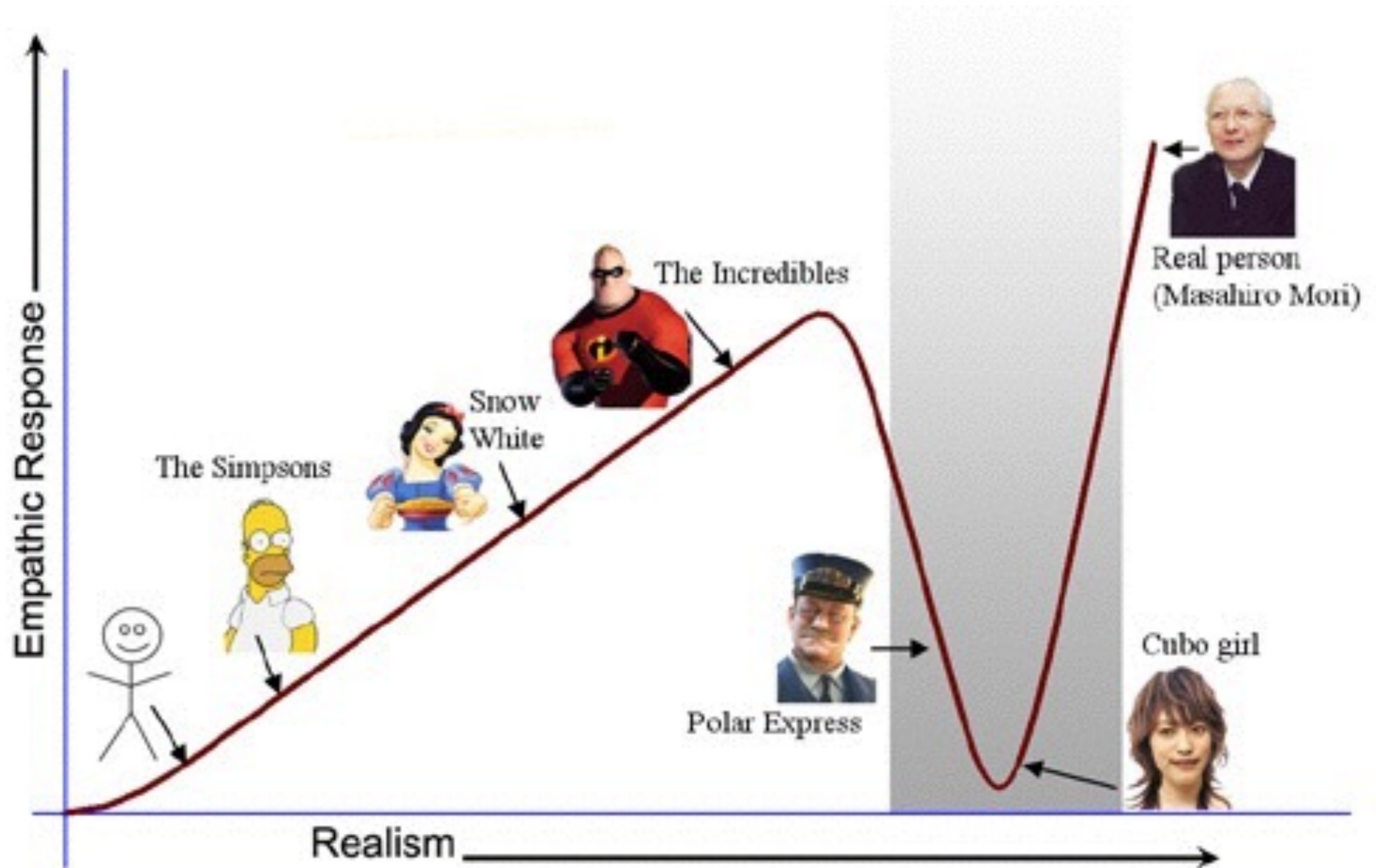
Motion Capture

Motion Capture

Motion Capture
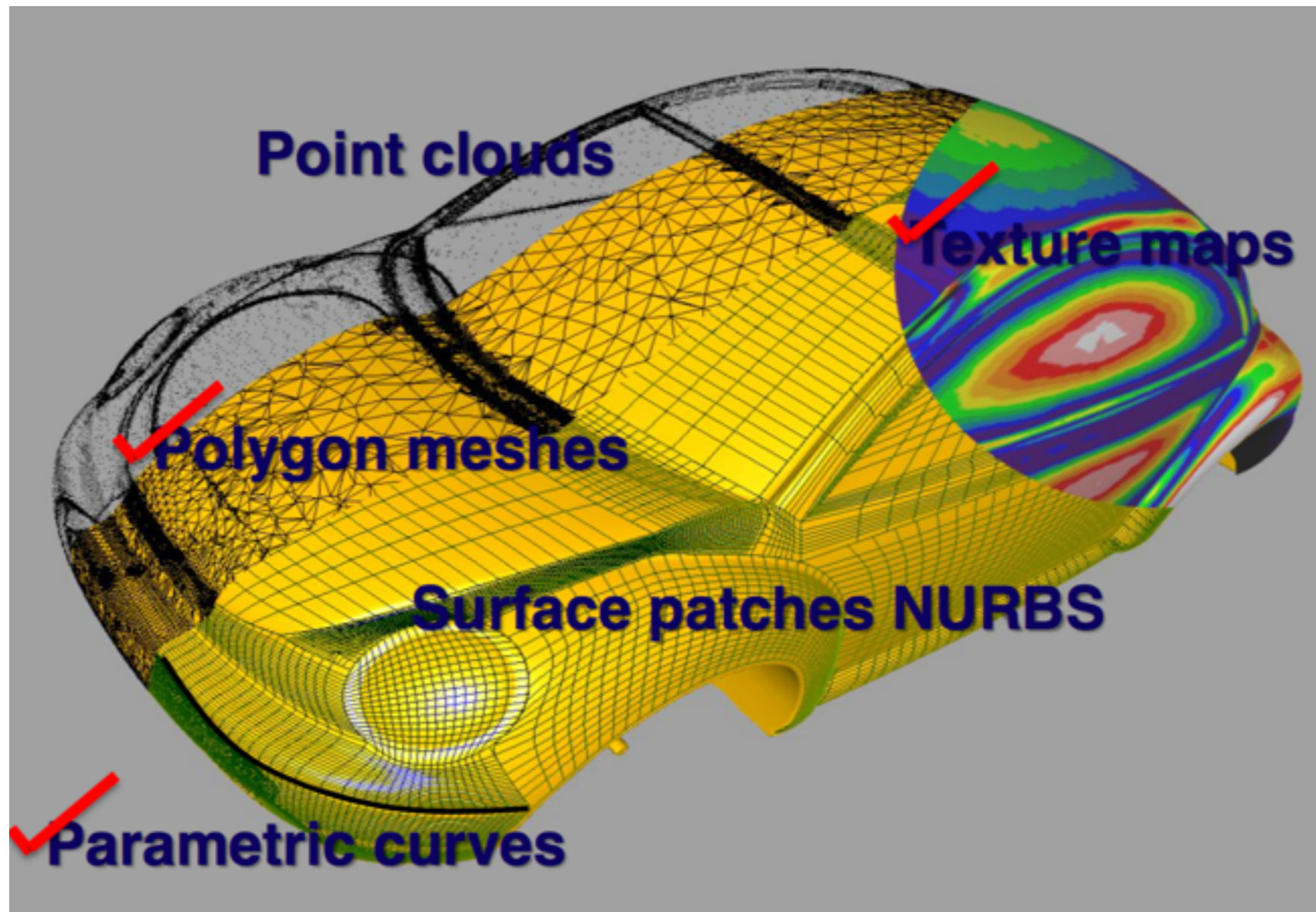
Uncanny Valley
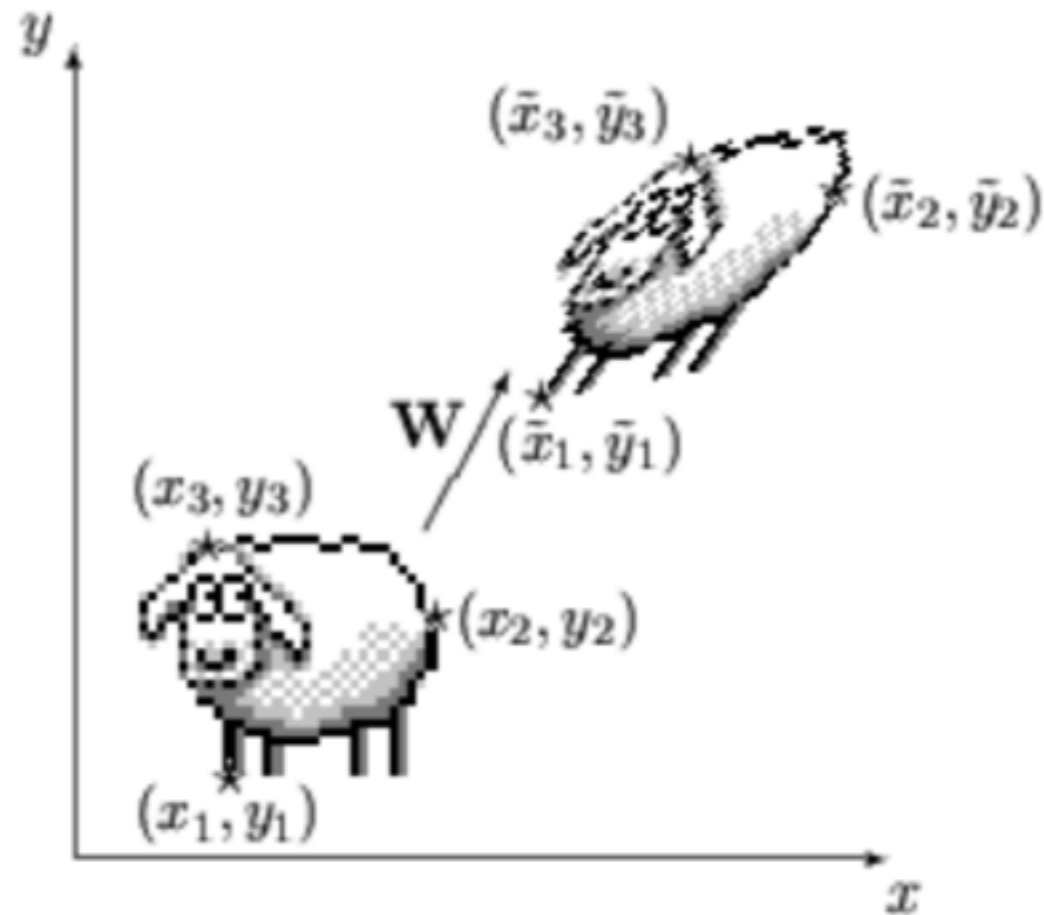
Uncanny Valley

Overview

Computer Graphics

Computer Graphics

- Computers…:
  accept, process, transform and present information.

- Computer Graphics…:
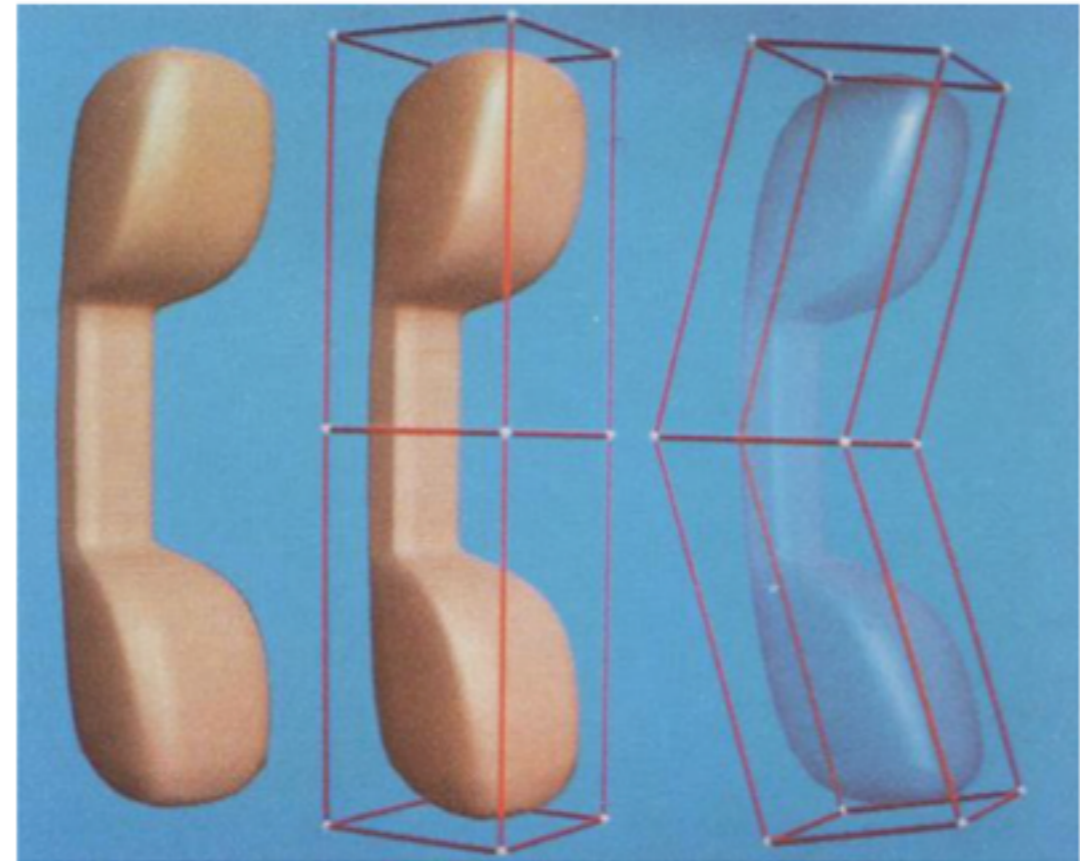 involves technology to accept, process, transform and present information in a *visual form*.

Elements of CG (modelling)

Elements of CG (transformation)

Affine transform

Free-form deformation (FFD)

Graphics Pipeline: Animation

Physical simulation

Key-Framing

Behavior rules

Elements of CG (rendering)

How does one represent a digital scene?

- **Scene graph:** Hierarchical description of objects and parts of objects relative to each other.
- **Lighting:** Where are the lights in the scene.
- **Cameras:** Where is the scene viewed from (pin-hole model)?
- **Projection:** How is the scene projected onto an image (parallel vs perspective)?
- **Visibility**
- **Clipping**
- **Scan conversion**
- **Illumination**
- **Textures**
- **Special Effects**

Key Topics

- Rasterization: line drawing.
- Homographies, Linear, Affine, Conformal, Rigid Transforms. Cameras and Projection (perspective).
- Graphics pipeline. Obj -> World -> Eye -> View -> Display.
- Visibility (BSP).
- Lighting (directional, point).
- Shading (Gouraud, Phong).
- Local illumination (Phong).
- Global illumination (Ray-tracing)
- More global illumination: stochastic effects and advanced features.
- Animation: keyframes, interpolation (linear, bilinear).
- Curves (basis matrix, functions, continuity, control).
- Bézier, cubic curves, cardinal splines…

Exam

- Two parts with a total of 20 questions.
- Part 1 are shorter answer questions. Part 2, longer answer.
- Don't spend too much time if you are stuck on the shorter answer questions. Move on and come back to them later.
- Tests your knowledge, understanding and your thinking.
- Weight: if (midtermMark > examMark) { examWeight = 35%} else { examWeight = 50%}
- For date/location/time check: www.artsci.utoronto.ca/current/exams