Animated computer graphics

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With material from:
- Fundamentals of Computer Graphics
- John Lasseter, “Principles of Traditional Animation Applied to 3D Computer Animation”, ACM Computer Graphics, 21(4), 1987, pp. 35-44
- PIXAR Animations
- Richard Tonge, NVIDIA Corporation

Keith Haring flipbook

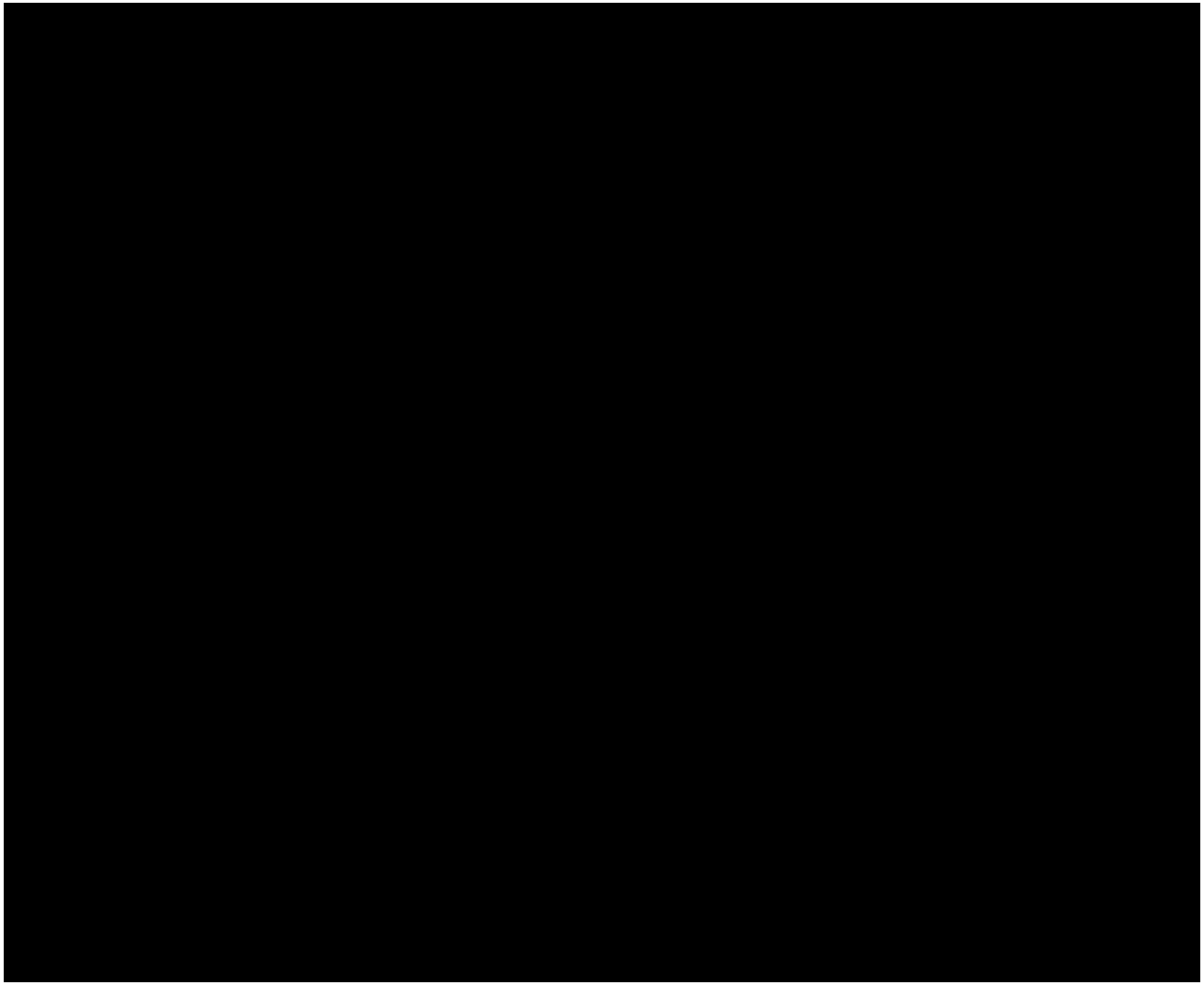
Overview

- Animation
- Keyframing
- Motion capture
- Physics-based animation

Animation

Luxo Jr.

Pixar, 1986
(2m18s)



Luxo Jr.

- By Pixar, 1986
- First CGI film nominated for an Academy Award
- RenderMan with programmable shading
- 1.5 hours to render each frame on a Convex 6/32 minicomputer

Animation

Lasseter's 12 fundamental principles of traditional animation (1987):

1. Squash and stretch
2. Timing
3. Anticipation
4. Follow through and overlapping action
5. Slow-in and slow-out
6. Staging
7. Arcs
8. Secondary actions
9. Straight-ahead and pose-to-pose action
10. Exaggeration
11. Solid drawing skills
12. Appeal

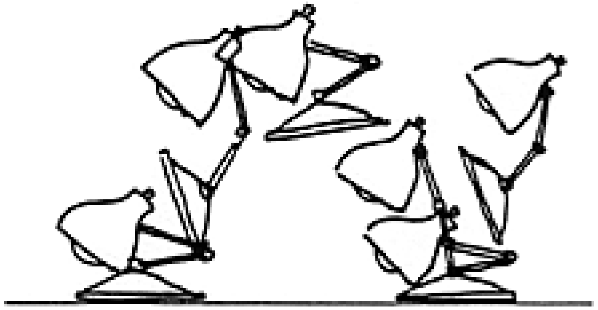
"*There is no particular mystery in animation… it's really very simple, and like anything that is simple, it is about the hardest thing in the world to do.*" Bill Tytle, Walt Disney Studio, 1937.

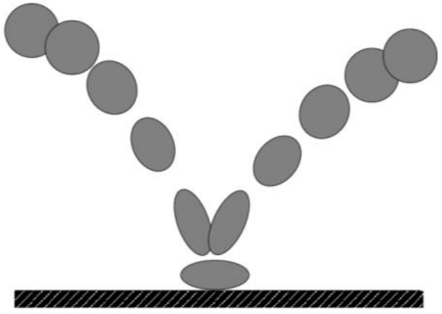
Quote in John Lasseter, "*Principles of Traditional Animation Applied to 3D Computer Animation*", ACM Computer Graphics, 21(4), 1987, pp. 35-44.

Lasseter’s 12 principles

1. Squash and stretch

- Distortion of a shape exhibits rigidity and mass properties

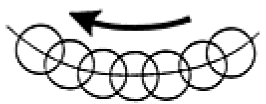




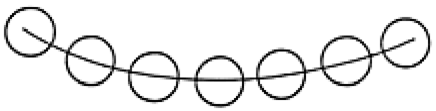
Lasseter’s 12 principles

1. Squash and stretch

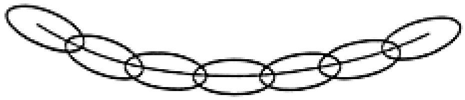
- Distortion of a shape exhibits rigidity and mass properties
- Strobing effect can occur in fast action
  - Similar to aliasing
  - Stretching can be used as an alternative to motion blur



In slow action, an object's position overlaps from frame to frame which gives the action a smooth appearance to the eye.



Strobing occurs in a faster action when the object's positions do not overlap and the eye perceives separate images.



Stretching the object so that it's positions overlap again will relieve the strobing effect .

Lasseter's 12 principles

2. Timing

- The speed of an action affects emotional state and even perceived weight
  - Fast moving objects appear to be less heavy than slow objects

Lasseter’s 12 principles

3. Anticipation

- Preparation of an action
- Action proper
- Termination of an action

Wally B.'s zip off shows use of squash and stretch, anticipation, follow through, overlapping action and secondary action.

Lasseter’s 12 principles

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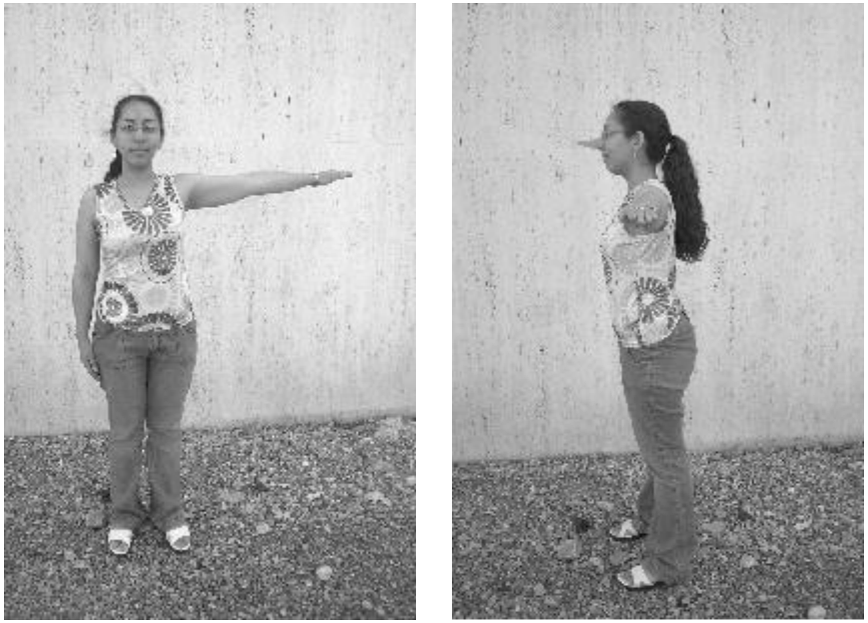
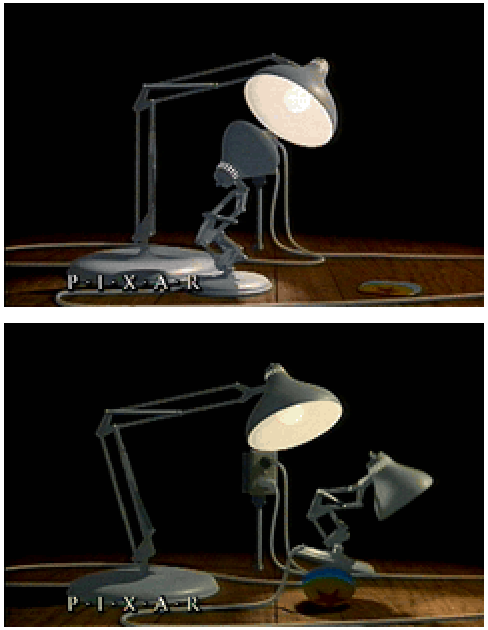
Lasseter's 12 principles

4. Staging

- Presenting an idea so that is completely and unmistakingly clear
- "look at his, now look at this" without using words
- Human perception plays an important role
  - Draw attention, e.g. through sudden motion or lack of motion



The raised arm is visible on the left, not on the right. The long nose is visible on the right, not on the left.

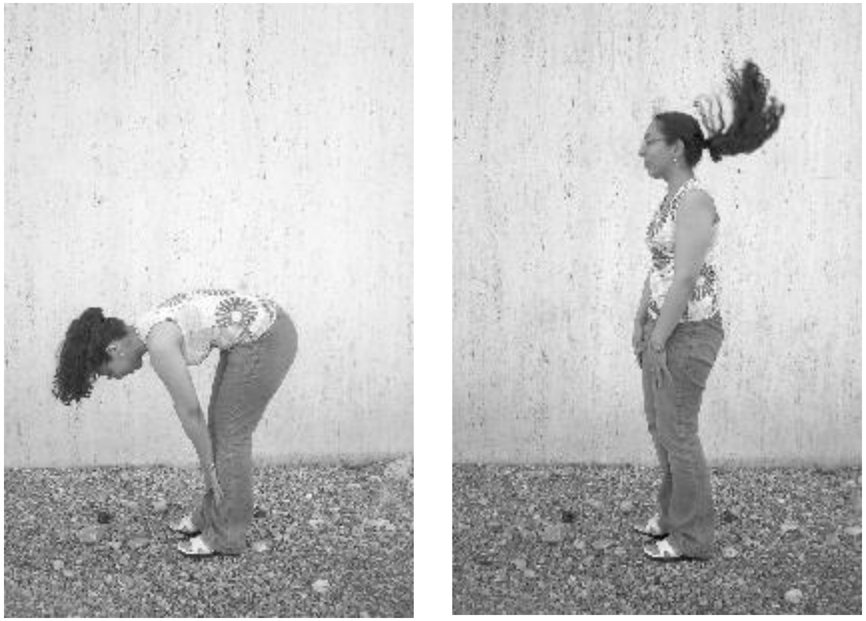


In Luxo Jr., all action was staged to the side for clarity.

Lasseter's 12 principles

5. Follow through and overlapping Action

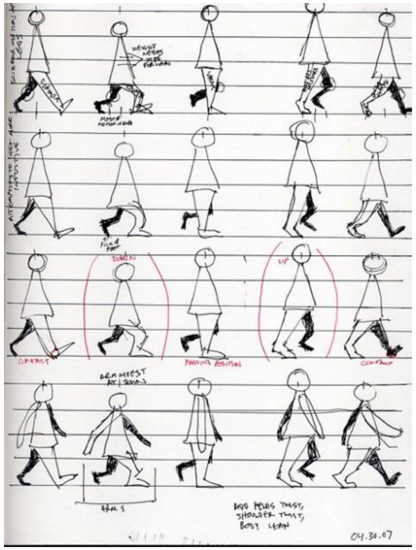
- Continuation of an action into the next
  - Appendages, loose parts "drag behind"
- Second actions overlap with prior actions
  - Continuity between actions



Secondary appendage (hair) follows the leading part (head). The motion of the head is simple but leads to non-trivial follow-through behaviour of the hair.

Lasseter's 12 principles

6. Straight Ahead Action and
   Pose-To-Pose Action



- Straight-ahead action
  - Specify each single frame
  - Very laborious
- Pose-to-pose action
  - Specify important (:"key") moments
  - Interpolate inbetweens
  - Also known as "keyframing"
- Balance between control and flexibility

Images source: About.com

Lasseter's 12 principles

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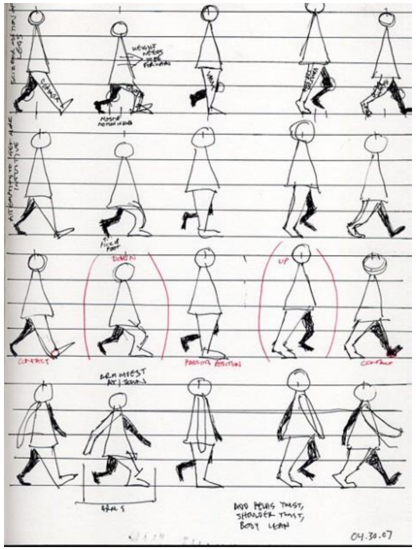

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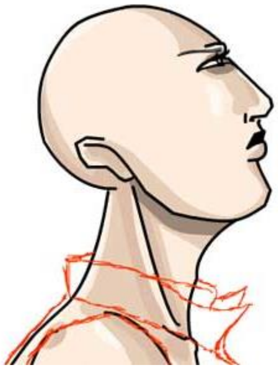

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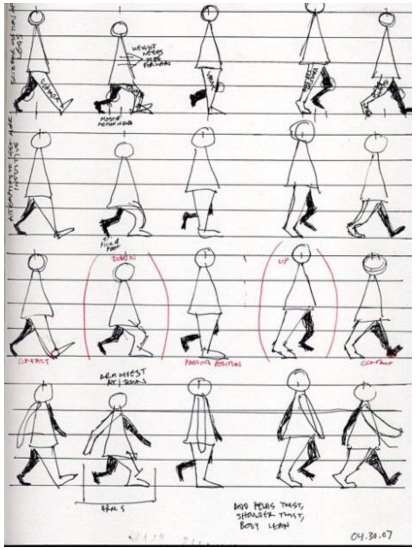

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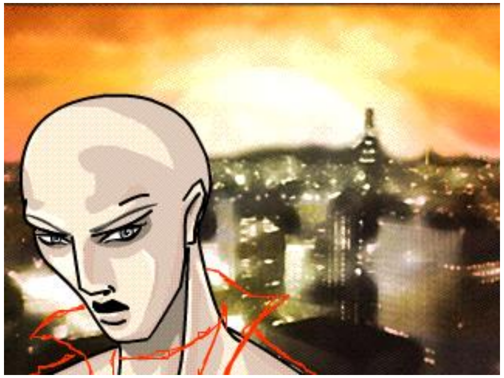
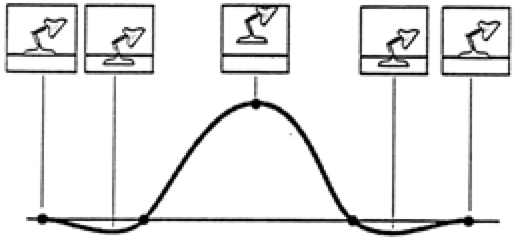


Images source: About.com

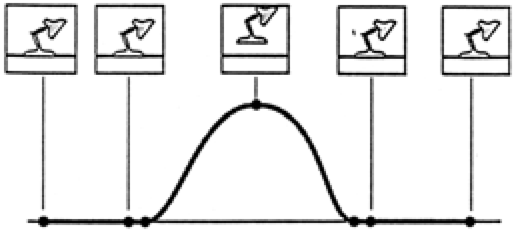
Lasseter's 12 principles

7. Slow in and out

- Non-even spacing between extreme poses
  - 2nd and 3rd order continuity of motion, i.e. acceleration and jerk
- Inbetweens calculated using spline interpolation
  - Potential problem: overshoot



This spline controls the Z (up) translation of Luxo Jr. Dips in the spline cause him to intersect the floor.

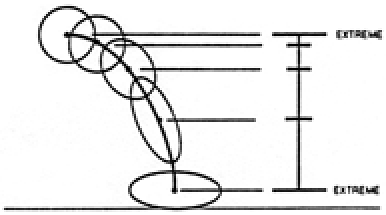


Two extra extremes are added to the spline which removes the dips and prevents Jr. from going into the basement.

Lasseter's 12 principles

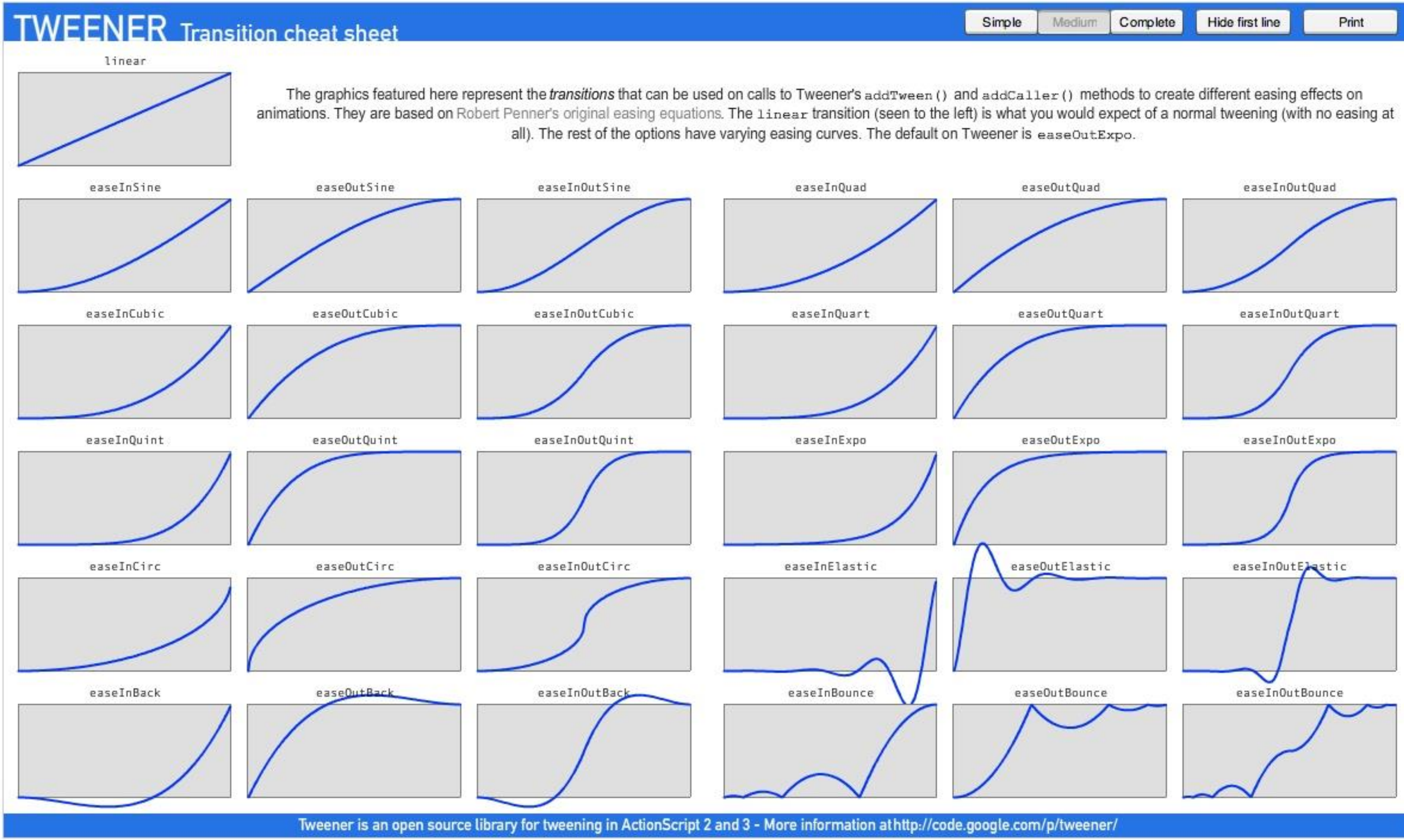
8. Arcs

- Visual path from one extreme to the next
- Make transitions from one state to the next appear smooth instead of stiff



Timing chart for a bouncing ball.

Tweening

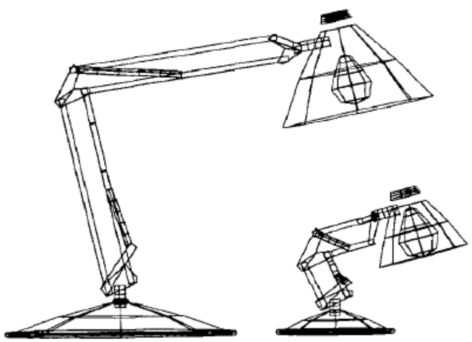


http://code.google.com/p/tweener/

Lasseter's 12 principles

9. Exaggeration

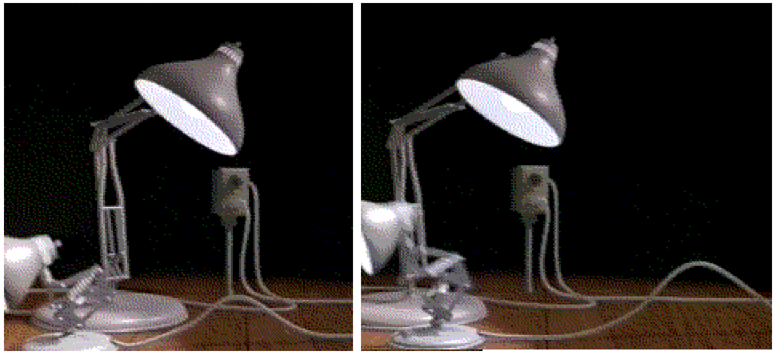
- Accentuate a property or emotion without distorting it
- Cannot be done in isolation
  - Must be balanced or it will stick out



Varying the scale of different parts of Dad created the child-like proportions of Luxo Jr.

10. Secondary action

- Action as a result of another action
  - Heightens interest
  - Adds realistic complexity to a scene

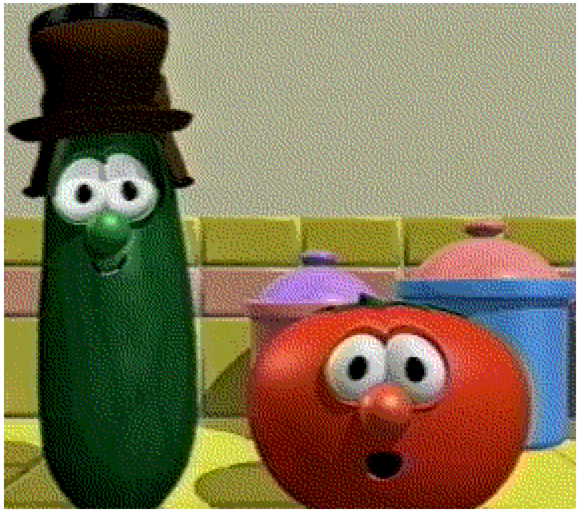


The secondary action of Luxo Jr's forward motion is the rippling of his power cord.

Lasseter's 12 principles

11. Appeal

- Anything that a person *likes* to see
  - Avoid unnatural qualities like symmetry

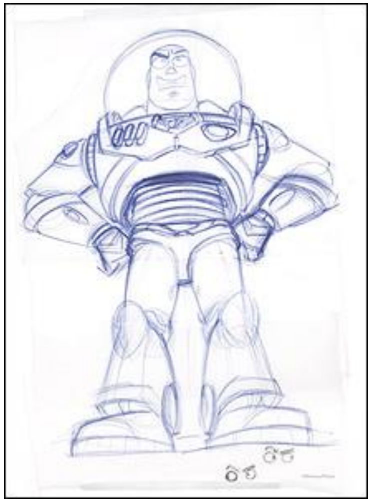


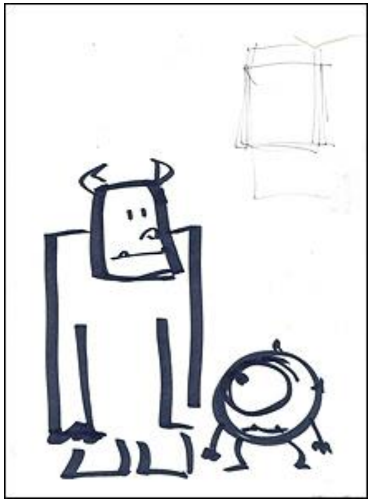
The image on the left is not very appealing. The image on the right is.

André's yawn was made more interesting by not duplicating the poses and the action from one side of his body to the other.

Lasseter’s 12 principles

12. Drawing skills

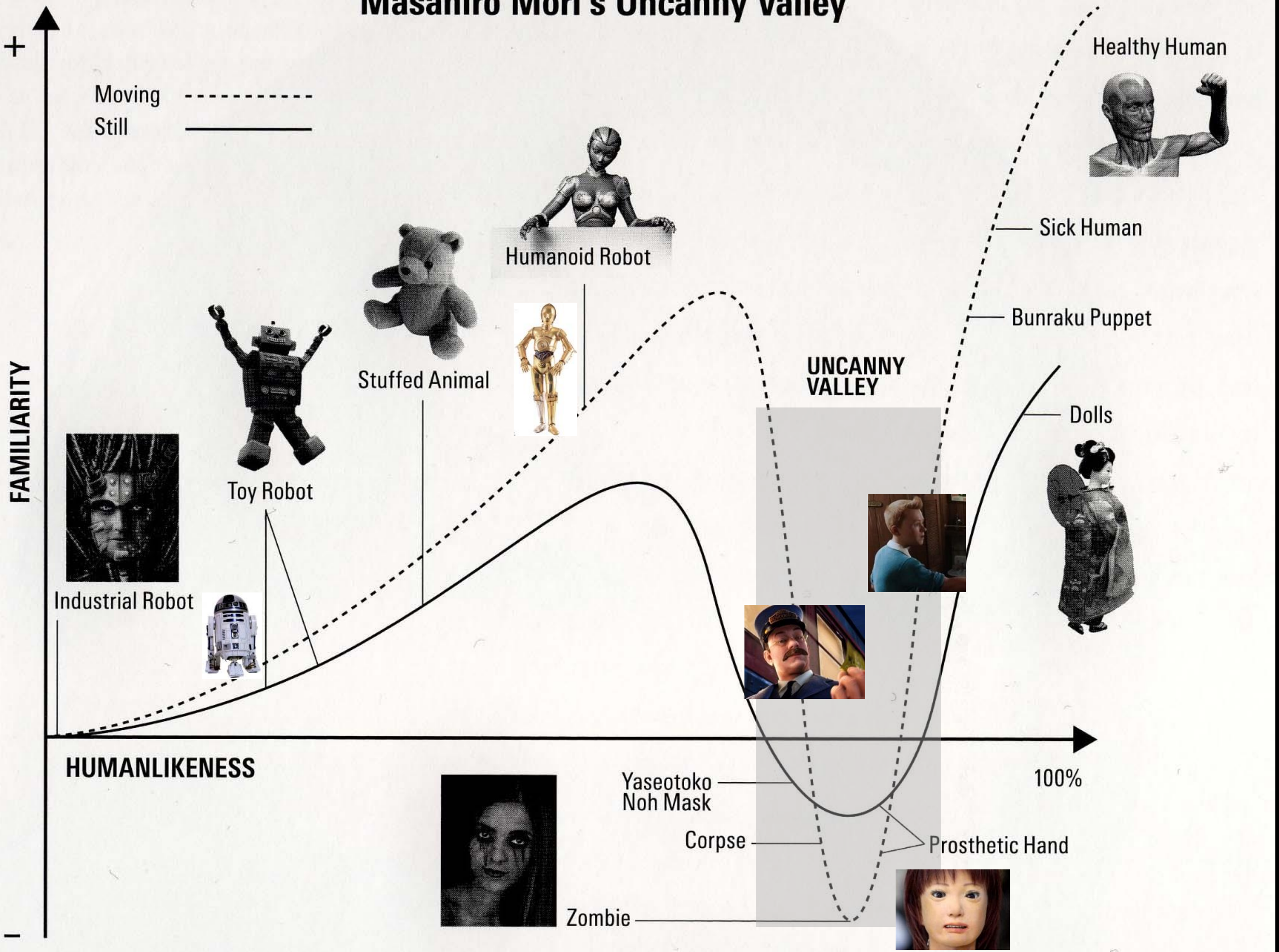




Tin Toy

Pixar, 1988
(4m57s)

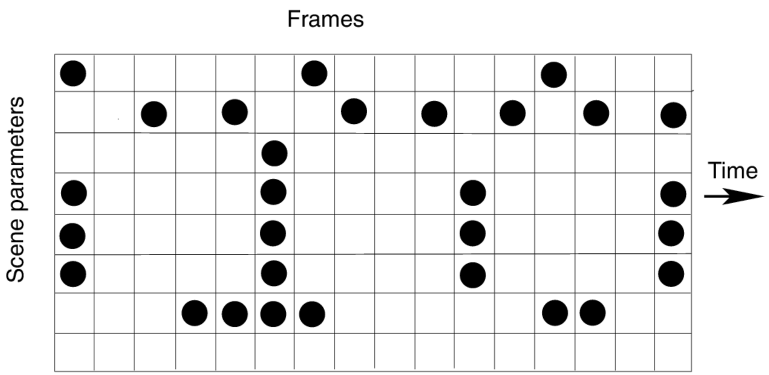
Masahiro Mori's Uncanny Valley



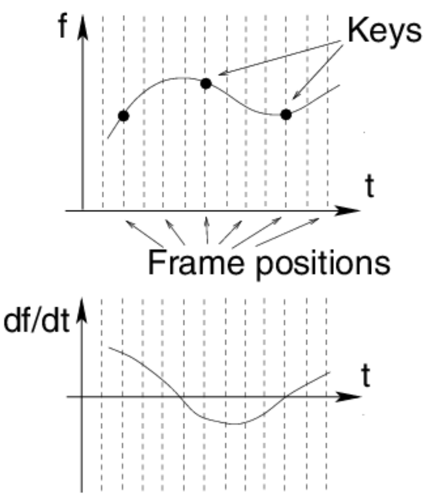
Keyframing

Keyframing

- Specify values of parameters at some points in time
  - Keyframe (t_k, f_k)
  - Large spacing between simple parts
  - Concentrated between more complex parts

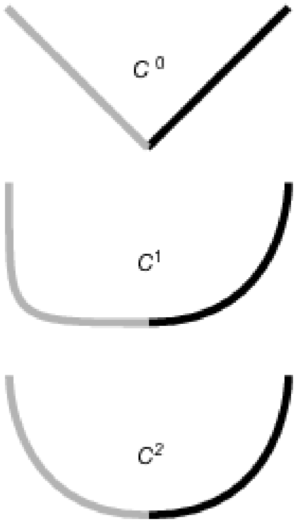


- System computes values for all frames
  - Fit a continuous curve to keyframes
    - Catmull-Rom splines (a.k.a. Cardinal splines)



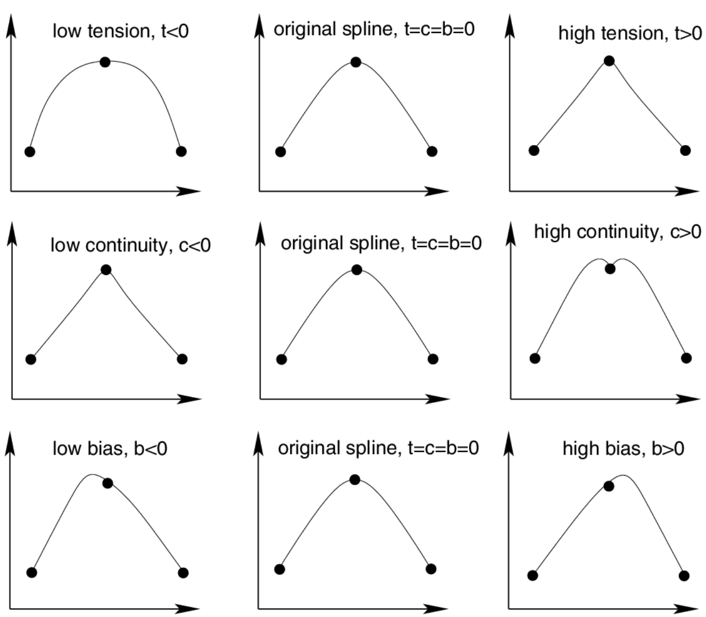
Catmull-Rom (or cardinal) splines

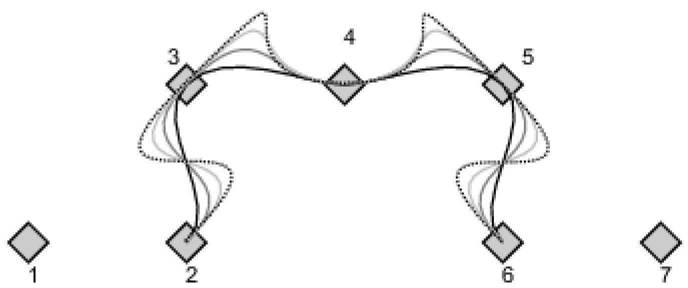
- Important properties in animation:
  - C^1 continuity (C^n: continuity in the n^{th} derivative)
  - No overshooting: positions at control points on the curve
  - Control is local: affected by four neighbouring points at most
  - Evaluation is local: changes do not require access to all control points



Catmull-Rom (or cardinal) splines

- Functional properties
  - Insertion/deletion/adjustment of control points
  - Control over tension, continuity and bias (TCB)
    - Tension controls the sharpness of the curve, i.e. the incoming and outgoing tangents
    - Bias increases/descreases the weight of control points
    - Continuity allows “kinks” to be created in the curve





Cardinal splines through seven control points with varying values of tension parameter *t*.

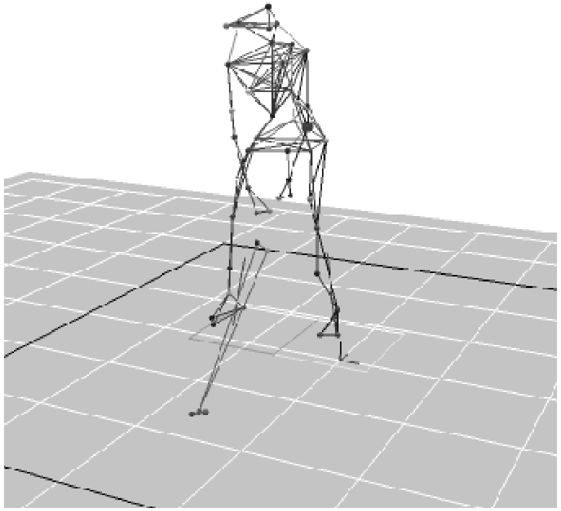
Geri’s Game

Pixar, 1997
(4m47s)

Motion capture

Motion capture

- Even with keyframing techniques, realistic-looking motion from scratch is extremely difficult
- Motion capture records an actor's motion in the real world and then applies it to computer-generated characters
- Optical/magnetic tracking (see also lecture on VR)



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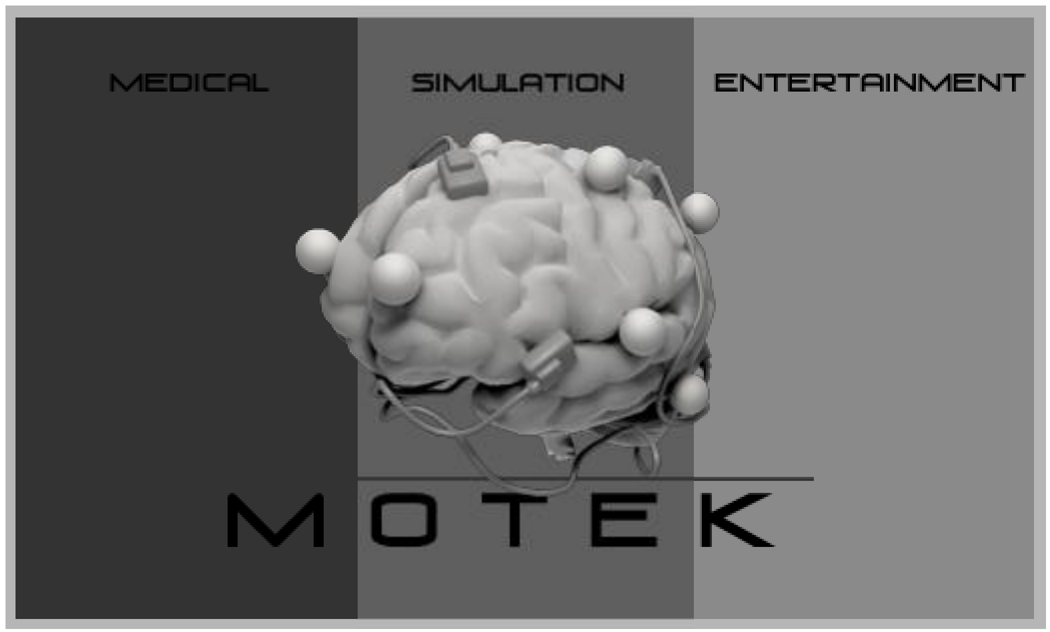
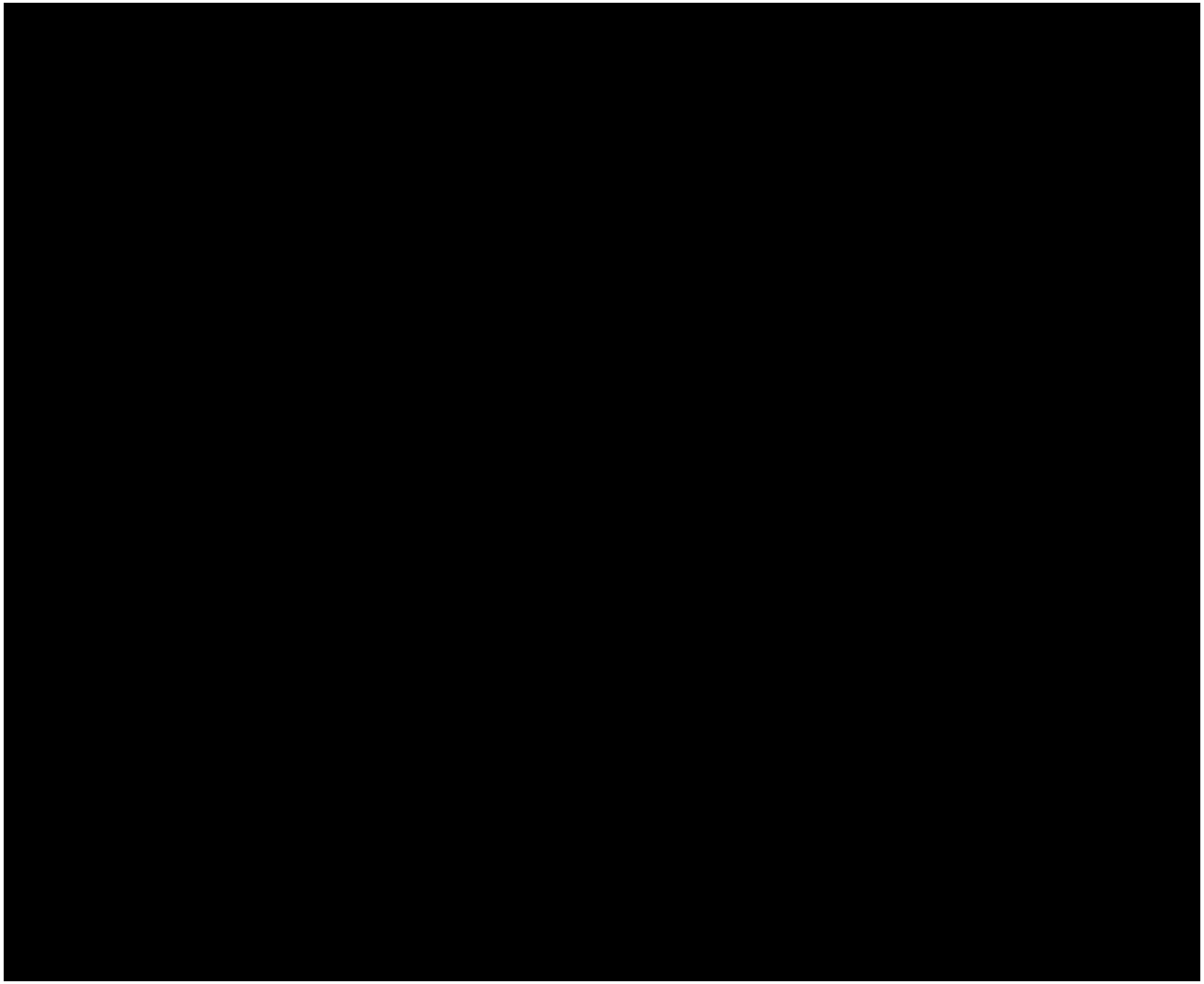


http://www.e-motek.com/

Motion capture



Physics-based animation

Physics

- Evaluate the laws of physics in sets of partial/ordinary differential equations
  - ODEs, PDEs
- Solve through numerical techniques
  - E.g. Finite differencing
- Stability of the solver is a major issue
  - Finite precision results in drift

- Examples
  - Particle systems
    - Smoke, clouds, fire
  - Cloth simulation
  - Rigid body dynamics

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Genesis effect in Star Trek, Wrath of Khan (1982).

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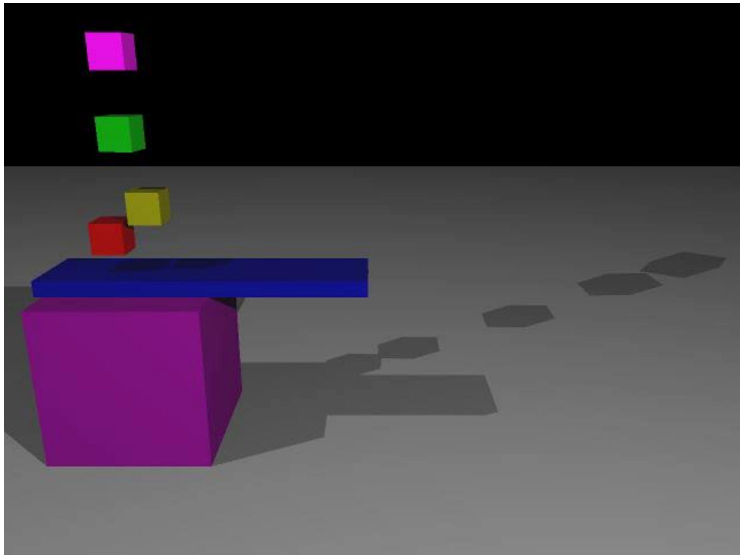
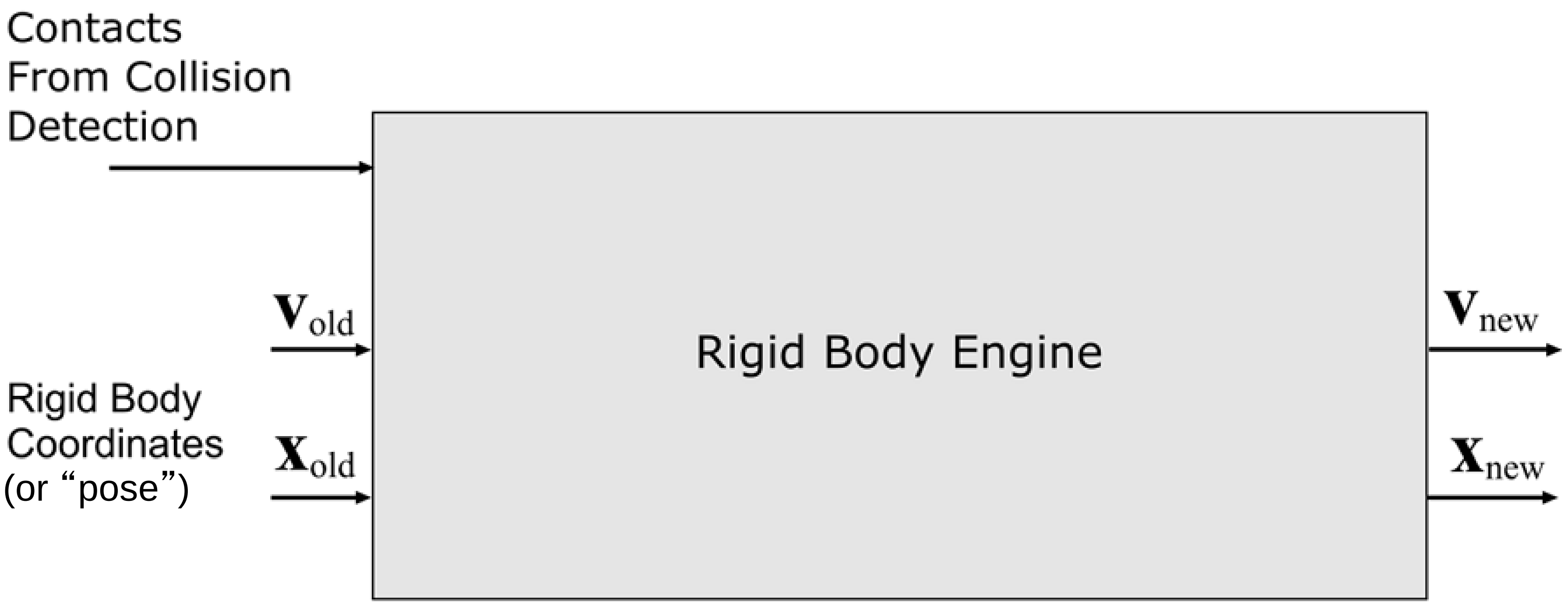


Rigid body dynamics with Open Dynamics Engine (ODE).

Rigid Body Solver

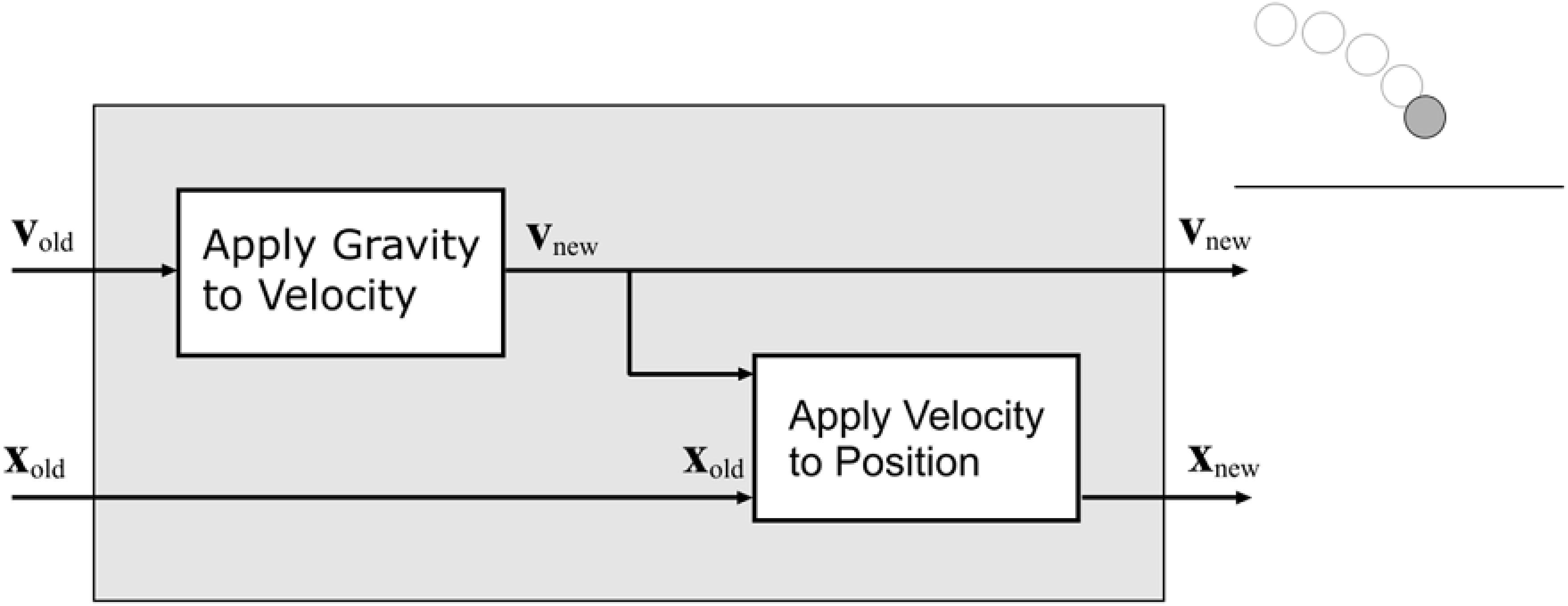
- "Black box" view of a Rigid Body Engine



Source: Richard Tonge, Iterative Rigid Body Solvers, Game Developers Conference, San Francisco 2013.

Rigid Body Solver

- Moving a body without collisions



Source: Richard Tonge, Iterative Rigid Body Solvers, Game Developers Conference, San Francisco 2013.

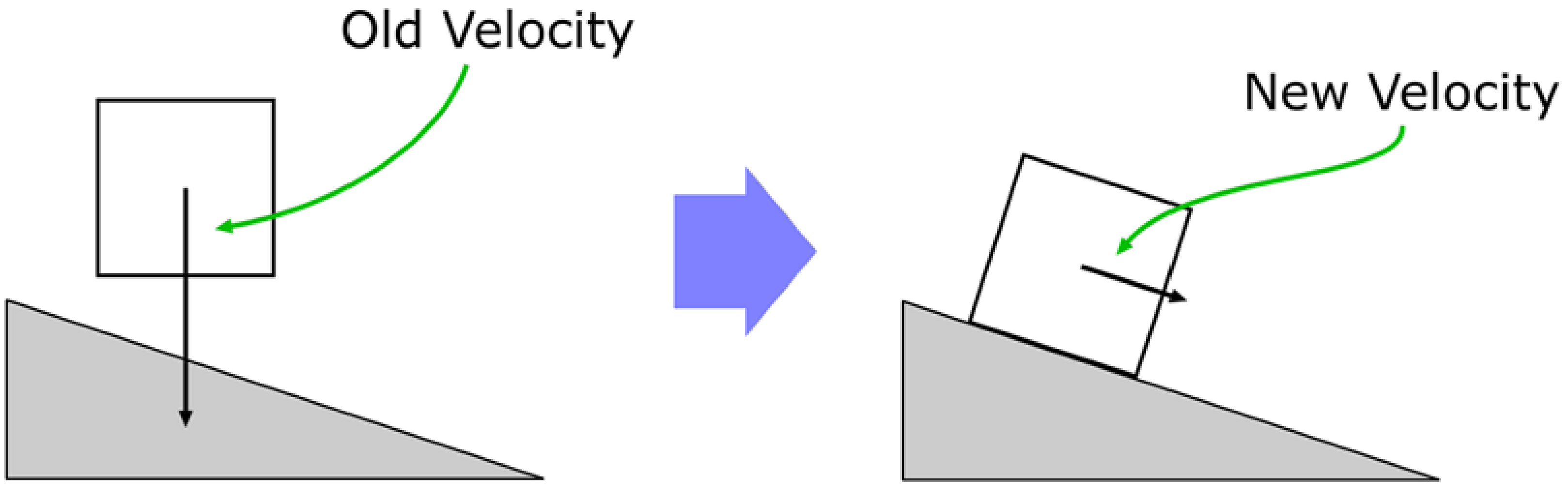
Rigid Body Solver

- Adding a single contact (inelastic contact, i.e.: no bouncing)

Source: Richard Tonge, Iterative Rigid Body Solvers, Game Developers Conference, San Francisco 2013.

Rigid Body Solver

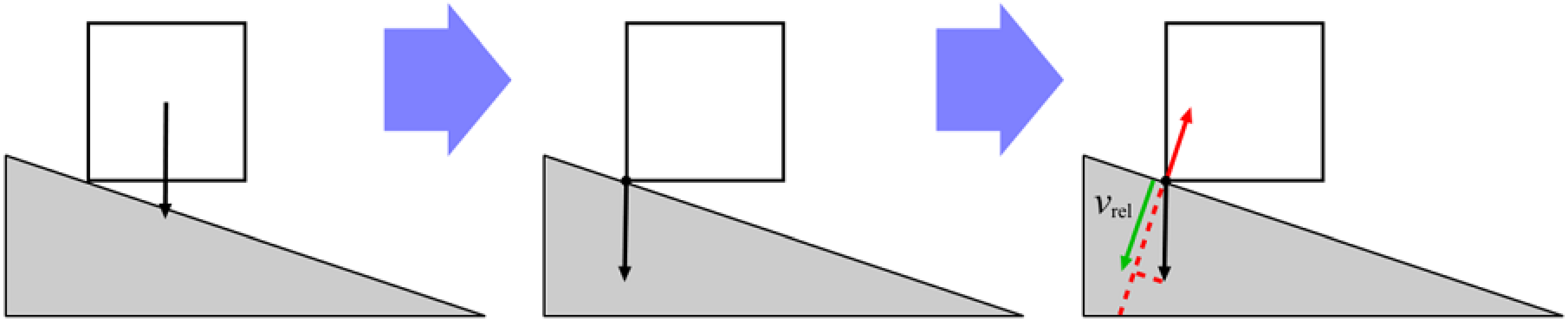
- Contact at the velocity level



Source: Richard Tonge, Iterative Rigid Body Solvers, Game Developers Conference, San Francisco 2013.

Rigid Body Solver

- Velocity at the contact

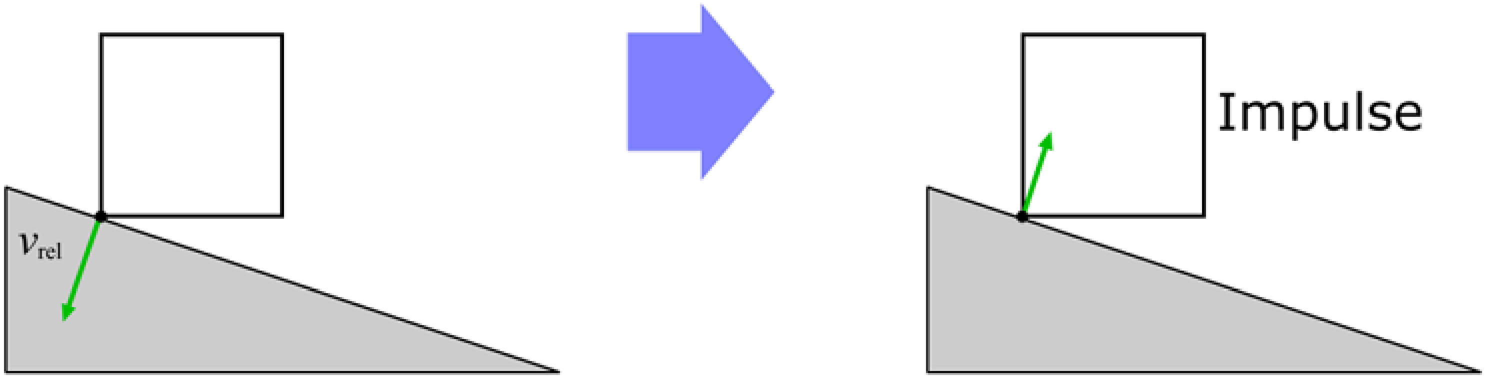


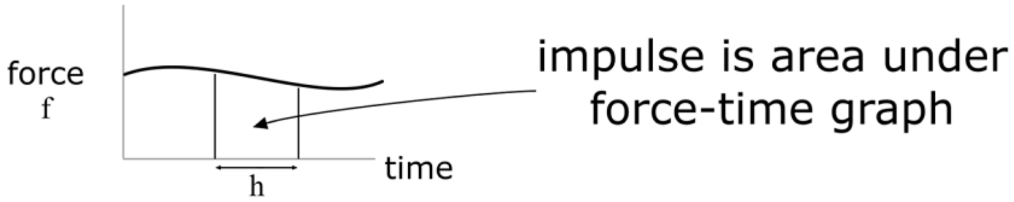
To avoid object penetration, apply an impulse to counteract the effect of gravity.

Source: Richard Tonge, Iterative Rigid Body Solvers, Game Developers Conference, San Francisco 2013.

Rigid Body Solver

- Calculating the impulse



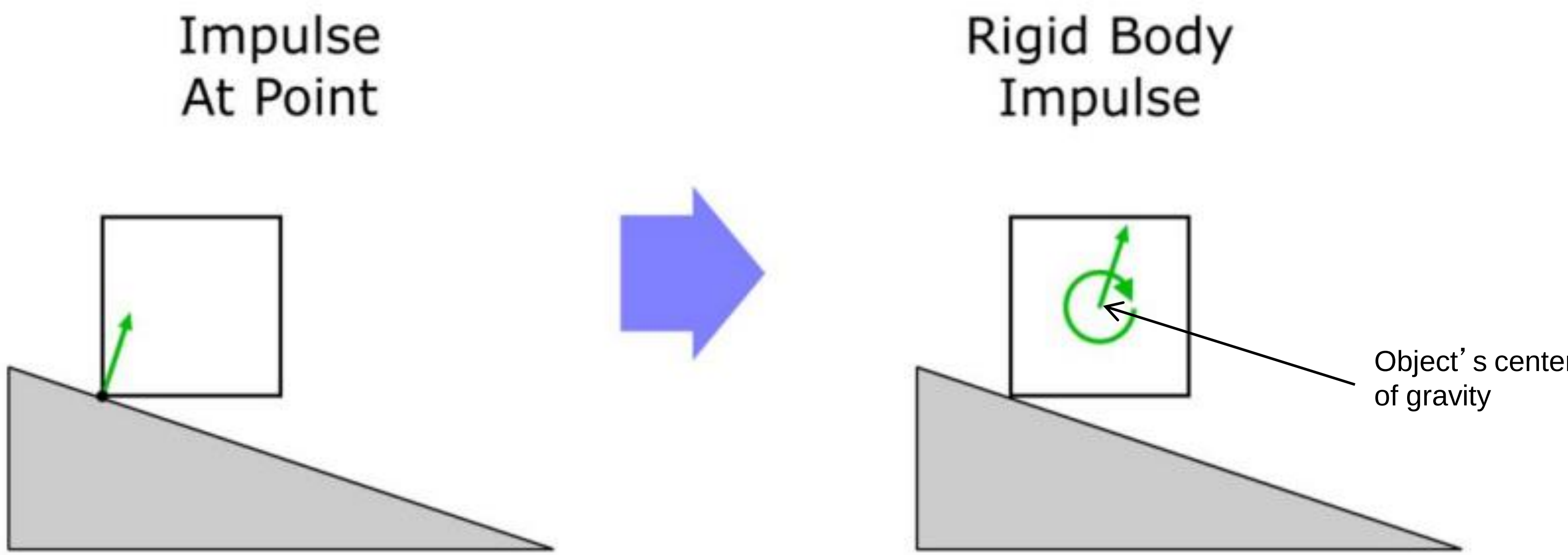


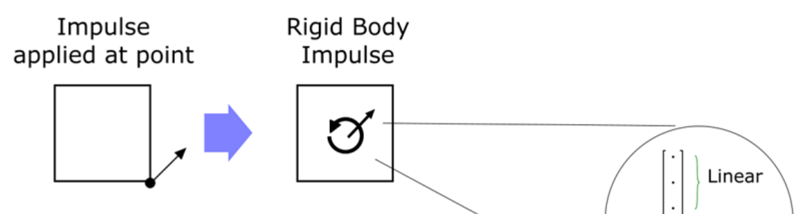
For a constant force: $I=hf$

Source: Richard Tonge, Iterative Rigid Body Solvers, Game Developers Conference, San Francisco 2013.

Rigid Body Solver

- Converting impulse to Rigid Body impulse



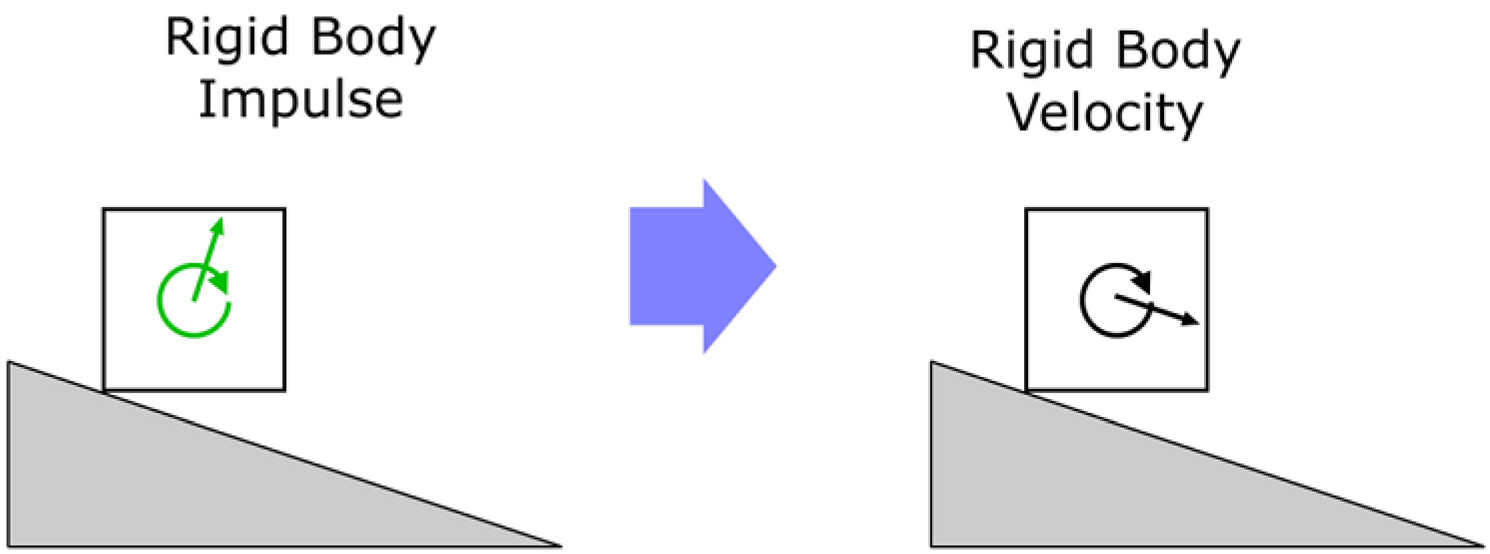


Applying impulse off-center causes a rotation as well as a linear impulse.

Source: Richard Tonge, Iterative Rigid Body Solvers, Game Developers Conference, San Francisco 2013.

Rigid Body Solver

- Applying the impulse

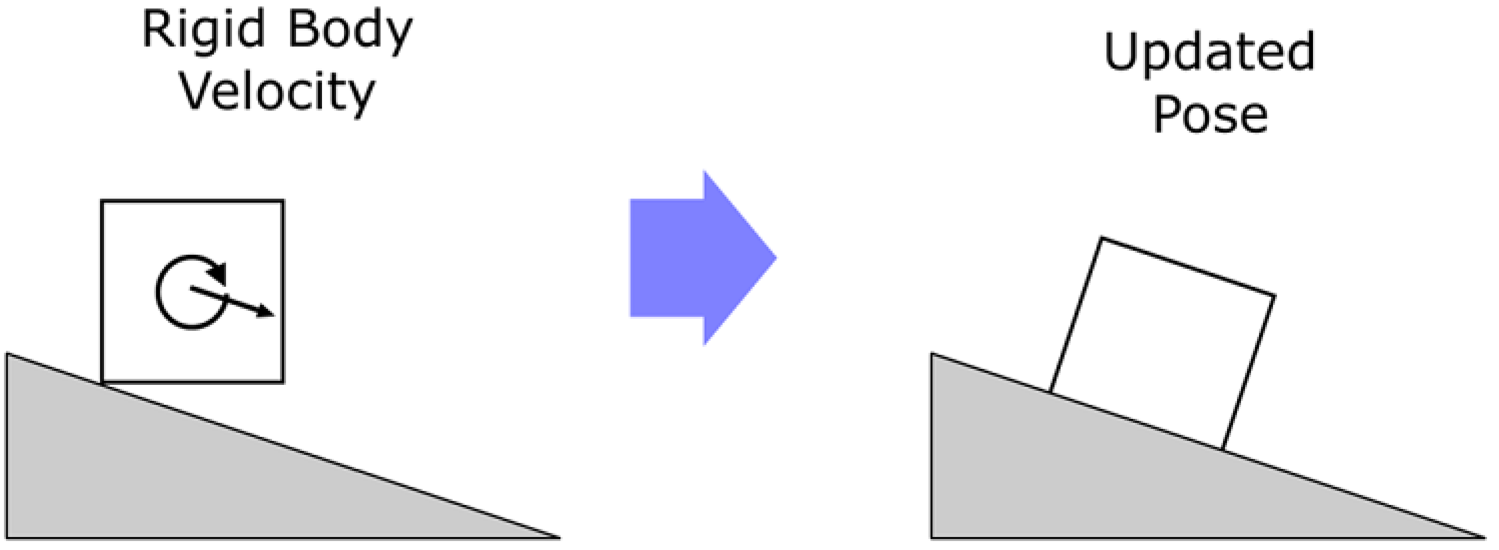


When you apply the impulse to the unconstrained velocity, the linear part of the new velocity aligns with the slope.

Source: Richard Tonge, Iterative Rigid Body Solvers, Game Developers Conference, San Francisco 2013.

Rigid Body Solver

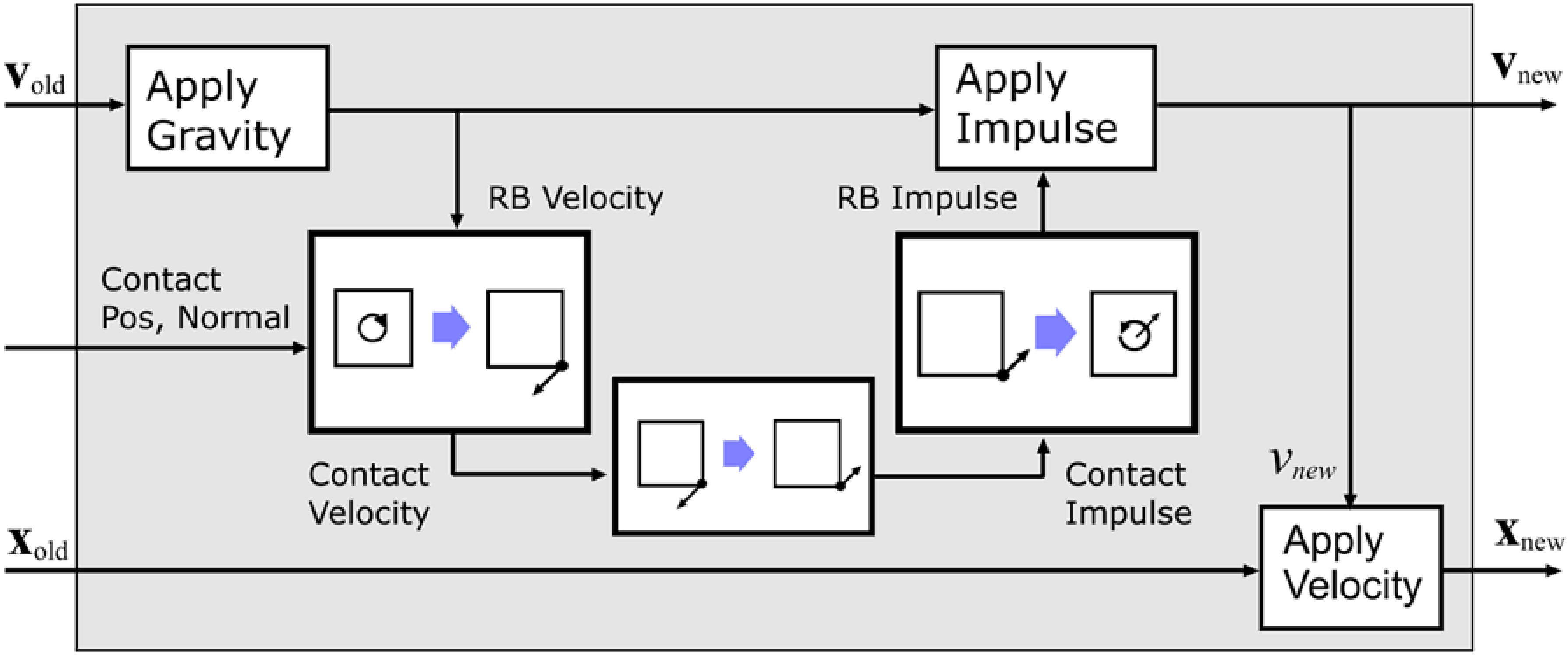
- Applying the velocity



Source: Richard Tonge, Iterative Rigid Body Solvers, Game Developers Conference, San Francisco 2013.

Rigid Body Solver

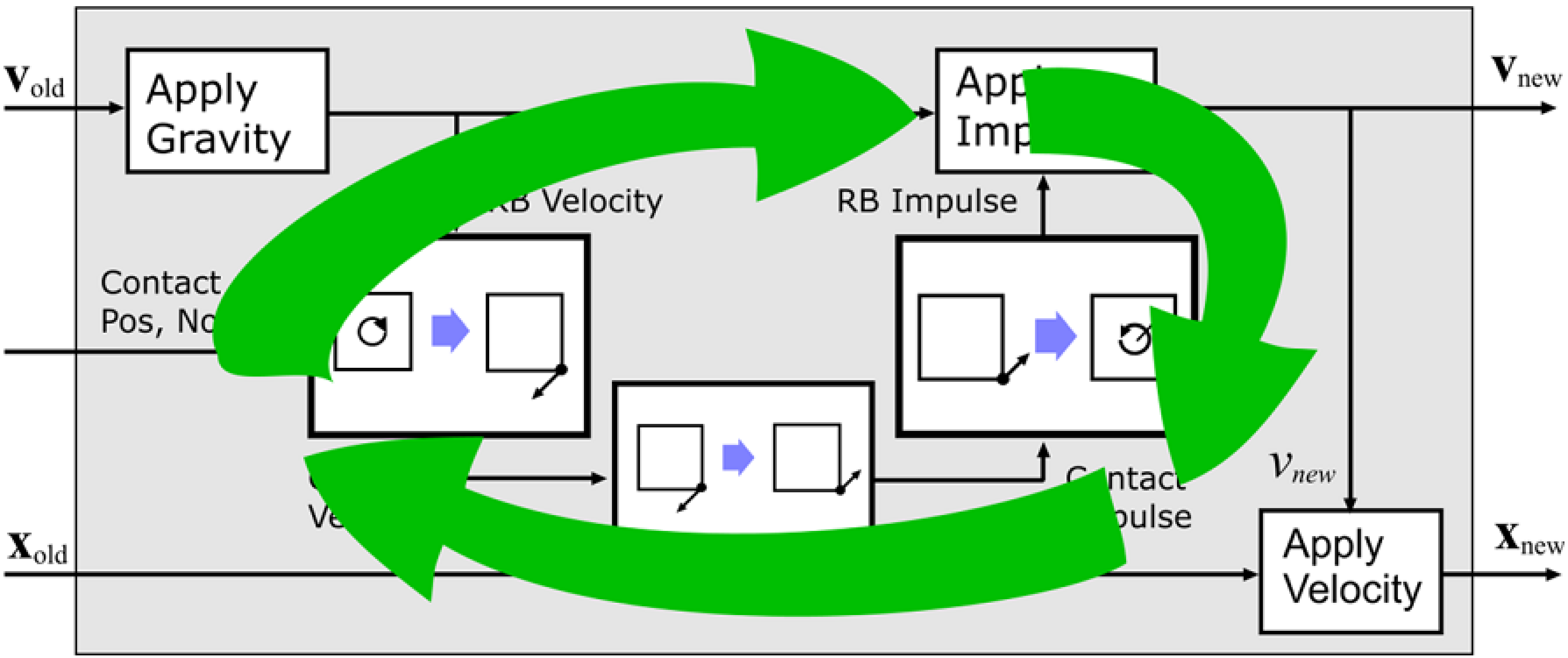
- Putting everything together



Source: Richard Tonge, Iterative Rigid Body Solvers, Game Developers Conference, San Francisco 2013.

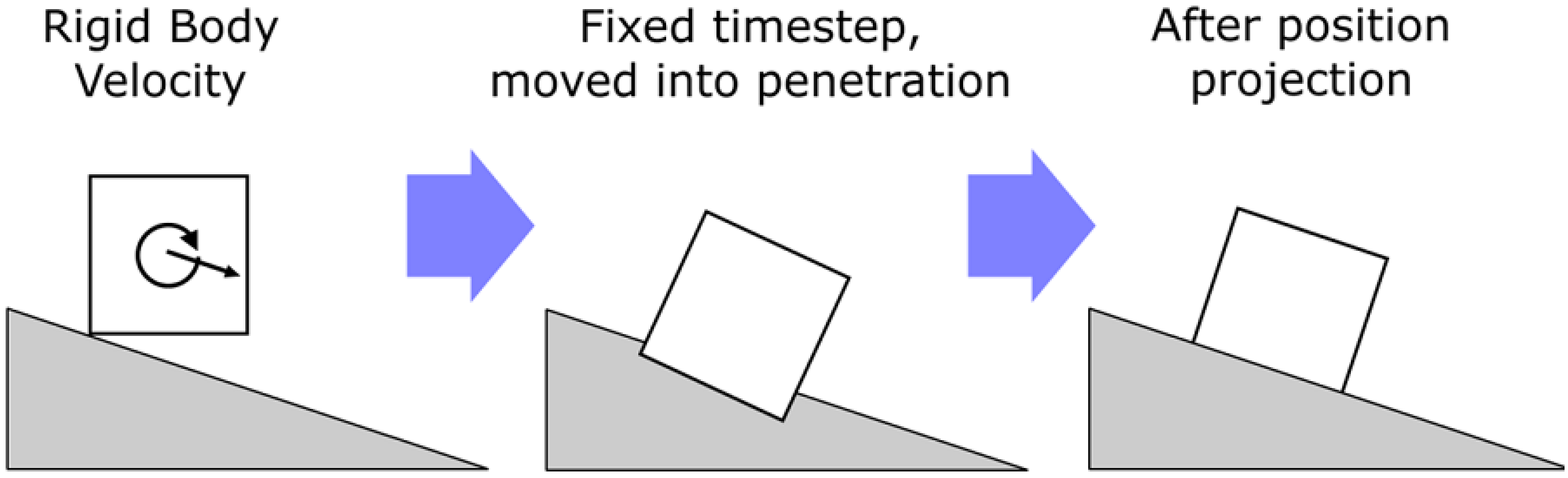
Rigid Body Solver

- Iteratively applying impulses



Rigid Body Solver

- Problem: fixed timesteps → position errors → object penetration
- Solution: Position Projection
- Problem with that: jitter



Mass Splitting for Jitter-Free Parallel Rigid Body Simulation

Richard Tonge
Feodor Benevolenski
Andrey Voroshilov

NVIDIA

Source: Richard Tonge, Iterative Rigid Body Solvers,
Game Developers Conference, San Francisco 2013.