the gamedesigninitiative at cornell university

Lecture 8

2D Animation

Animation Basics: Sprite Sheets

- Animation is a sequence of **hand-drawn frames**
  - Smoothly displays action when change quickly
  - Also called flipbook animation
- Arrange animation in a **sprite sheet** (one texture)
  - Software chooses which frame to use at any time
  - So programmer is actually the one doing animation

Anatomy of SpriteNode Class

```
/**
 * Sets the active frame as the given index.
 *
 * @param frame the index to make the active frame
 */
void SpriteNode::setFrame(int frame) {
    this->frame = frame;
    int x = (frame % cols)*bounds.size.width;
    int y = (frame / cols)*bounds.size.height;
    bounds.origin.set(x,y);
    setPolygon(bounds);
}
```

Anatomy of AnimationNode Class

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```

Actual code has some minor optimizations

Adjusting your Speed

- Do not want to go too fast
  - 1 animation frame = 16 ms
  - Walk cycle = 8/12 frames
  - Completed in 133-200 ms
- General solution: *cooldowns*
  - Add an int timer to your object
  - Go to next frame when it is 0
  - Reset it to > 0 at new frame
- Simple but tedious
  - Have to do for each object
  - Assumes animation is in a loop

Matching Your Translation

- Movement is *two* things
  - **Animation** of the filmstrip
  - **Translation** of the image
  - These two must align
- **Example:** Walking
  - Foot is point of contact
  - "Stays in place" as move
  - This constrains translation
- Make movement regular
  - Measure distance per frame
  - Keep same across frames

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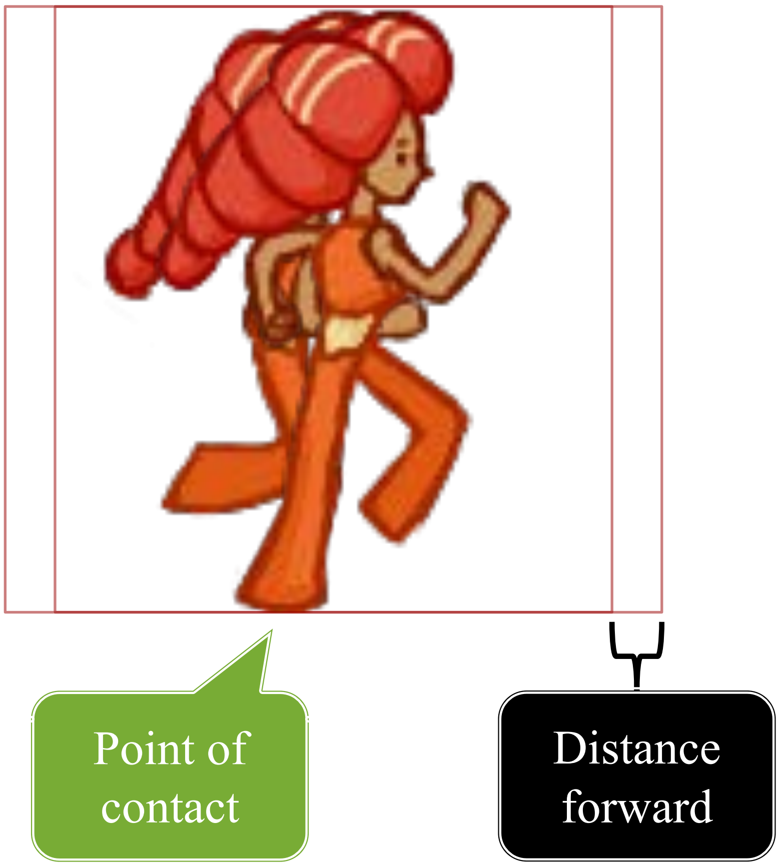


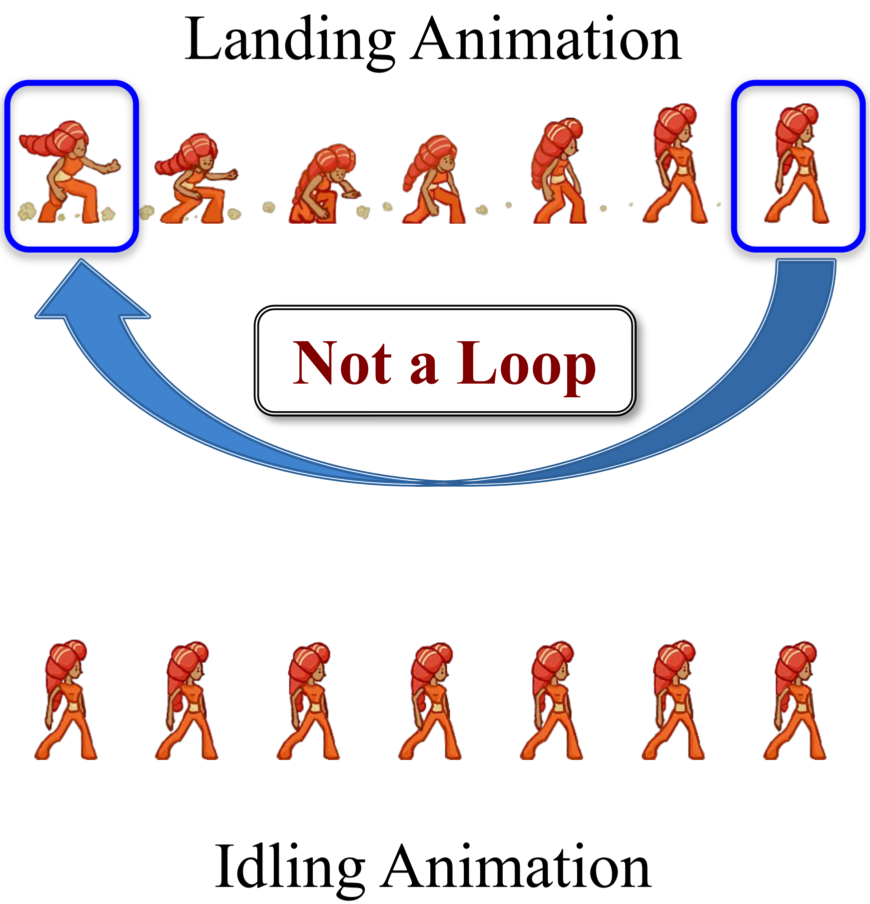
Combining Animations

Landing Animation

Idling Animation

- Characters do a lot of things
  - Run, jump, duck, slide
  - Fire weapons, cast spells
  - Fidget while player AFK
- Want animations for all
  - Is loop appropriate for each?
  - How do we transition?
- **Idea**: shared boundaries
  - End of loop = start of another
  - Treat like advancing a frame

Combining Animations



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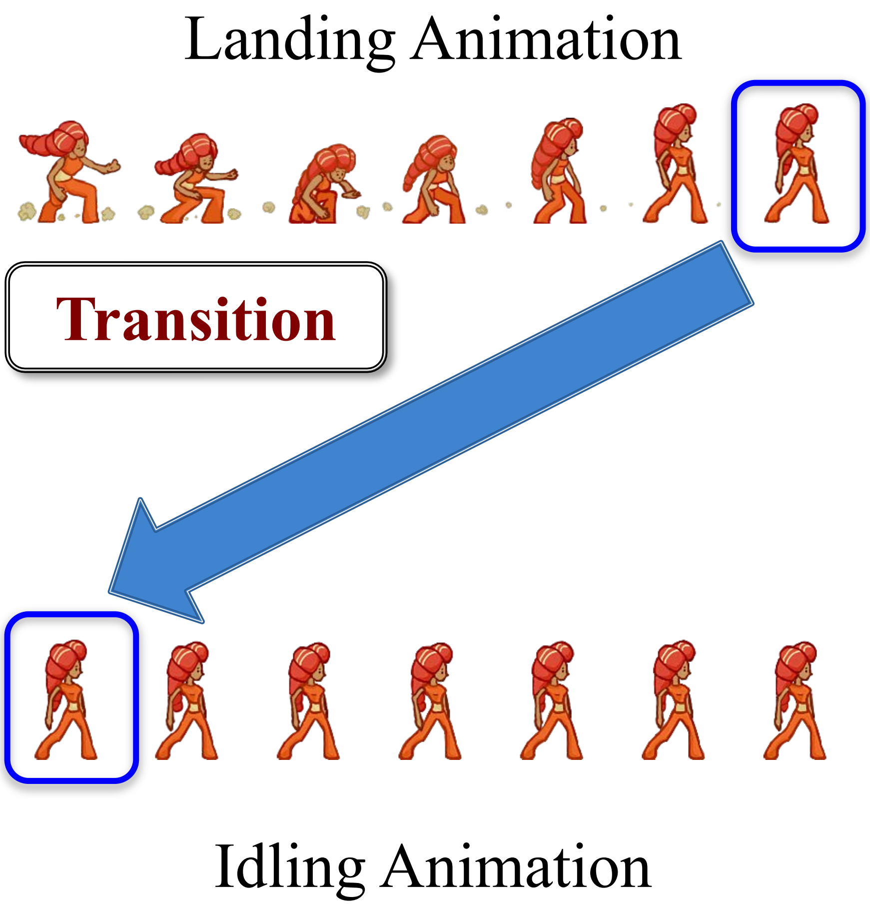

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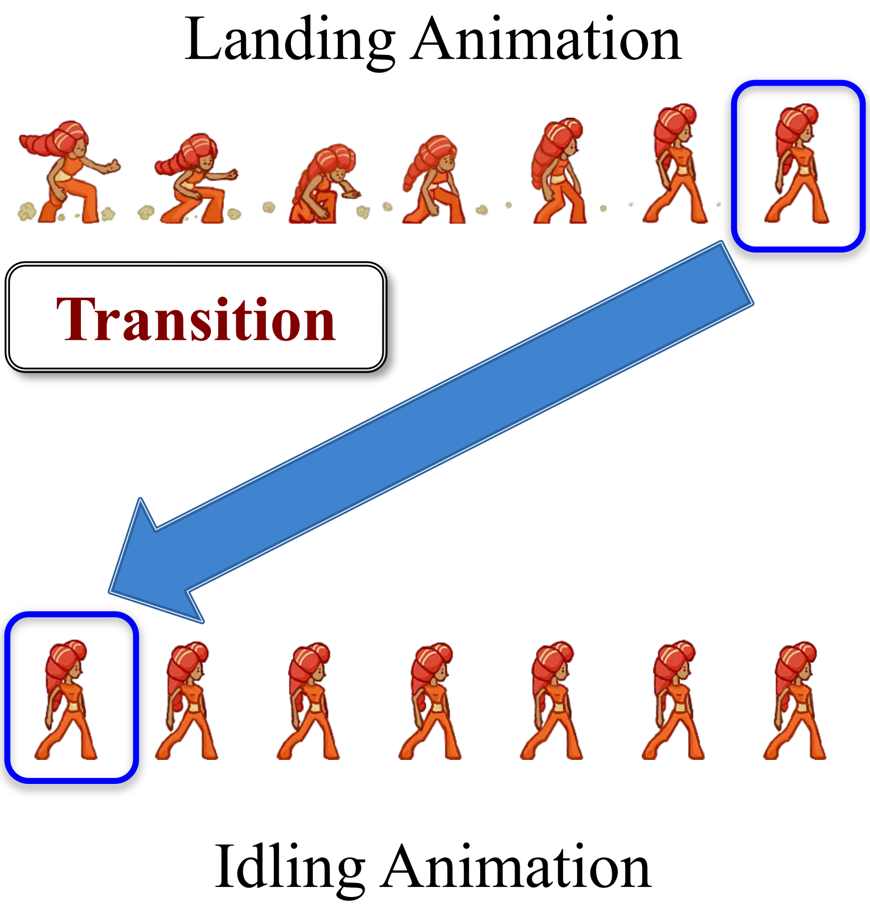

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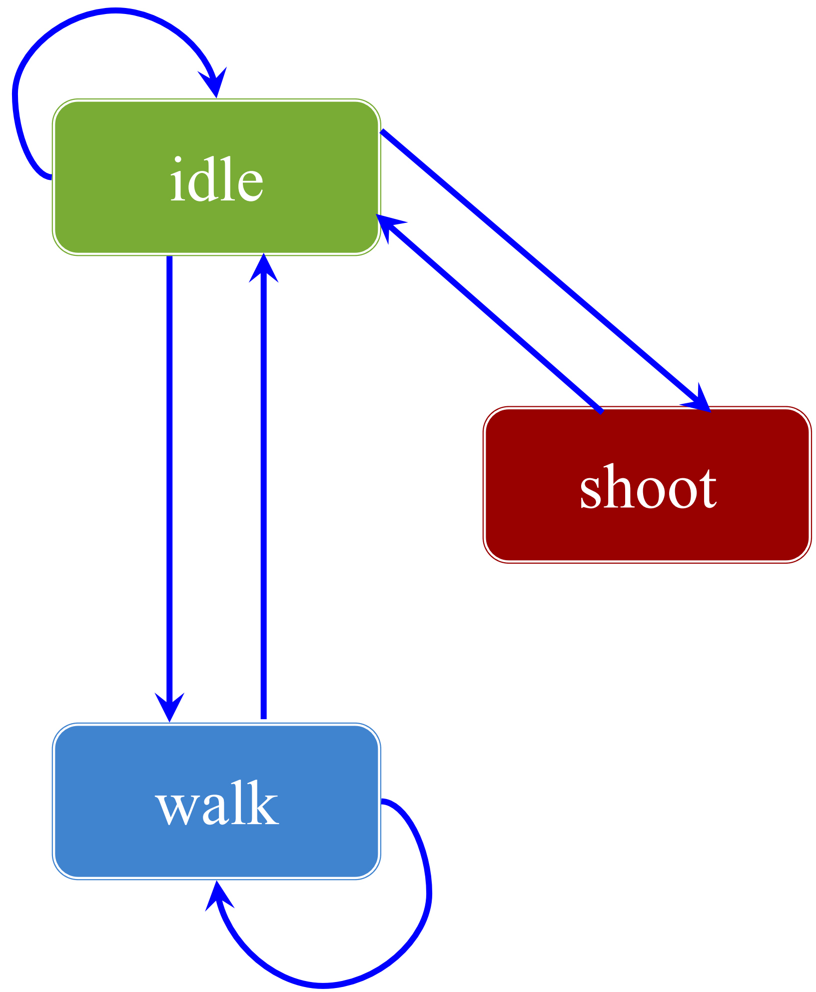
  - F … er
  - T …

But do not draw ends twice!

Animation and State Machines

- Idea: Each sequence a state
  - Do sequence while in state
  - Transition when at end
  - Only loop if loop in graph
- A graph edge means…
  - Boundaries match up
  - Transition is allowable
- Similar to data driven AI
  - Created by the designer
  - Implemented by programmer
  - Modern engines have tools



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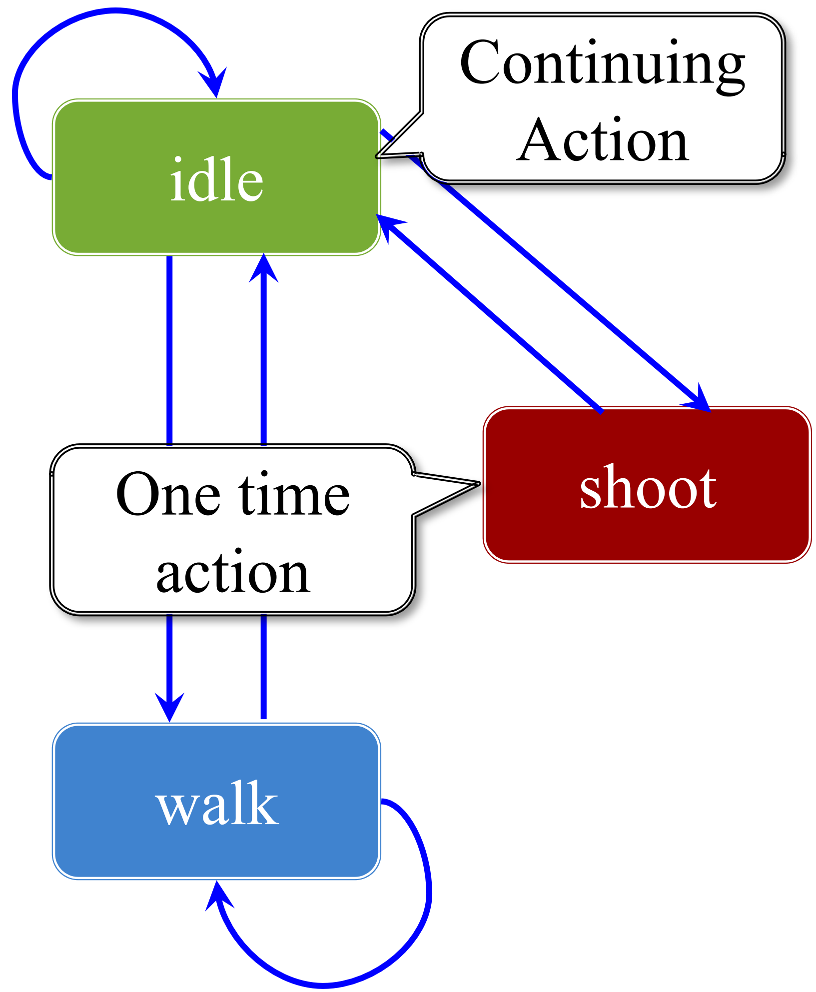
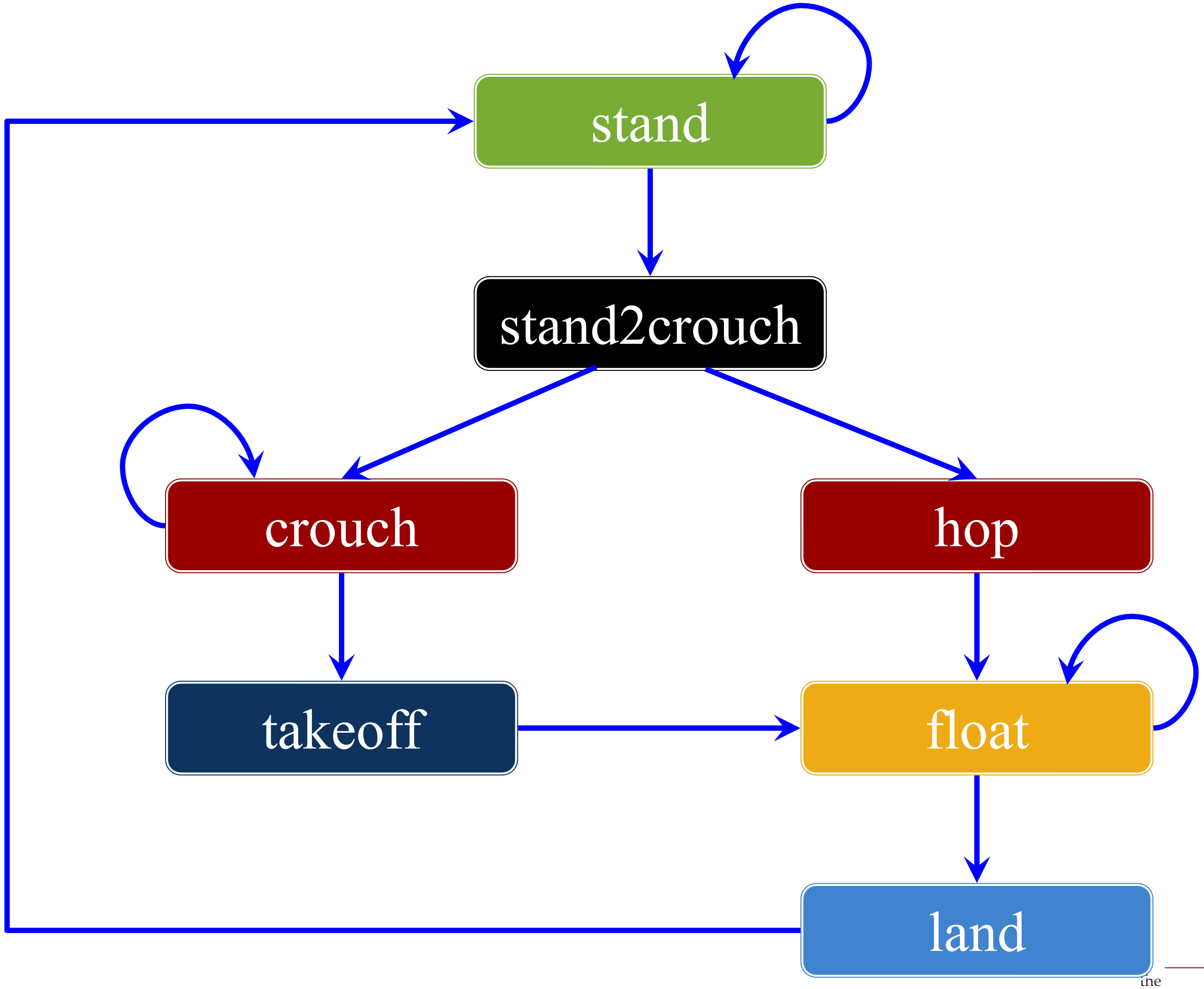


Complex Example: Jumping



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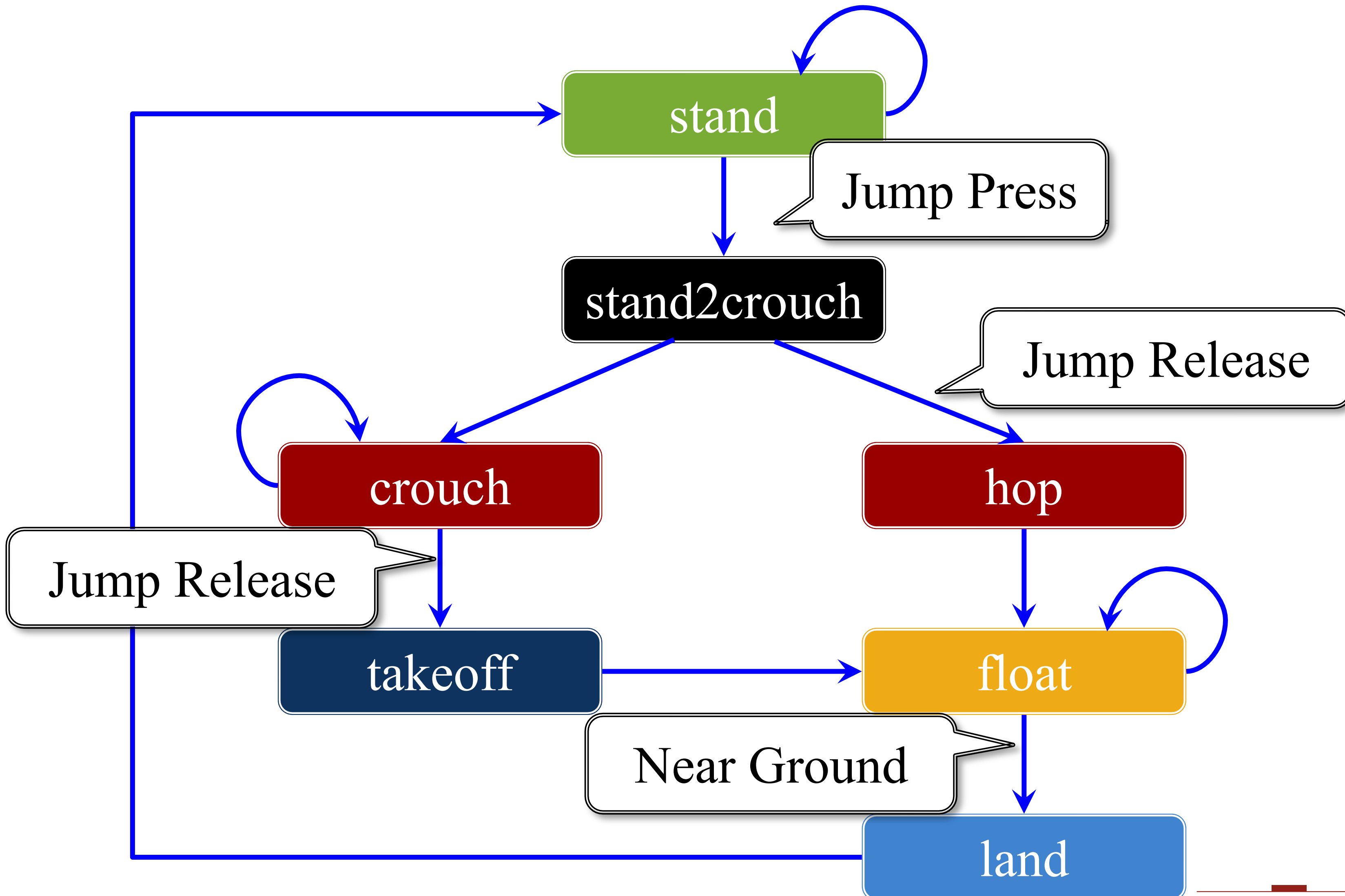

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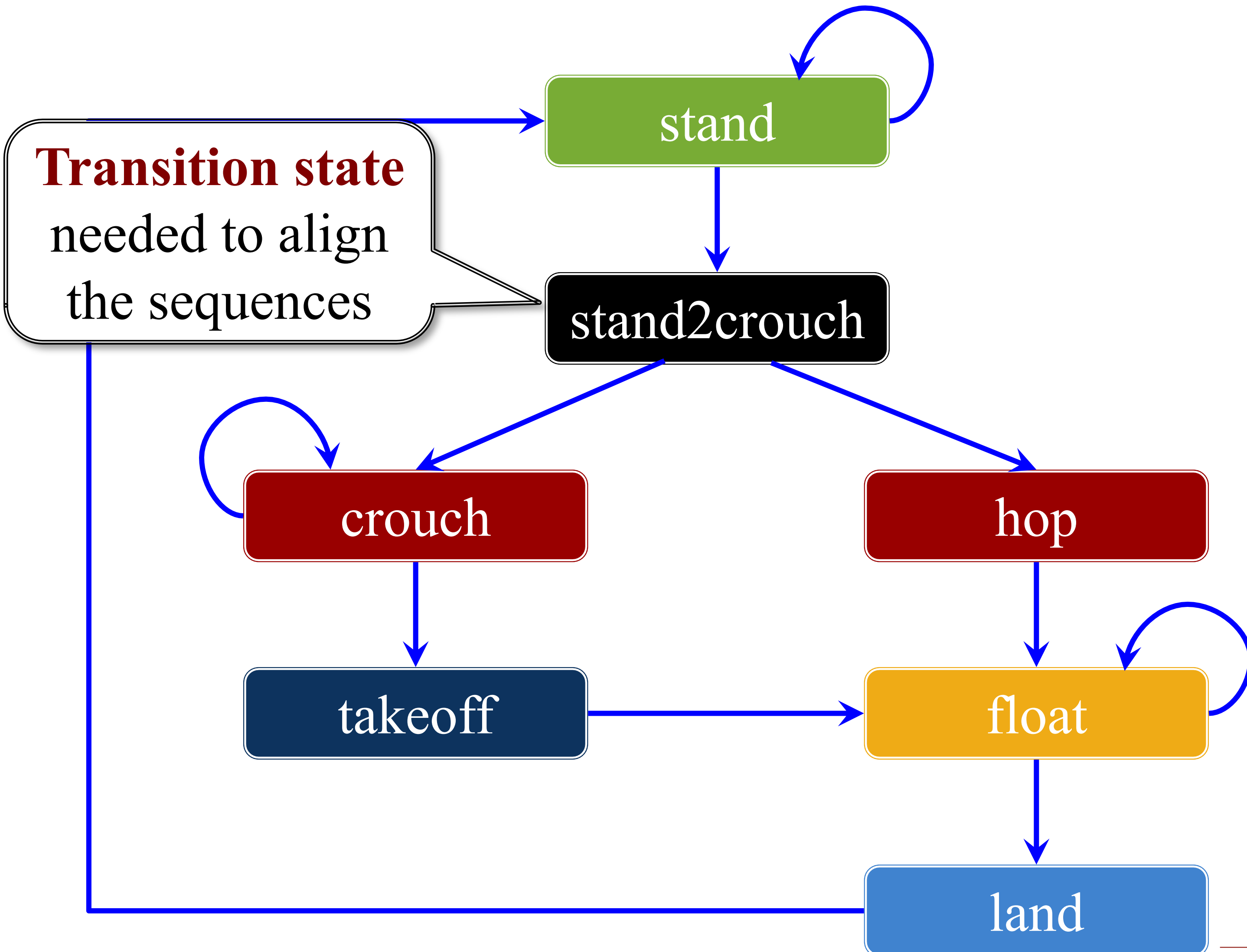
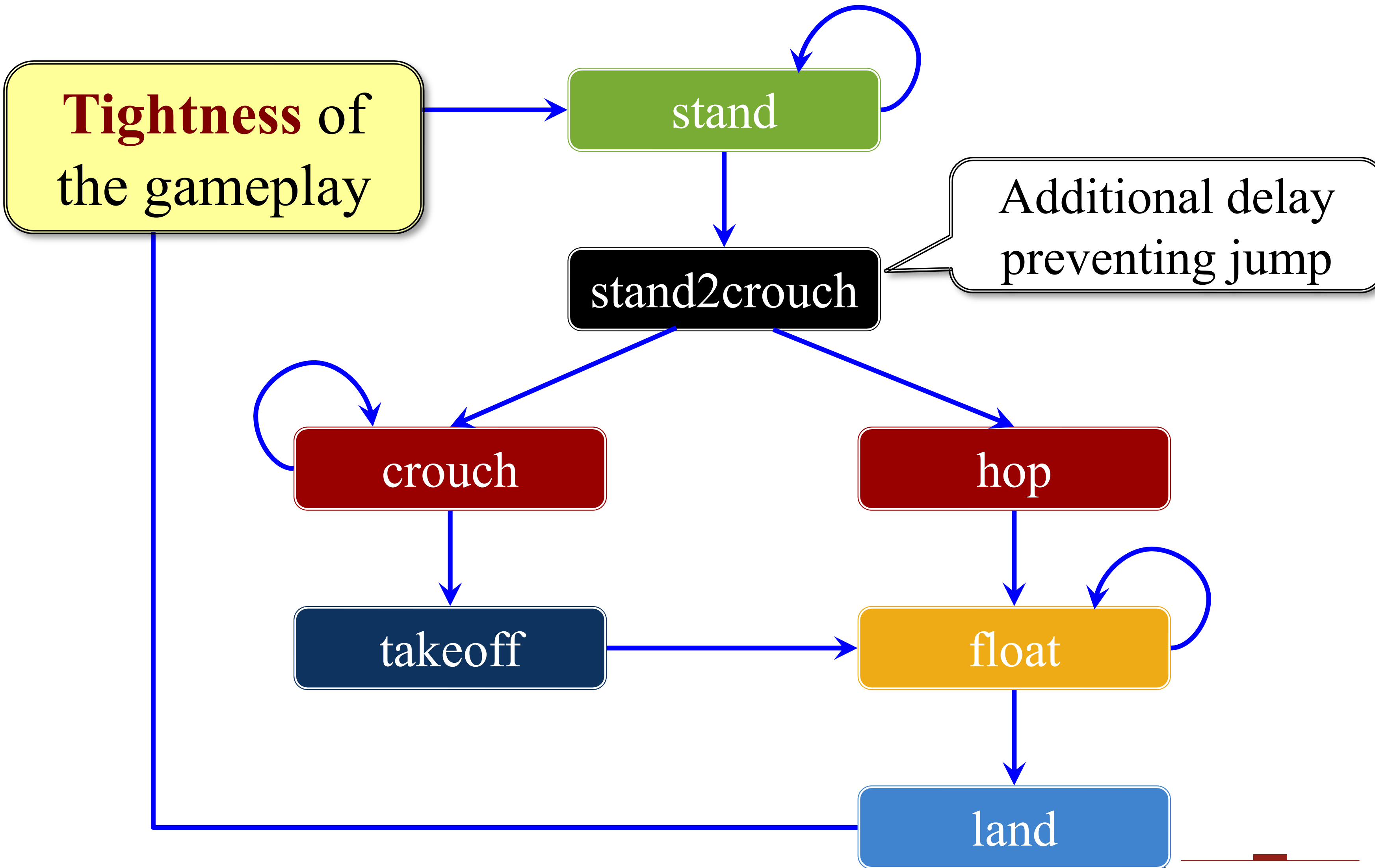
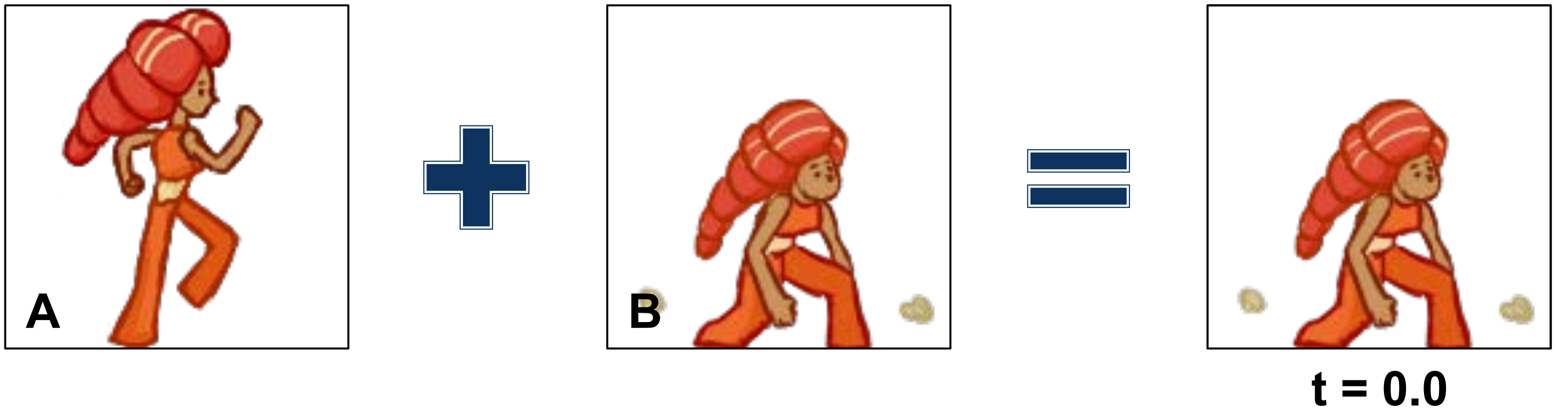


Aside: Sync Kills

The Responsiveness Issue



Fast Transitions: Crossfade Blending

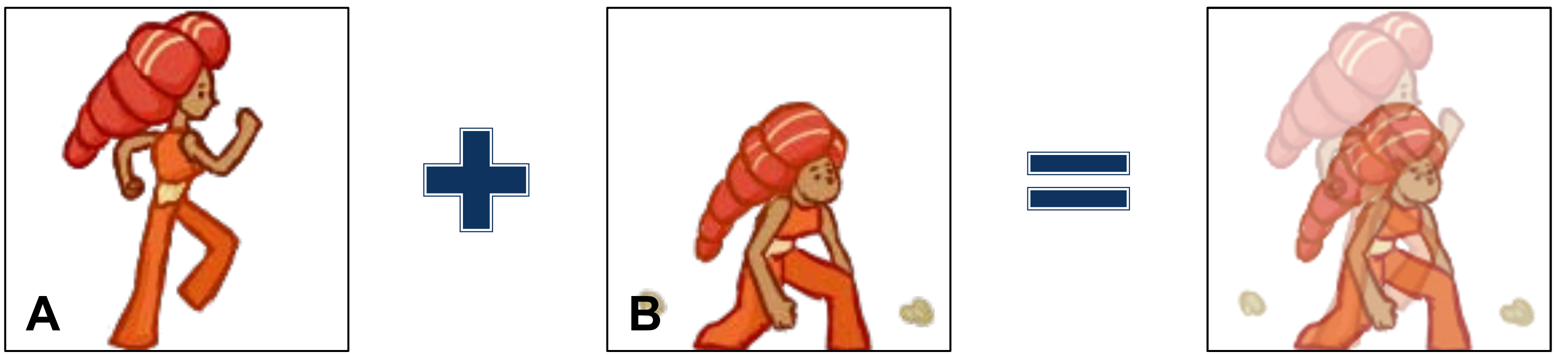


- Linear interpolation on colors

$$r_c = tr_a + (1-t)r_b$$
$$g_c = tg_a + (1-t)g_b$$
$$b_c = tb_a + (1-t)b_b$$

Note weights sum to 1.0

Fast Transitions: Crossfade Blending



t = 0.3

- Linear interpolation on colors

$$r_c = tr_a + (1-t)r_b$$
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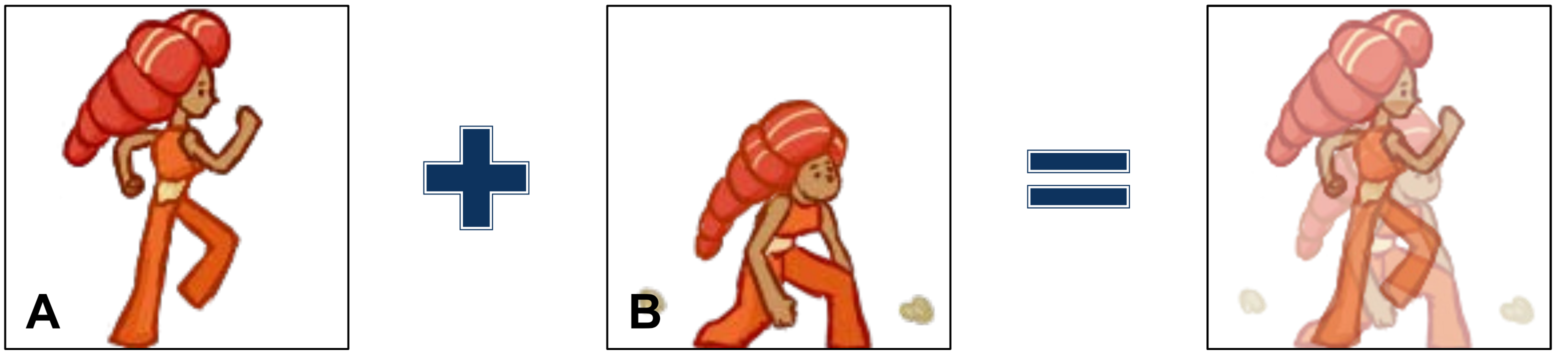


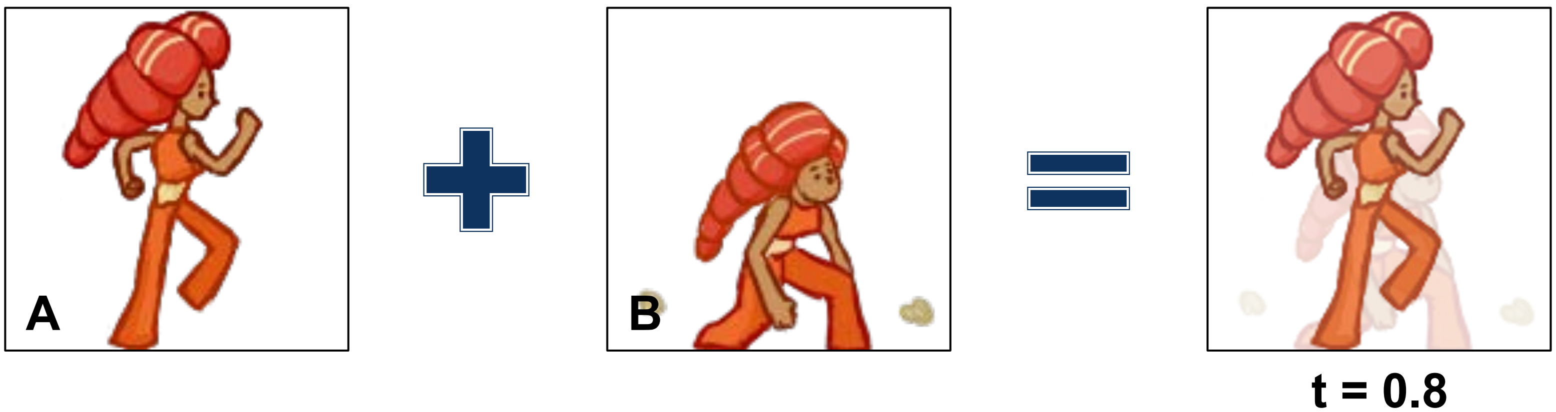
t = 0.6

- Linear interpolation on colors

$$
\left.\begin{aligned}
r_c &= tr_a + (1-t)r_b \\
g_c &= tg_a + (1-t)g_b \\
b_c &= tb_a + (1-t)b_b
\end{aligned}\right\}
$$

Note weights sum to 1.0

Fast Transitions: Crossfade Blending



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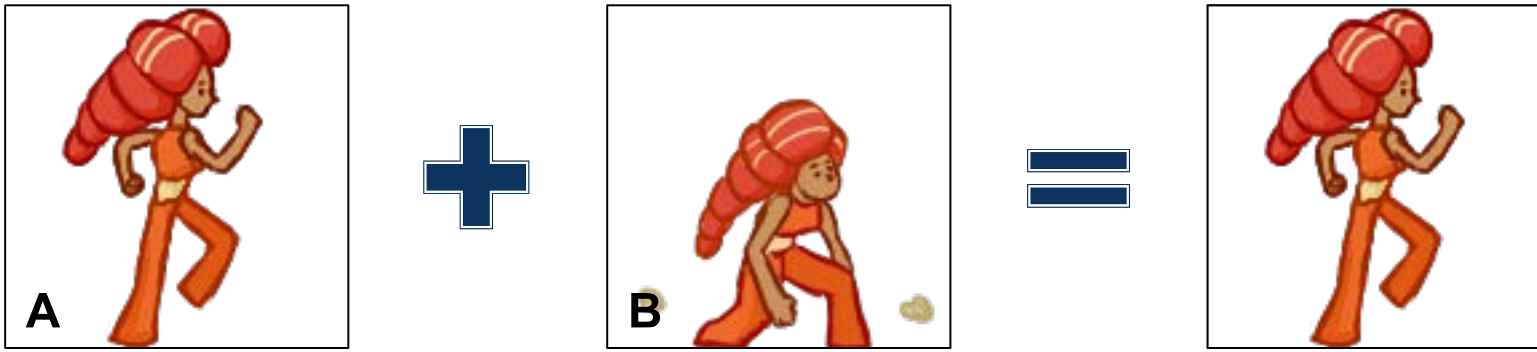
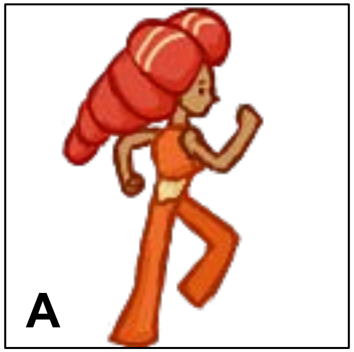


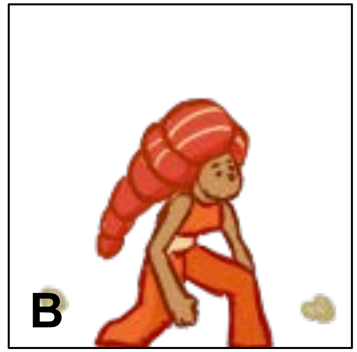
t = 1.0

- Linear interpolation on colors

$$\left.\begin{aligned} r_c &= t r_a + (1-t) r_b \\ g_c &= t g_a + (1-t) g_b \\ b_c &= t b_a + (1-t) b_b \end{aligned}\right\}$$ Note weights sum to 1.0

Combining With Animation



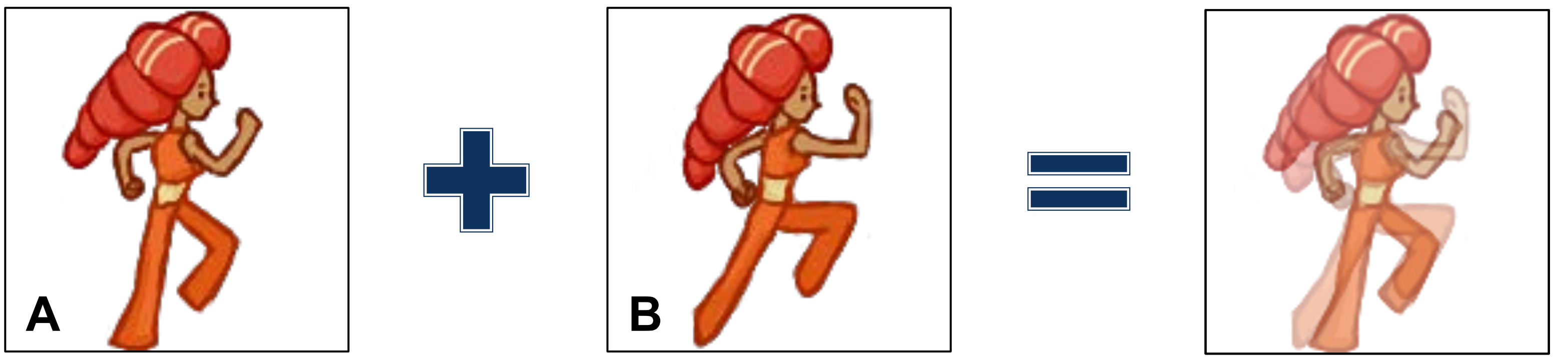


Cycle the filmstrip normally

Cycle the filmstrip normally

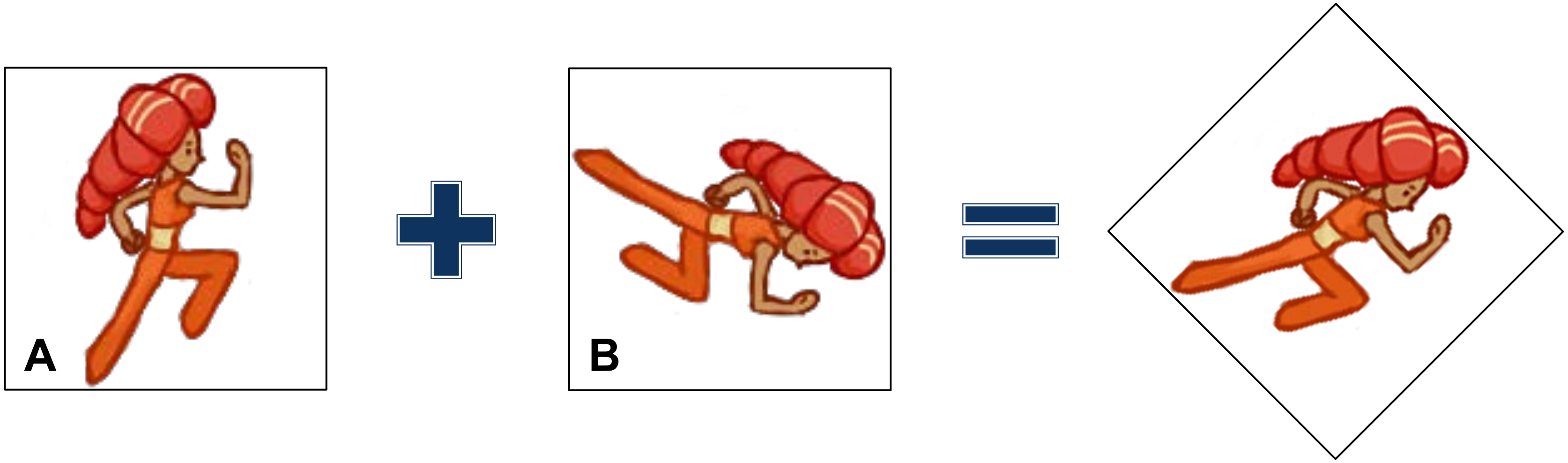
Combine with alpha blending

Related Concept: **Tweening**



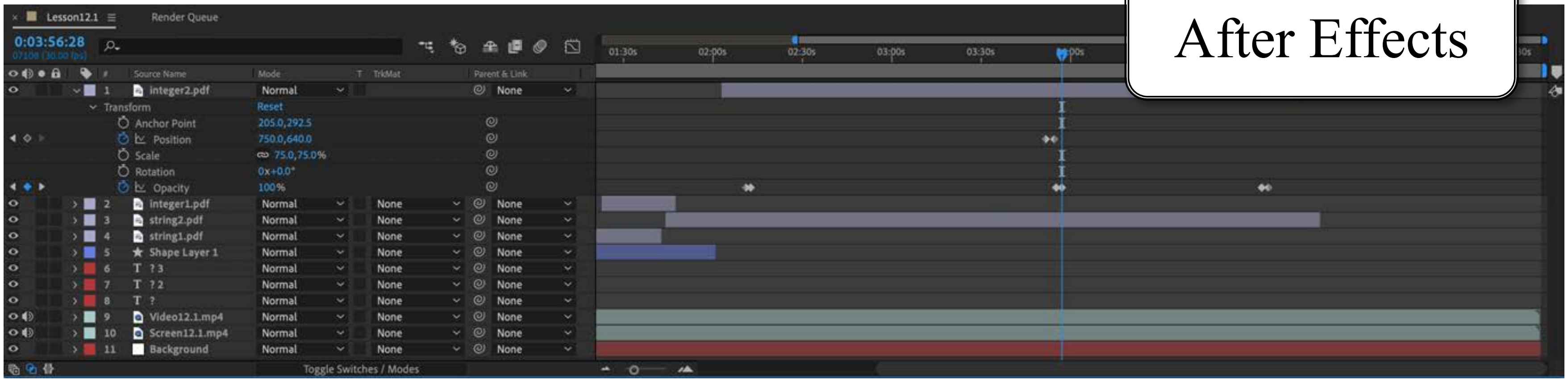
- Act of linear interpolating between animation frames
  - Because we cycle filmstrip slower than framerate
  - Implements a form of motion blur
- If animation **designed right**, makes it smoother

Tweening Works for Transforms Too

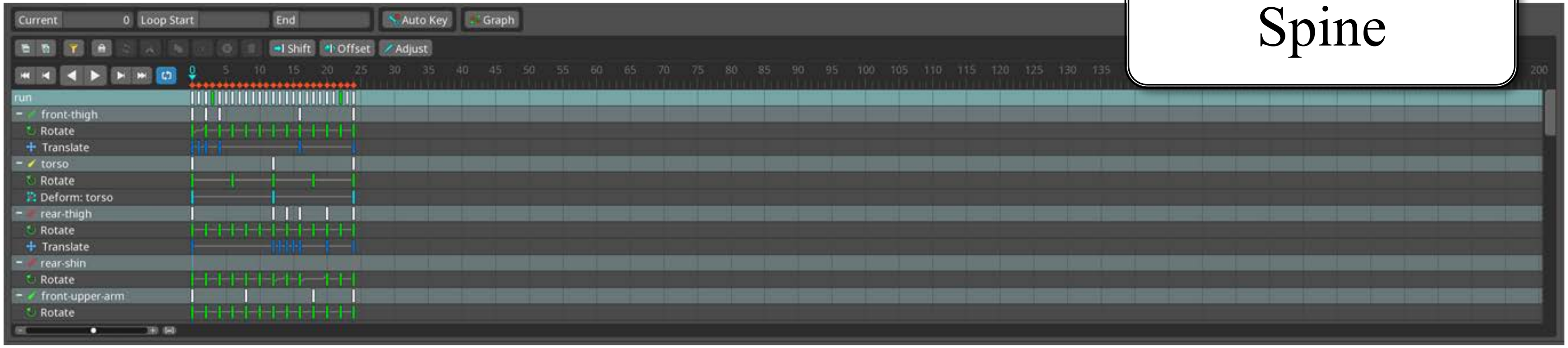


- Any transform is represented by a matrix
  - Can linearly interpolate matrix components
  - Gives a reasonable transform "in-between"
- **Aside**: This is a motivation for quaternions
  - Gives smoother interpolation for rotation

Tweening vs Keyframes



After Effects



Spine

Tweening vs Keyframes

Tweening

- Specify the action
  - Give an action and a time
  - Frames are interpolations
- **Programmer** centric

Keyframes

- Specify the result
  - Give start and end points
  - Middle is interpolated
- **Designer** centric

Essentially the same concept.
Difference is the specification.

Supporting Tweened Animations

Actions

- Represents animation type
  - Moving, rotating, scaling
  - Filmstrip sequences
- But not active animation
  - Can be reused and replayed
  - Can be copied safely
- Think of as a "template"
  - Defines the tweening
  - But has no internal state

ActionManager

- Manages active animations
  - Maps actions to scene graph
  - Allocates animation state
- Has a separate update loop
  - Initialization step at start
  - Update step to increment
- Similar to **asset manager**
  - Animations have key id
  - Run `update()` to fit budget

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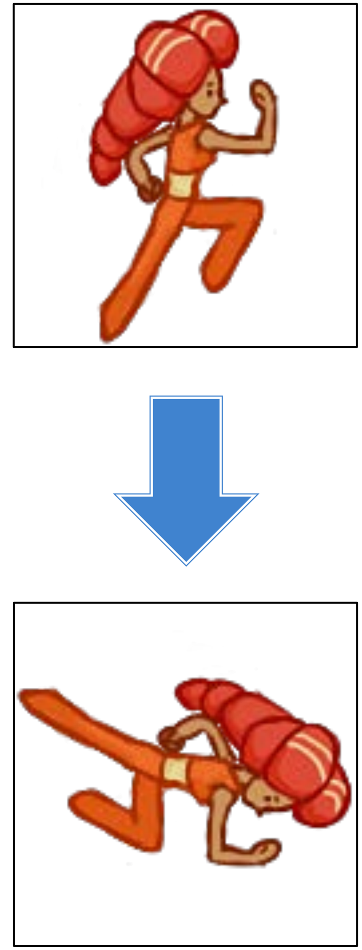
Executing Actions: **Transforms**

```
auto mgr = ActionManager::alloc();
auto action = RotateBy::alloc(90.0f,2.0f);
mgr->activate(key,action,sprite);

while (mgr->isActive(key)) {
    mgr->update(TIMESTEP);
}
// No clean-up.  Done automatically
```



Executing Actions: Transforms

ActionManager

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Map Action to key and start

Increments animation state

Tweens rotation

Executing Actions: **Sprite Sheets**

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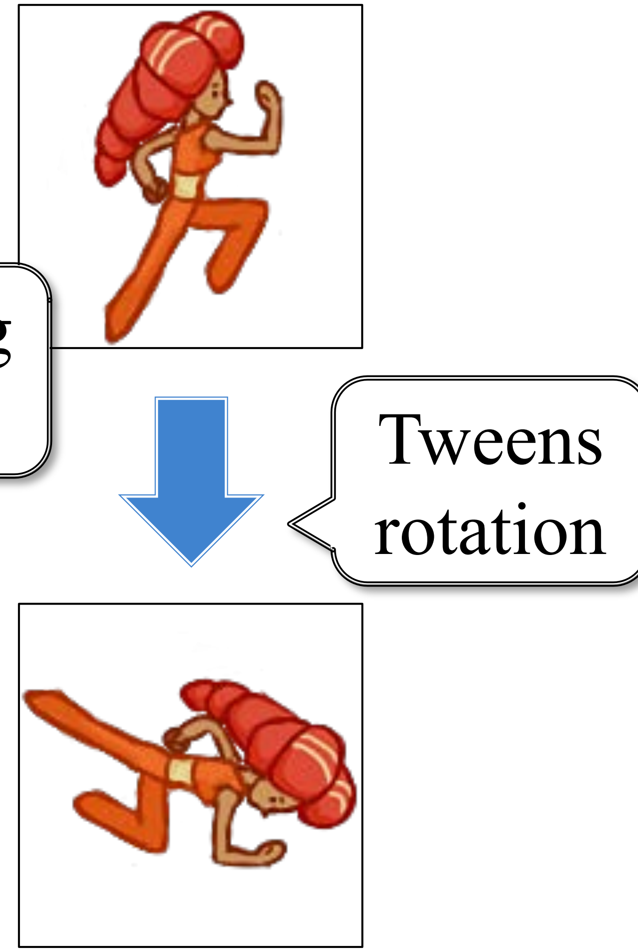
How long to spend

Maps to framerate



Executing Actions: Sprite Sheets

```
auto mgr = ActionManager::alloc();

std::vector<int> frames;
frames.push_back(f1);
 ...
frames.push_back(f8);

auto action = Animate::alloc(frames,2.0f);

mgr->activate(key,action,sprite);
while (mgr->isActive(key)) {

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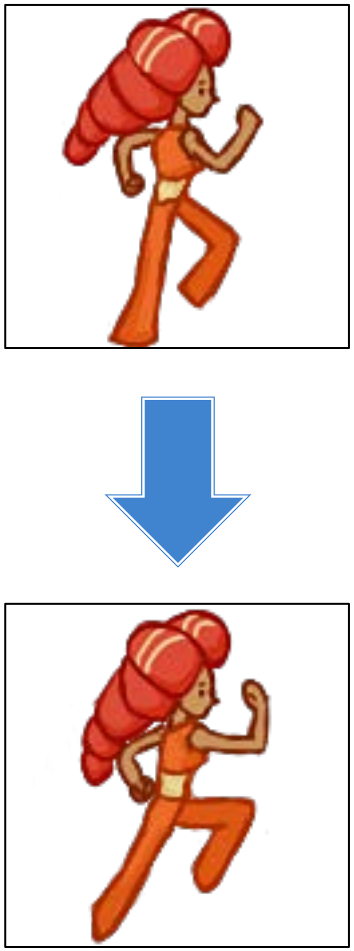

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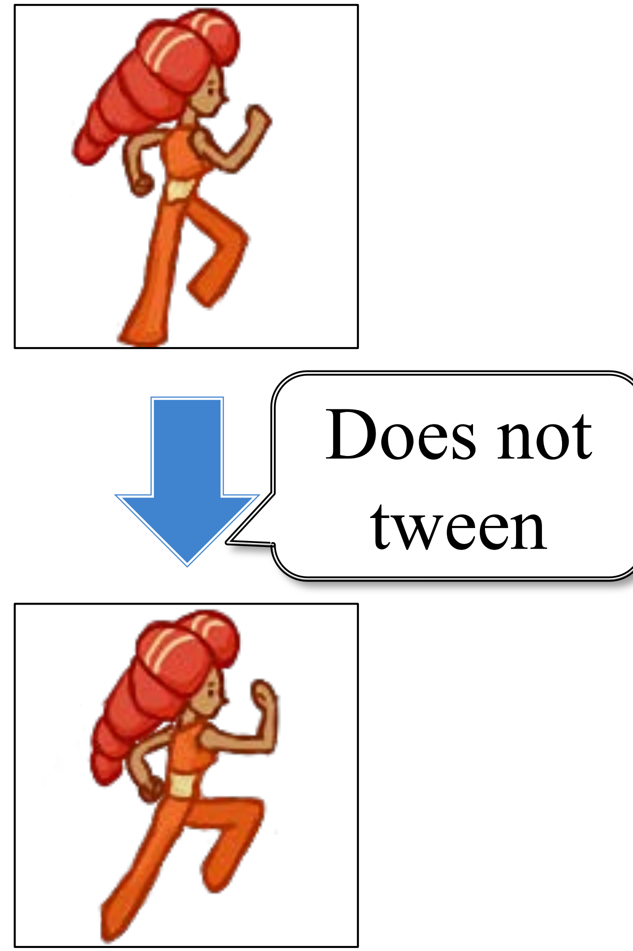
Sequence indices

Frames displayed uniformly



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auto action

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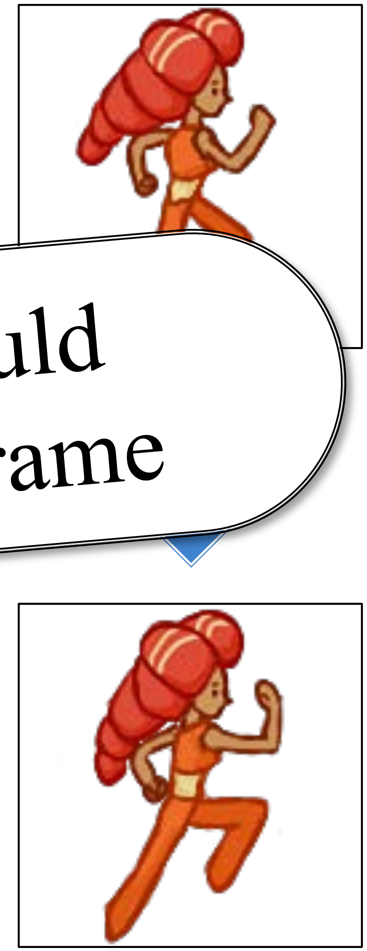
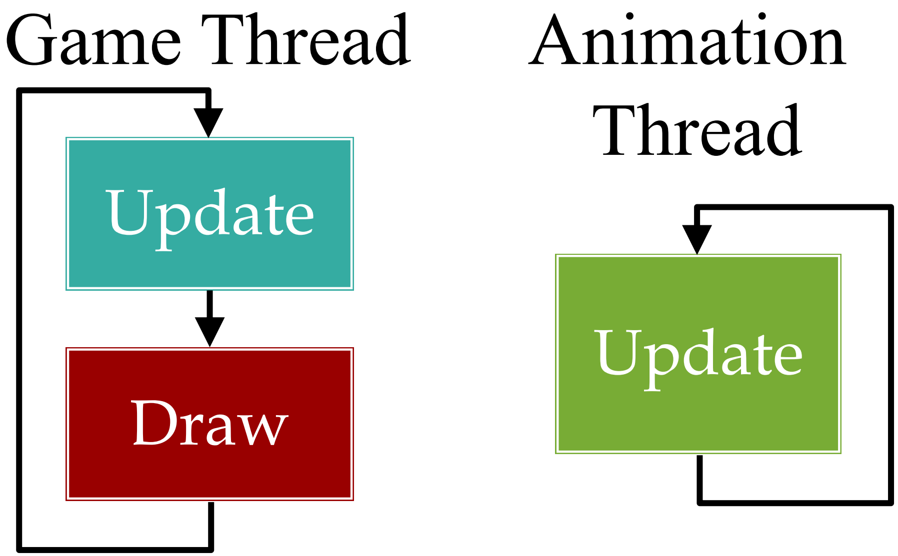
Alternatively, could specify time per frame



Related: Animating vs Rendering

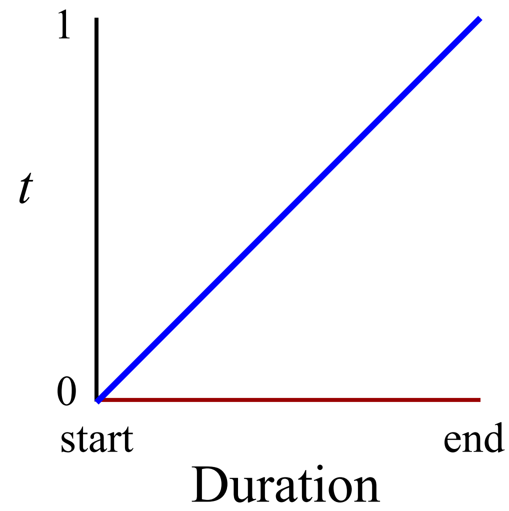
- You do not have to animate in the main thread
  - Main thread is for rendering (drawing on screen)
  - But animation is simply "posing" your models
- Allows for smoother animation (VSync problem)



Example: *Hi Fi Rush*

Easing Function

- Basic approach to tweening
  - Specify duration to animate
  - Set $t = 0$ at beginning
  - Normalize $t = 1$ at end
  - Interpolate value with t
- How does t change?
  - Usually done *linearly*
  - Could be some other way
- **Easing**: how to change t
  - Used for bouncing effects
  - Best used for *transforms*



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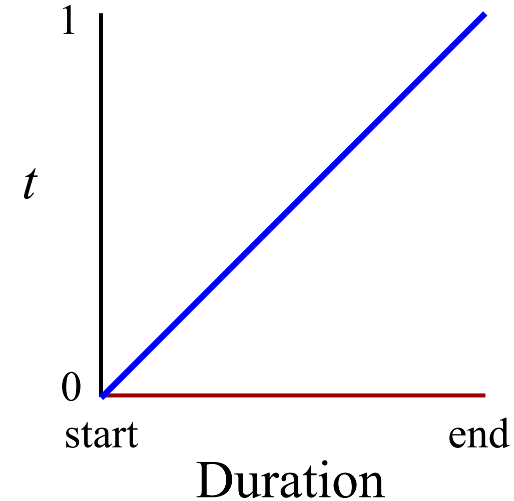
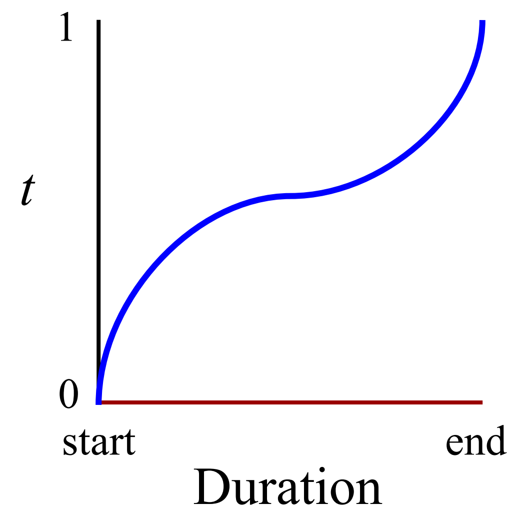
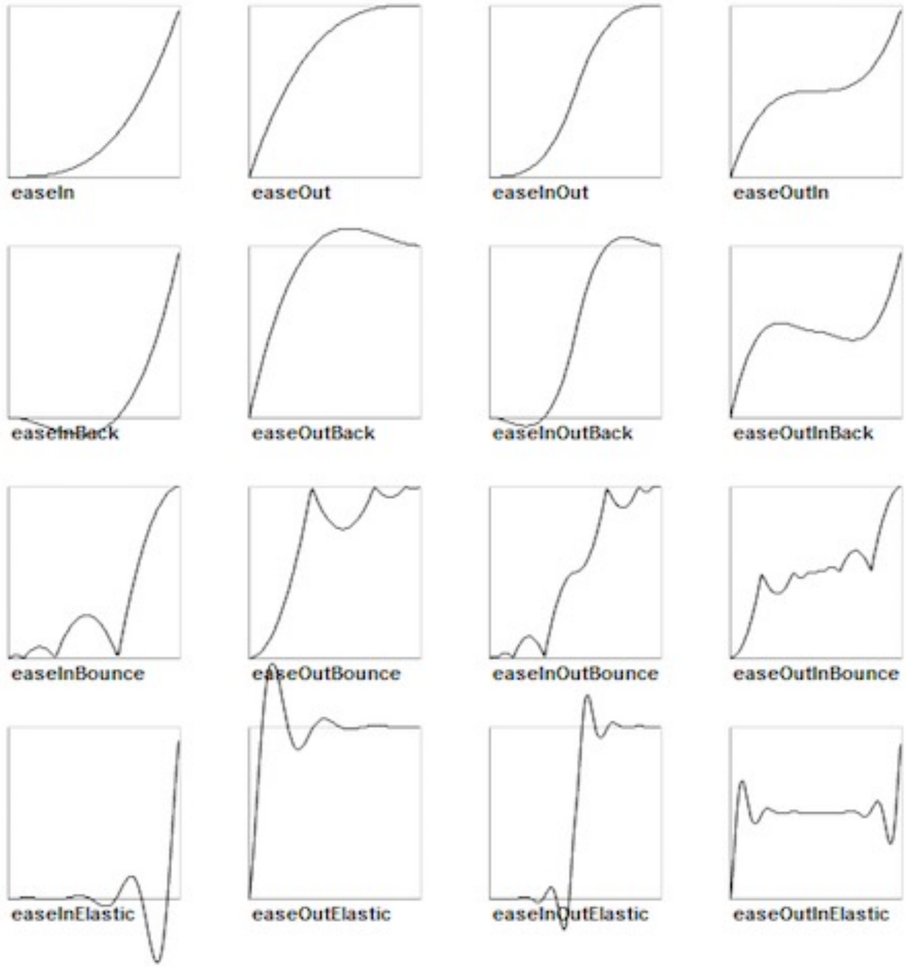




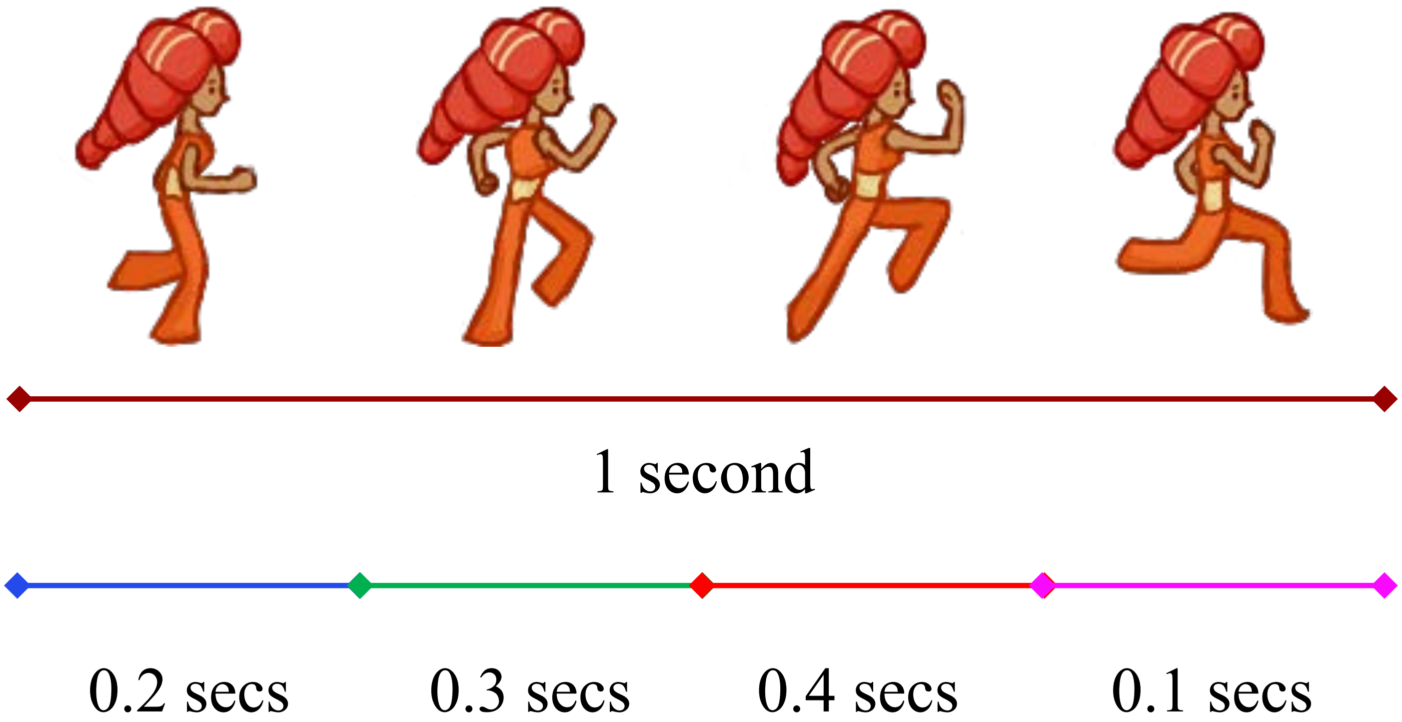
Classic Easing Functions



Classic Easing Functions

http://easings.net

Application to Sprite Animation



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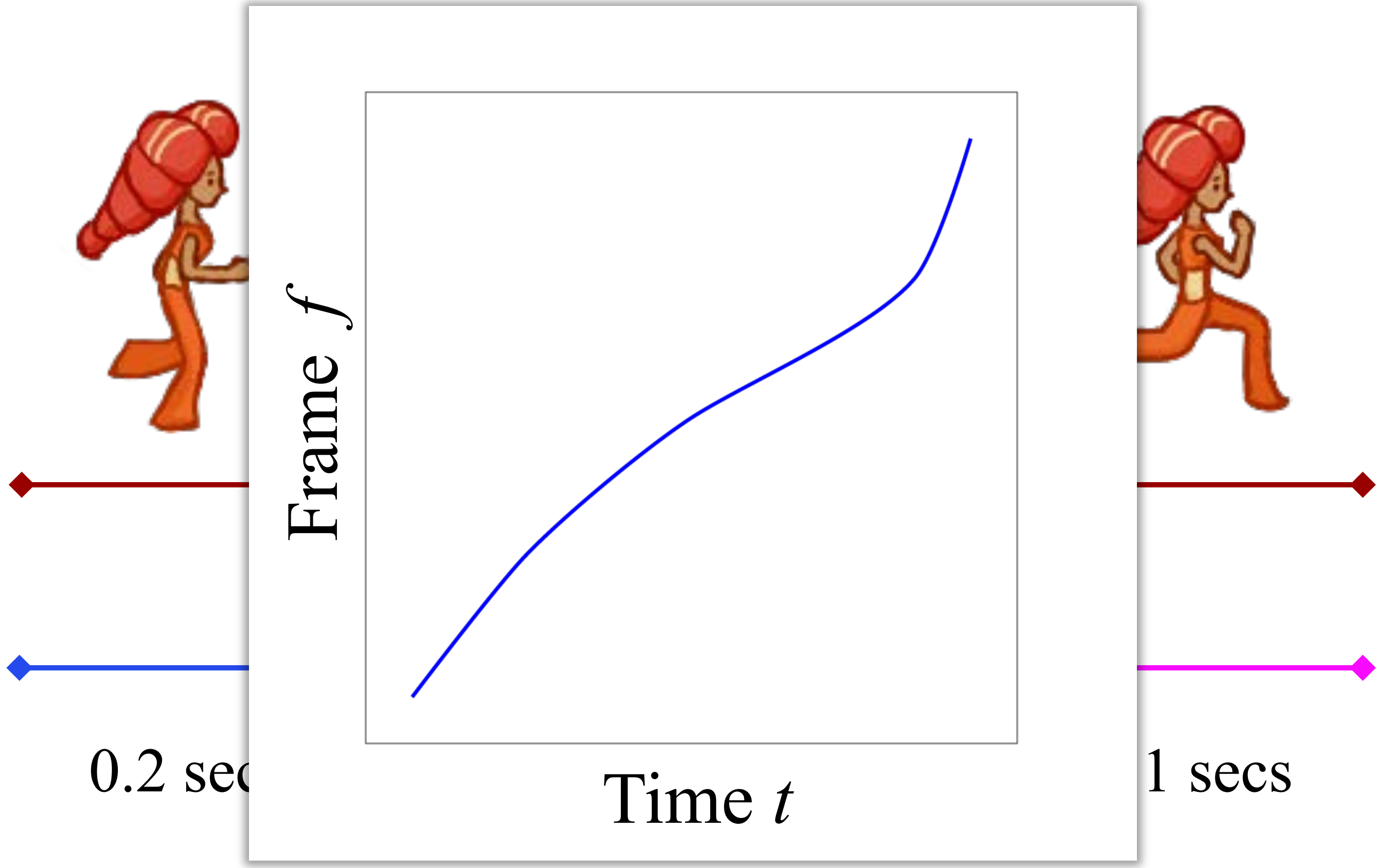

Problems With Decoupled Animation

```
auto mgr = ActionManager::alloc();

auto action = RotateBy::alloc(90.0f,2.0f);

mgr->activate(key,action,sprite);
```

What if we change our mind before 2 seconds?

Problems With Decoupled Animation

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```

Compatible: Combine

Incompatible: Replace

Modular Animation

- Break asset into parts
  - Natural for joints/bodies
  - Animate each separately
- Cuts down on filmstrips
  - Most steps are transforms
  - Very natural for tweening
  - Also better for physics
- Several tools to help you
  - **Example**: *Spriter, Spine*
  - Great for visualizing design

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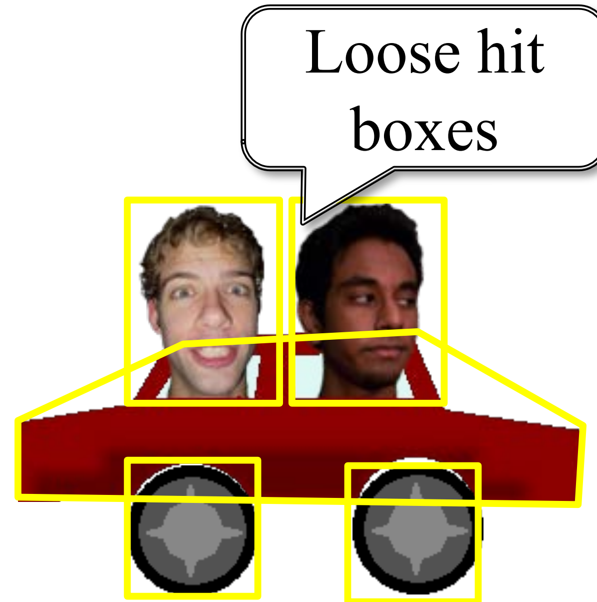


- Inside hit box can safely
  - Transform with duration
  - Tween animations
  - Manage multiple actions

Problems With Decoupled Animation

Transform Tweening

+

Physical Animation

=

Complete Disaster

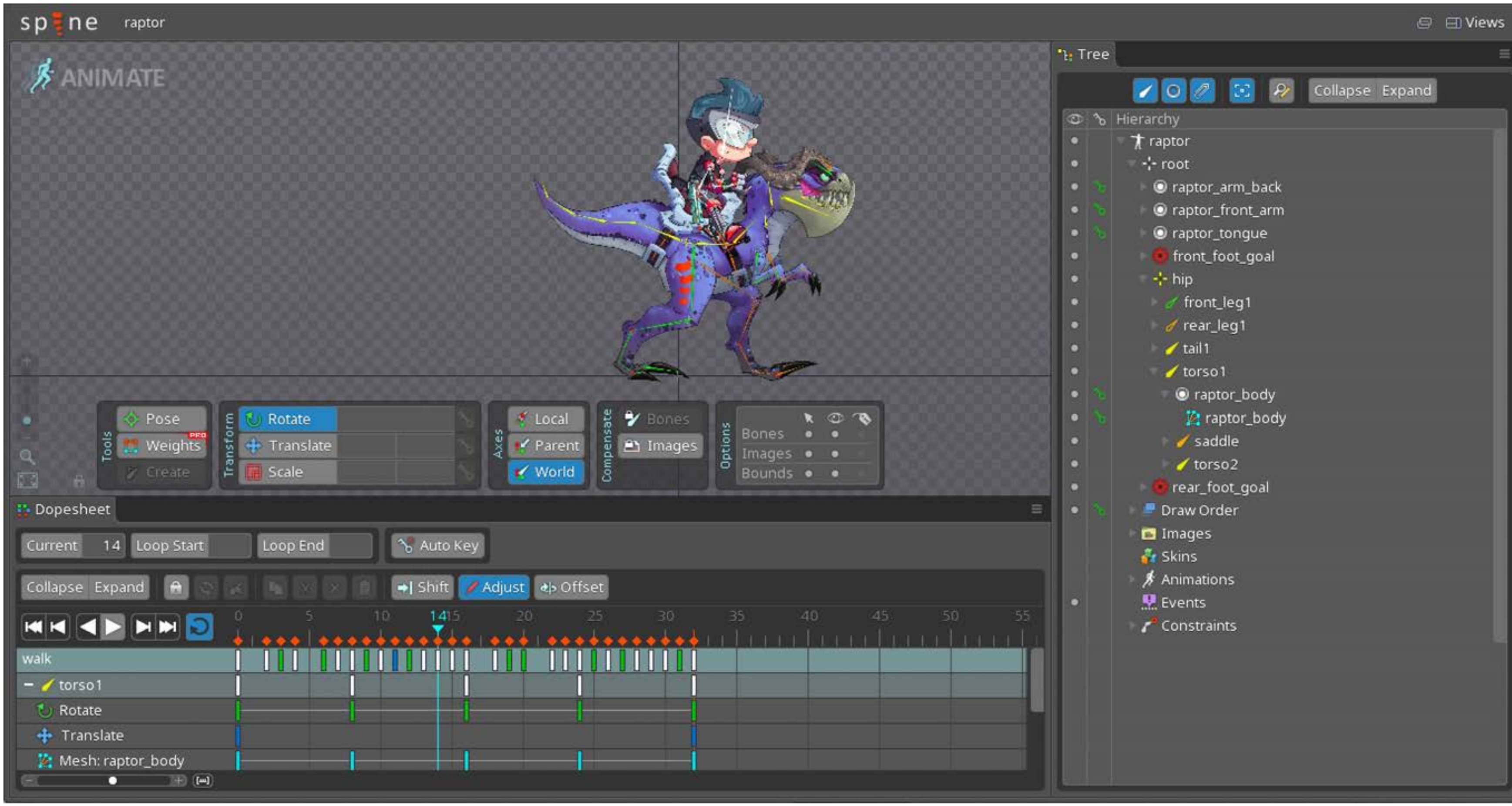
Aside: Skinning

Way to get extra usage of hand-drawn frames

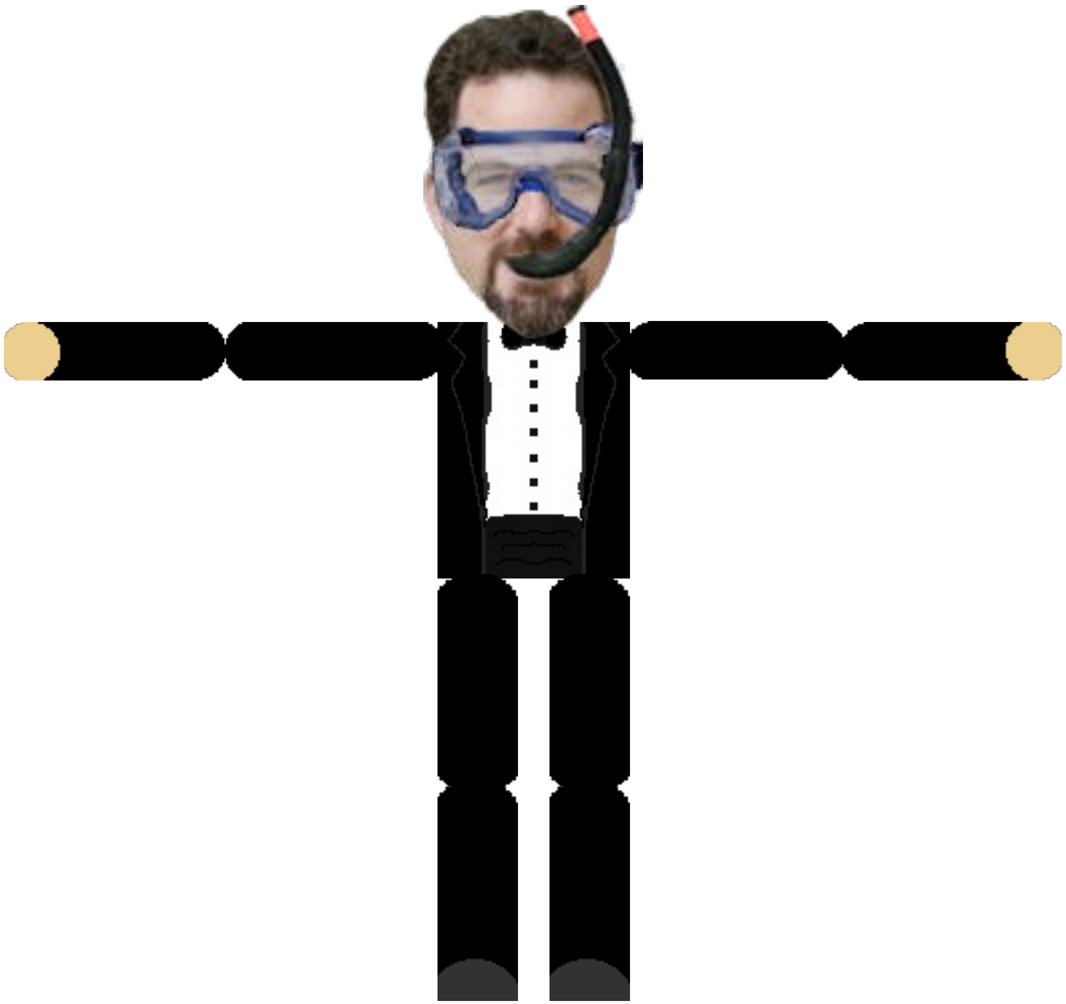
Aside: Skinning

Way to get extra usage of hand-drawn frames

Spine Demo


spine
raptor
Views
ANIMATE
Tree
Collapse
Expand
Hierarchy
raptor
root
raptor_arm_back
raptor_front_arm
raptor_tongue
front_foot_goal
hip
front_leg1
rear_leg1
tail1
torso1
raptor_body
raptor_body
saddle
torso2
rear_foot_goal
Draw Order
Images
Skins
Animations
Events
Constraints
Tools
Pose
Weights
Create
Transform
Rotate
Translate
Scale
Axes
Local
Parent
World
Compensate
Bones
Images
Options
Bones
Images
Bounds
Dopesheet
Current
14
Loop Start
Loop End
Auto Key
Collapse
Expand
Shift
Adjust
Offset
0
5
10
14
15
20
25
30
35
40
45
50
55
walk
torso1
Rotate
Translate
Mesh: raptor_body

Basic Idea: **Bones**



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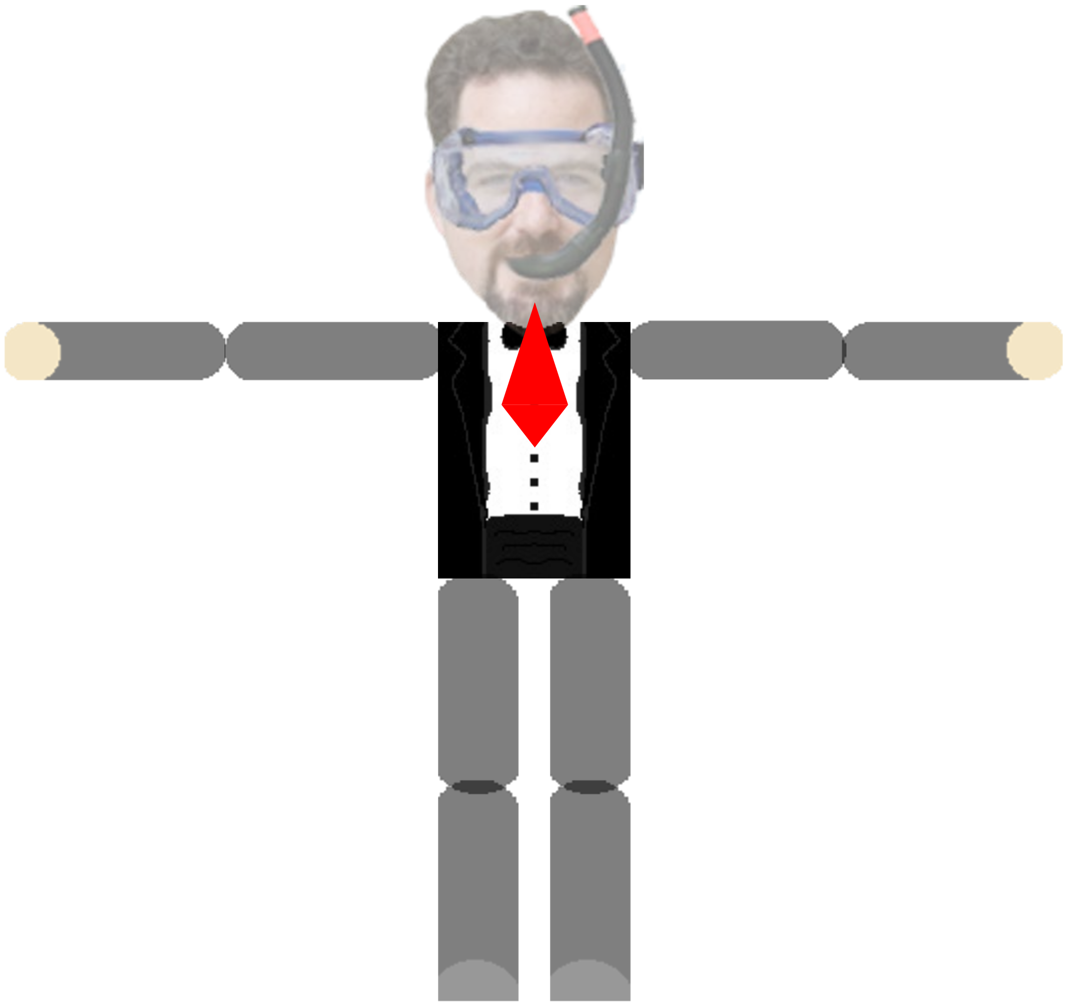

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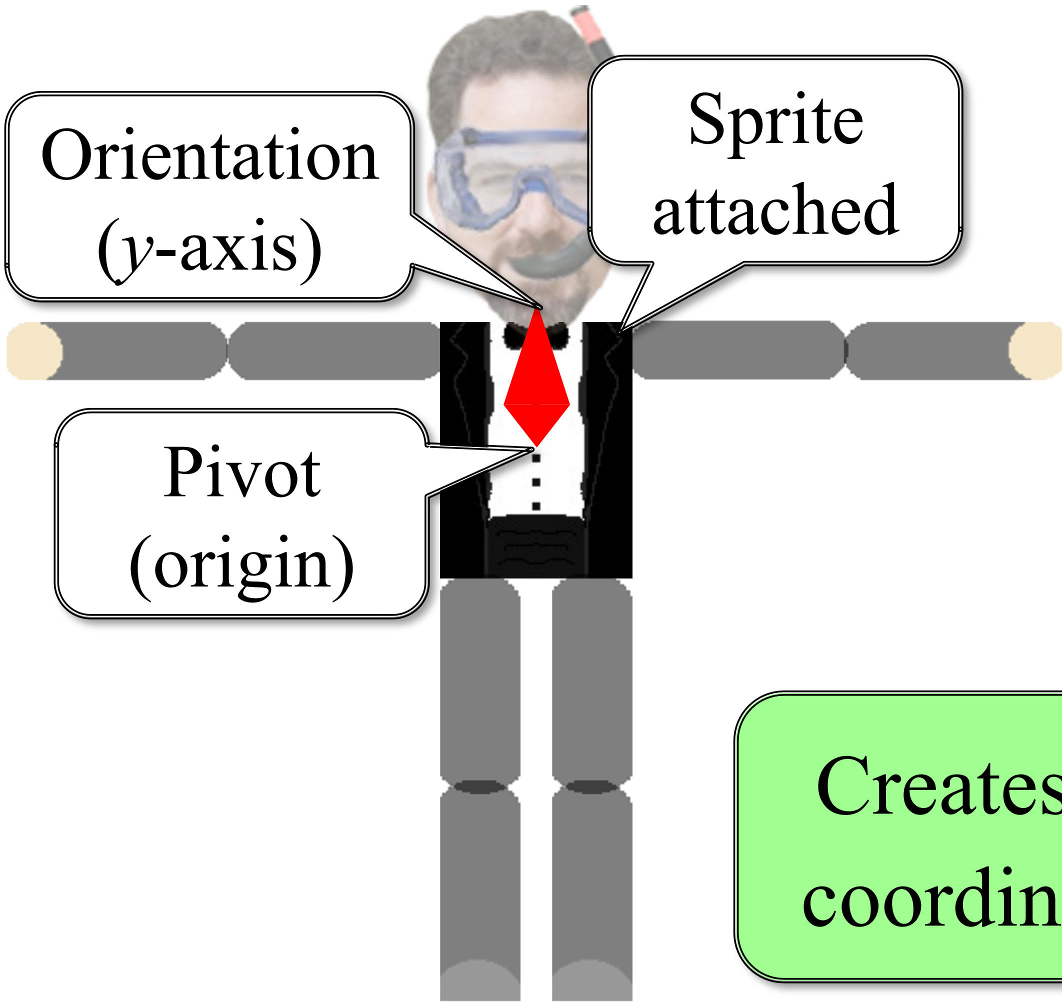
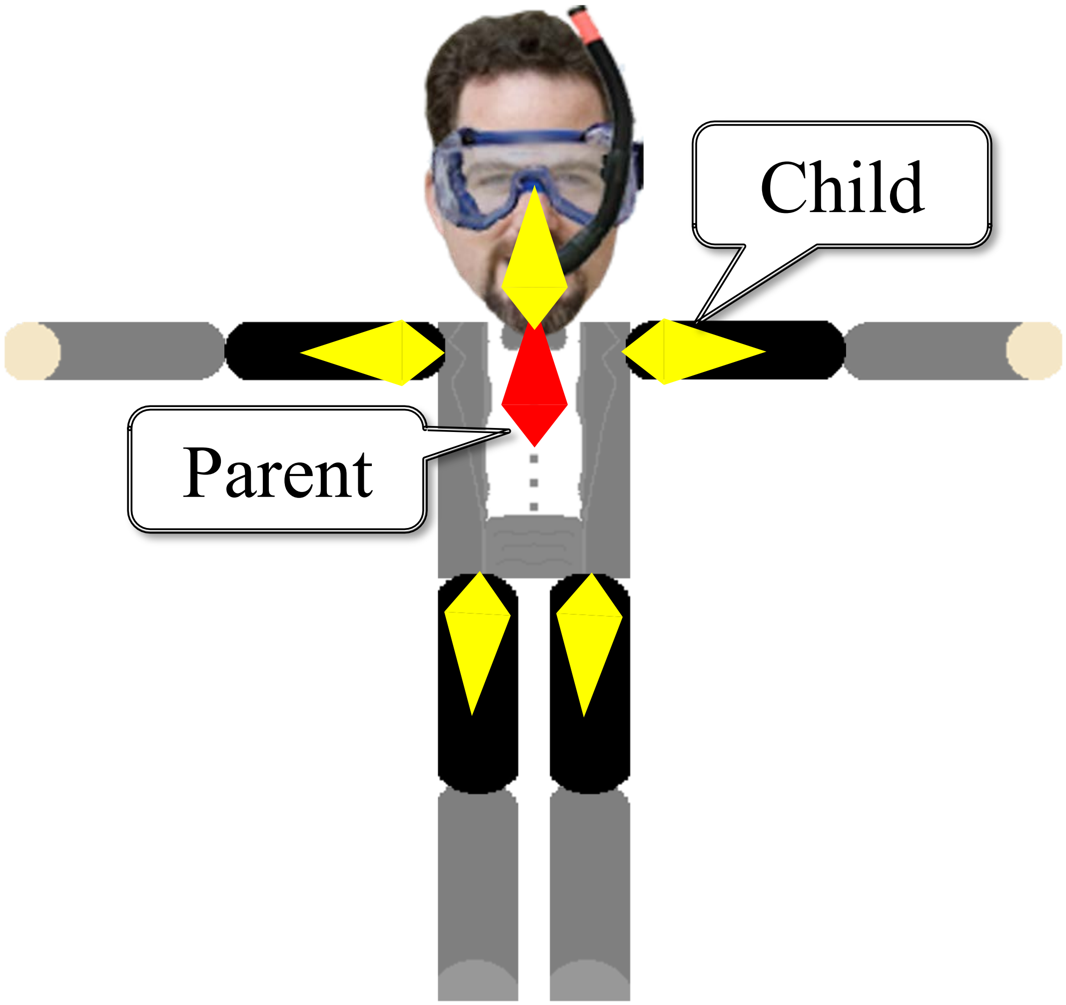


Creates implicit coordinate space

Bones are Heirarchical



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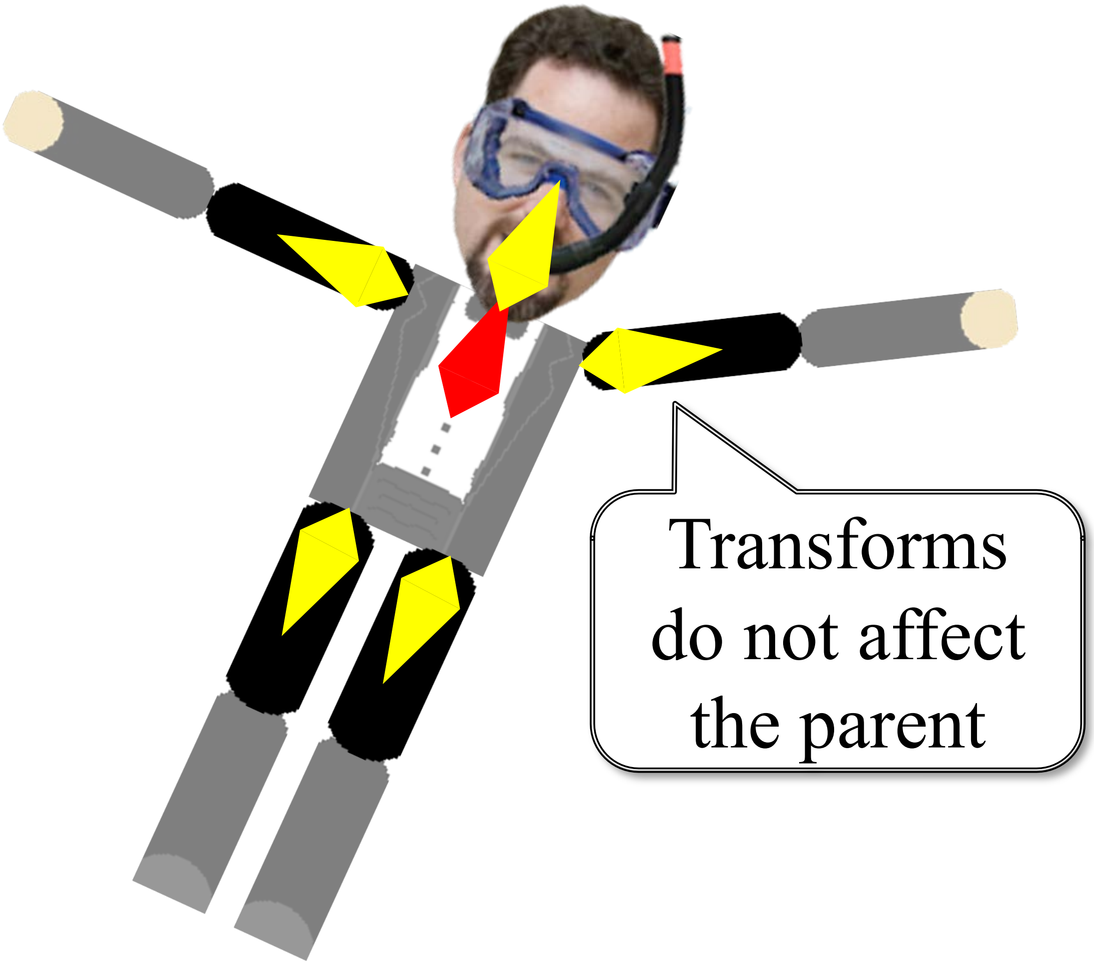
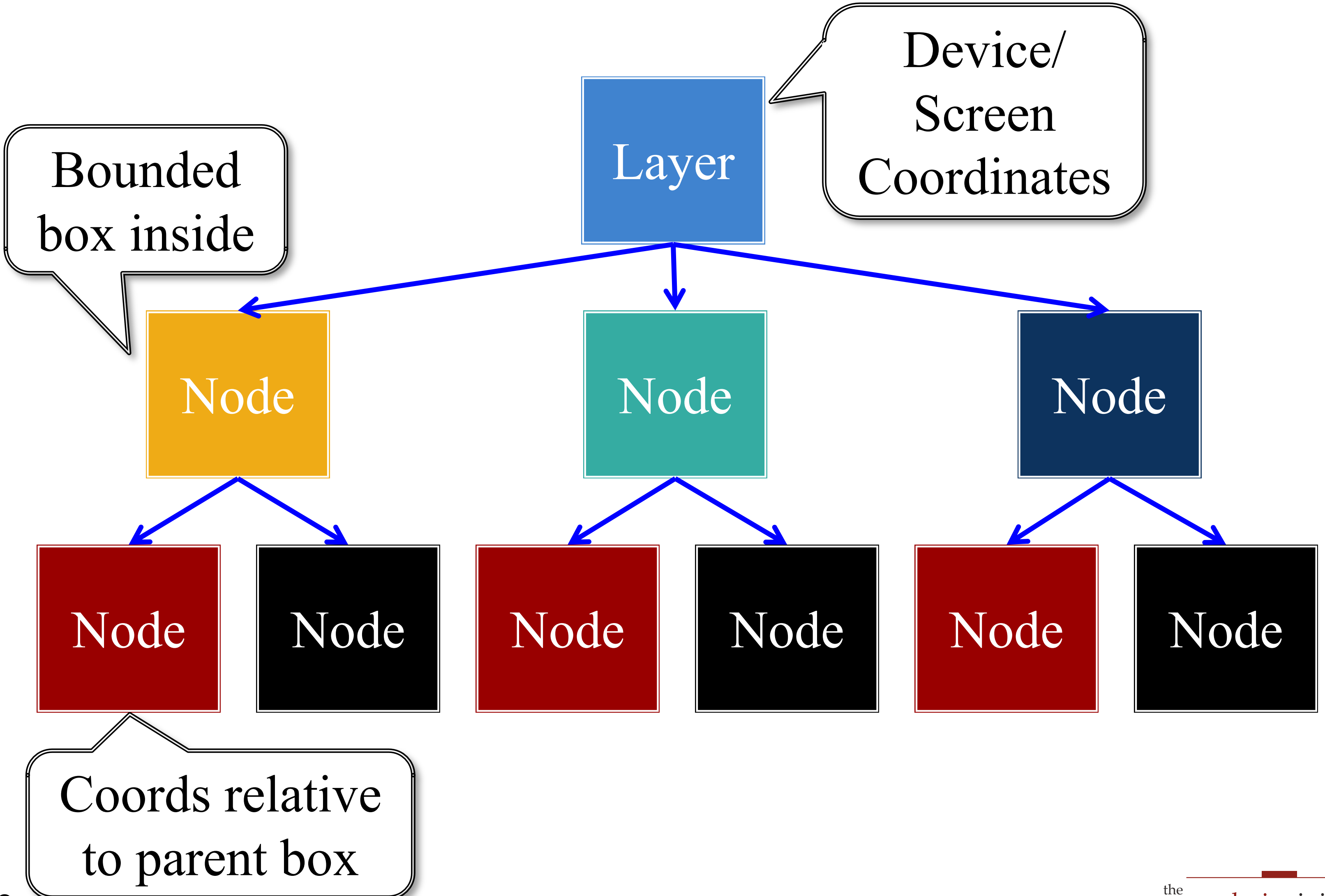
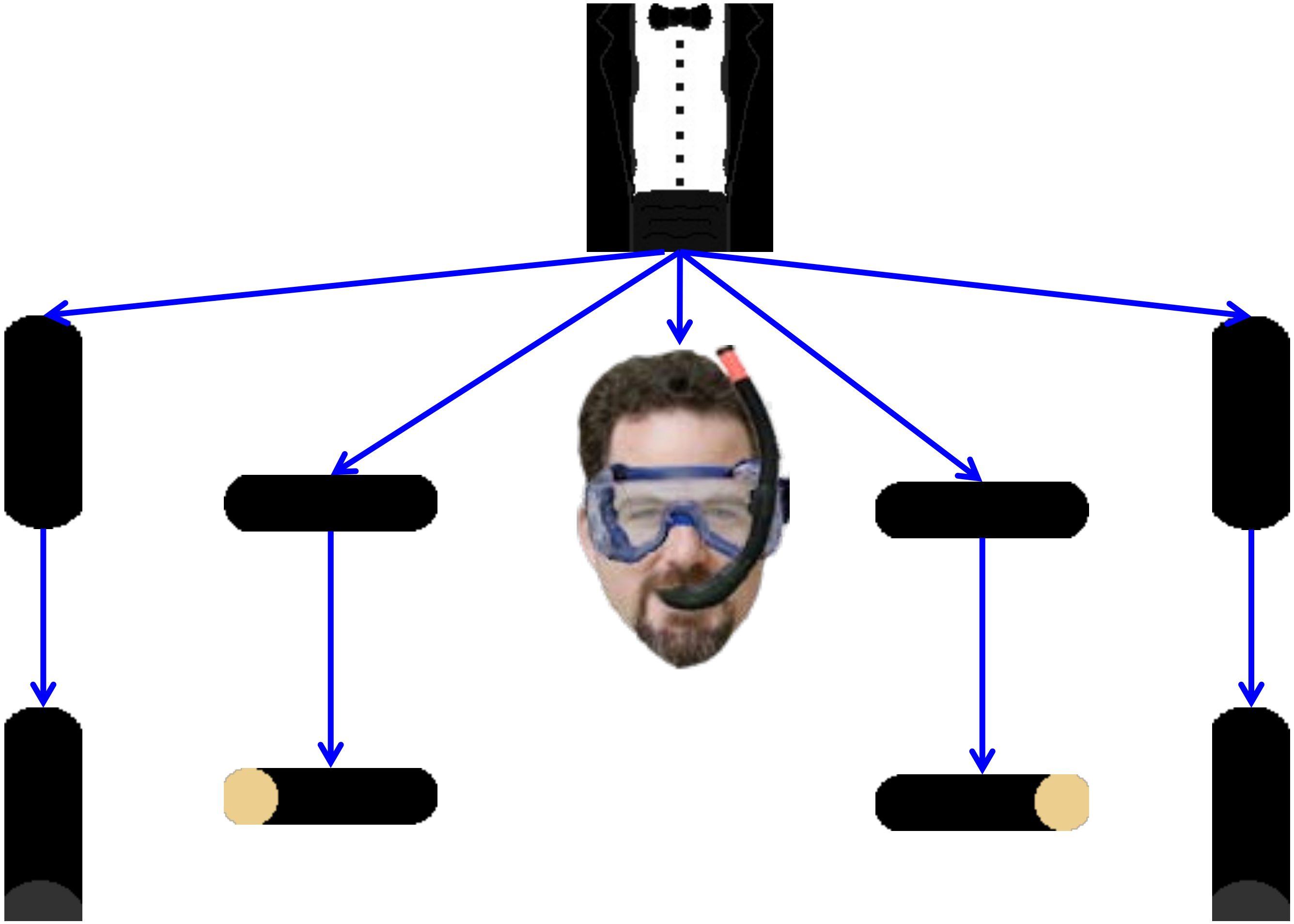


Recall: Scene Graph Hierarchy

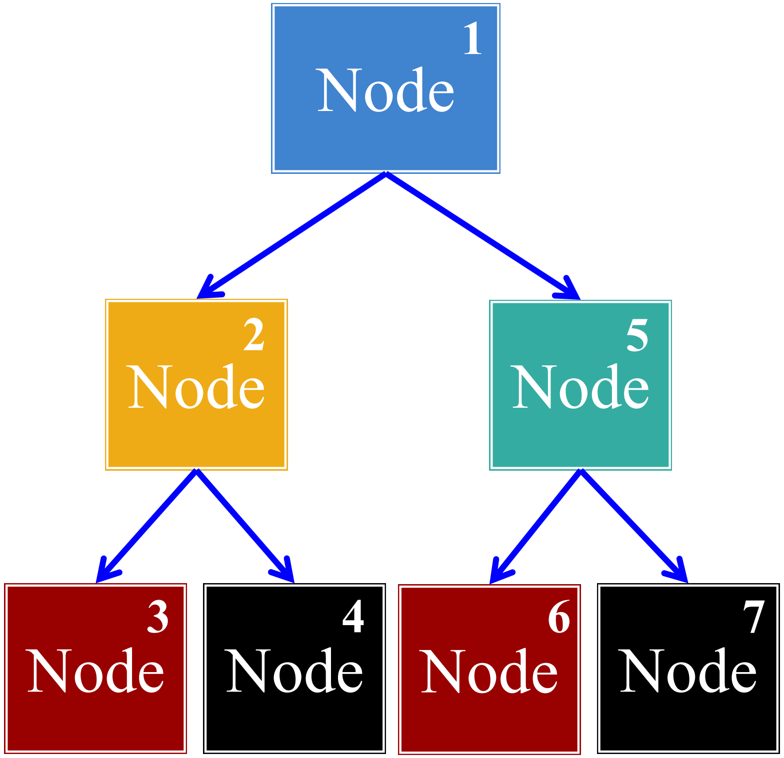


Bones are a Scene Graph Visualization



Problem: Scene Graphs are Preorder

- **Parents are drawn first**
  - Children are drawn in front
  - Ideal for UI elements
  - Bad for modular animation
- New class: `OrderedNode`
  - Puts descendents into a list
  - Sorts based on priority value
  - Draws nodes in that order
- Acts as a render barrier
  - What if nested `OrderedNode`?
  - Each `OrderedNode` is a unit
  - Priorities do not mix



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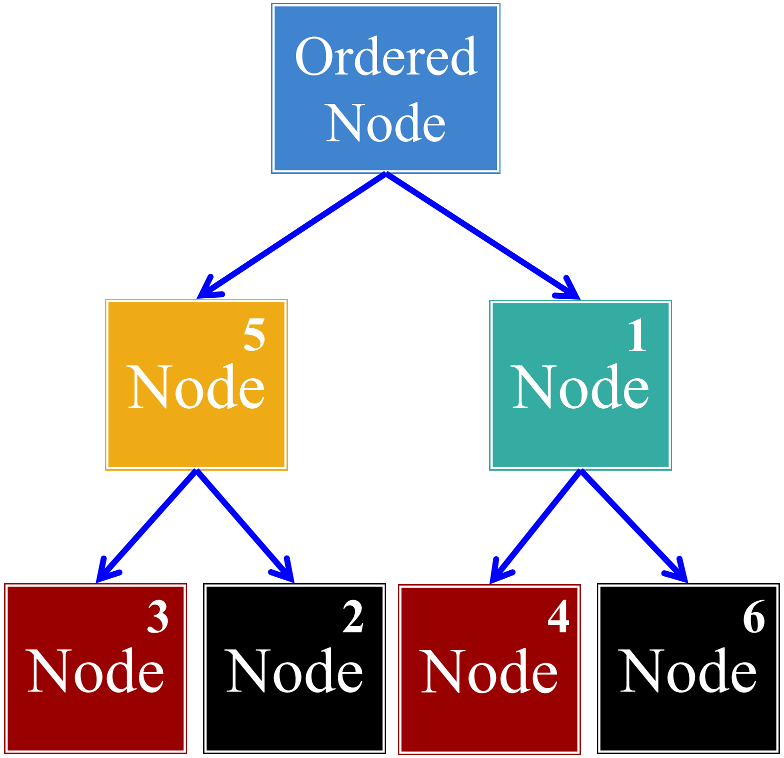

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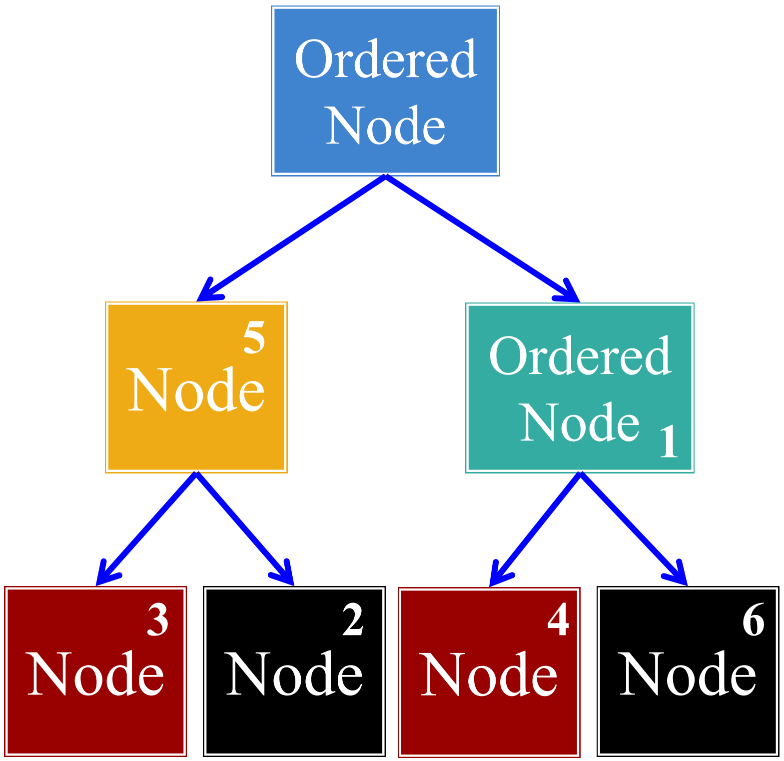

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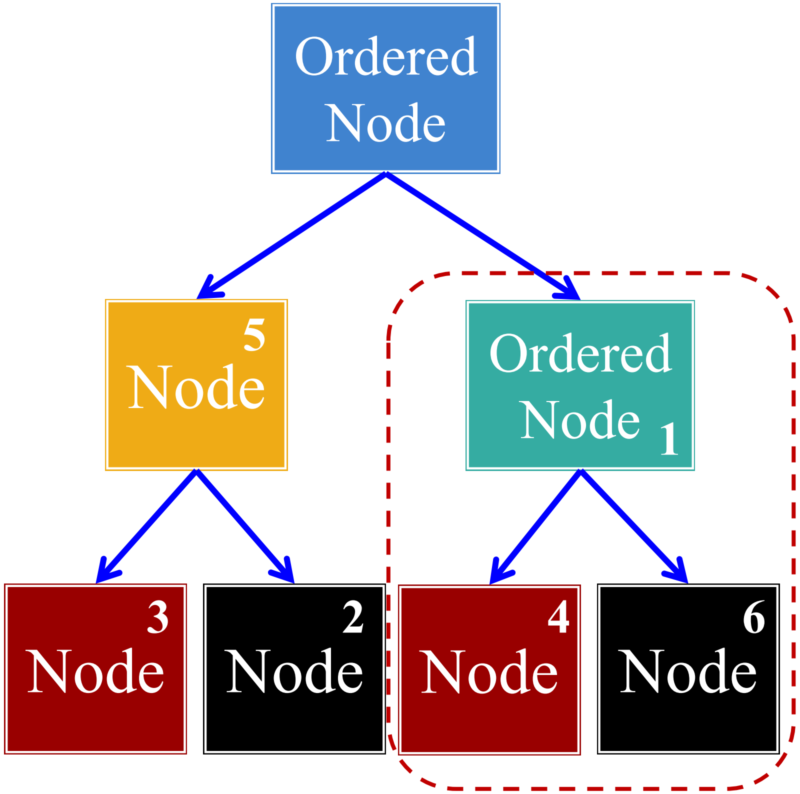

Summary

- Standard 2D animation is **flipbook** style
  - Create a sequence of frames in sprite sheet
  - Switch between sequences with state machines
- **Tweening** supports interpolated transitions
  - Helpful for motion blur, state transitions
  - Transforms can be combined with easing functions
- Professional 2D animation uses **modular sprites**
  - Scene graphs are a simplified form of model rigging
  - State machine coordination can be very advanced