
the
gamedesigninitiative
at cornell university

Animation (2D)

Animation Basics: The FilmStrip



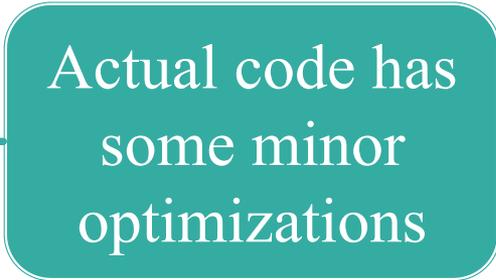
- Animation is a sequence of **hand-drawn frames**
 - Smoothly displays action when change quickly
 - Also called flipbook animation
- Arrange animation in a **sprite sheet** (one texture)
 - Software chooses which frame to use at any time
 - So programmer is actually the one doing animation

Anatomy of AnimationNode Class

```
/**
 * Sets the active frame as the given index.
 *
 * @param frame the index to make the active frame
 */
void AnimationNode::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);
}
```

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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 int timer to your object
 - Go to next frame when = 0
 - Reset it to > 0 at new frame
- Simple but tedious
 - Have to do for each object
 - **And** for each animation



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



Matching Your Translation

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Point of
contact

Distance
forward

Combining Animations

Landing Animation

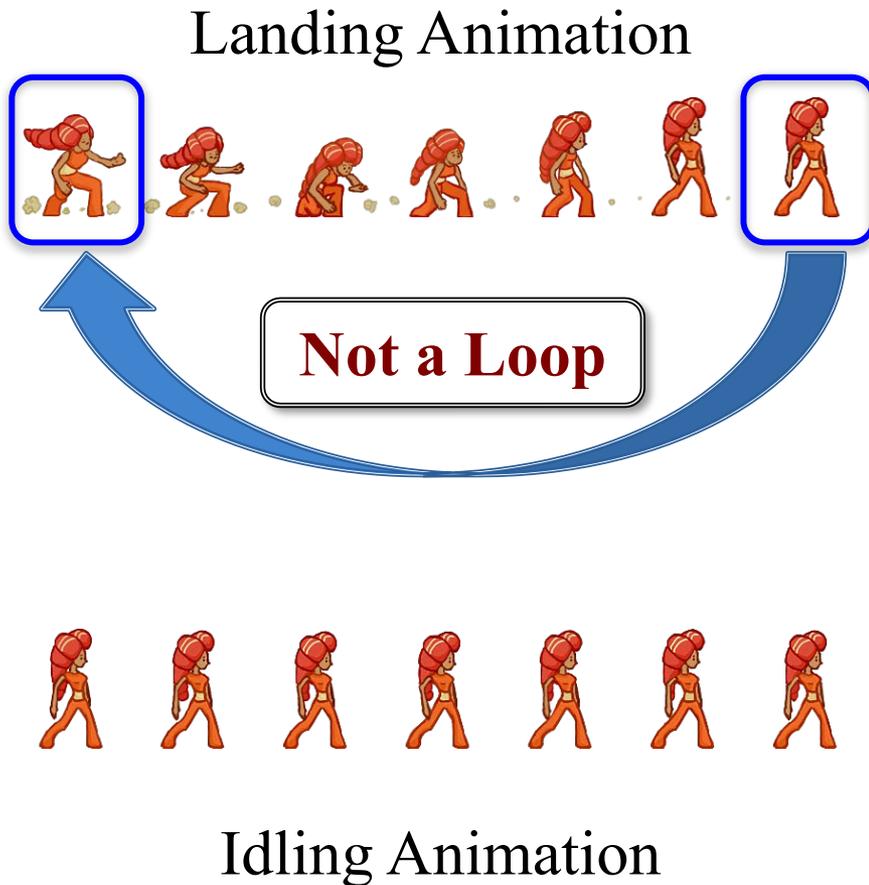


- Characters to a lot of things
 - Run, jump, duck, slide
 - Fire weapons, cast spells
 - Fidget while player AFK
- Want animations for all
 - Is loop appropriate for each?
 - How do we transition?
- **Idea:** shared boundaries
 - End of loop = start of another
 - Treat like advancing a frame



Idling Animation

Combining Animations



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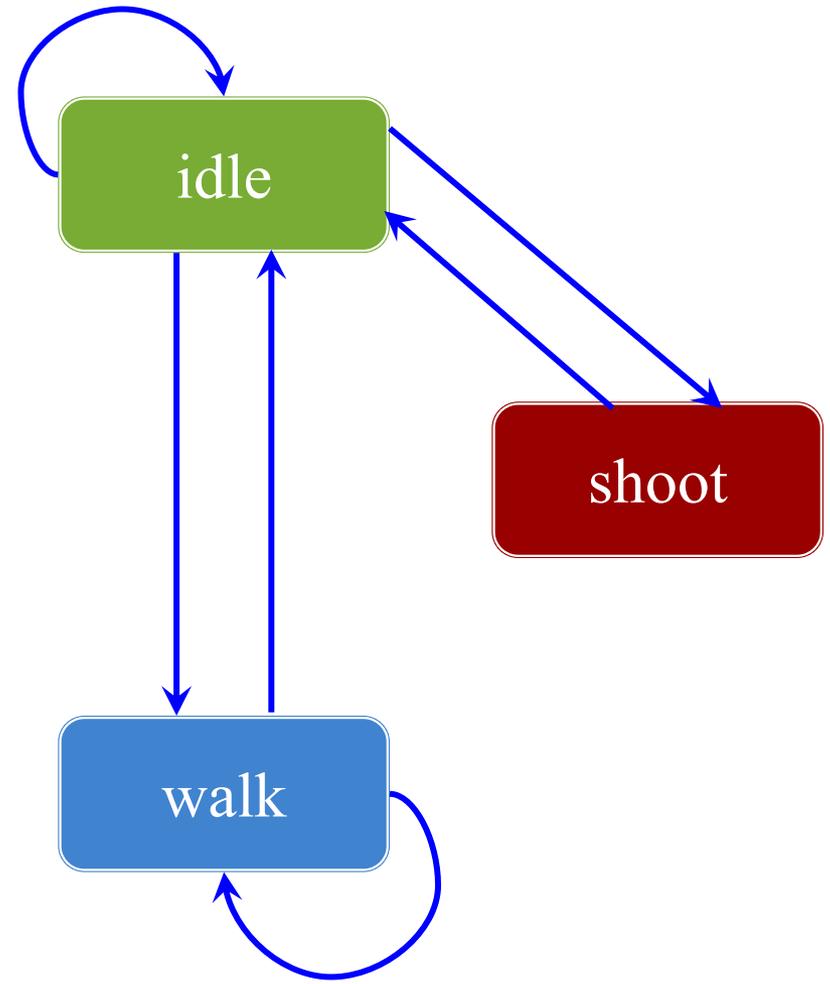
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 - F
 - T

**But do not draw
ends twice!**

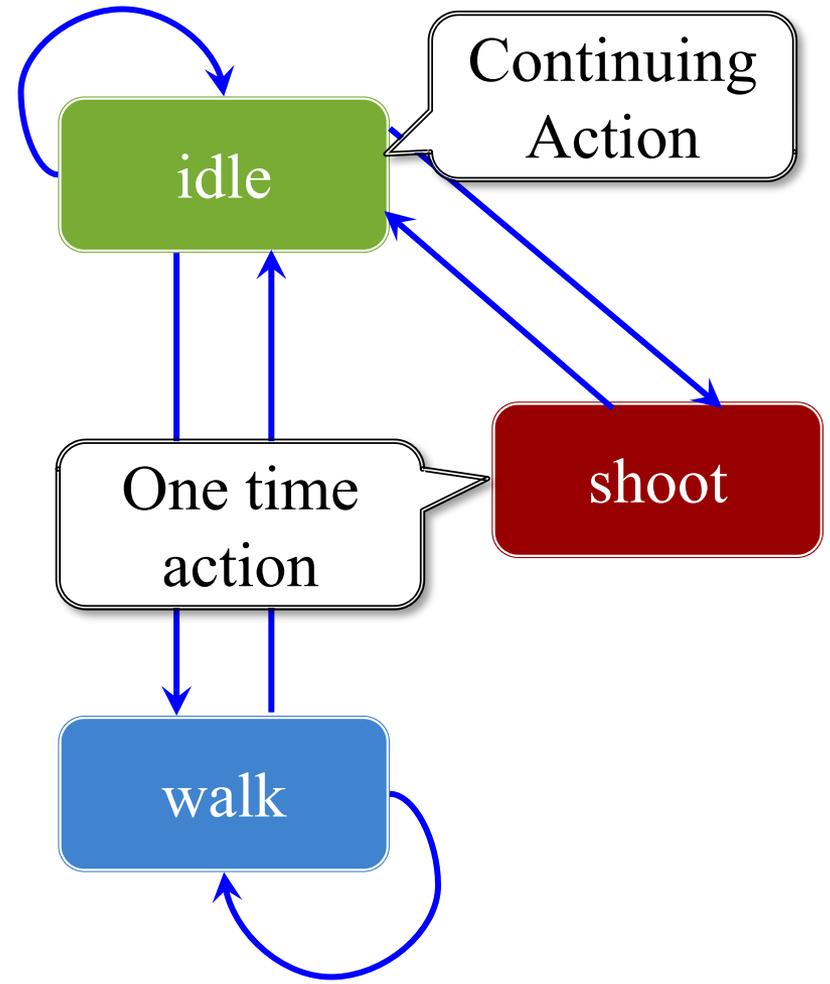
Animation and State Machines

- 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

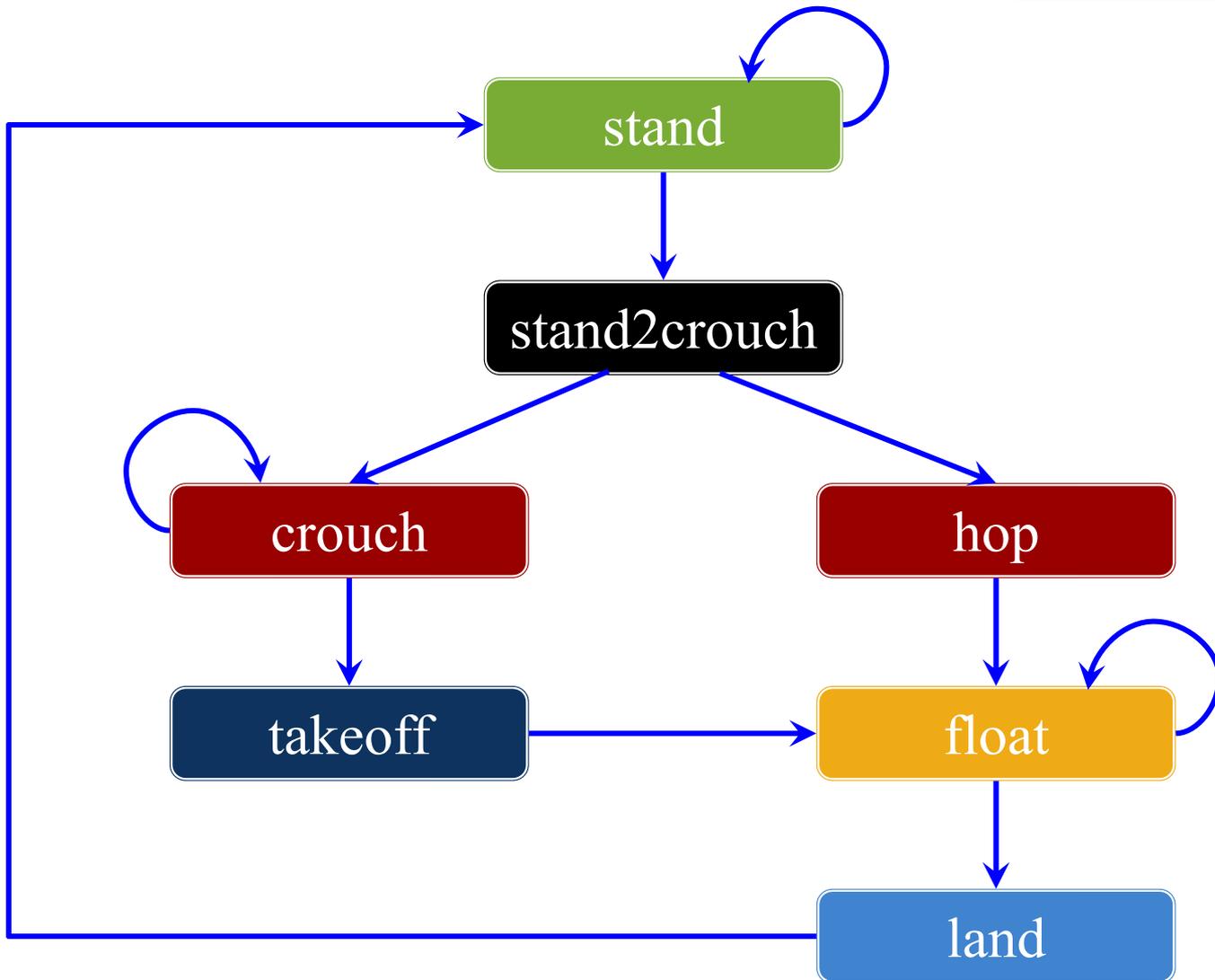


Animation and State Machines

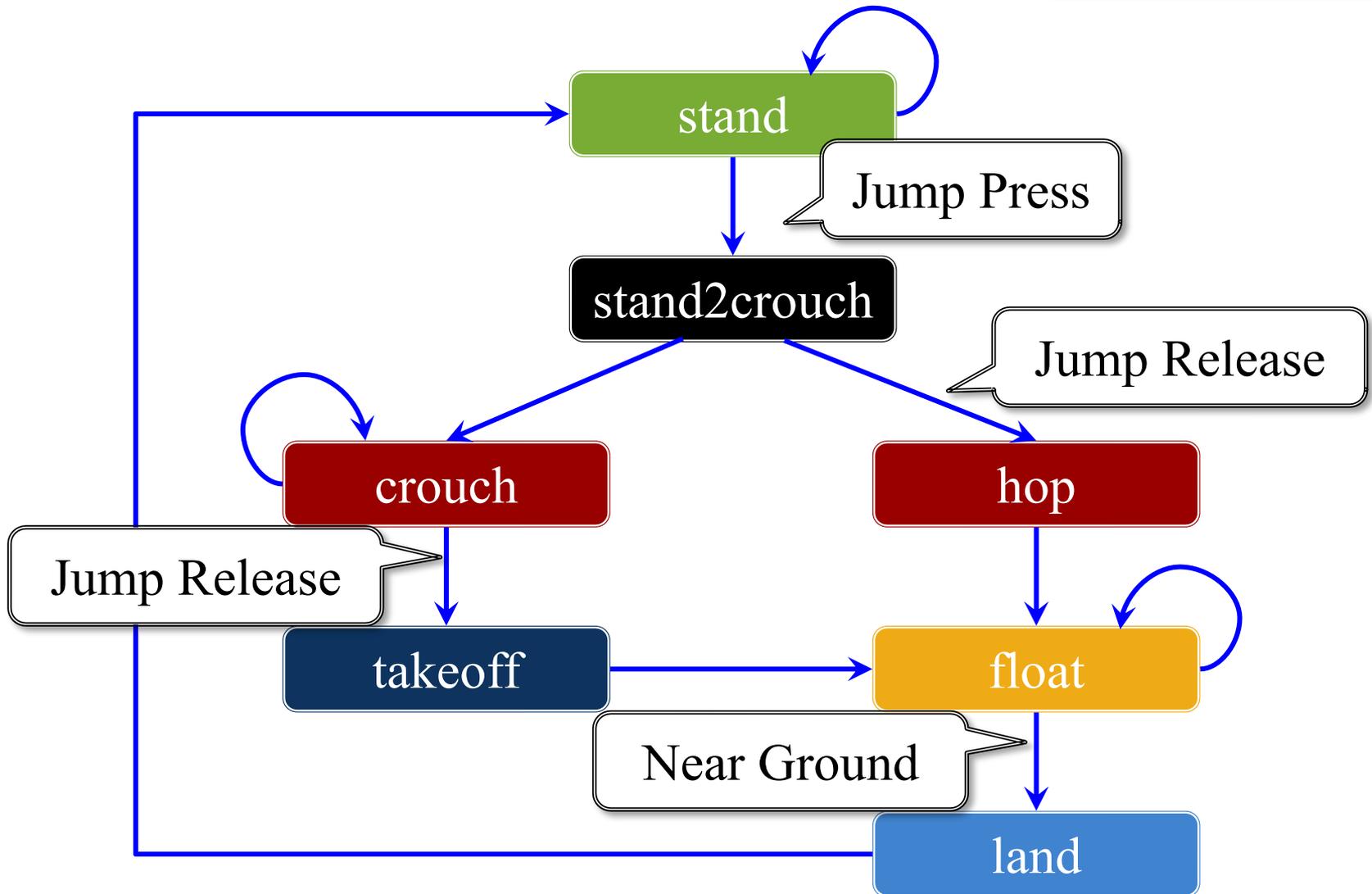
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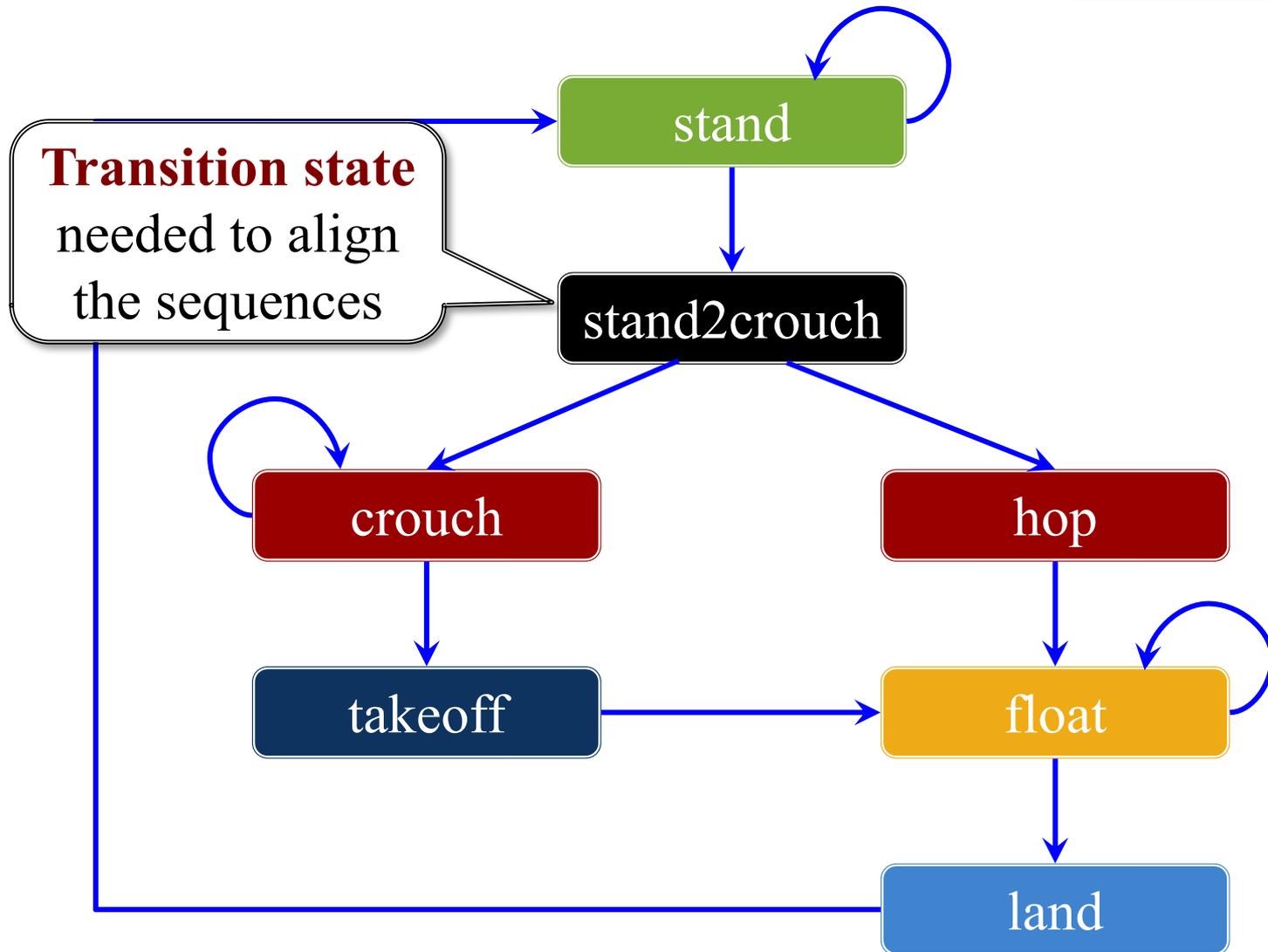
Complex Example: Jumping



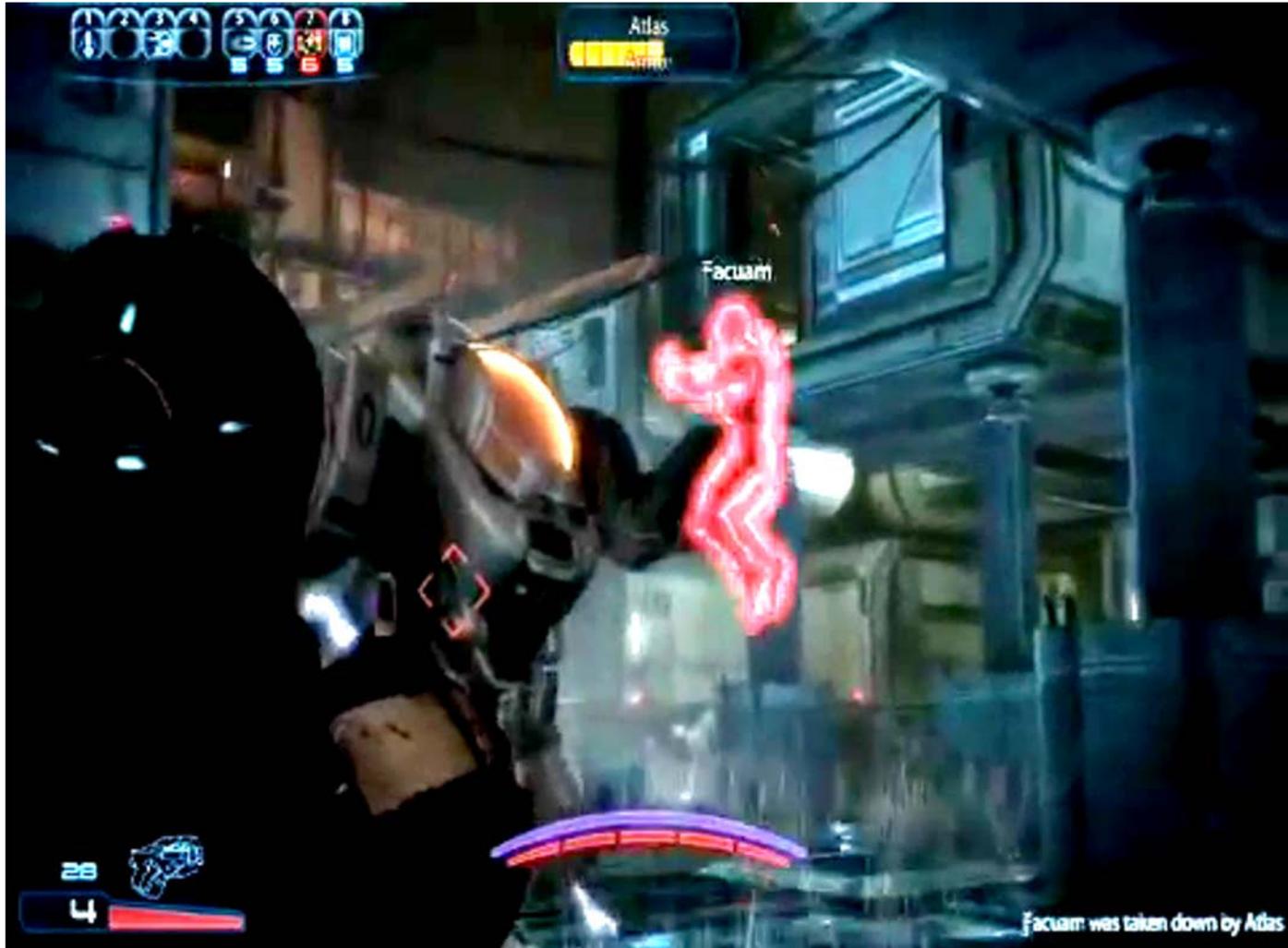
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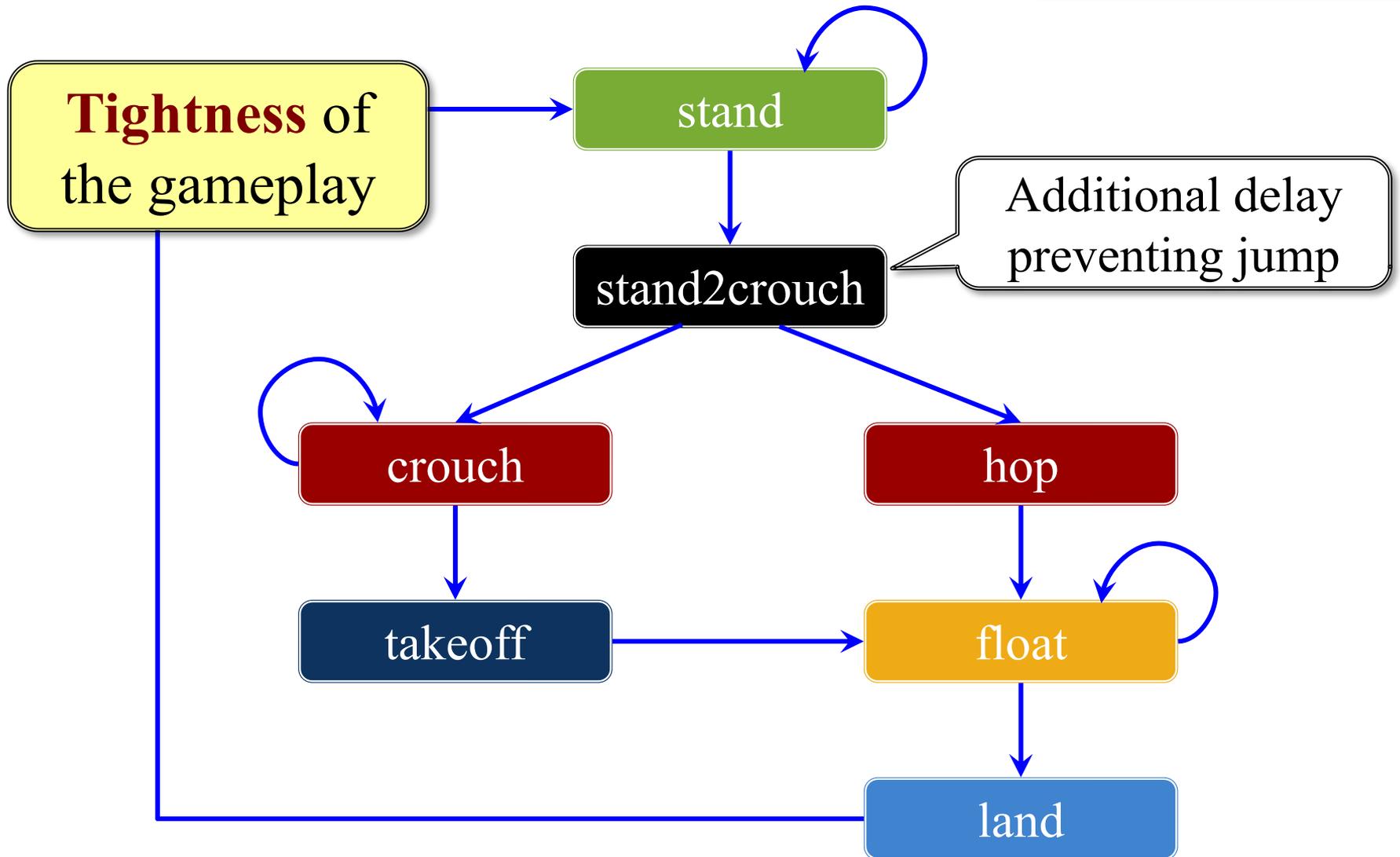
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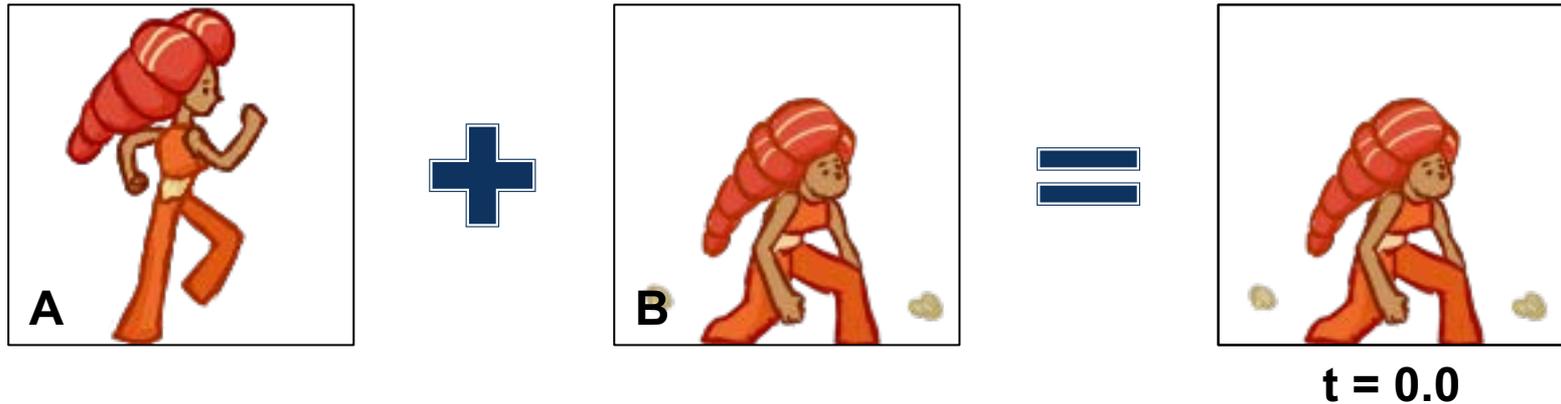
Aside: Sync Kills



The Responsiveness Issue



Fast Transitions: Crossfade Blending



- Linear interpolation on colors

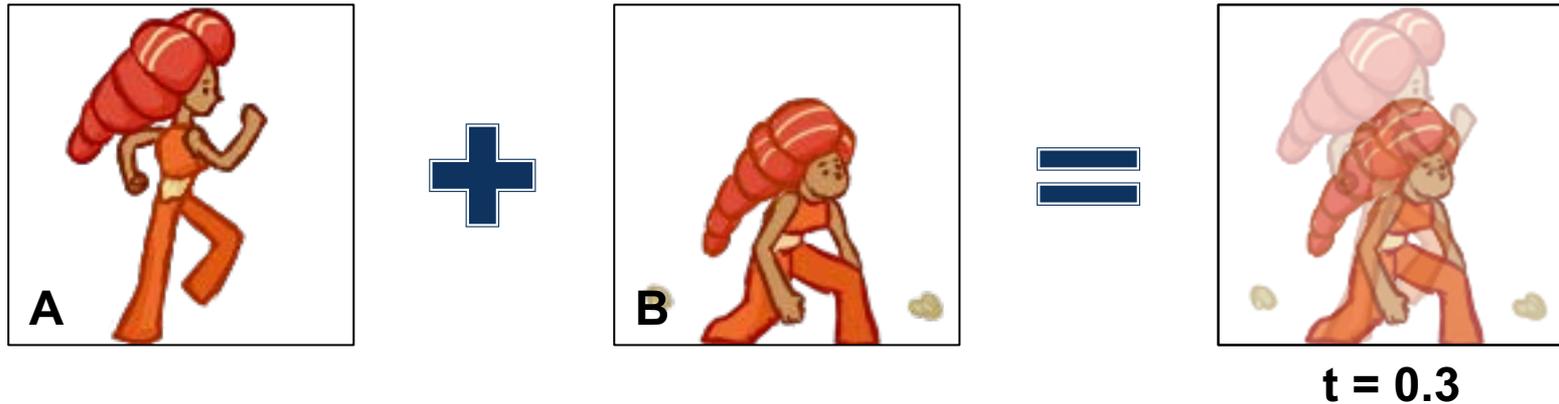
$$r_c = tr_a + (1 - t)r_b$$

$$g_c = tg_a + (1 - t)g_b$$

$$b_c = tb_a + (1 - t)b_b$$

Note weights sum to 1.0

Fast Transitions: Crossfade Blending



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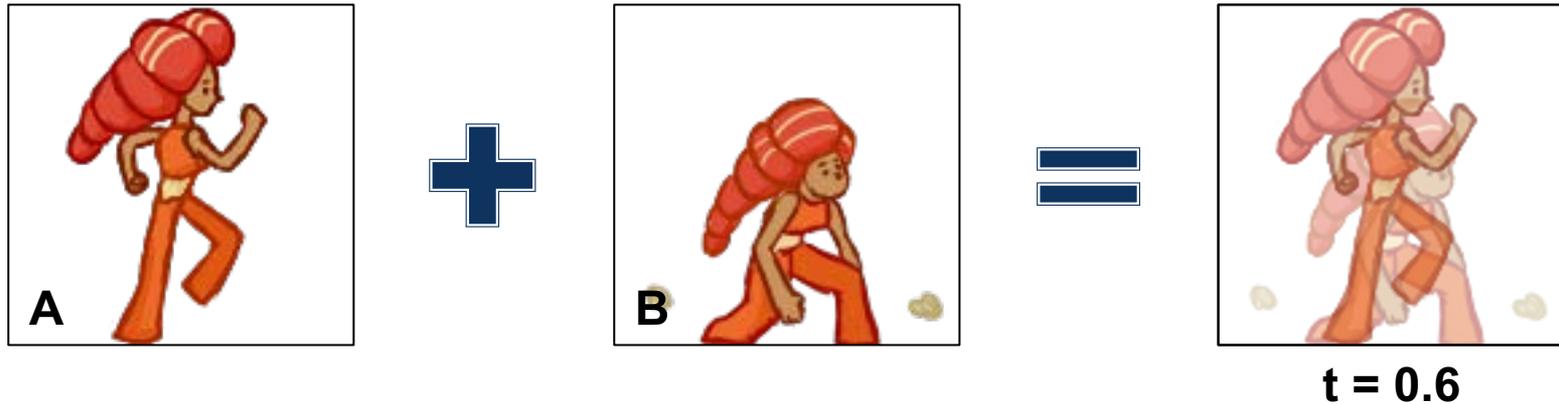
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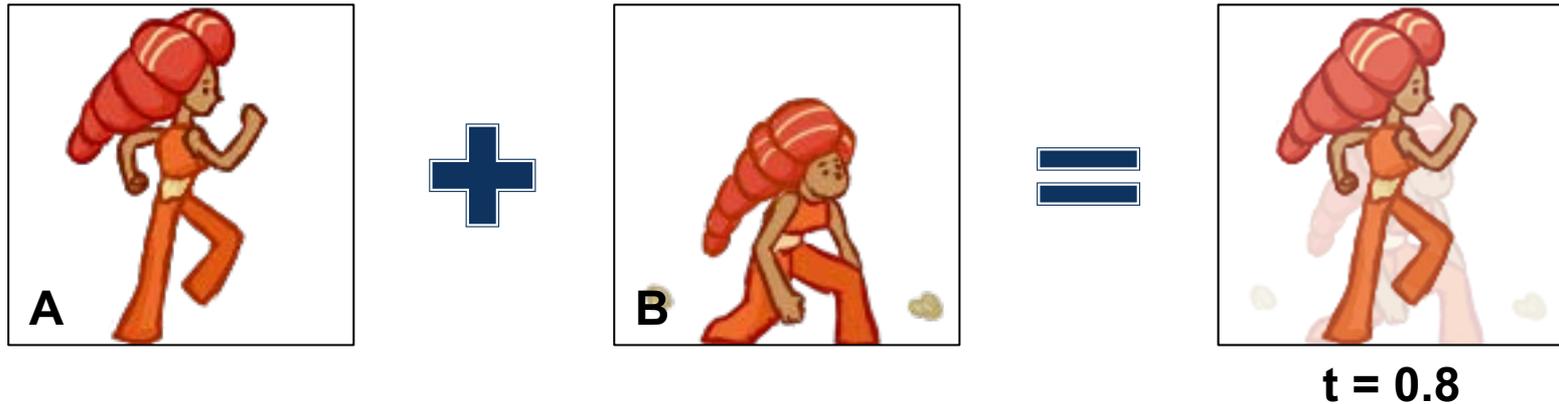
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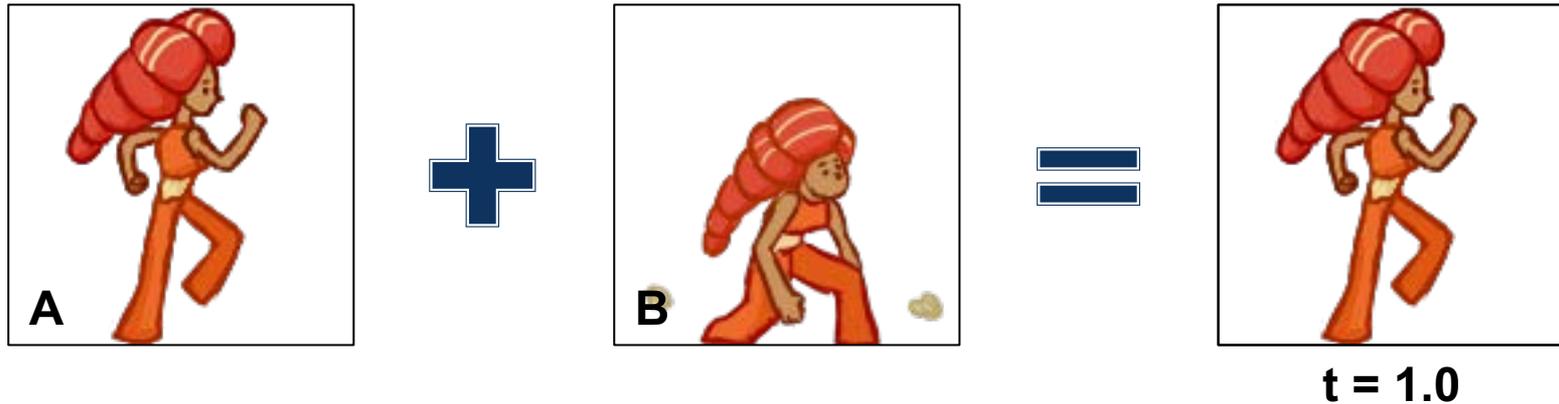
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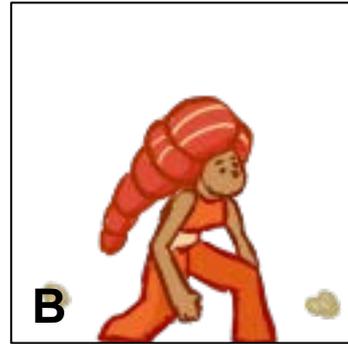
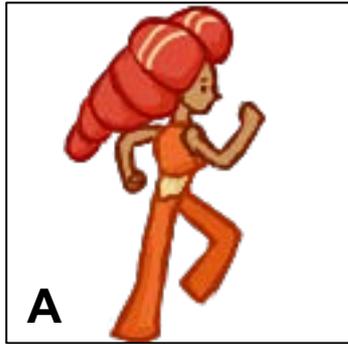
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Combining With Animation

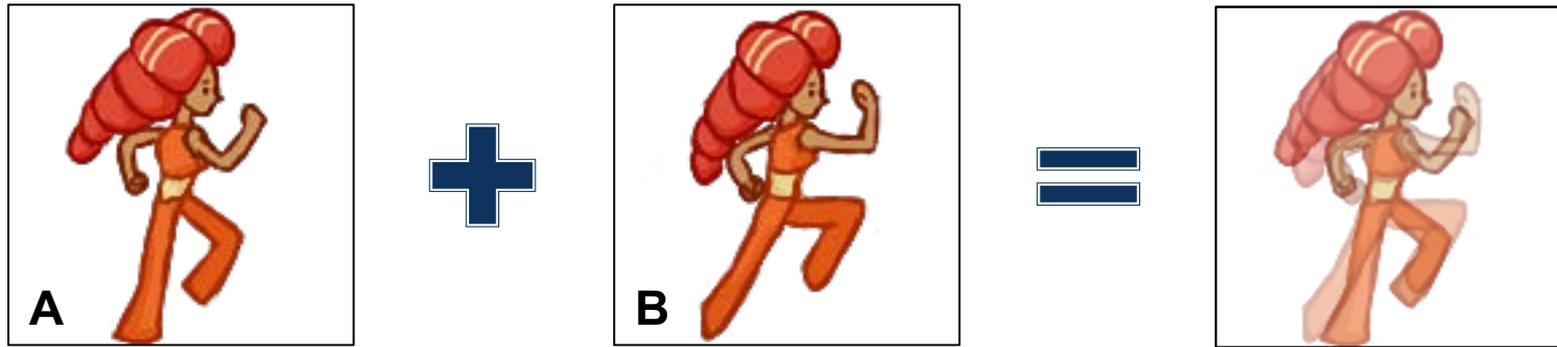


Cycle the
filmstrip
normally

Cycle the
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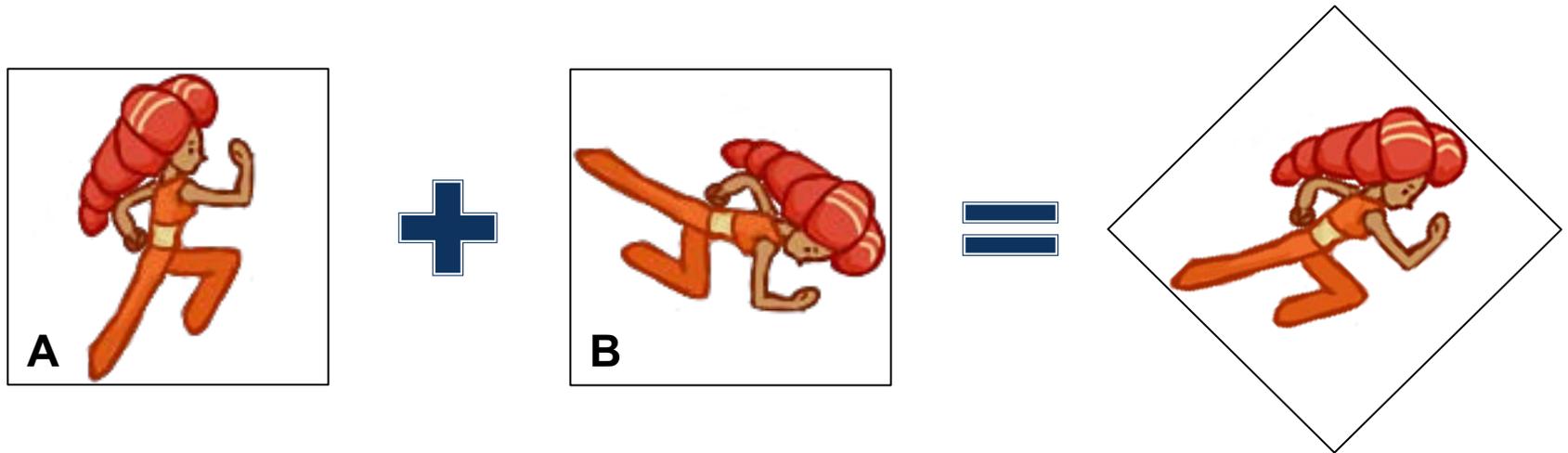
Combine
with alpha
blending

Related Concept: **Tweening**



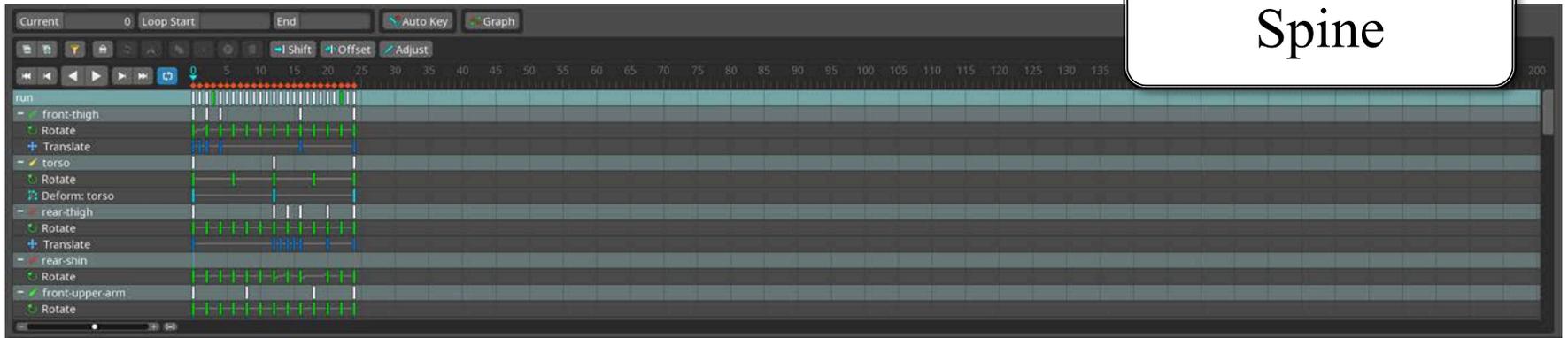
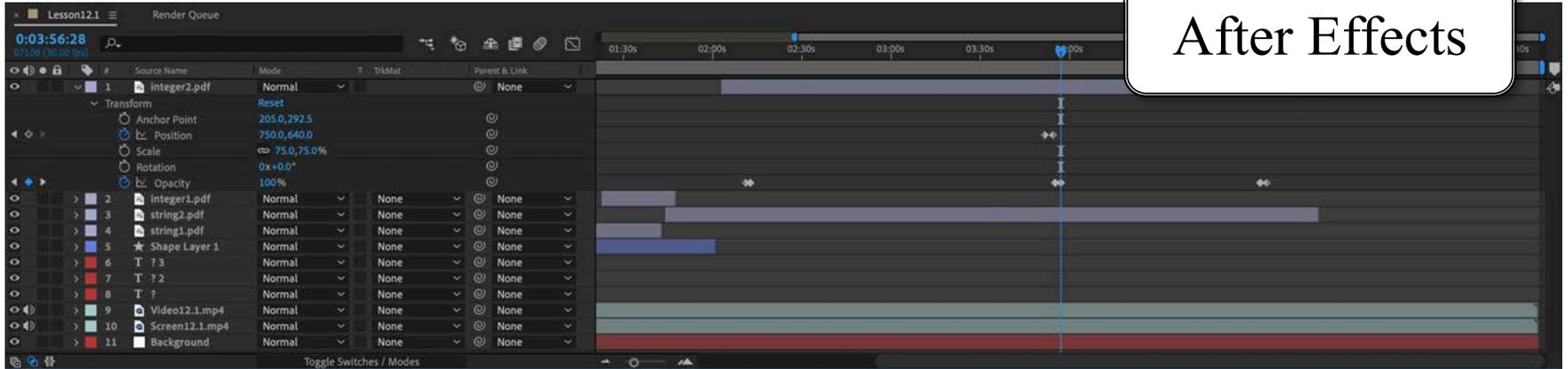
- Act of linear interpolating between animation frames
 - Because we cycle filmstrip slower than framerate
 - Implements a form of motion blur
- If animation **designed right**, makes it smoother

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



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

Supporting Tweened Animations



ActionManager

- Manages active animations
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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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```

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

Map Action to
key and start

```
while (mgr->isRunning(key))
```

```
mgr->update(TIMESTEP);
```

```
}
```

```
// No clean-up
```

Increments
animation state

Action



Tweens
rotation



Executing Actions: Transforms

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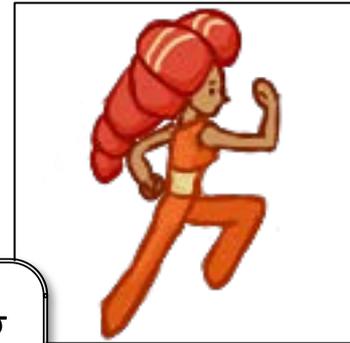
```
    mgr->update(TIMESTEP);
```

```
}
```

```
// No clean-up. Done at
```

How long
to spend

Maps to
framerate



Tweens
rotation



Executing Actions: **FilmStrips**

```
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)) {
```

```
    mgr->update(TIMESTEP);
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```
}
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// No clean-up. Done automatically
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Executing Actions: FilmStrips

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```

```
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```
...
```

```
frames.push_back(f8);
```

Sequence
indices

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

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

```
while (mgr->isActive(key)) {
```

```
    mgr->update(TIMESTEP);
```

```
}
```

```
// No clean-up. Done a
```

Frames
displayed
uniformly



Does not
tween



Executing Actions: **FilmStrips**

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

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

```
...  
frames.push_back(f2);
```

```
auto action
```

```
mgr->activate
```

```
while (mgr->is
```

```
    mgr->update(TIMESTEP);
```

```
}
```

```
// No clean-up. Done automatically
```

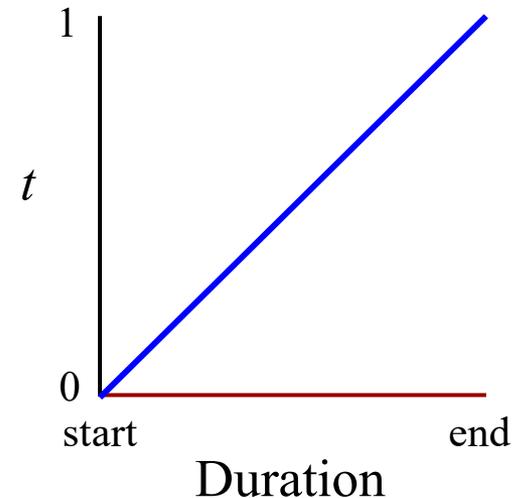


Alternatively, could
specify time per frame



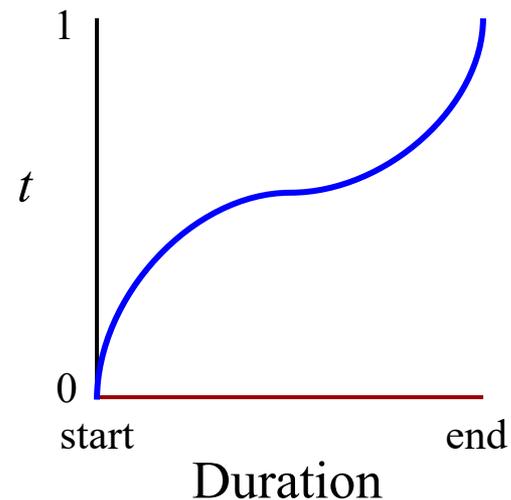
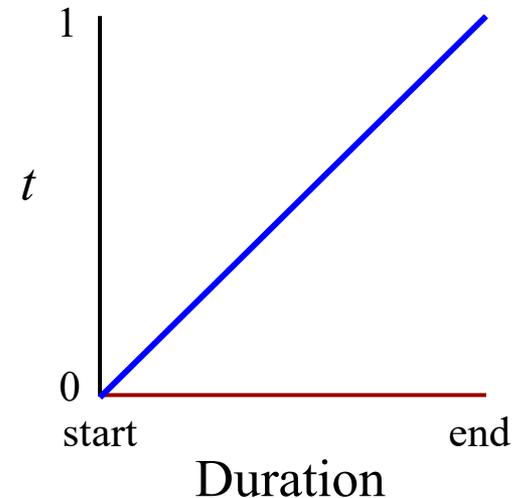
Easing Function

- 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*

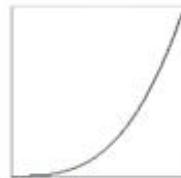


Easing Function

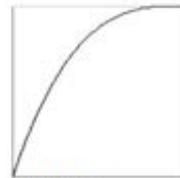
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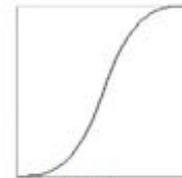
Classic Easing Functions



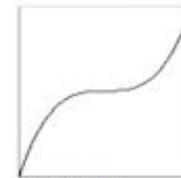
easeIn



easeOut



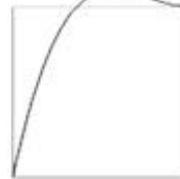
easeInOut



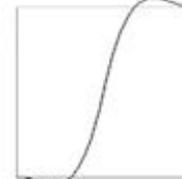
easeOutIn



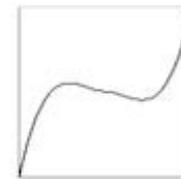
easeInBack



easeOutBack



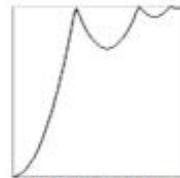
easeInOutBack



easeOutInBack



easeInBounce



easeOutBounce



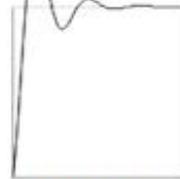
easeInOutBounce



easeOutInBounce



easeInElastic



easeOutElastic

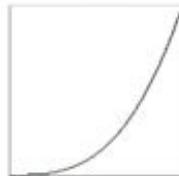


easeInOutElastic

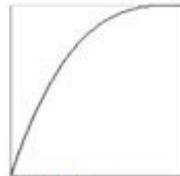


easeOutInElastic

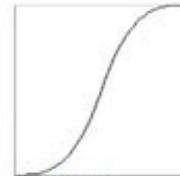
Classic Easing Functions



easeIn



easeOut



easeInOut



easeOutIn



easeInBounce



easeOutBounce



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easeInElastic



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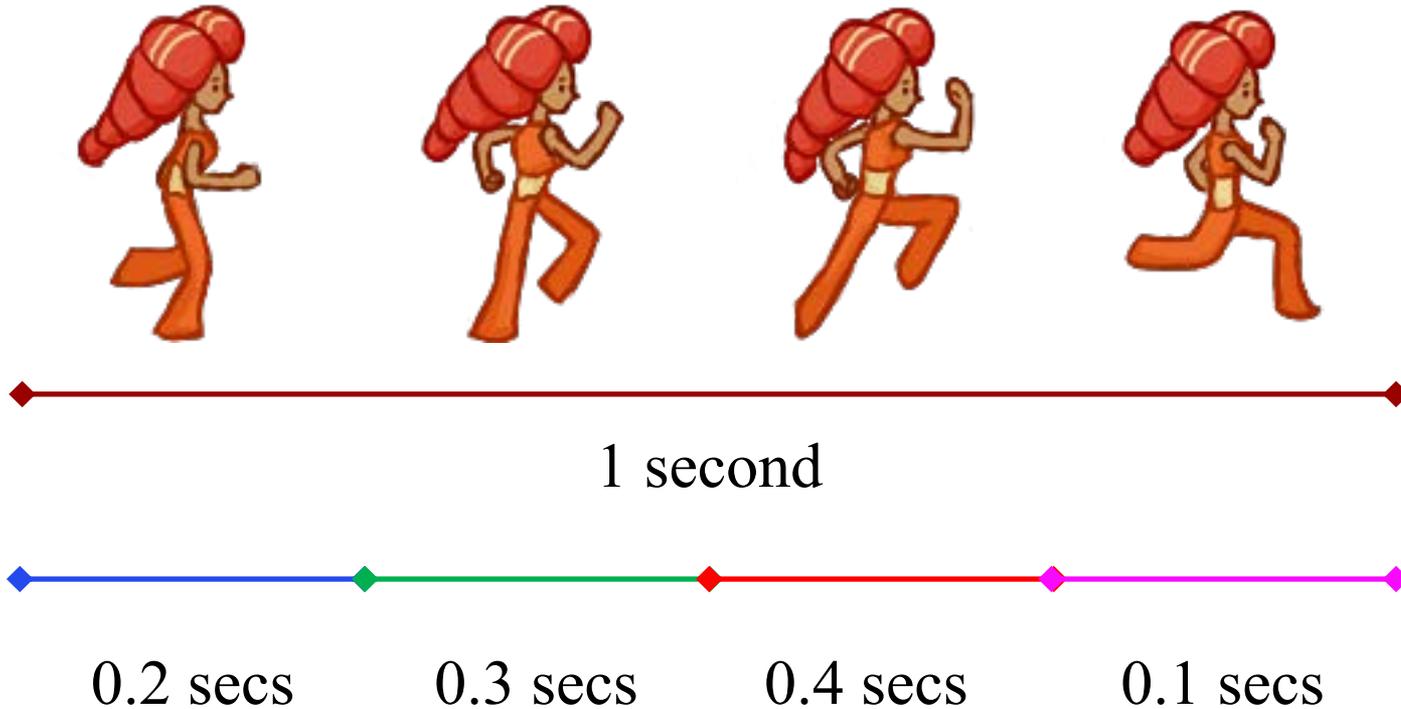
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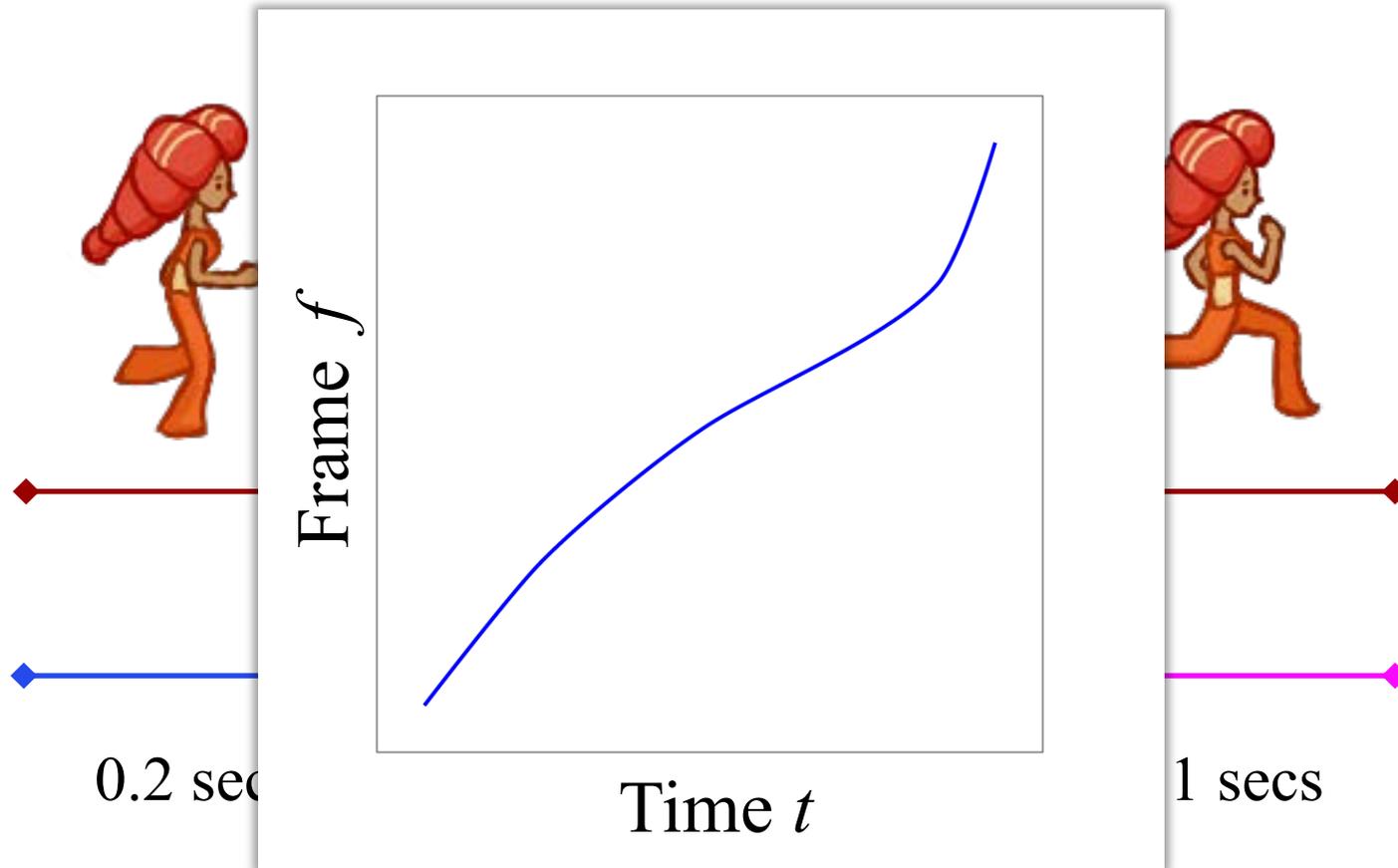
easeOutInElastic

<http://easings.net>

Application to Sprite Animation



Application to Sprite Animation



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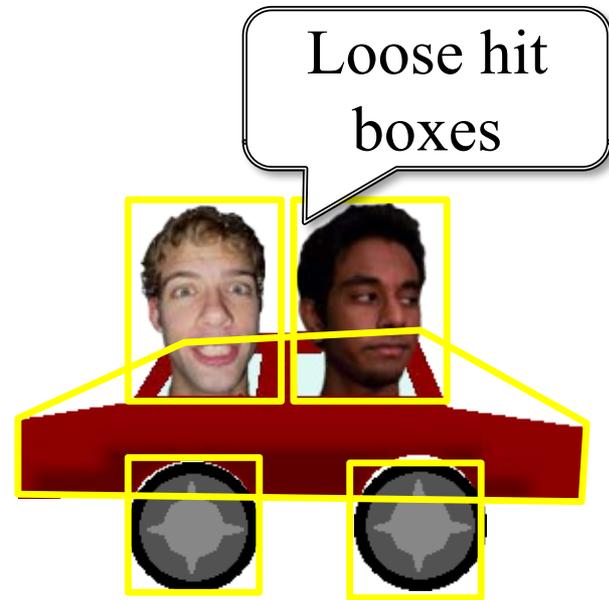
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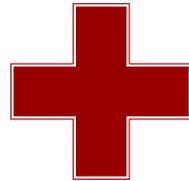
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- Inside hit box can safely
 - Transform with duration
 - Tween animations
 - Manage multiple actions

Problems With Decoupled Animation

Transform Tweening



Physical Animation

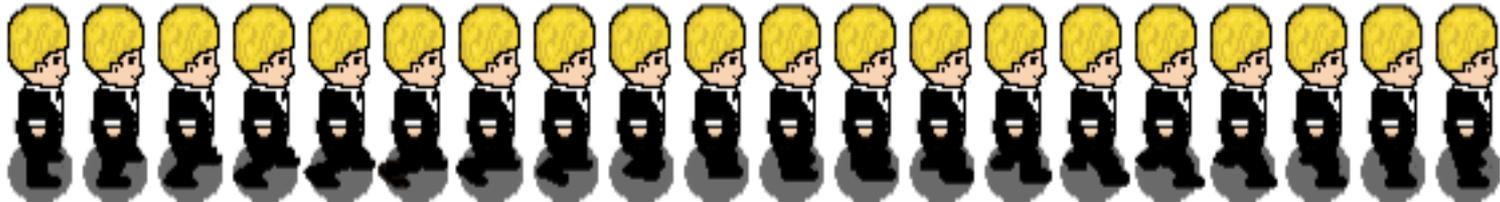


Complete Disaster

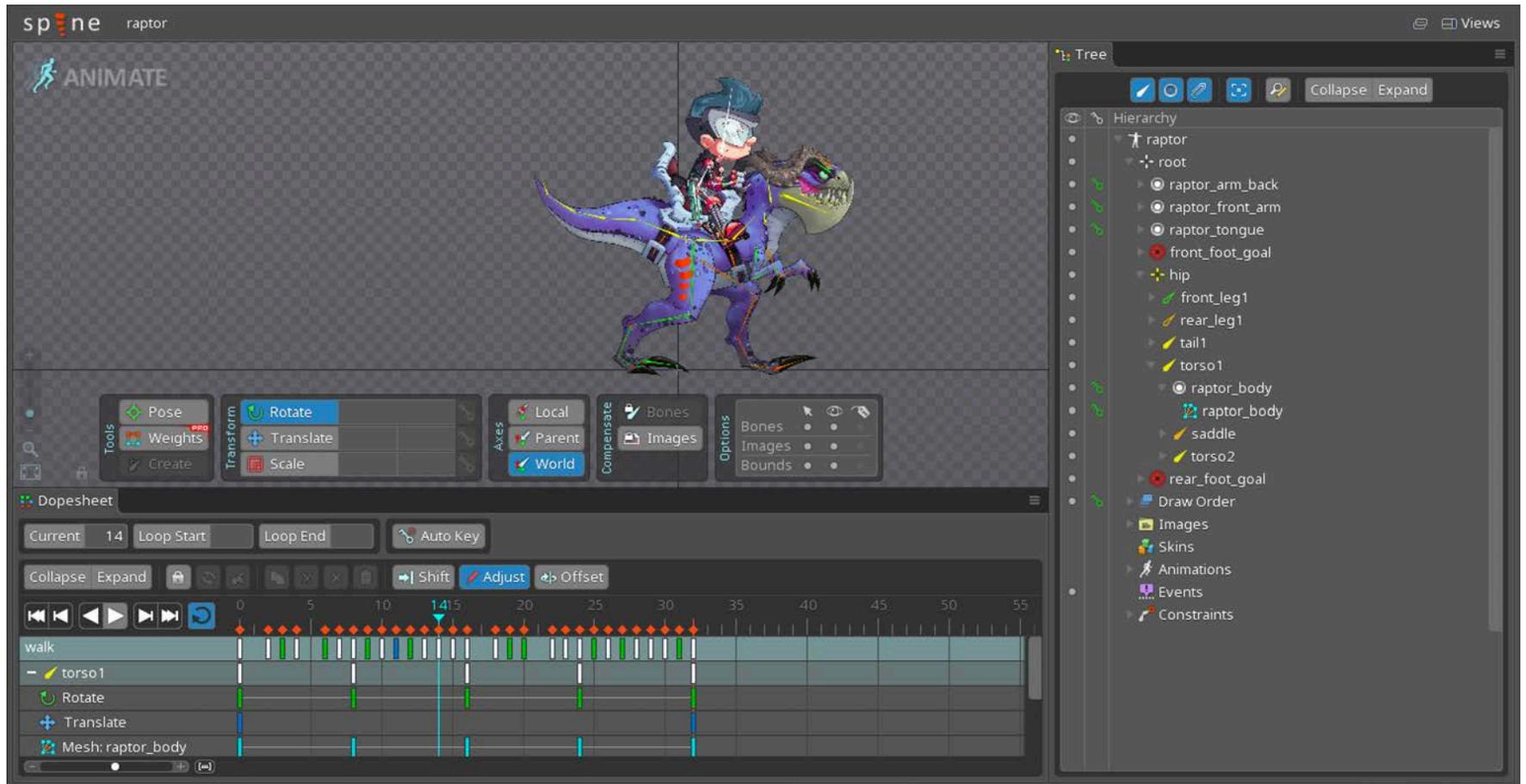
Aside: Skinning



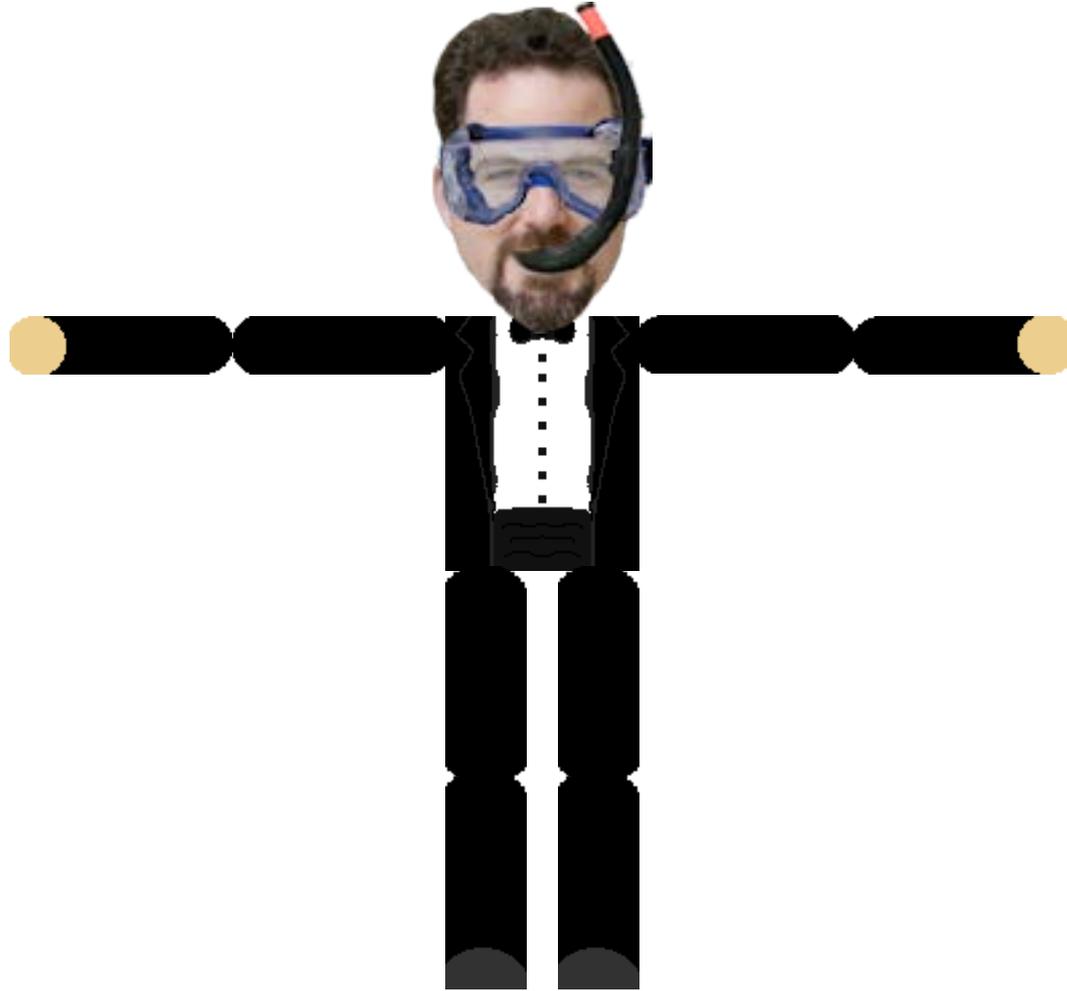
Way to get extra usage
of hand-drawn frames



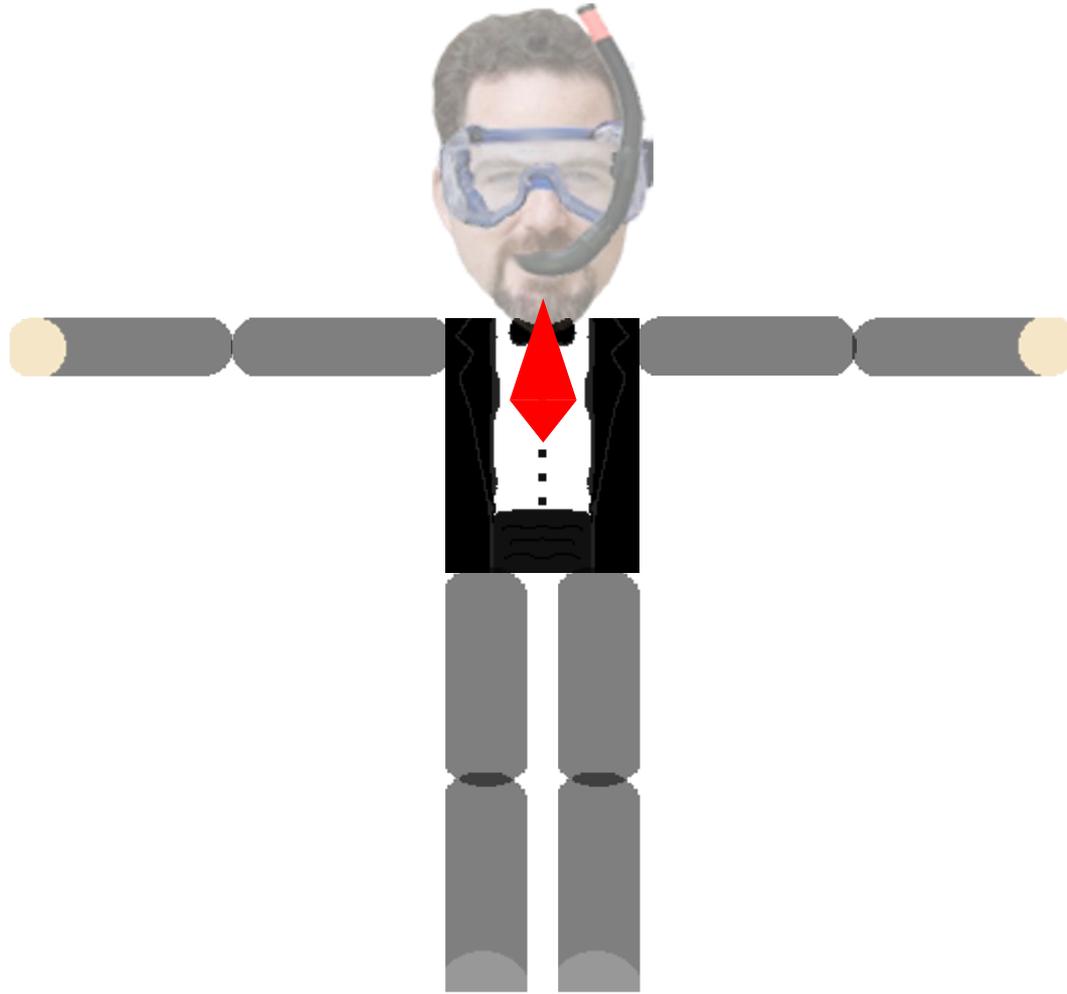
Spine Demo



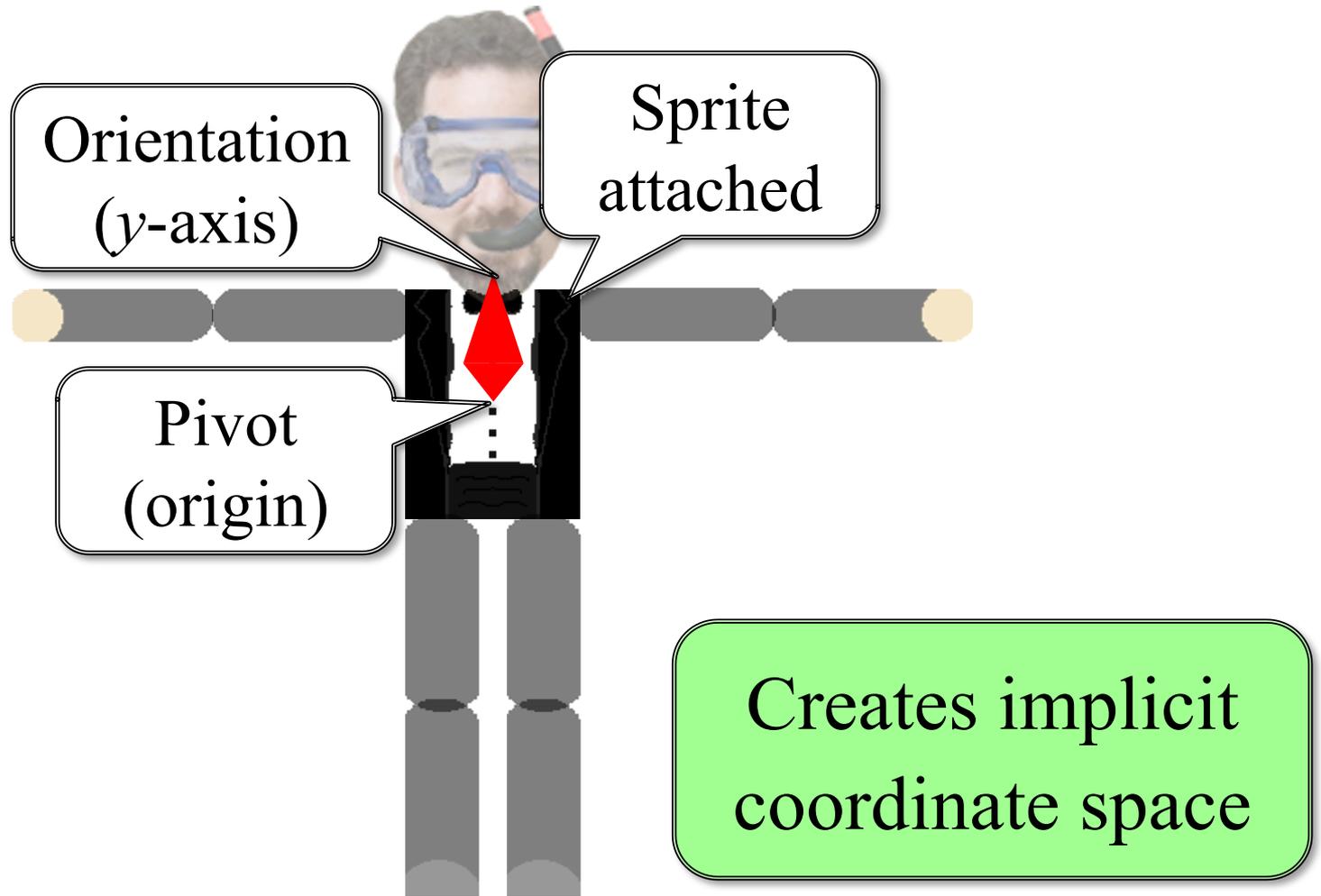
Basic Idea: **Bones**



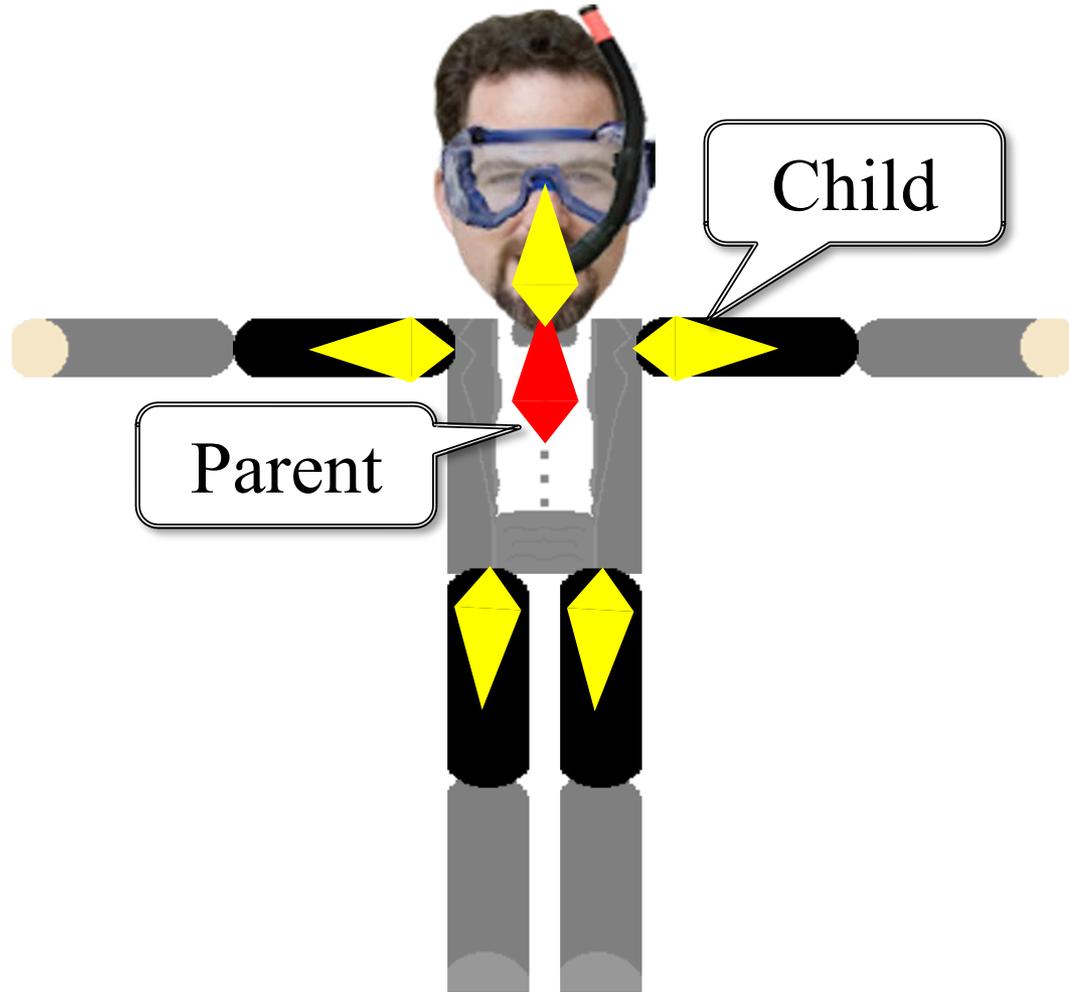
Basic Idea: **Bones**



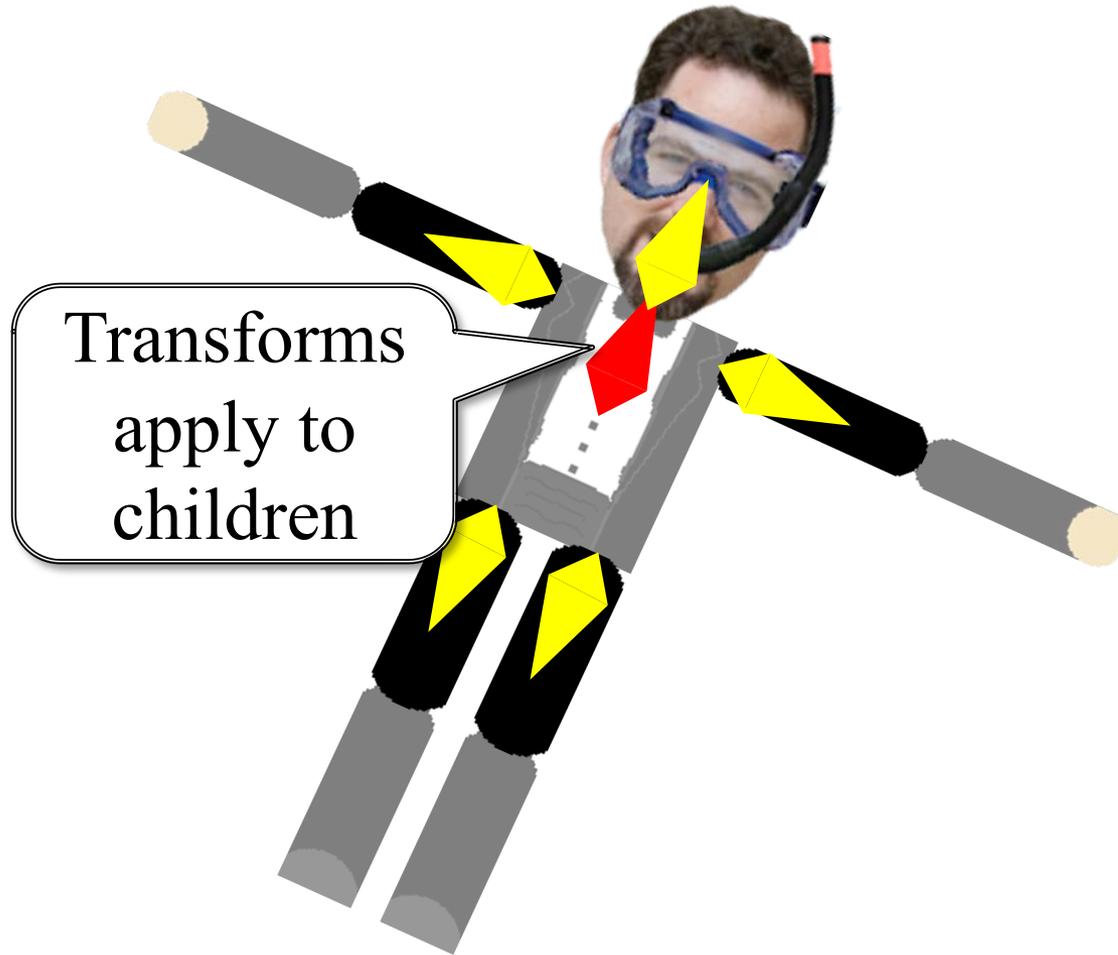
Basic Idea: **Bones**



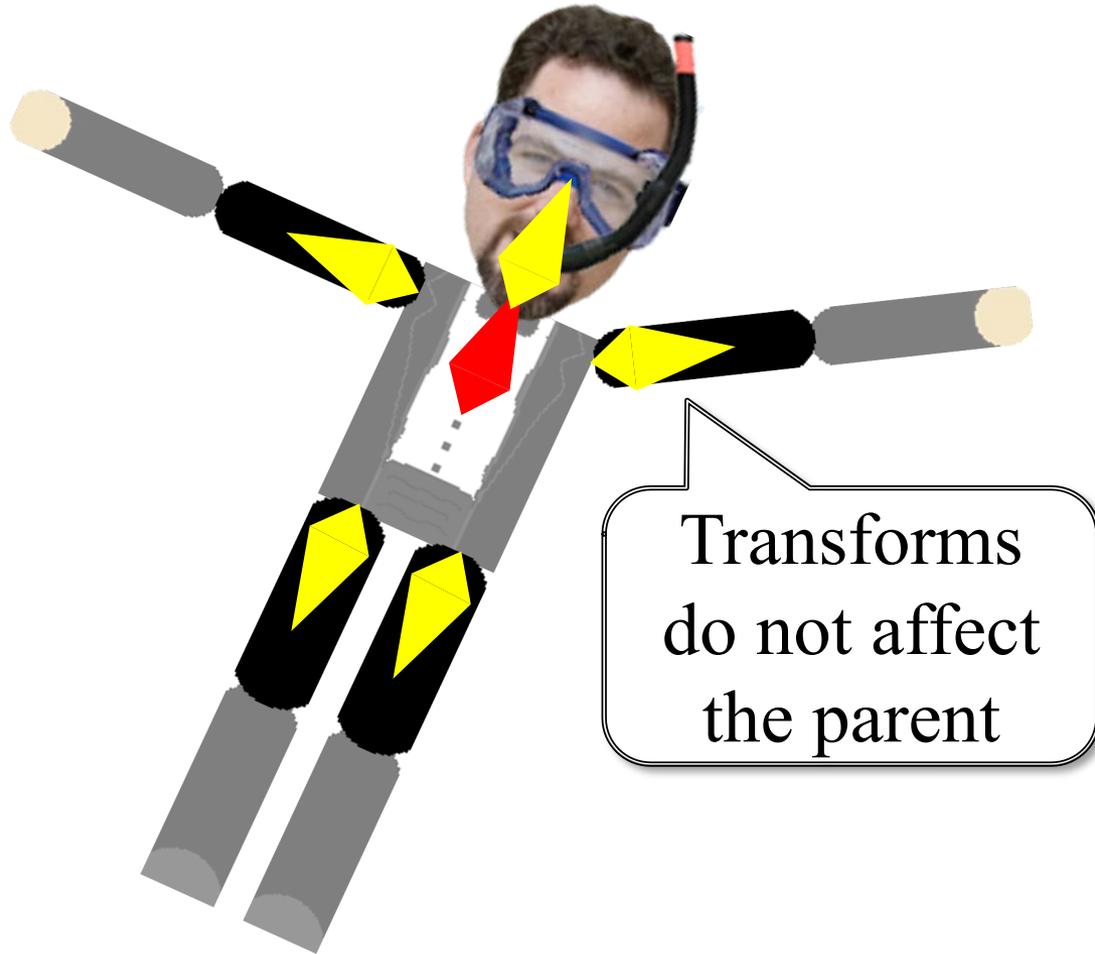
Bones are Heirarchical



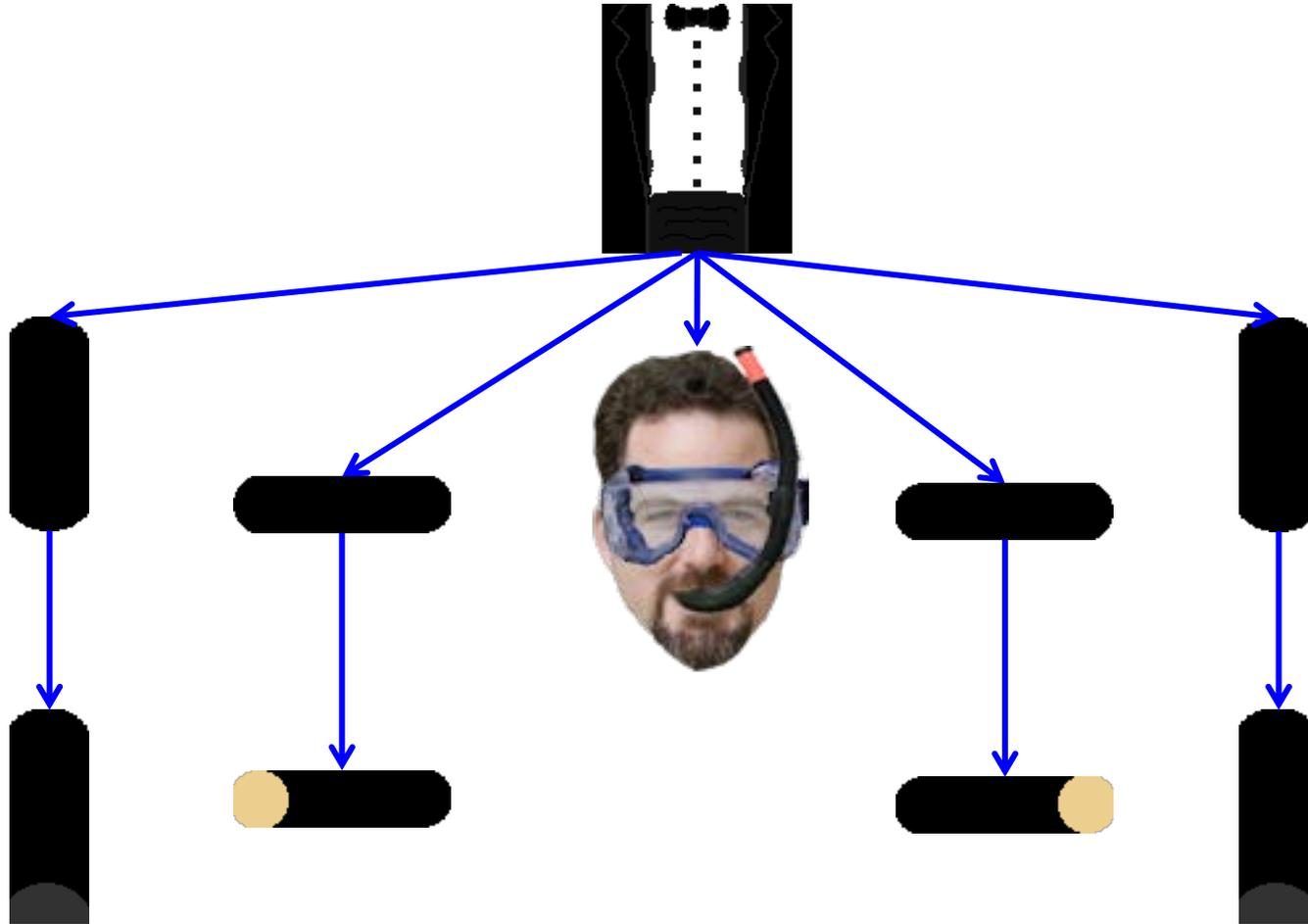
Bones are Heirarchical



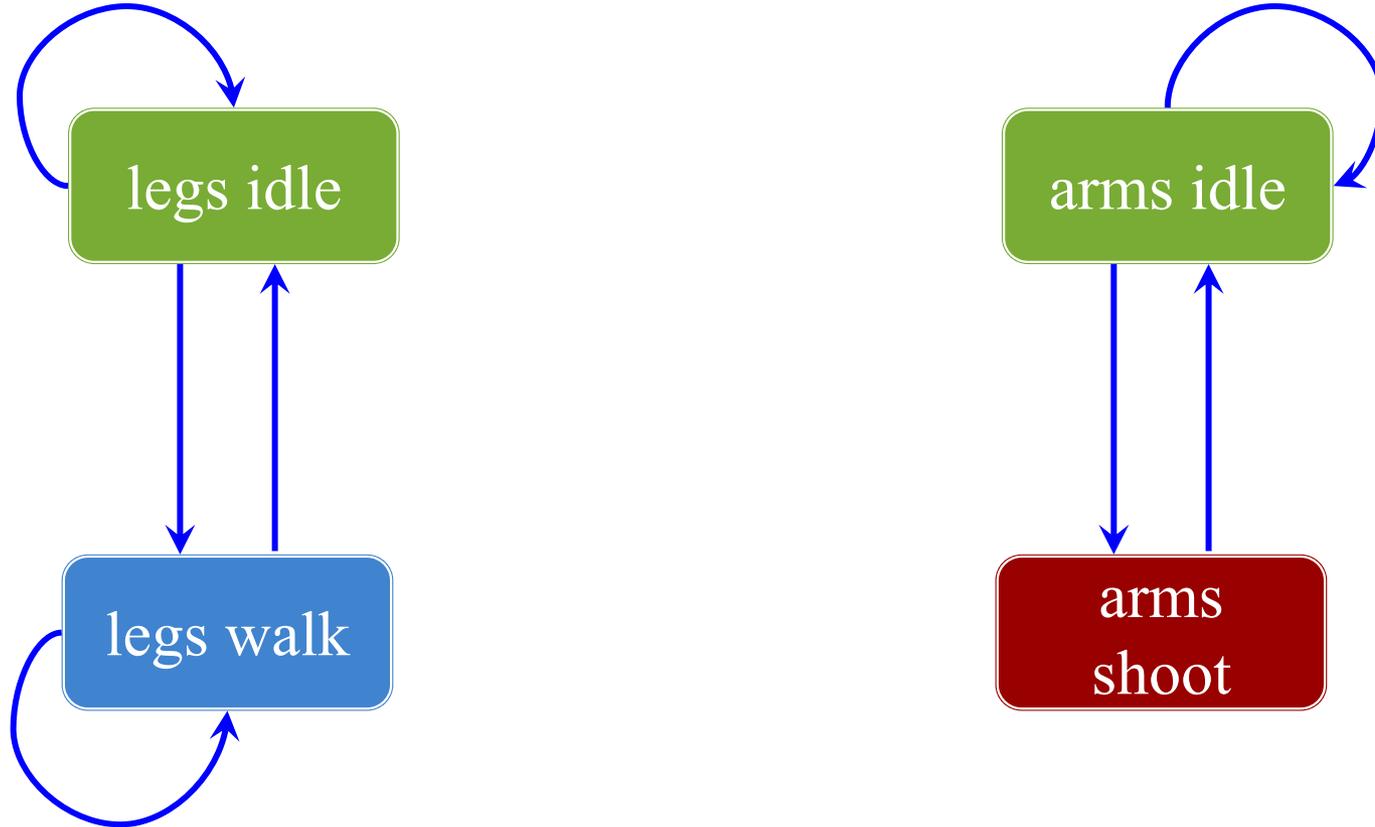
Bones are Heirarchical



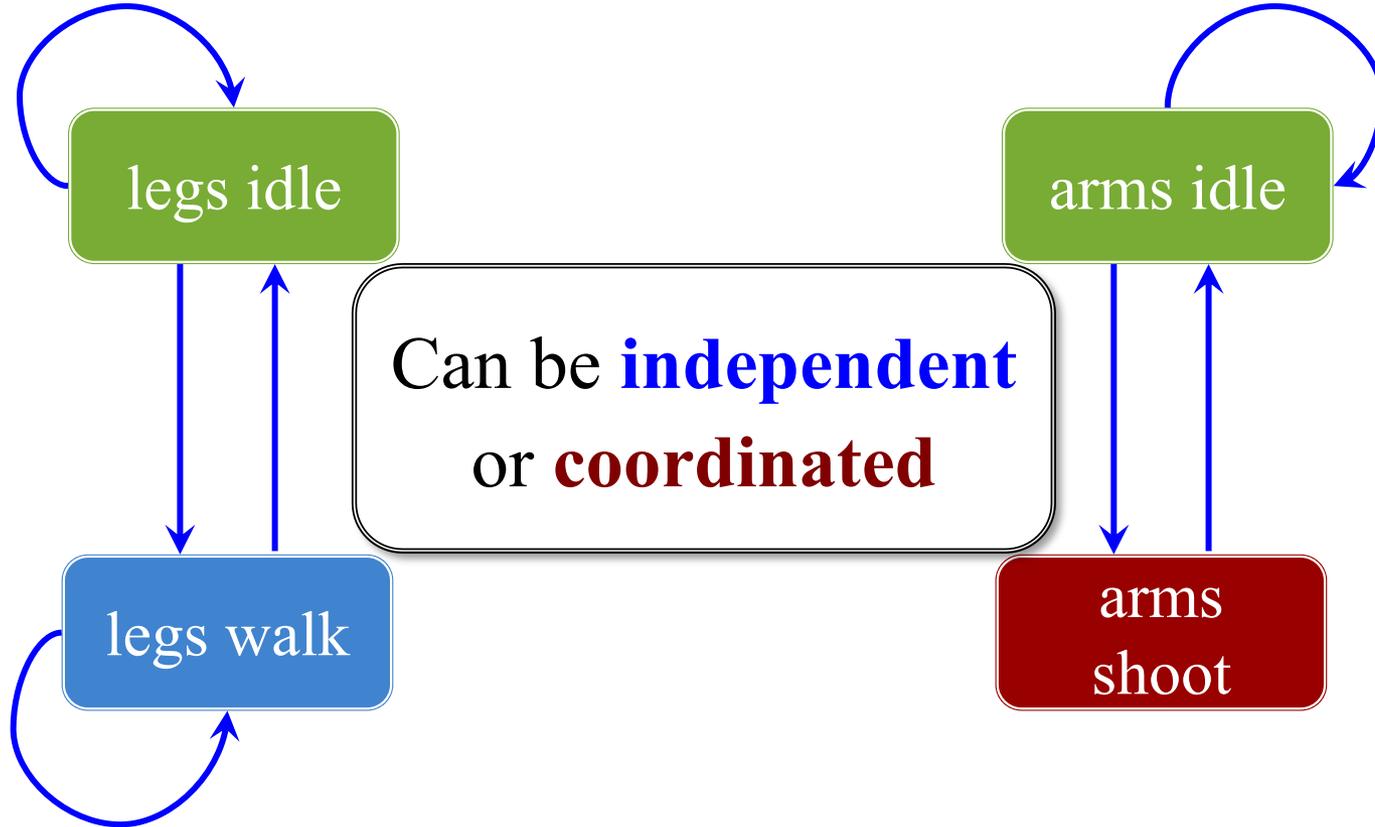
Bones are a Scene Graph Visualization



Manage With Multiple State Machines



Manage With Multiple State Machines



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