GDC 14

Multi-Actor Behavior Sequencing in The Sims 4

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GAME DEVELOPERS CONFERENCE®
SAN FRANCISCO, CA
MARCH 17–21, 2014
EXPO DATES: MARCH 19–21
2014

Introduction

- The Sims franchise is the best-selling PC game franchise of all time
- We have a really broad, diverse audience
- We work hard to provide a good experience on a really broad range of PC hardware
  - We run on less recent PCs by most standards
  - We pay a lot of attention to laptops w/ integrated graphics

Delivering The Sims

- We must deliver a quality experience on all hardware that we support
- We have to look “like a Sims game”
  - Precise synchronization and registration between Sims/objects
  - Sequence integrity
    - No skipping important steps
    - No harsh interruptions
- The simulation is king
    - Always in charge of what happens and how

Challenges

- Running our deep simulations at consistently interactive frame rates is difficult
  - Inherently spike-prone
  - Huge set of options for each Sim at any given time
- We’re constantly adding new complexity
  - The Sims 4 has taken on some performance-sensitive problems like multi-tasking
  - Every expansion adds even MORE options for the Sims to consider

Implementation Goals

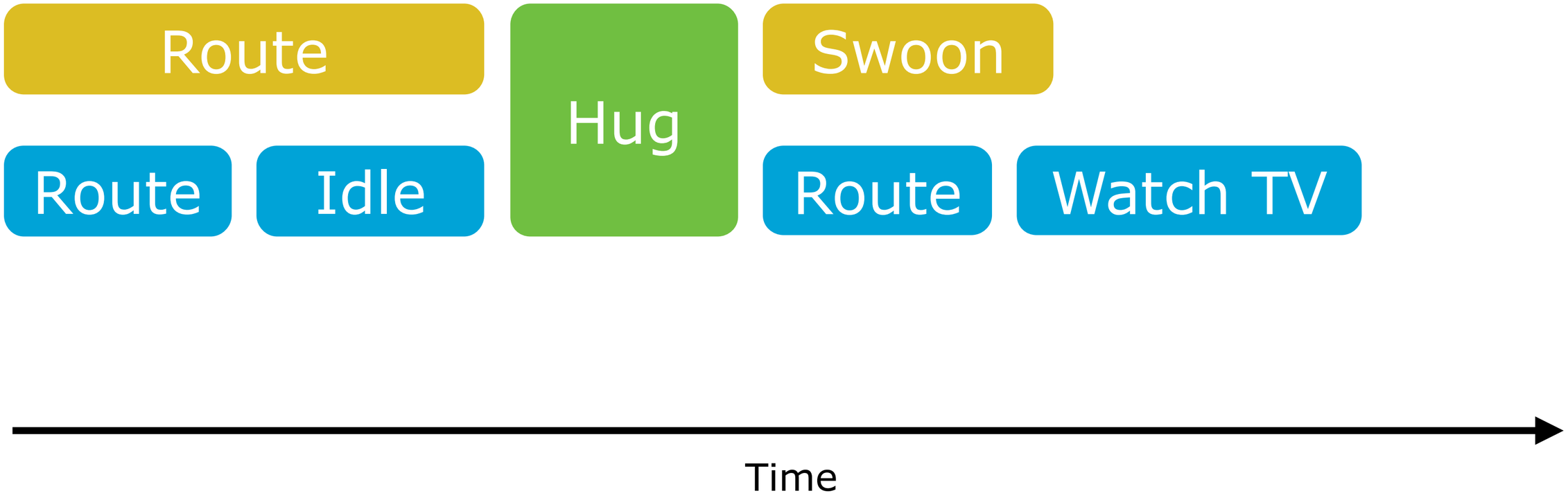
- Decouple the simulation from the renderer entirely
  - Protect the renderer from simulation spikes
  - Protect the simulation from difficult performance requirements
- Keep all impactful decision making in the simulation
  - Path planning, animation selection, etc.
- Move all high-frequency behavior to the renderer
  - Path following, animation playback, etc.

Variable Time Shifting

- We allow for variable time shifting on the renderer
  - Perceived delta from the simulation timeline may be different depending on which object(s) you are observing
- Especially important when dealing with transient divergences from the simulation timeline on the renderer, due to…
  - Animation branch restrictions
  - Dynamic avoidance
  - Etc.


ALPHA SOFTWARE
ALPHA SOFTWARE

Dependent Timelines



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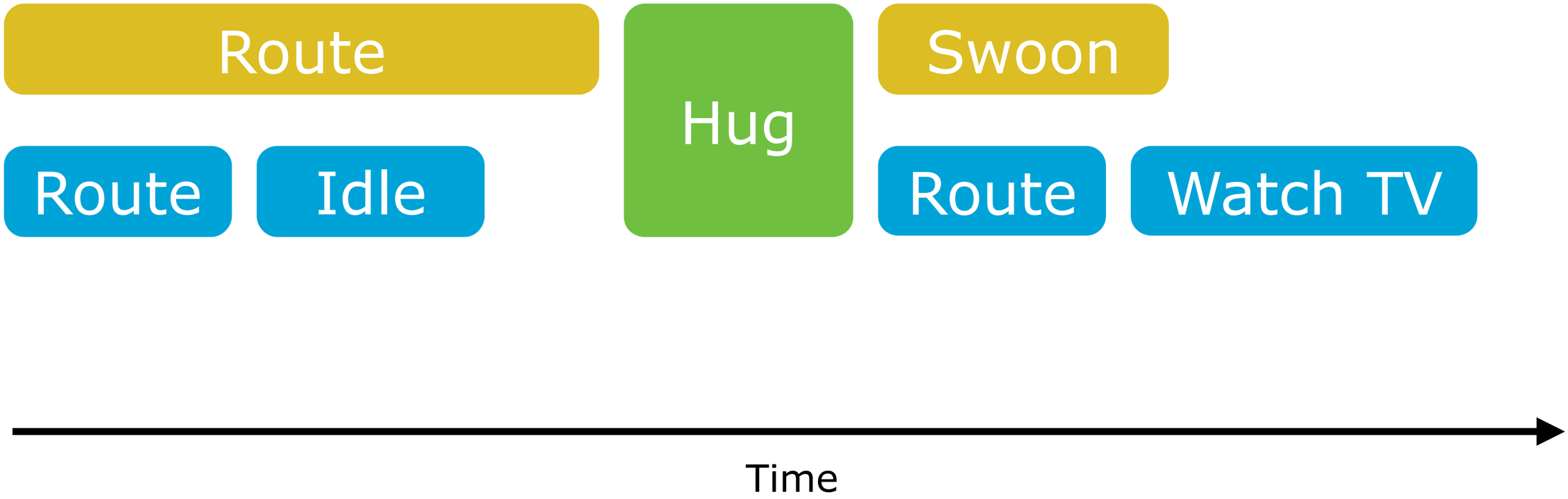

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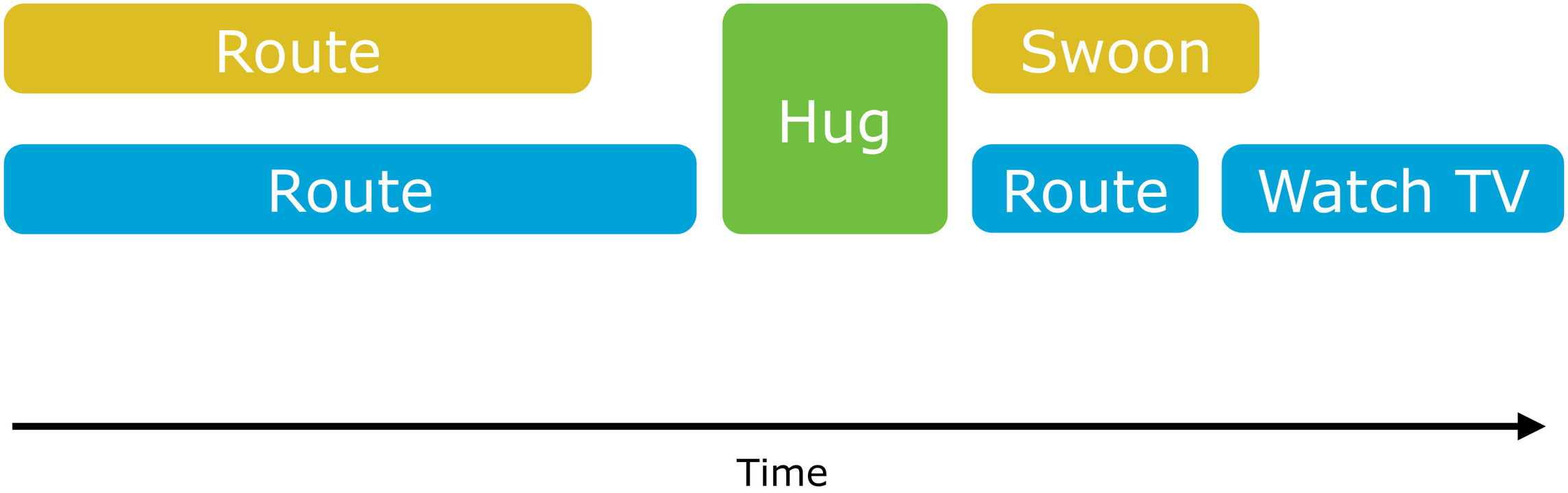

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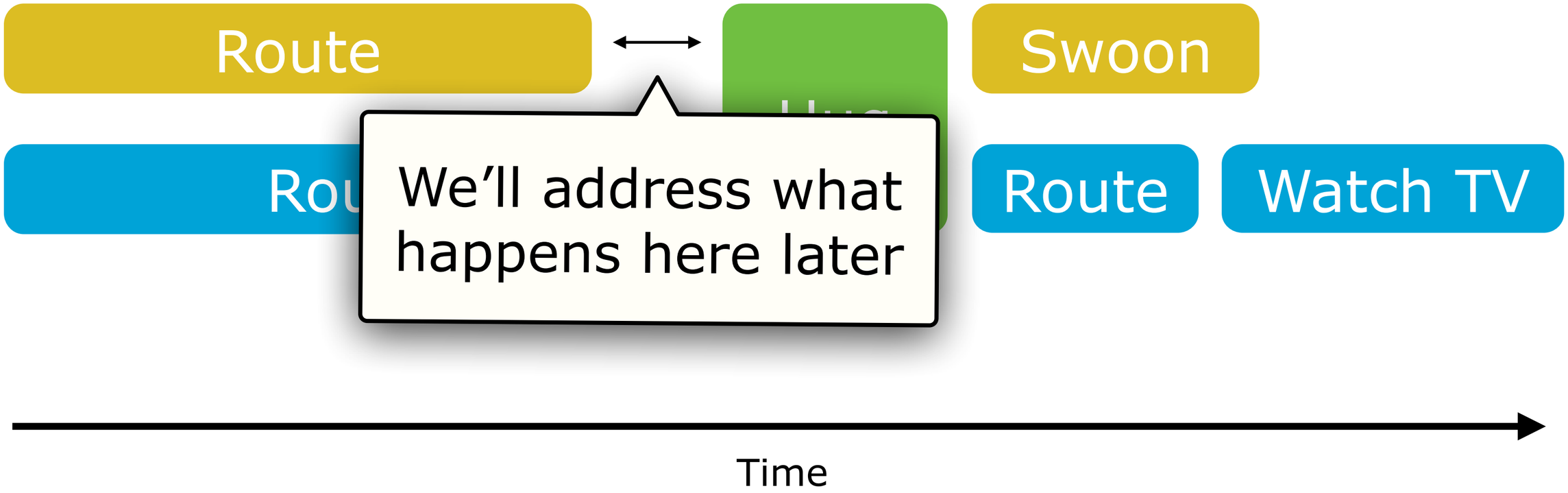
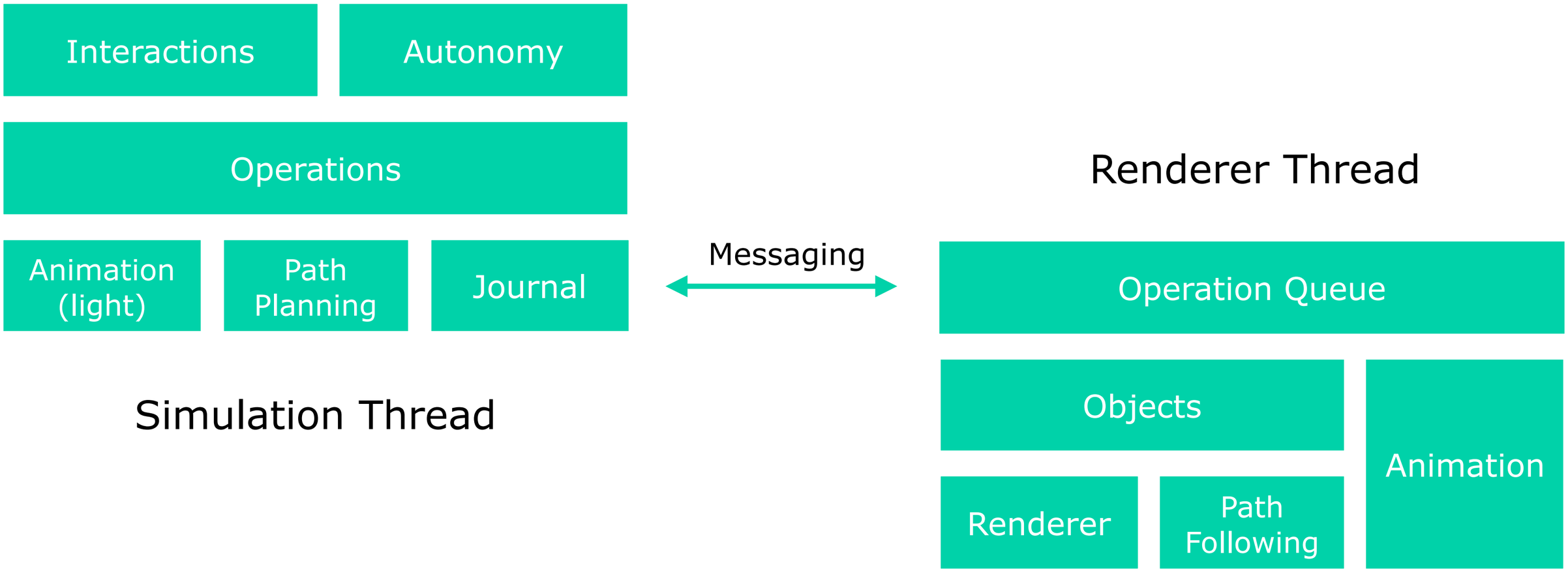
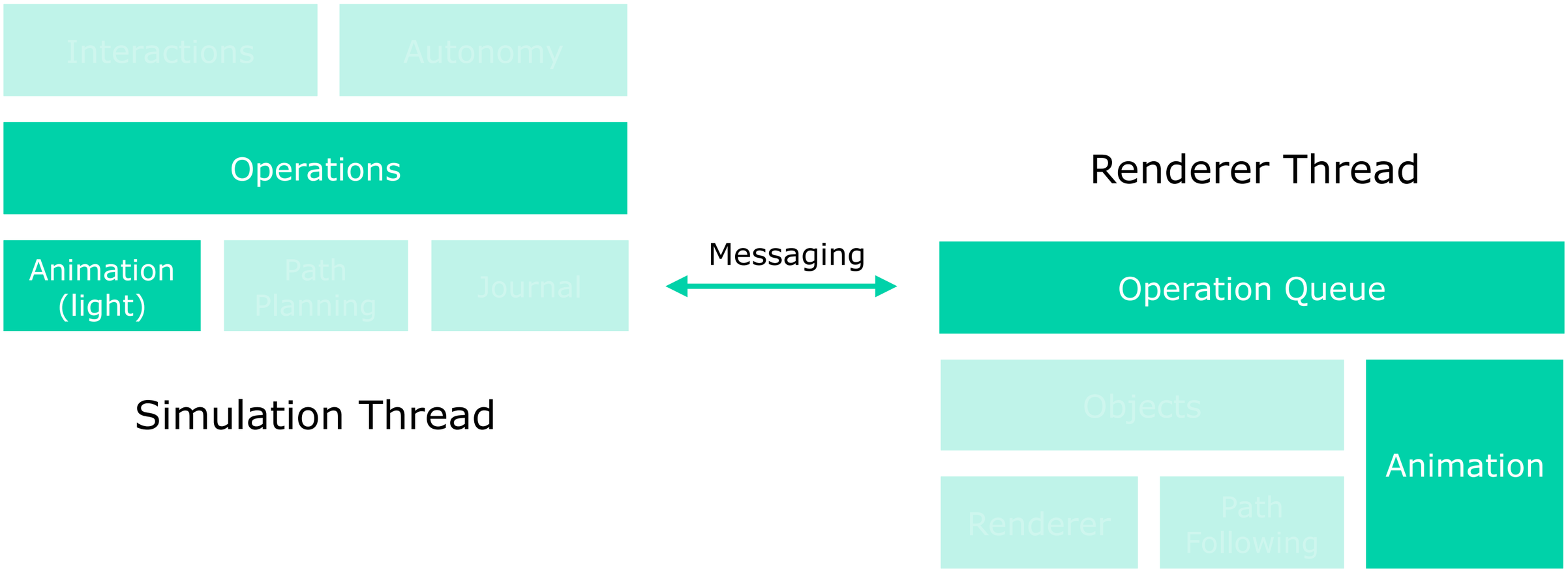


Implementation

The Sims 4 Simulation Architecture



The Sims 4 Simulation Architecture



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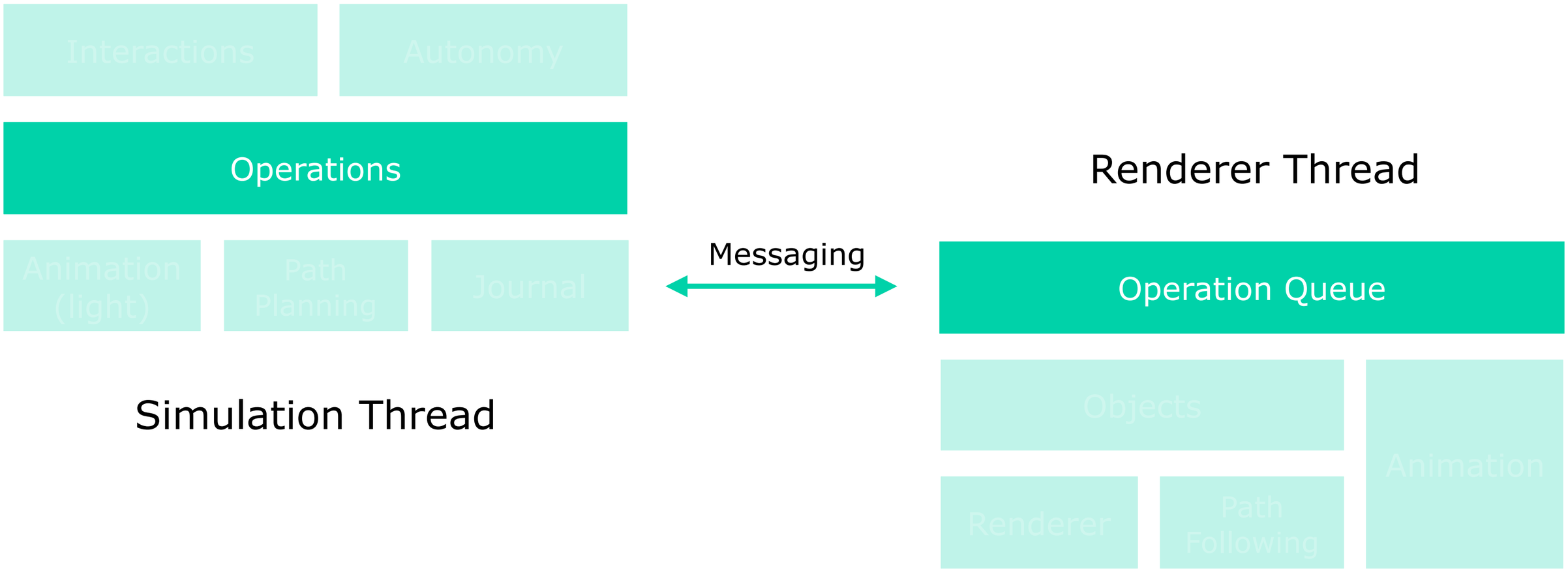


Operations and Channels

- Operations are things the renderer can do…
  - Set a transform
  - Play some animation
  - Follow a path
  - Play a sound
  - Start VFX
  - Trigger some UI
  - Etc.
- An Operation consists of a payload and a set of channels

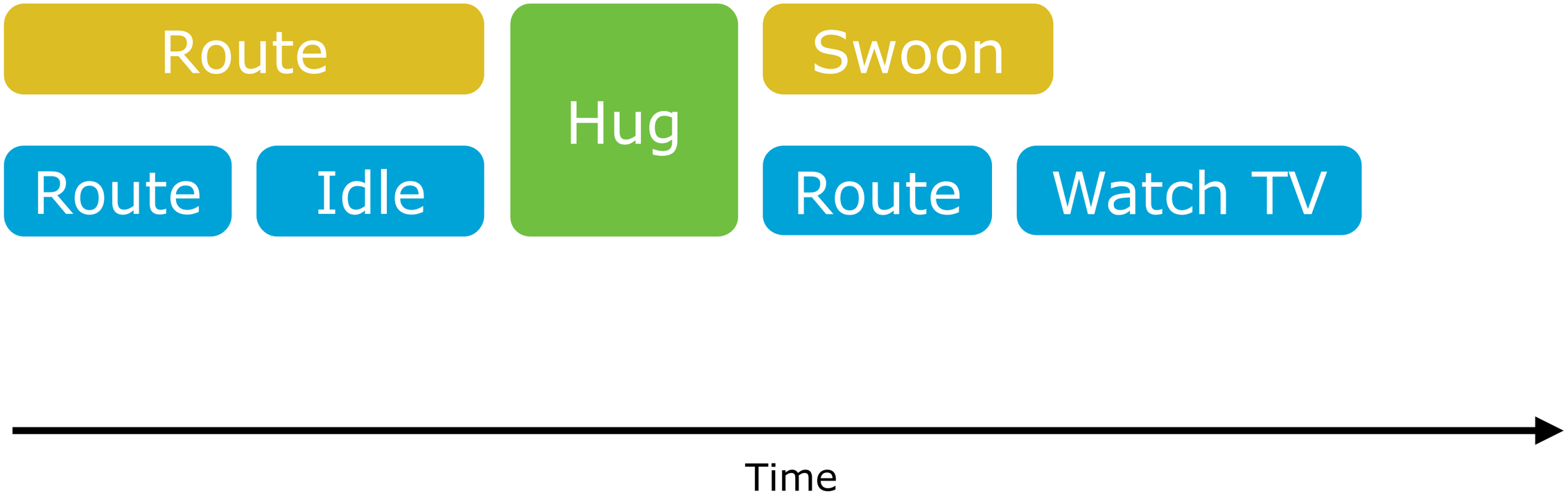
Operations and Channels

- Channels define timelines
  - Each Sim/object in the world is a channel
  - We create other channels too
- A Channel (for us) consists of…
  - An Object ID
  - A 32-bit mask (used for “multi-part” objects)

Operations and Channels

- Channels determine what operations must be executed serially, and which can be run in parallel
- There may be multiple, unrelated chains of serial operations (timelines) at any given time, which can merge and split as necessary
- Operations are inserted into the Operation Queue, which is responsible for maintaining these timelines

Dependent Timelines



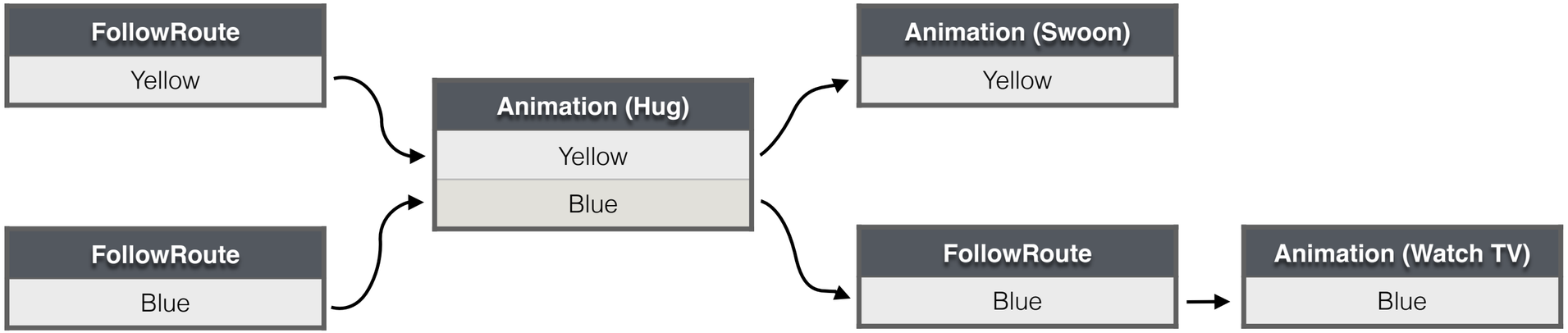
The Operation Queue

- Entirely passive - it is not actively ticked
- Only does work via one of the three public functions
  - Enqueue, AddBarrier, RemoveBarrier
  - All work is performed synchronously
- Enqueue and RemoveBarrier can invoke operation handlers
- When an operation is handled, it is removed from the queue immediately afterward

Enqueue

- On Enqueue, an operation is blocked if any of its channels overlap with the channels of any operation ahead of it in the queue
  - The overlap test is (`a.id == b.id && a.mask & b.mask`)
- If the new operation is blocked, it is pushed onto the back of the queue
- If not, its handler is invoked immediately

Operations and Channels



Operations and Channels

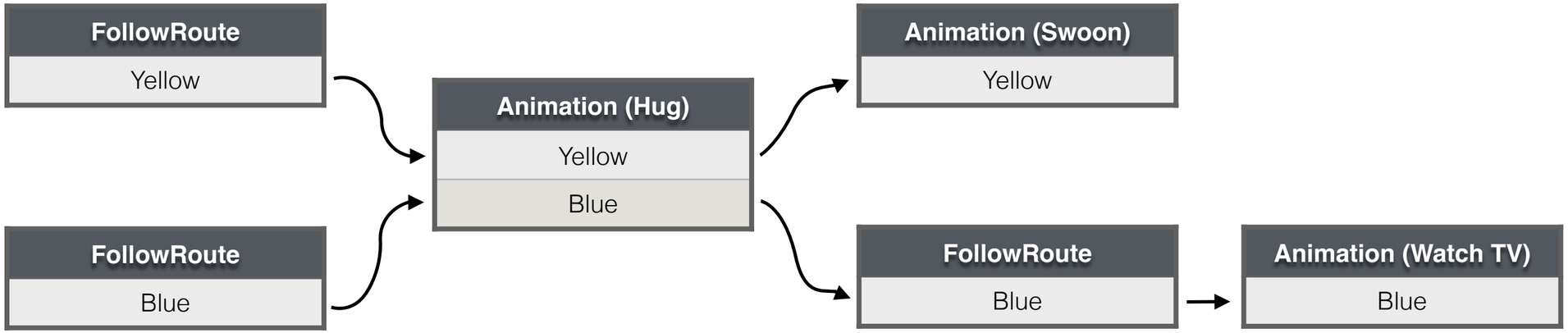
Barriers & Taking Time

- We use barriers as a way to let external systems gate progress through the queue
- Barriers are simply a special type of Operation which are not processed upon becoming unblocked. RemoveBarrier must be called to remove them
- When barriers are removed, we check to see whether any operations located behind the barrier in the queue are now unblocked, and if so, their handlers are run immediately

Barriers & Taking Time

- Barriers are added from an operation handler, function, and are added immediately behind the operation being handled
- Barriers are generally removed from separate systems (e.g. animation) when they have reached a logical place to clear them
  - *For animation, we use "eligible for branch out"… More on this later*
  - When we remove a barrier, we re-evaluate all operations behind the barrier in the queue to see if they are unblocked

Barriers In Practice



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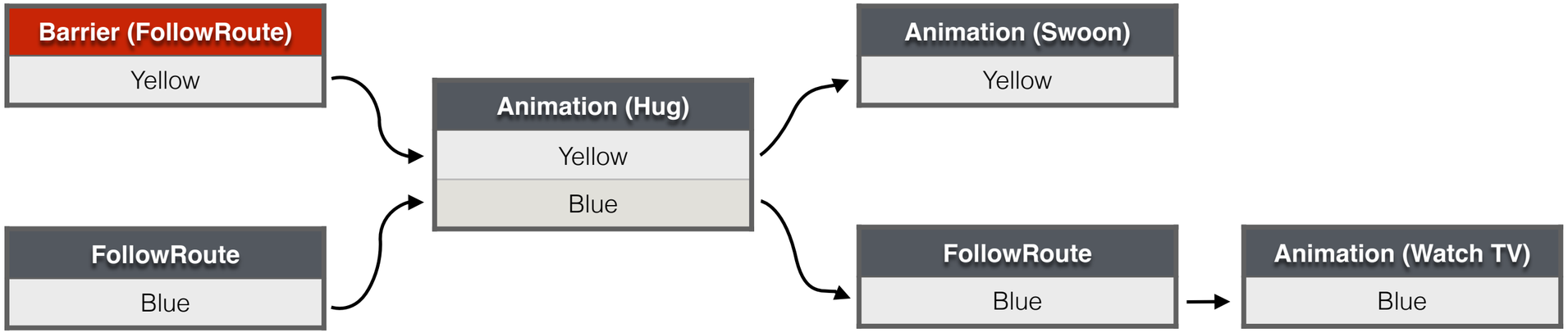

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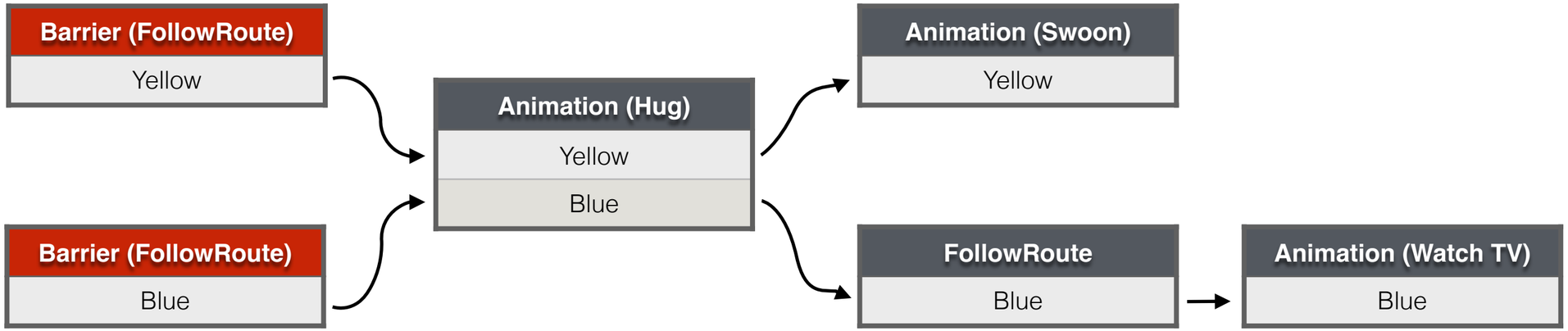

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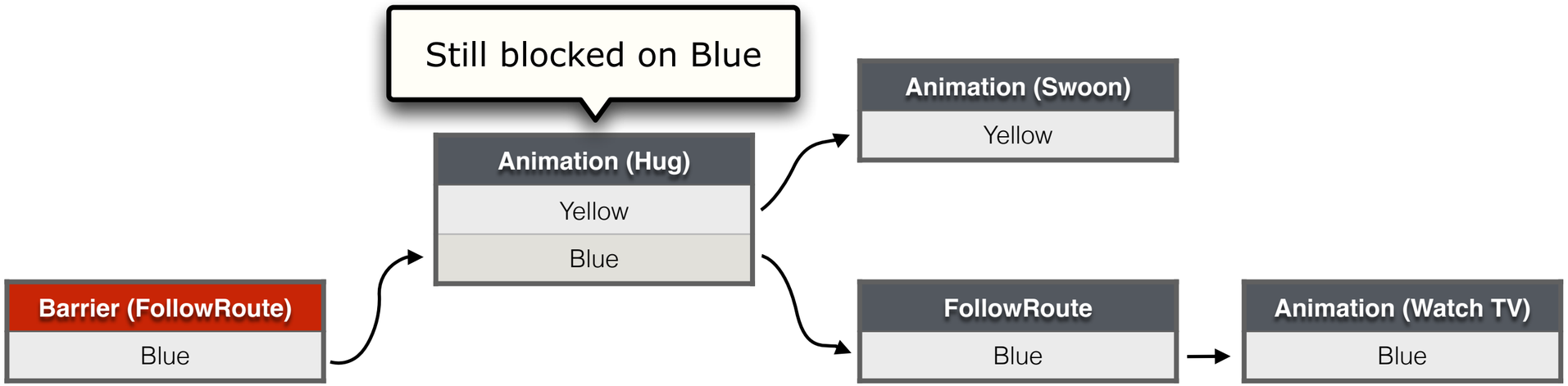

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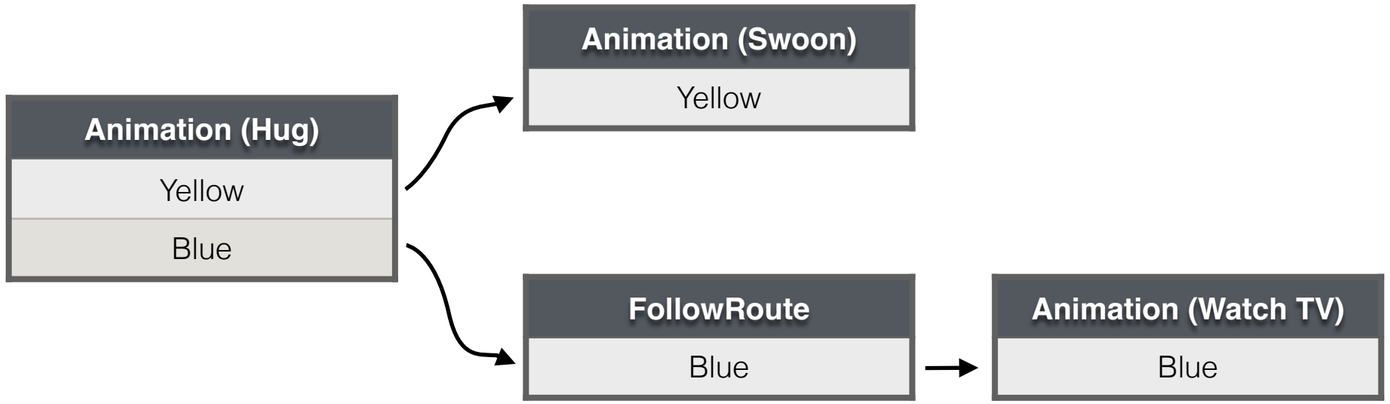

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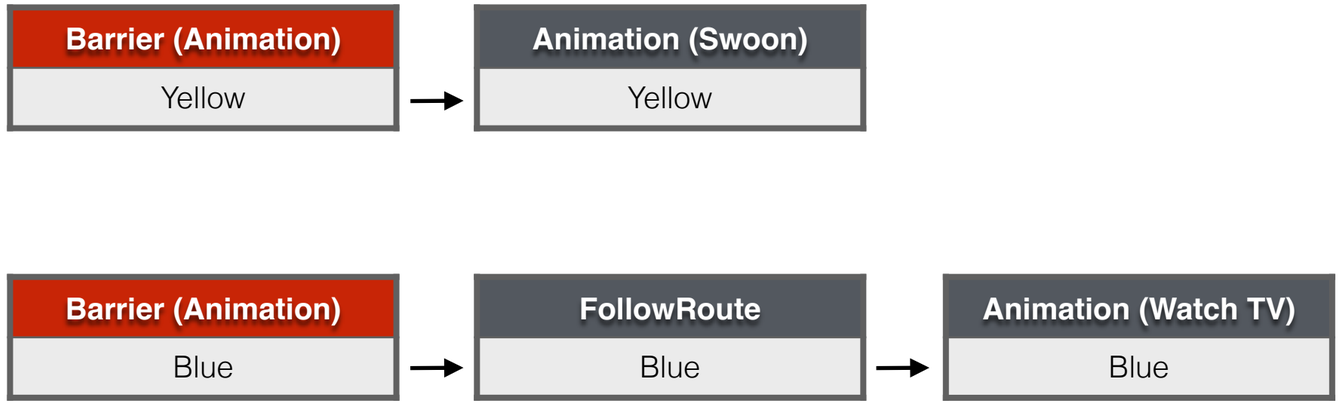
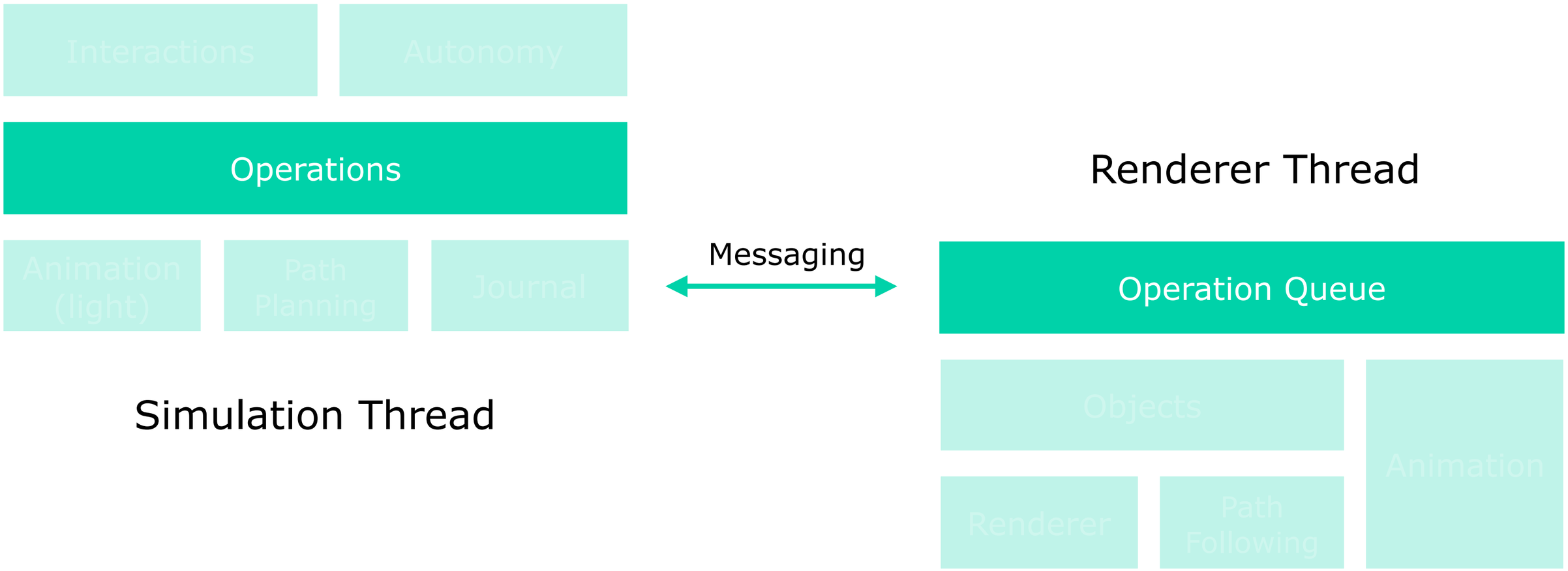
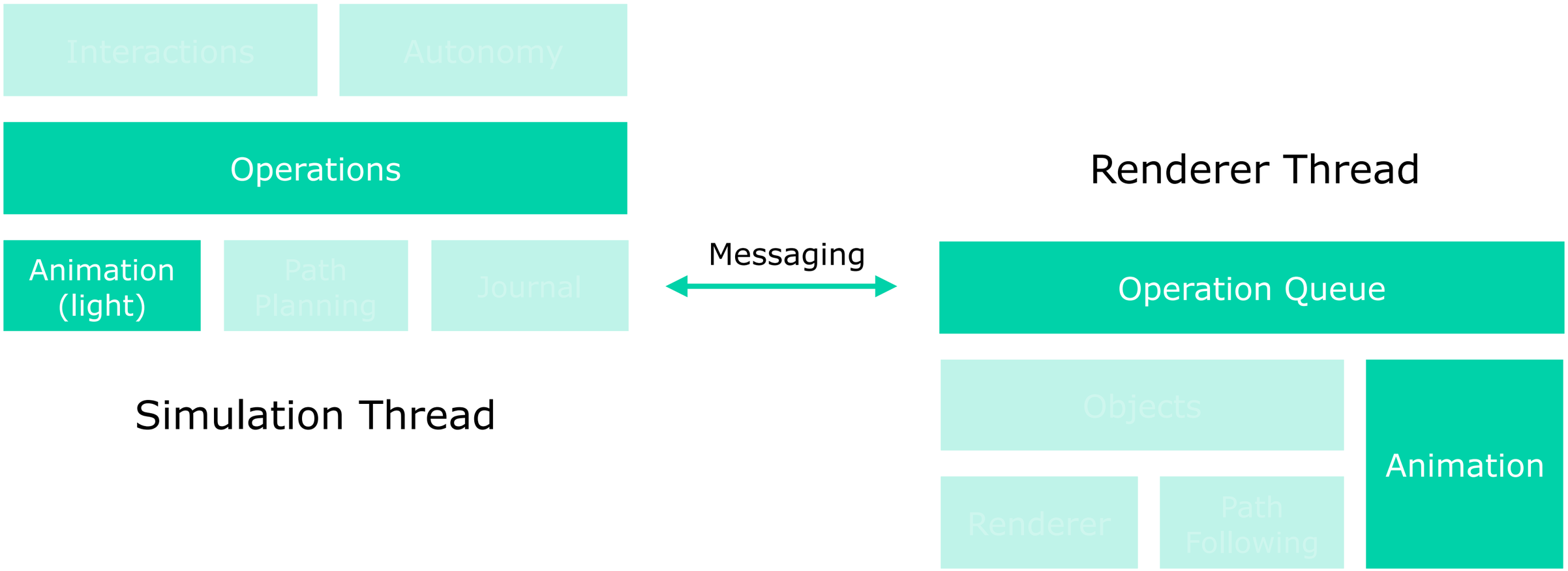


Multi-Actor Animation



Multi-Actor Animation



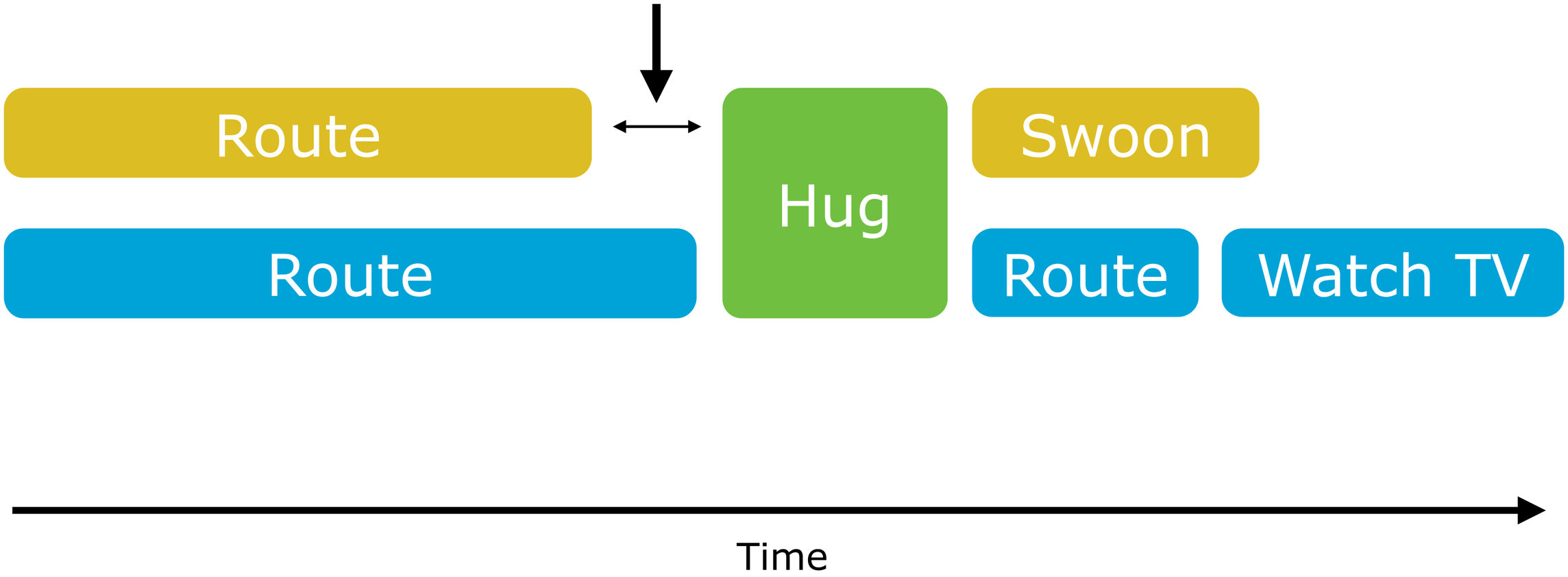
Animation Request Block (ARB)

- We need a generic way to specify multi-actor animation for serialization, including support for frame-accurate synchronization
  - Because we may be time-shifting things on the renderer, simply starting the animations at the same time is not an option
- We need to support sequences with reliable internal animation blending

ARB Structure

- ARBs contain a sequence of controller records, each of which contains…
  - Controller
    - Target Actor
    - Animation Clip
    - IK Information
    - Etc.
  - Blending Info
  - Synchronization Group ID
  - Flags

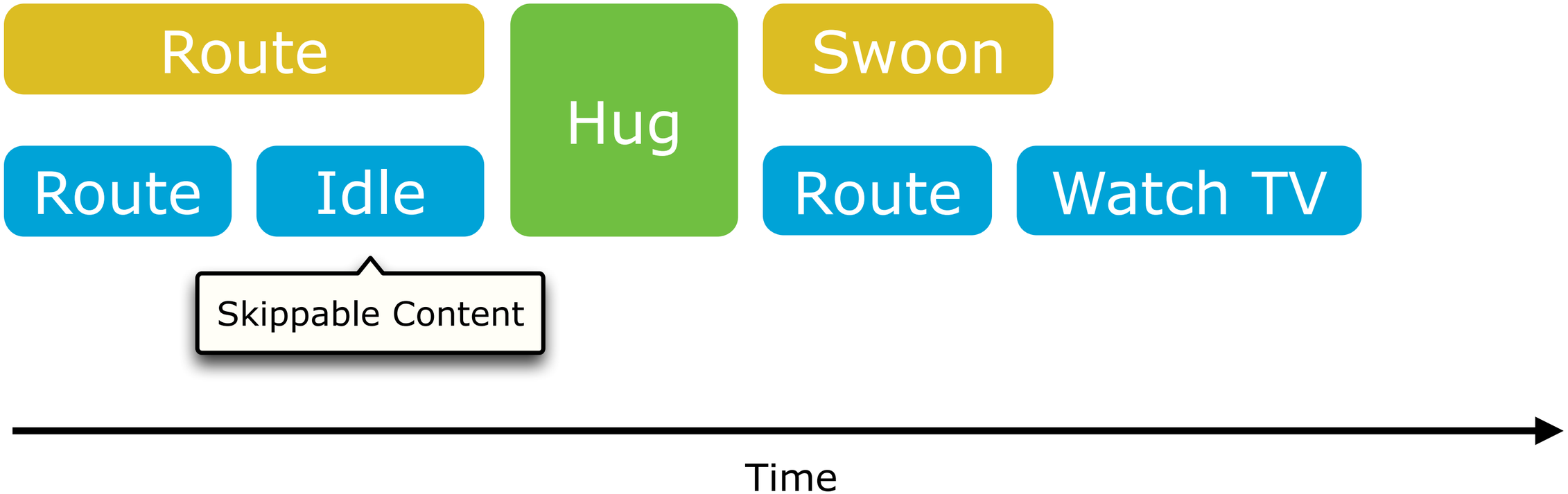
Gap Coverage?



Skippable Content

- Animation scheduled as “skippable” is key to ensuring good gap coverage
- Each ARB generally ends with some interruptible/skippable content
  - Designed to be unobtrusive and easy to blend quickly out of, but just active enough not to look dead
- If we’ve received another ARB affecting the actor in question before the skippable content would start, the skippable content is discarded entirely

Dependent Timelines



ARB Handling (Simulation)

- We do not actually run the animation system on the simulation thread
- We load just enough to support the construction of ARBs
- When the simulation executes an ARB, we compute a rough estimated duration for the ARB which related tasklets then sleep for
  - This duration is generally fairly accurate, and takes into account blend times, but is not perfect

ARB Handling (Renderer)

- When the ARB operation is handled, we…
  - Add barriers to the queue - one for each affected actor/event
  - These barriers are removed when the last non-skippable clip is eligible for blend out
    - For non-interruptible clips, this is (duration - blend out time)
    - For interruptible clips, this is when the clip is started
  - This allows us to unblock each actor individually as soon as possible, allowing for smoother transitions when timelines split

Animation Events

- We make heavy use of animation events to support frame-accurate changes to state, like…
  - Reparenting objects
  - Playing sounds
  - Triggering UI
  - Etc.
- Many of these events require the simulation to make decisions about how to handle them
  - Handling them on the renderer would require replicating a tremendous amount of state and logic

ARB Structure - Event Records

- ARBs also contain a sequence of event records, each of which contains…
  - Event Channel
  - Event Source Record
    - Which of the controller records generates the event
  - Event Type/ID

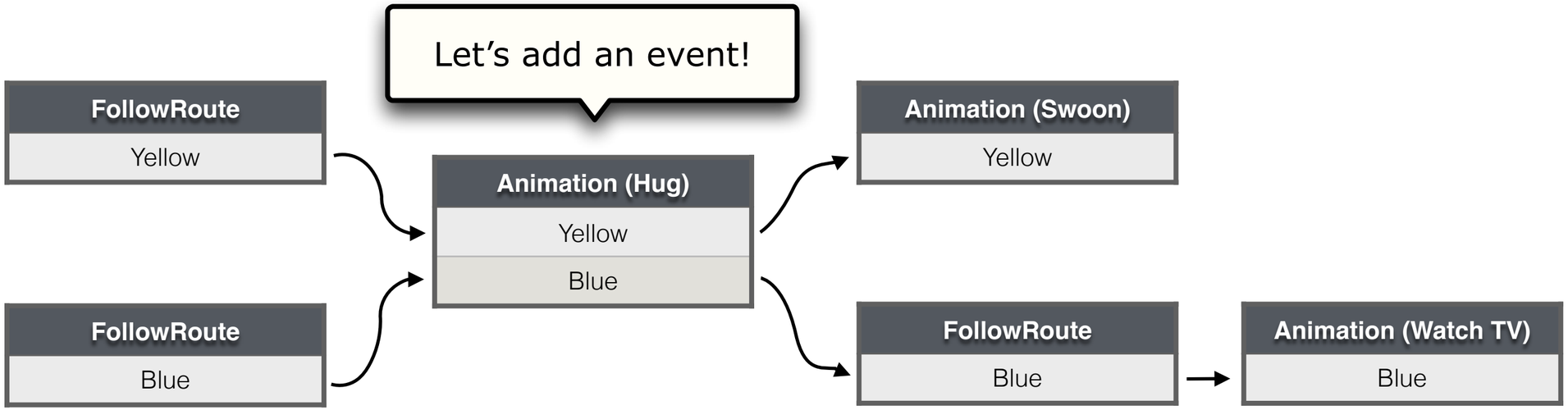
Animation Event Handling (Simulation)

- On the simulation, event handlers are run synchronously when the ARB is started
  - For each event we run handlers for, we allocate a unique channel that doesn’t map to a real object
  - Event handlers can do most supported operations
- Any operations that get enqueued during this time are automatically blocked ONLY on the event channel

Animation Event Handling (Renderer)

- We add barriers for each event channel, along with the per-actor barriers
- We remove these barriers when the event is actually fired in the animation system
  - All event-blocked operations are handled synchronously
- The renderer does handle SOME events natively
  - Simple sound events, one-shot FX, etc.
  - The simulation dictates everything else

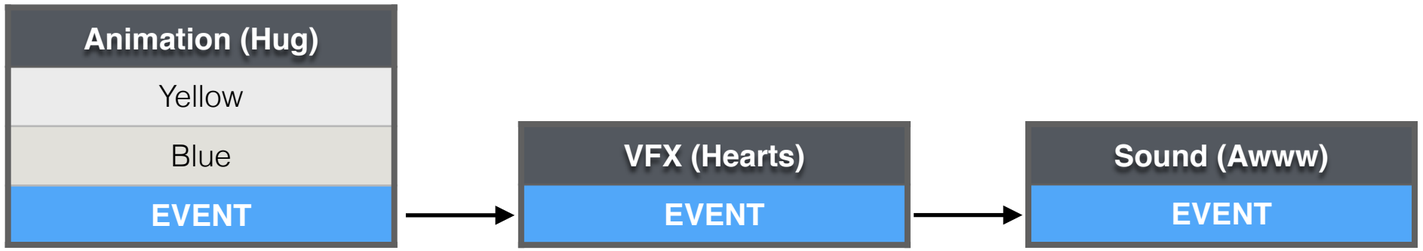
Event Handling



Event Handling

Animation (Hug)
Yellow
Blue

Event Handling



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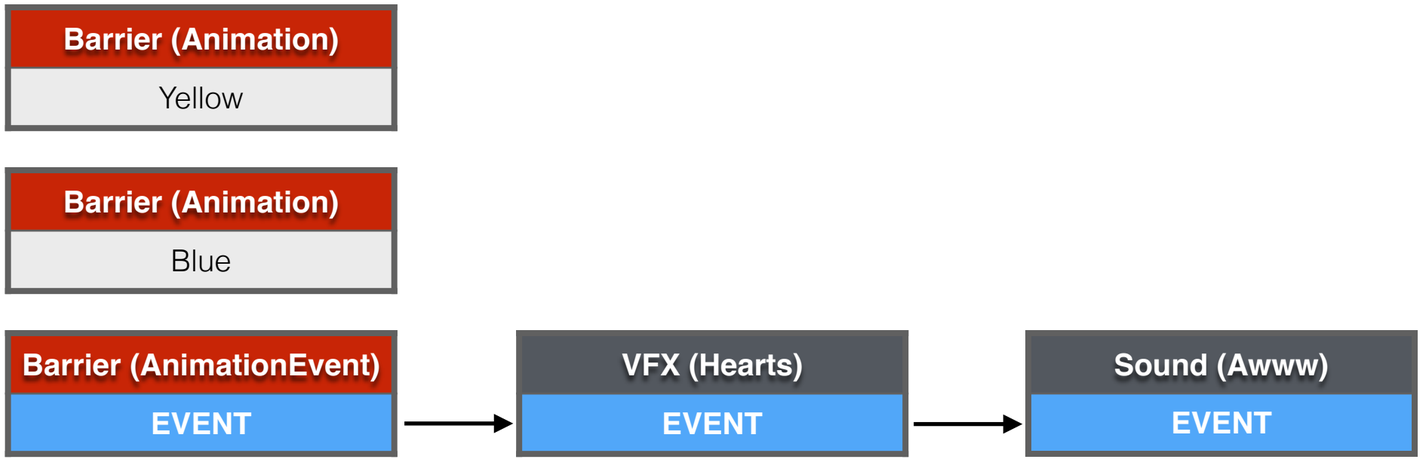

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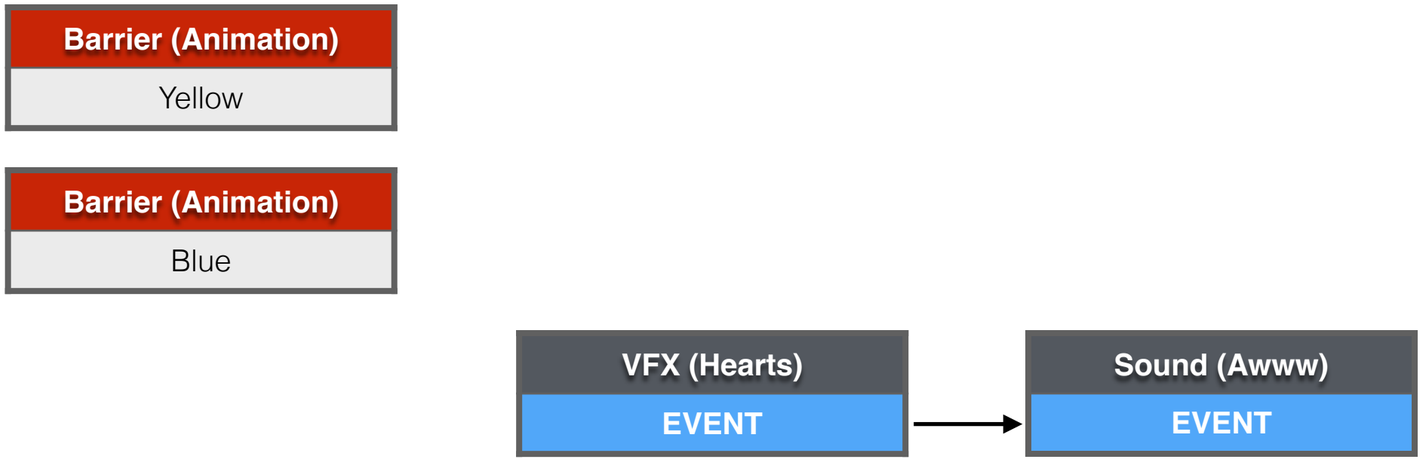

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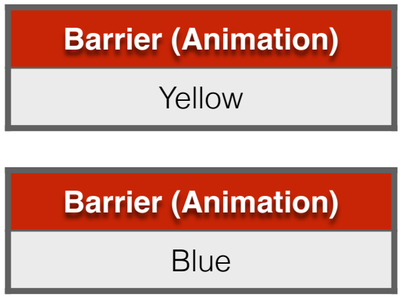

Issues

Nothing's perfect

Complexity

- Decoupling adds a fair amount of complexity to feature implementation
- Requires implementing simulation-side and renderer-side functionality to support a feature
  - This may sound familiar to some of you…
- Careful design of which Operations you support can mitigate the issue
  - The more re-usable/composable the better

Managing Desync

- Transient desync is okay (and expected)
- Excessive, persistent desync is not
- For ops that take time/create barriers...
  - Timestamp
  - Scale
  - Interrupt/Skip
    - Work with your content partners to come up with visually appealing “filler”

Managing Desync

- Many of our interactions involve interruptible looping content that runs on the simulation for a tunable amount of time, which is time we can get back when necessary
- We do the vast majority of our “catch up” during route following, where we have a variety of good looking options for recovering the drift
- In hard to manage cases, the renderer can talk back to the simulator to limit desync
  - Effectively implements a “re-sync” on certain operations

Debugging

- The most common trap that catches people when working with this system is inadvertently creating operations whose blocking channel sets do not match the actual behavior in the simulator
- This manifests as…
  - Operations happening too early, or “out of order”
  - MASSIVE desynchronization due to operations being serialized on the renderer, but not on the simulator

Debugging

- Having good debugging tools is a big help here
- Our toolset consists of…
  - A timestamped simulation side log of all operations and their channels sent to the renderer
  - A cheat command which outputs the current contents of the queue (all pending operations/barriers and their associated channels)
  - Between these two, we can pretty easily reconcile discrepancies and problems without having to touch the debugger

Other Applications

Dynamic Cutscene Sequencing

- Allow for in-gameplay cutscenes
- No need to interrupt in-progress behaviors
- No need to warp actors at synchronization points
- Could run in parallel to regular gameplay

Latency-Tolerant Online

- Our approach could be used to build online games where sequences are more important than sync
  - Probably excludes MOST competitive games
- Can scale down to very tight synchronization, so long as operations know how to scale/sync themselves
  - Relatively straightforward, with some visual degradation

Summary

Summary

- Allowing for variable time shifting has given us the flexibility to decouple completely, while retaining the “look” of The Sims
  - Sequences are preserved
  - Individual steps are shortened or skipped, but only when we’ve specifically allowed it

Summary

- Decoupling our simulation and renderer has allowed both systems to deliver a higher quality experience
  - Rendering frame rates are more predictable
  - The simulation is allowed to do the work it needs to, when it needs to

Summary

- Having a robust multi-actor sequencer that supports dynamic behaviors is broadly applicable
- Applicable to any scenario where…
  - Sequentiality is important
  - Multiple actors are involved and are sometimes synchronized
  - Simulation runs separately from rendering

Q&A

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