Near-exhaustive Precomputation of Secondary Cloth Effects

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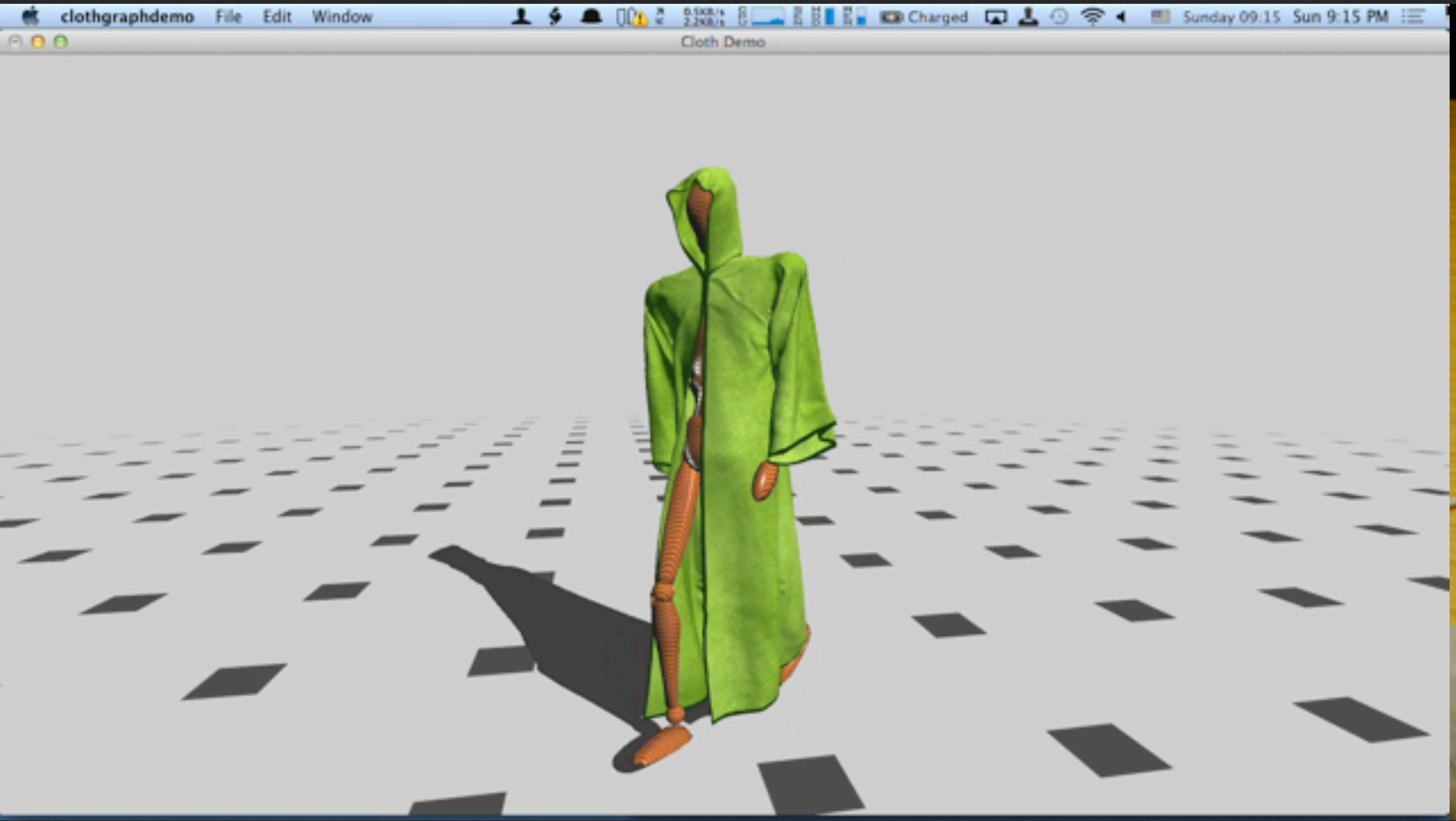
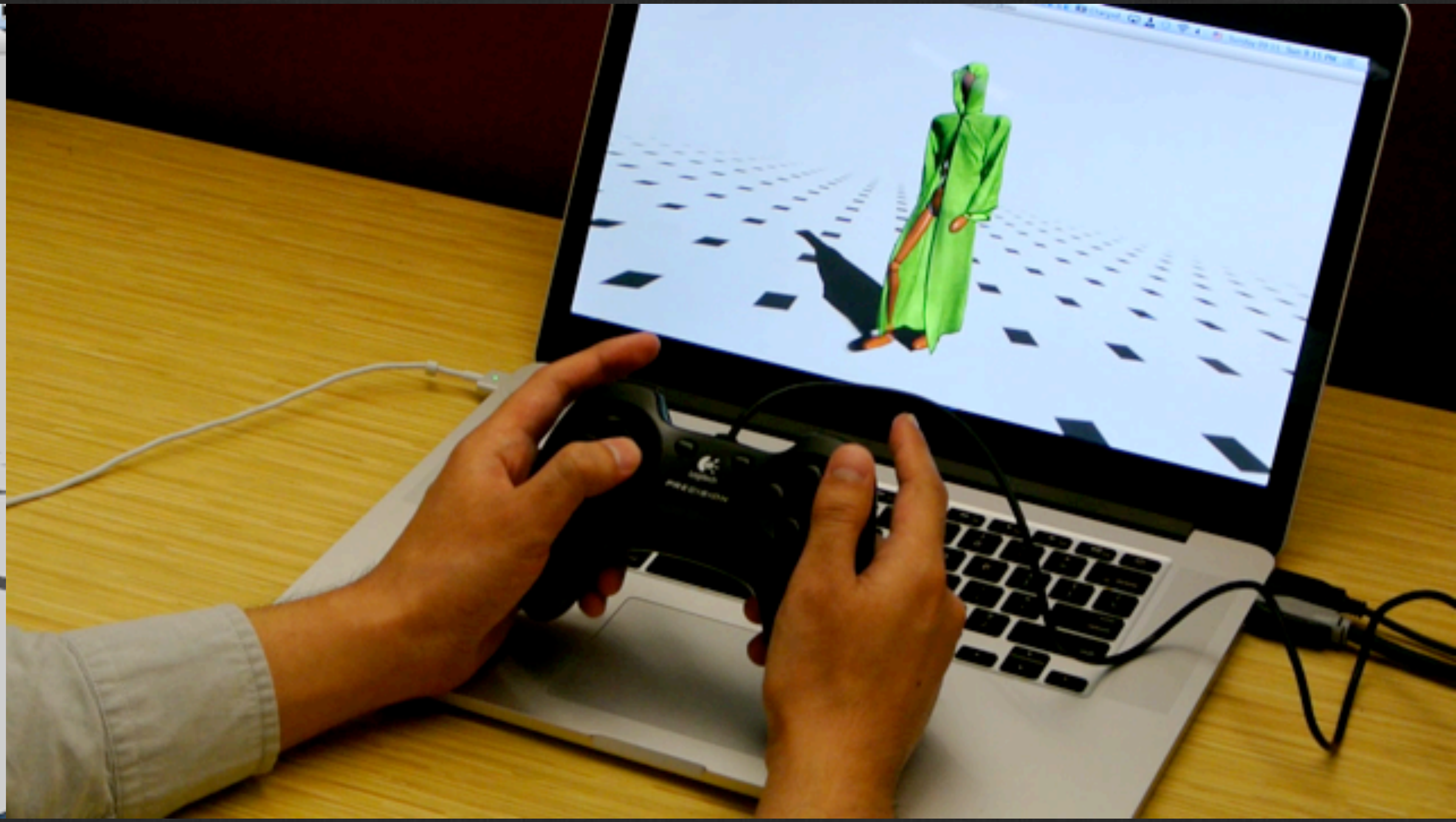
SIGGRAPH2013

Real-time Cloth Animation Made Possible by Near-exhaustive Precomputation





29,654 vertices cloth mesh
4,550 CPU-hours of precomputation
66 MB run-time footprint

Data-driven Simulation

Run low-res simulation and add detail

- Wang et al. 2010, Kavan et al. 2010, Feng et al. 2010

Model reduction

- Treuille et al. 2006, Wicke et al. 2009

Tabulate the dynamics

- James and Fatahalian 2003

Curse of dimensionality

- System under very controlled settings
- Low resolution / limited quality

Wang et al. 2010

Treuille et al. 2006

James and Fatahalian 2003

Leverage modern scale computing system to solve really hard problems

- Computer vision, speech recognition, machine translation, etc

May not be possible to have *everything*, but possible to have *almost* important data

- Halevy and Norvig, “The Unreasonable Effectness of Data”, 2009

Goals

High-quality cloth animation on a human character

- As good as any off-line simulator

High-performance real-time implementation

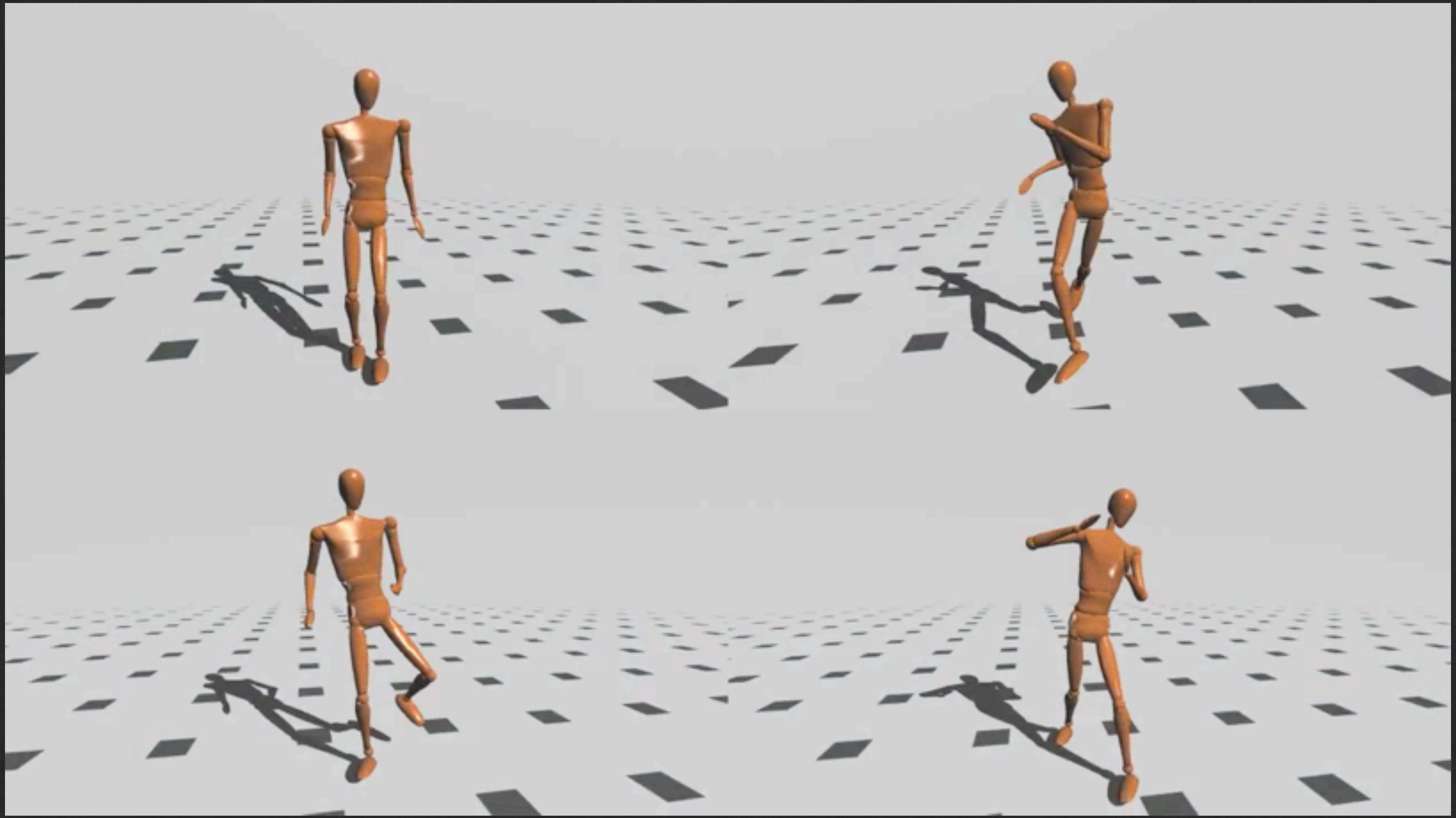
- Real-time execution on resource-constrained devices

Approach

- Leverage massive-scale precomputation to explore space of cloth dynamics
- Compactly represent the result of precomputation in a motion graph

Representing Cloth Dynamics

Input: Traditional Motion Graph

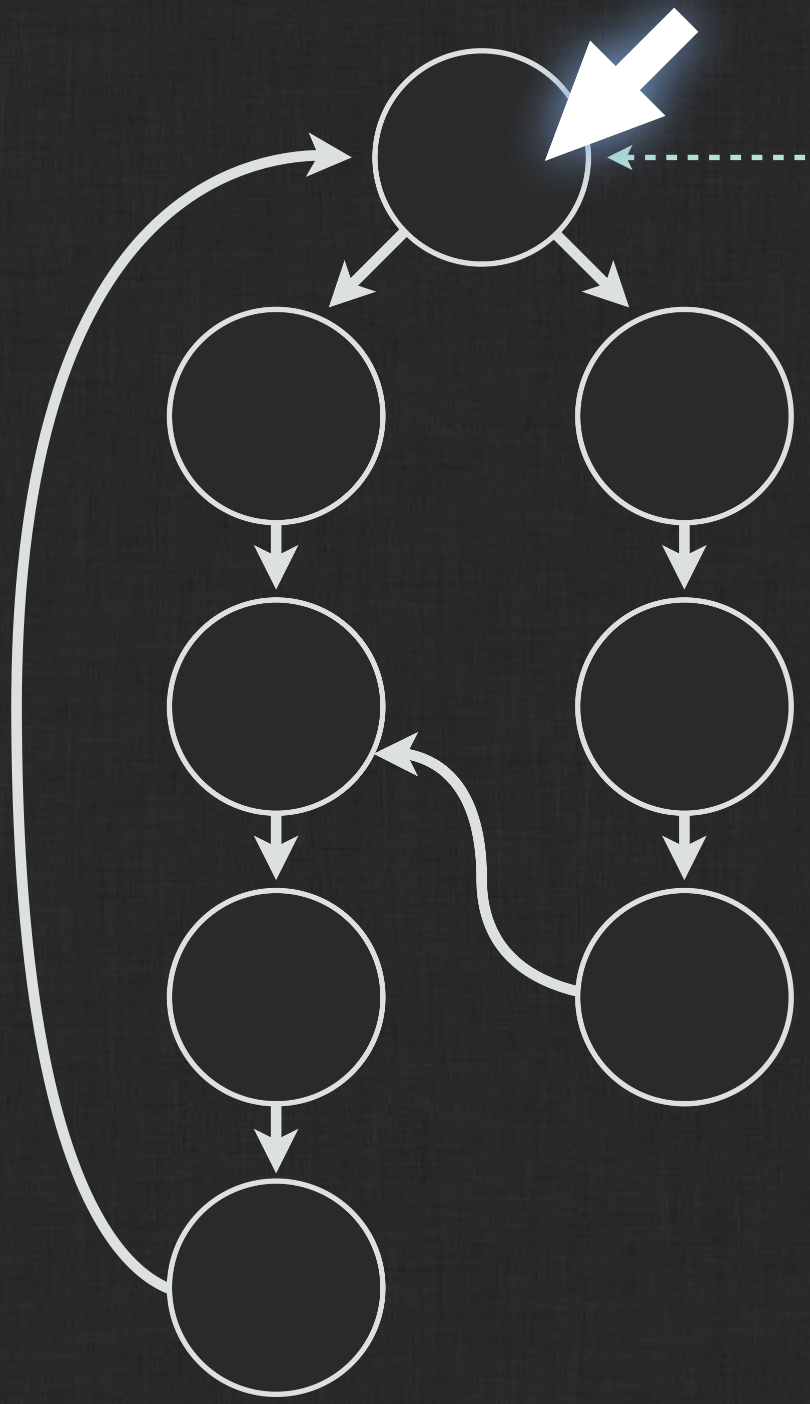


12 motion capture clips

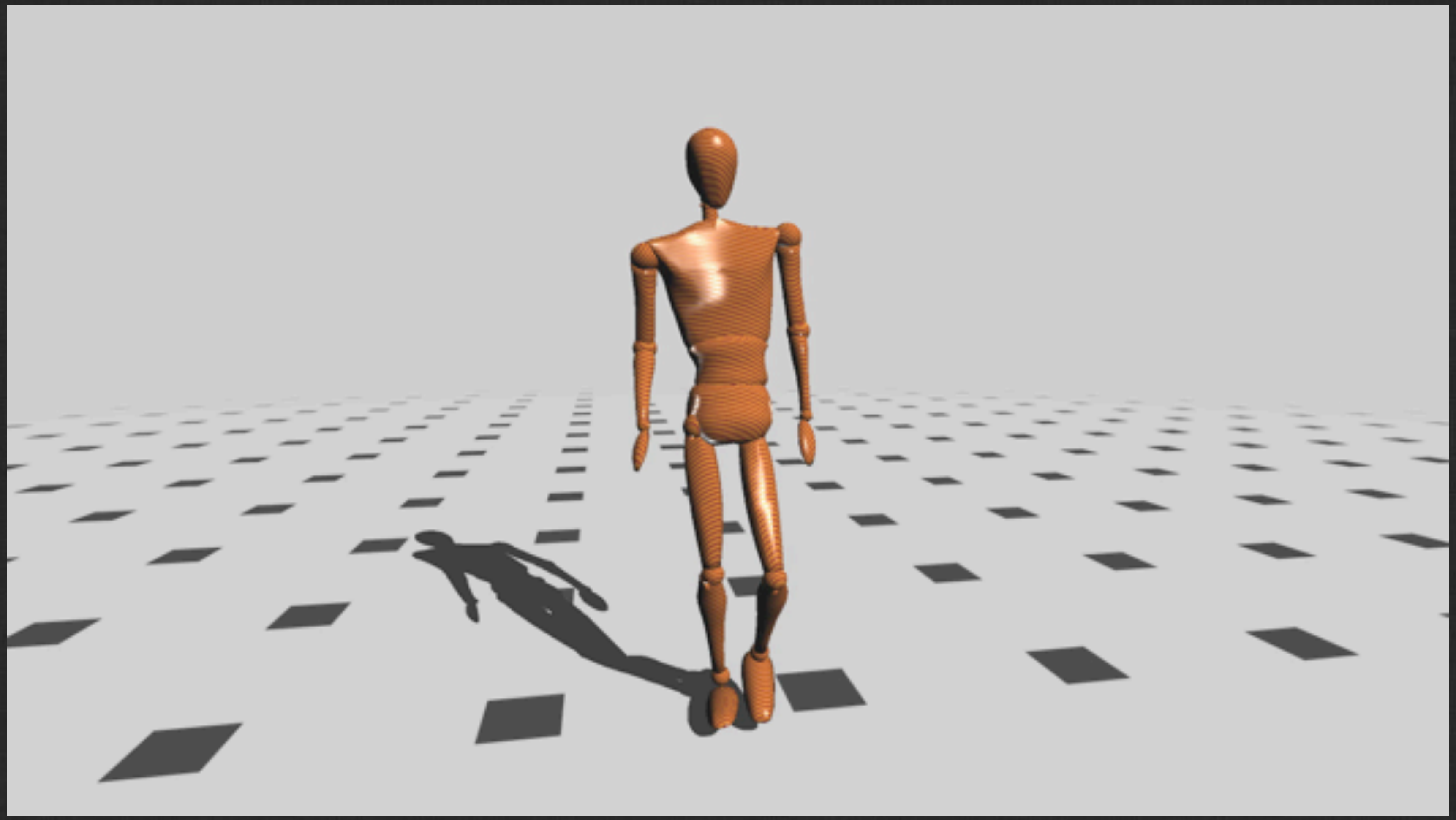
3,115 frames

Source from HDM05

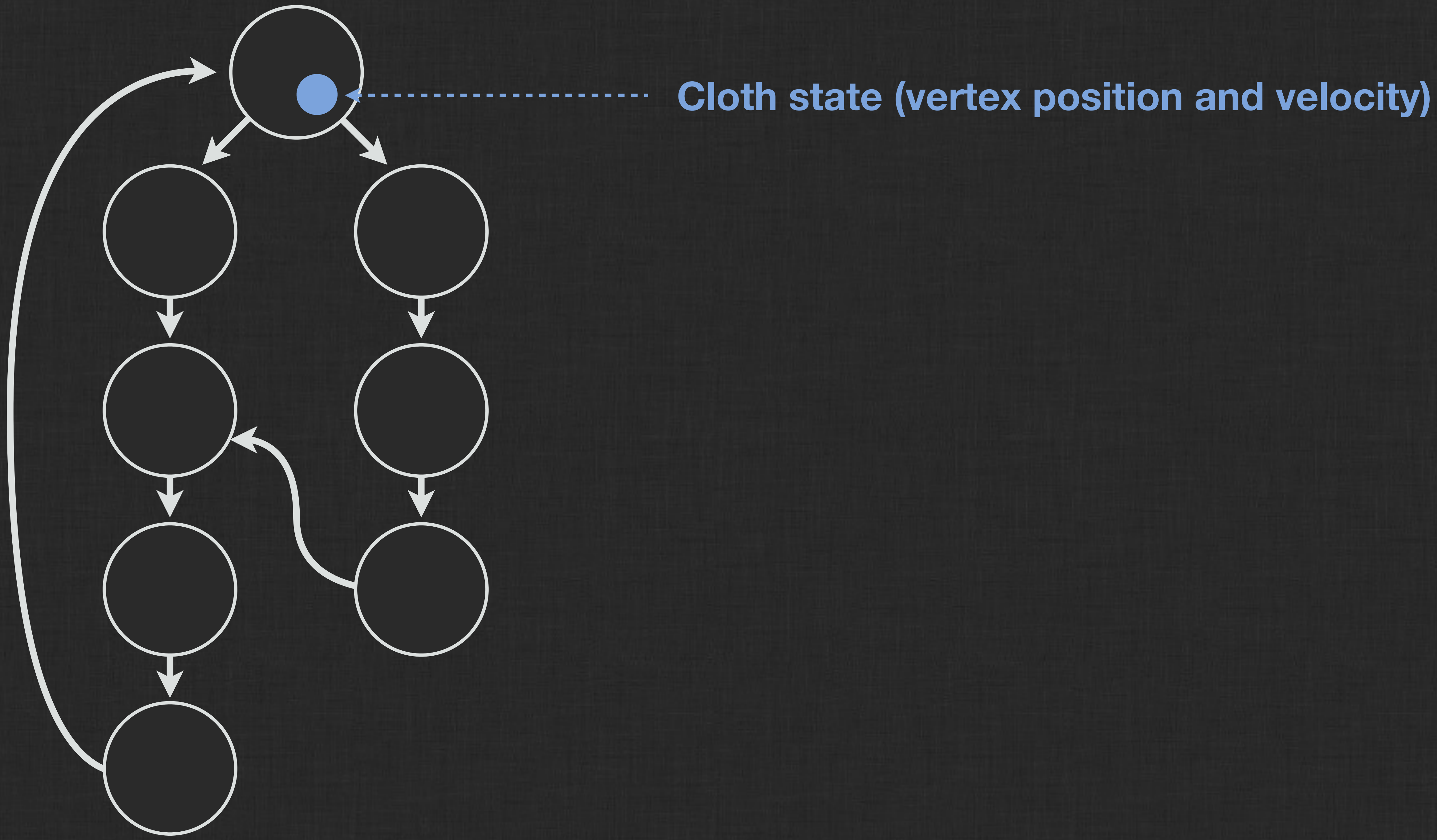
Primary Motion Graph



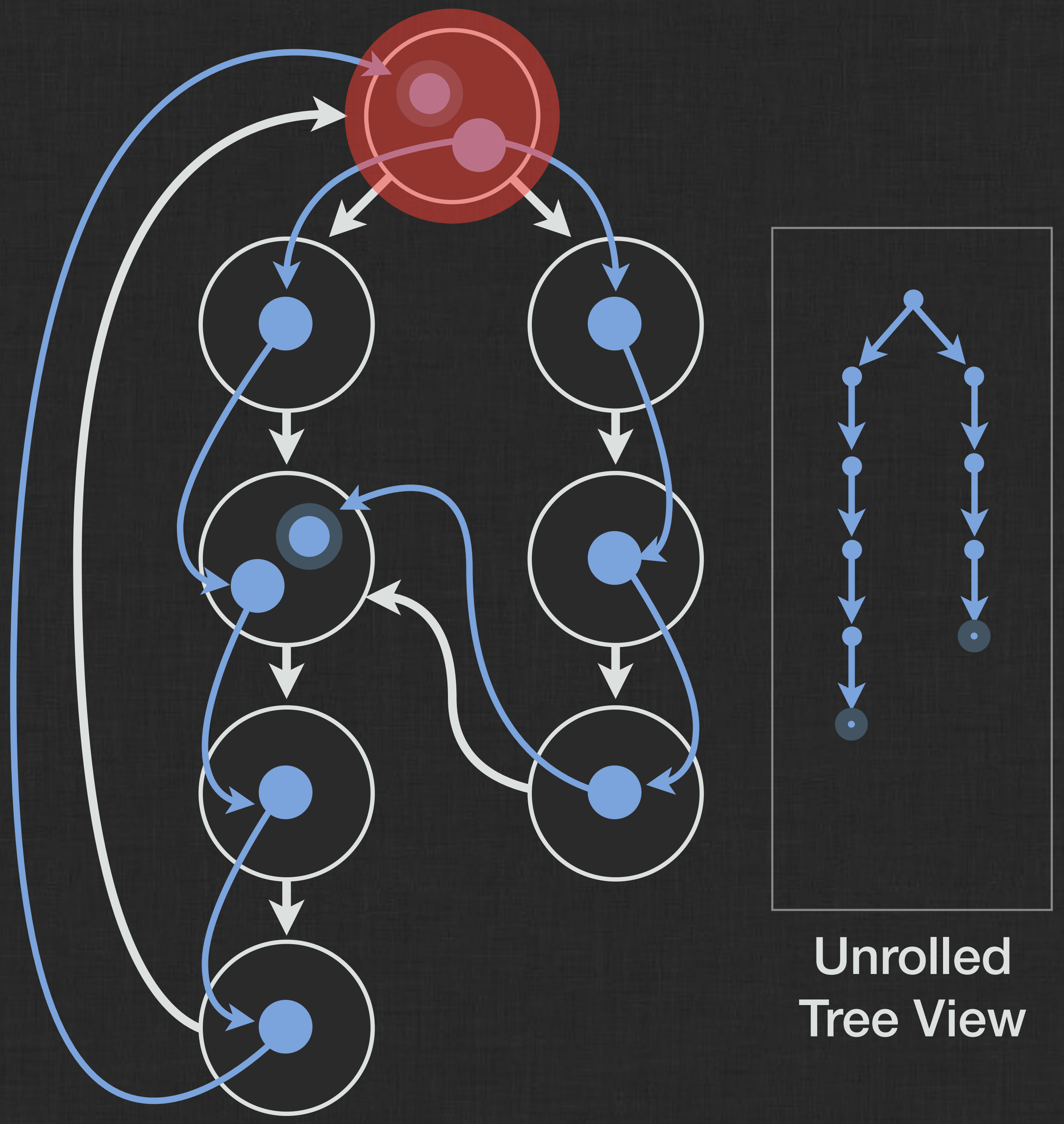
Character Skeleton Pose State



Secondary Cloth Motion Graph

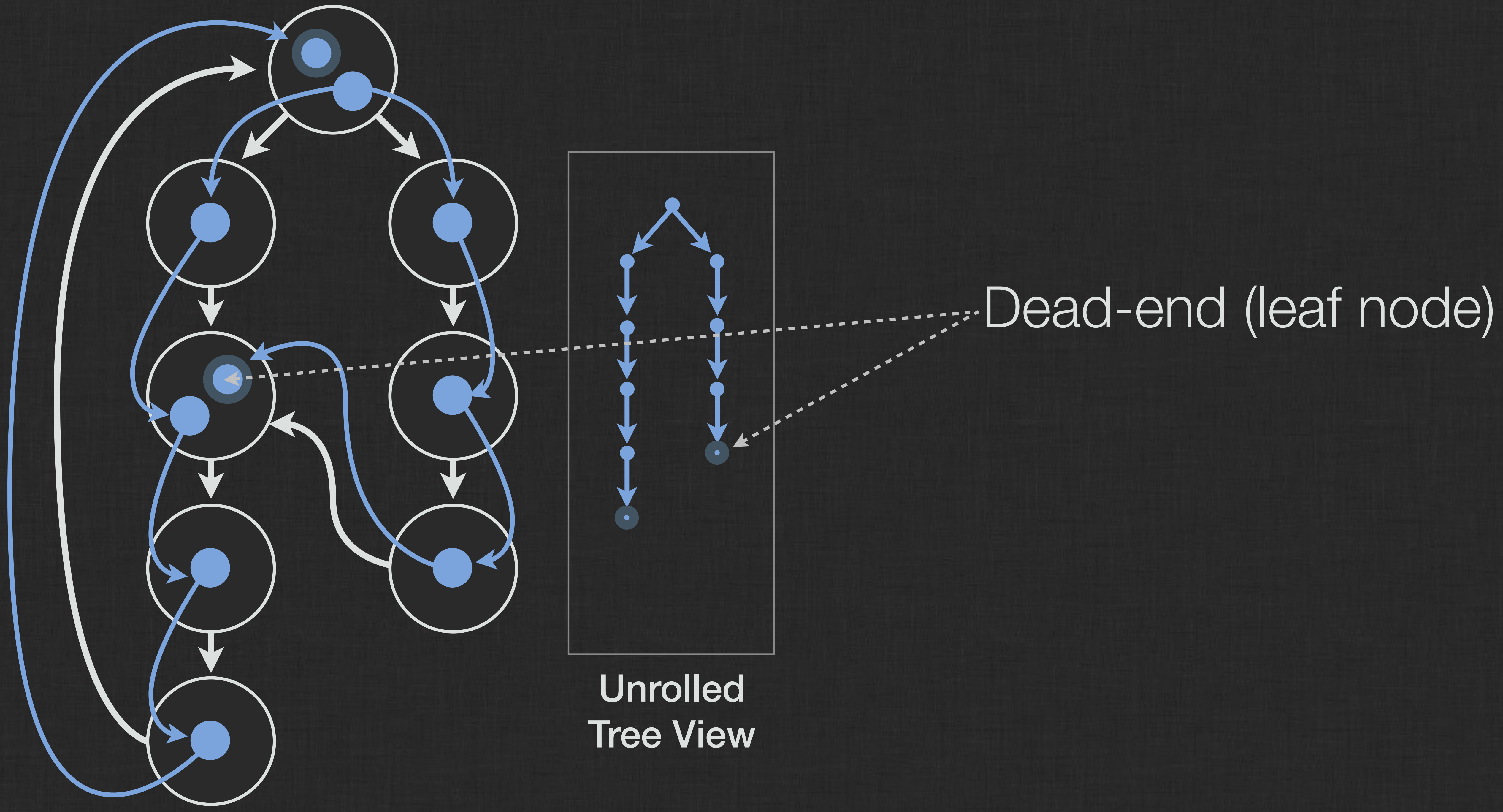


Secondary Cloth Motion Graph

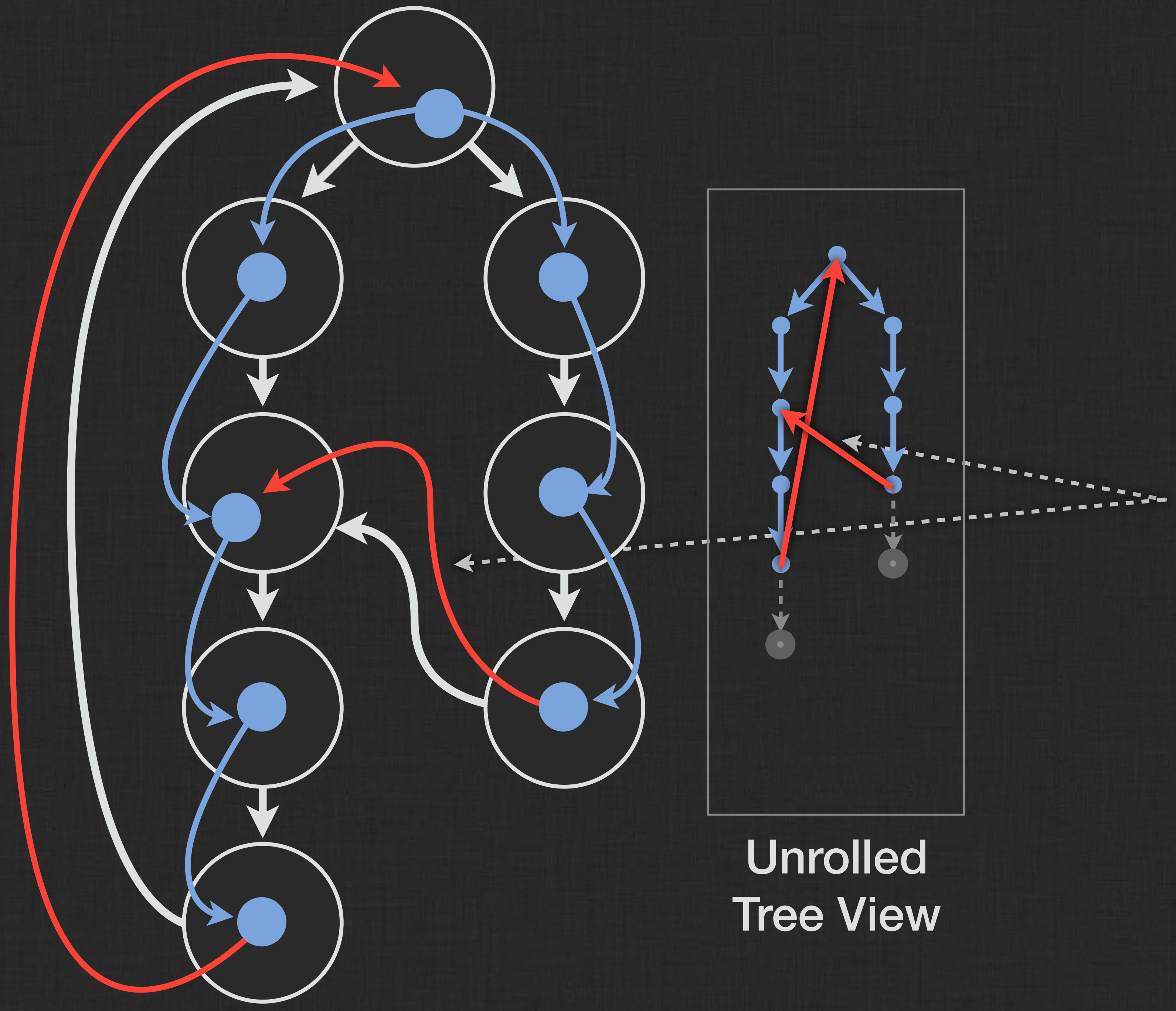


Unrolled
Tree View

Secondary Cloth Motion Graph



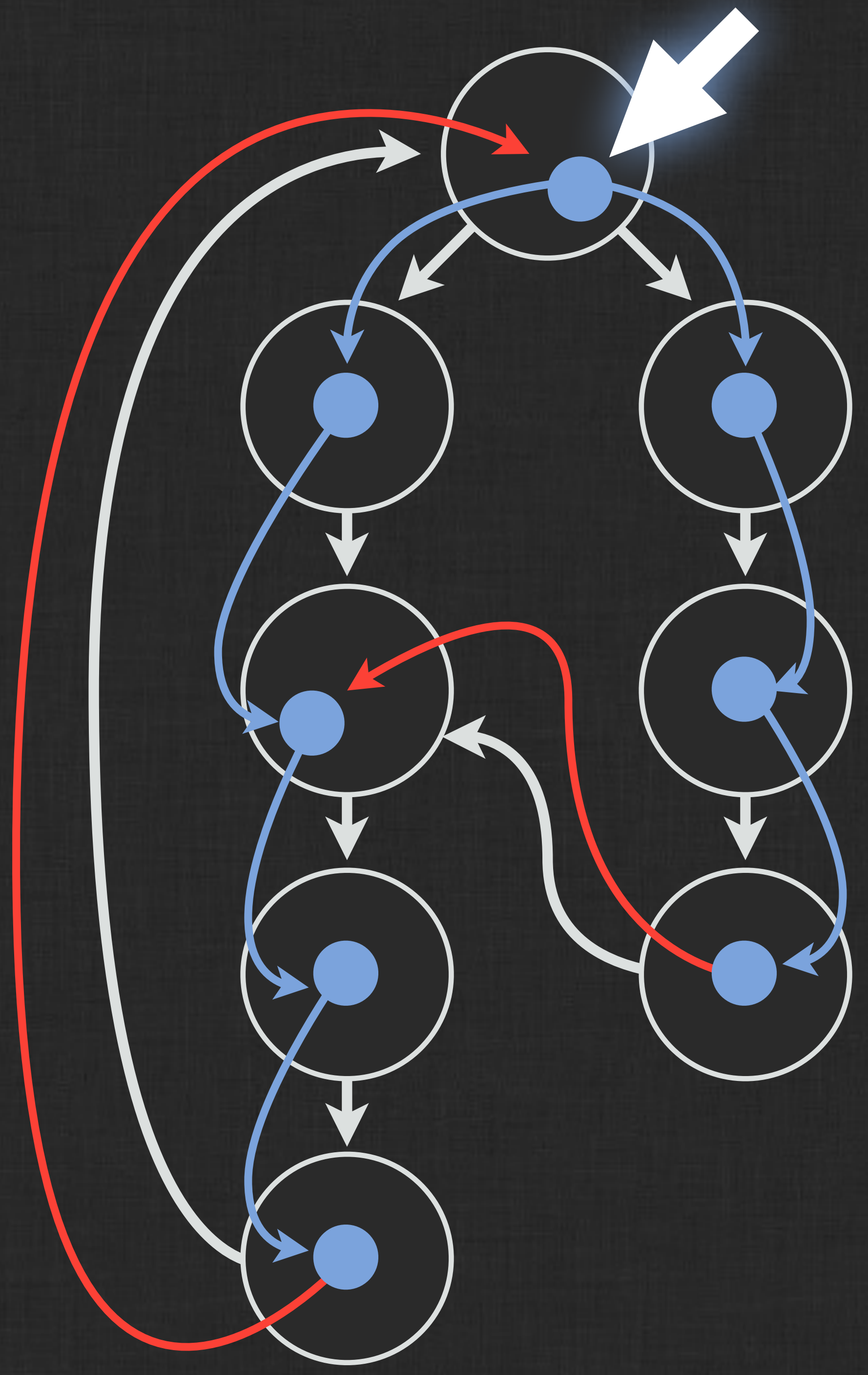
Secondary Cloth Motion Graph



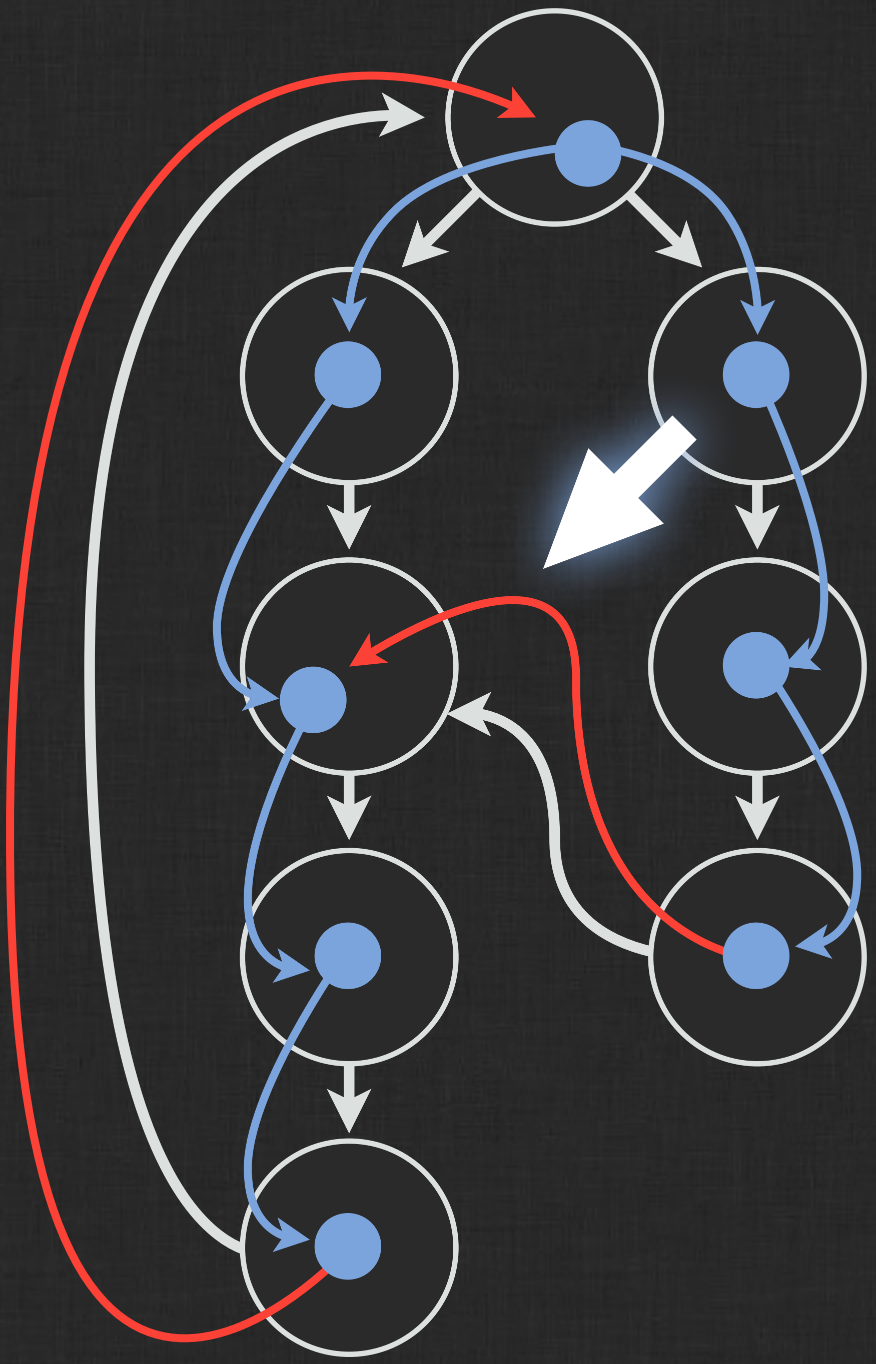
Back-links

Find the closest neighbor node in same primary state. If found, merge by adding back-link.

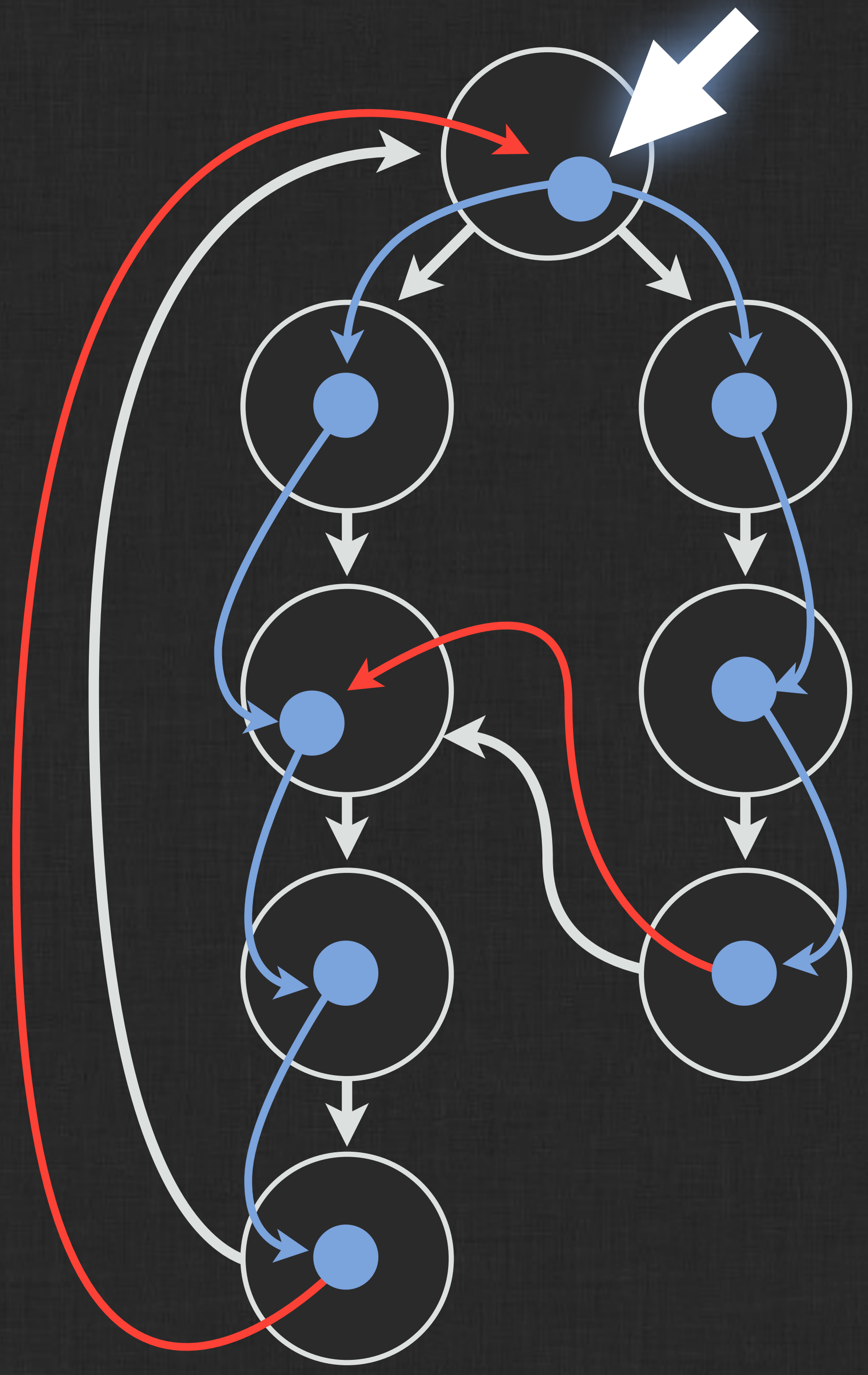
No Back-link Blending



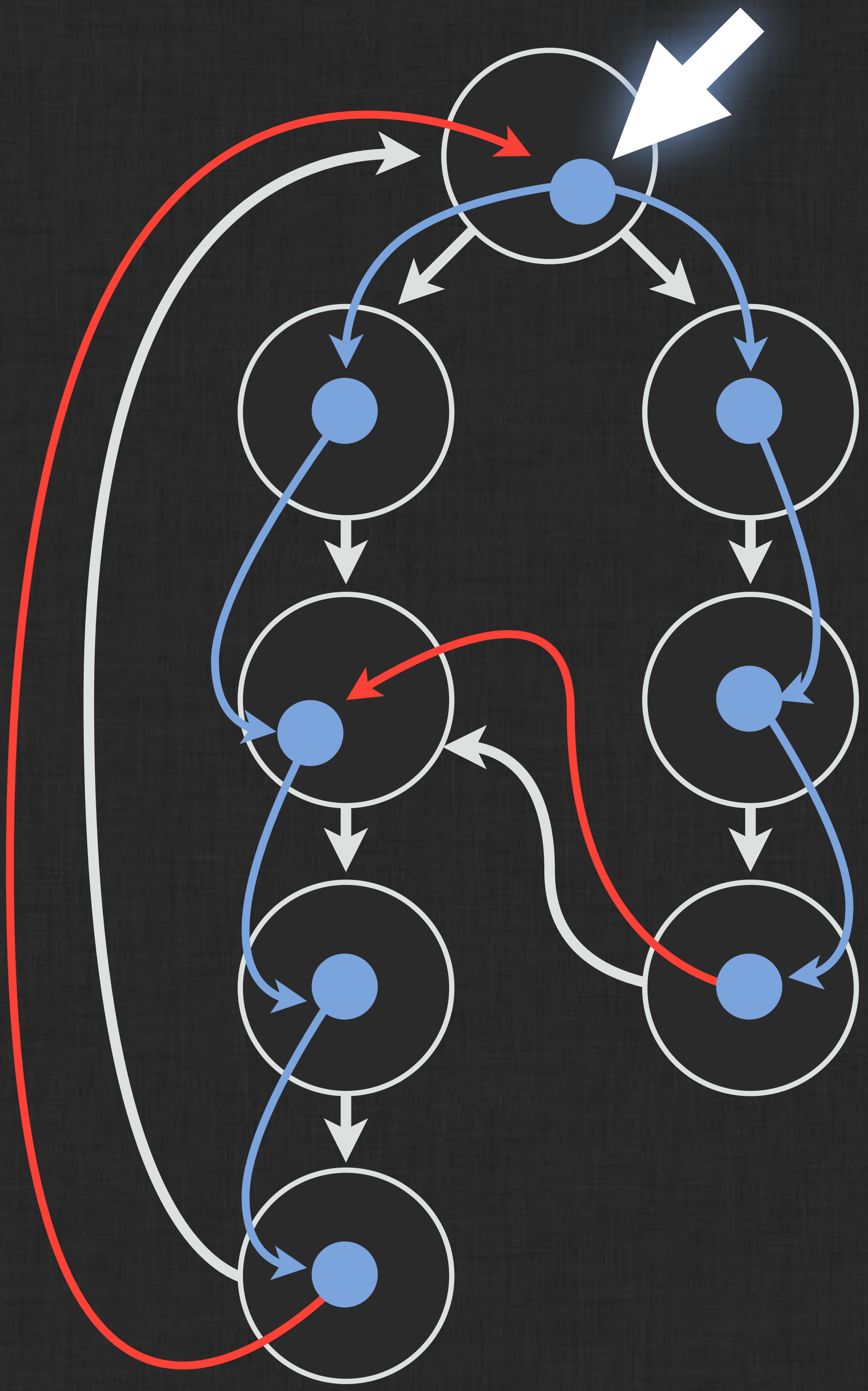
No Back-link Blending

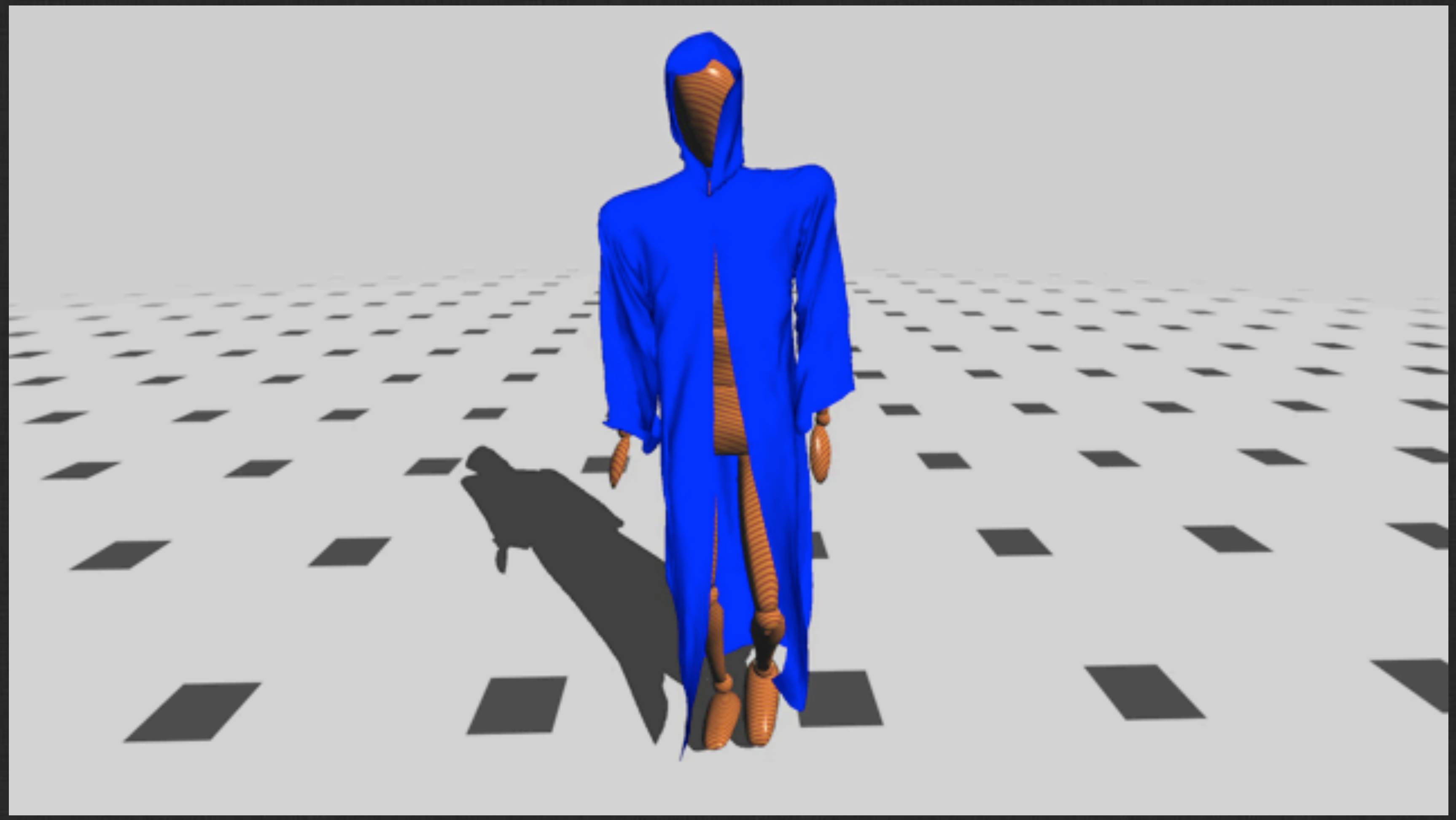


With Blending

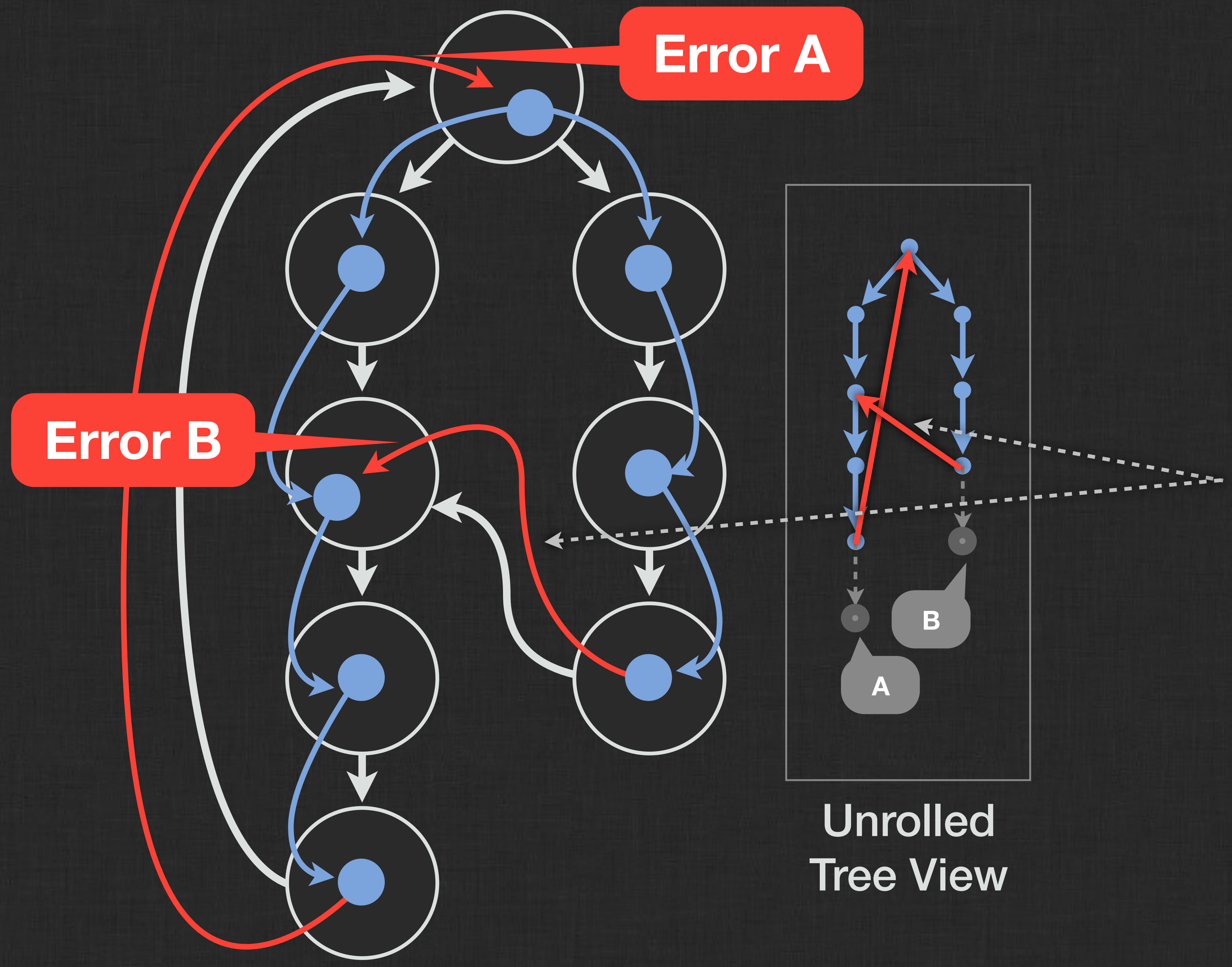


With Blending + Error Visualization





Secondary Cloth Motion Graph



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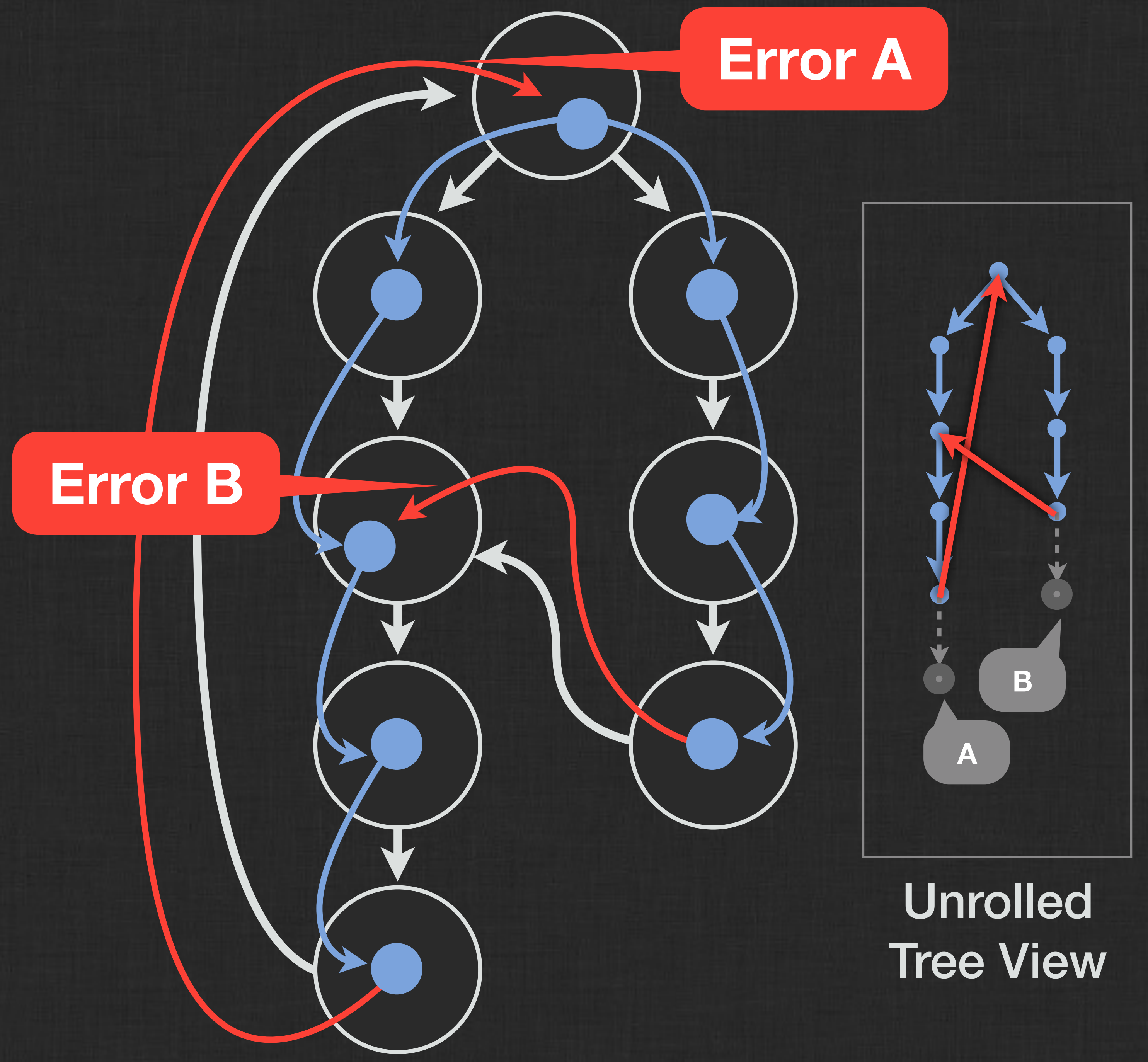
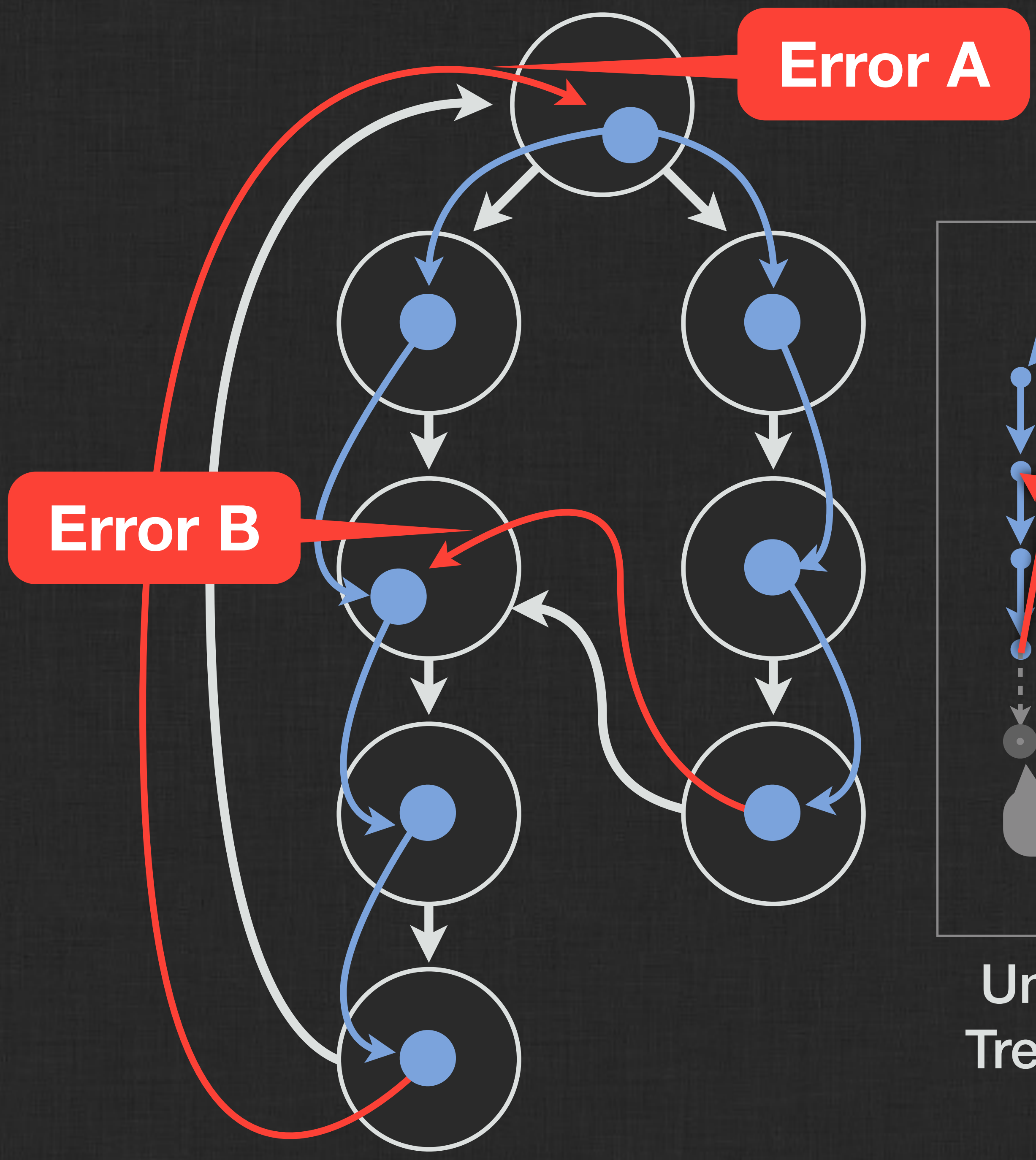
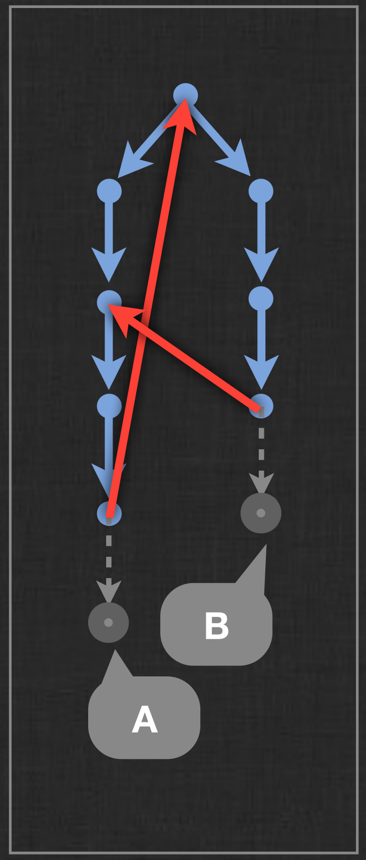
Secondary Graph Expansion



Continually run additional simulations to remove largest errors in secondary graph

Secondary Graph Expansion





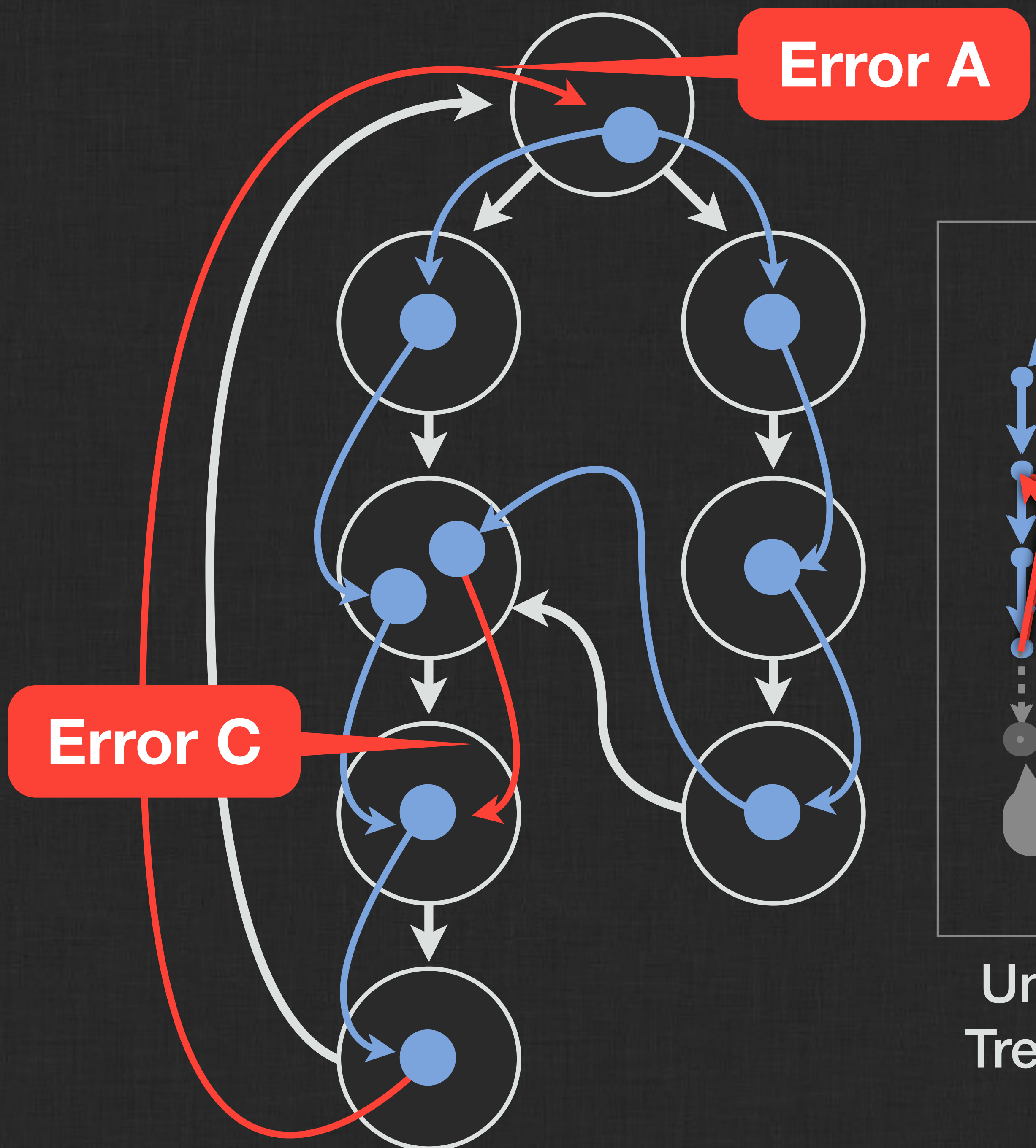
Unrolled
Tree View

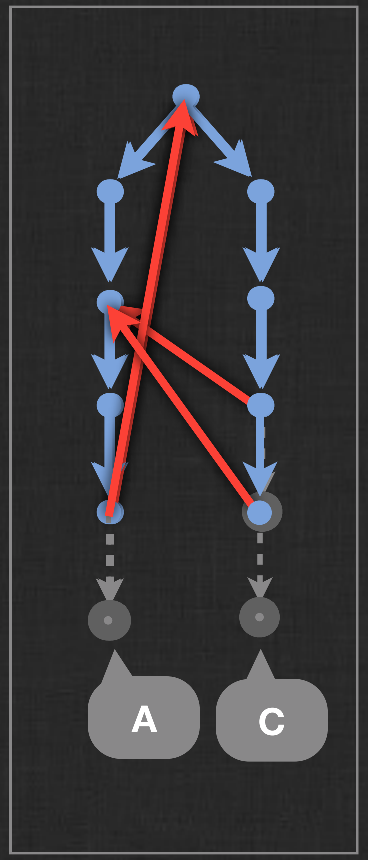
Simulation Work Queue

Sort the order of the dead-ends based on the merge error.

A : Sim. work to extend from node A

Secondary Graph Expansion



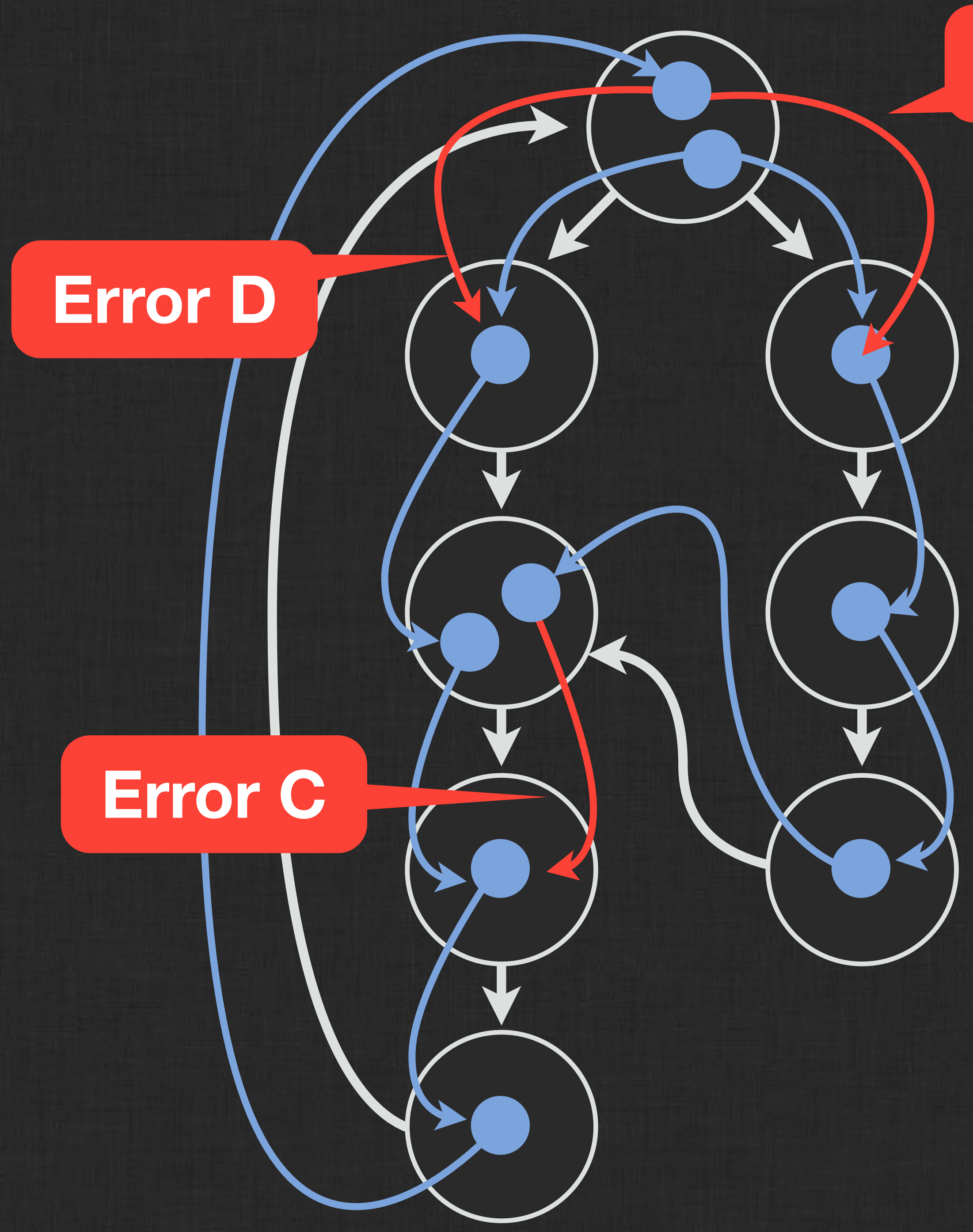


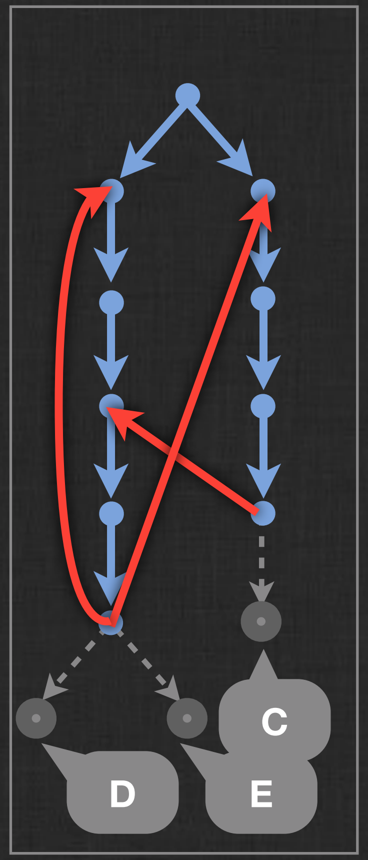
Unrolled
Tree View

Simulation Work Queue

Sort the order of the dead-ends based on the merge error.
Then, pop-out the highest-error node and extend the graph.

Secondary Graph Expansion





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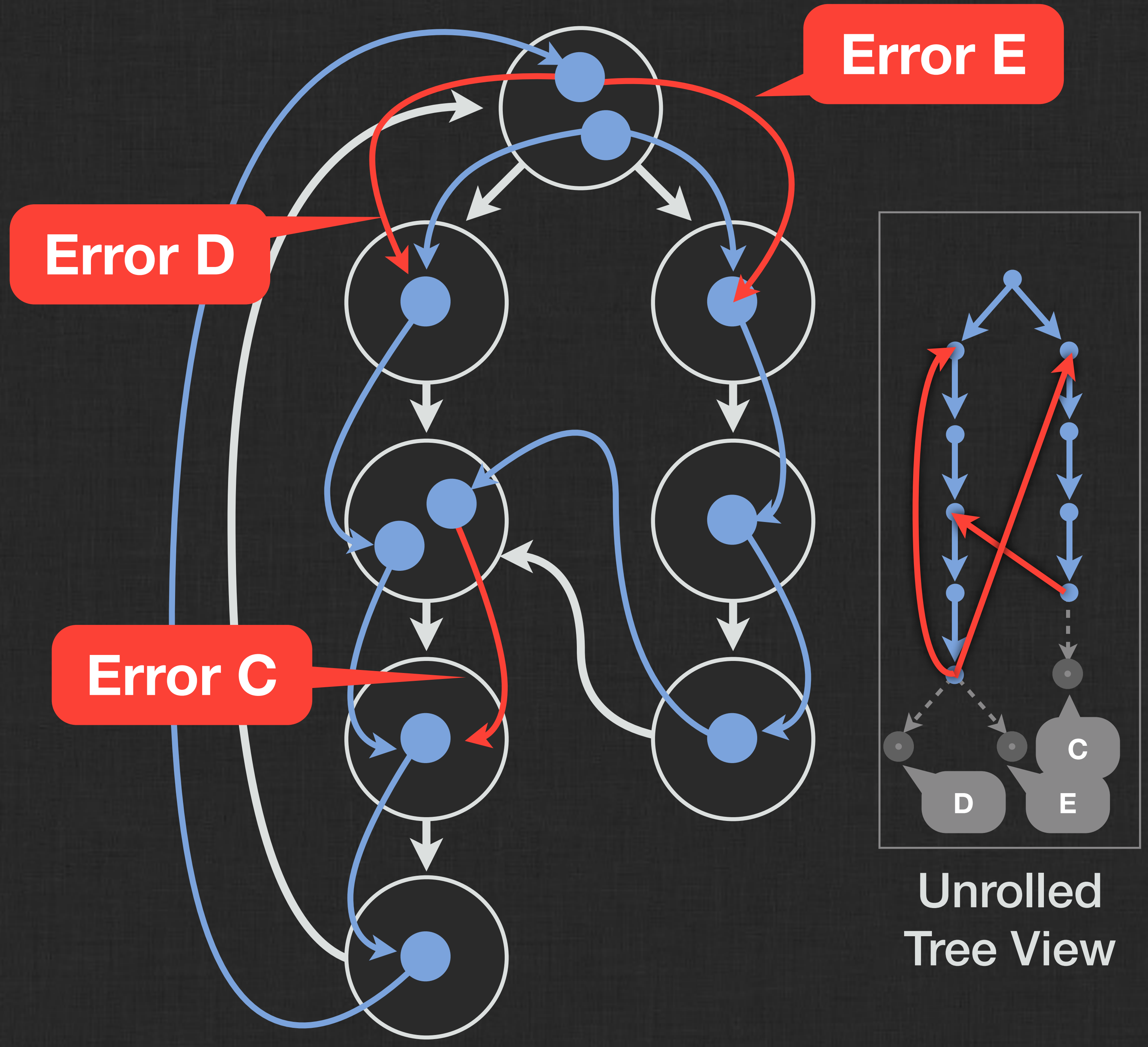
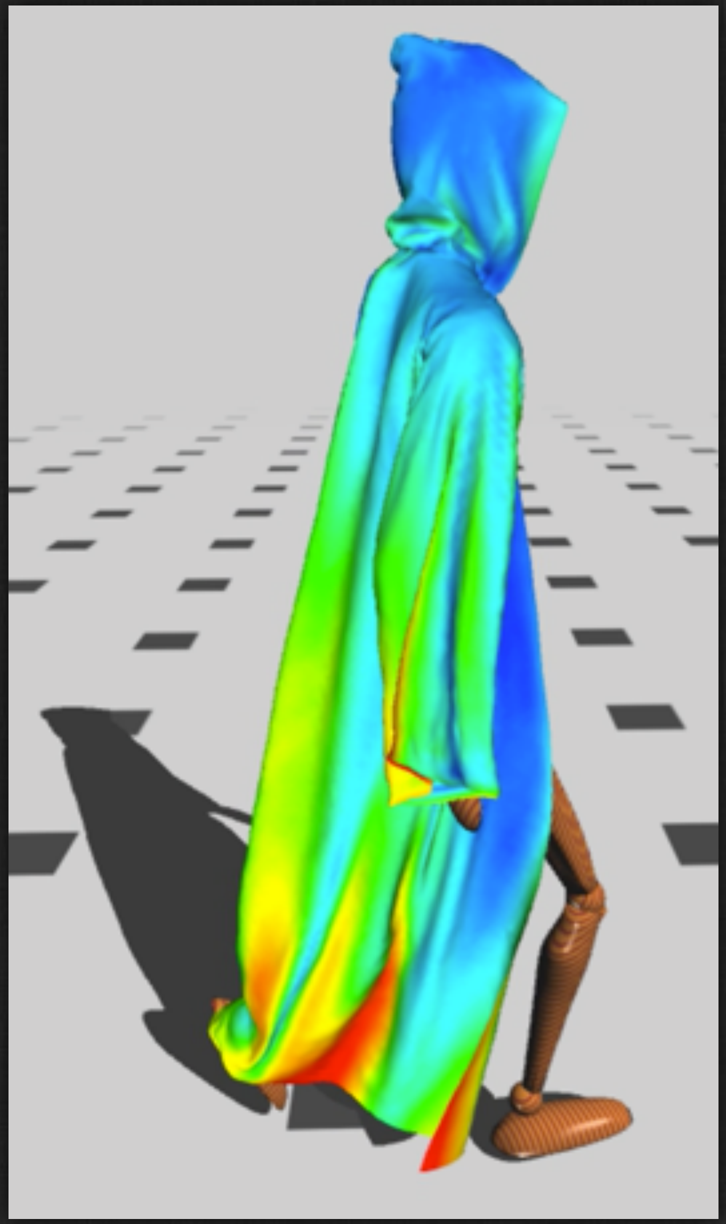
Quantifying Transition Error

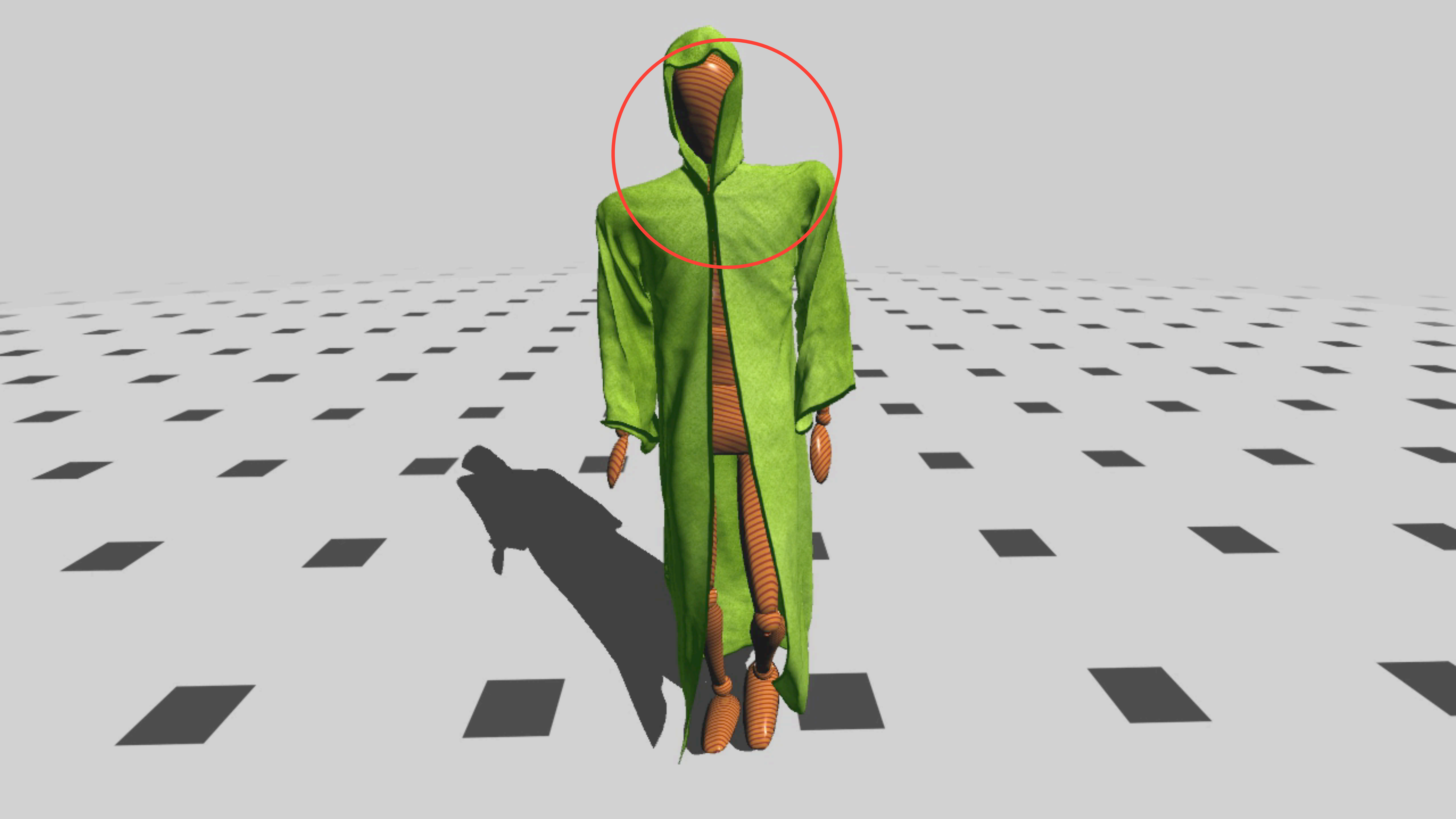


Unrolled
Tree View

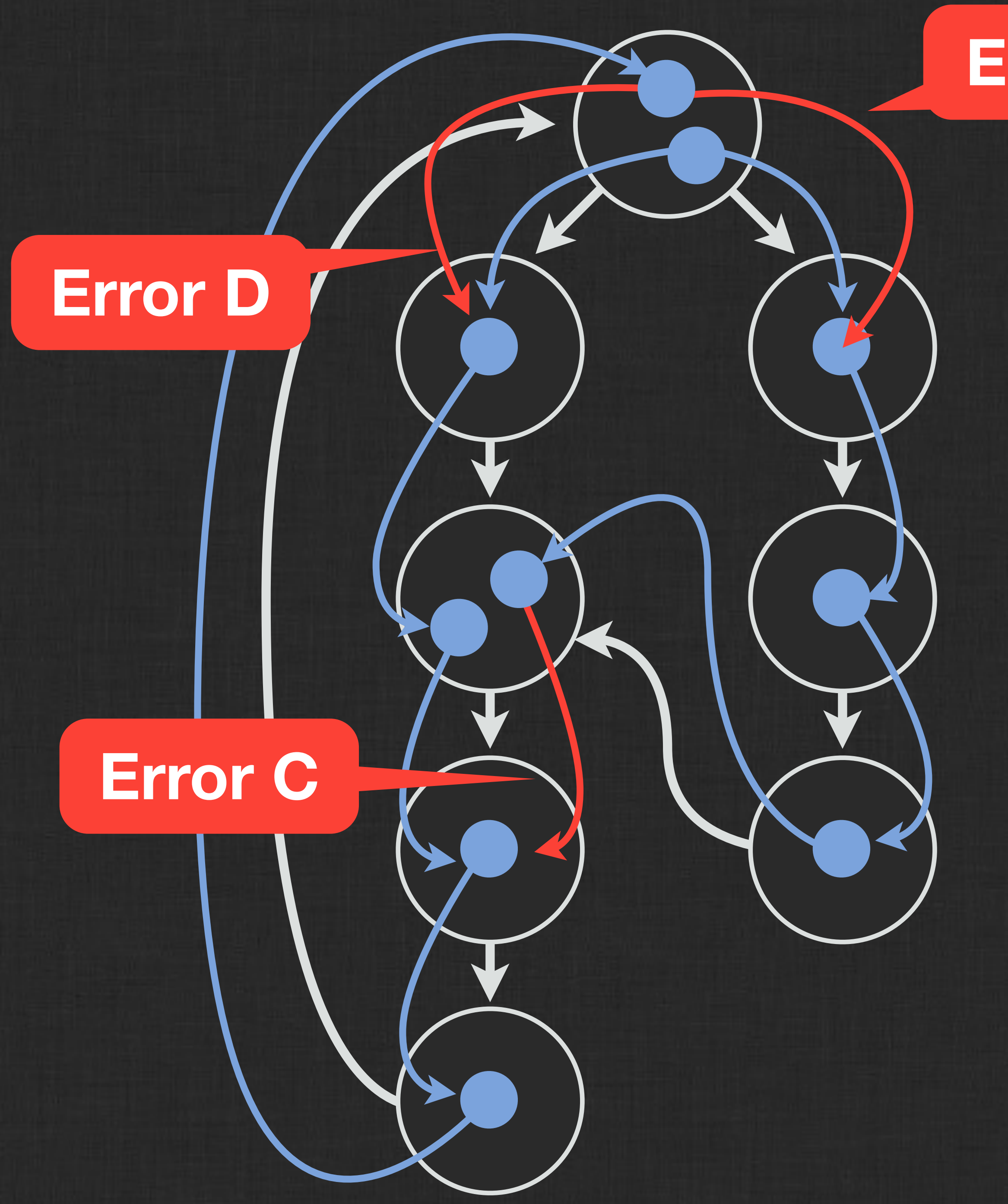


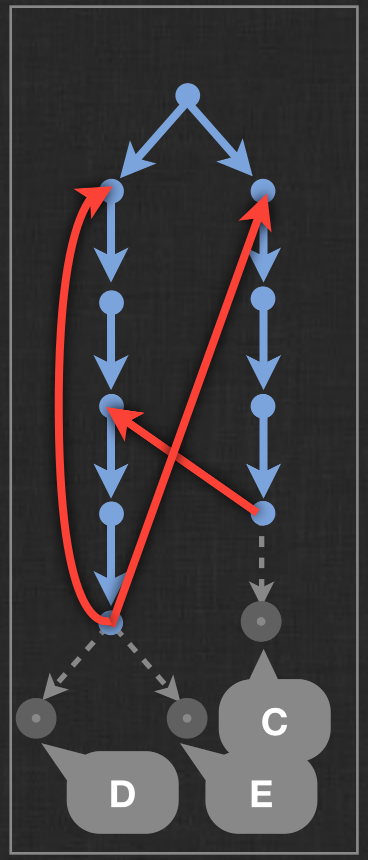
Error Function

Max vertex position + time-scaled velocity difference



Geometric + Custom Error Metric

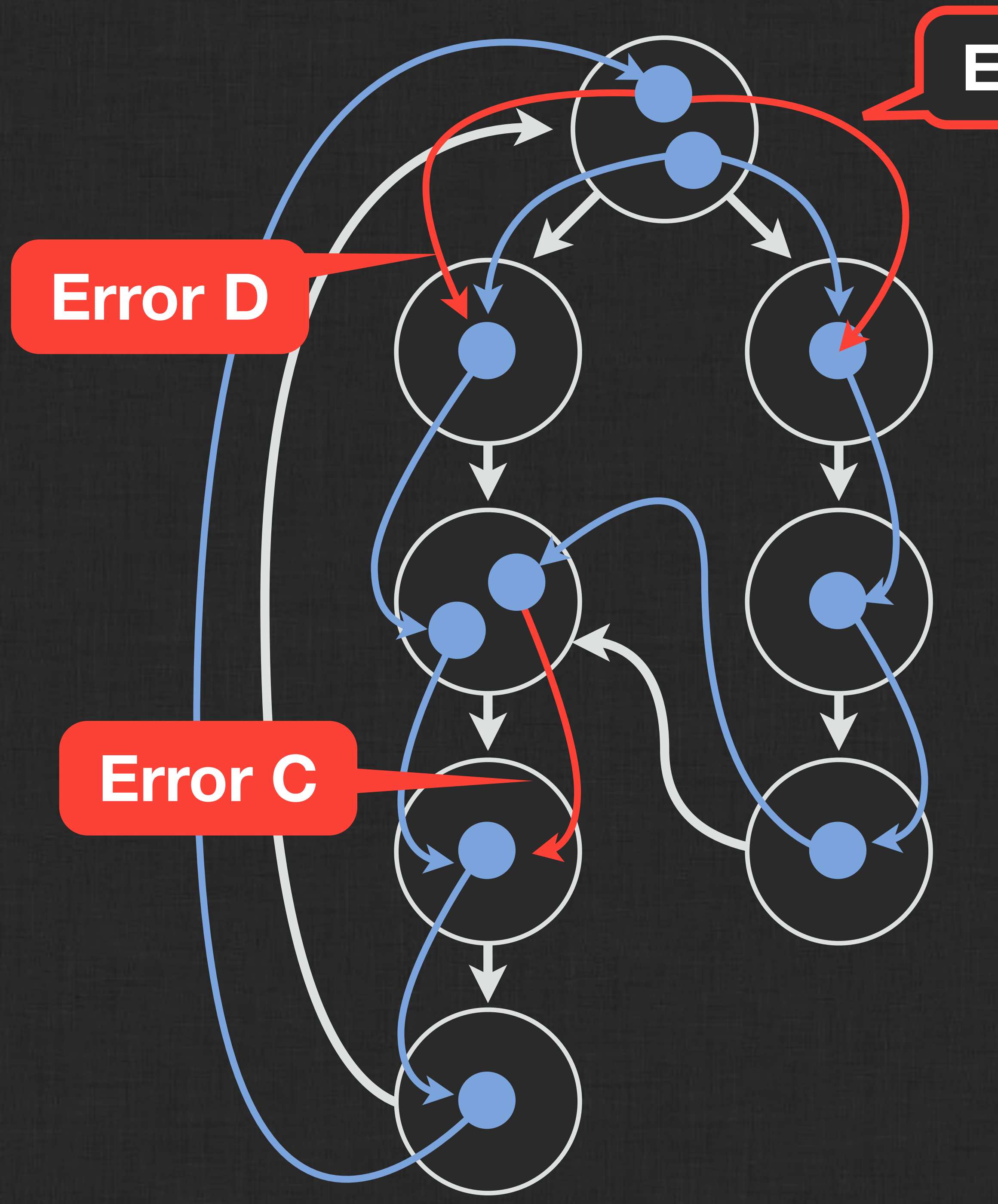


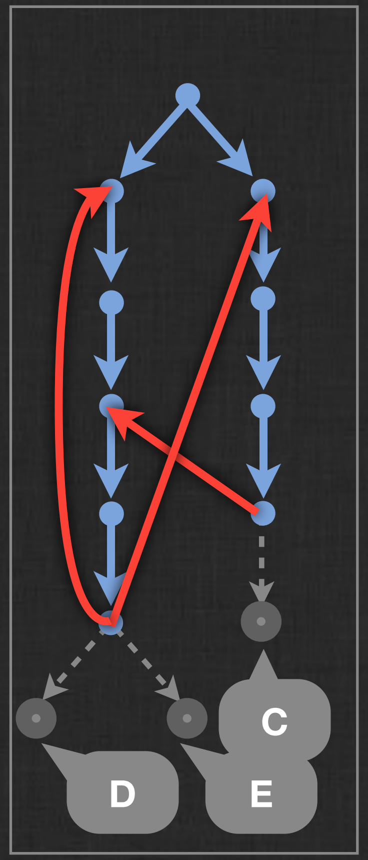


Unrolled
Tree View

D E C

Geometric + Custom Error Metric





Unrolled
Tree View

Classification

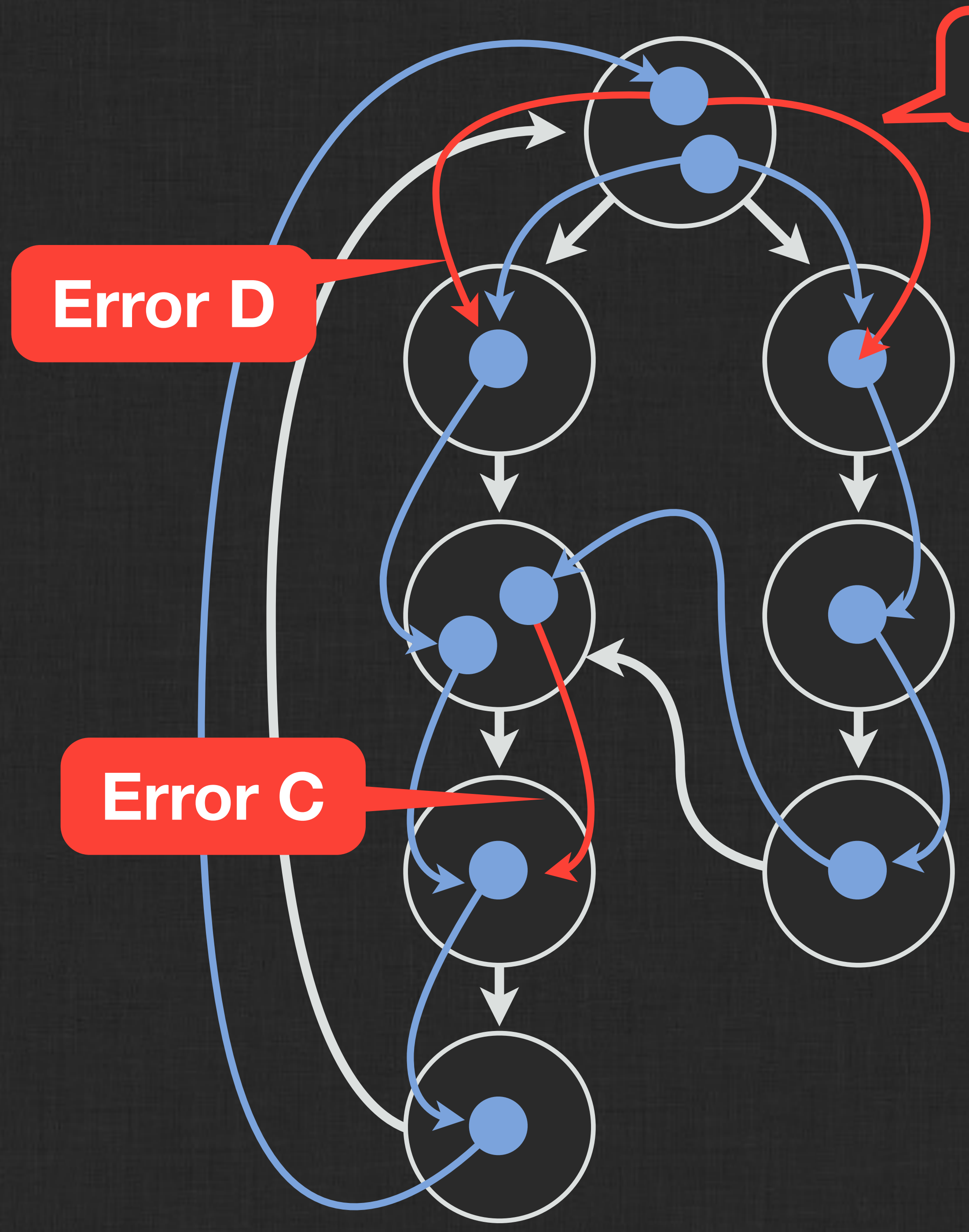
We can categorize the states with arbitrary metric, such as hood's state. For example, E is merging two different state of the hood (up and down).

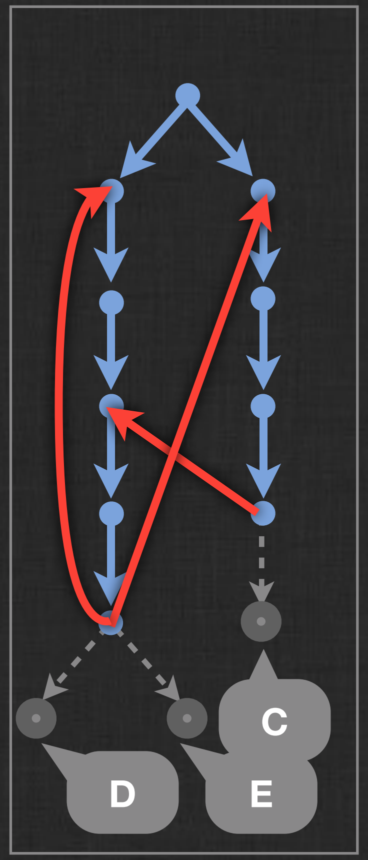

225 CPU-hours
4,906 Frames


1,653 CPU-hours
36,073 Frames


4,554 CPU-hours
99,352 Frames

Geometric + Custom Error Metric





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Tree View

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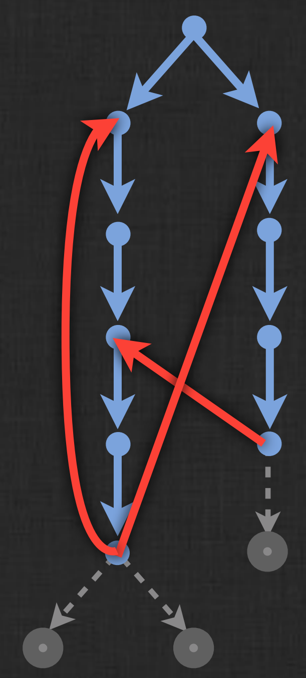


Colored Edges

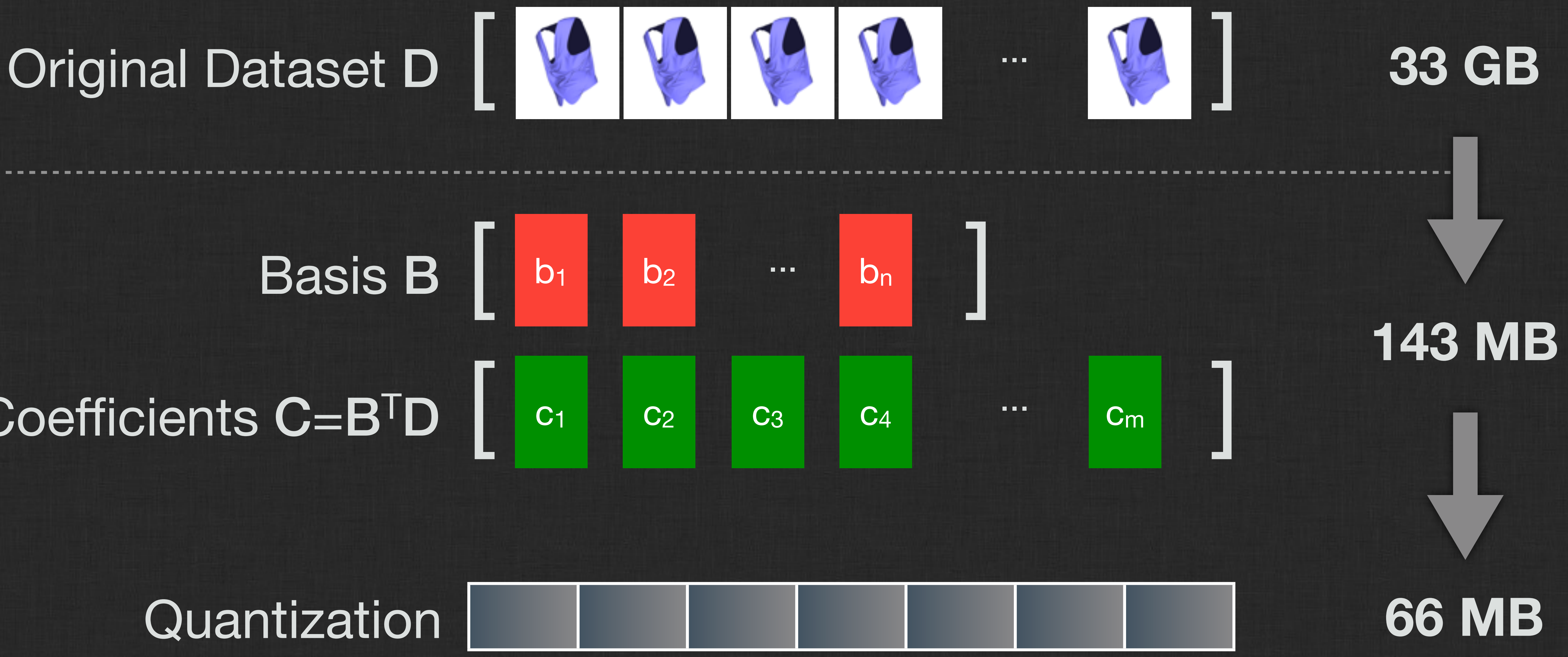
Color-coded character motion type
(e.g. run, jump, cartwheel, etc)

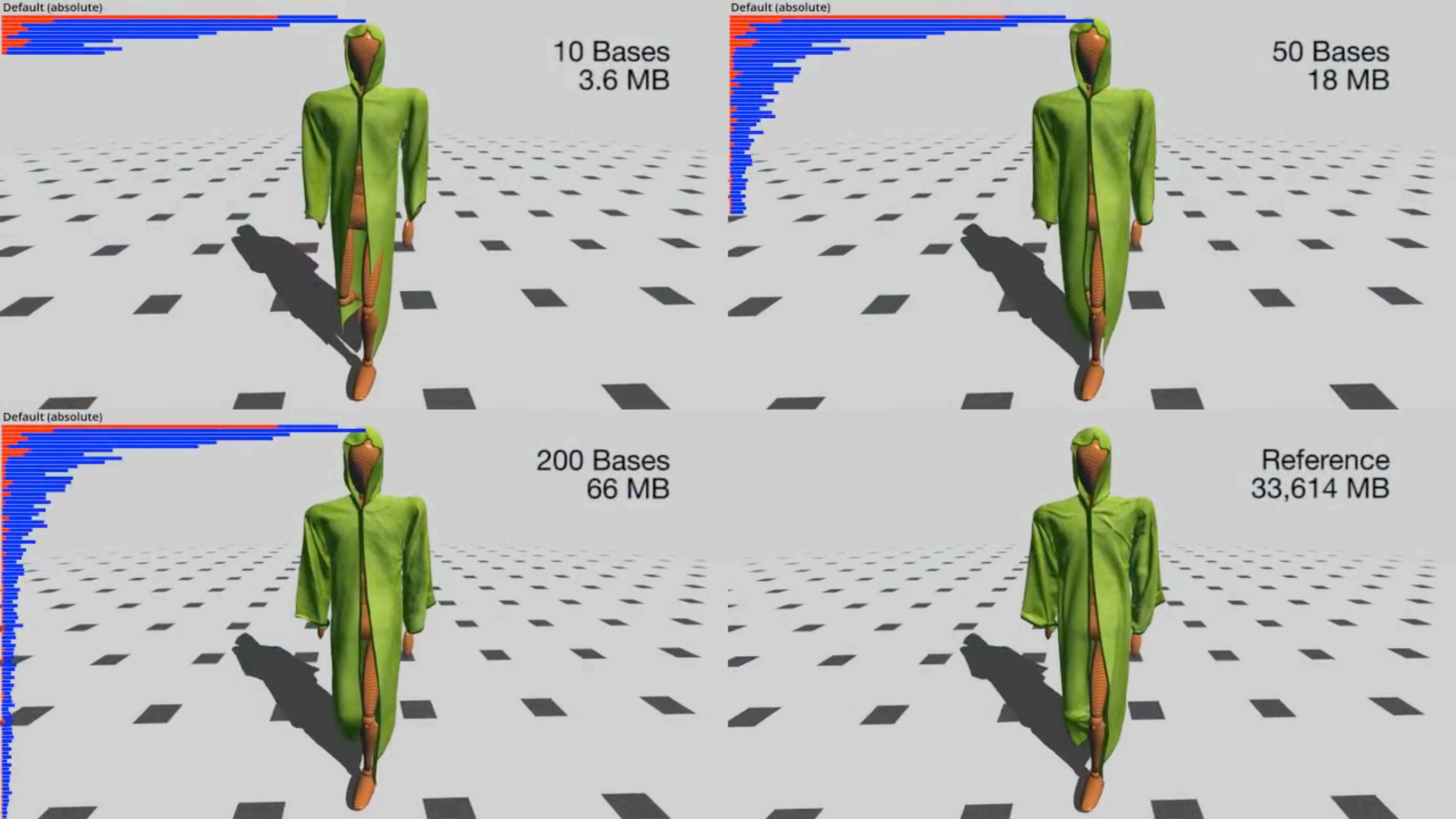
Gray Edges

Back-links

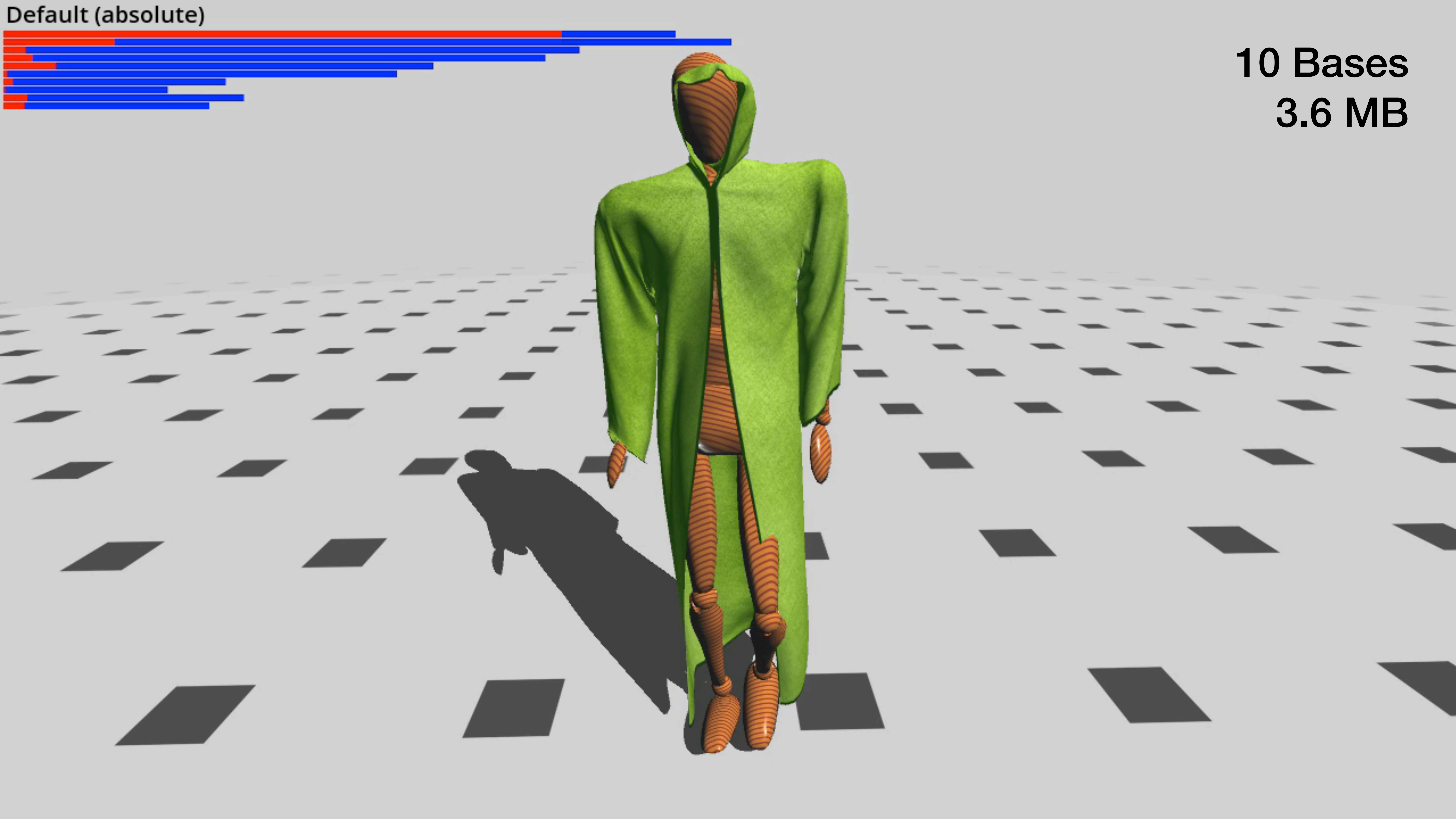
Secondary Graph Compression

Out-of-core SVD Compression

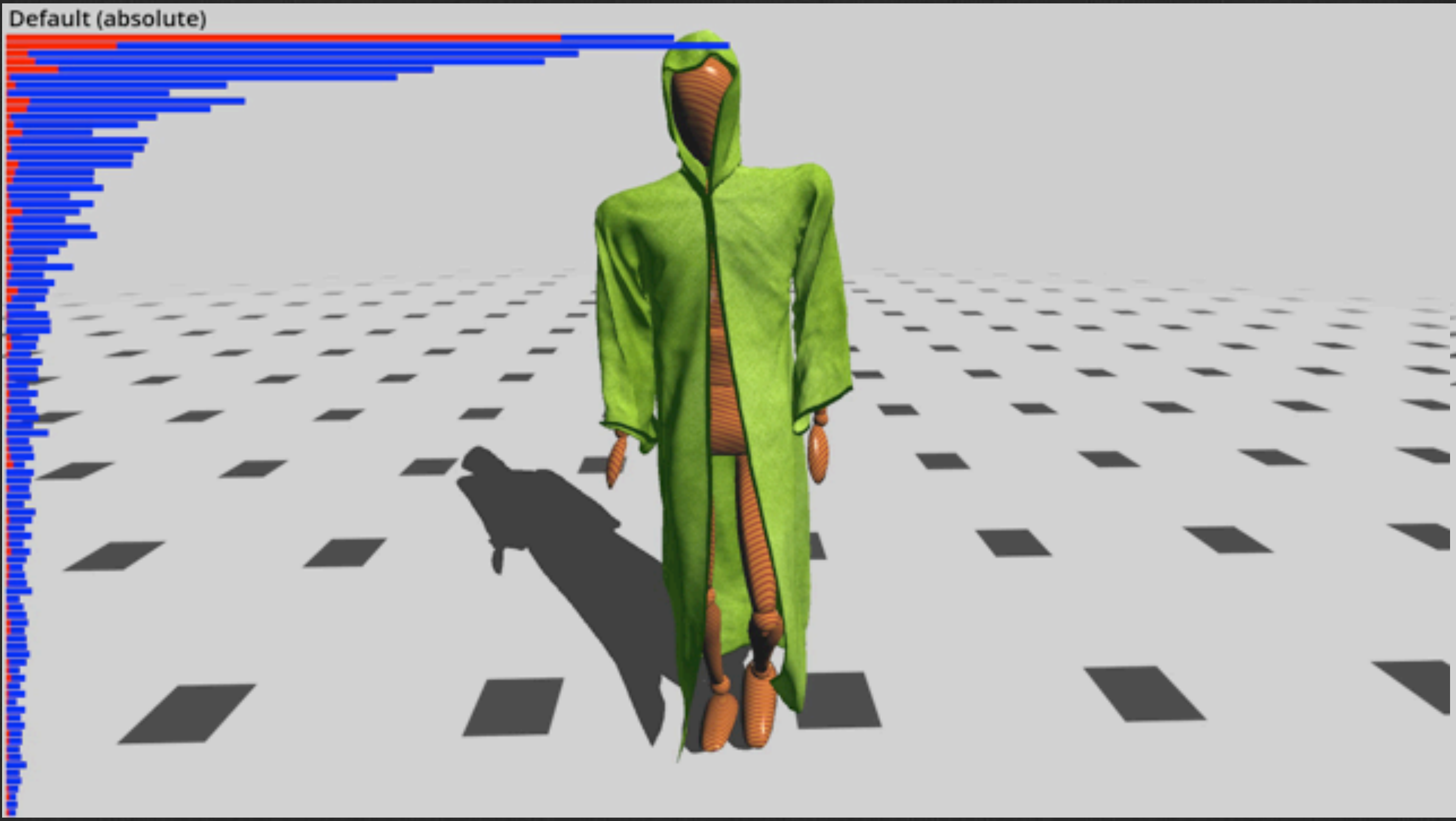




Default (absolute)
10 Bases
3.6 MB
Default (absolute)
50 Bases
18 MB
Default (absolute)
200 Bases
66 MB
Reference
33,614 MB

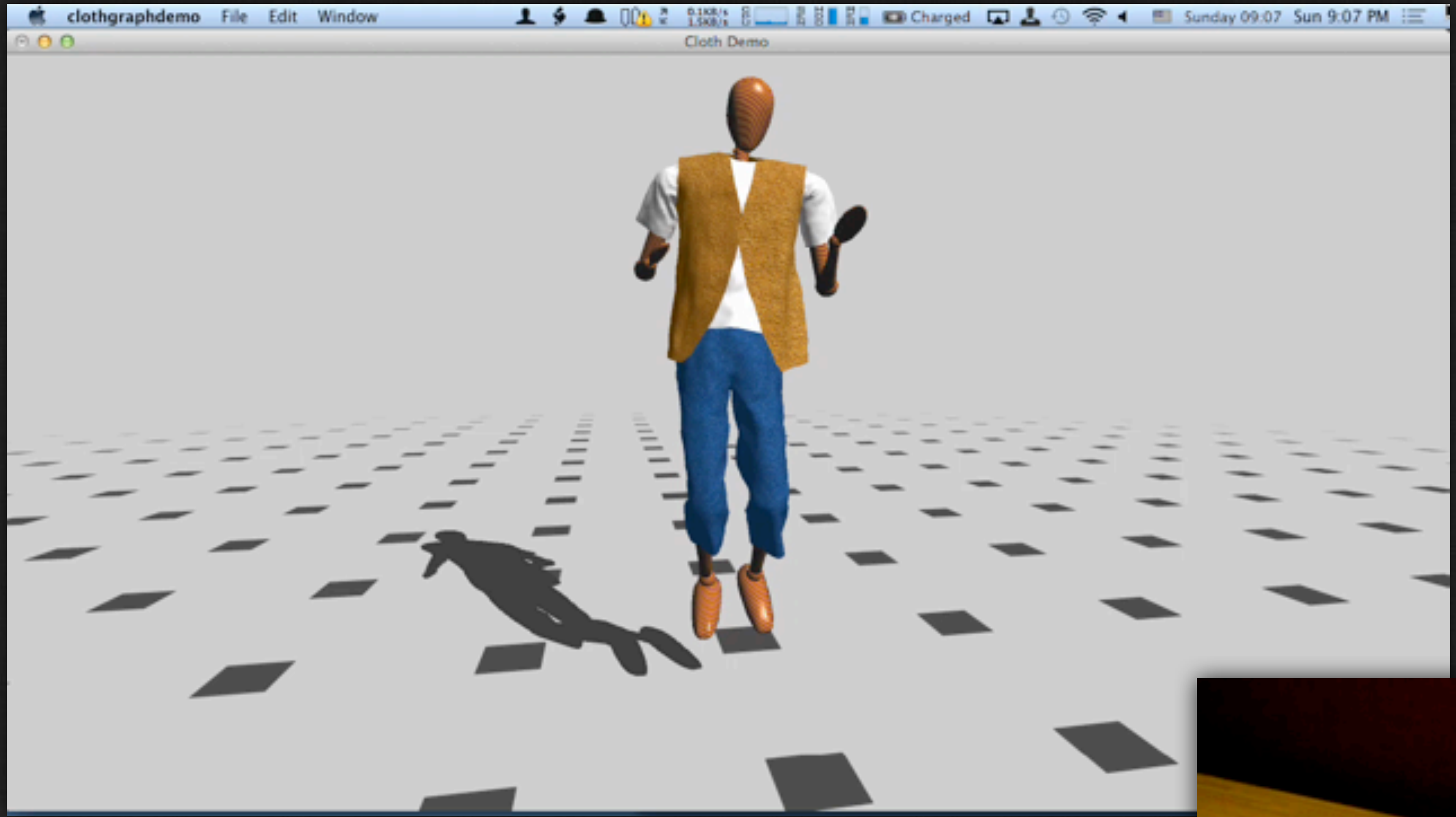


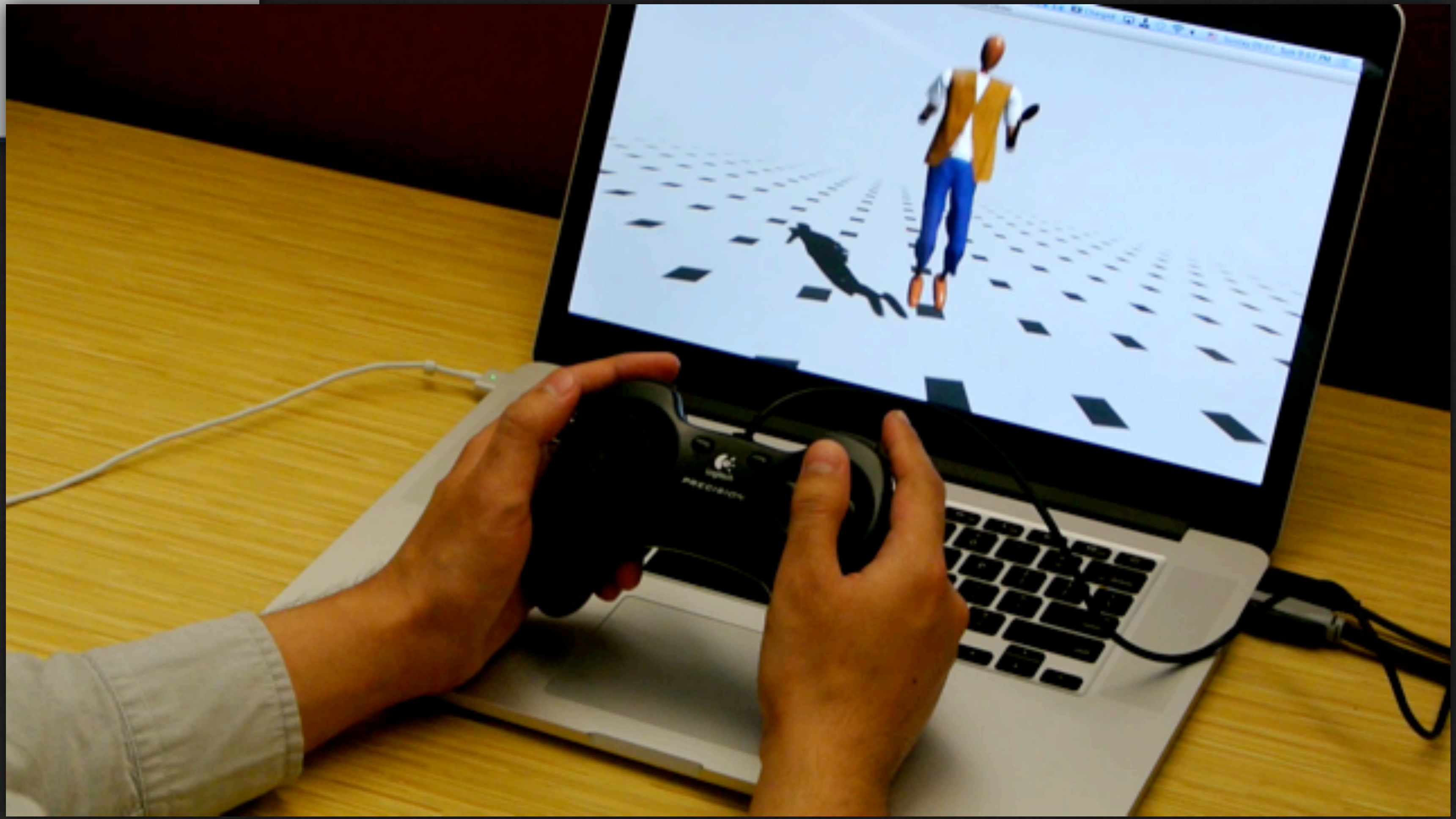
Default (absolute)
10 Bases
3.6 MB



200 Bases (66 MB)

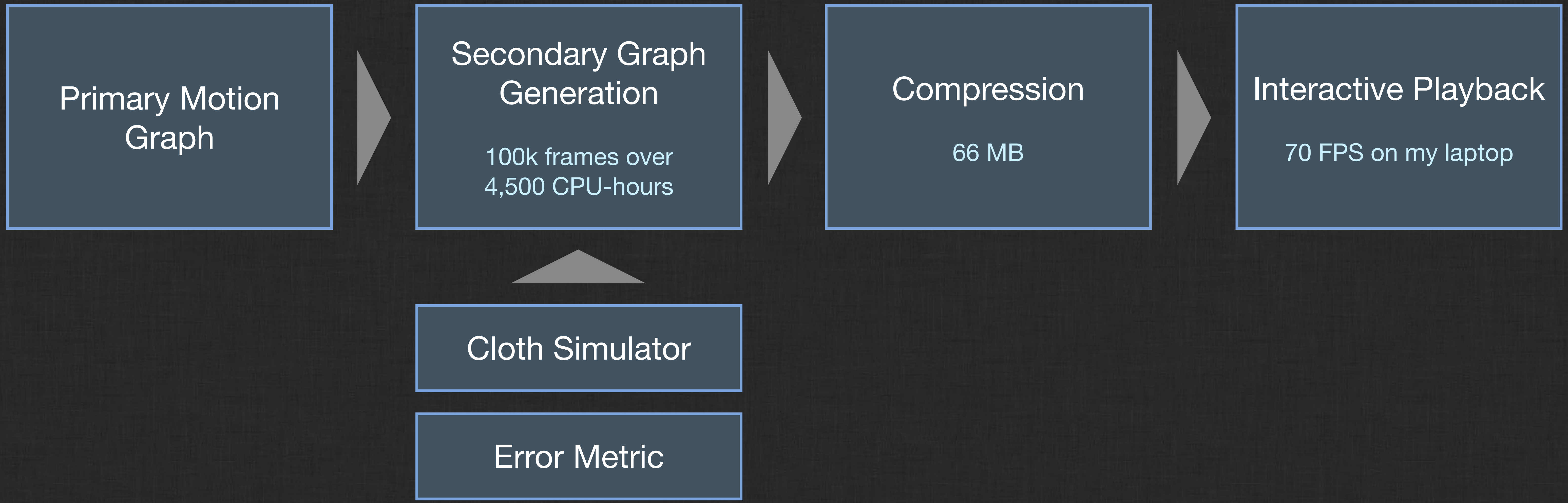
Reference (33,614 MB)


clothgraphdemo File Edit Window
Charged
Sunday 09:07 Sun 9:07 PM
Cloth Demo

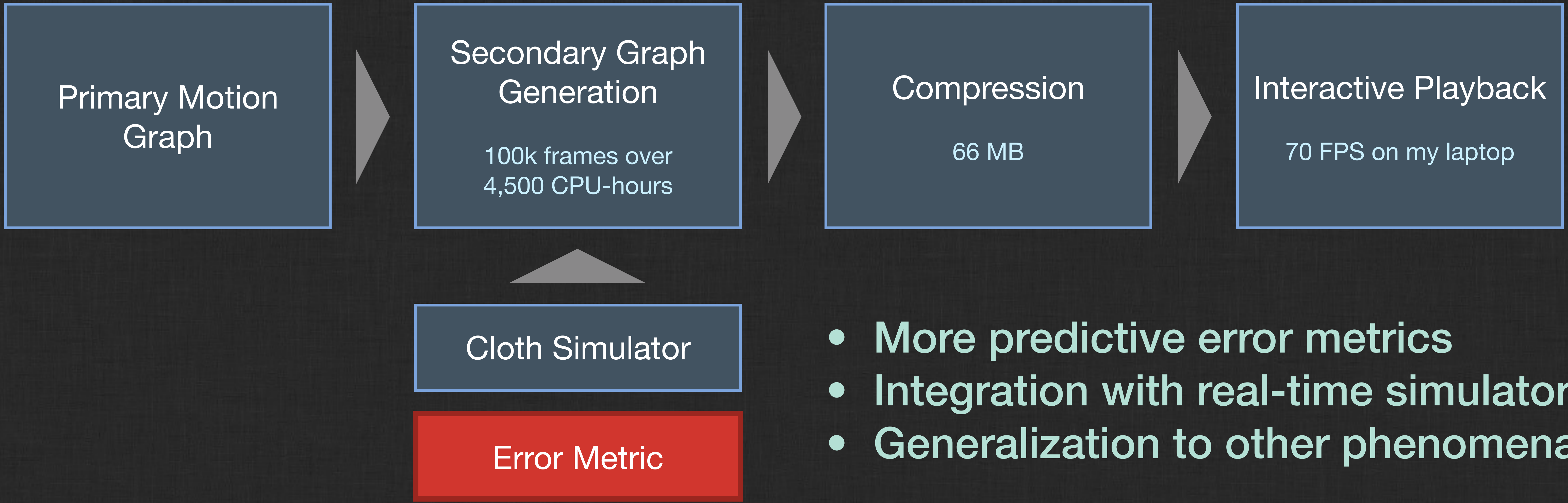


Live Demo

Summary


Primary Motion Graph
Secondary Graph Generation
100k frames over 4,500 CPU-hours
Compression
66 MB
Interactive Playback
70 FPS on my laptop
Cloth Simulator
Error Metric

Future Work

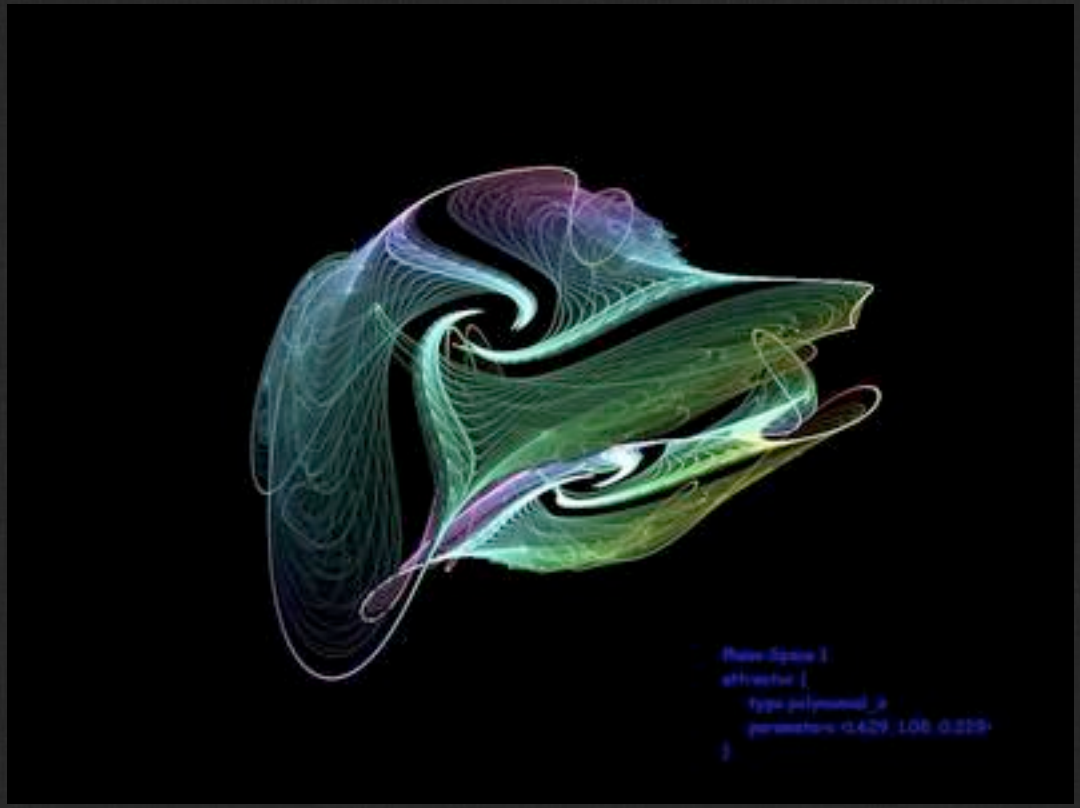


- More predictive error metrics
- Integration with real-time simulator
- Generalization to other phenomena

Potential for Precomputing the Behavior of Complex Physical Systems

Massive-scale computation

Intelligent exploration of complex phase portrait



Thanks to...

Alexander Roshetov and Alexi Soupikov

- Cloth simulator optimization

Juan Miguel de Joya

- Cloth and character modeling

Intel Science and Technology Center for Visual Computing

- Intel research cluster

NSF Grants, UC Lab Fees Research Program Grant
Samsung, Google, Qualcomm, Adobe, Pixar, and the Okawa Foundation

Thank You