CHI 2018
Engage with CHI

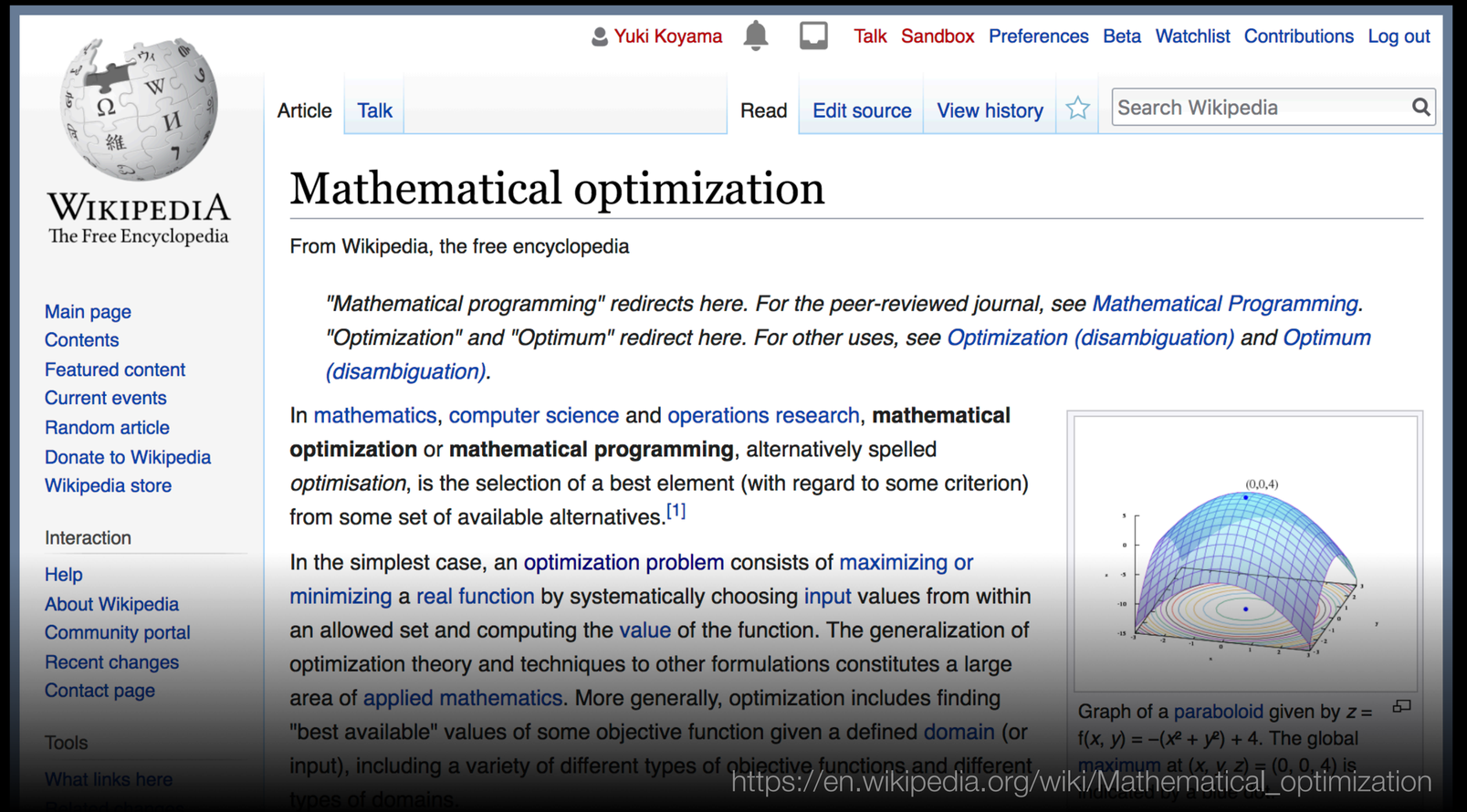
OptiMo: Optimization-Guided Motion Editing for Keyframe Character Animation

Yuki Koyama & Masataka Goto

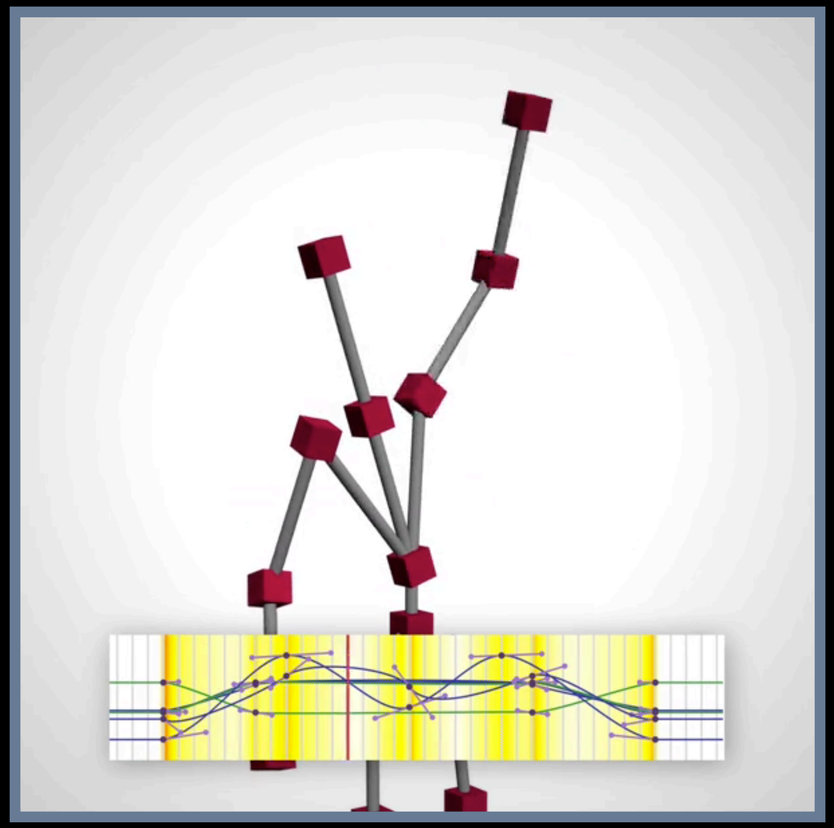
AIST

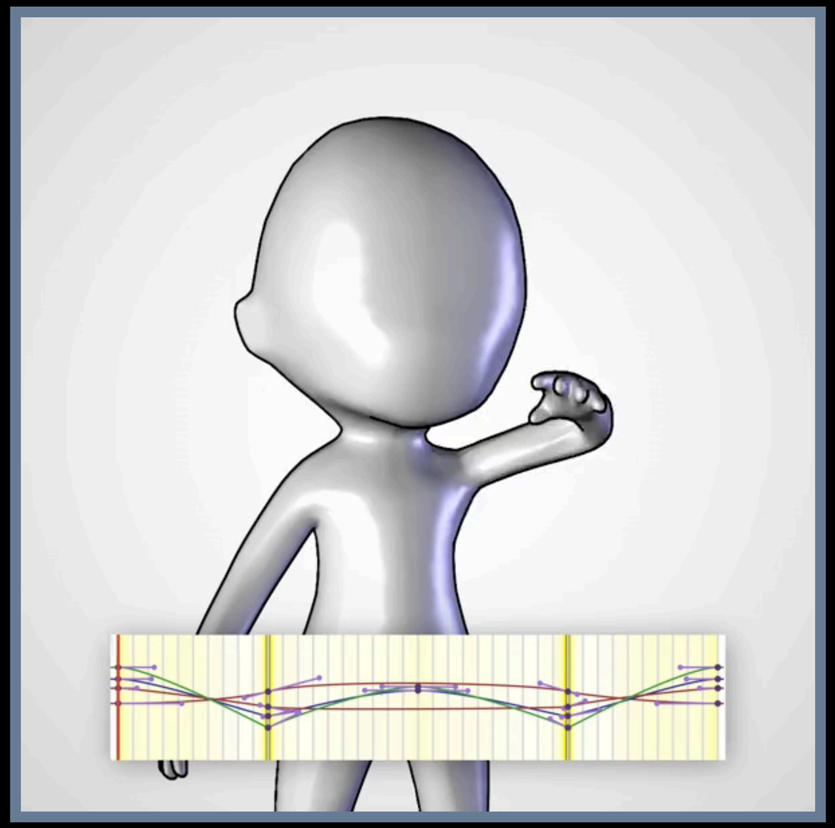
Optimization Techniques:

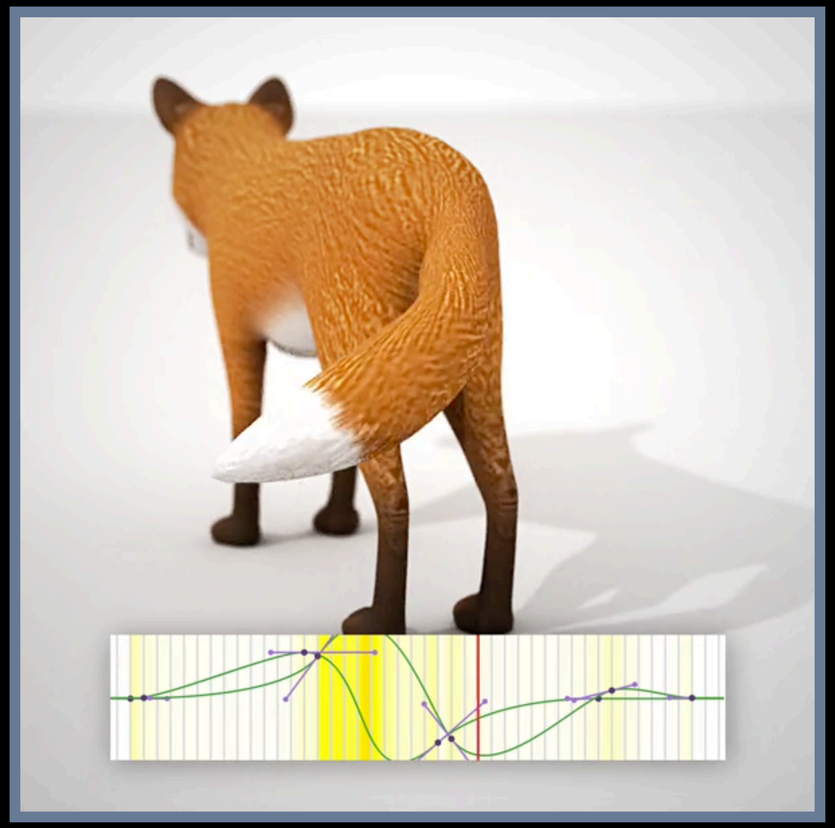
- Powerful
- Used in computer science and engineering



https://en.wikipedia.org/wiki/Mathematical_optimization

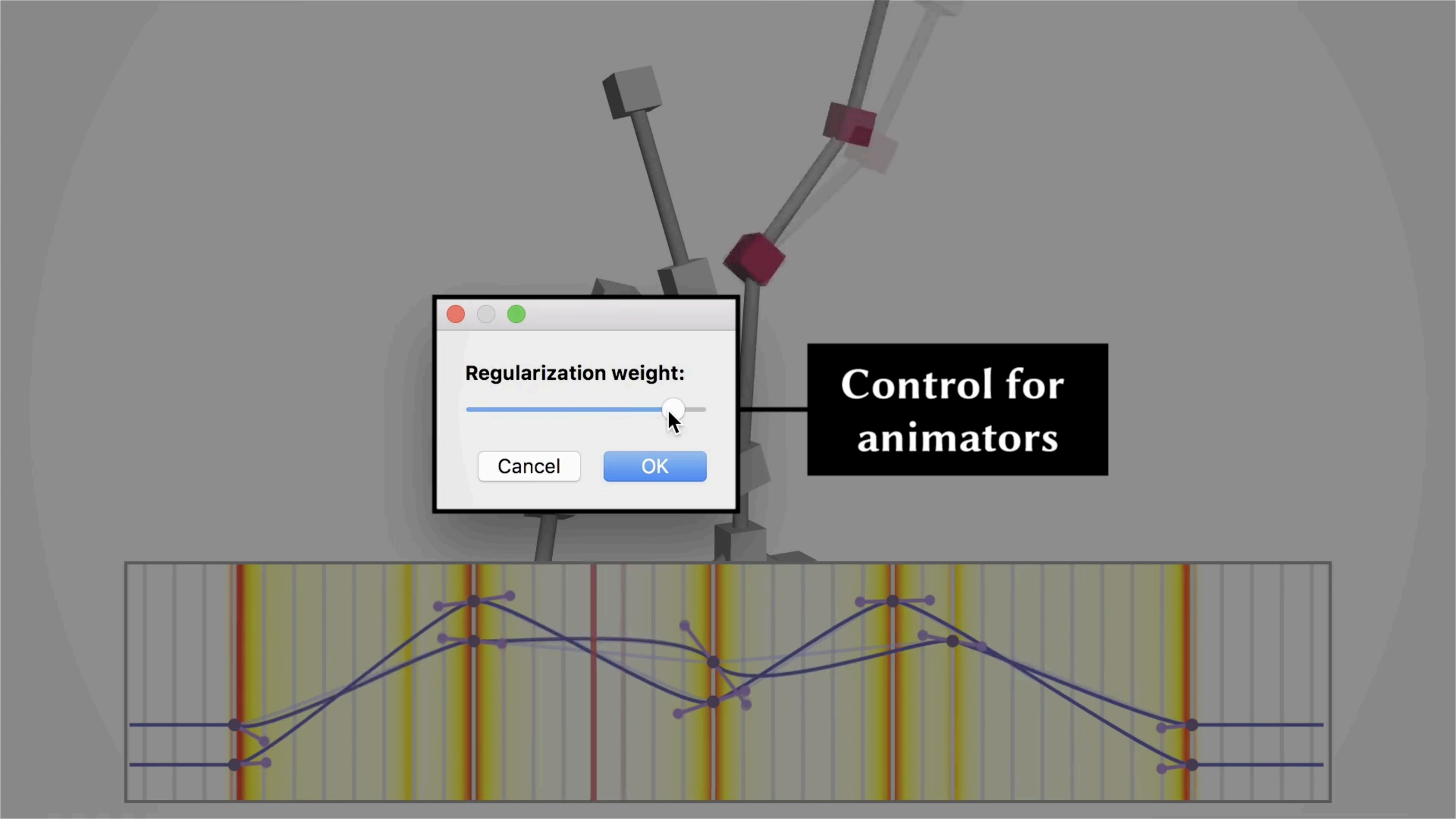






How can animators utilize optimization techniques for motion editing effectively?

We propose
“Optimization-Guided Motion Editing”


Regularization weight:
Cancel
OK
Control for animators

Background: How Do Animators Create Motions?

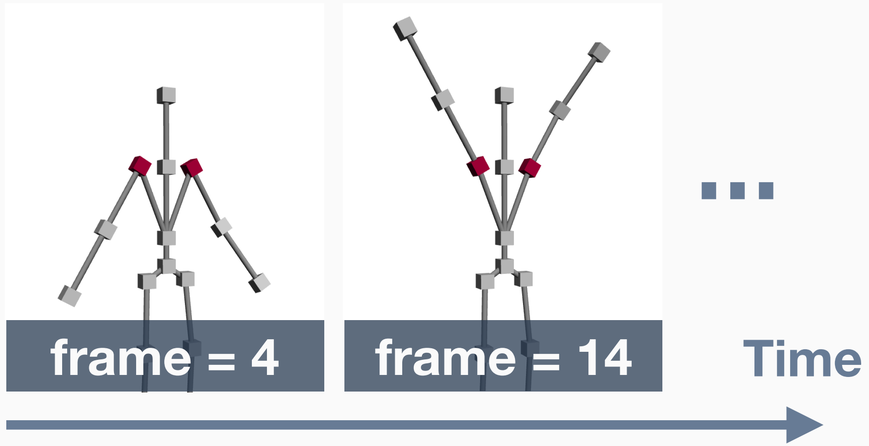
How Do Animators Create Motions?

1. Keyframing

2. Curve Editing

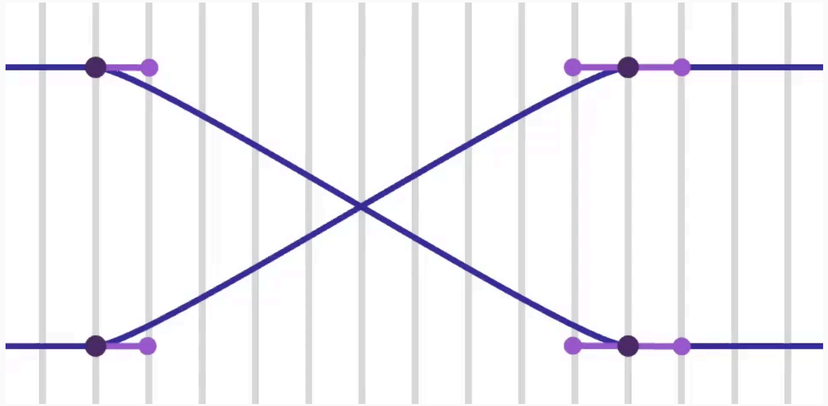
How Do Animators Create Motions?

1. Keyframing



Define **key poses** at several **keyframes**

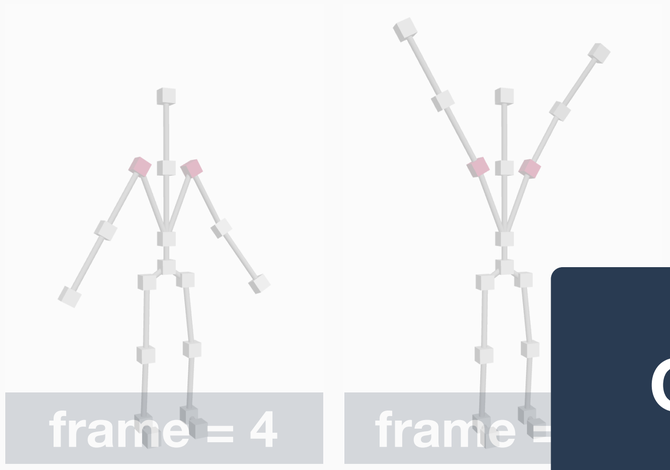
2. Curve Editing



Adjust **interpolation curves**
(how key poses are interpolated between keyframes)

How Do Animators Create Motions?

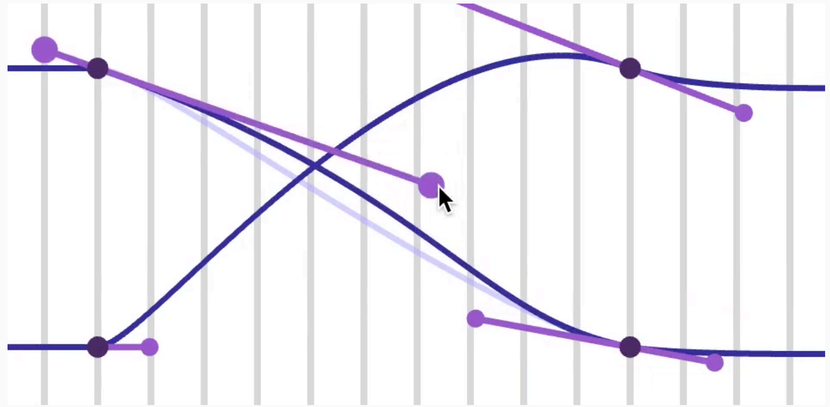
1. Keyframing



Define **key poses** at several **keyframes**

Our Target

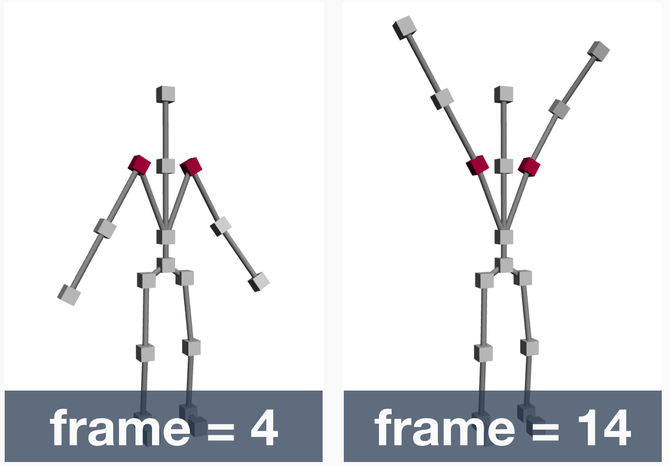
2. Curve Editing

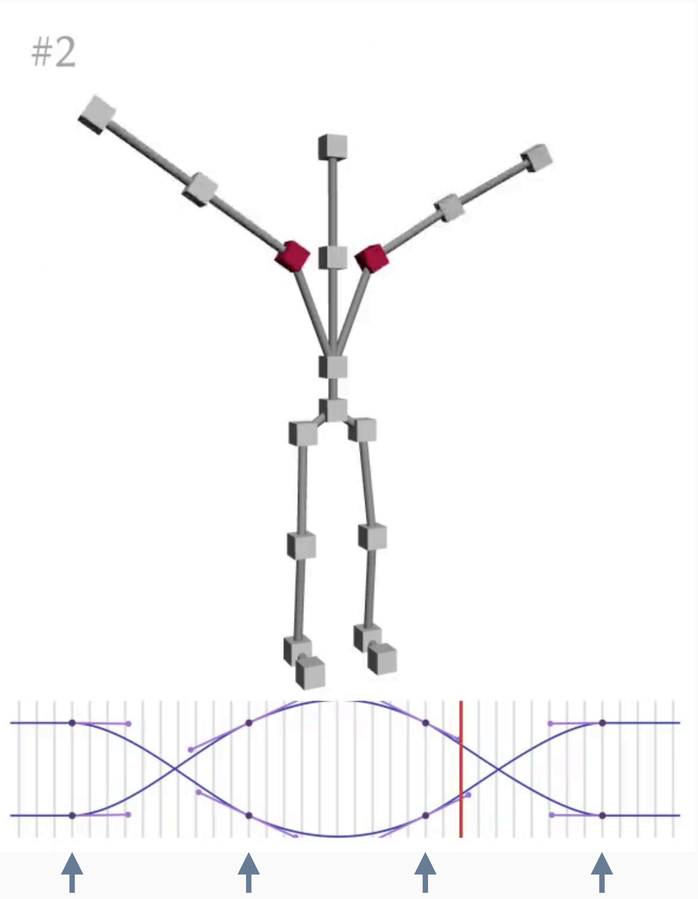


Adjust **interpolation curves**
(how key poses are interpolated between keyframes)

Curve Editing is Important for Nuances

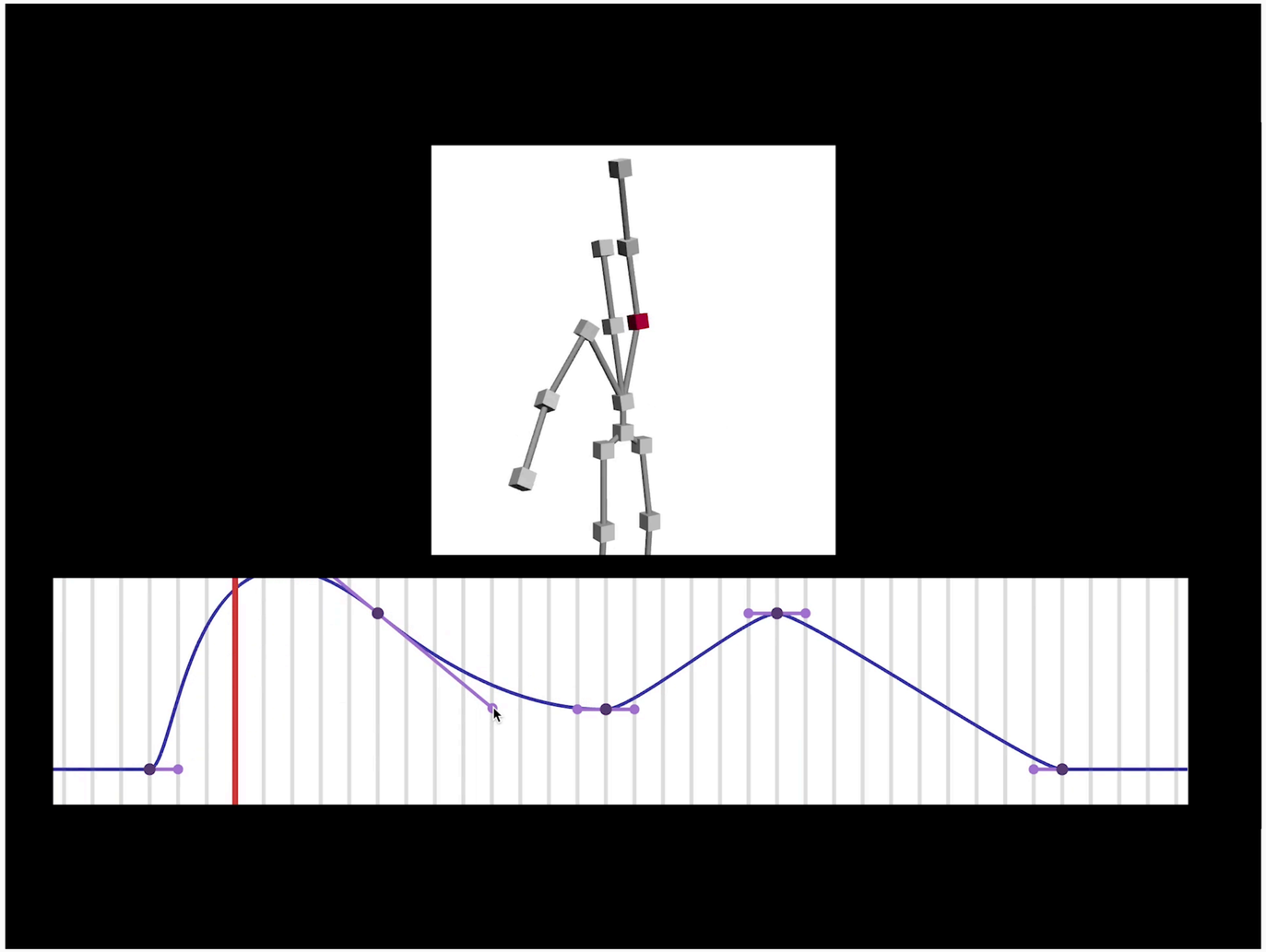
Even with **the same keyframing**, motions could be very **different in nuances**





Difficulties in Curve Editing

Difficulties in Curve Editing



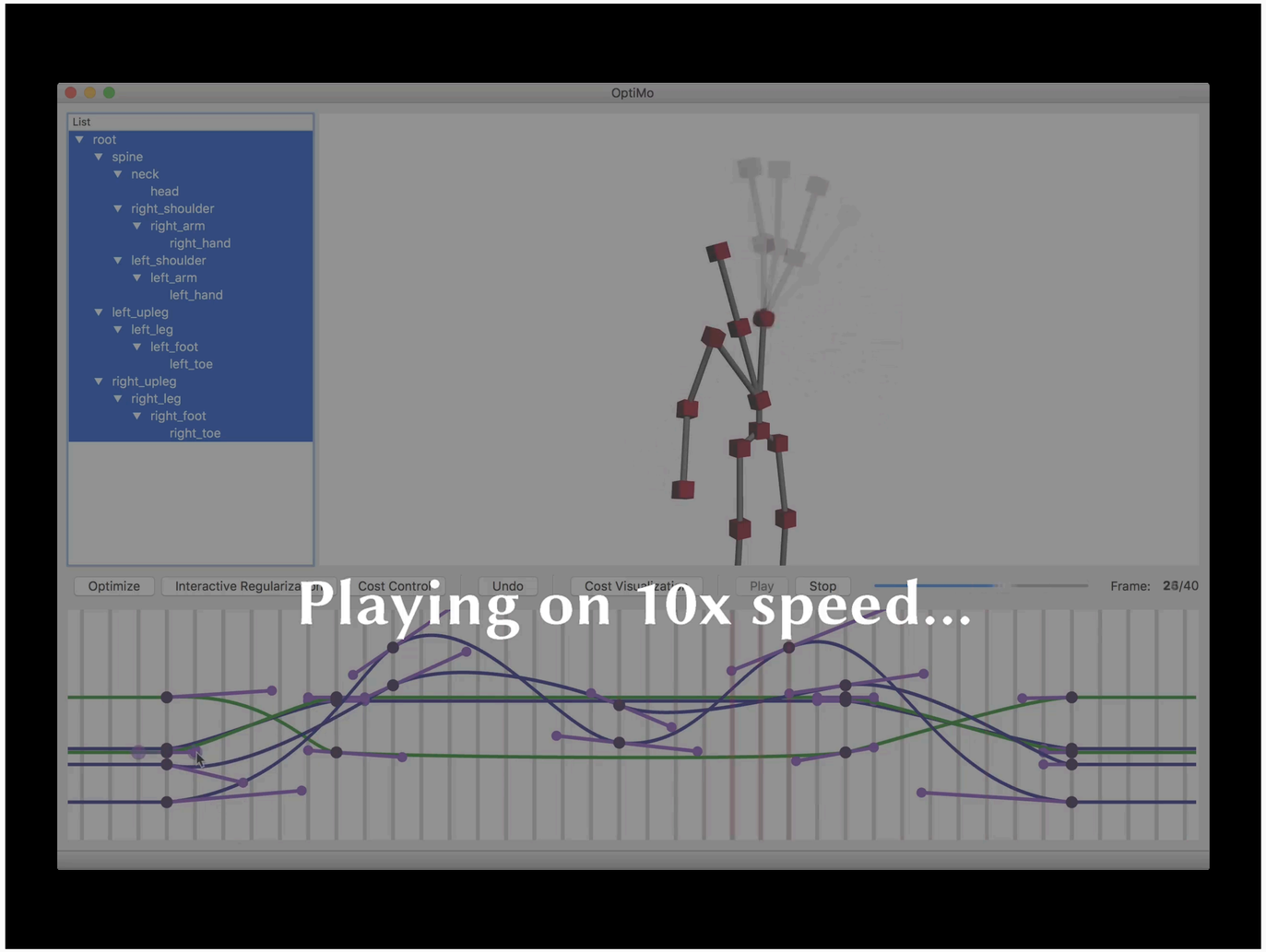
Unintuitive (indirect) effects

Need to play motions every time manipulating handles

Many parameters

High-dimensional search task

Difficulties in Curve Editing



Unintuitive (indirect) effects

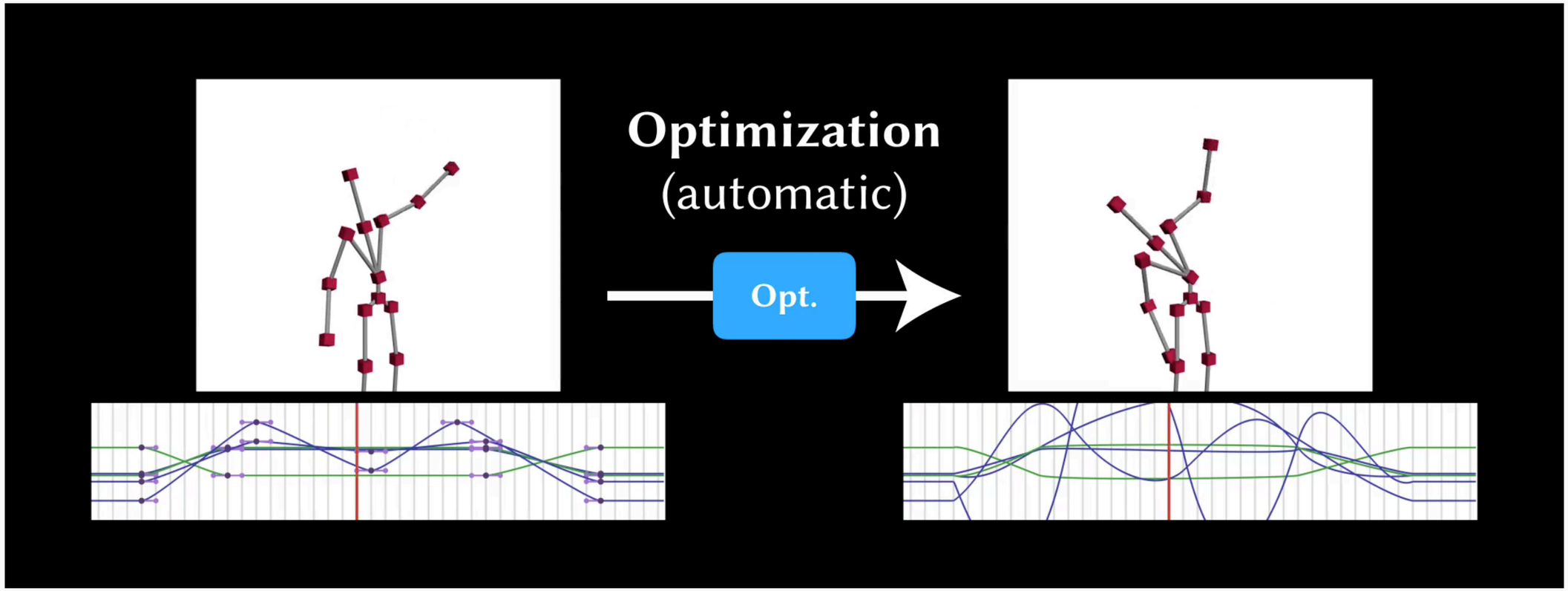
Need to play motions every time manipulating handles

Many parameters

High-dimensional search task

A Possible (?) Solution: Naïve Optimization

Optimization for Full Automation?



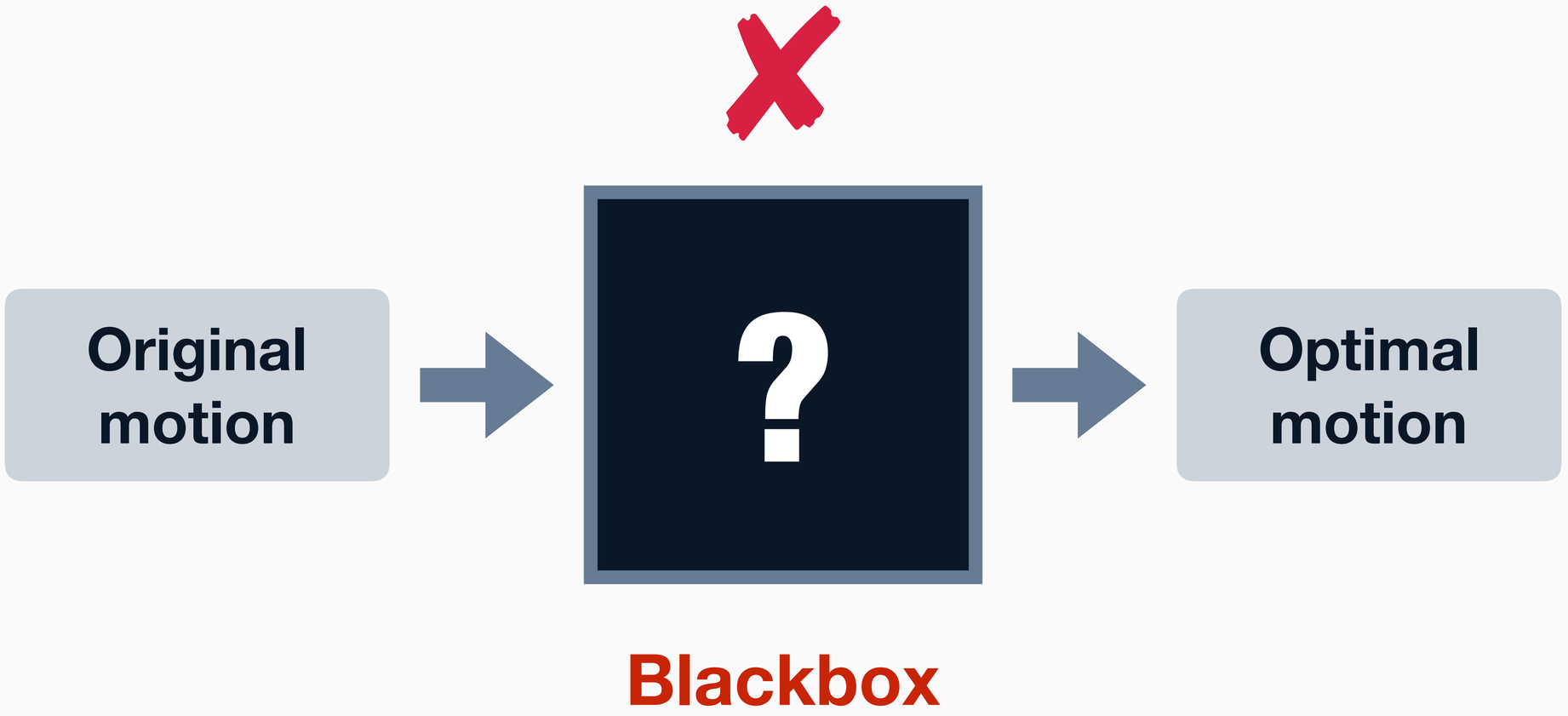
Optimization can fully automate the task,
but results are **not always satisfactory (no control…)**

Optimization-Guided Motion Editing

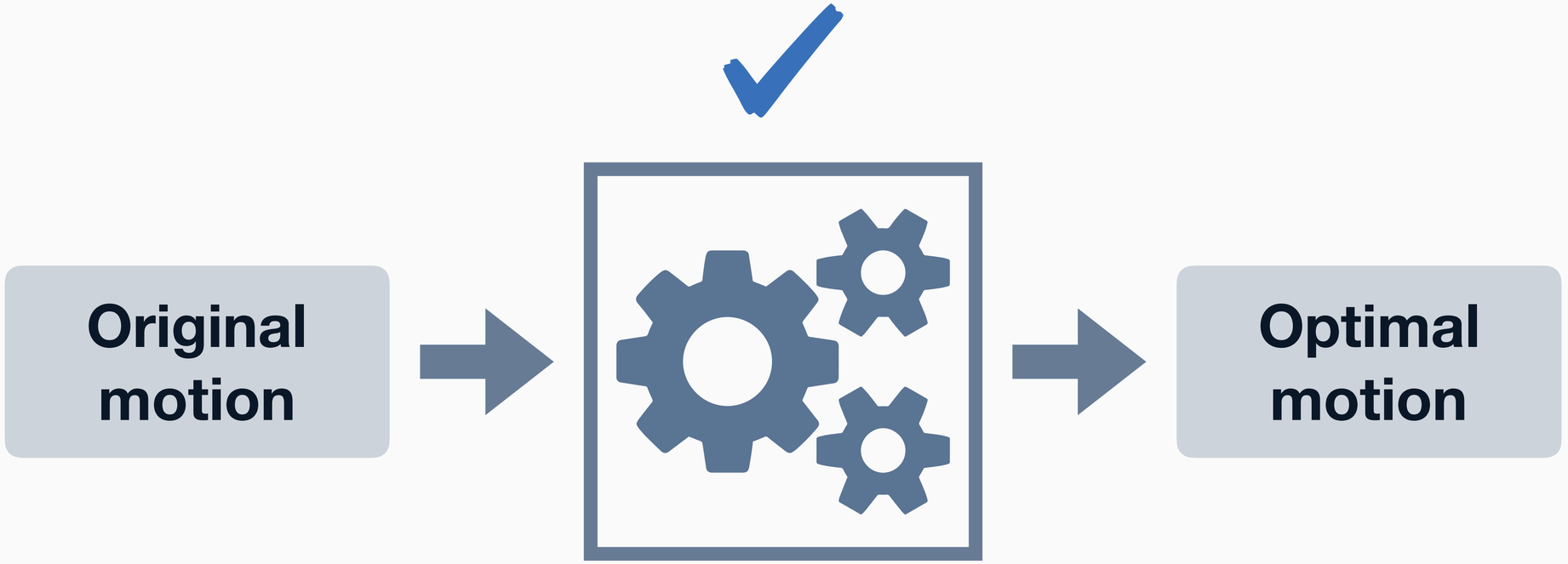
Live Demo!

Design Goals:
What Should be Considered for Effective Interaction?

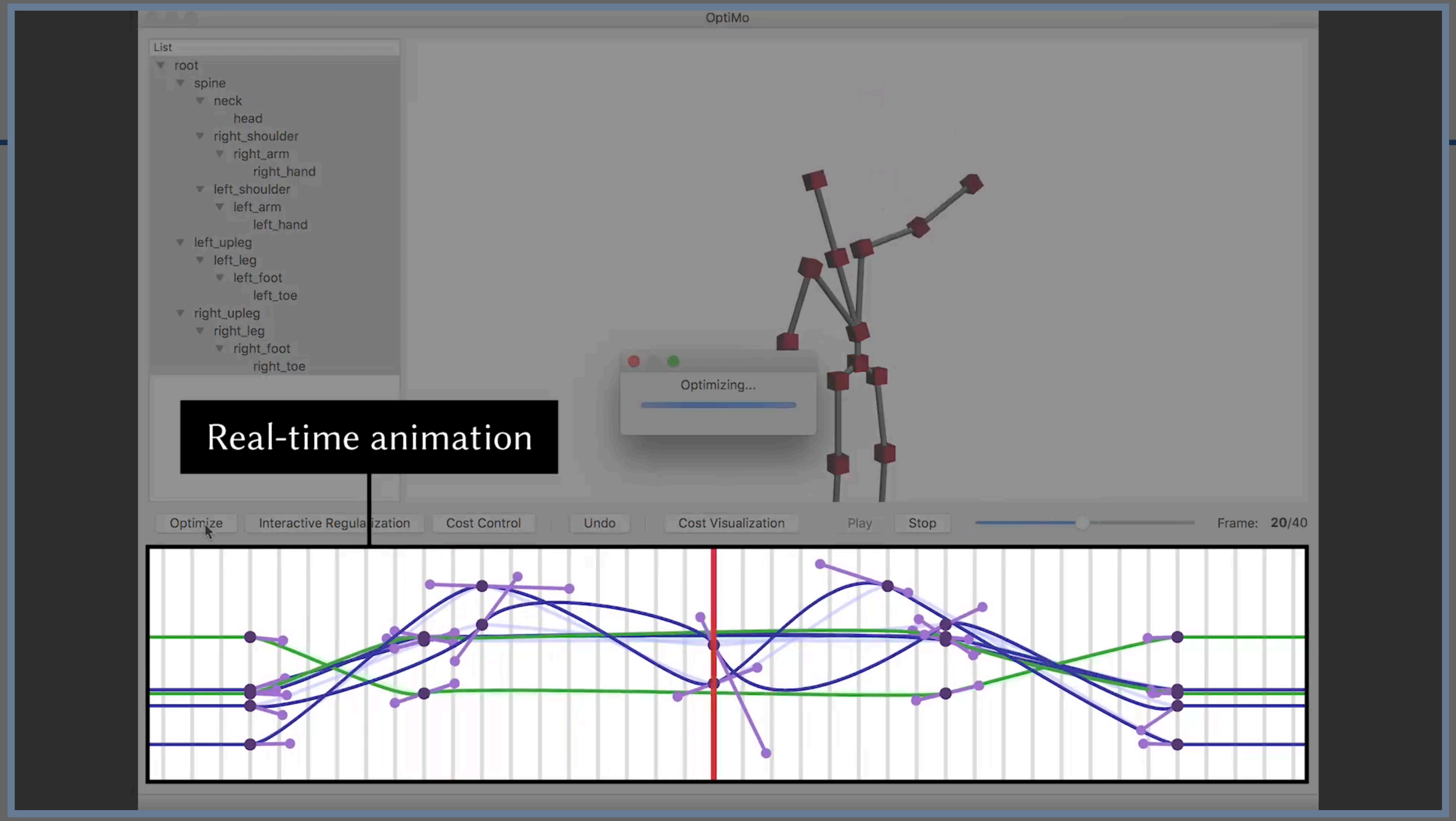
Three Design Goals



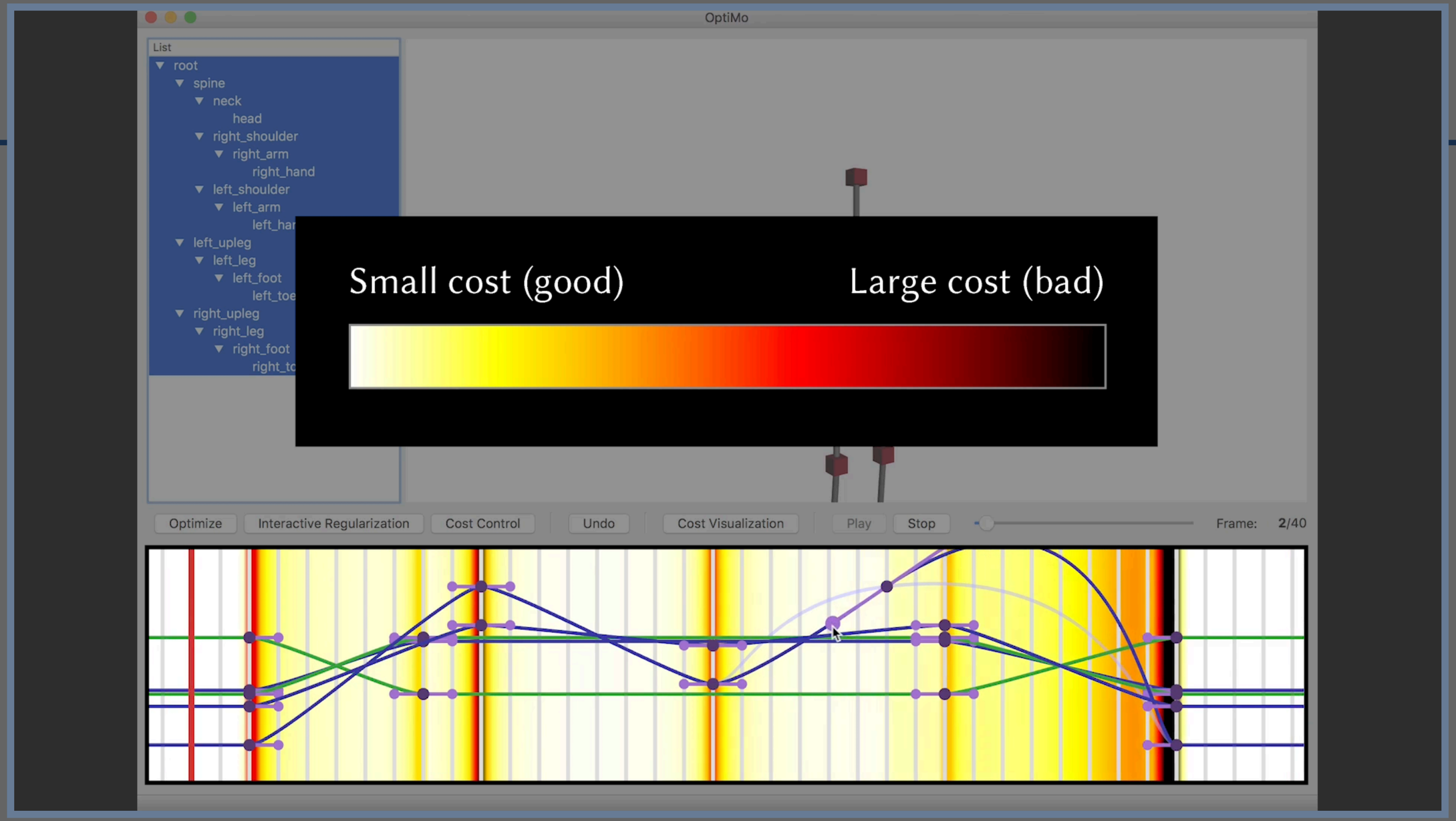
Three Design Goals



1. Transparent

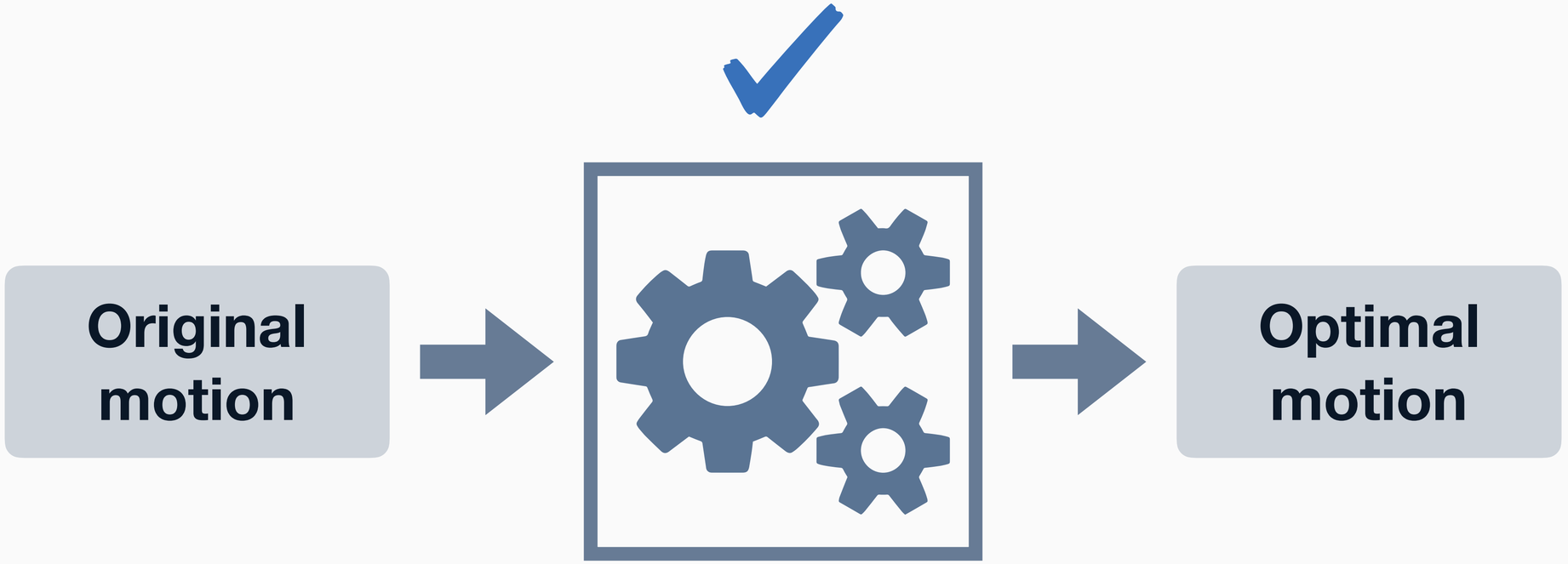


Feature: Optimization Process Visualization (for Transparency)



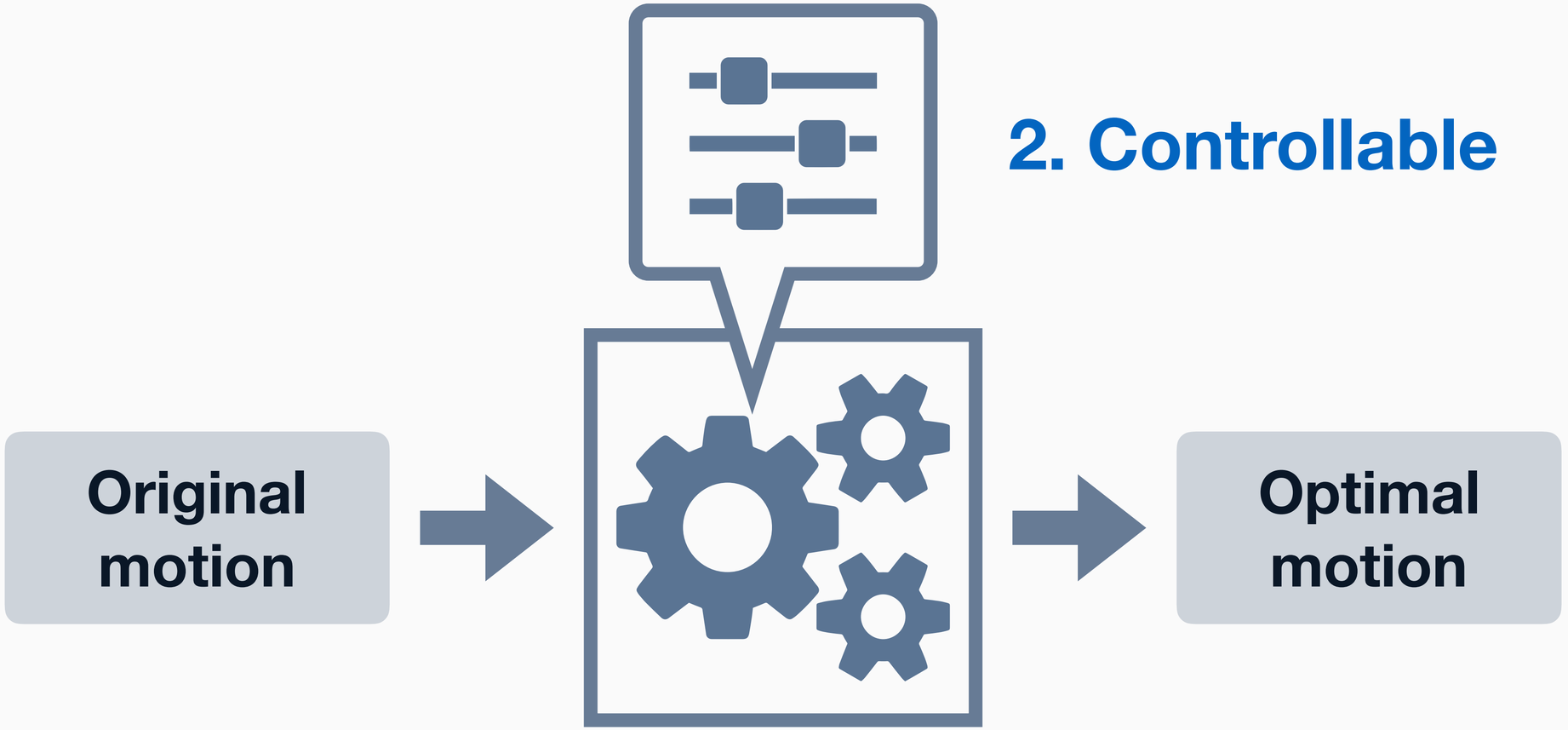
Feature: Cost Visualization (for Transparency)

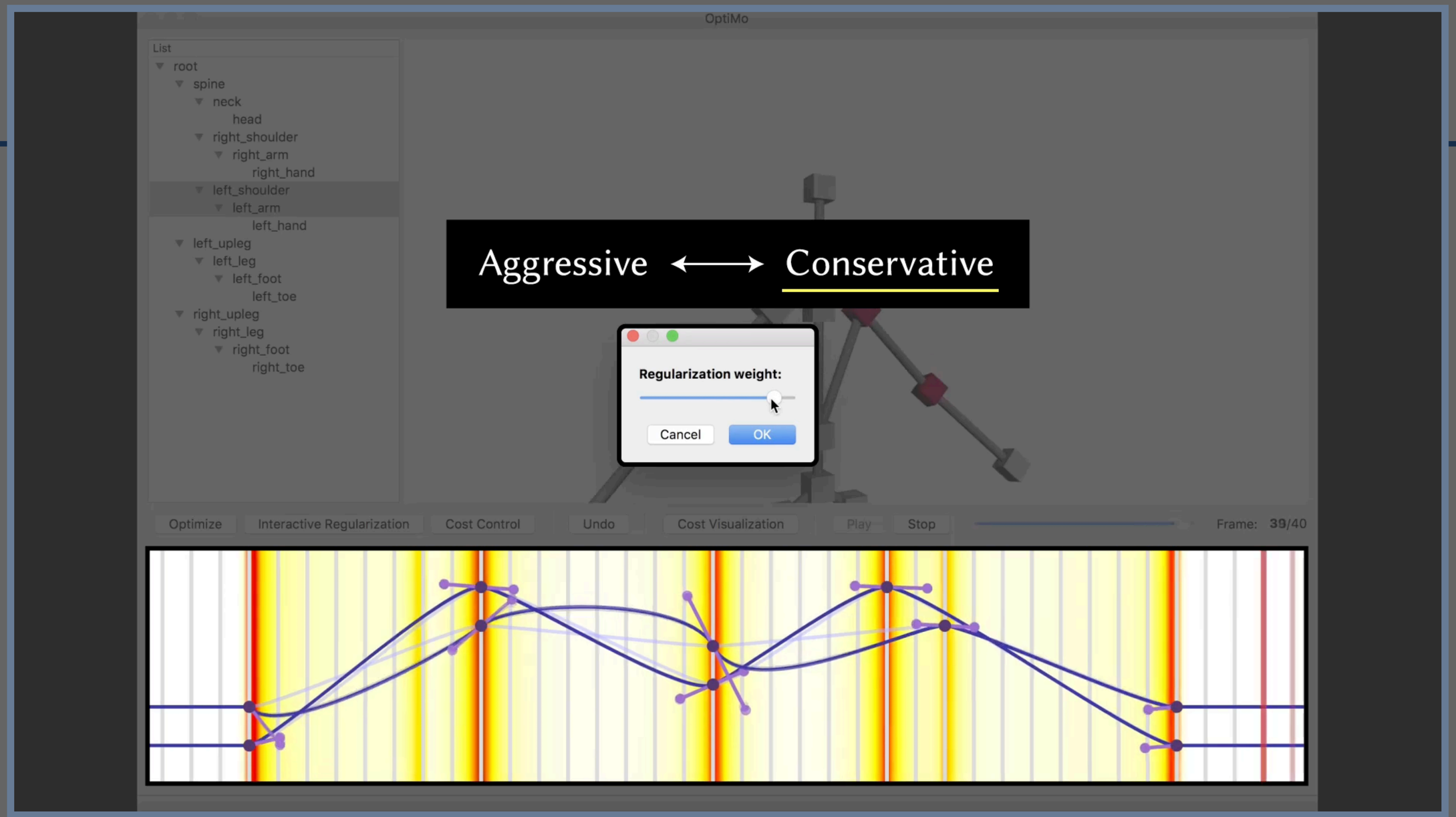
Three Design Goals



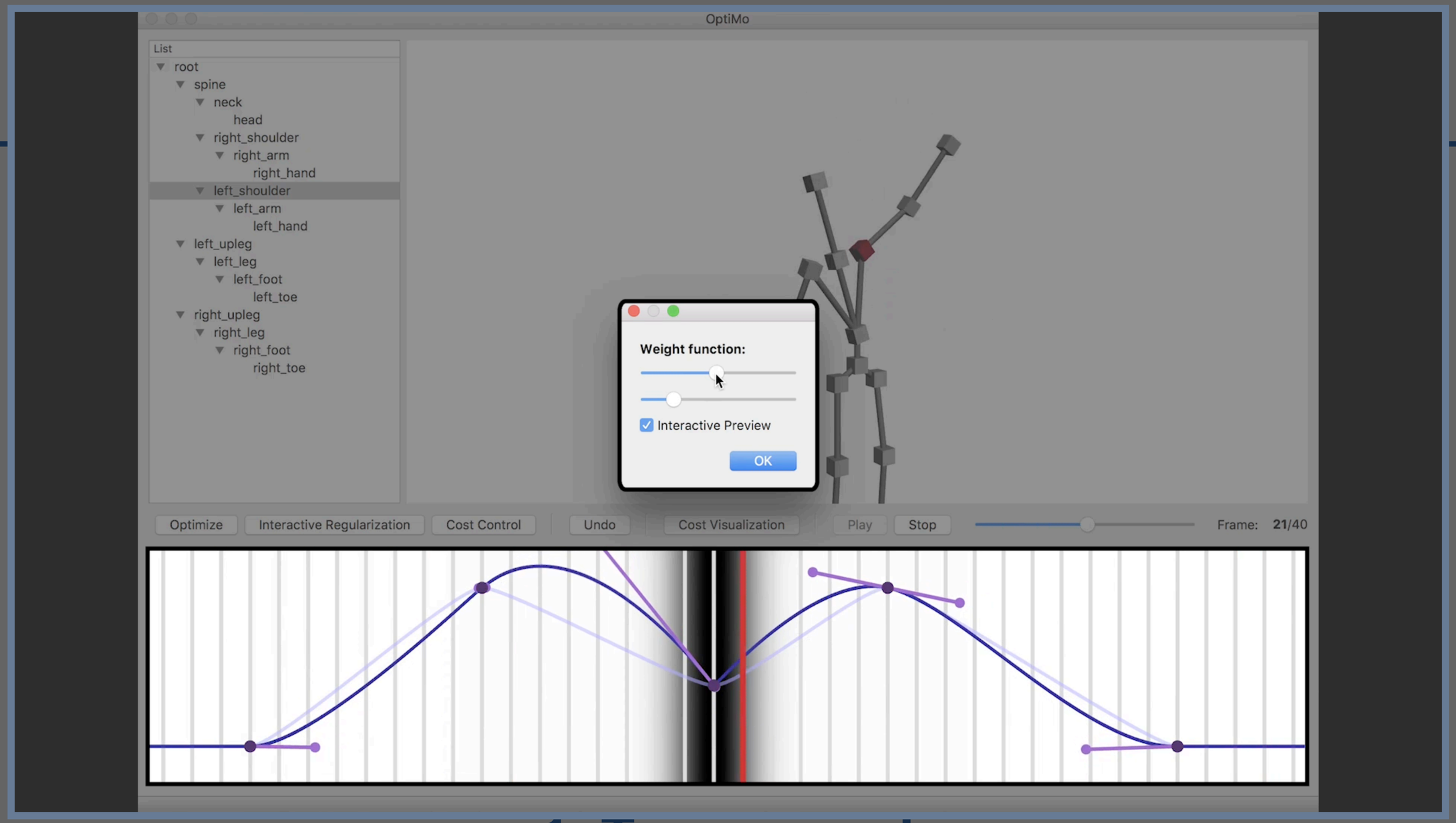
1. Transparent

Three Design Goals



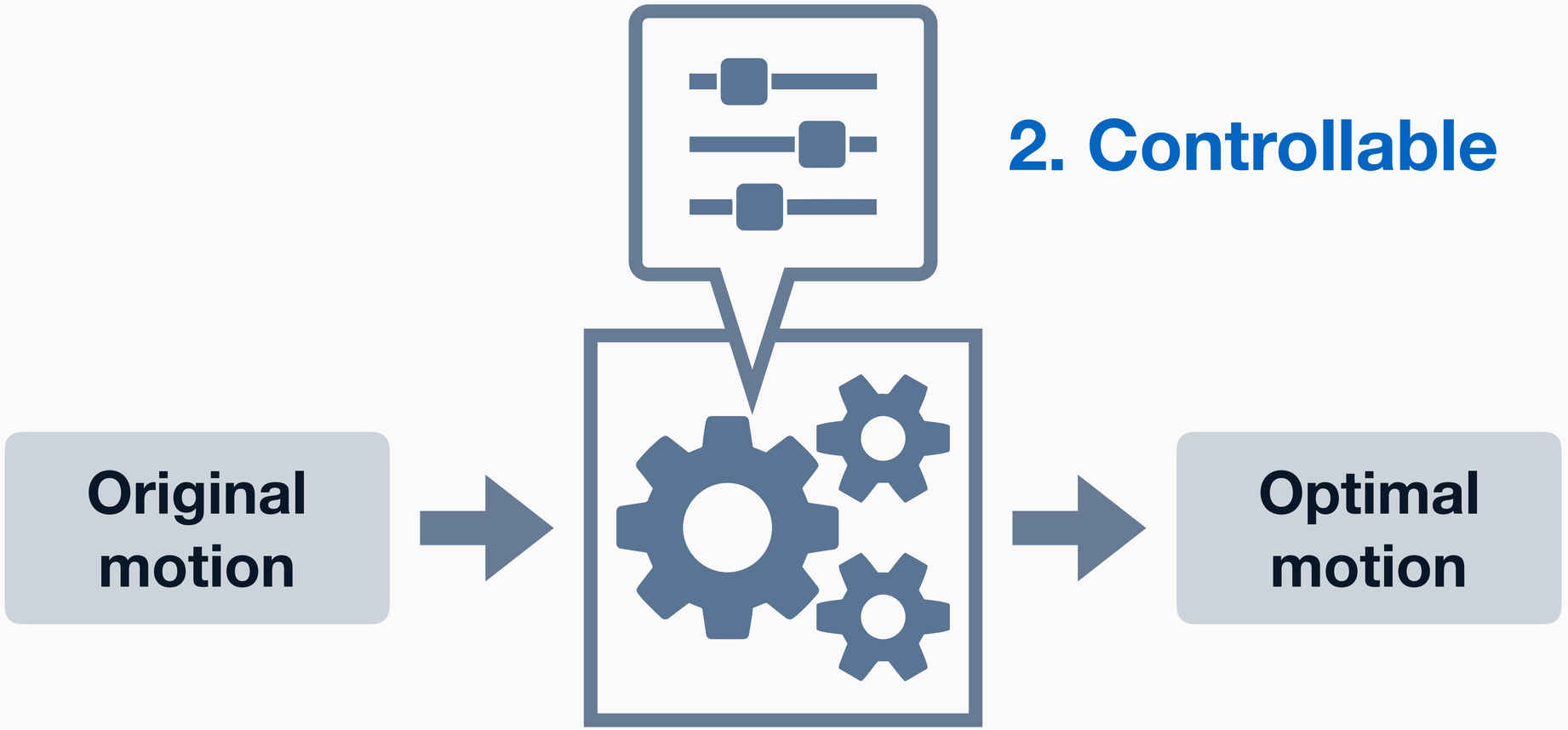


1. Transparent
Feature: Interactive Regularization (for Controllability)

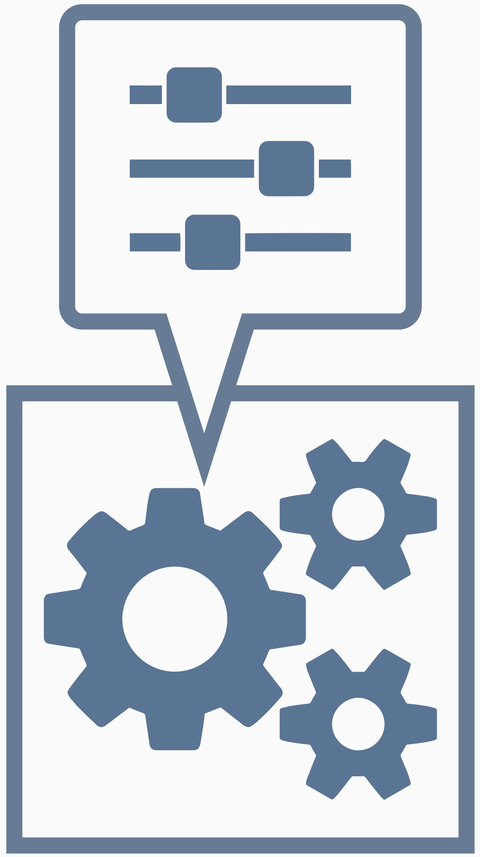


1. Transparent
Feature: Time-Varying Cost Control (for Controllability)

Three Design Goals



Three Design Goals



2. Controllable

3. Editable

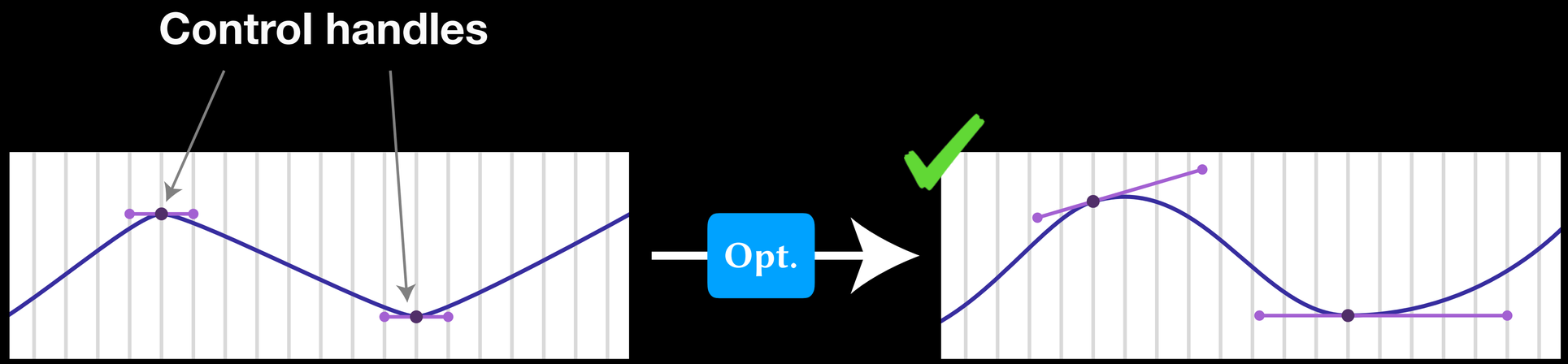
Original motion

Optimal motion

...

Manual revision allowed

1. Transparent

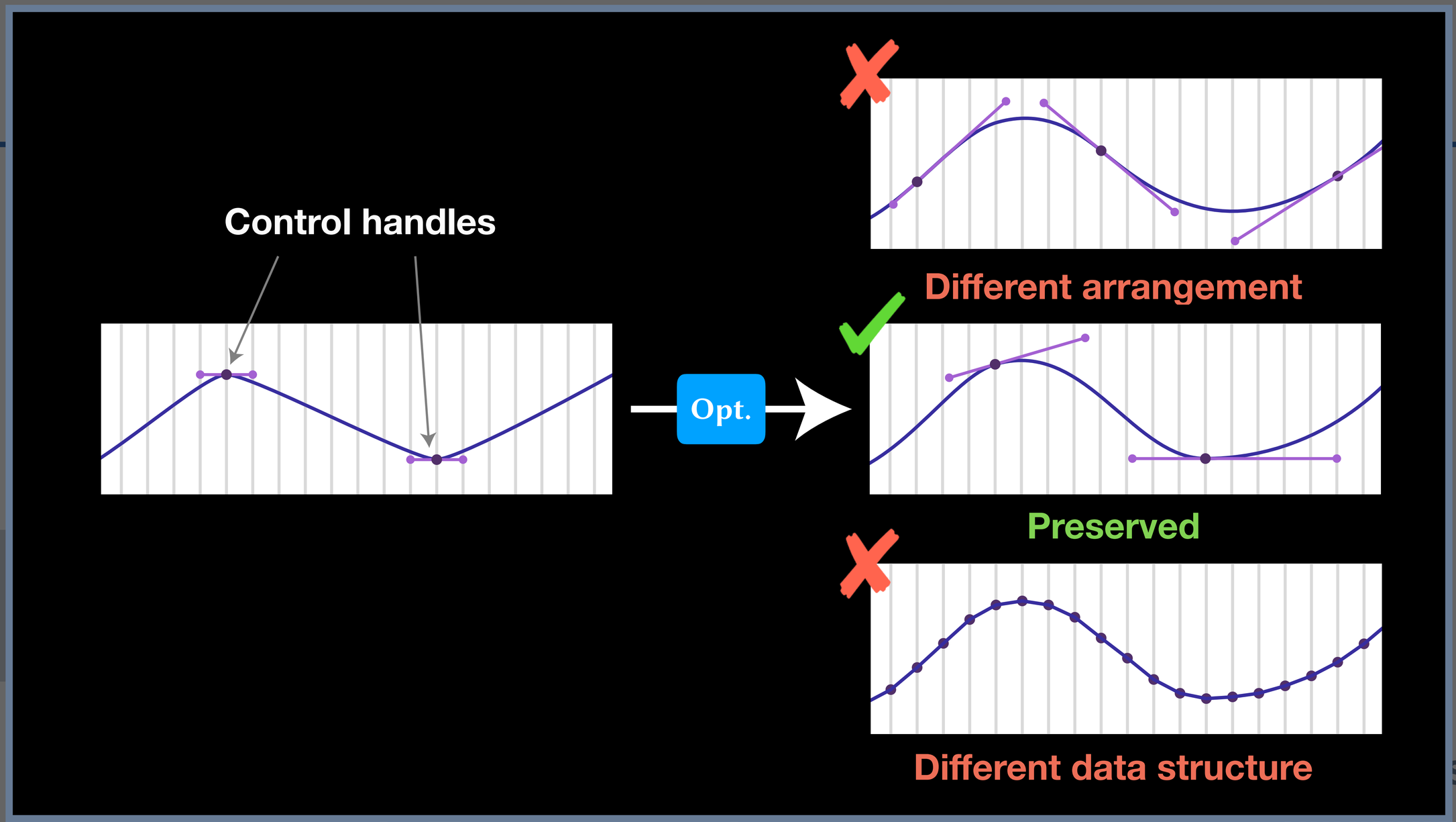


1. Transparent

sion

allowed

Feature: Preservation of Control Handles (for Editability)



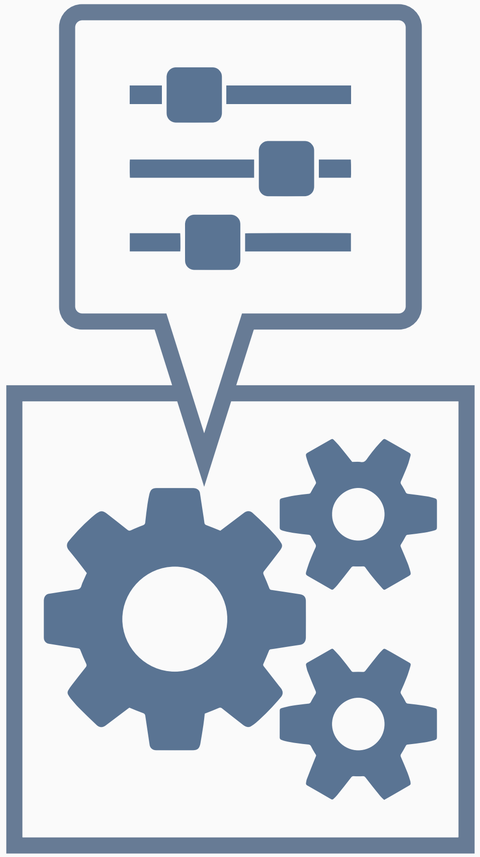
1. Transparent

sion

allowed

Feature: Preservation of Control Handles (for Editability)

Three Design Goals



2. Controllable

3. Editable

Original motion

Optimal motion

...

Manual revision allowed

1. Transparent

Math: How to Formulate Optimization with Controllability

Optimization with Controllability

Typical optimization

$$\min_{\mathbf{x}} \left\{ \int C(\mathbf{x}, t) dt \right\}$$

Optimization with Controllability

Typical optimization

$$\min_{\mathbf{x}} \left\{ \int C(\mathbf{x}, t) dt \right\}$$

Controllable optimization

$$\min_{\mathbf{x}} \left\{ \int w^{\mathrm{cost}}(t) C(\mathbf{x}, t) dt + w^{\mathrm{reg}} D(\mathbf{x}, \mathbf{x}^{\mathrm{init}}) \right\}$$

Control by time-varying cost weight

Control by regularization weight

Optimization with Controllability

Typical optimization

$$\min_{\mathbf{x}} \left\{ \int C(\mathbf{x}, t) dt \right\}$$

Adjusted in real time

Controllable optimization

$$\min_{\mathbf{x}} \left\{ \int \underline{w^{\mathrm{cost}}}(t) C(\mathbf{x}, t) dt + \underline{w^{\mathrm{reg}}} D(\mathbf{x}, \mathbf{x}^{\mathrm{init}}) \right\}$$

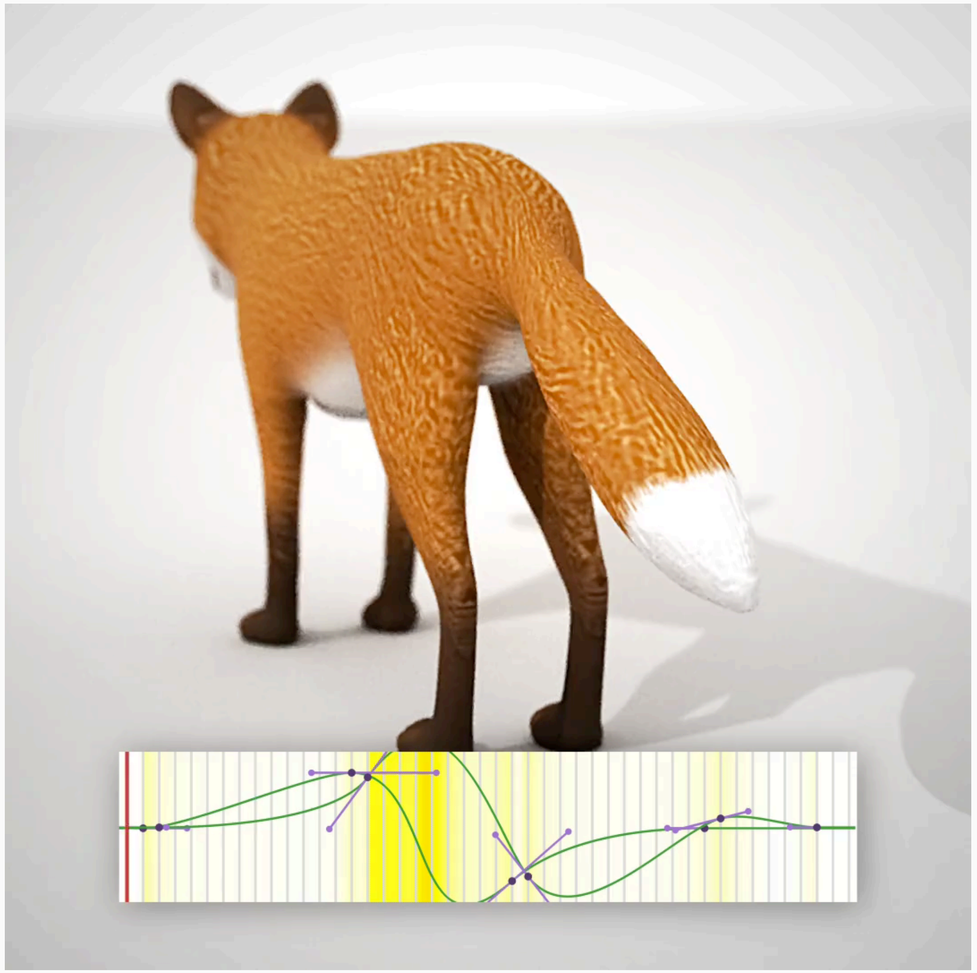
Control by time-varying cost weight

Control by regularization weight

Example Usage Scenarios

Example: Fox Tail

- #parameters: 27
- Rig: Forward kinematics (FK)

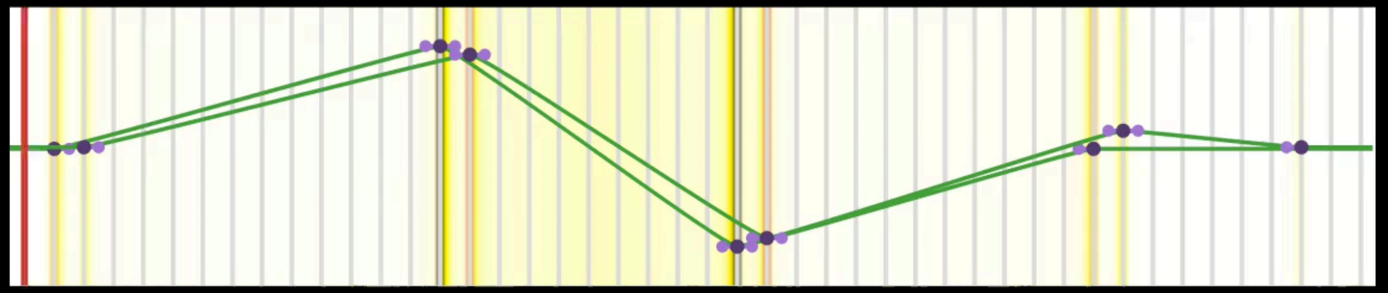


Example: Fox Tail

Initial motion

- Too robotic…

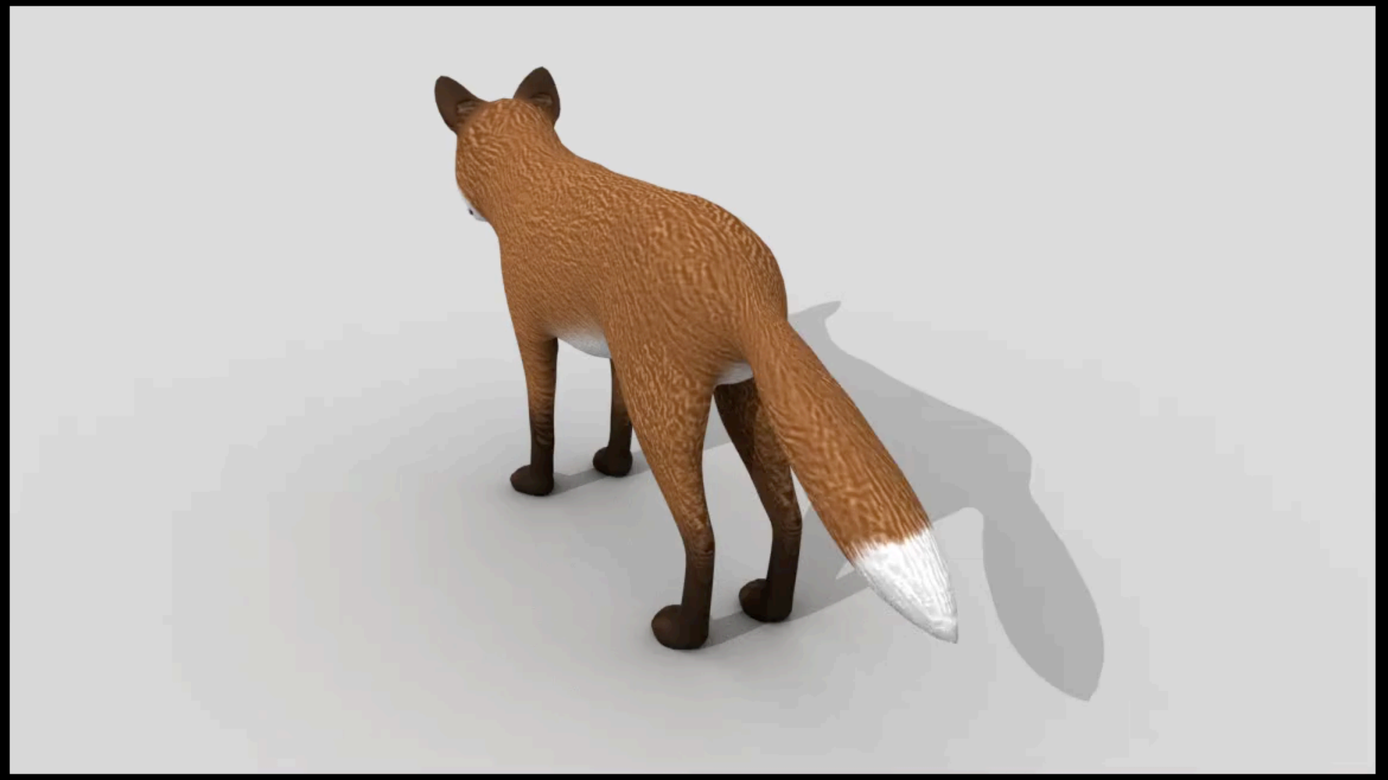
Let’s apply the (naïve) optimization first

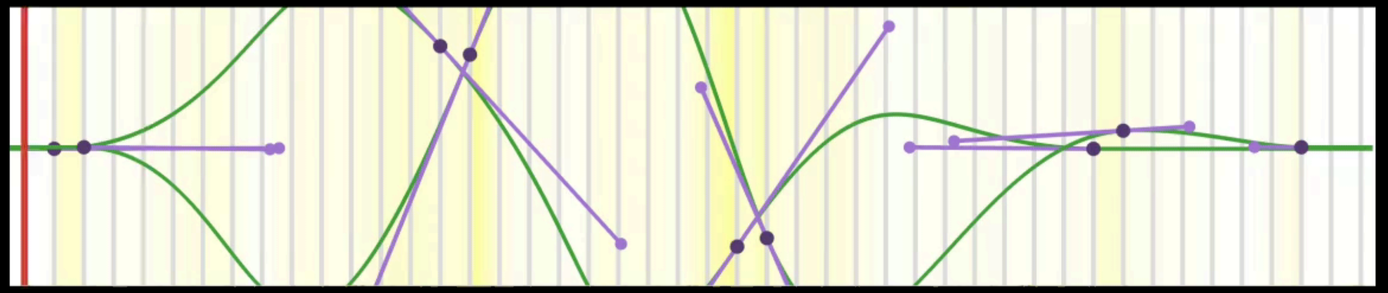


Example: Fox Tail

Naïve optimization

- Too much changed!





Let’s control it by regularization

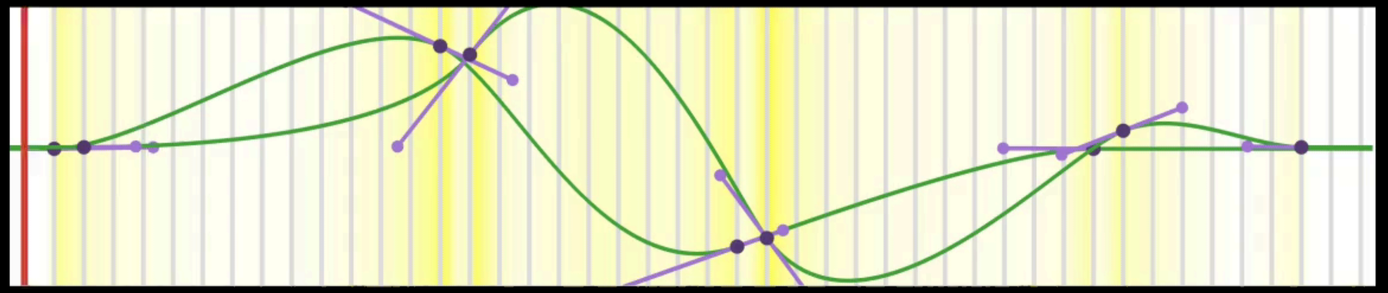
Example: Fox Tail

Optimization with regularization

- Looks good!!

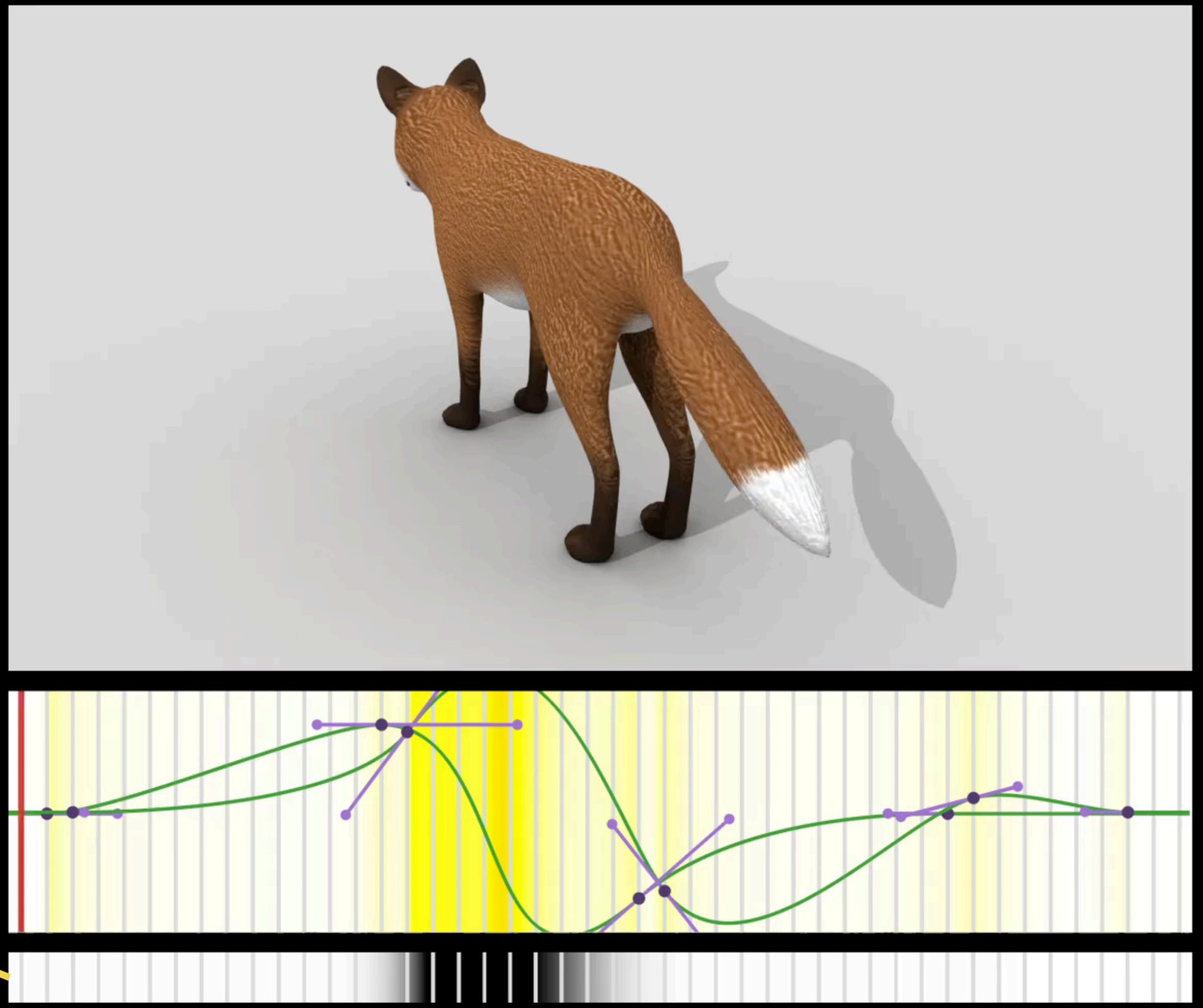
Inspiration:

How about making the swing speedier?



Example: Fox Tail

Optimization
with regularization
& time-varying cost



Time-varying
cost weight

Validation: Interview with Professional Animators

Informal Interview

- **Goals**
  - Validation of our approach (design goals, interactions, etc.)
- **Participants**
  - 2 professional animators (**A1** & **A2**) who are familiar with 3D character animation authoring
- **Procedure**
  - Explain our design goals, explain our system features, and ask feedback comments (approx. 1 hour)

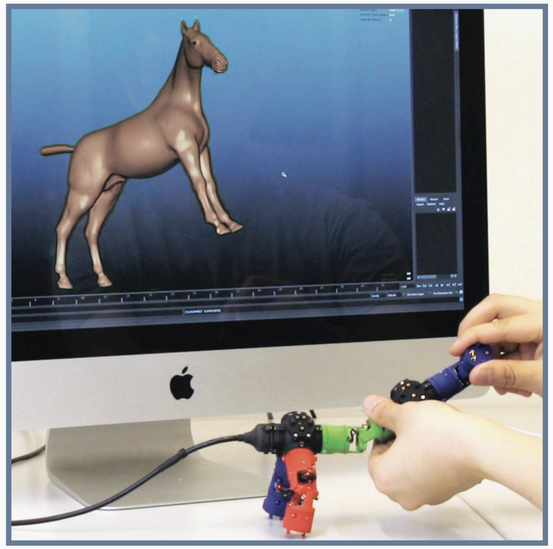
Results

- **Editability**
  - Both **A1** and **A2** loved editability, which was described "***indispensable***" (**A1**)
- **Transparency**
  - We observed that both **A1** and **A2** **easily understood the concept of optimization** by just seeing the visualizations
- **Controllability**
  - All features on controllability were ***strongly appreciated***
  - The **interactivity** makes the adjustment **"*easier*" and "*less stressful*"** (**A1**)

Discussions

Related Work: Motion Editing Techniques

Tangibles



[Glauser+16]

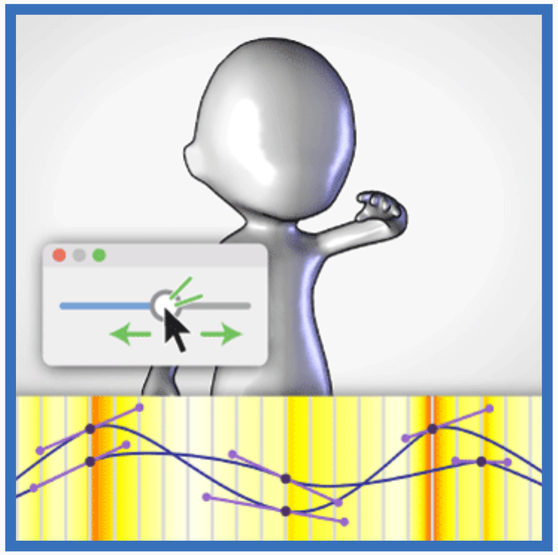
Sketches

[Choi+16]

Principles

[Kazi+16]

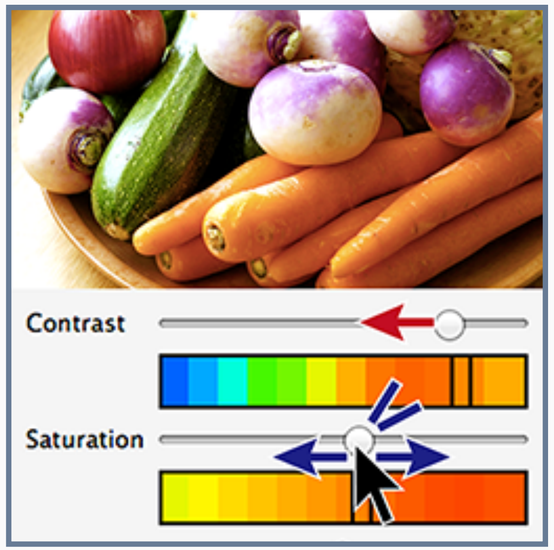
Optimization



Ours

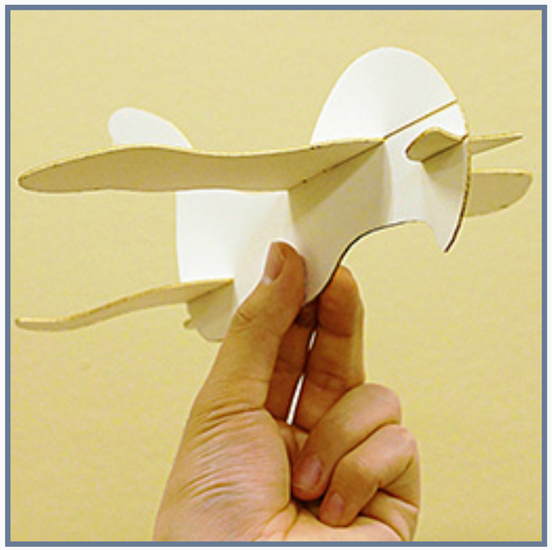
Related Work: Design Interface with Optimization

Photo color adjustment, etc.



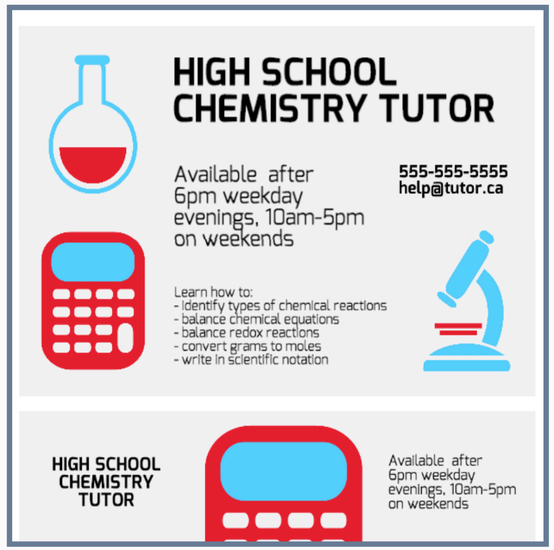
[Koyama+14]

Paper airplanes



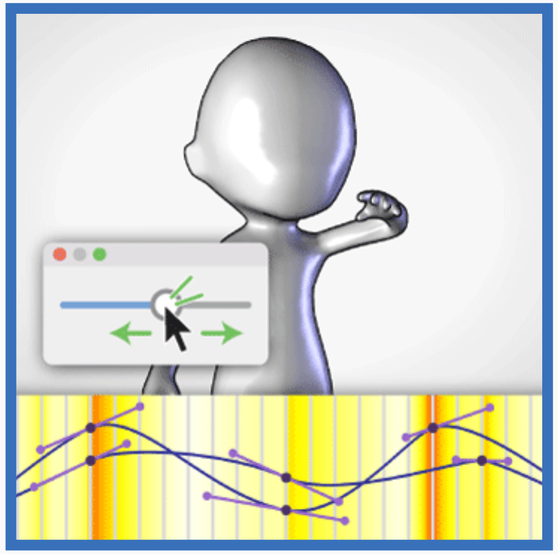
[Umetani+14]

Graphic layout



[O'Donovan+15]

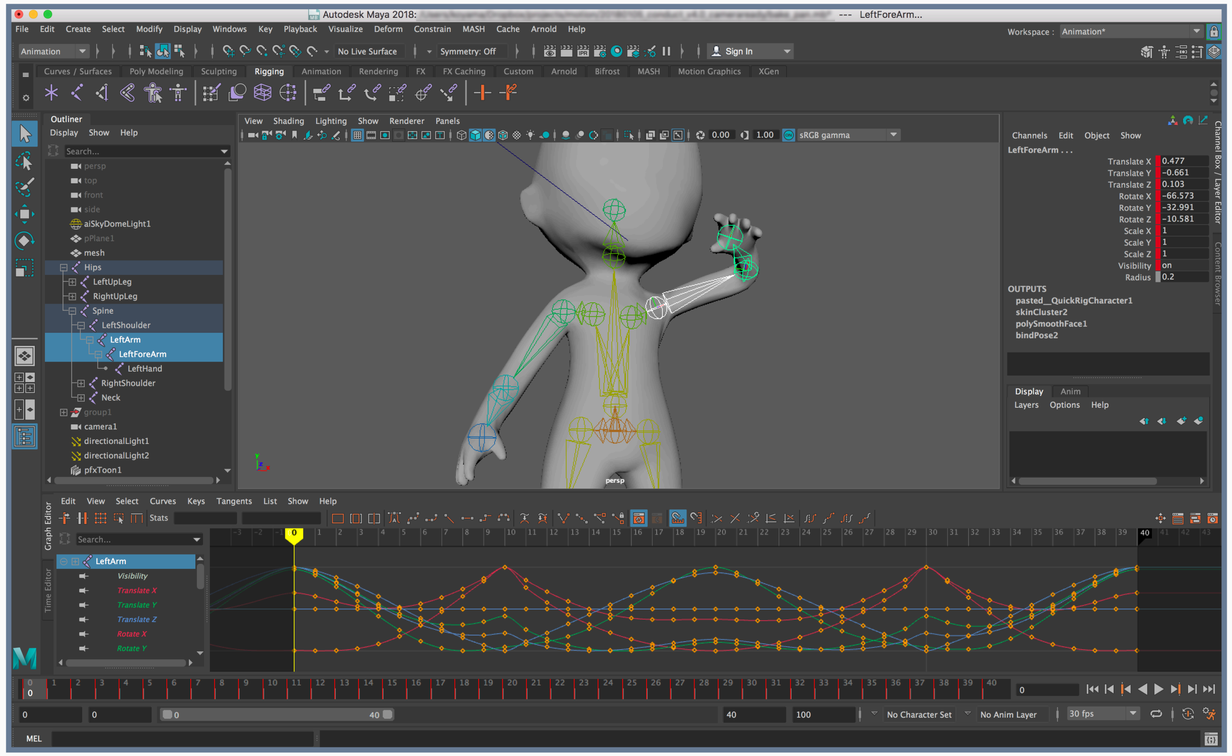
Character motions



Ours

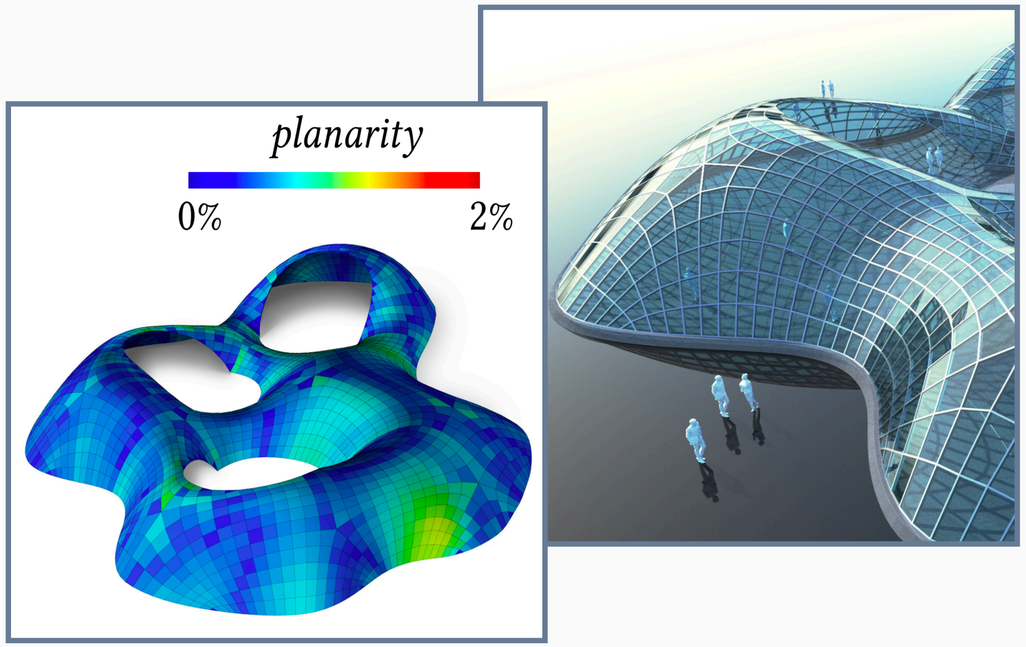
Future Work

Integration to & evaluation in professional workflow



E.g., Autodesk Maya

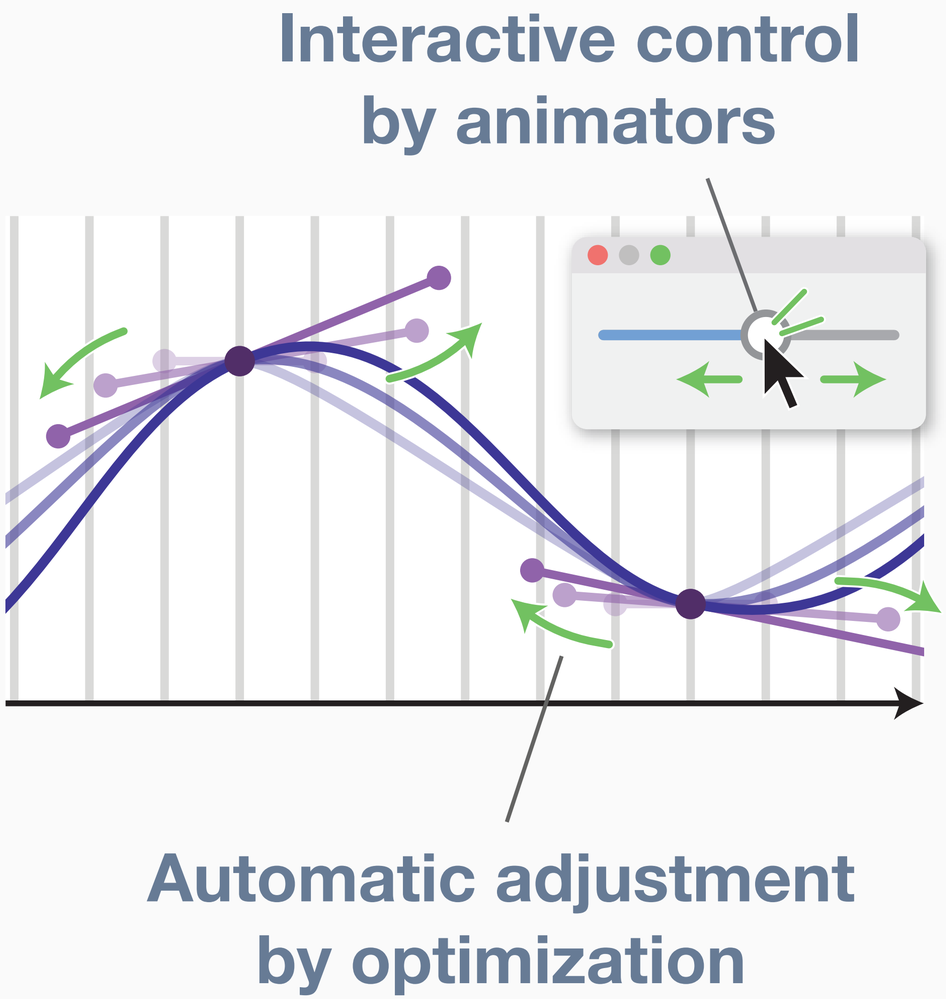
Applications to other design domains



E.g., architecture design [Kilian+17]

Summary

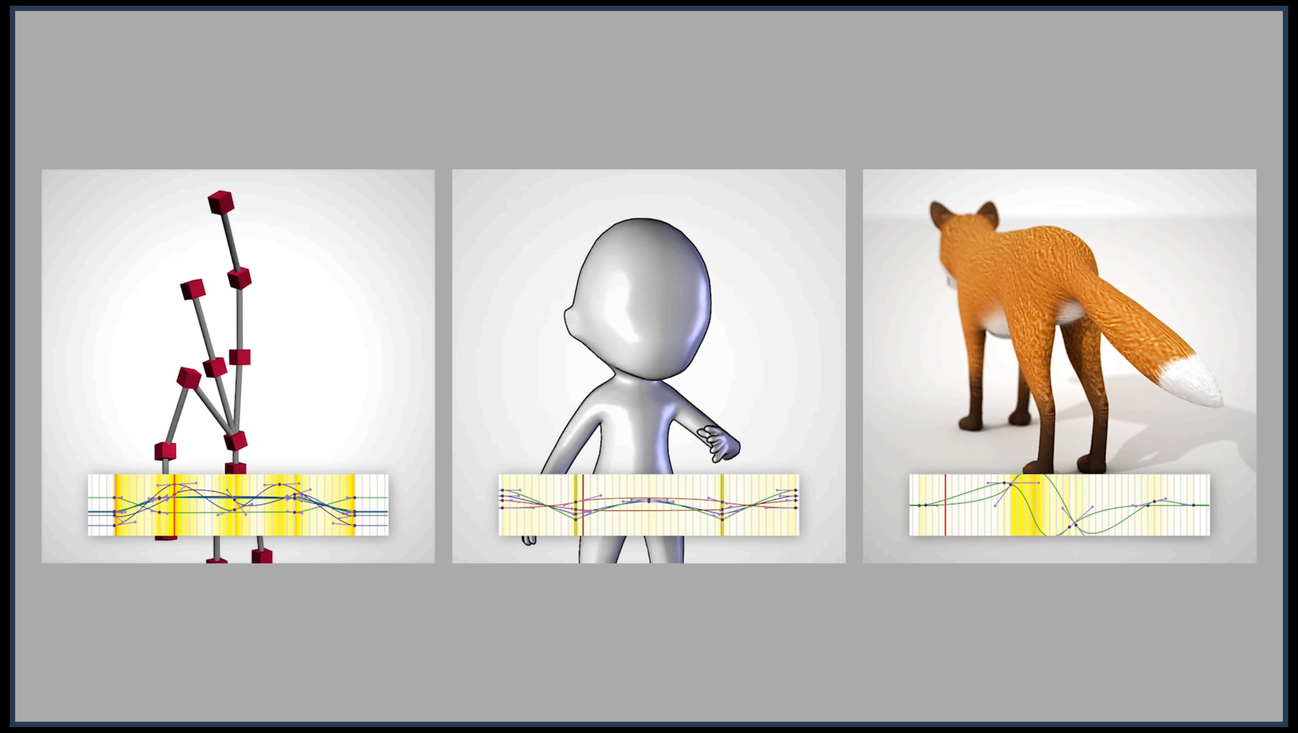
Optimization-Guided Motion Editing



- **Optimization** is used for **enhancing manual editing**
- OptiMo allows animators to **interactively control** optimization

http://koyama.xyz/project/optimo/

Slides & videos available! We also plan to release our source codes!



Yuki Koyama and Masataka Goto. OptiMo: Optimization-Guided Motion Editing for Keyframe Character Animation. CHI 2018.

CHI 2018
Engage with CHI

OptiMo: Optimization-Guided Motion Editing for Keyframe Character Animation

Yuki Koyama & Masataka Goto

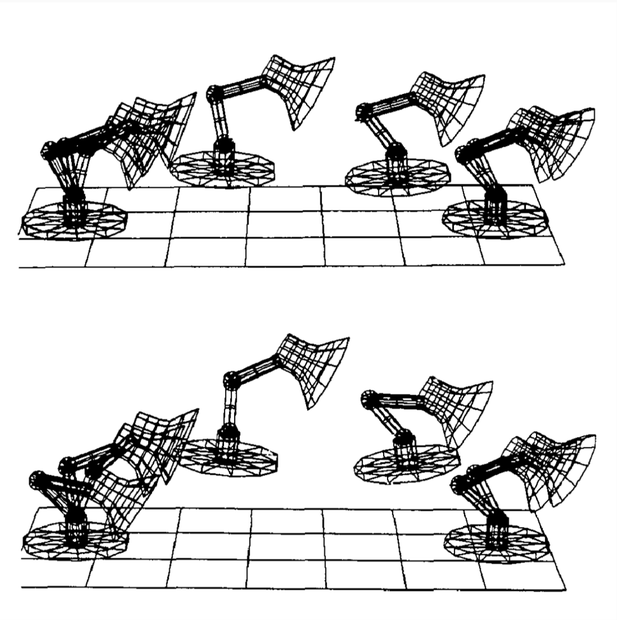
AIST

Appendix

Related Work

Motion Editing Techniques — Automatic

Optimization with space-time constraints



[Witkin+88]

Use of learned motion controllers

[Merel+17]

Difficult to reflect artistic intention

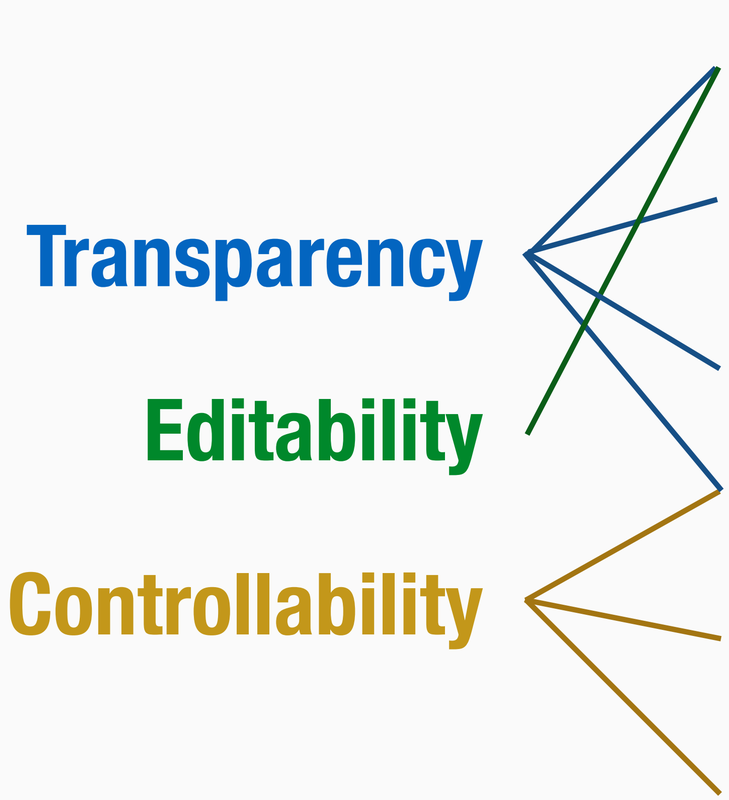
➡ **Lack of controllability**

Resulting motions do not have curve-based data representation

➡ **Lack of editability**

OptiMo’s Features

We Designed 6 Features for OptiMo



1. Preservation of control handles **[T & E]**
2. Optimization process visualization **[T]**
3. Cost visualization **[T]**
4. Interactive regularization **[T & C]**
5. Per-Joint regularization **[C]**
6. Time-varying cost control **[C]**

Algorithm:
How Does Optimization Work?

Typical Optimization Formulation

$$\min_{\mathbf{x}} \left\{ \int C(\mathbf{x}, t) dt \right\}$$

Search parameters

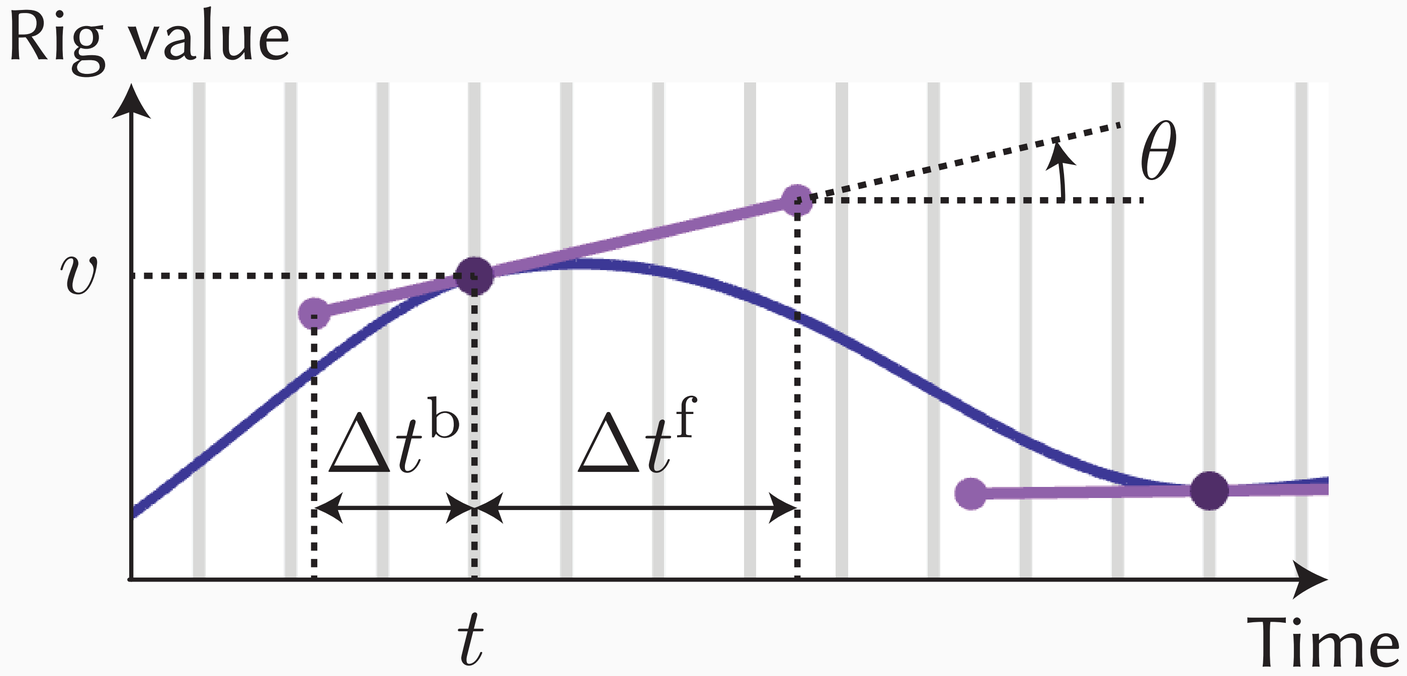
x

Cost function

***C*(x, *t*)**

Parametrization (Search Space)

Use the control handle parameters (that animators otherwise manipulate manually) as the search parameters of the optimization



➡ This ensures **editability** (and also transparency)

Cost Function: Our (Current) Choice

$$C(\mathbf{x}, t) = \sum_{j \in \mathcal{J}} \|\boldsymbol{\tau}_j(\mathbf{x}, t)\|^2$$

- Is well-established and used in computer graphics and robotics (c.f. [Safonova+04])
- Is a summation of necessary **torques** (rotational forces) on each joint
- Is useful for **avoiding physically unfeasible motions**

Validation: Interview with Professional Animators

Comments on Editability

- Both **A1** and **A2** loved editability
  - **A1**: Editability is "***indispensable***"
- This comment especially validates our parametrization:
  - **A2**: It is acceptable for "*the [tangent] handles to change*," but "*the keyframes (key points) should not be change*" by optimization

Comments on Transparency

- Both **A1** and **A2** loved the visualization features
  - **A1**: The process visualization "*is **very interesting***"
- We observed that both **A1** and **A2** **easily understood the concept of optimization** by seeing the visualizations

Comments on Controllability

- All features on controllability were **strongly appreciated**
  - **A2**: "*I would be puzzled if I can't use this*"
- The **interactivity** of control features was appreciated
  - **A1**: These features could make adjustment **"*easier*" and "*less stressful*"**

Comments on Usages in Production

- The current system is not perfect yet, but it could be useful…
  - **A2**: For "*sub-characters' motion*," or
  - **A1**: In "*projects with only limited time*"
- Both **A1** and **A2** got very excited about the (production-level) quality of the fox tail animation
  - **A2**: "*It is possible to provide it by hand, but it requires much tweaking to make it (the motion) look natural*"

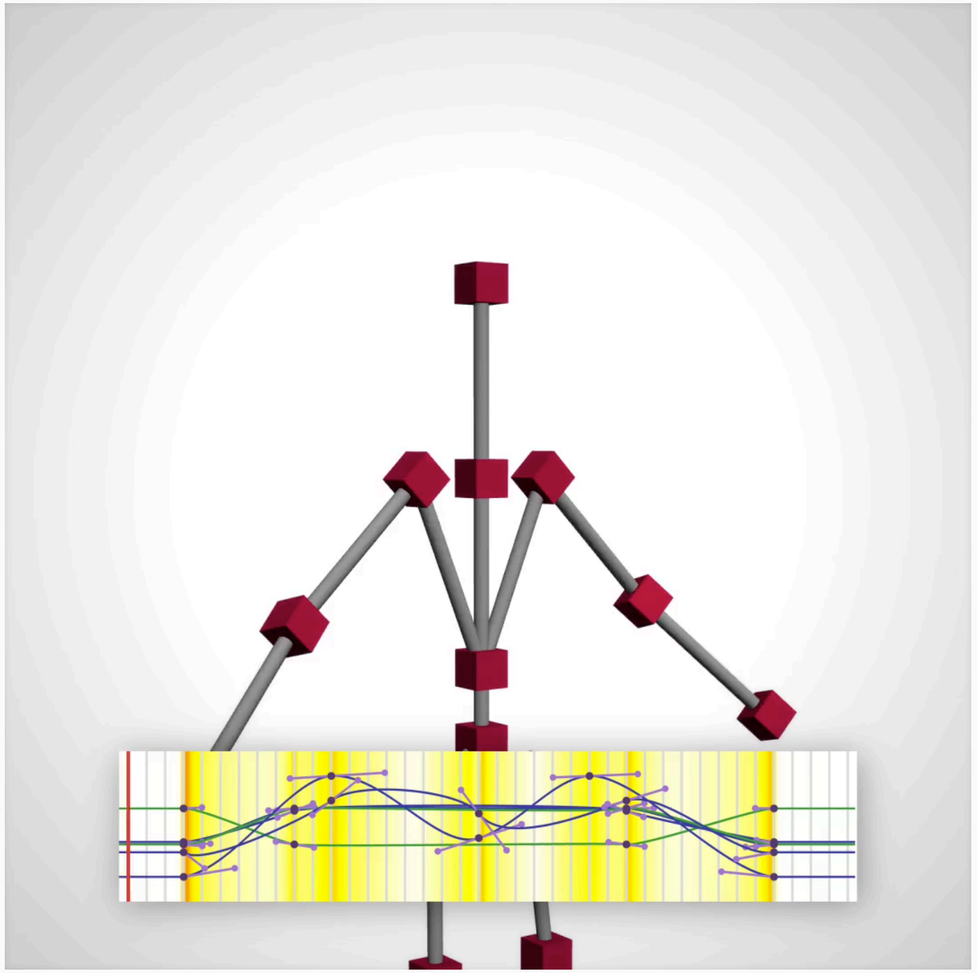
Other Comments

- It would be nice if **motion styles** could be handled in the cost function as well as physics
  - **A2**: "*Each art project has a specific style of motions*" and "*it would be nice if it automates [the process of applying such styles]*"

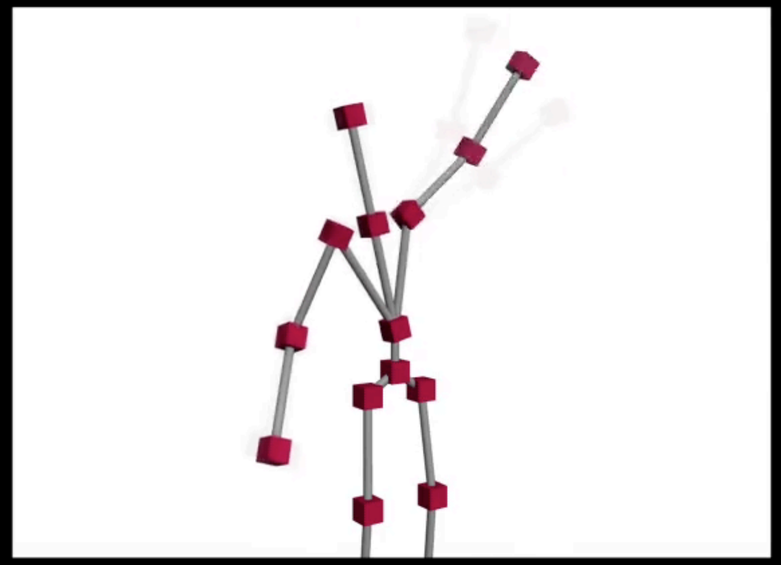
Example Usage Scenarios

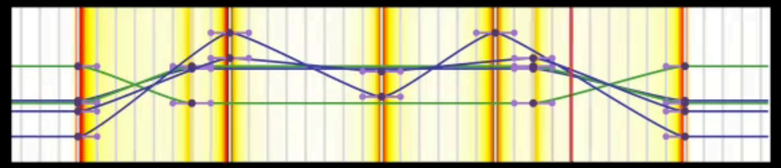
Example: Stick Figure Waving His Arm

- #parameters: 78
- Rig: Forward kinematics (FK)



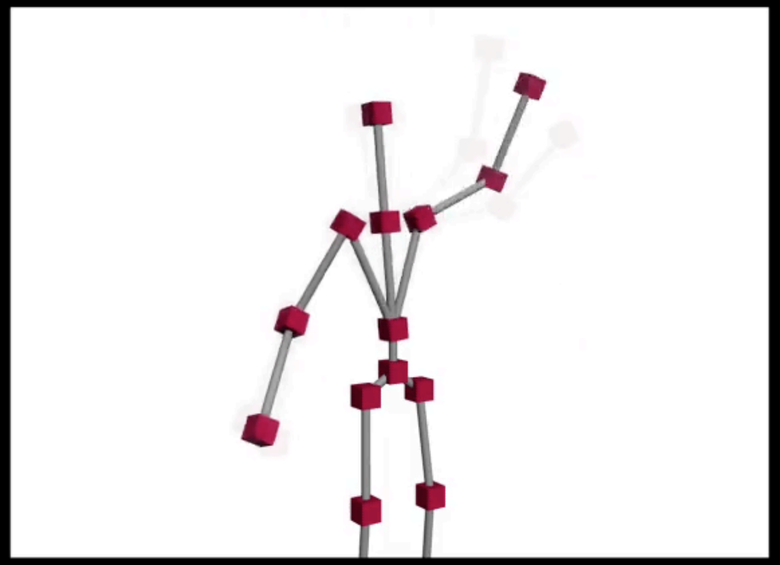
Example 1: Stick Figure Waving His Arm

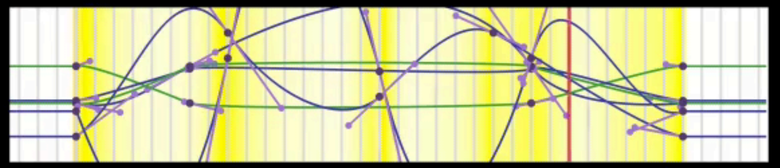




Initial

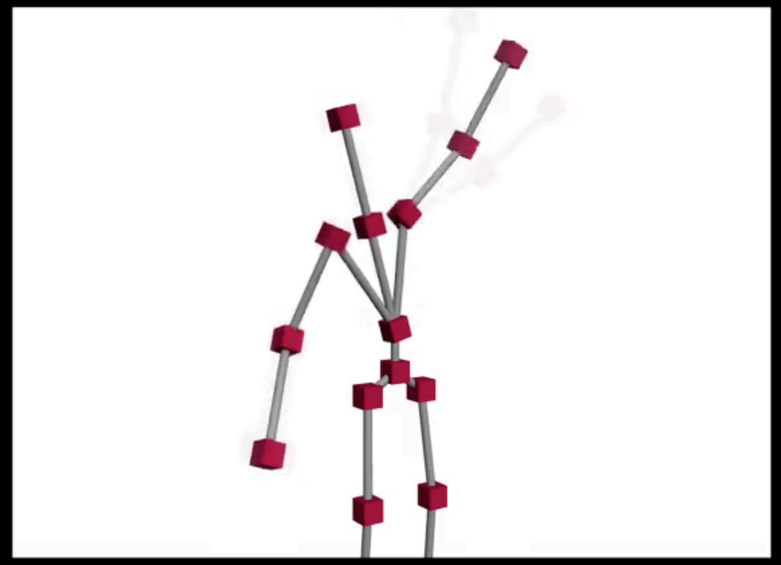
Too robotic…

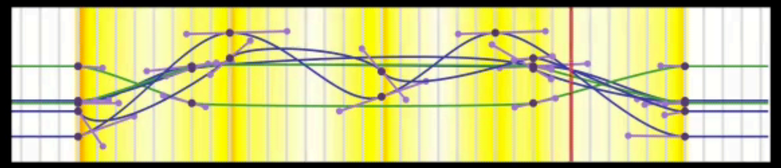




Naïve opt.

The spine/elbow bend wrongly…



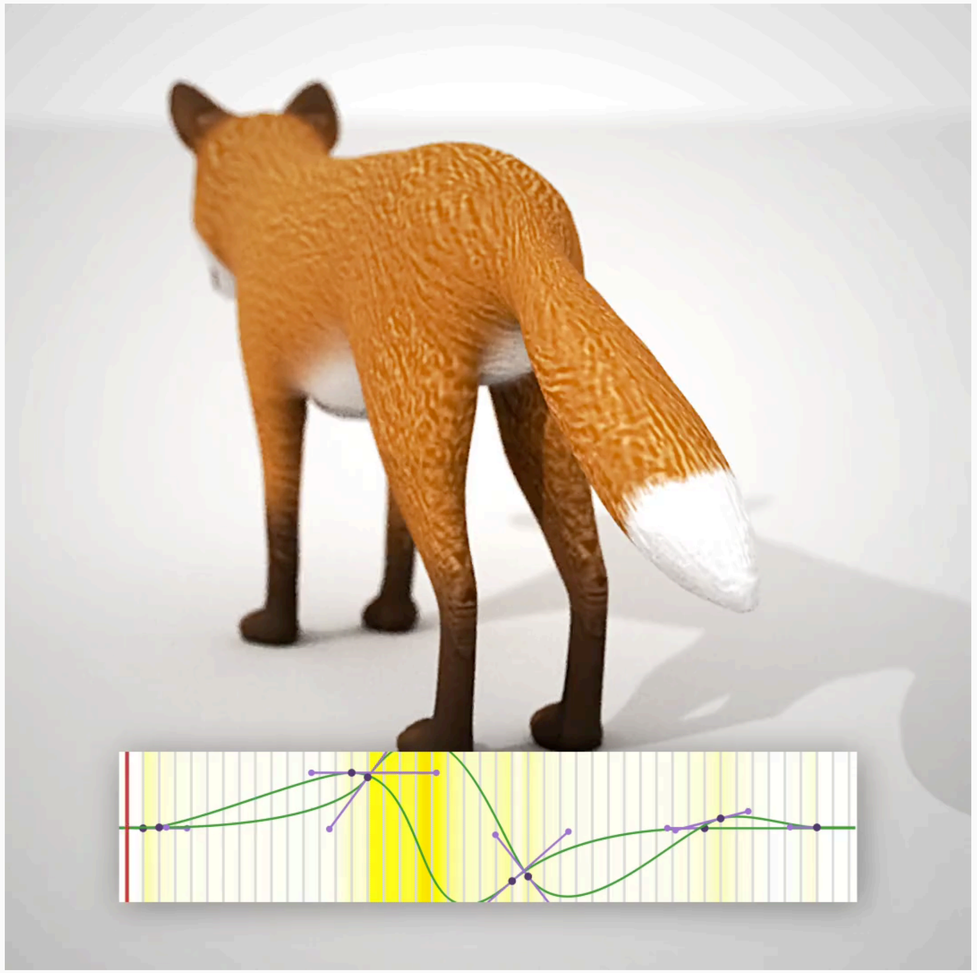


Controlled opt.

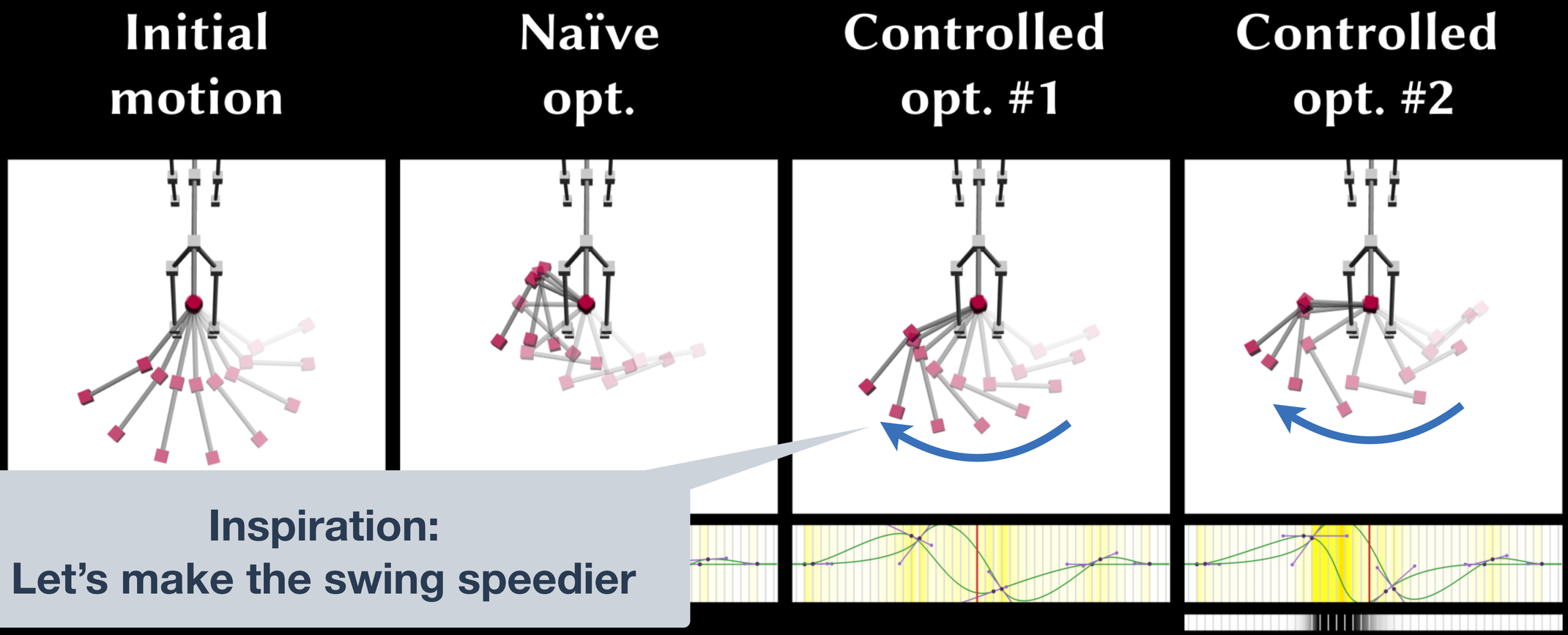
Looks natural :)

Example: Fox Tail

- #parameters: 27
- Rig: Forward kinematics (FK)



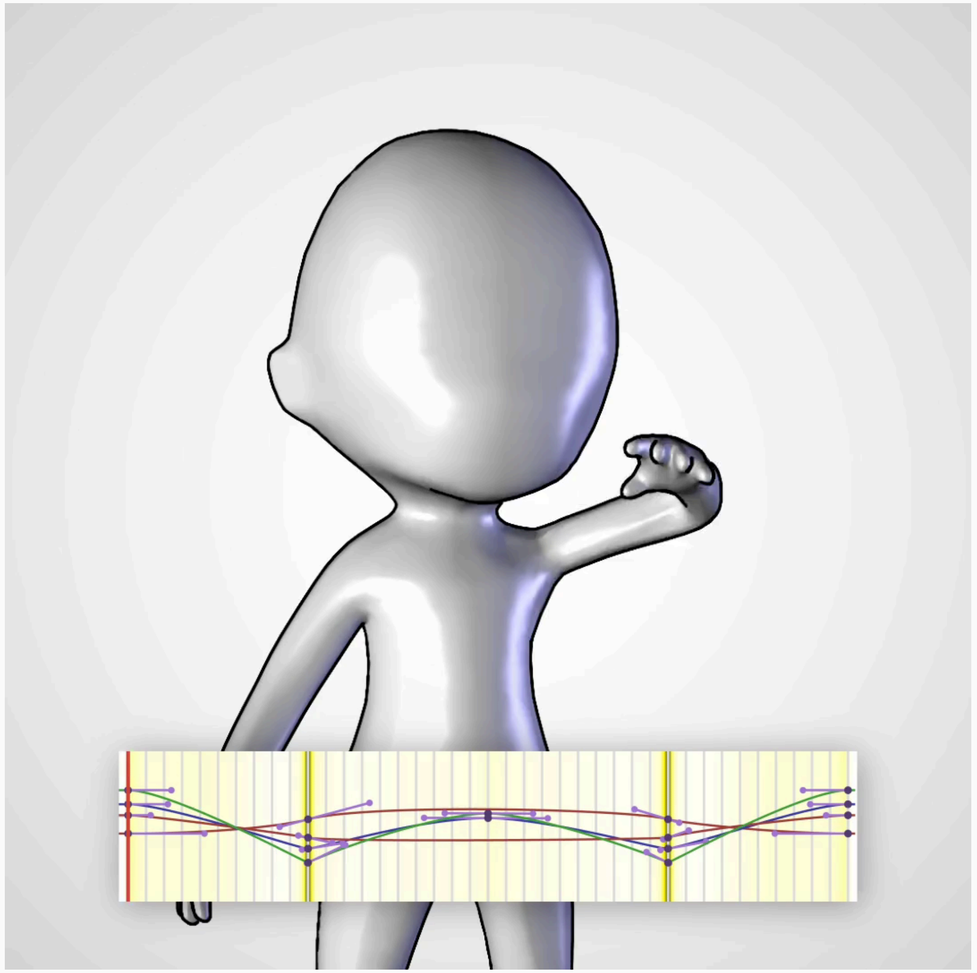
Example: Fox Tail



Example: Music Conductor

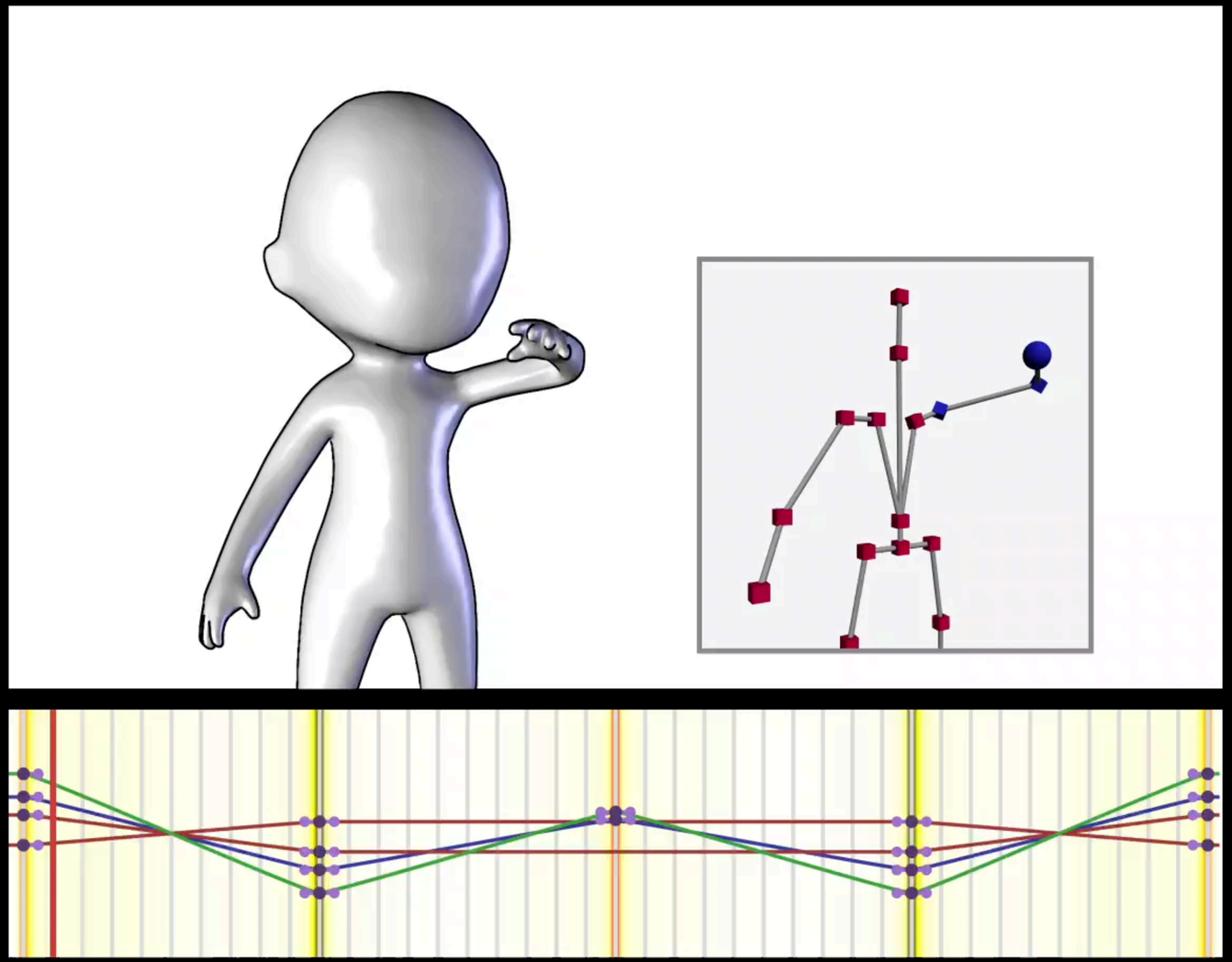
- #parameters: 54
- Rig: Forward kinematics (FK) and inverse kinematics (IK)

The next slide contains audio!



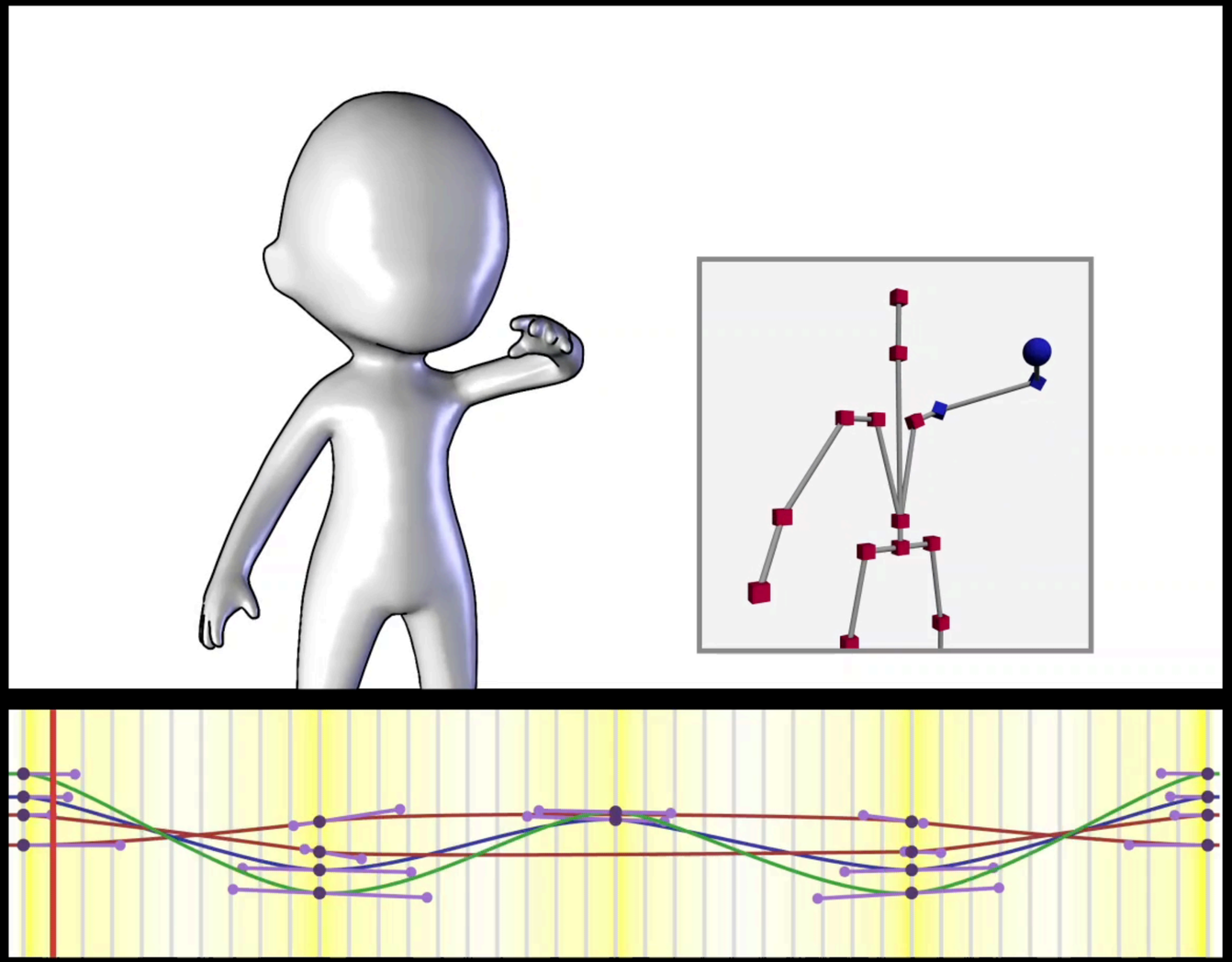
Example: Music Conductor

Initial motion



Example: Music Conductor

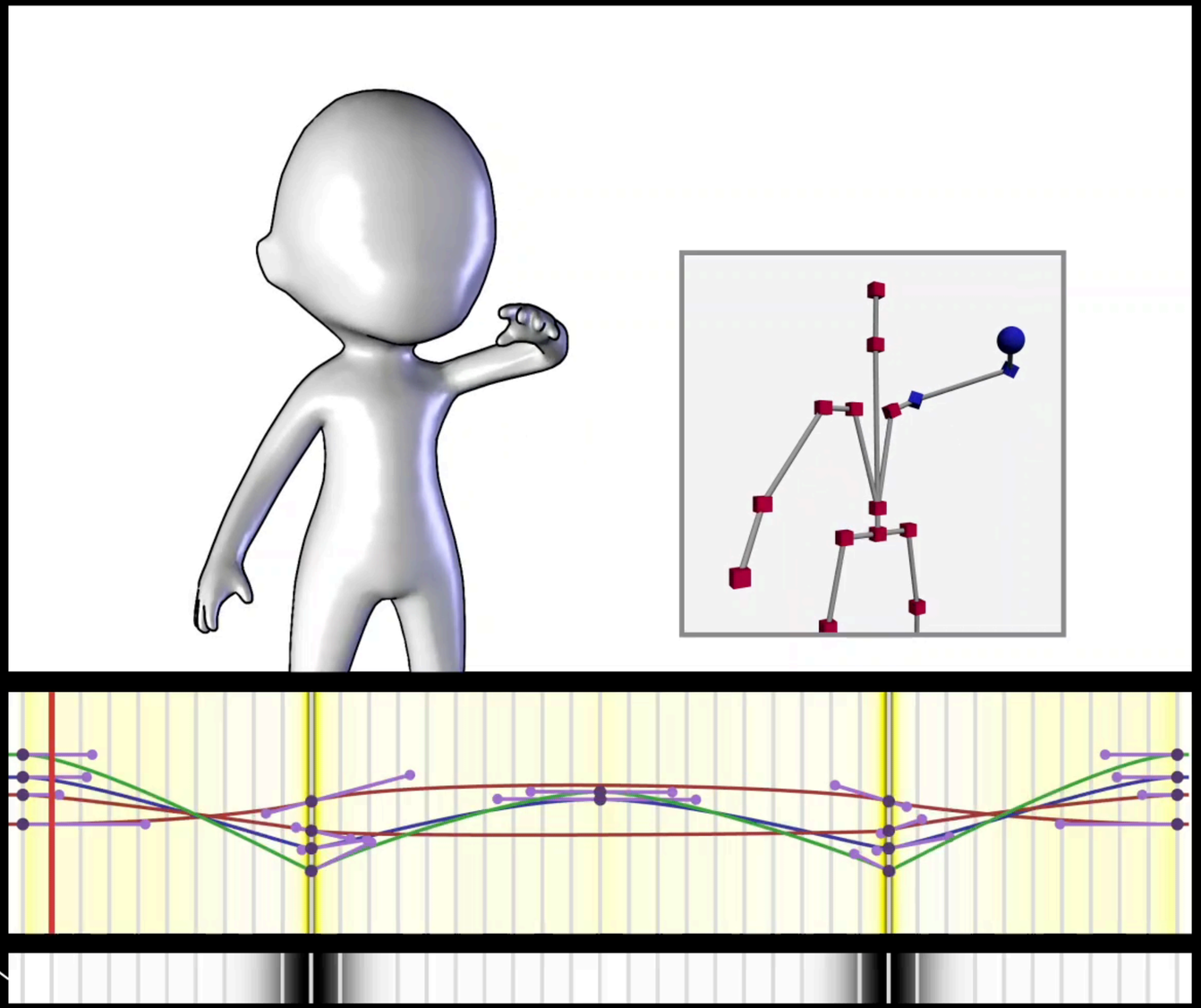
Naïve optimization



Example: Music Conductor

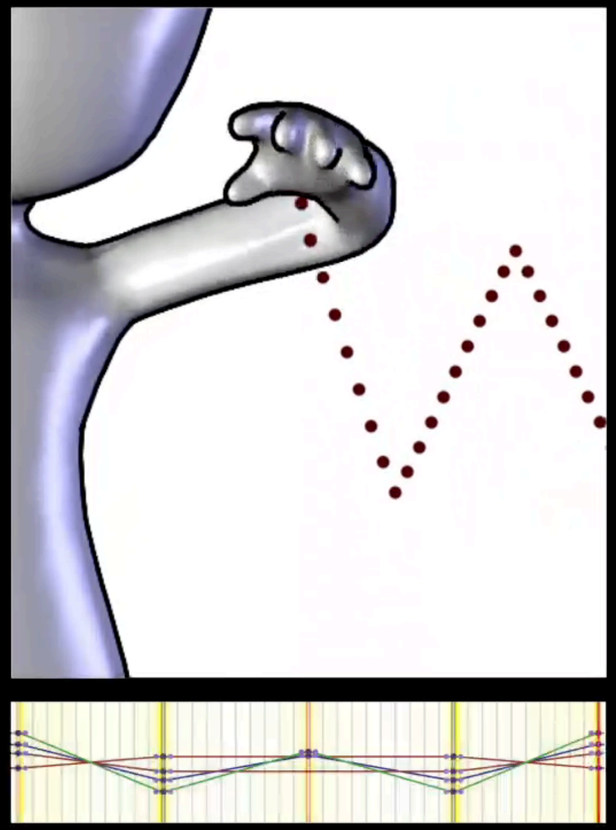
Controlled optimization

- Time-varying cost control

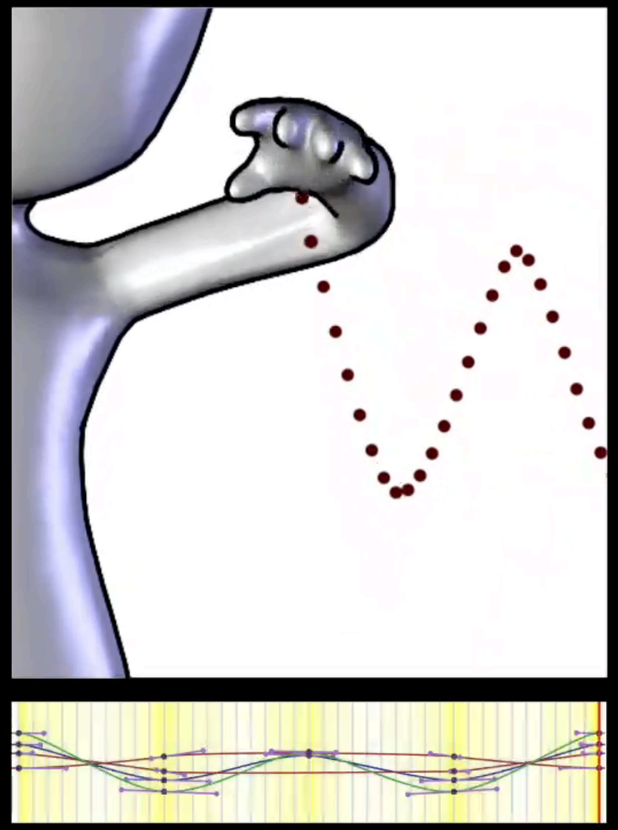


Example: Music Conductor

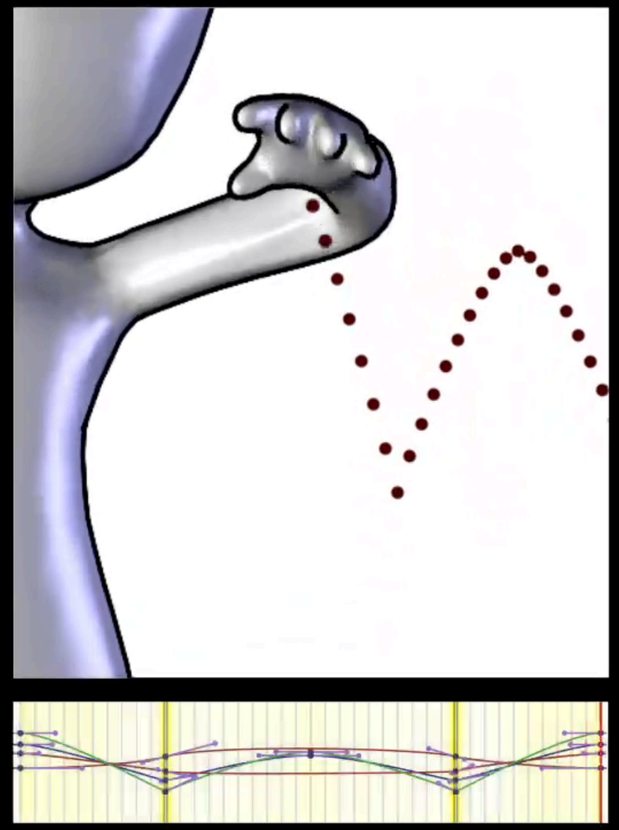
Initial motion



Naïve optimization



Controlled optimization

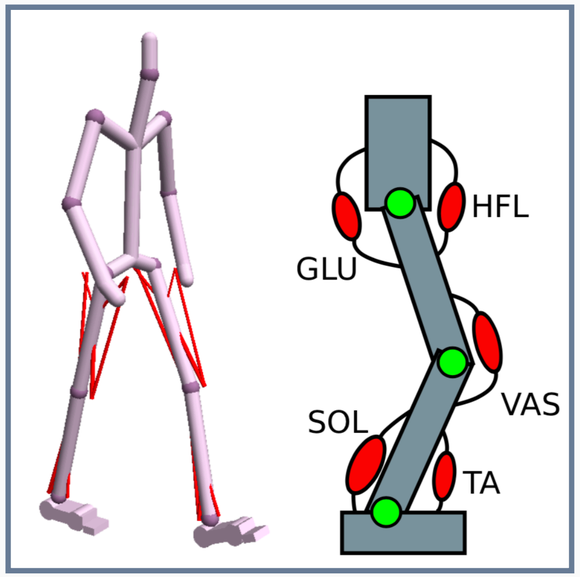


Trajectry Visualization & Playing on 0.5x speed...

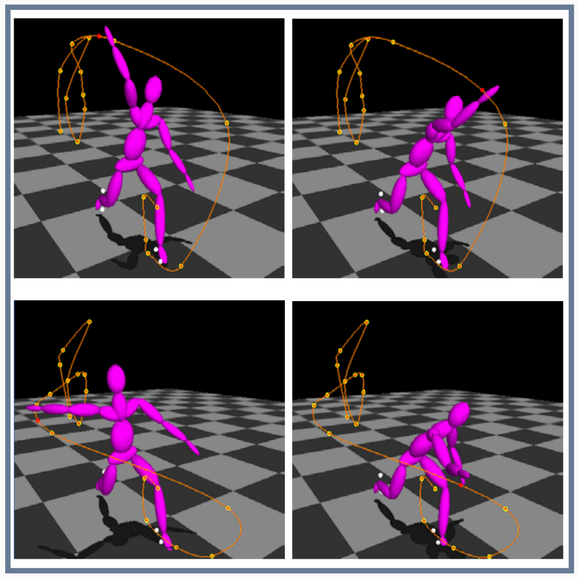
Discussions

Discussion: “One is not Enough”

Providing **more options of cost functions** as well as our physics-based cost function — One is not enough!



Muscle models [Wang+12]



Motion styles [Grochow+04]