UIST 2022

BO as Assistant: Using Bayesian Optimization for Asynchronously Generating Design Suggestions

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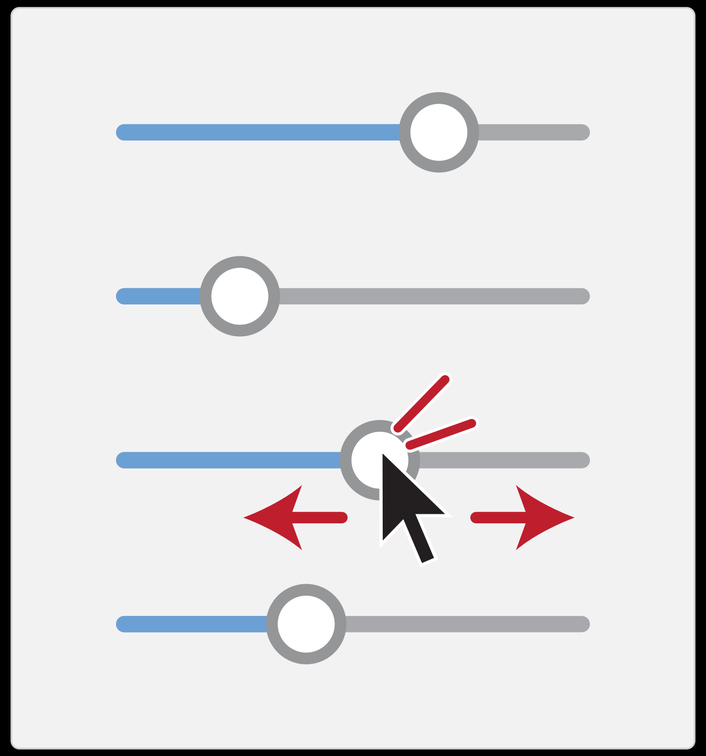
National Institute of Advanced Industrial Science and Technology (AIST)

Background: Human-in-the-Loop Optimization

Parametric design is ubiquitous in digital content creation



Parametric design is ubiquitous in digital content creation

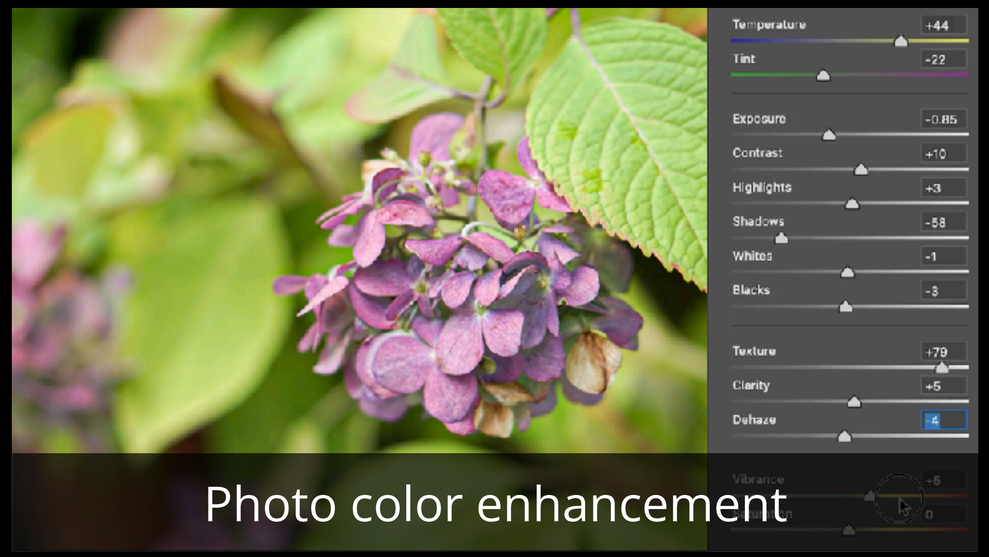
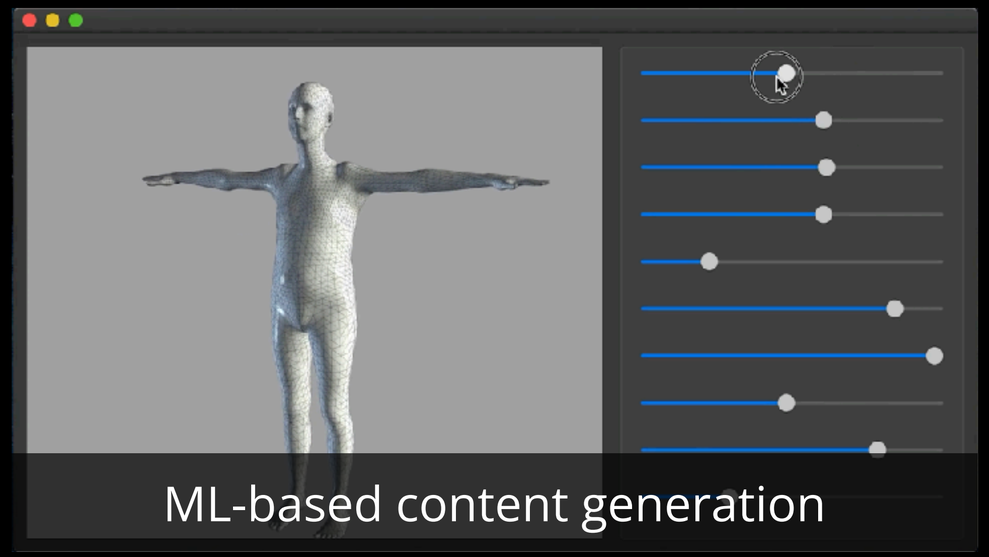
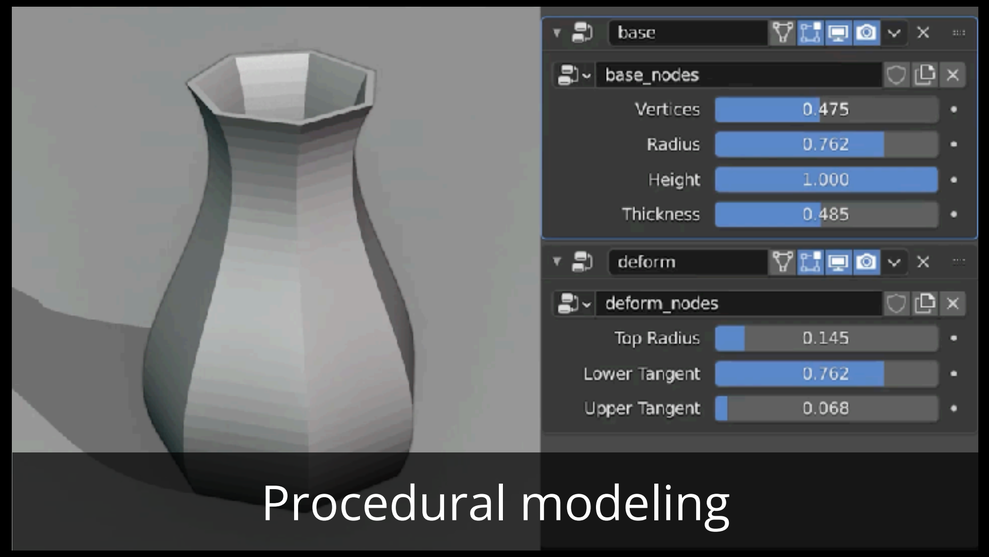


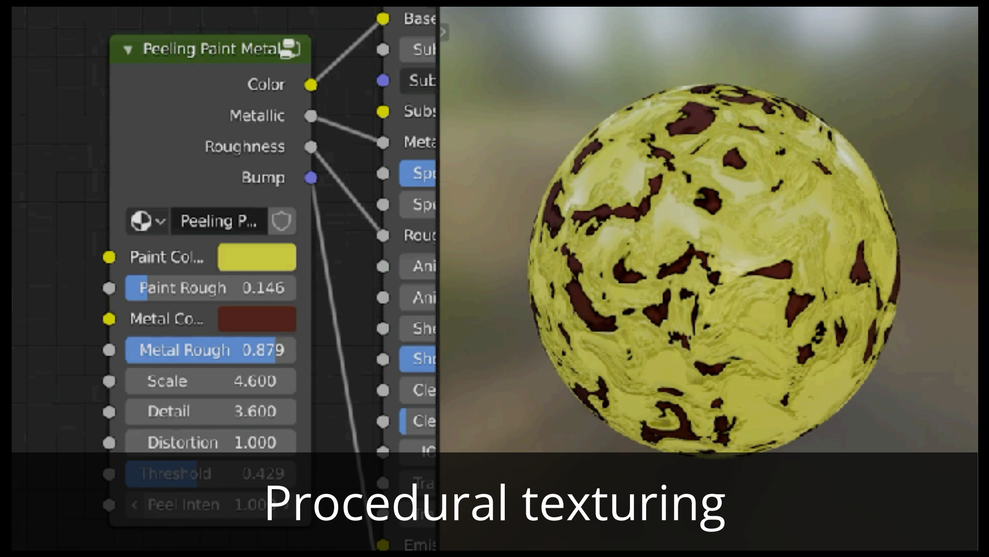
Photo color enhancement



ML-based content generation

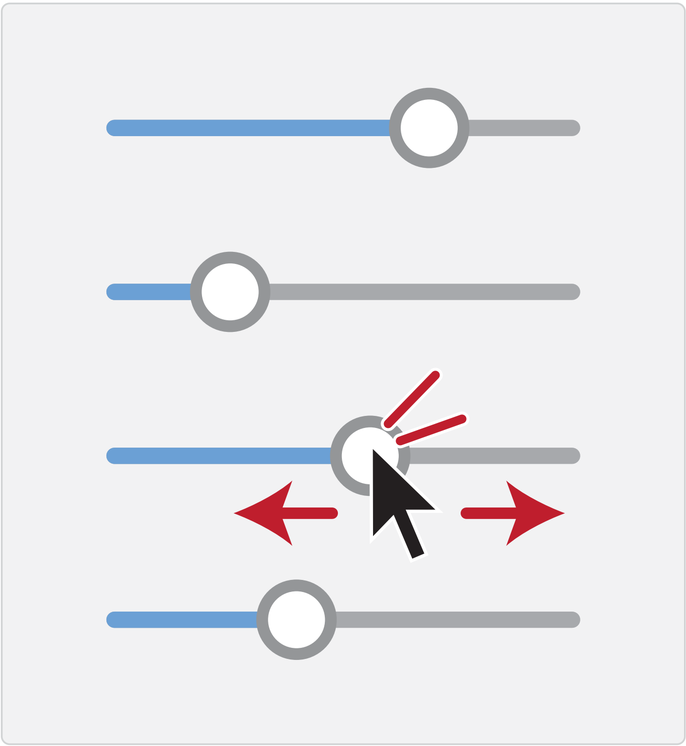


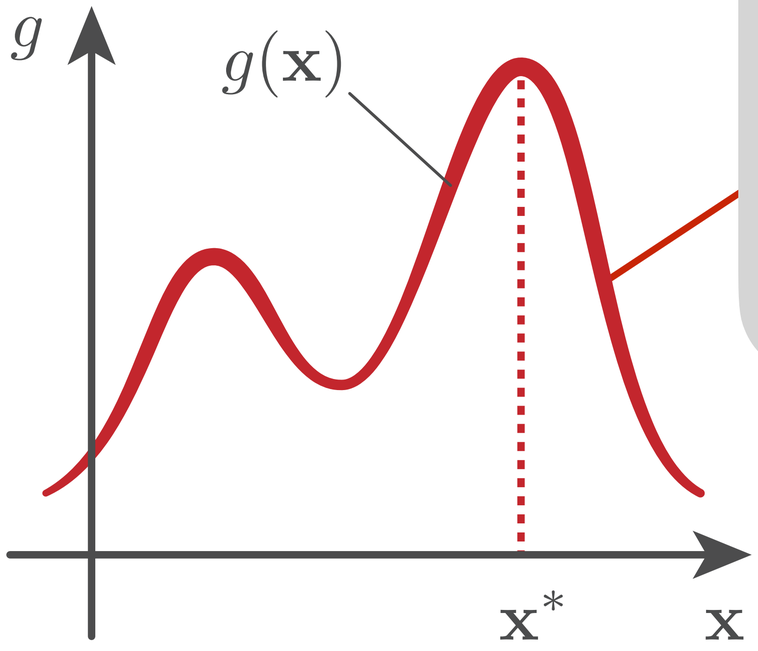
Procedural modeling



Procedural texturing

Math Viewpoint





$$\mathbf{x}^* = \arg\max_{\mathbf{x}} g(\mathbf{x})$$

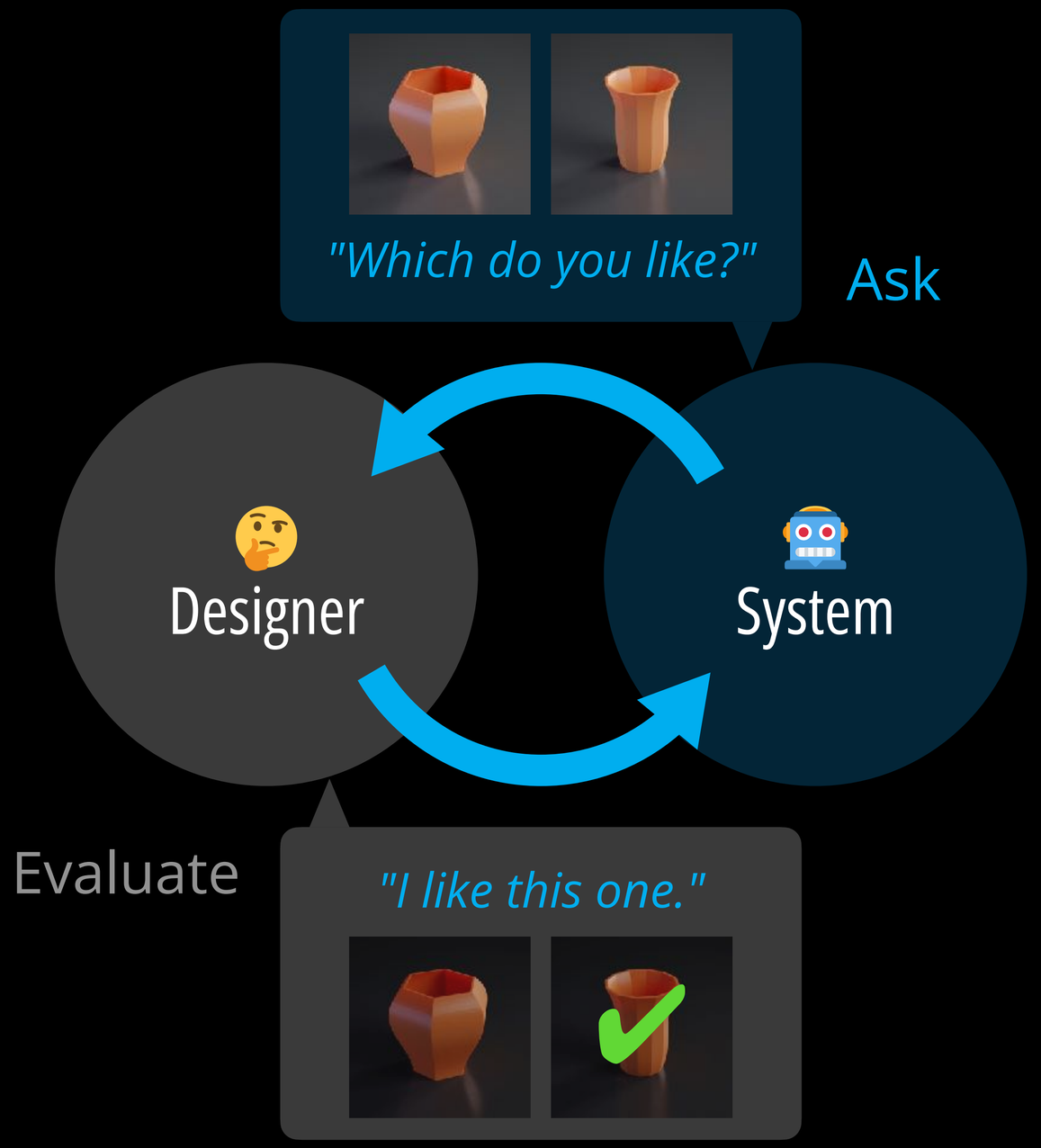
Challenge: Defined by human preference

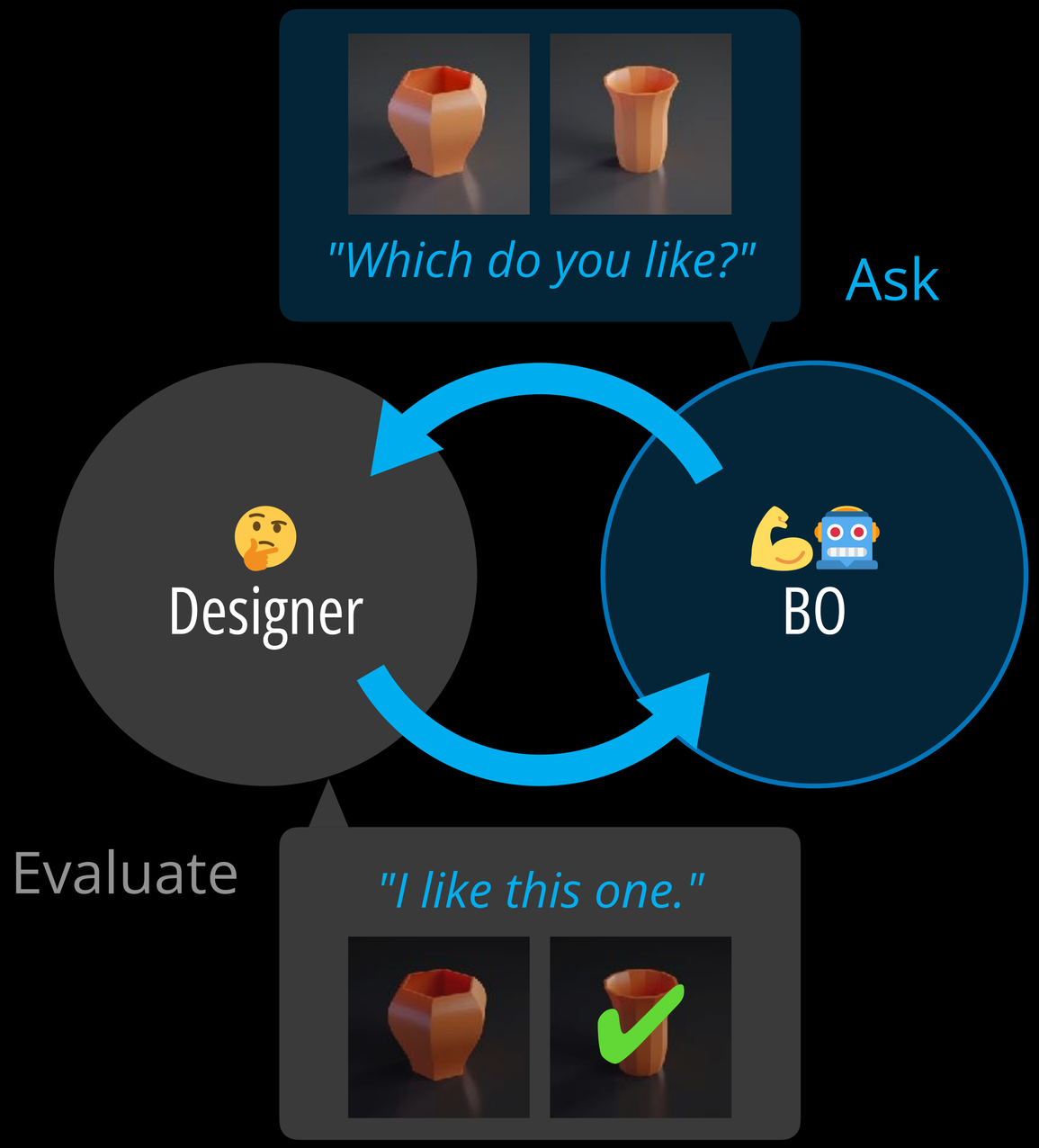
Design parameter tweaking

Mathematical optimization

Human-in-the-loop optimization

solves optimization problems with perceptual objective functions (e.g., preference)





Bayesian optimization (BO)

- Intelligent sampling strategy
  - *"Exploration and exploitation"*
- Able to find a good solution within a small number of iterations (sample efficient)
  - Less burden on the evaluator

Previous Work: Human-in-the-Loop Bayesian Optimization

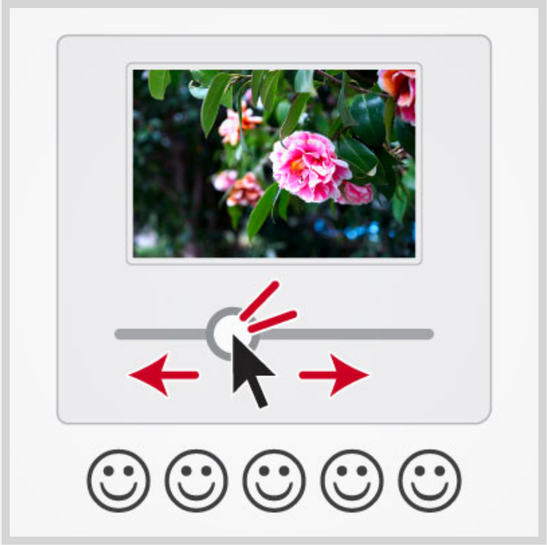
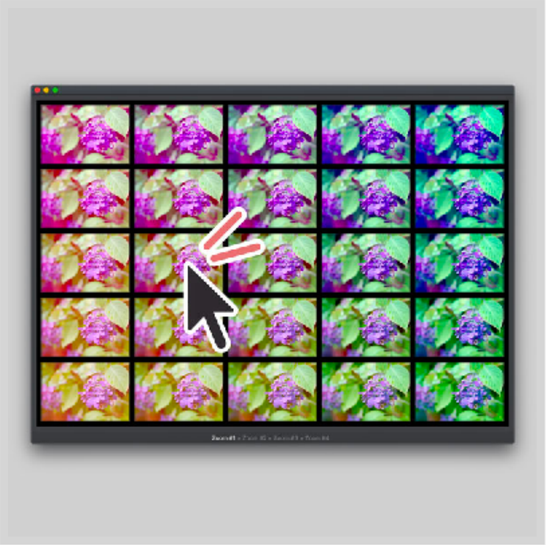
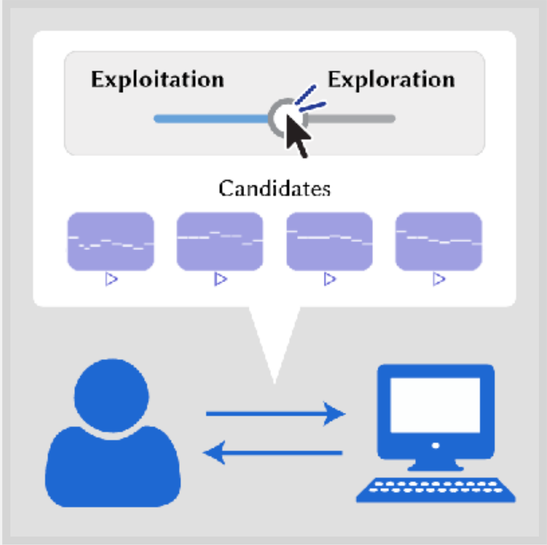


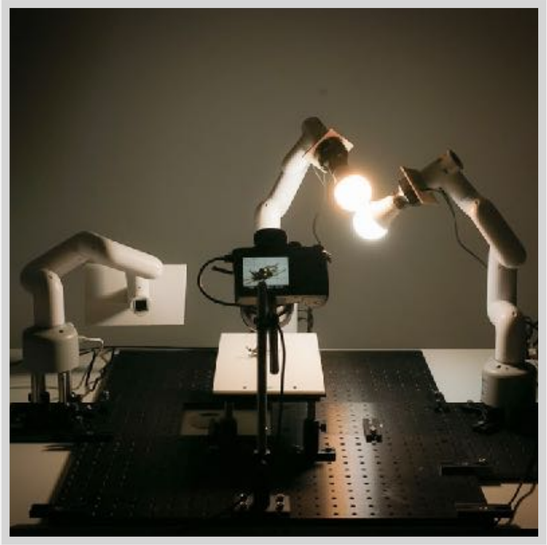
Photo Enhancement
Koyama+
SIGGRAPH 2017



3D Computer Graphics
Koyama+
SIGGRAPH 2020



Melody Generation
Zhou+
IUI 2020



Photographic Lighting
Yamamoto+
UIST 2022

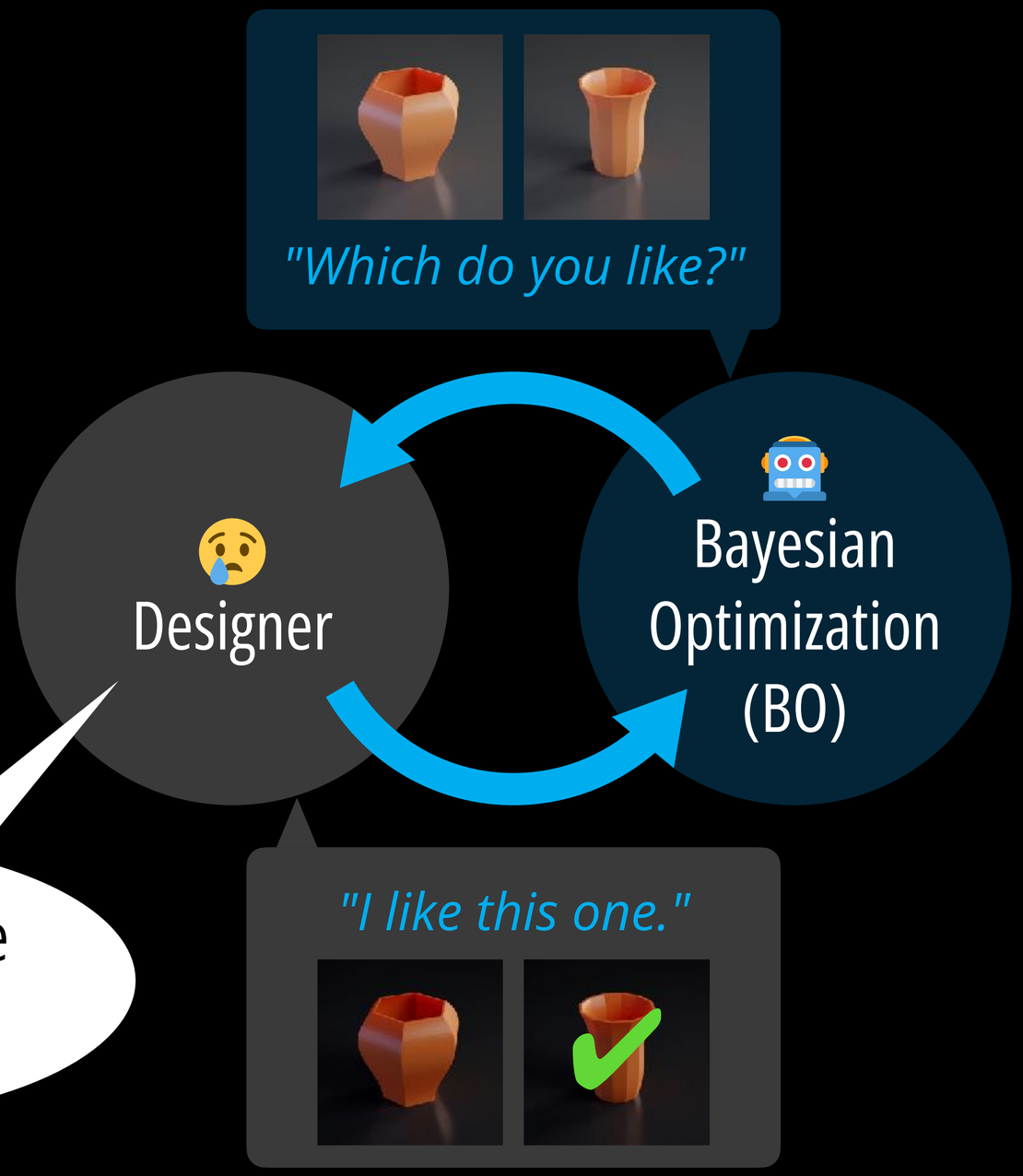
→ Successfully used in previous work to enable efficient search

Problem & Motivation

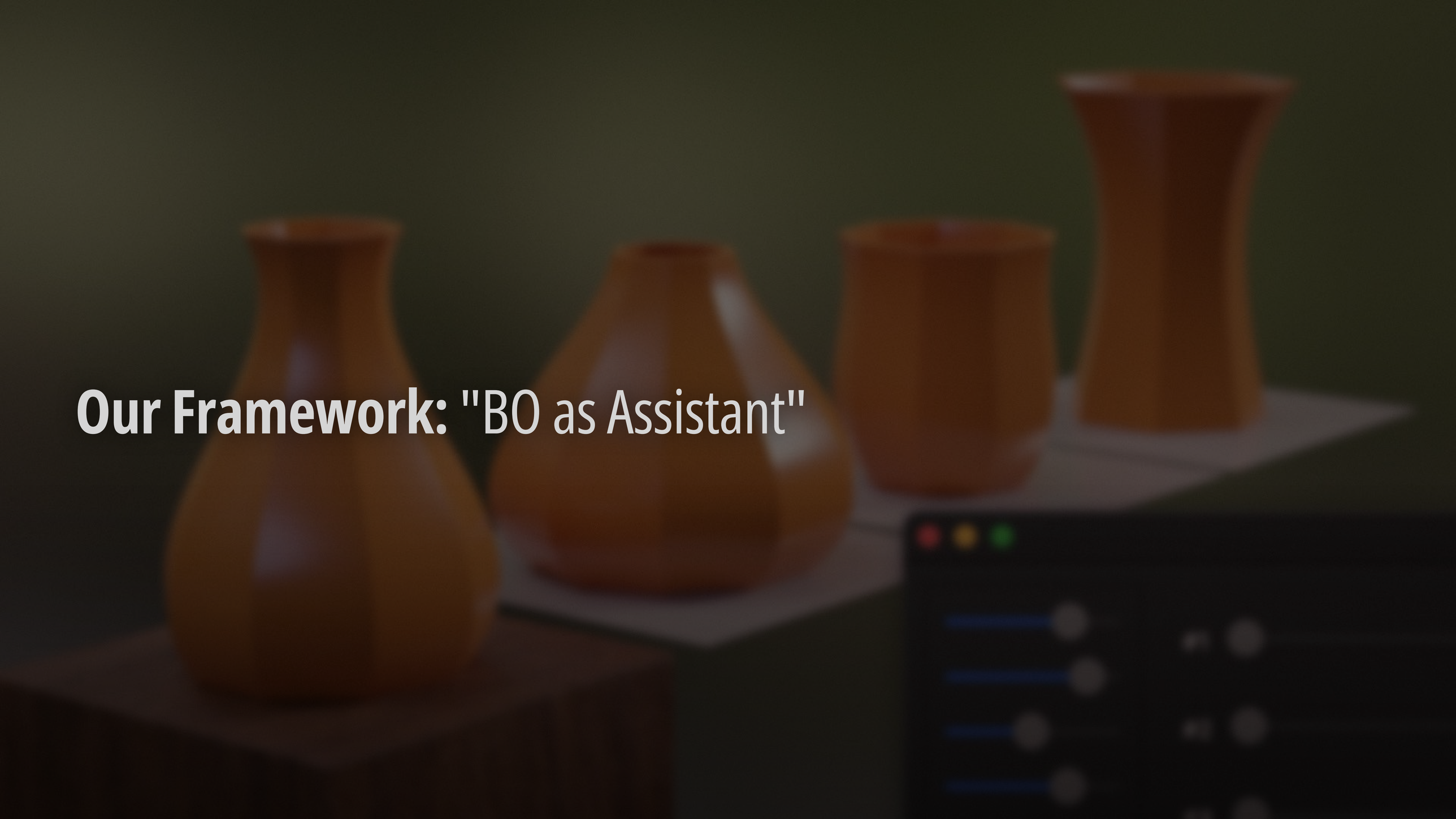
Problem: No freedom for designer, reducing agency and creativity

[Chan+, CHI 2022]

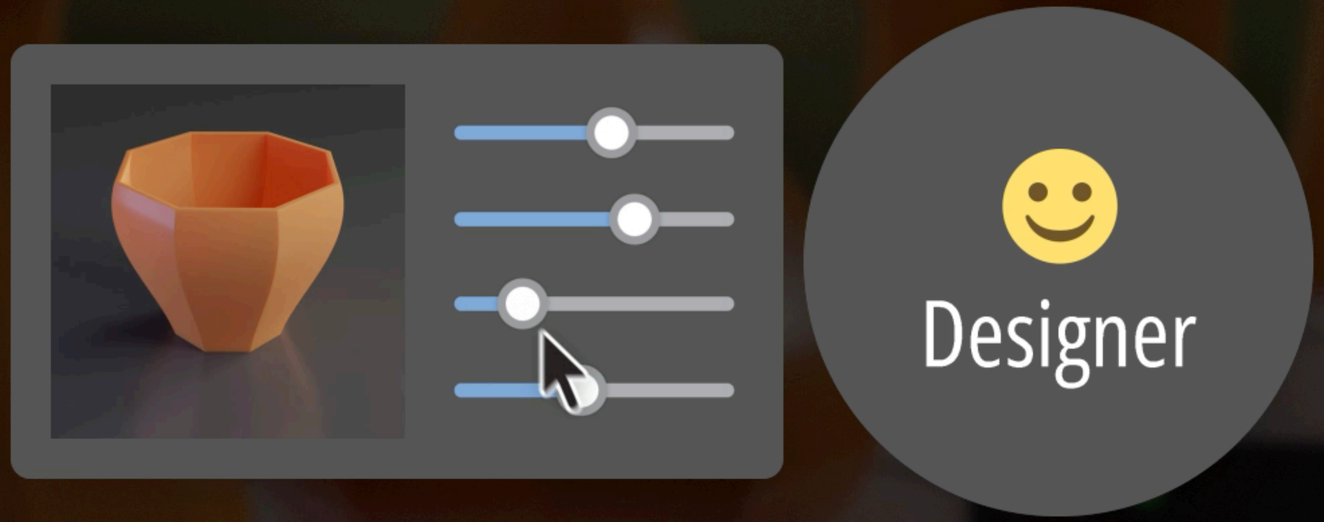
Q: Can we benefit from BO's intelligence while providing the designer with freedom?



[Chan+, CHI 2022] L. Chan et al. 2022. Investigating Positive and Negative Qualities of Human-in-the-Loop Optimization for Designing Interaction Techniques. In Proc. CHI 2022.

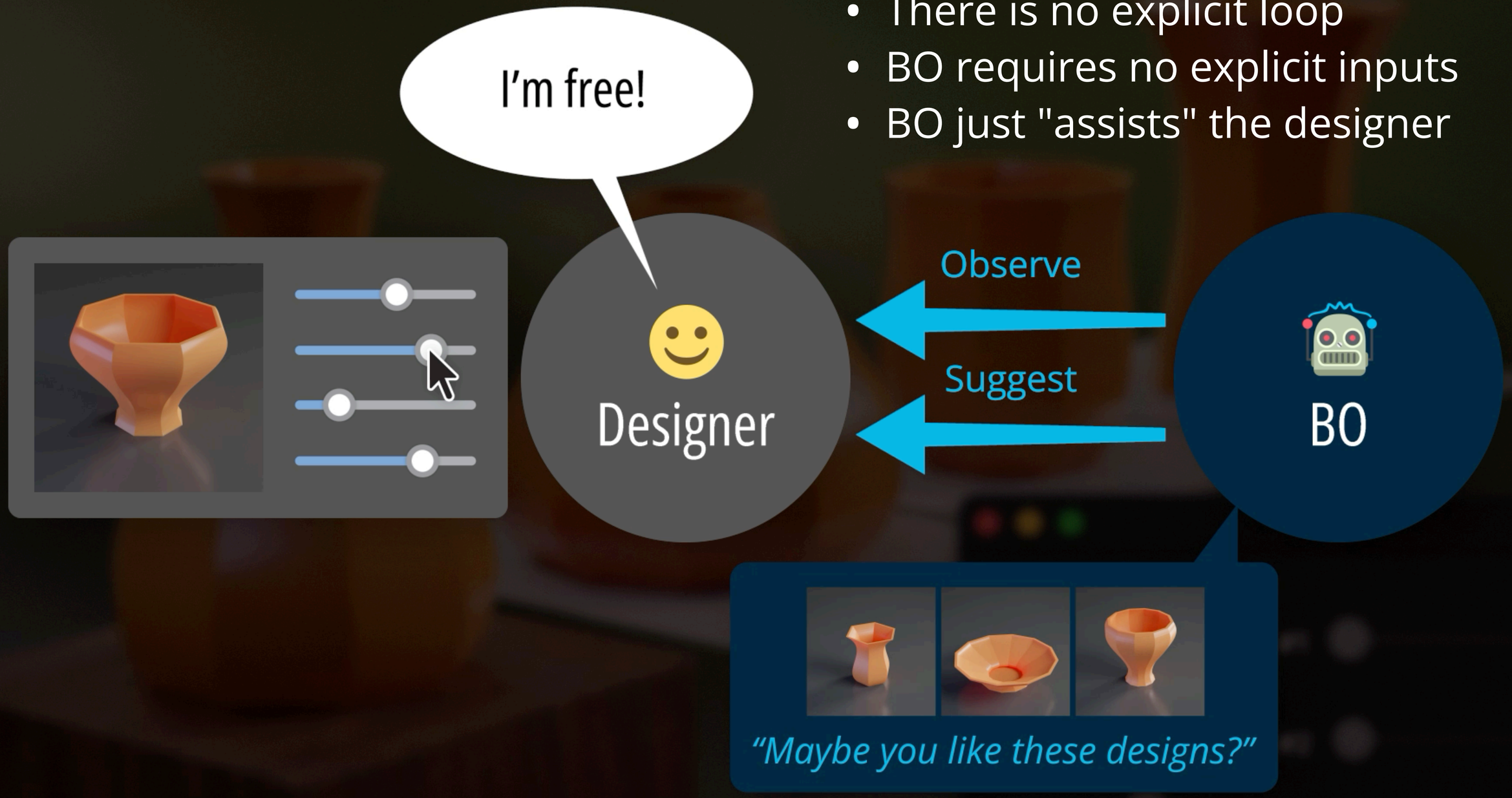


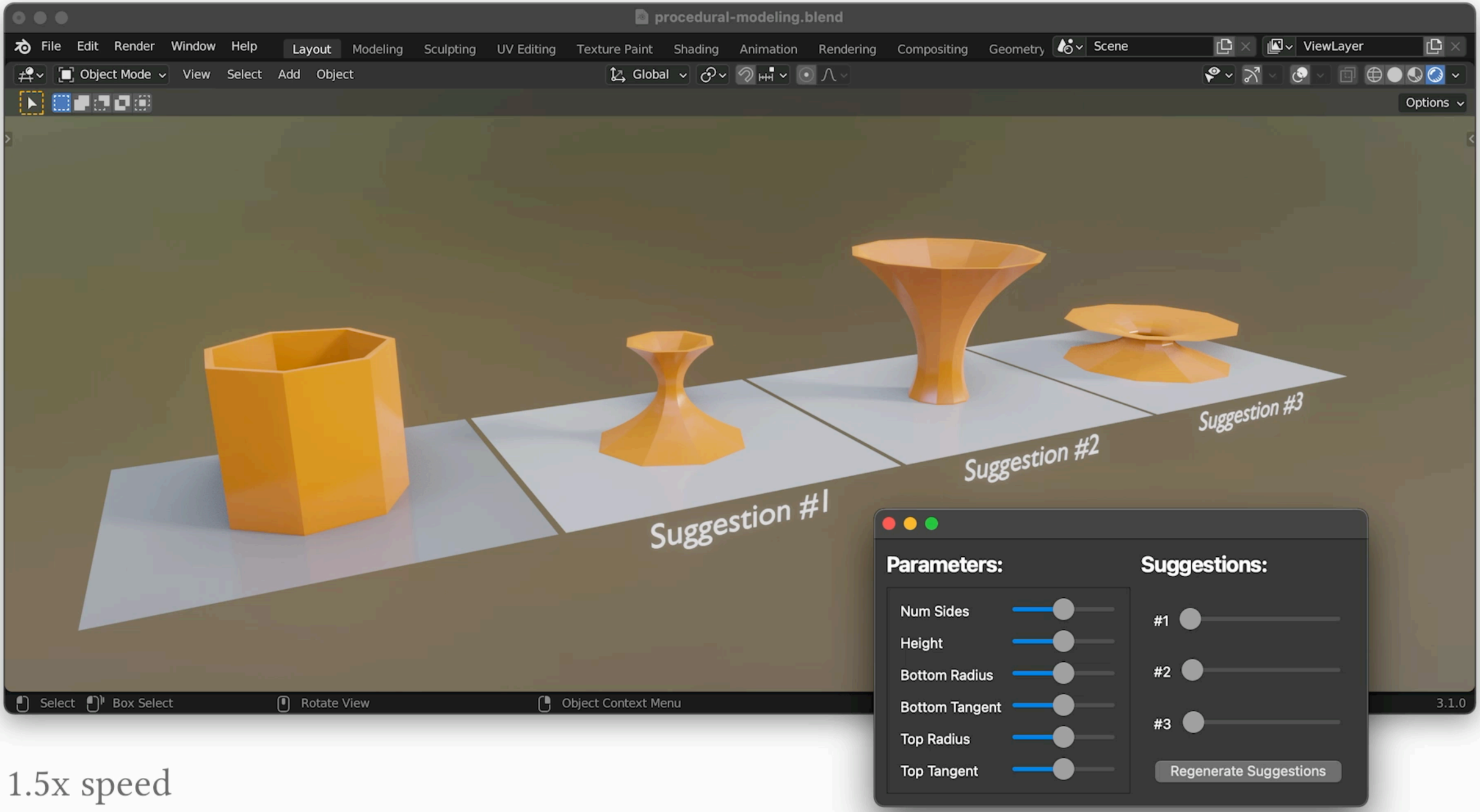
Our Framework: "BO as Assistant"


Designer

Learning the designer's preference

- There is no explicit loop
- BO requires no explicit inputs
- BO just "assists" the designer




procedural-modeling.blend
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Texture Paint
Shading
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Geometry
Scene
ViewLayer
Object Mode
View
Select
Add
Object
Global
Options
Suggestion #1
Suggestion #2
Suggestion #3
Parameters:
Num Sides
Height
Bottom Radius
Bottom Tangent
Top Radius
Top Tangent
Suggestions:
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#3
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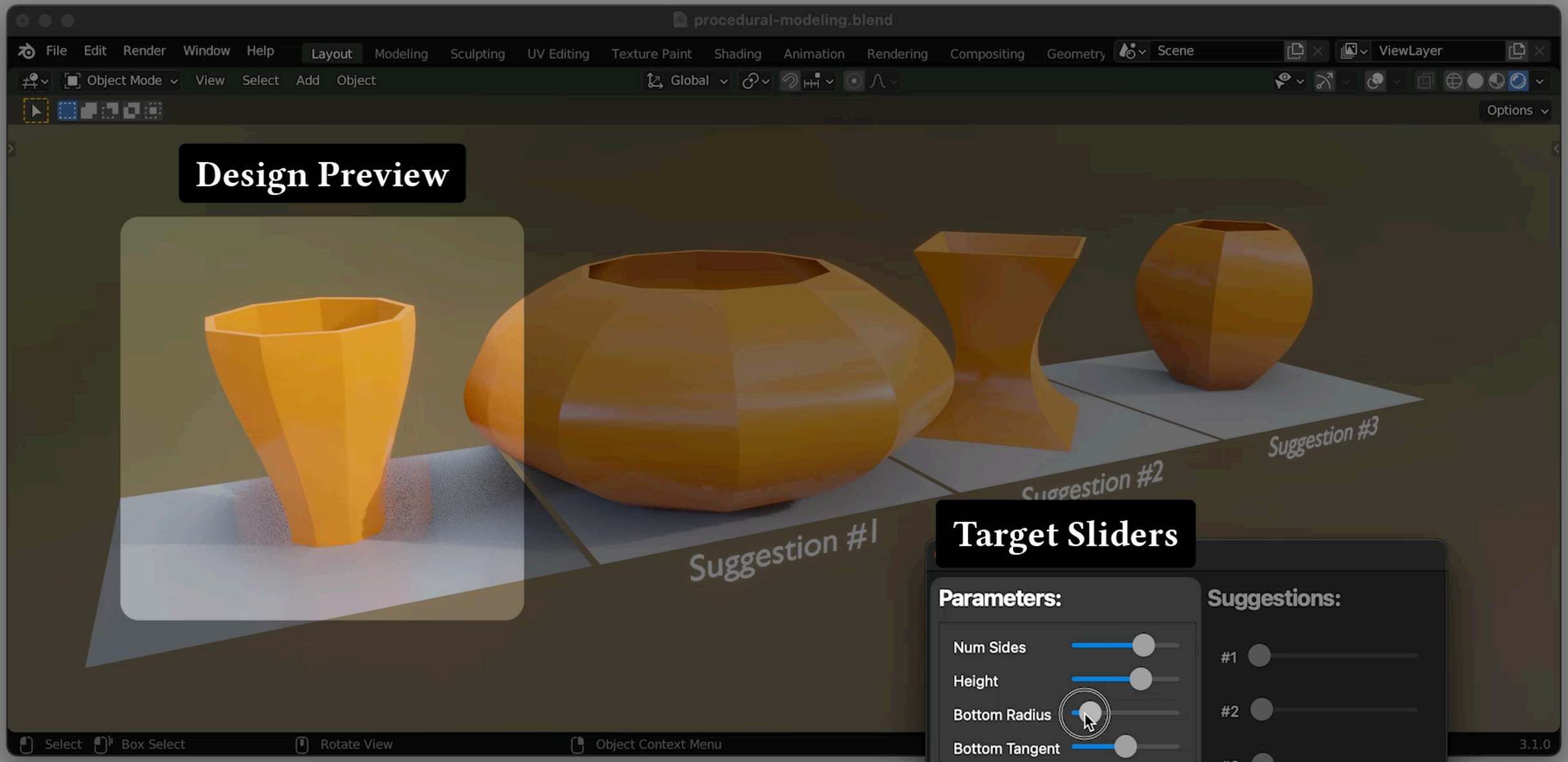
Select
Box Select
Rotate View
Object Context Menu
3.1.0

1.5x speed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Suggestion #1
Suggestion #2
Suggestion #3
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Top Radius
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Suggestions:
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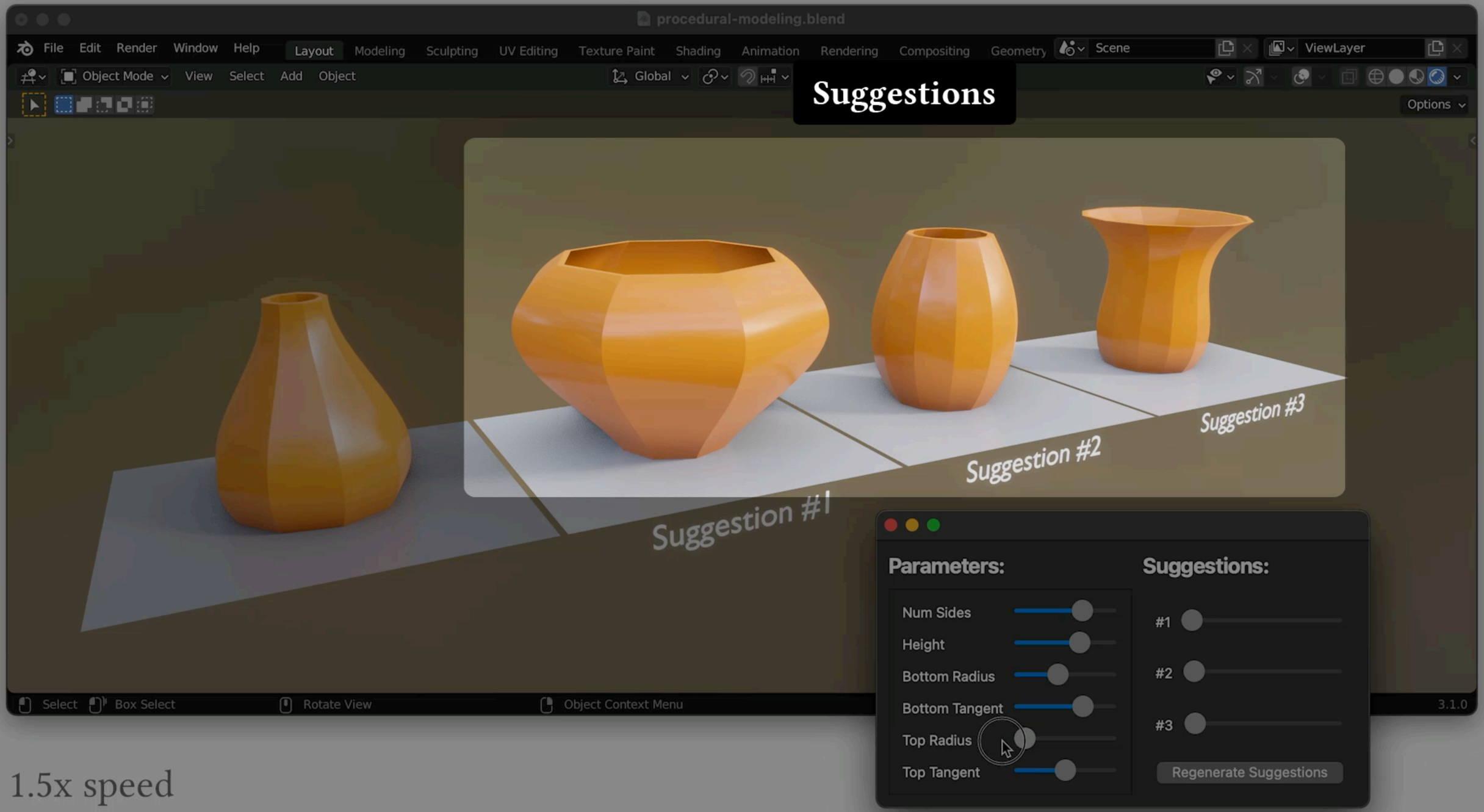
#3
Regenerate Suggestions
Select
Box Select
Rotate View
Object Context Menu
3.1.0

1.5x speed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Suggestions
Suggestion #1
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Suggestion #3
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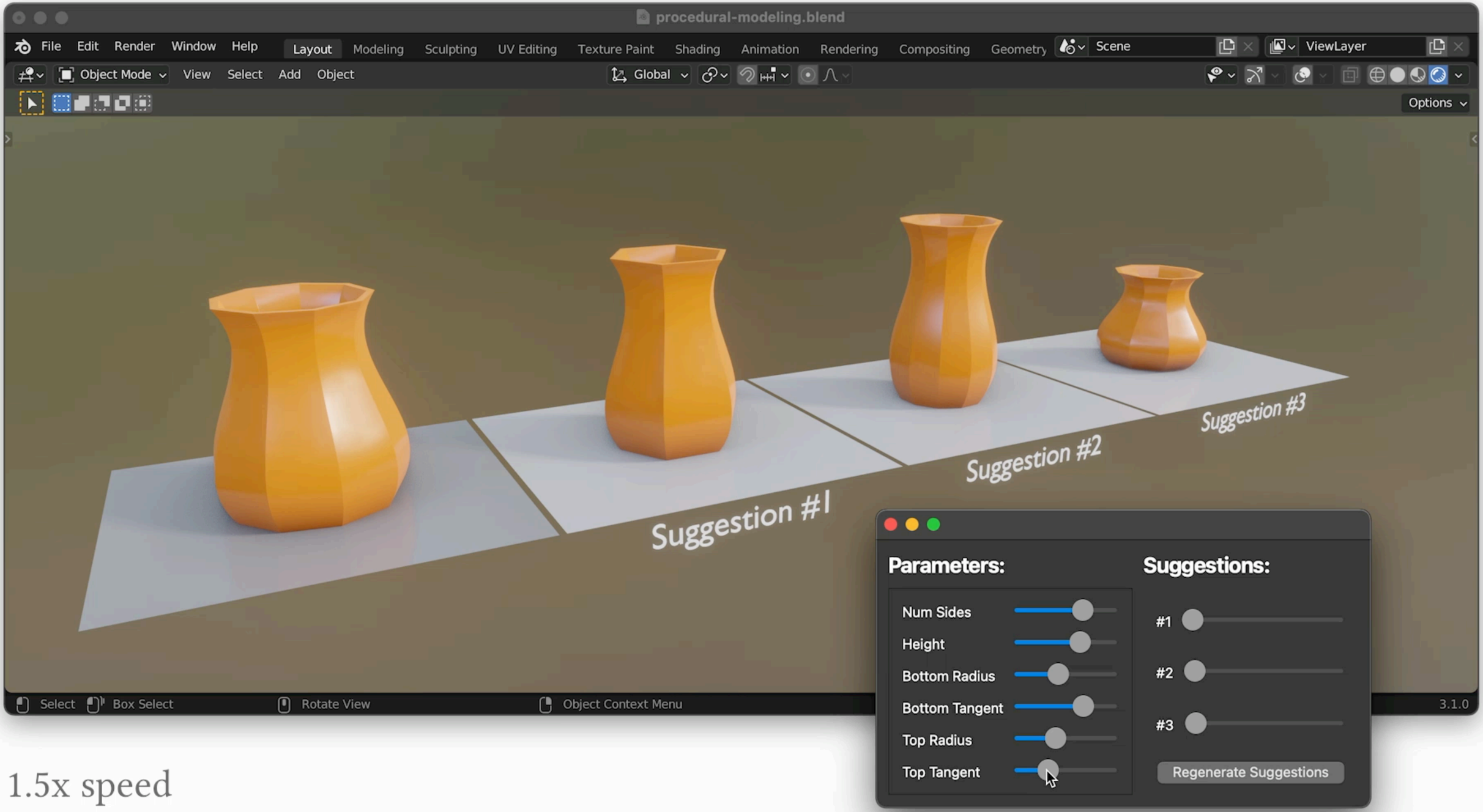
1.5x speed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Suggestion #3
Parameters:
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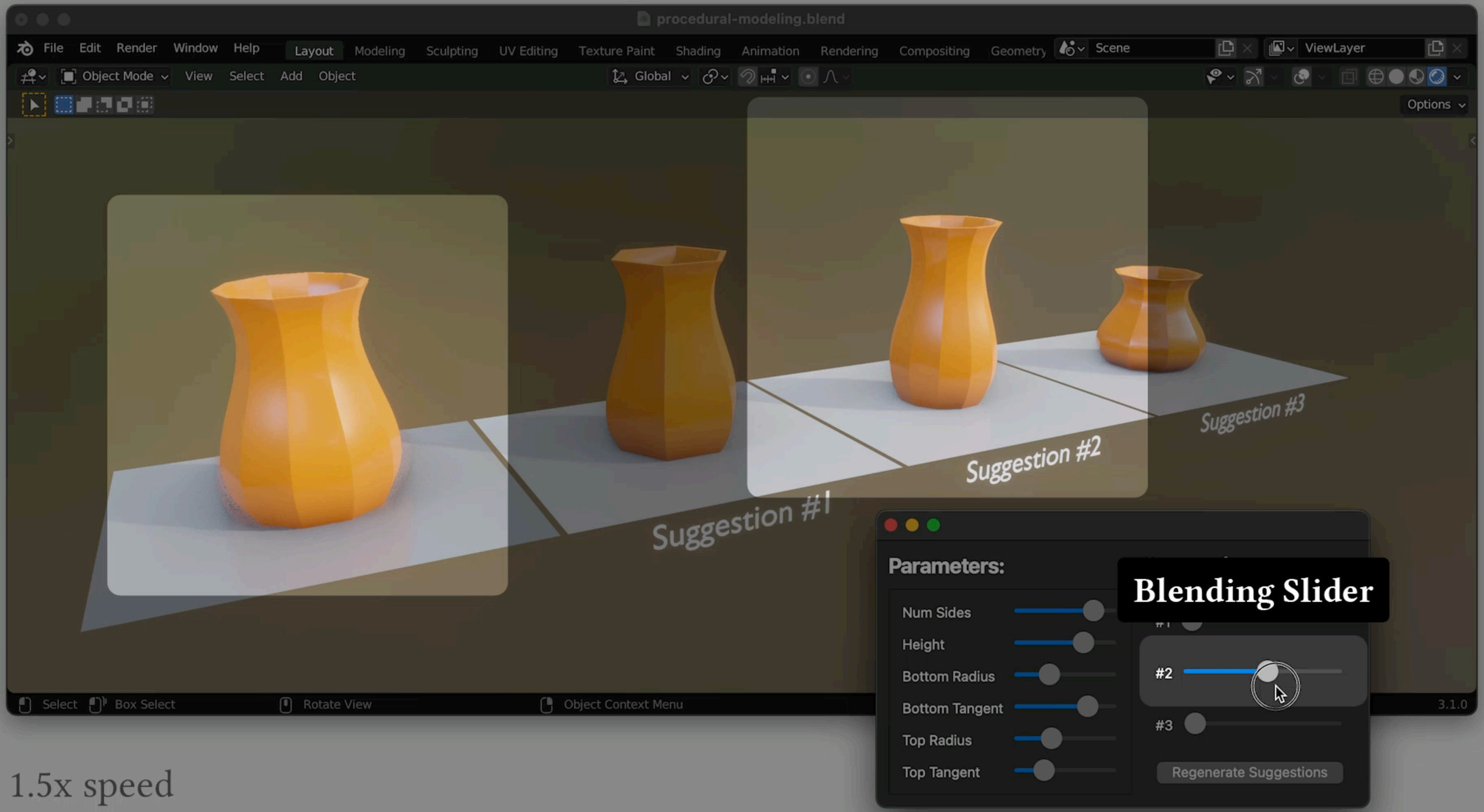
1.5x speed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Global
Options
Suggestion #1
Suggestion #2
Suggestion #3
Parameters:
Num Sides
Height
Bottom Radius
Bottom Tangent
Top Radius
Top Tangent
Blending Slider
#2
#3
Regenerate Suggestions
Select
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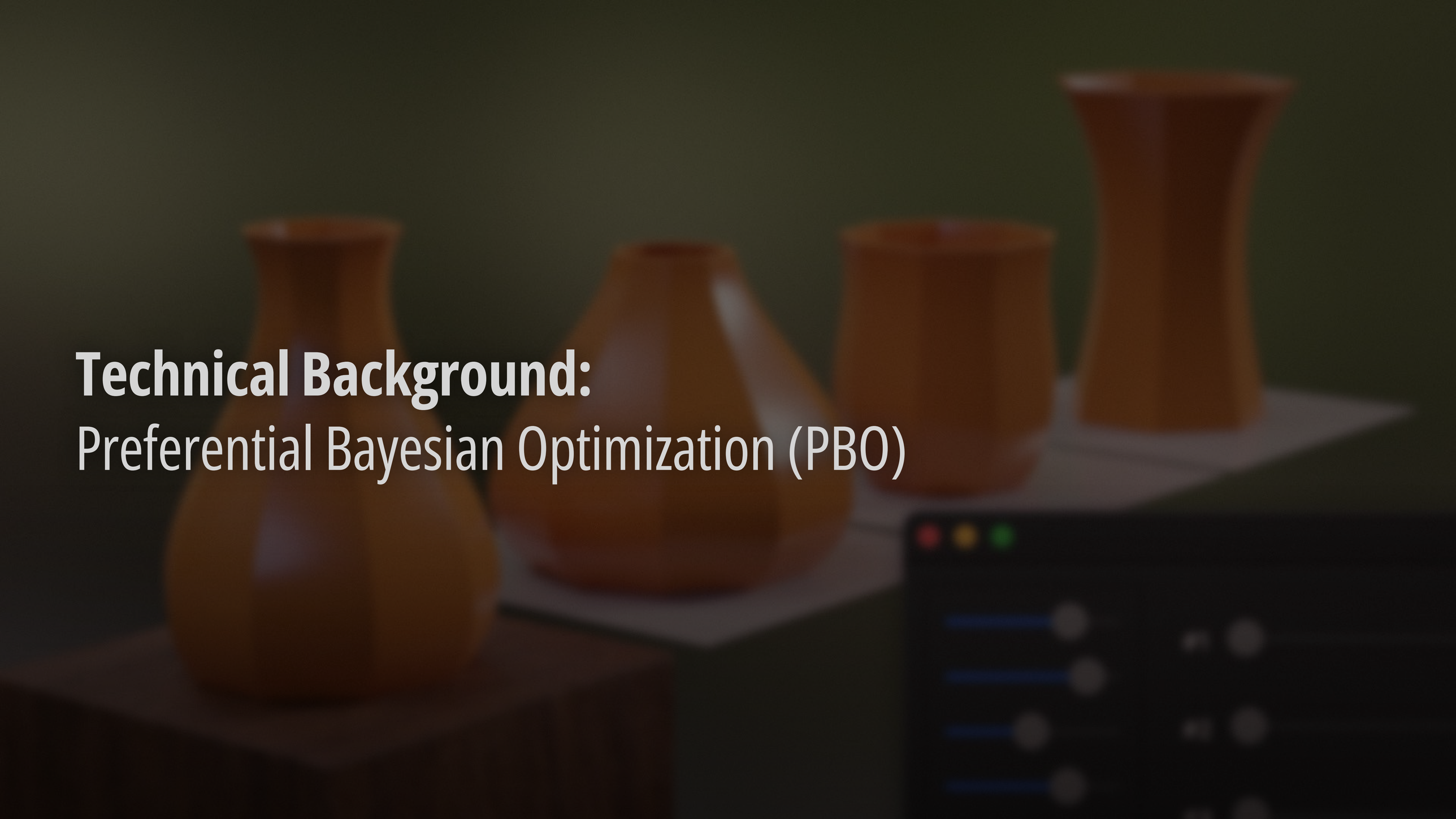
Rotate View
Object Context Menu
3.1.0

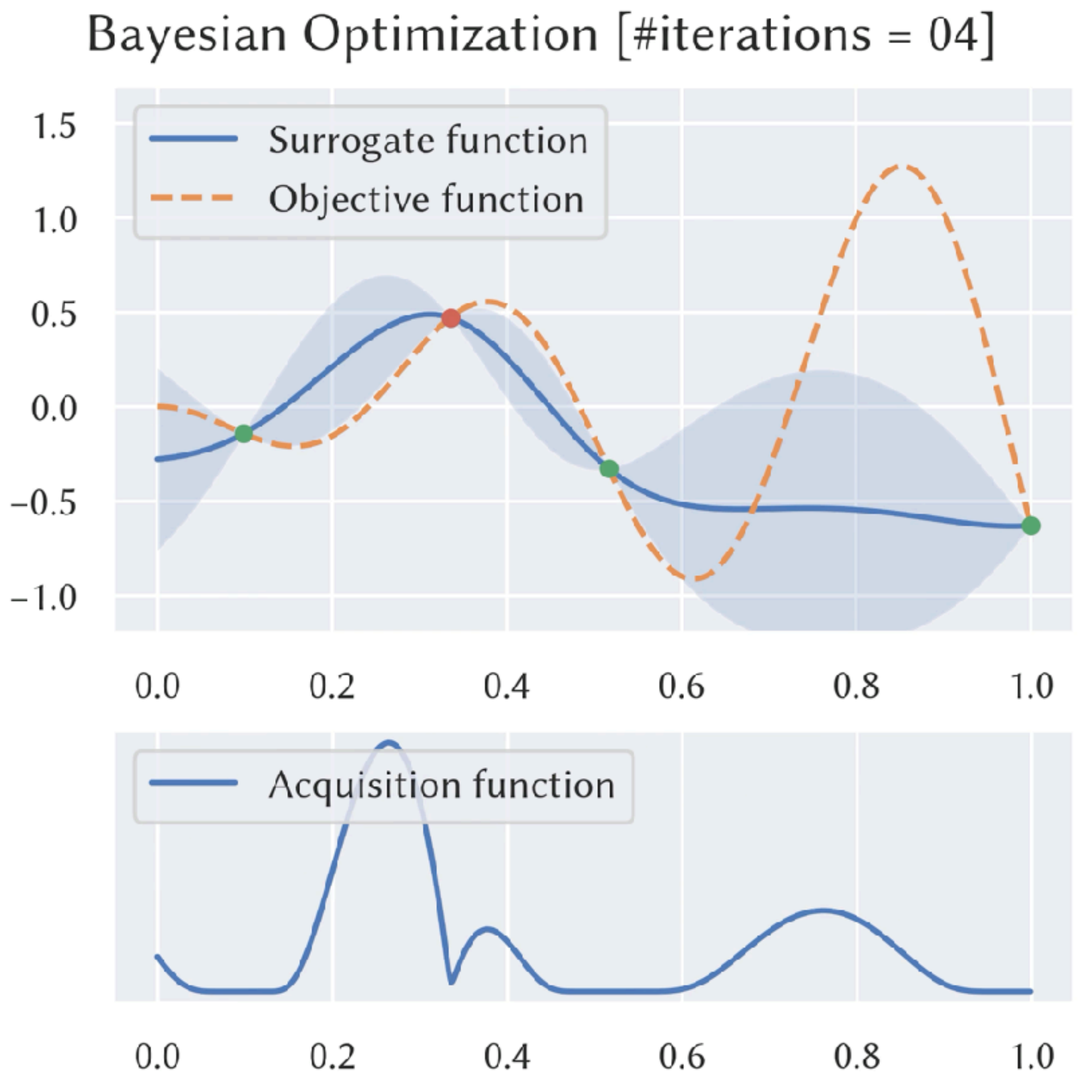
1.5x speed



Technical Background:
Preferential Bayesian Optimization (PBO)

Bayesian Optimization (BO)

- A global “black-box” optimization algorithm
- It can find optimal solutions with only a small number of iterations
- **Intelligent sampling strategy**
  - **Exploration:** Favor unexplored regions
  - **Exploitation:** Favor high-expectation regions
- E.g., Hyperparameter tuning in deep learning [Akiba+, KDD 2019]

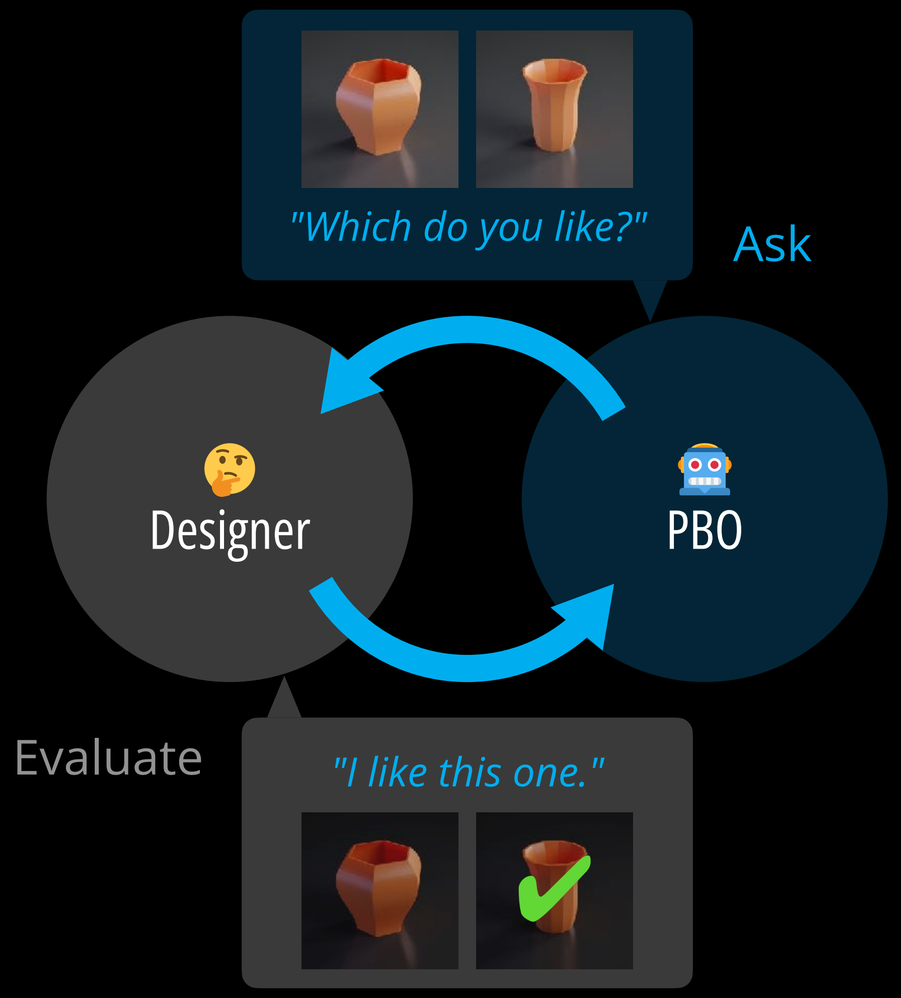


Shahriari et al., Taking the Human Out of the Loop: A Review of Bayesian Optimization, Proc. IEEE, 2016, doi: 10.1109/JPROC.2015.2494218

Preferential Bayesian Optimization (PBO)

- A variant of BO [Brochu+, NIPS 2007]
- Runs with relative preference data (rather than absolute scoring)
- Better suited for human-in-the-loop

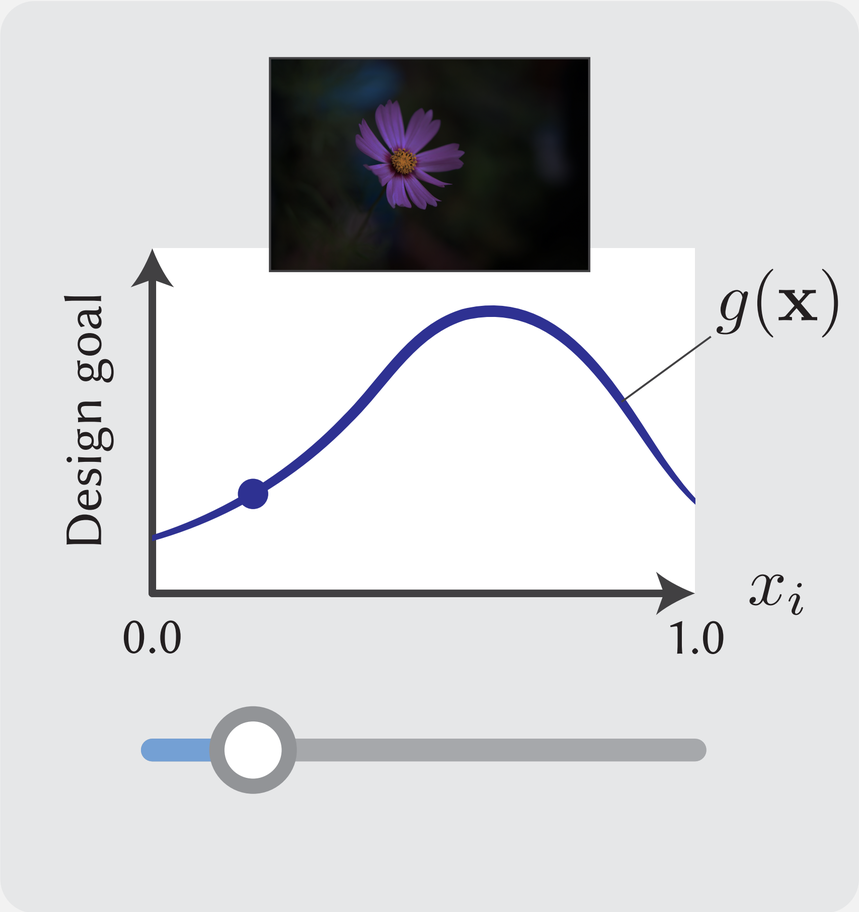
Q: Can we extract relative preference data implicitly from slider manipulation?



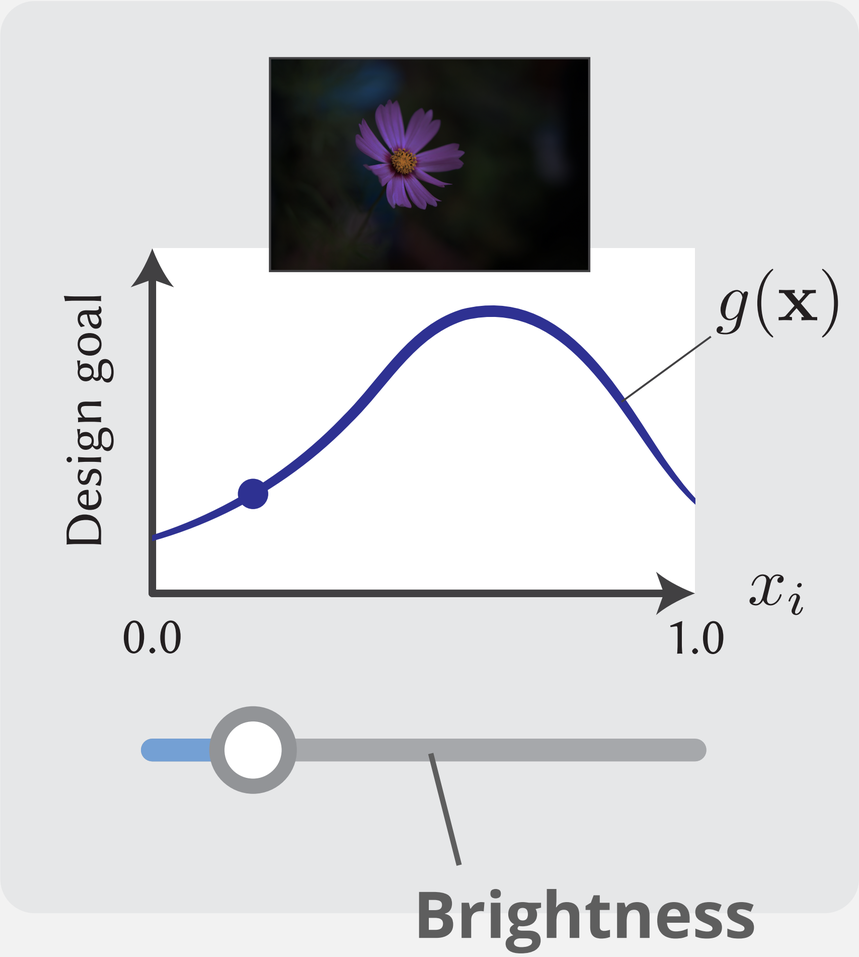
Our Technique:

Extraction of Preferential Data for PBO

A Closer Look: Slider Manipulation Session

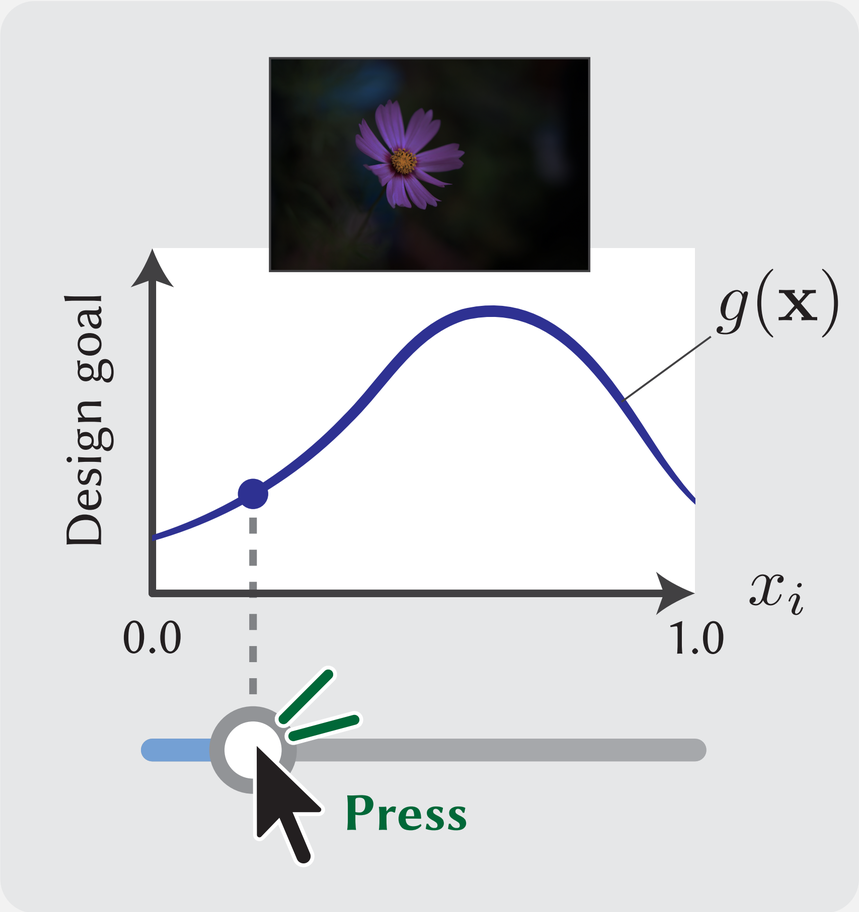


A Closer Look: Slider Manipulation Session



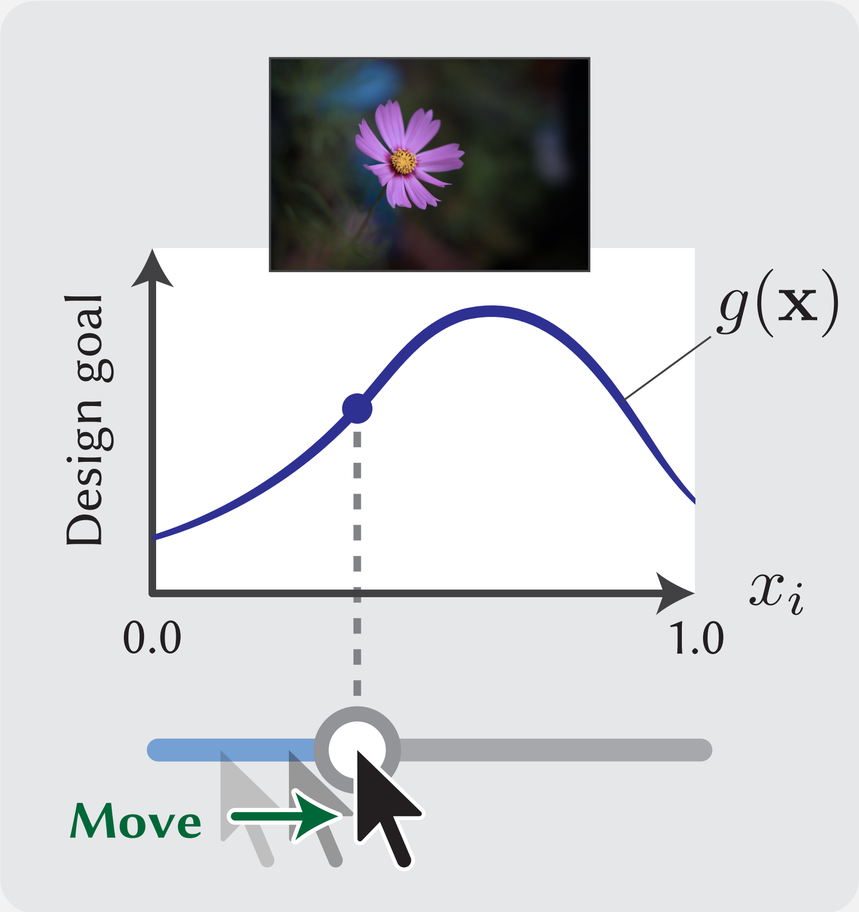
The photo looks too dark.
Let’s manipulate "brightness".

A Closer Look: Slider Manipulation Session



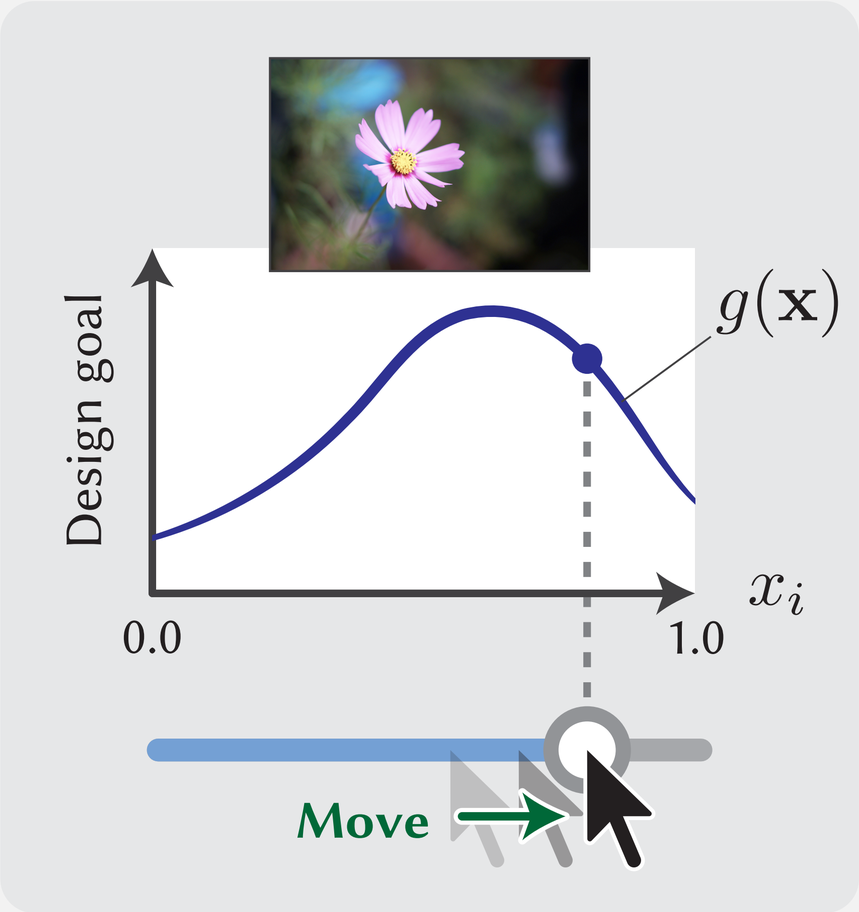
Let's increase the value.

A Closer Look: Slider Manipulation Session



Still dark. Increase more.

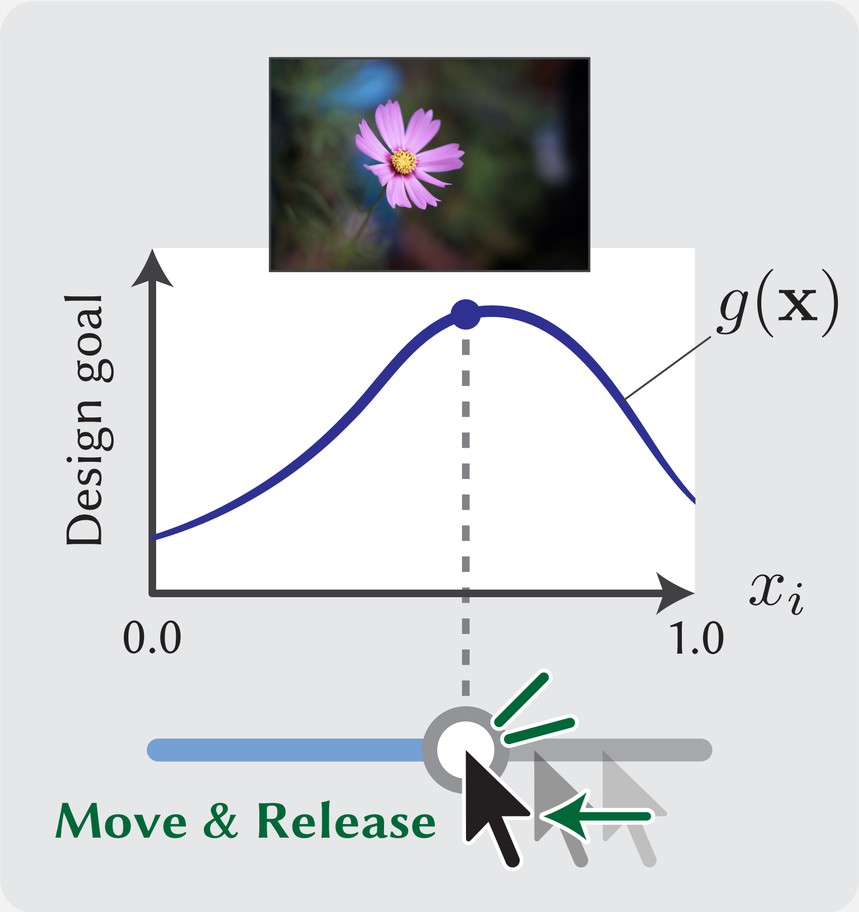
A Closer Look: Slider Manipulation Session



Oh! Too much!!

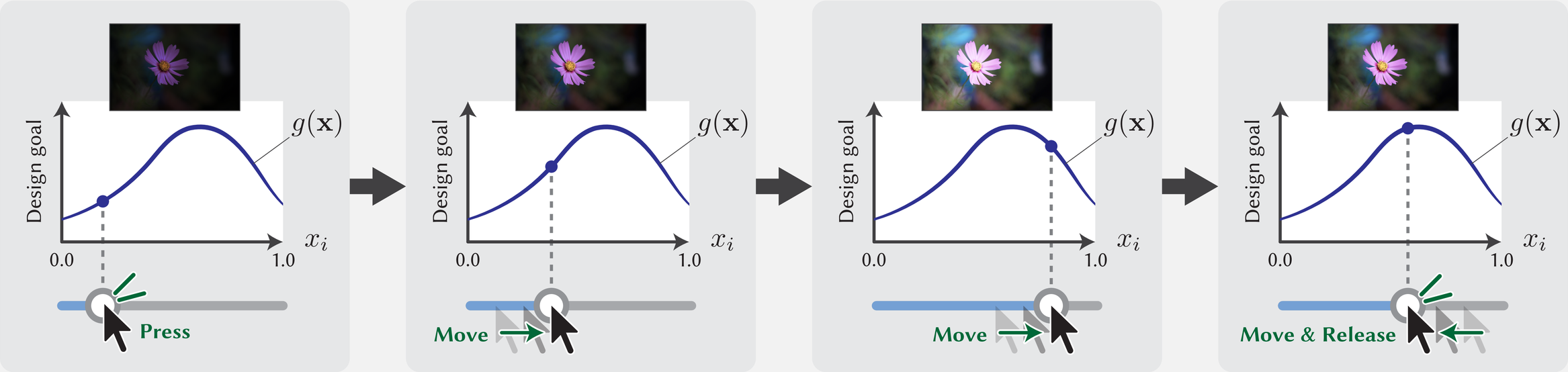
Let's decrease the value.

A Closer Look: Slider Manipulation Session



Now the photo looks nice.
Let's stop.

A Closer Look: Slider Manipulation Session



Observations:

- The "last" point is likely to be desirable
- The "turning" points are likely to be undesired

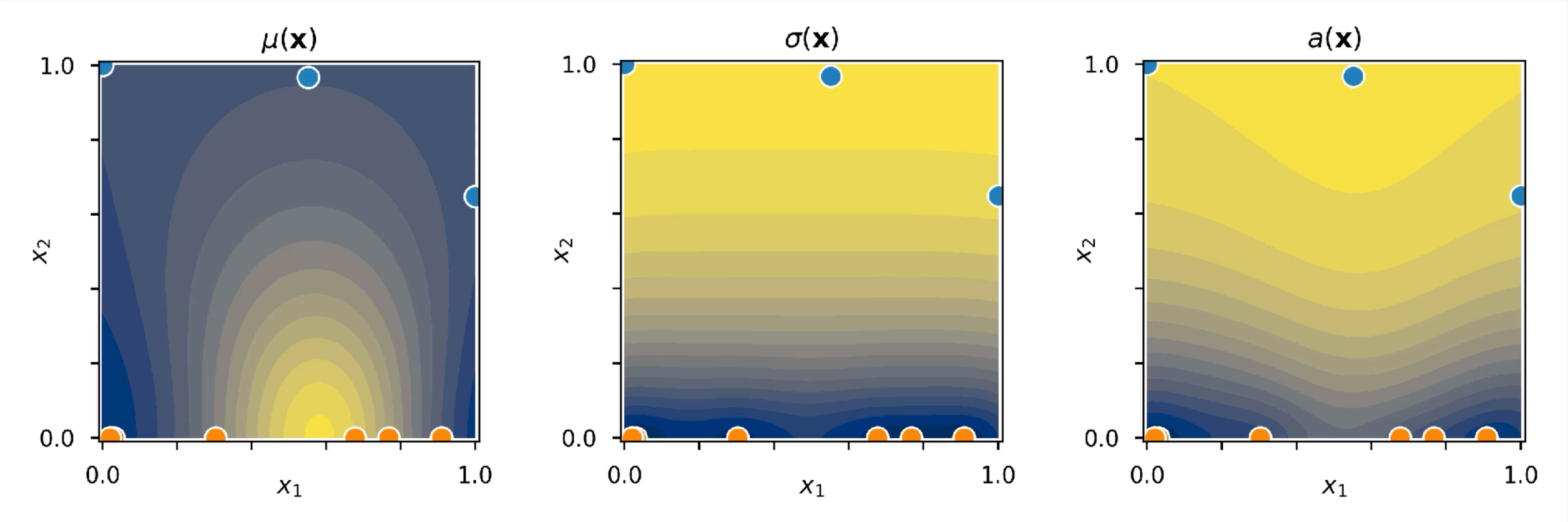
Extracted preferential data:

The "last" point is preferred over the "turning" points

Predicted mean
Estimated preference

Predicted standard deviation
Estimation uncertainty

Acquisition function
Priority in sampling



● : Data points extracted from slider manipulation

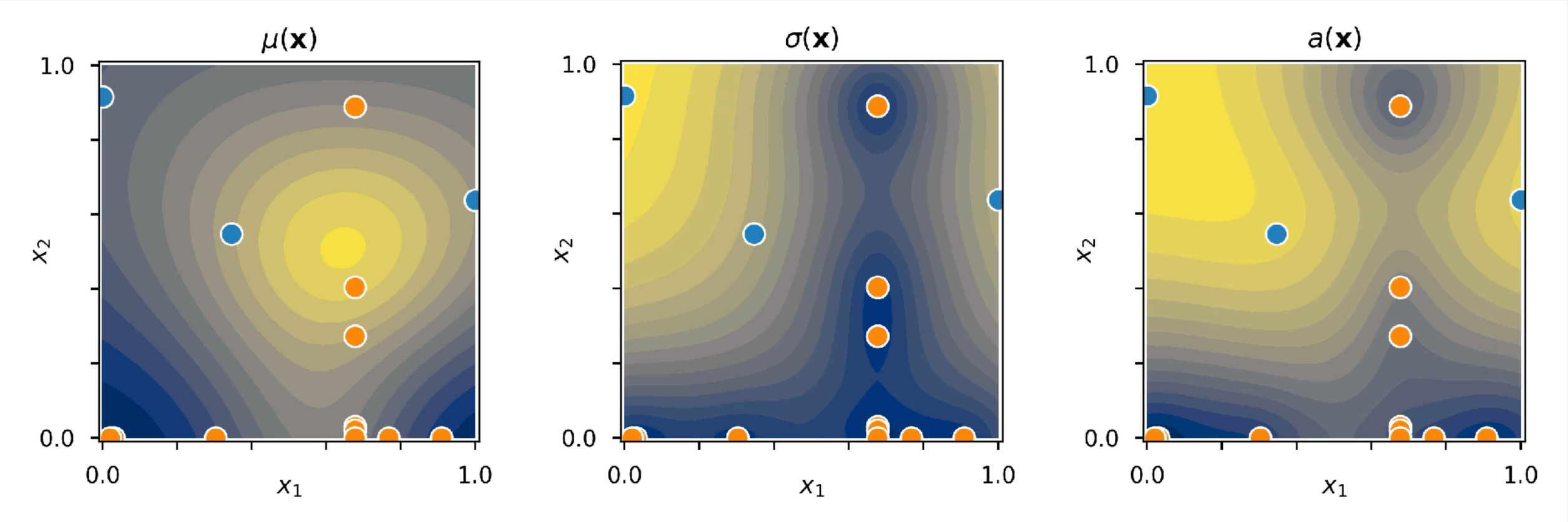
● : Suggestions generated by BO

→ **Please refer to the paper for details**

Predicted mean
Estimated preference

Predicted standard deviation
Estimation uncertainty

Acquisition function
Priority in sampling



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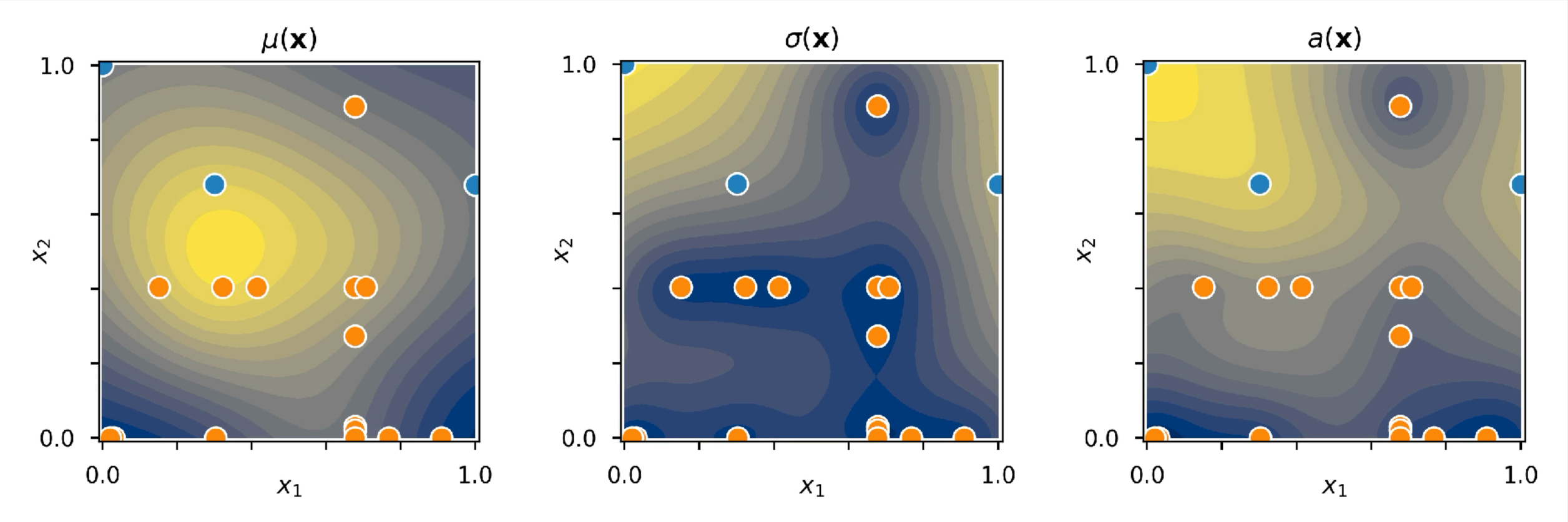

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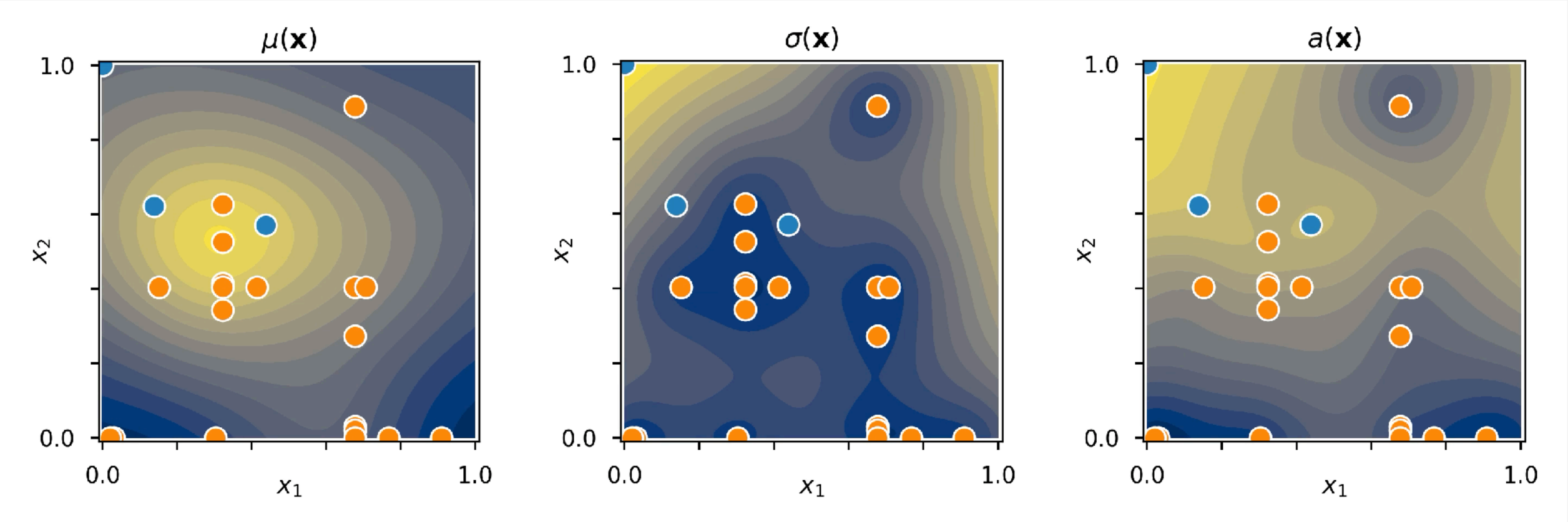


● : Data points extracted from slider manipulation

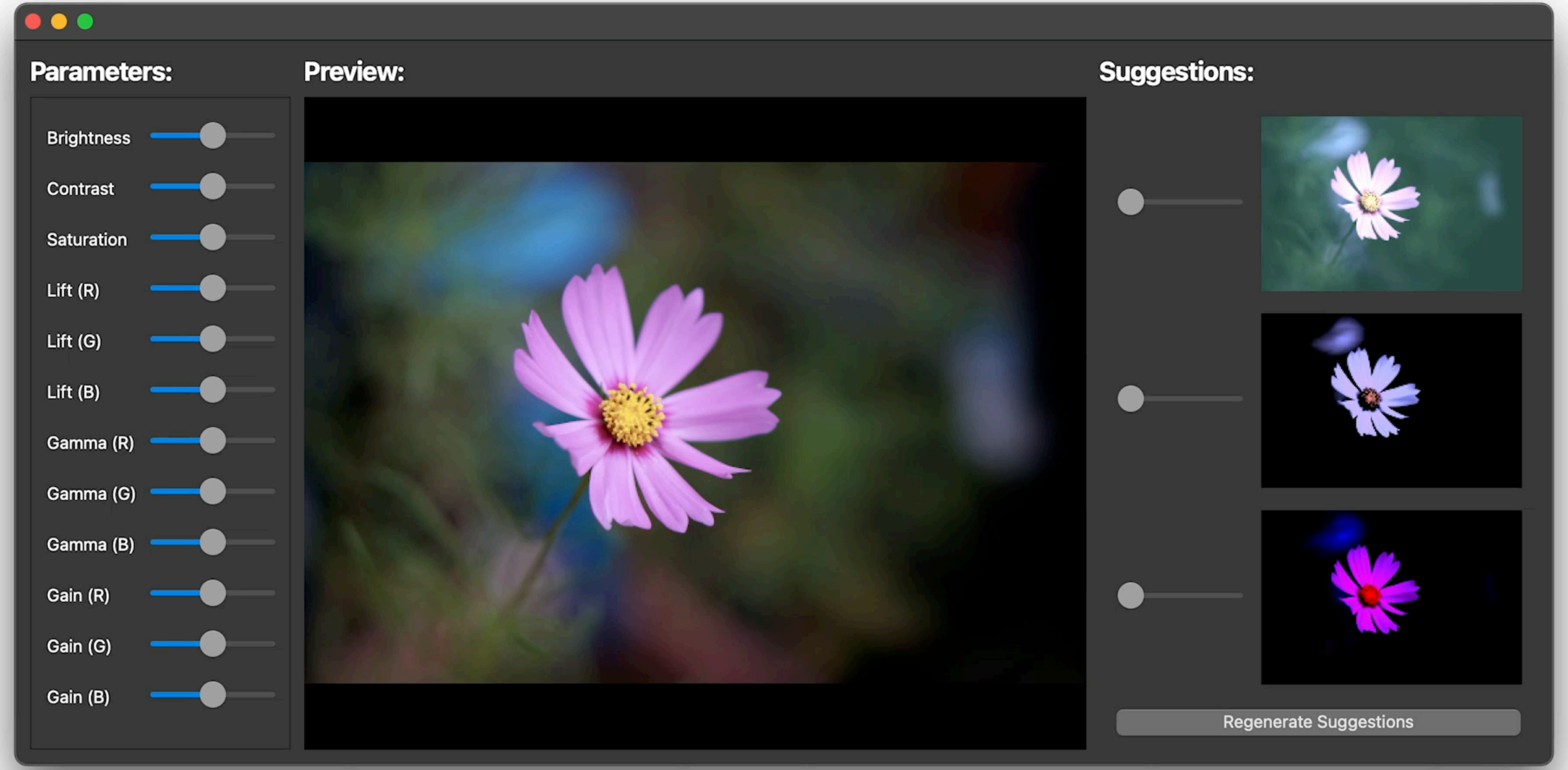
● : Suggestions generated by BO

→ **Please refer to the paper for details**

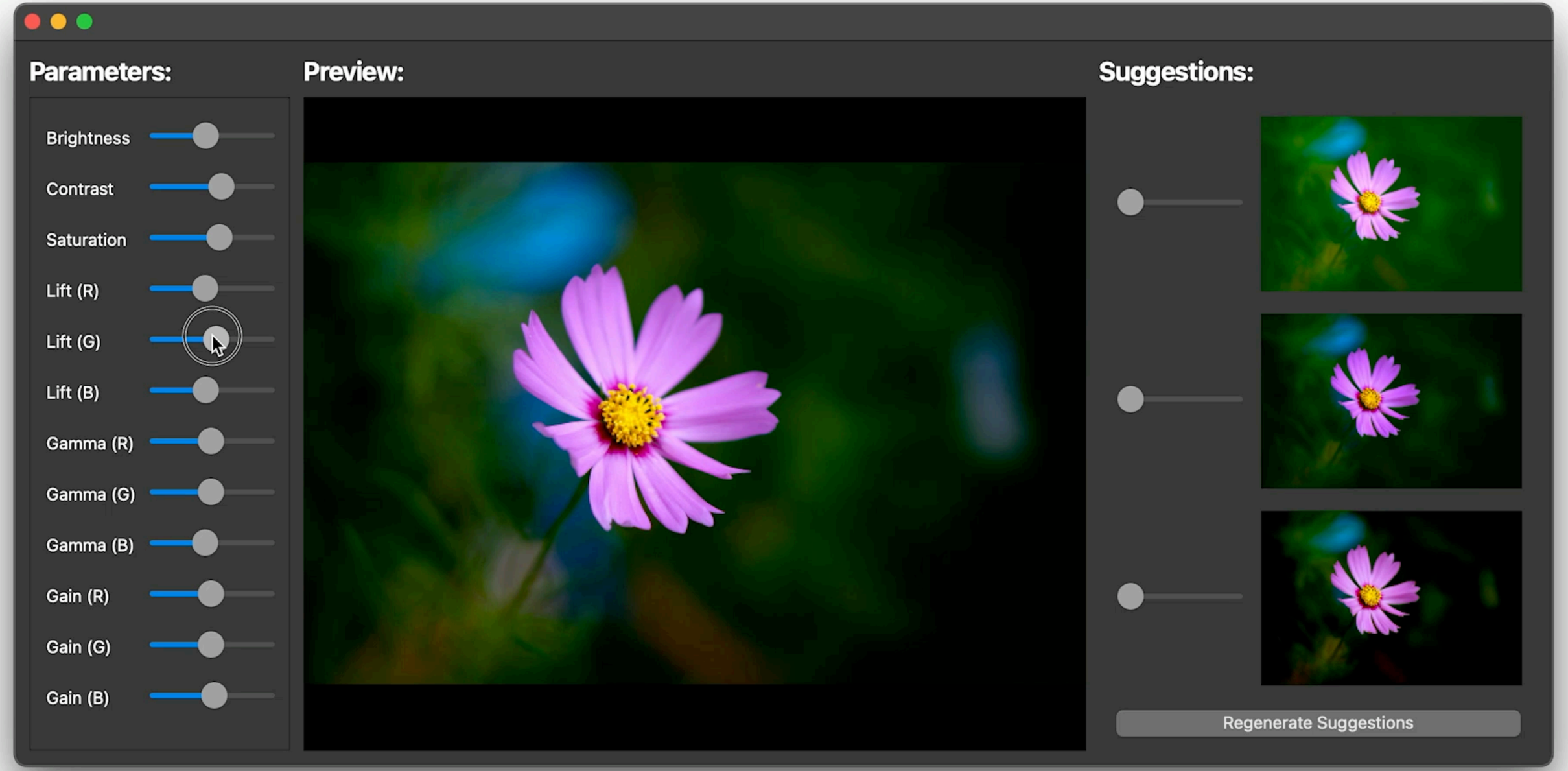
Demonstrations

Photo Color Enhancement

- #Parameters: 12
  - Brightness
  - Contrast
  - Saturation
  - Lift (RGB)
  - Gamma (RGB)
  - Gain (RGB)


Parameters:
Preview:
Suggestions:
Brightness
Contrast
Saturation
Lift (R)
Lift (G)
Lift (B)
Gamma (R)
Gamma (G)
Gamma (B)
Gain (R)
Gain (G)
Gain (B)
Regenerate Suggestions

x5


Parameters:
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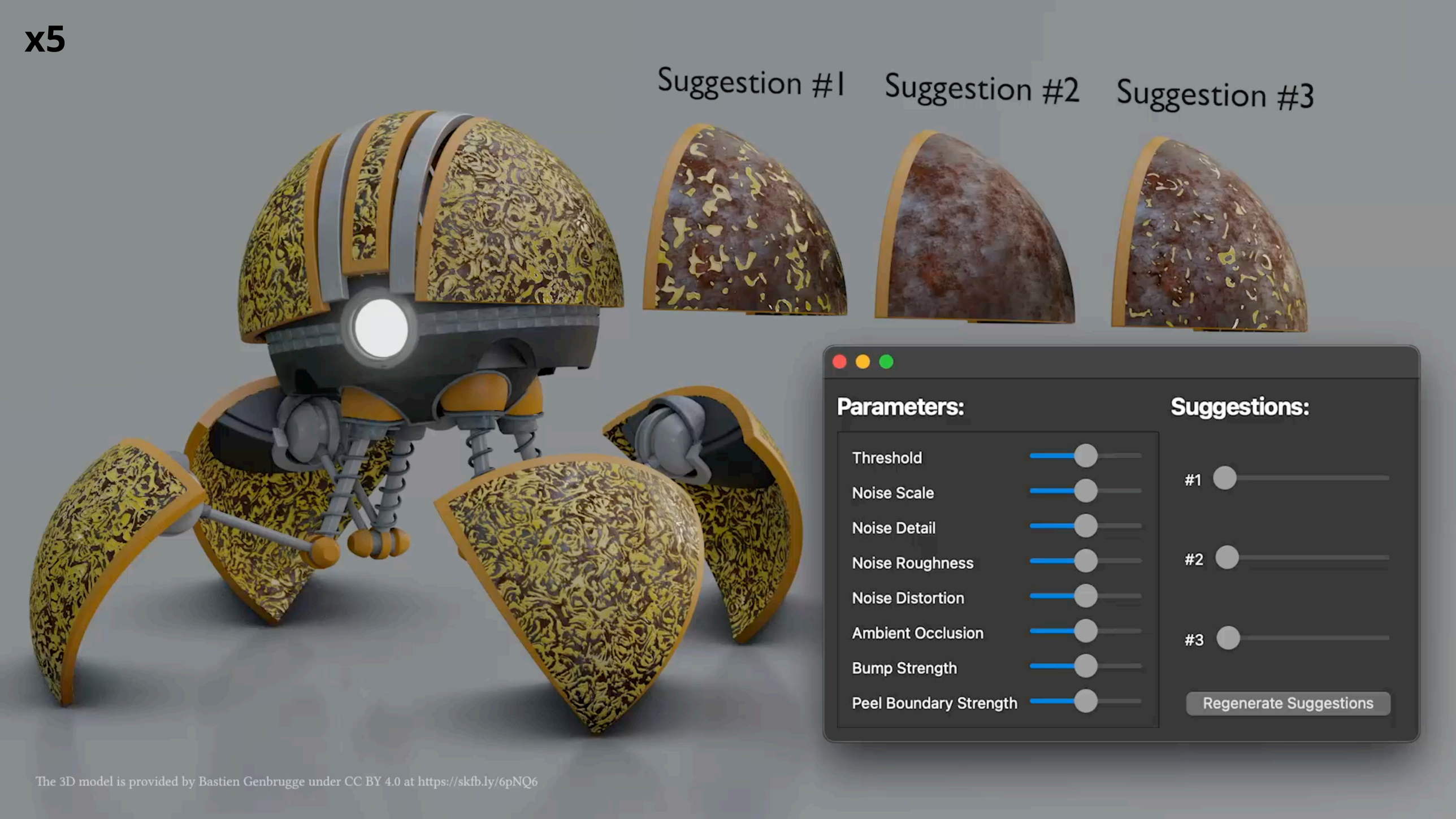
Lift (B)
Gamma (R)
Gamma (G)
Gamma (B)
Gain (R)
Gain (G)
Gain (B)
Regenerate Suggestions

x5

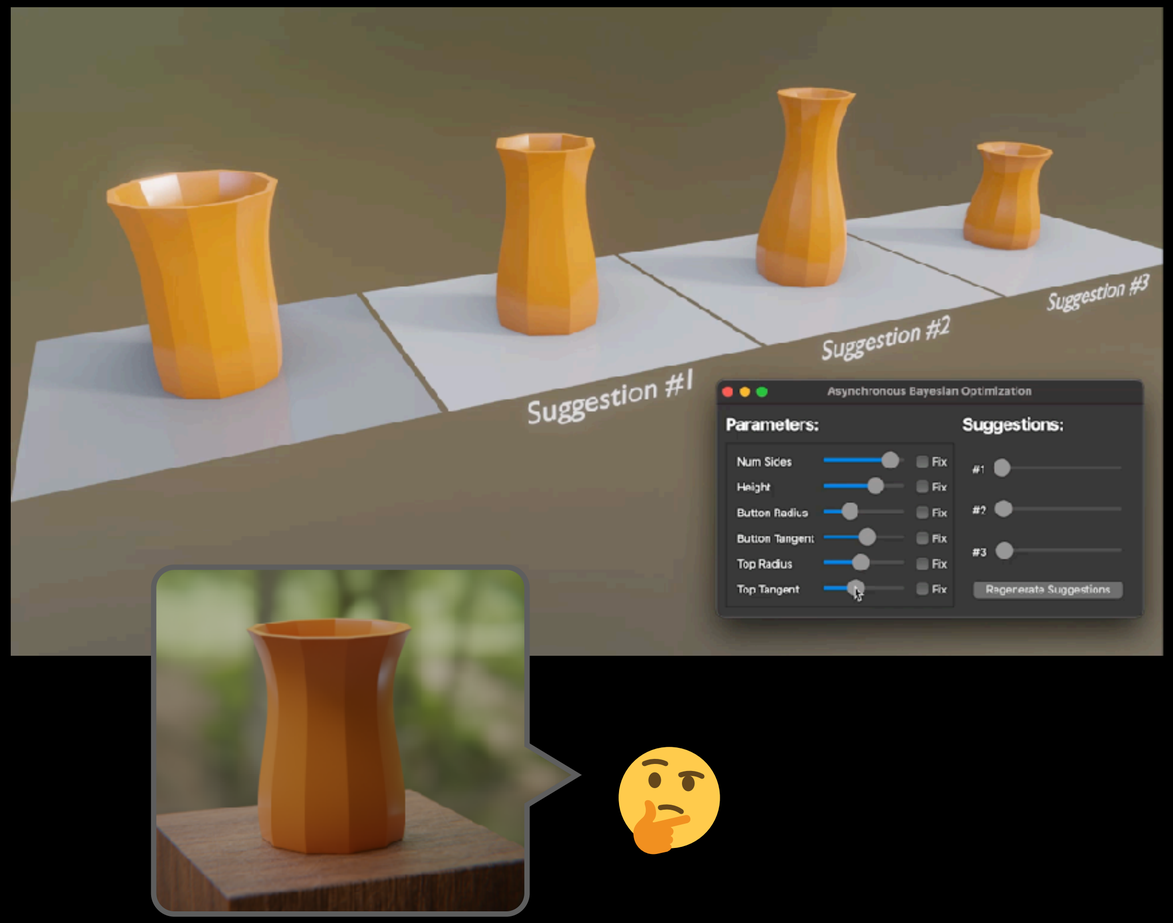
Procedural Material Design

- #Parameters: 8
  - Threshold
  - Noise Scale
  - Noise Detail
  - Noise Roughness
  - Noise Distortion
  - Ambient Occlusion
  - Bump Strength
  - Peel Boundary Strength
- Design goal: Rusted metal with peeled painting

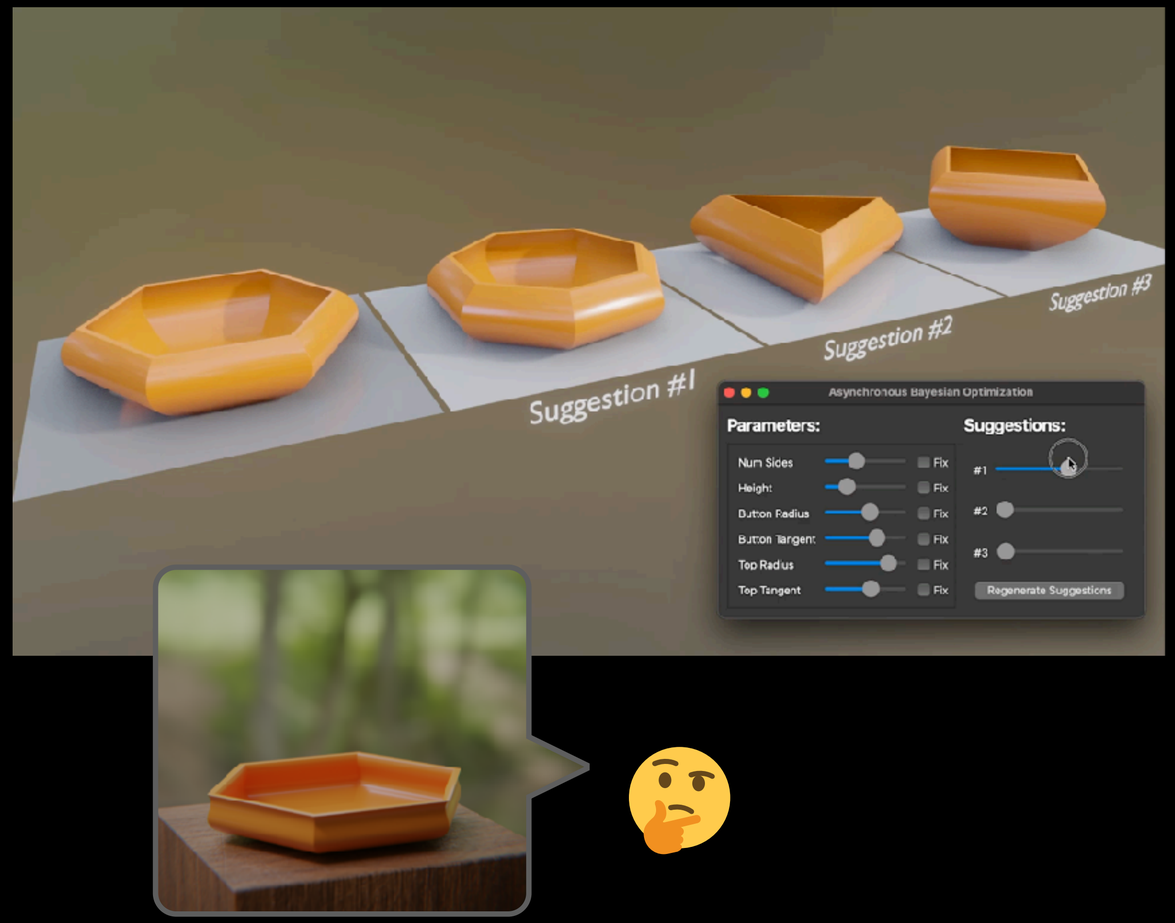
x5



Discussion: Different Preferences Can Be Learned Appropriately

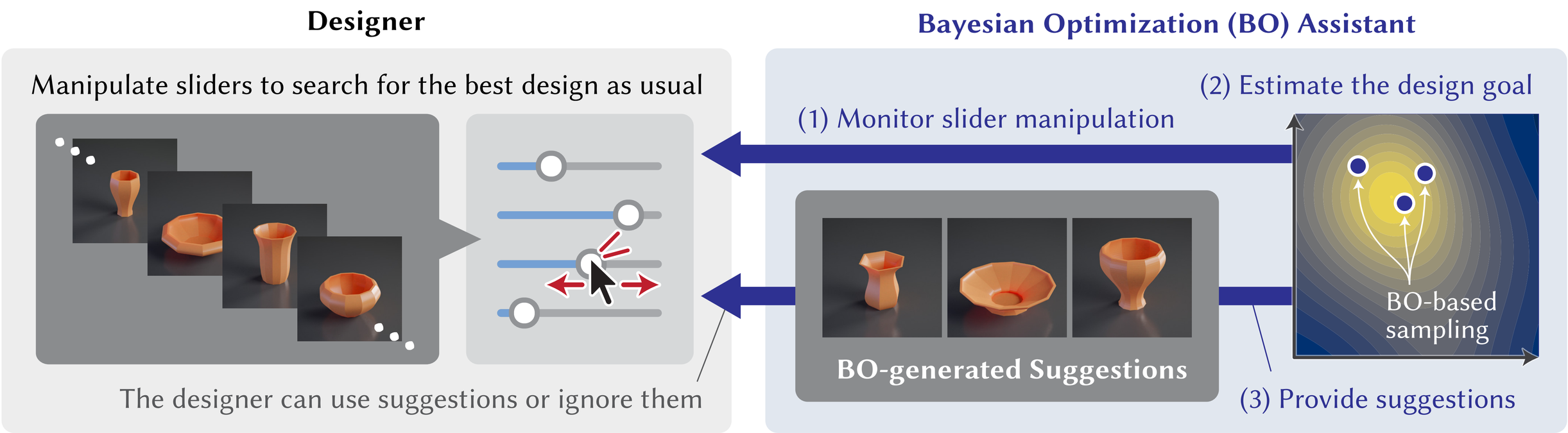


Goal



Goal

Summary



Summary:

- Using BO as an "assistant" of a designer (rather than human-in-the-loop)
- New techniques to generate suggestions using BO just by observing slider manipulation (without requiring explicit input)
- Applicable to various design domains (as demonstrated in three domains)