

Decomposing Time-Lapse Paintings into Layers

Jianchao Tan

George Mason University

Marek Dvorožňák

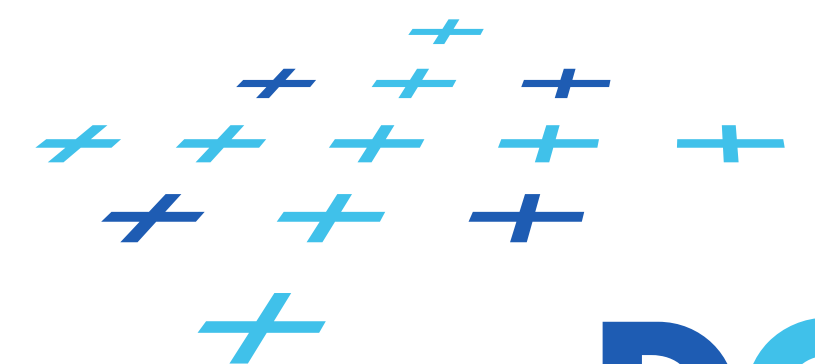
Czech Technical University in Prague

Daniel Sýkora

Czech Technical University in Prague

Yotam Gingold

George Mason University



Background: Digital Painting



[Angela Sasser, <https://www.artstation.com/artwork/nariko-heavenly-guardian>]

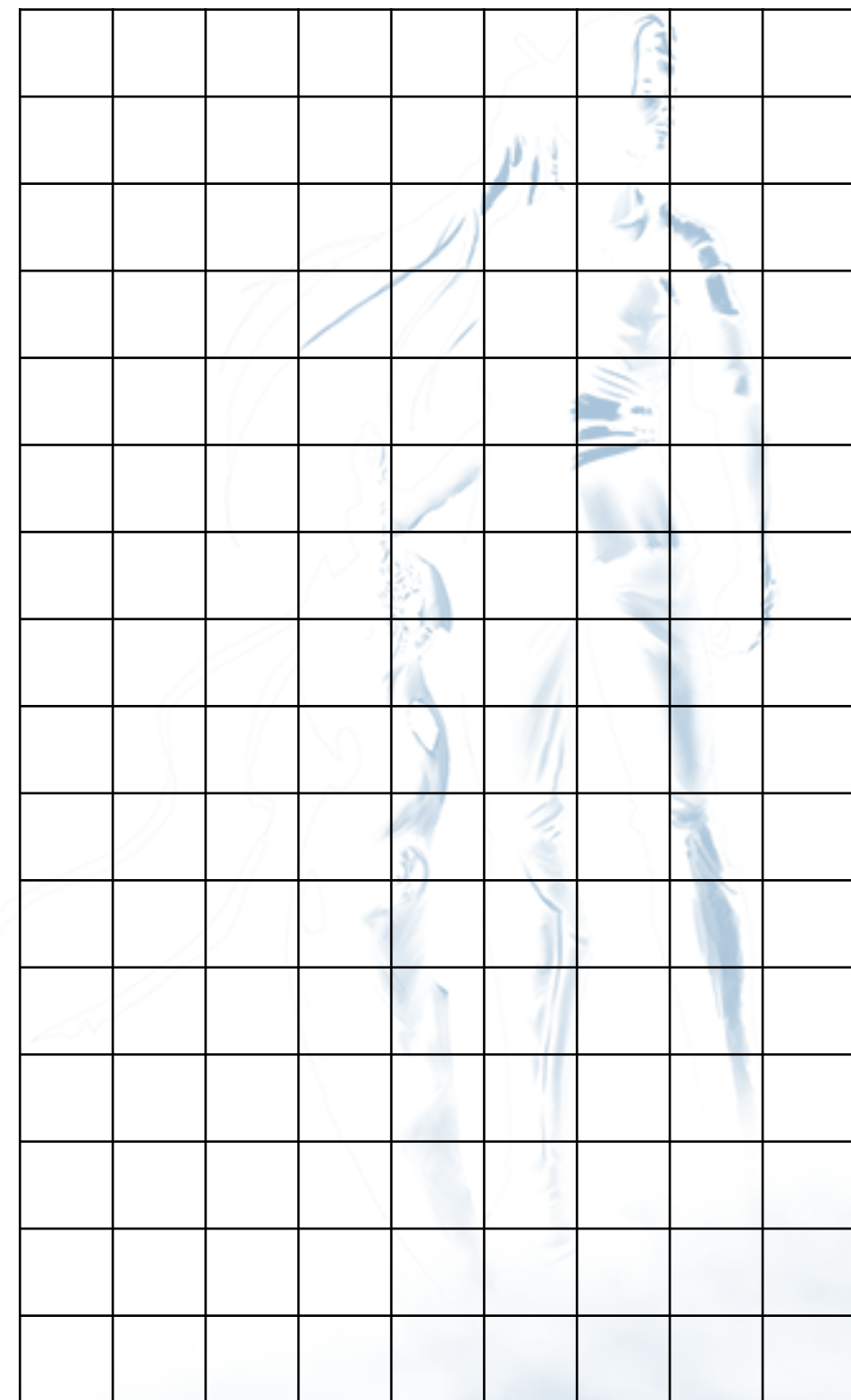
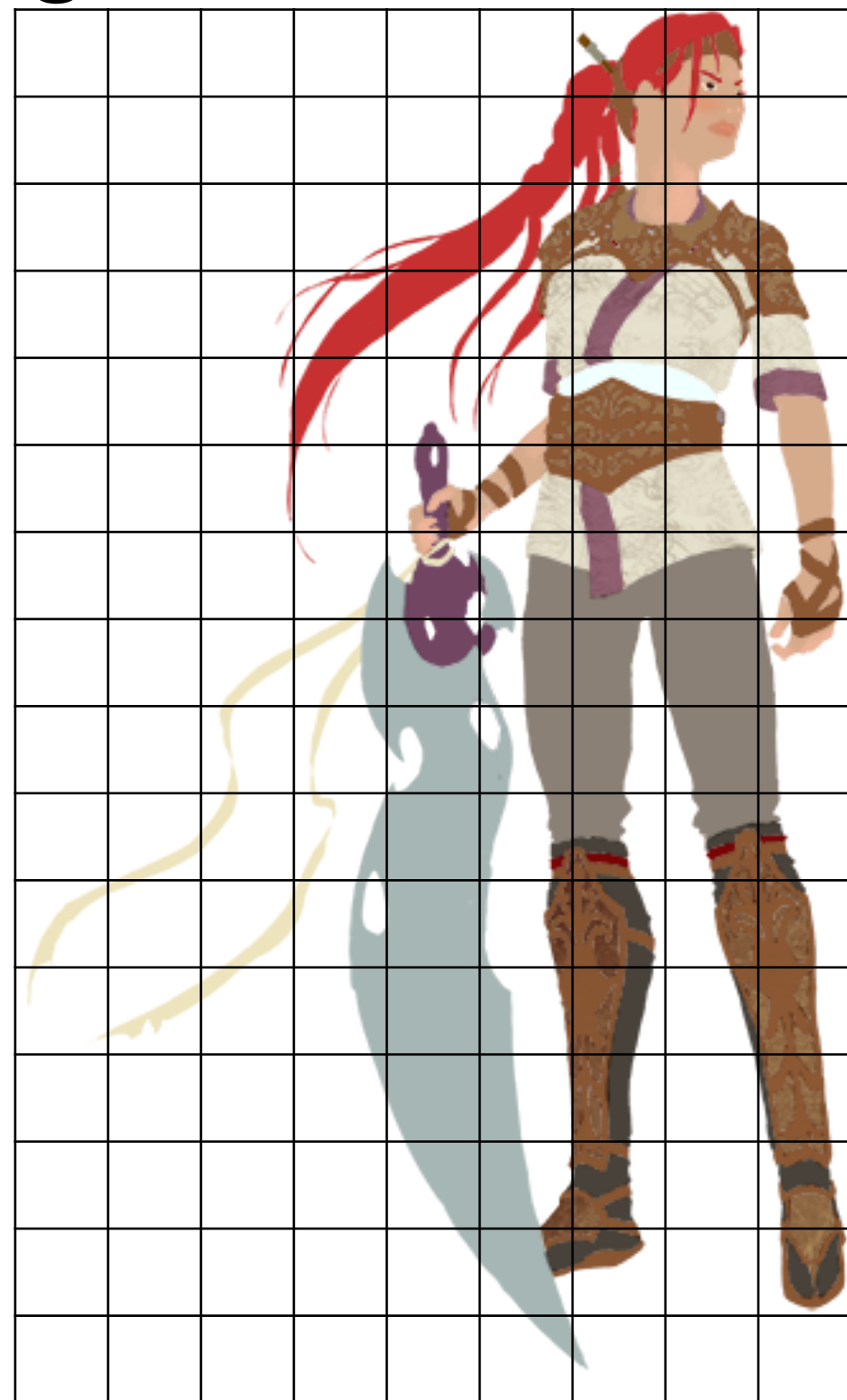
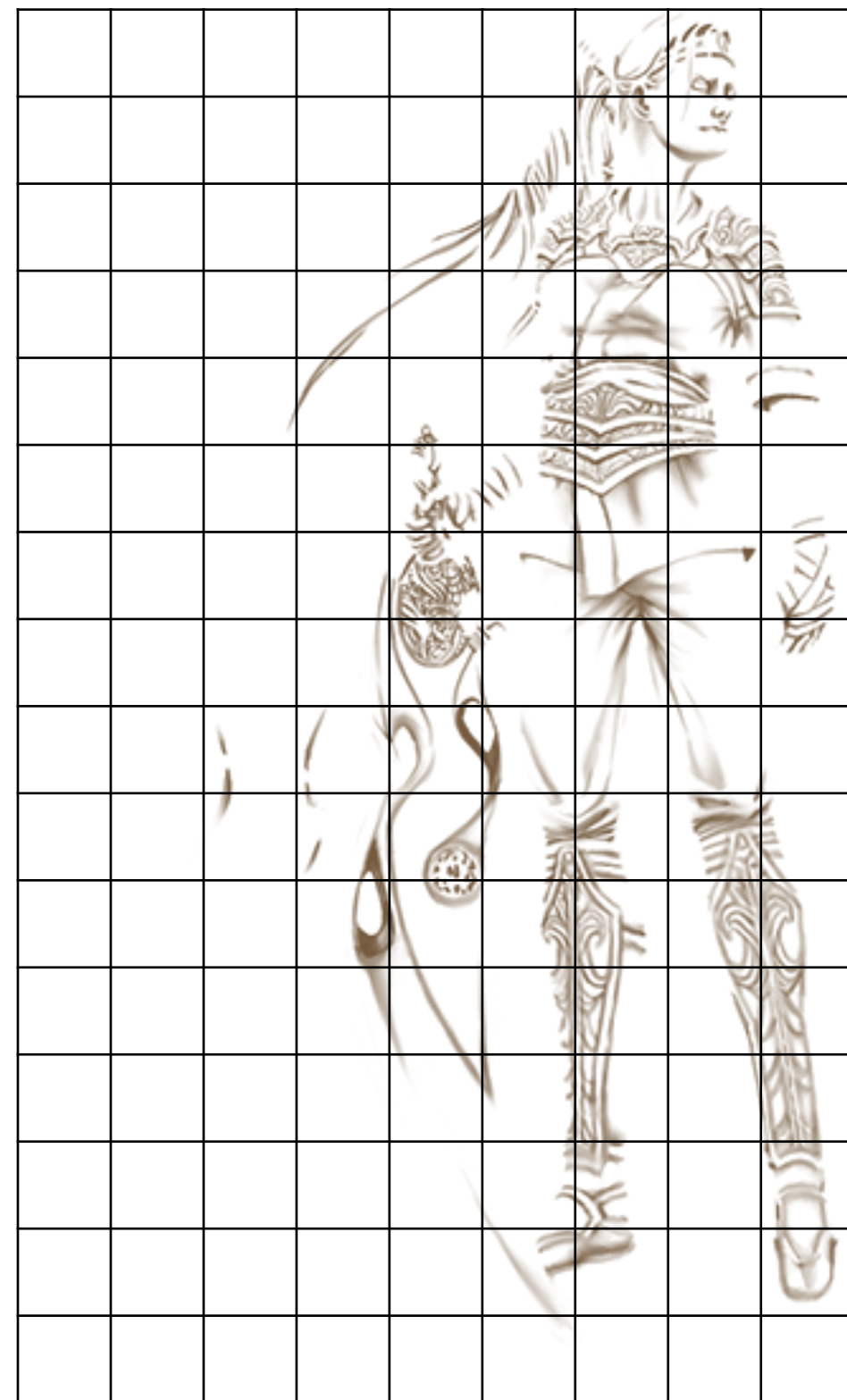
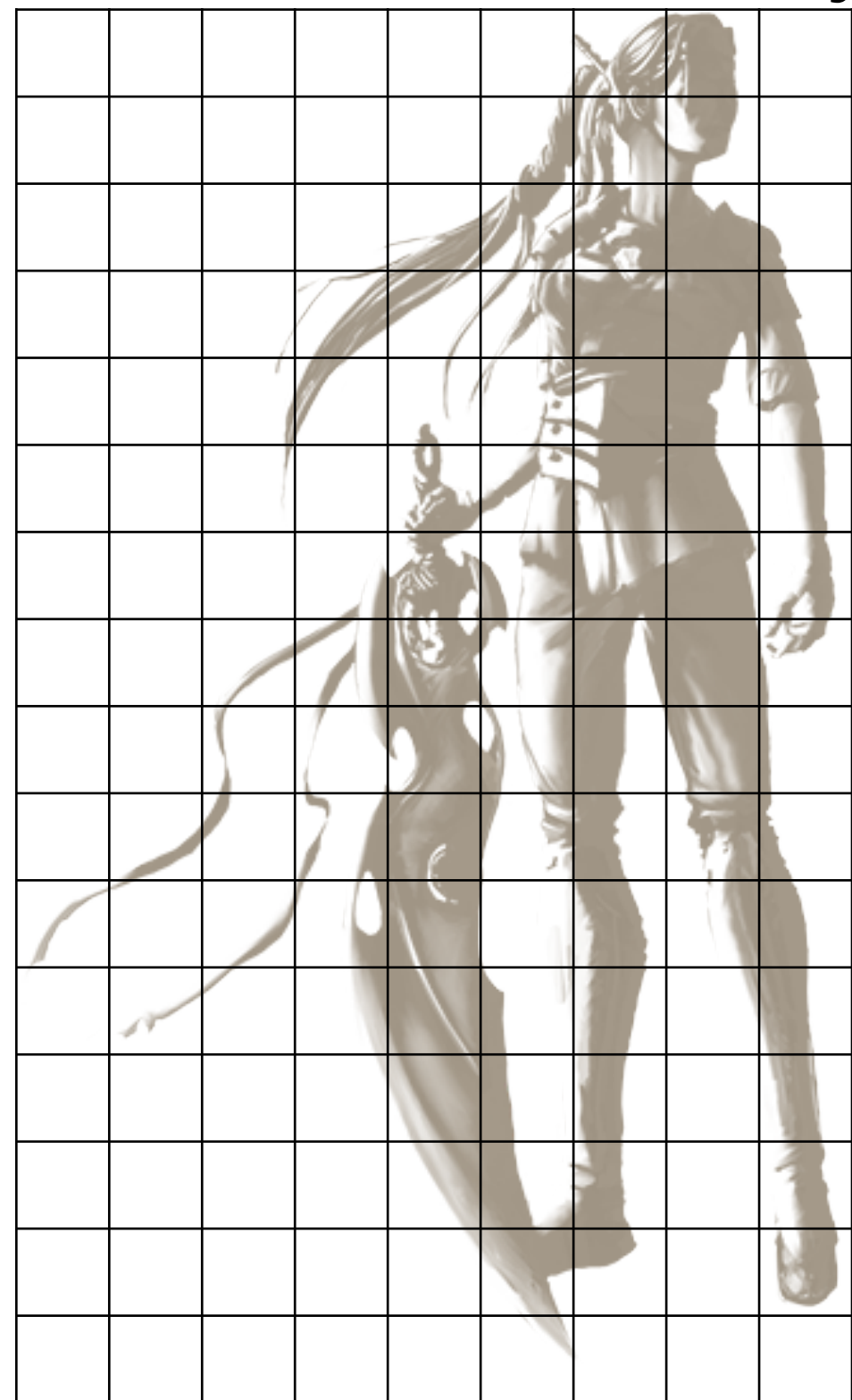
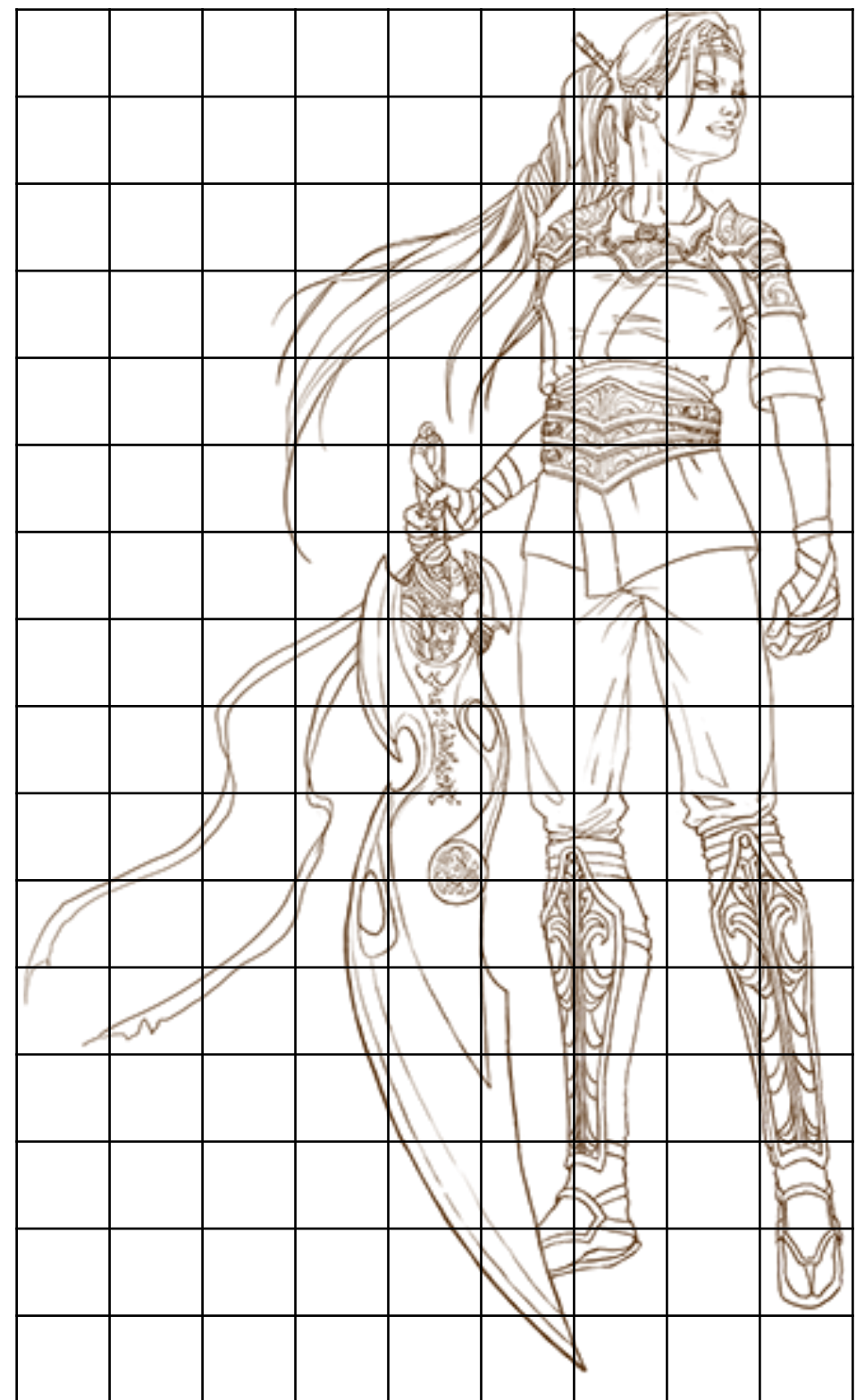
Background: Digital Painting

← Layers →



Background: Digital Painting

← Layers are RGBA images →



Background: Digital Painting



[Angela Sasser, <https://www.artstation.com/artwork/nariko-heavenly-guardian>]

Motivation

- Physical paintings are hard to edit.



Motivation

- What if we have a time lapse video?



Motivation

- What if we have a time lapse video?

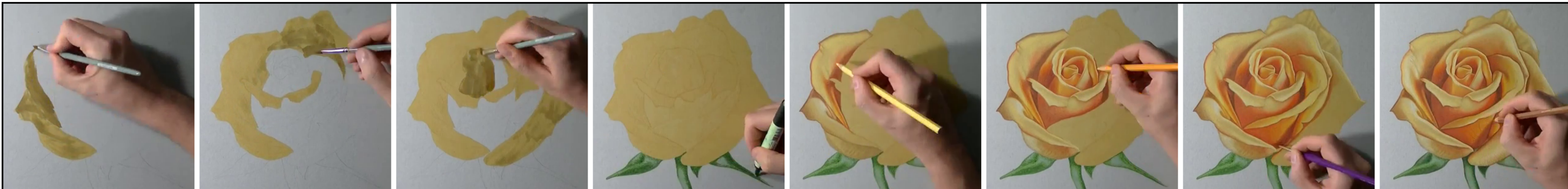


Goal

- Decompose a time-lapse painting video into layers

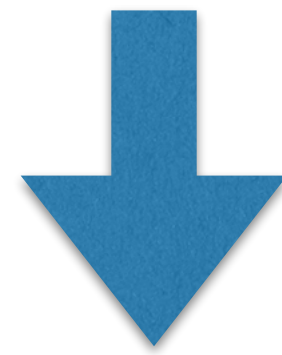
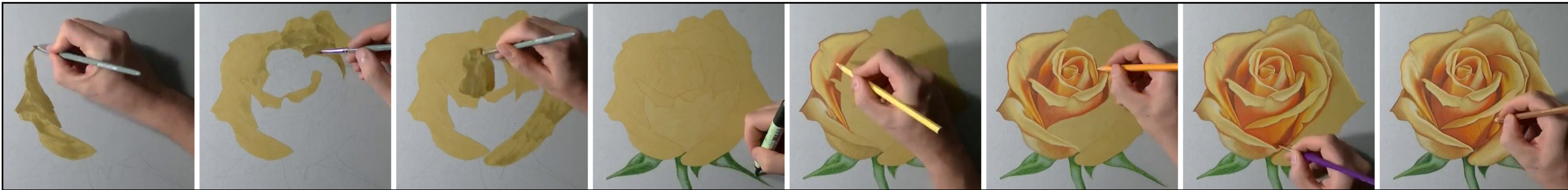
Goal

- Decompose a time-lapse painting video into layers



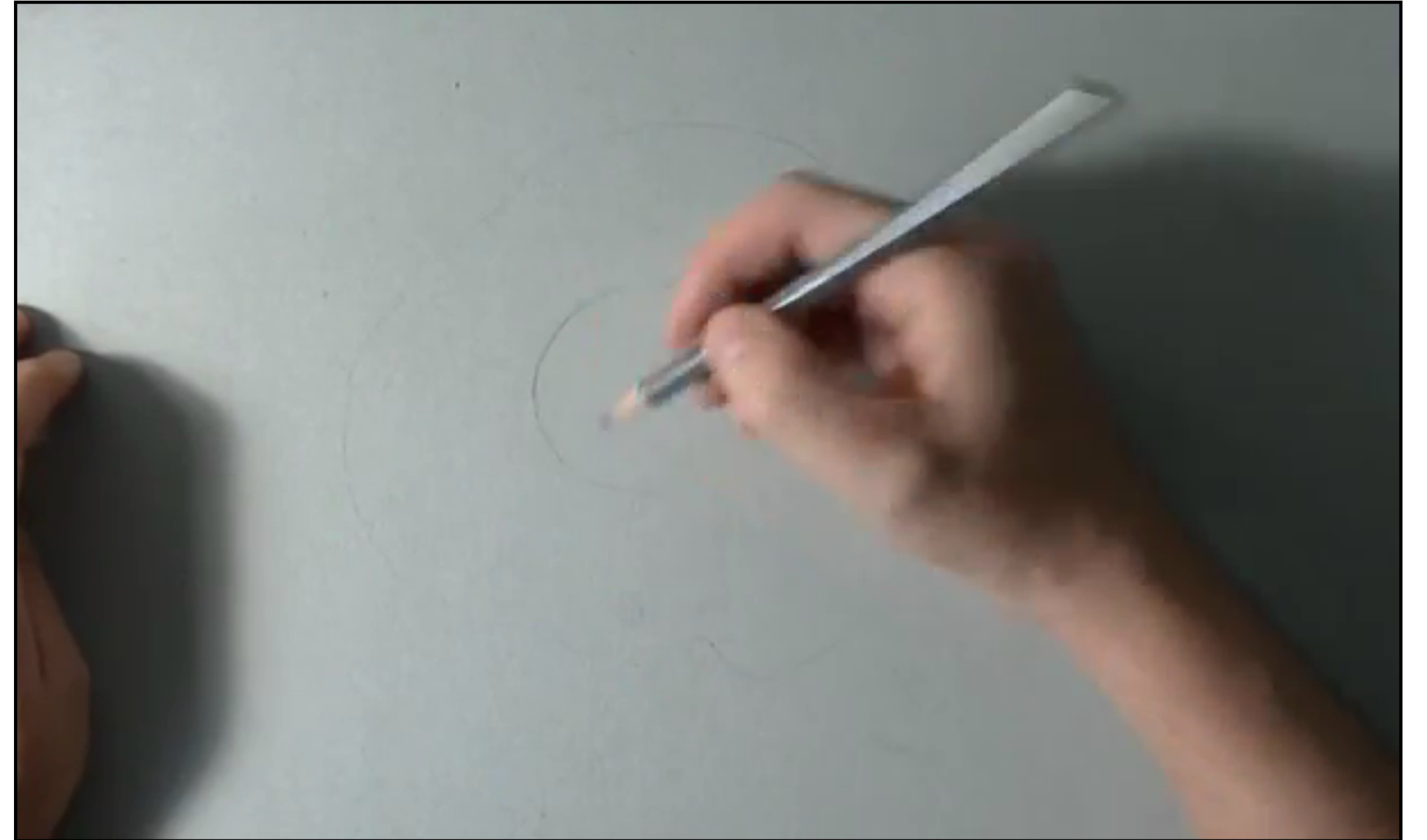
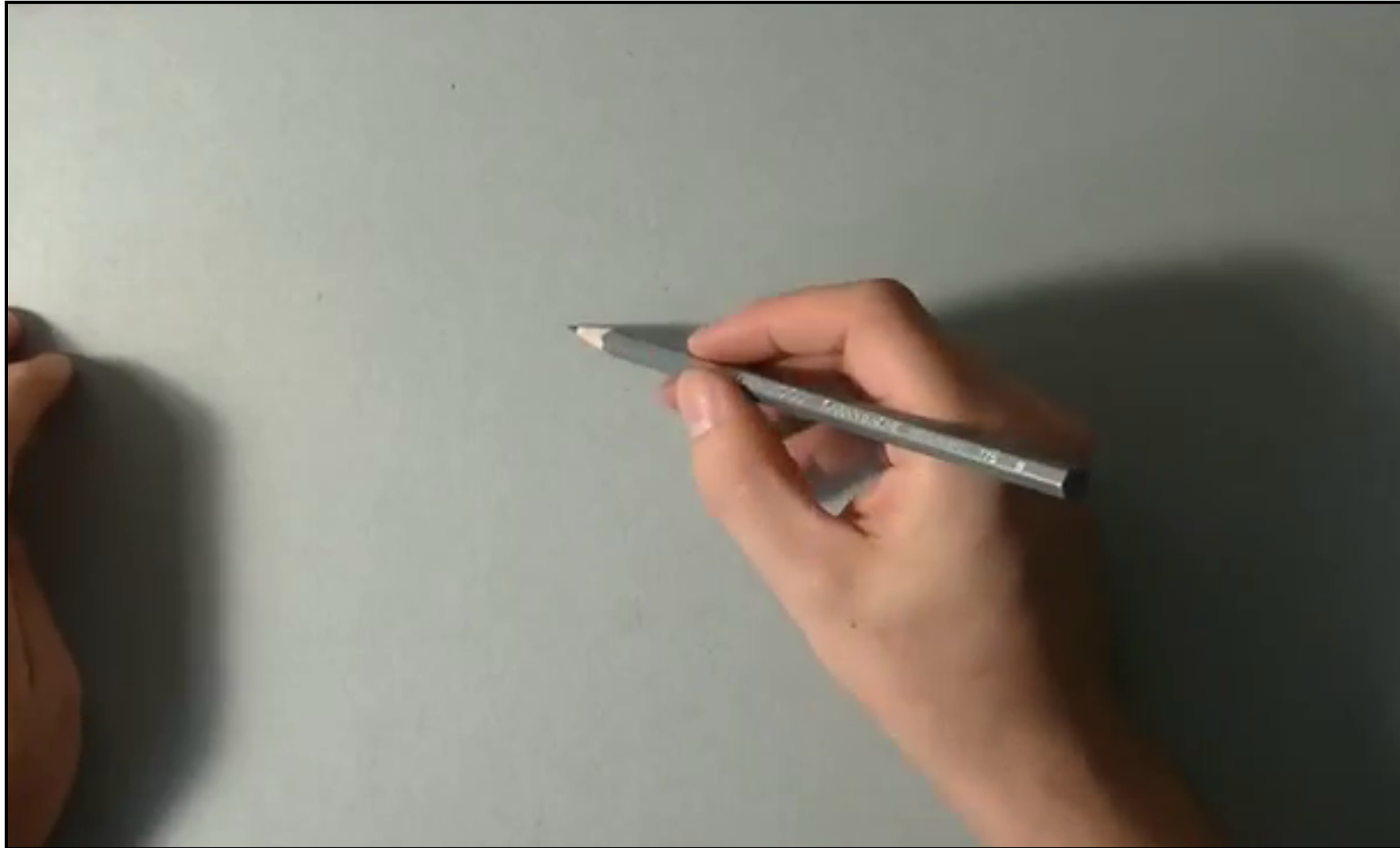
Goal

- Decompose a time-lapse painting video into layers



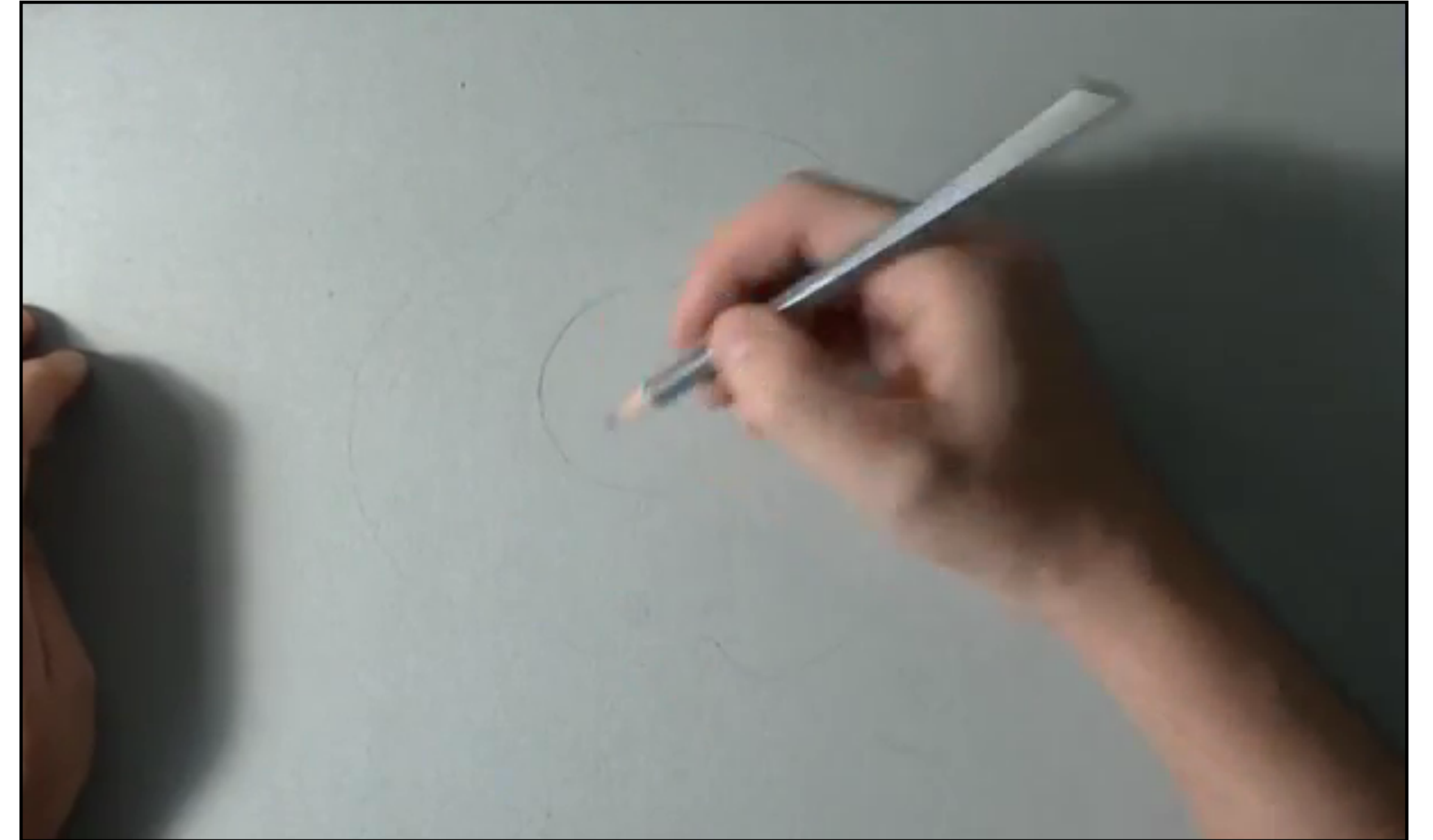
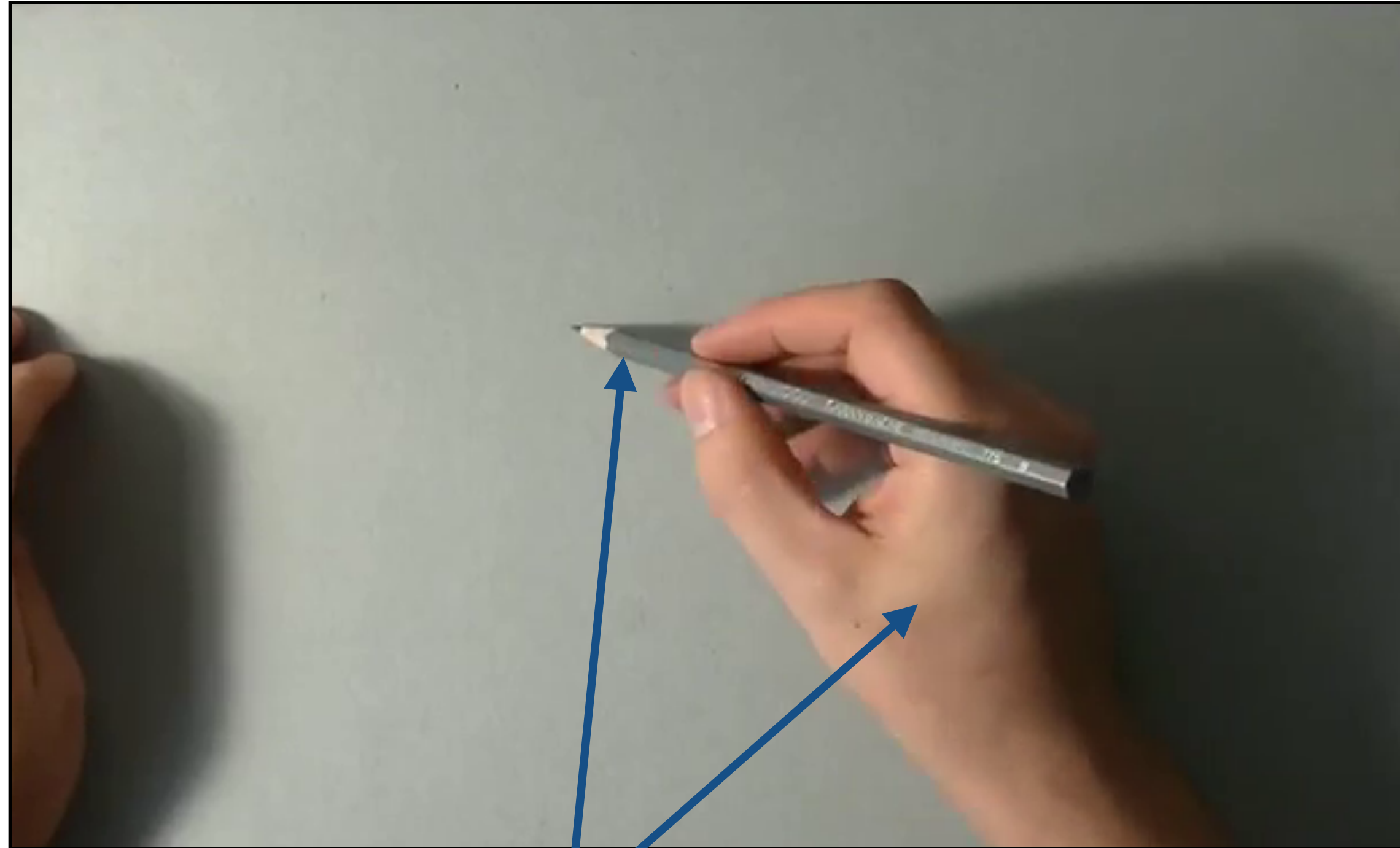
Challenges

- Preprocessing:



Challenges

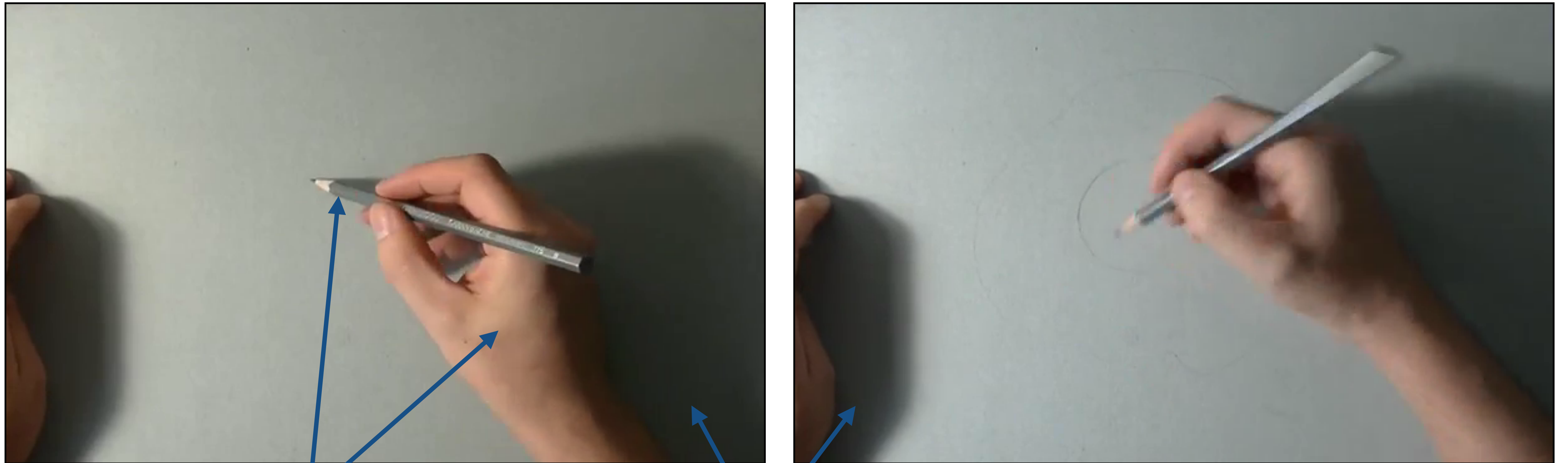
- Preprocessing:



painter

Challenges

- Preprocessing:

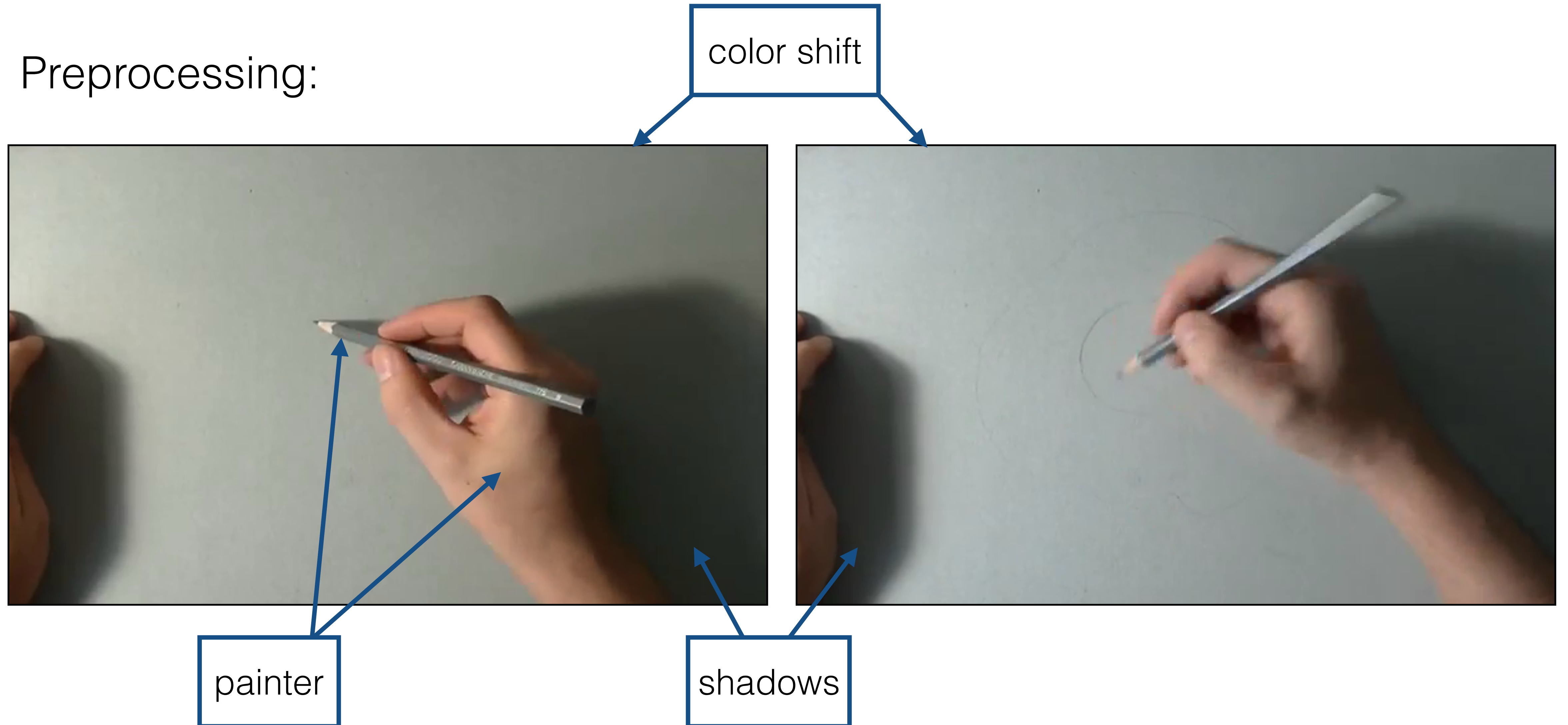


painter

shadows

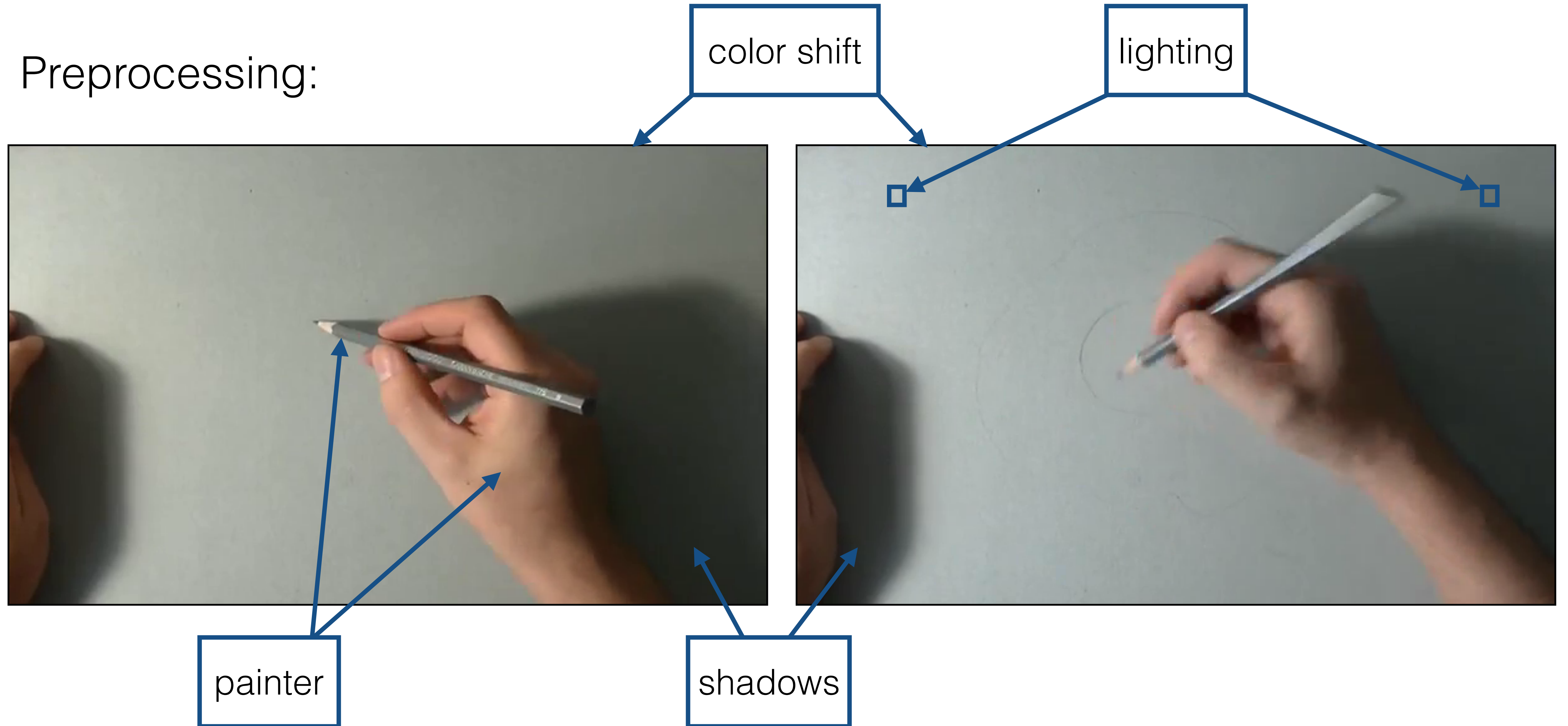
Challenges

- Preprocessing:



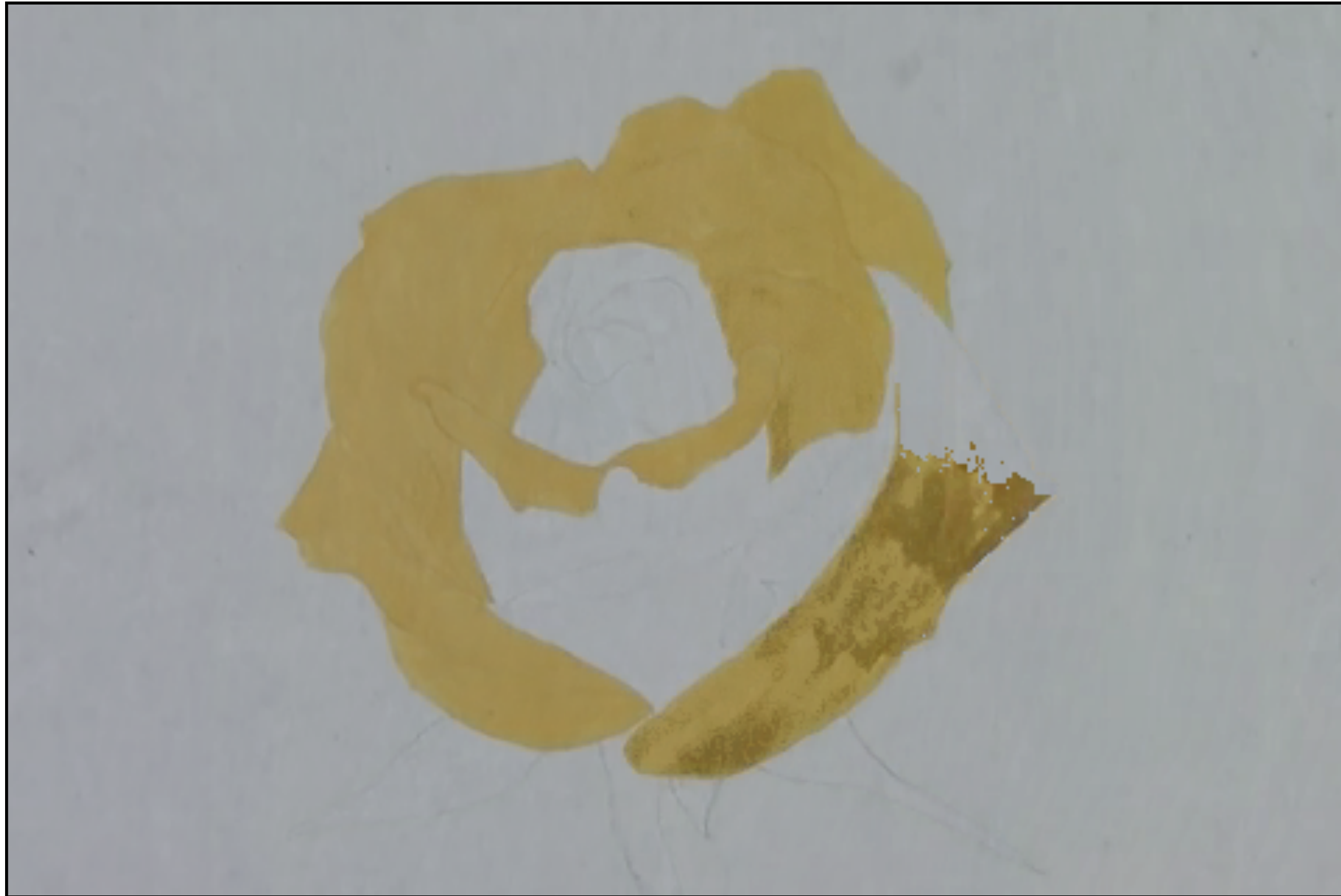
Challenges

- Preprocessing:

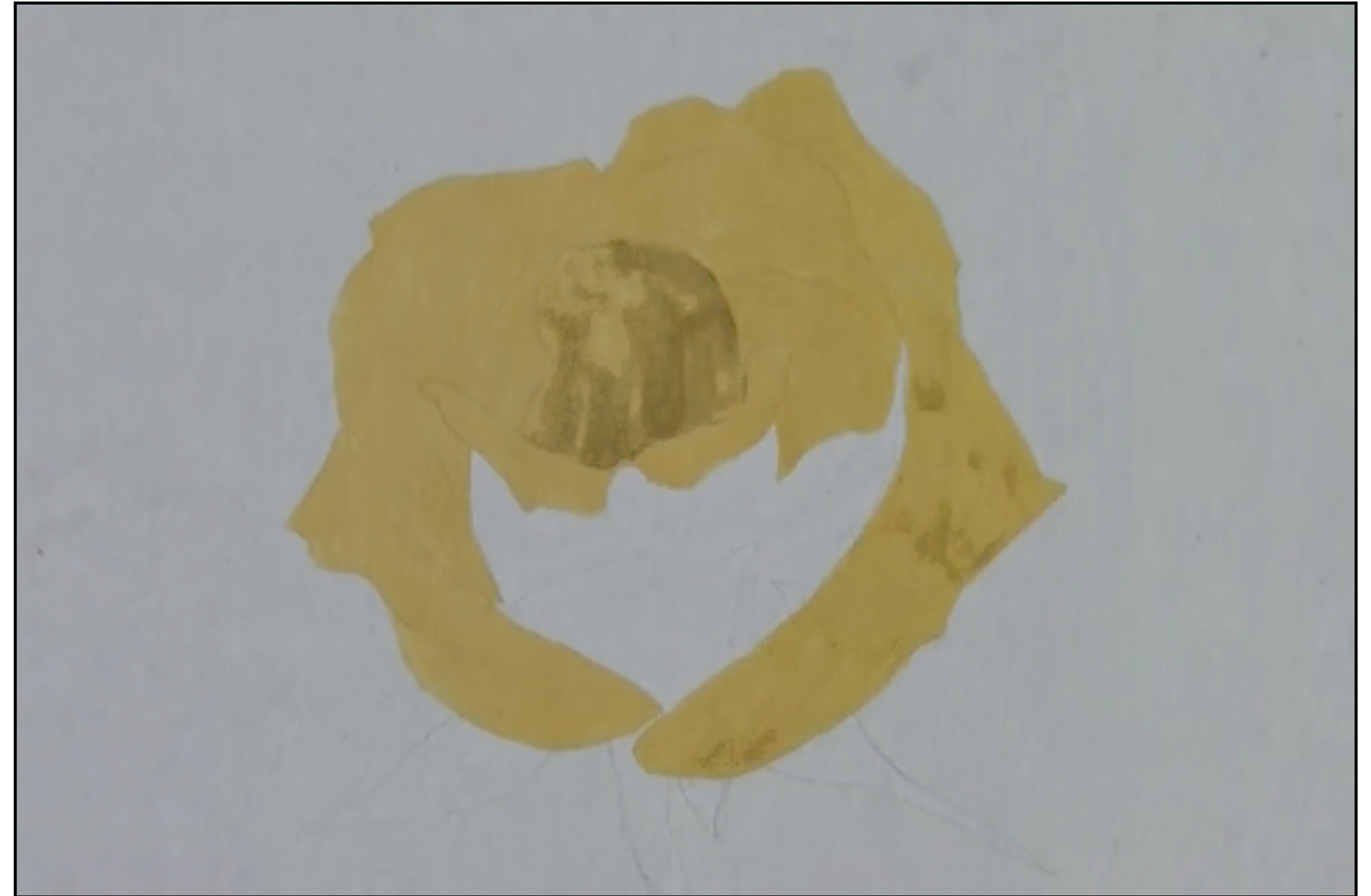


Challenges

- Recovering paint layers



before

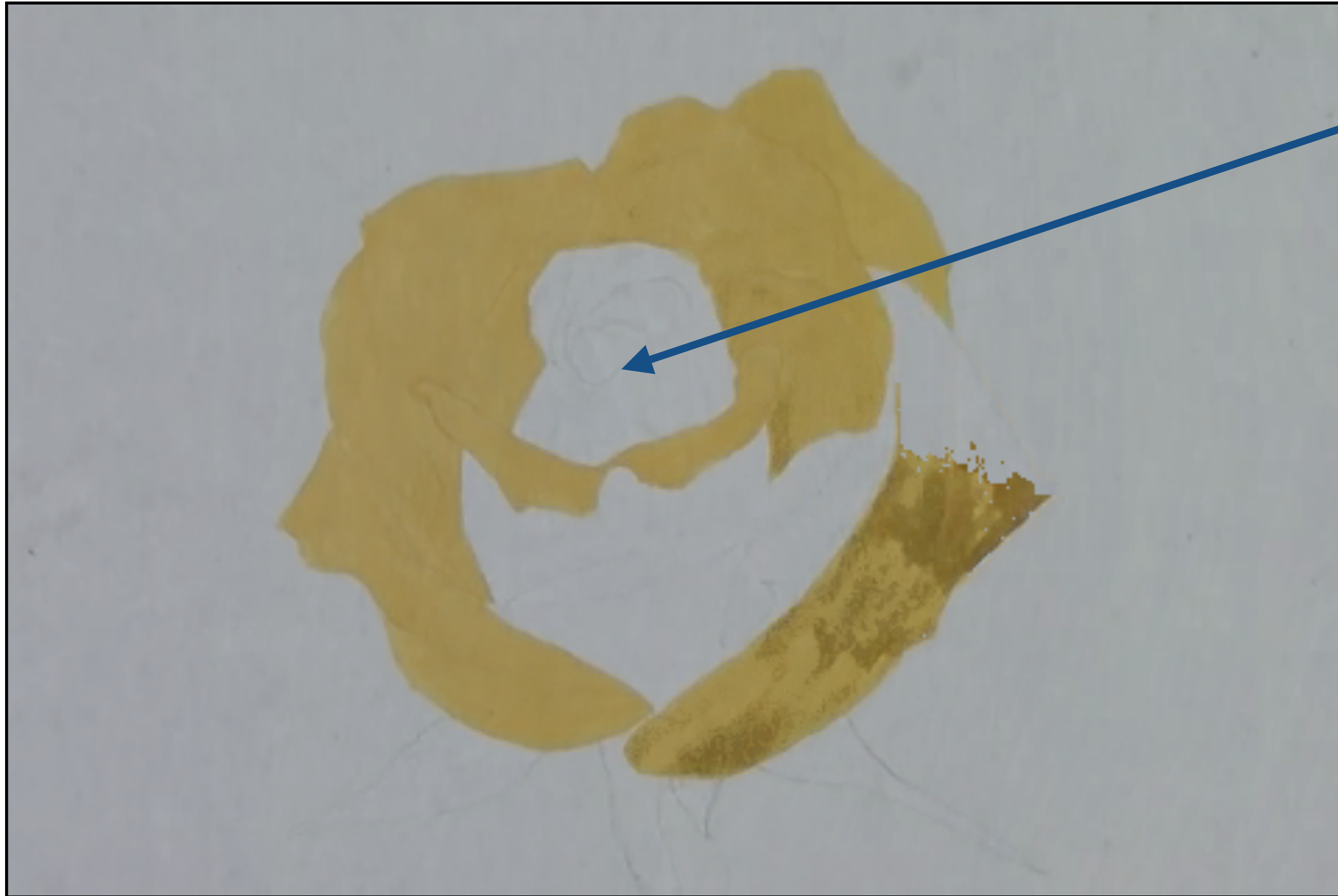


after

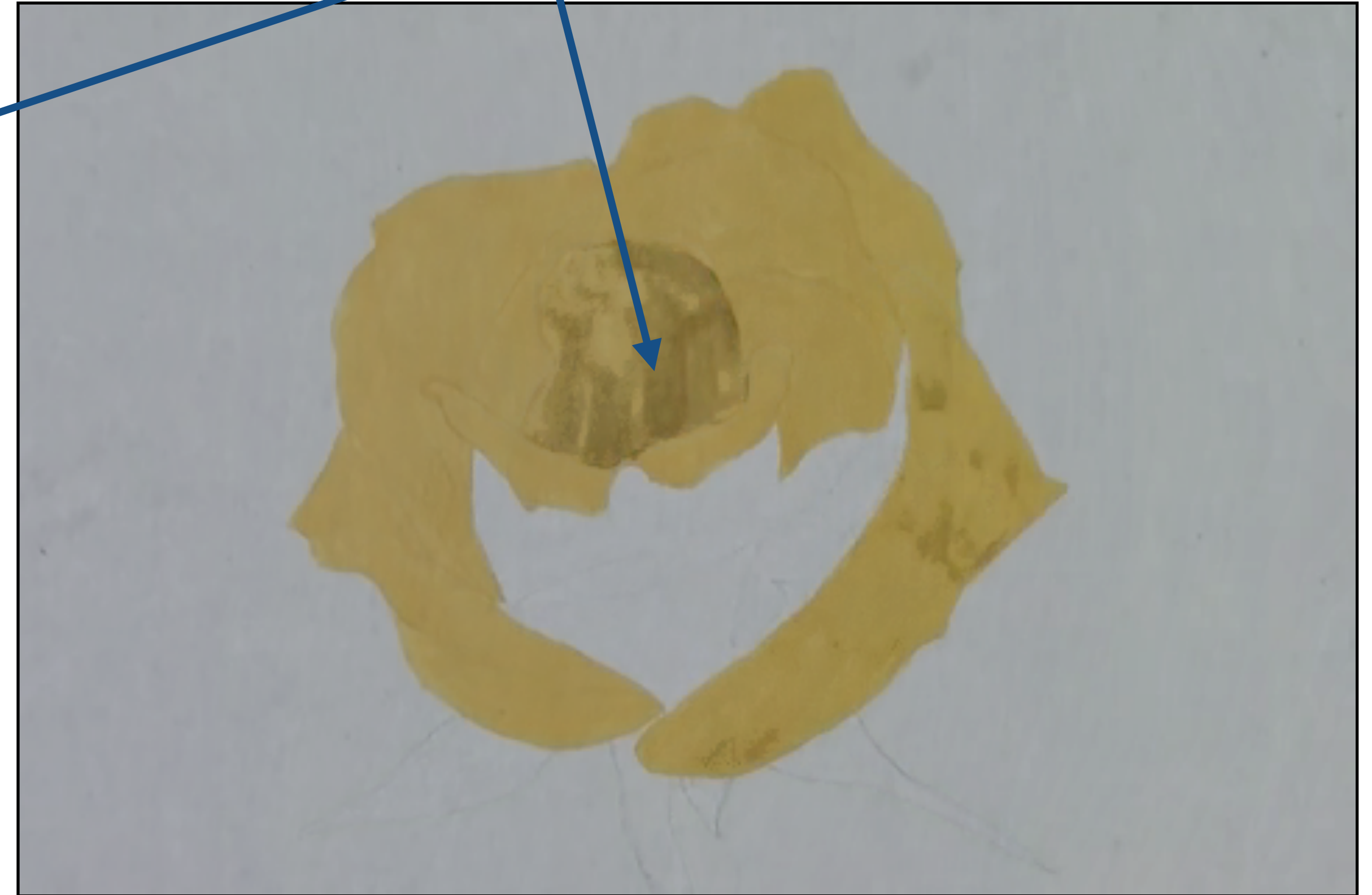
Challenges

- Recovering paint layers

color change



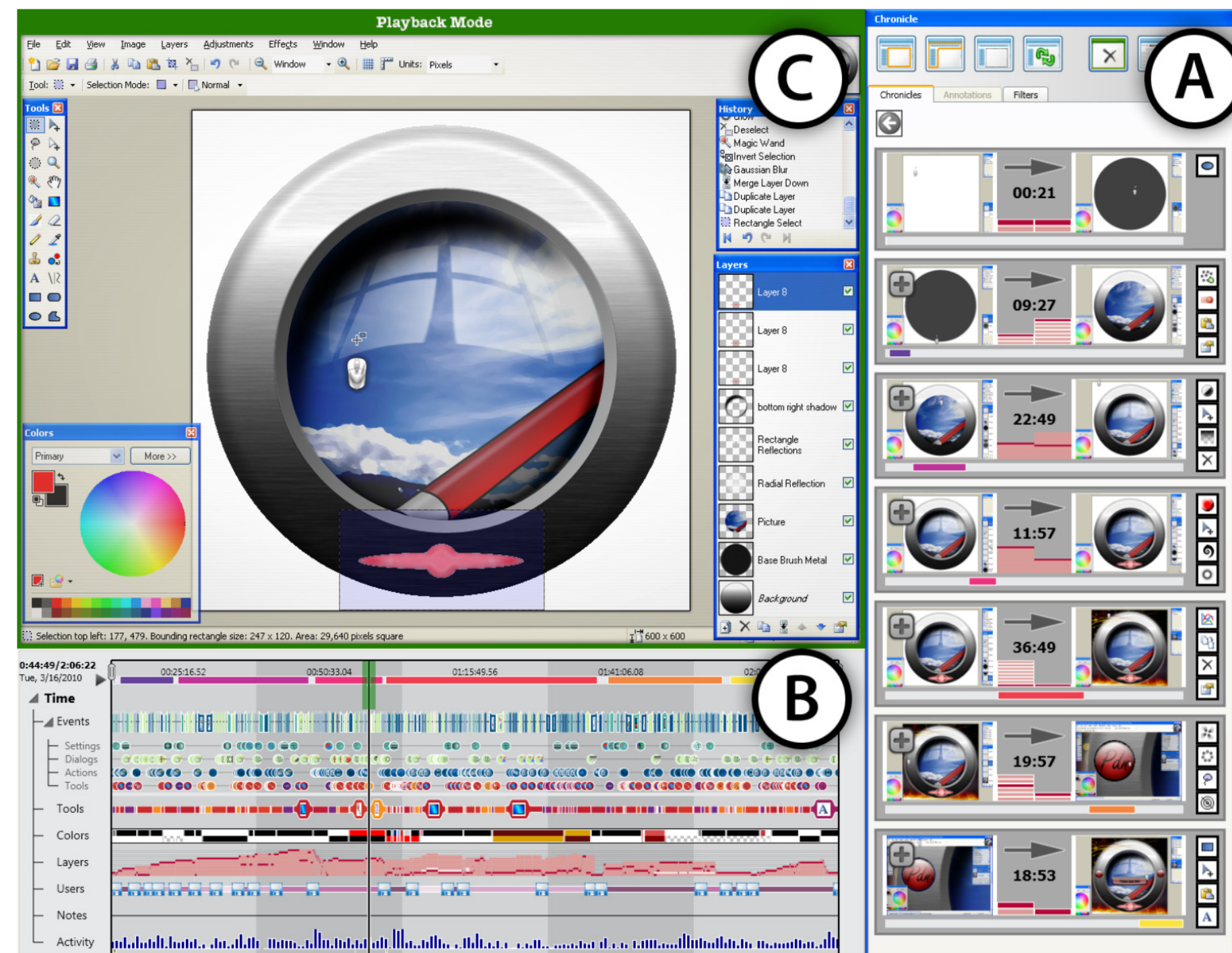
before



after

Related Work

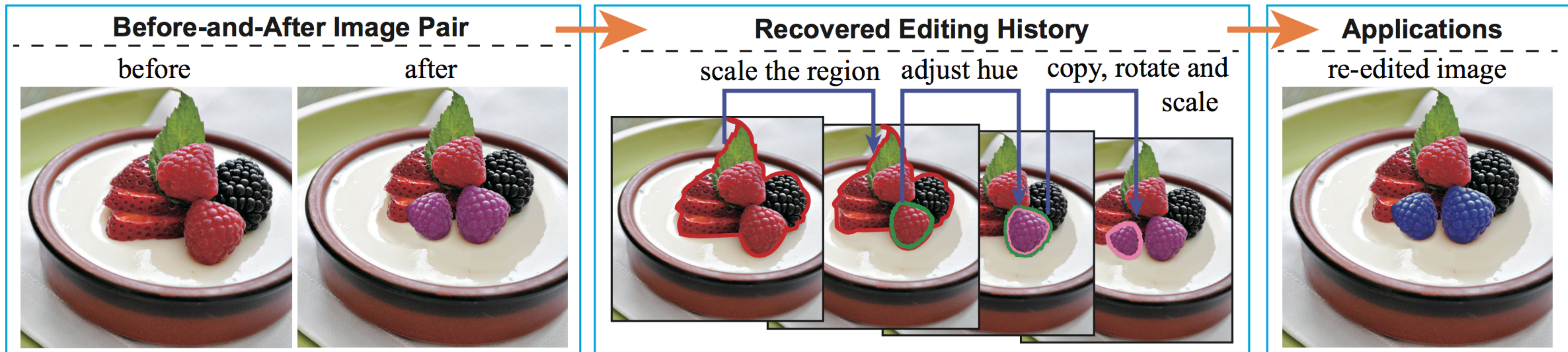
- Interacting with editing history
 - Su et al. [2009], VisTrails [2009], McCann and Pollard [2009; 2012], Grossman et al. [2010], Noris et al. [2012], Denning and Pellacini [2013], Chen et al. [2014], Matzen and Snavely [2014], Karsch et al. [2014].



Chronicle [Grossman et al. 2010]

Related Work

- Decomposing edits
 - Xu et al. [2006], Amati and Brostow [2010], Fu et al. [2011], Hu et al. [2013], Richardt et al. [2014].



Inverse Image Editing [Hu et al. 2013]

Related Work

- Image matting
 - Smith and Blinn [1996], Zongker et al. [1999], Farid and Adelson [1999], Szeliski et al. [2000], Levin et al. [2006; 2007]



Blue Screen Matting [Smith and Blinn 1996]

Pipeline



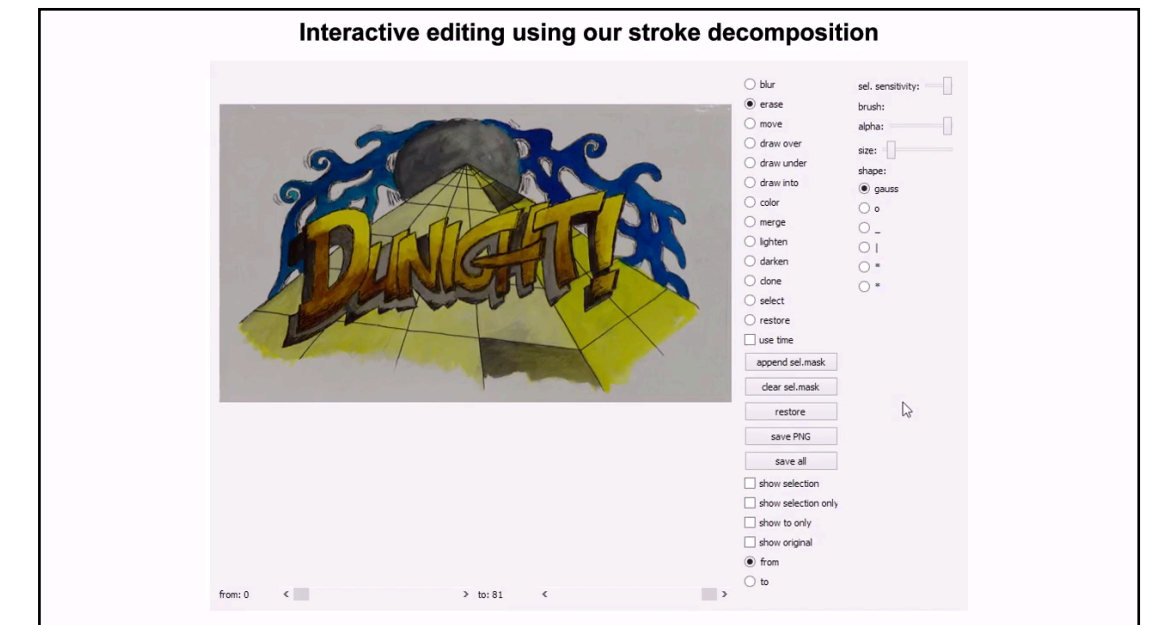
Input



Preprocess



Extract Layers



Edit

Pipeline



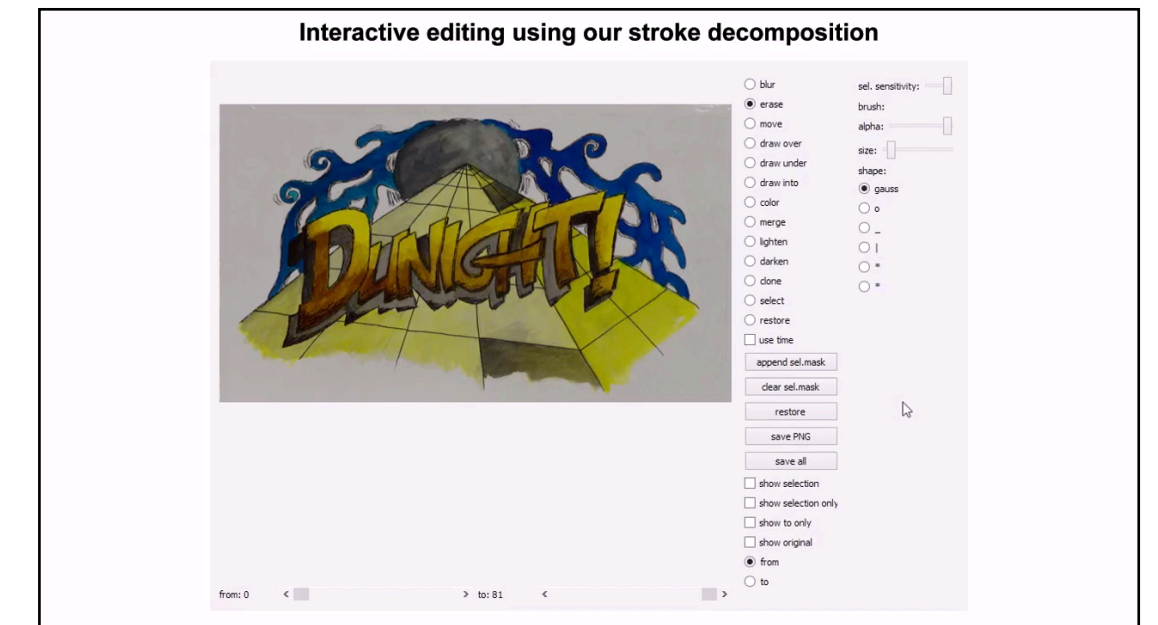
Input



Preprocess



Extract Layers

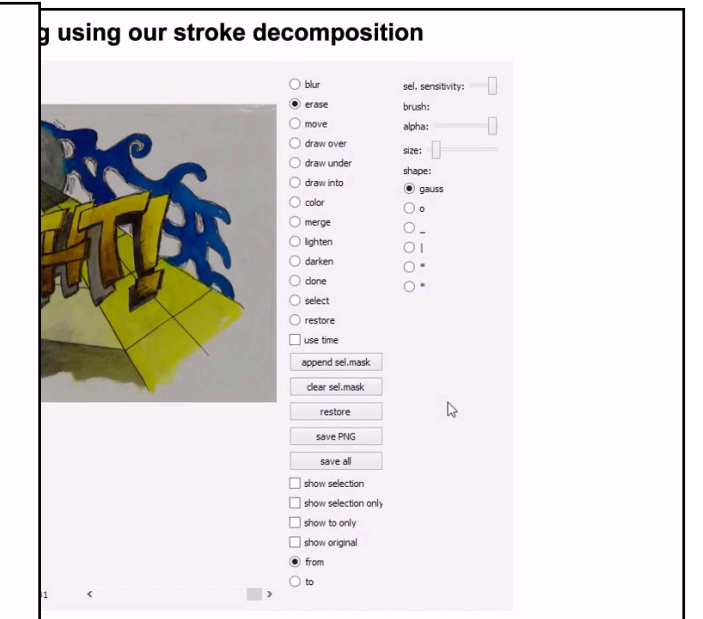


Edit

Pipeline



Input

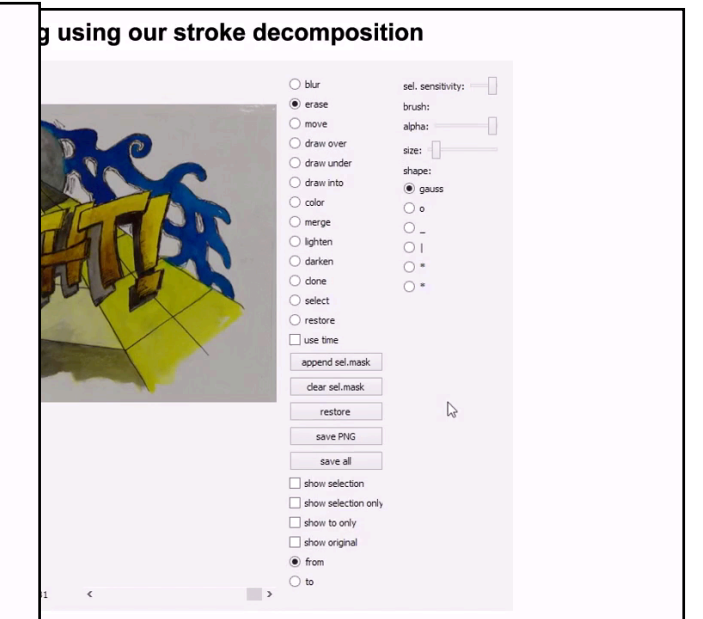


Edit

Pipeline

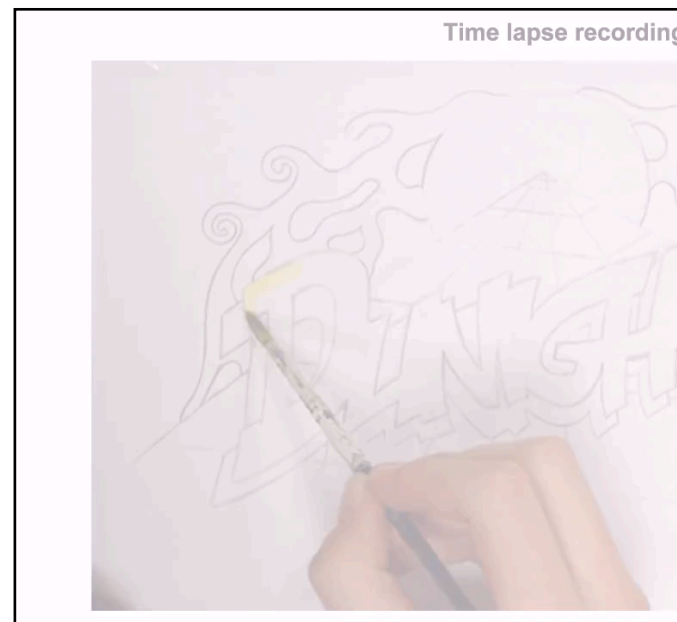


Input

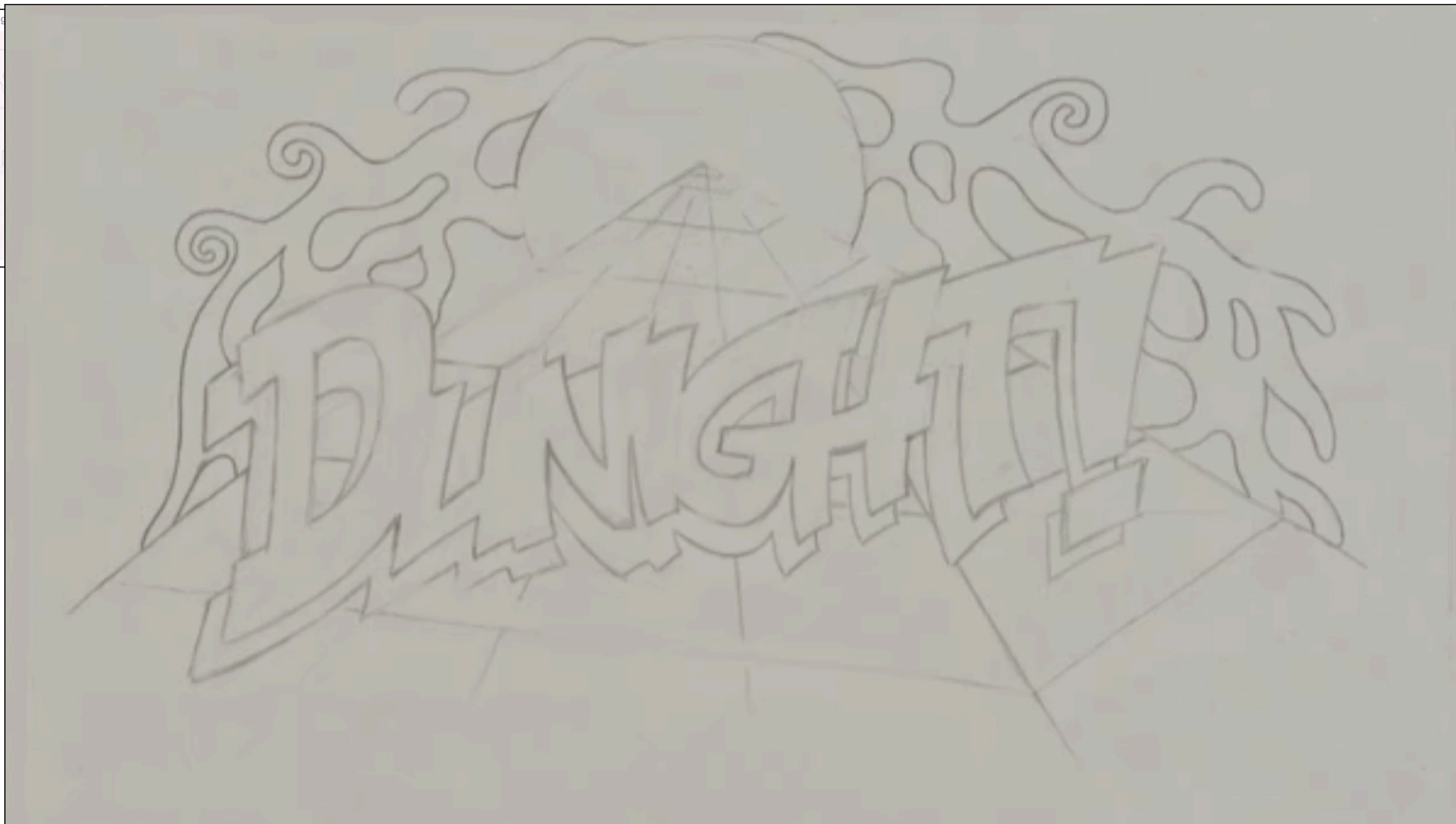


Edit

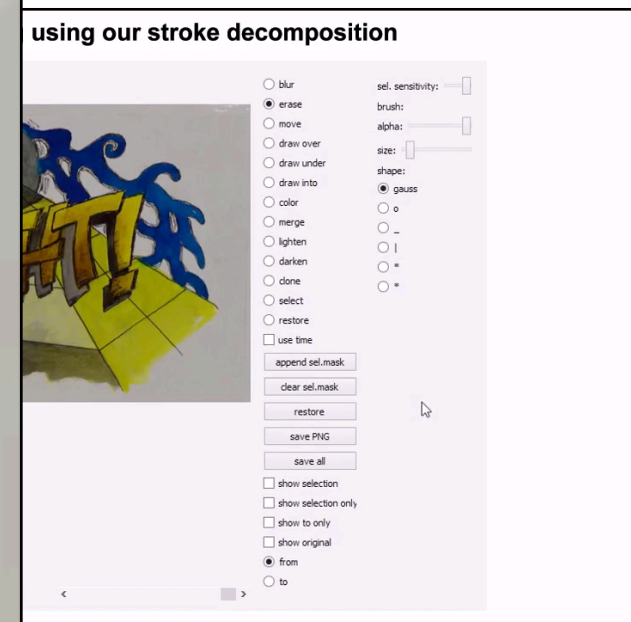
Pipeline



Input

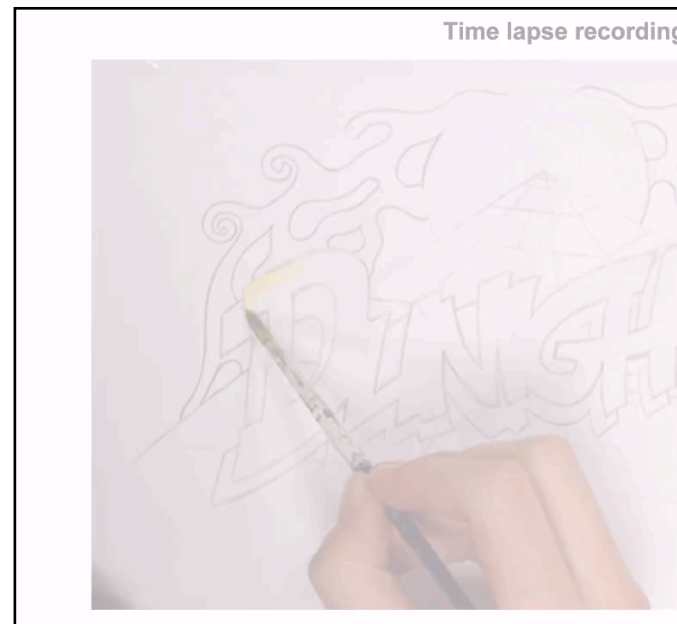


Preprocess

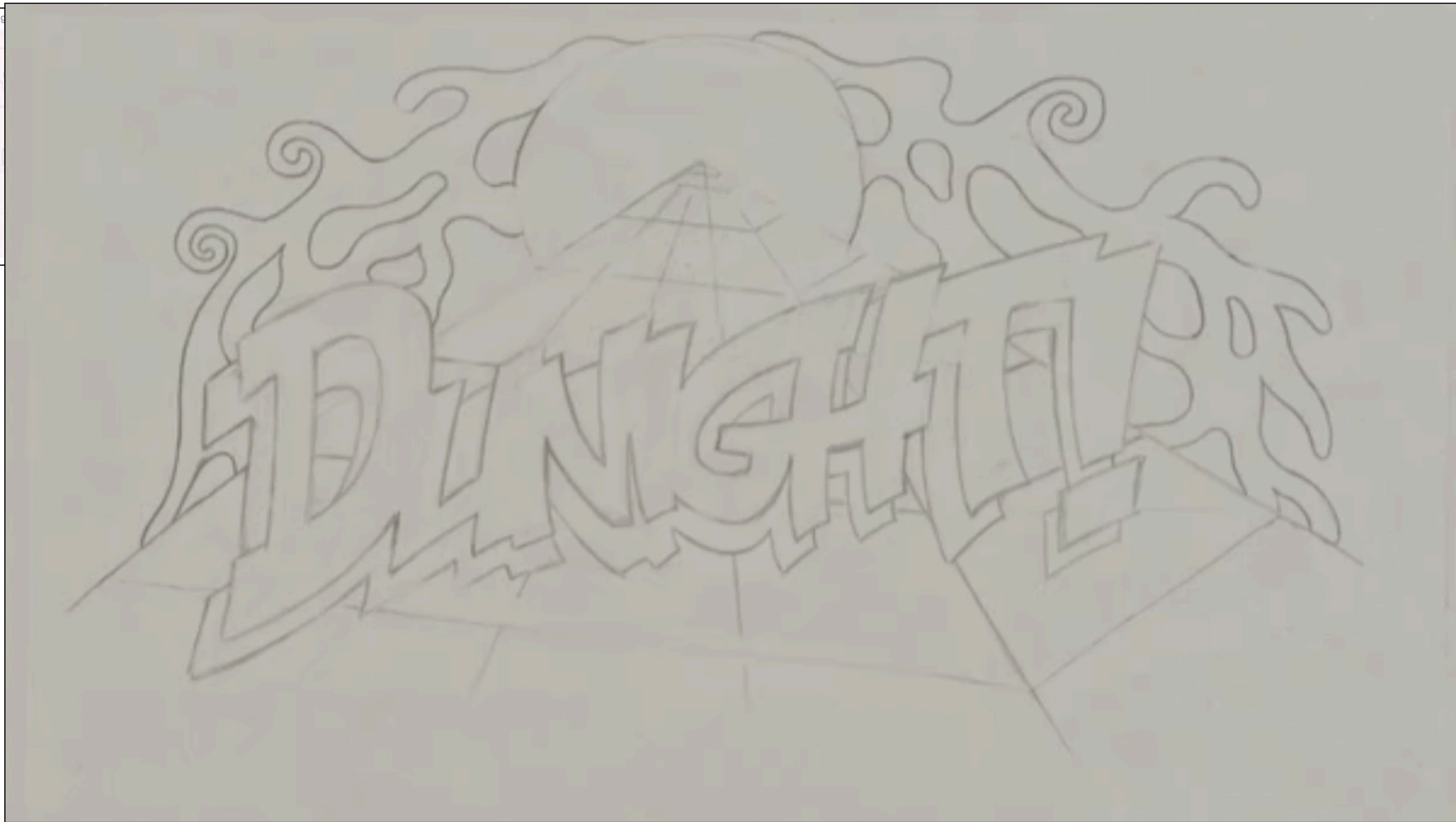


Edit

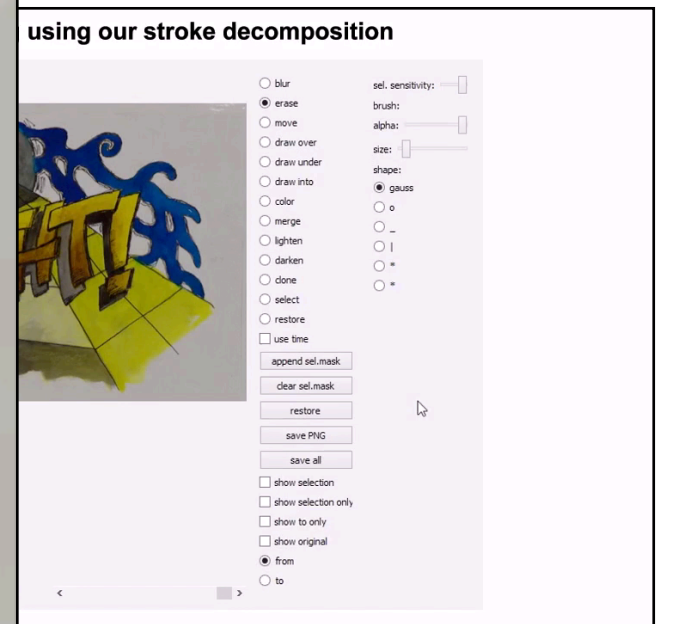
Pipeline



Input

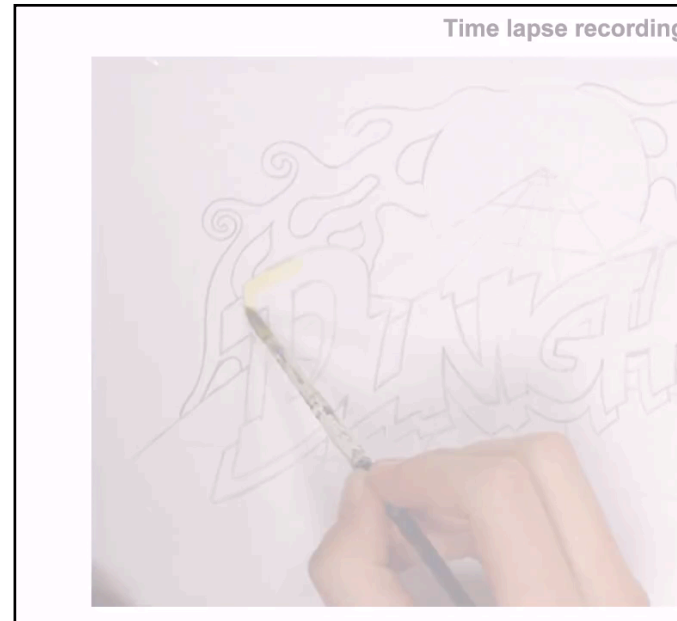


Preprocess



Edit

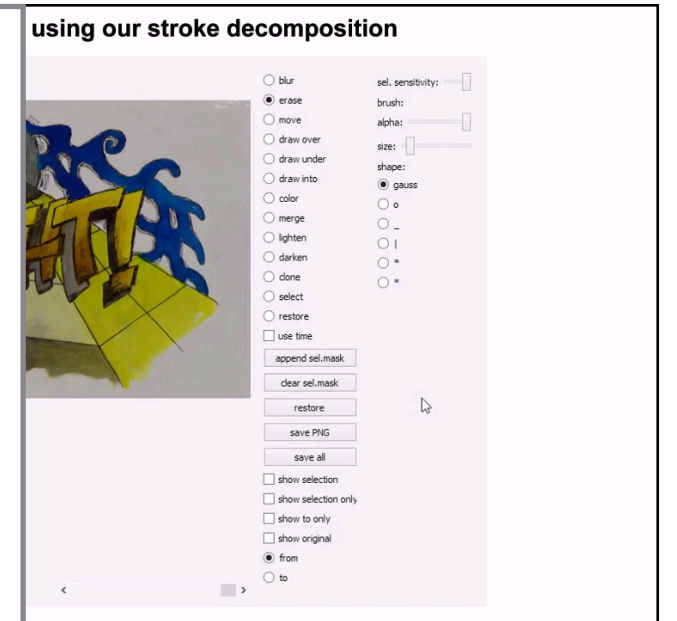
Pipeline



Input

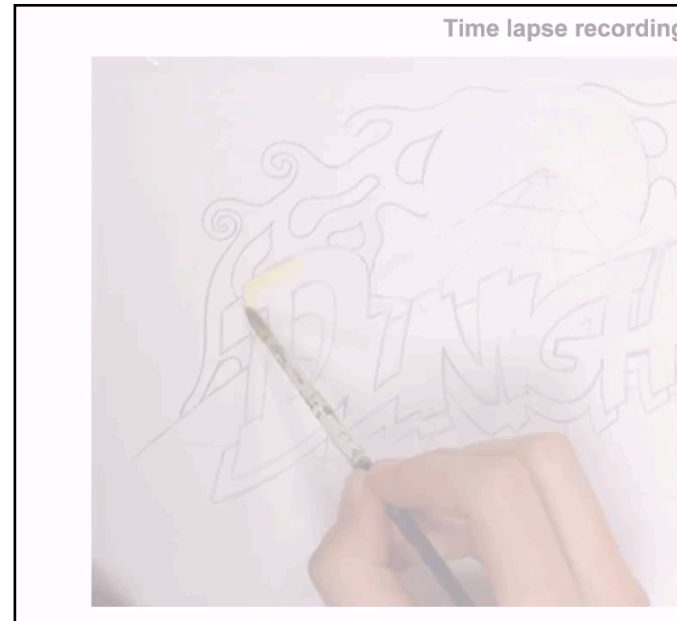


Extract Layers



Edit

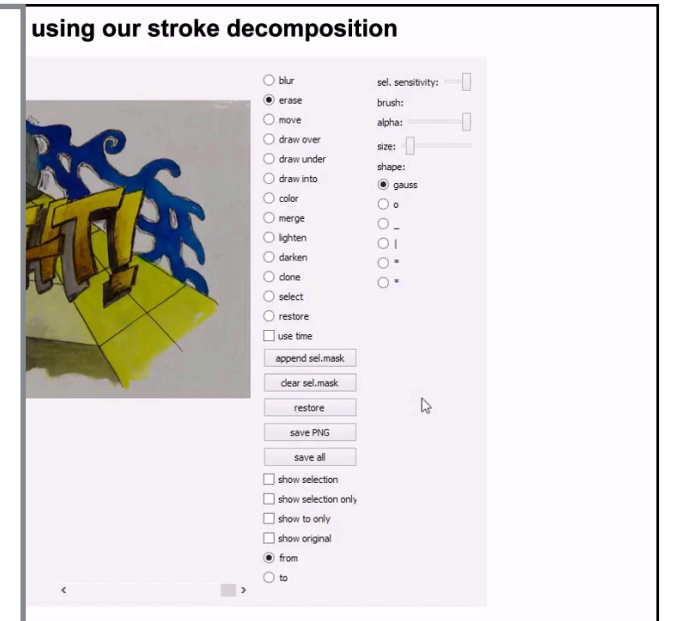
Pipeline



Input



Extract Layers



Edit

Pipeline



Input

Interactive editing using our stroke decomposition

Interactive editing using our stroke decomposition

- blur
- erase
- move
- draw over
- draw under
- draw into
- color
- merge
- lighten
- darken
- done
- select
- restore
- use time
- append sel.mask
- clear sel.mask
- restore
- save PNG
- save all
- show selection
- show selection only
- show to only
- show original
- from
- to

sel. sensitivity:

brush:

alpha:

size:

shape:

- gauss
- o
- _
- |
- *
- *

from: 0 < > to: 81 < >

Edit

Pipeline



Input

Interactive editing using our stroke decomposition

blur
 erase
 move
 draw over
 draw under
 draw into
 color
 merge
 lighten
 darken
 done
 select
 restore
 use time

sel. sensitivity:
brush:
alpha:
size:
shape:
 gauss
 o
 _
 |
 *
 *

append sel.mask
clear sel.mask
restore
save PNG
save all

show selection
 show selection only
 show to only
 show original
 from
 to

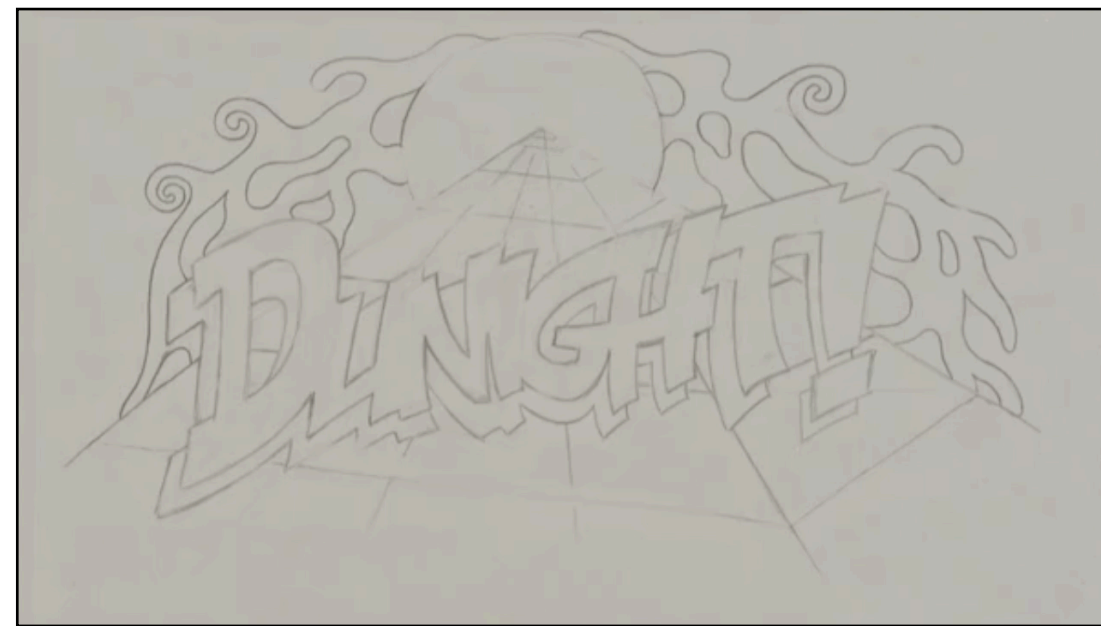
from: 0 < > to: 81 < >

Edit

Pipeline



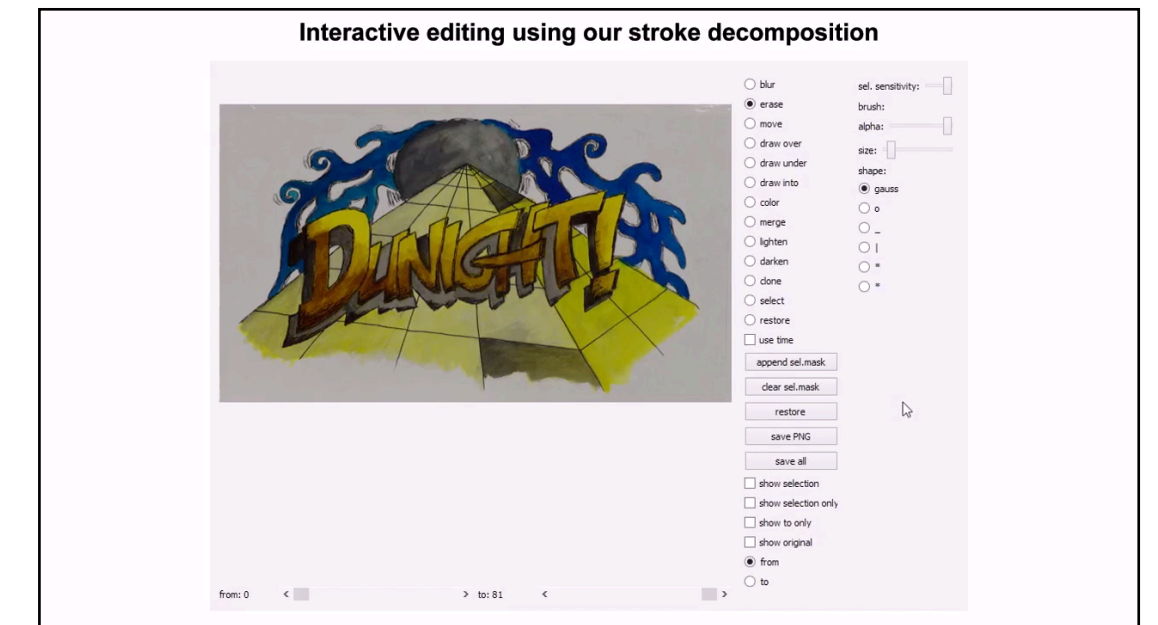
Input



Preprocess



Extract Layers



Edit

Pipeline



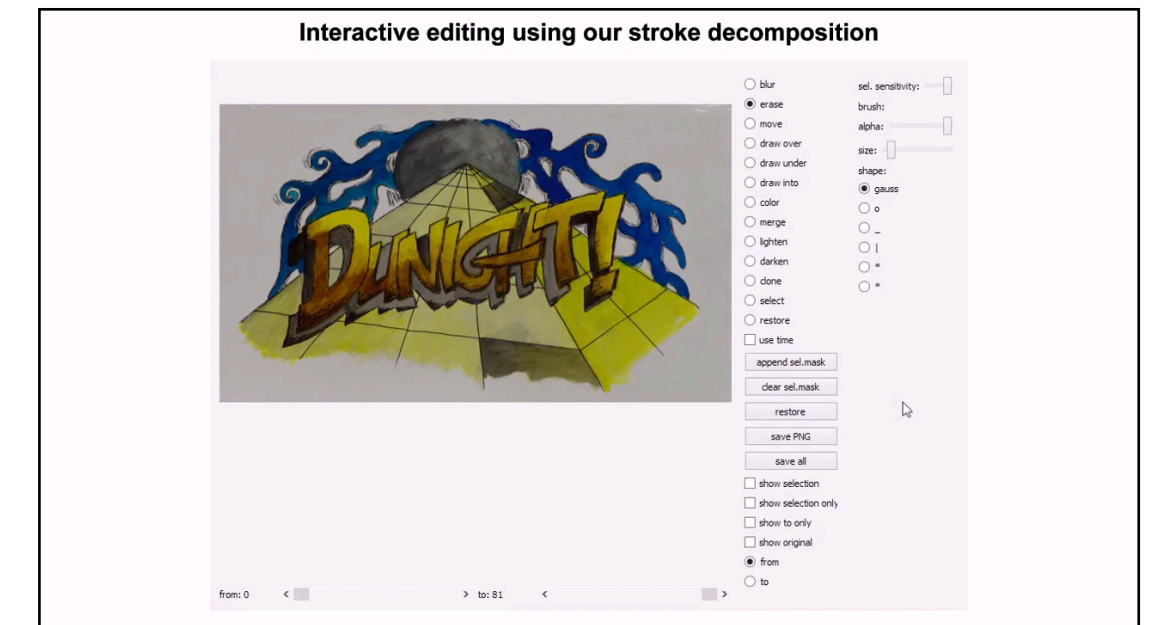
Input



Preprocess

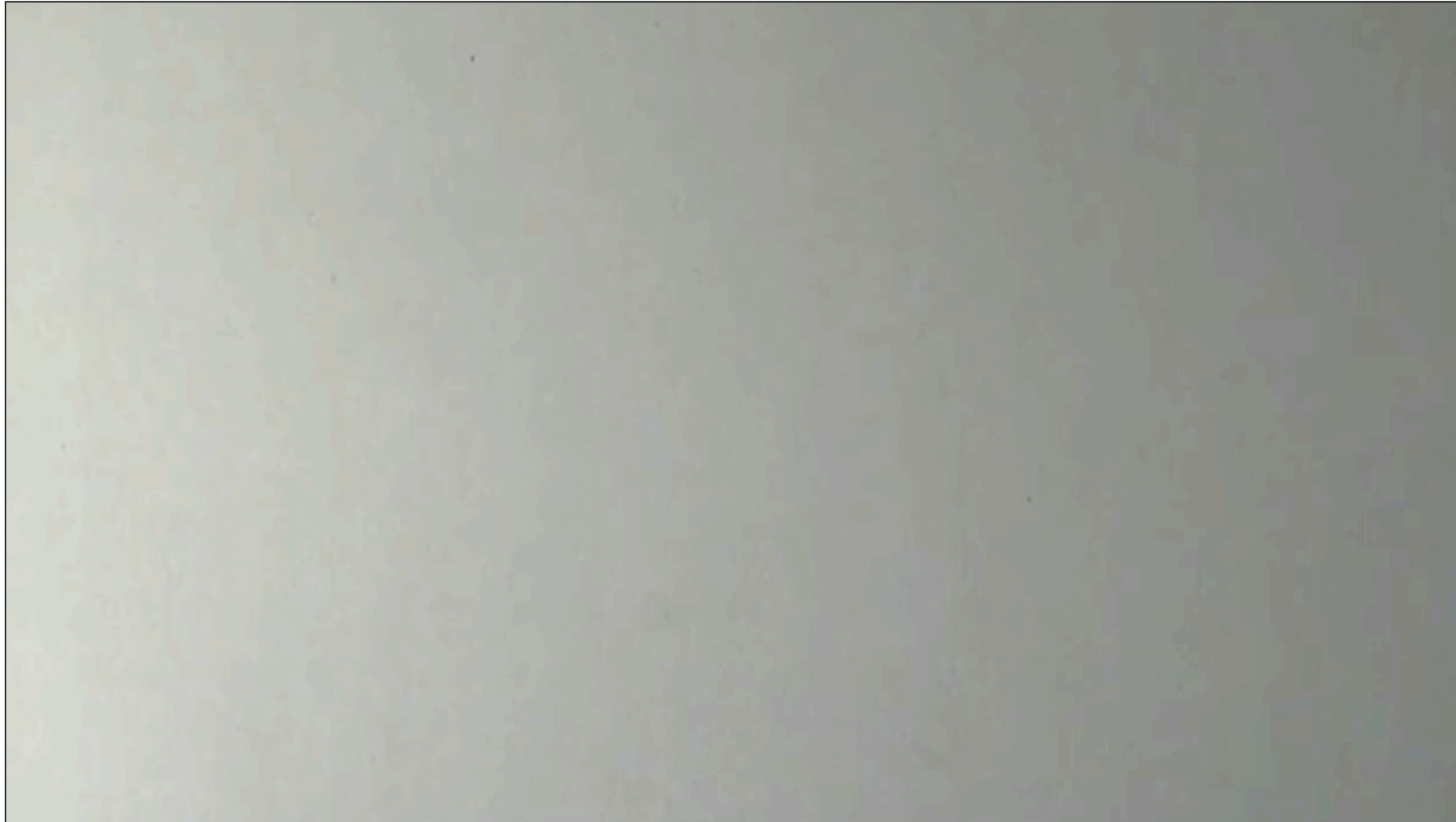


Extract Layers

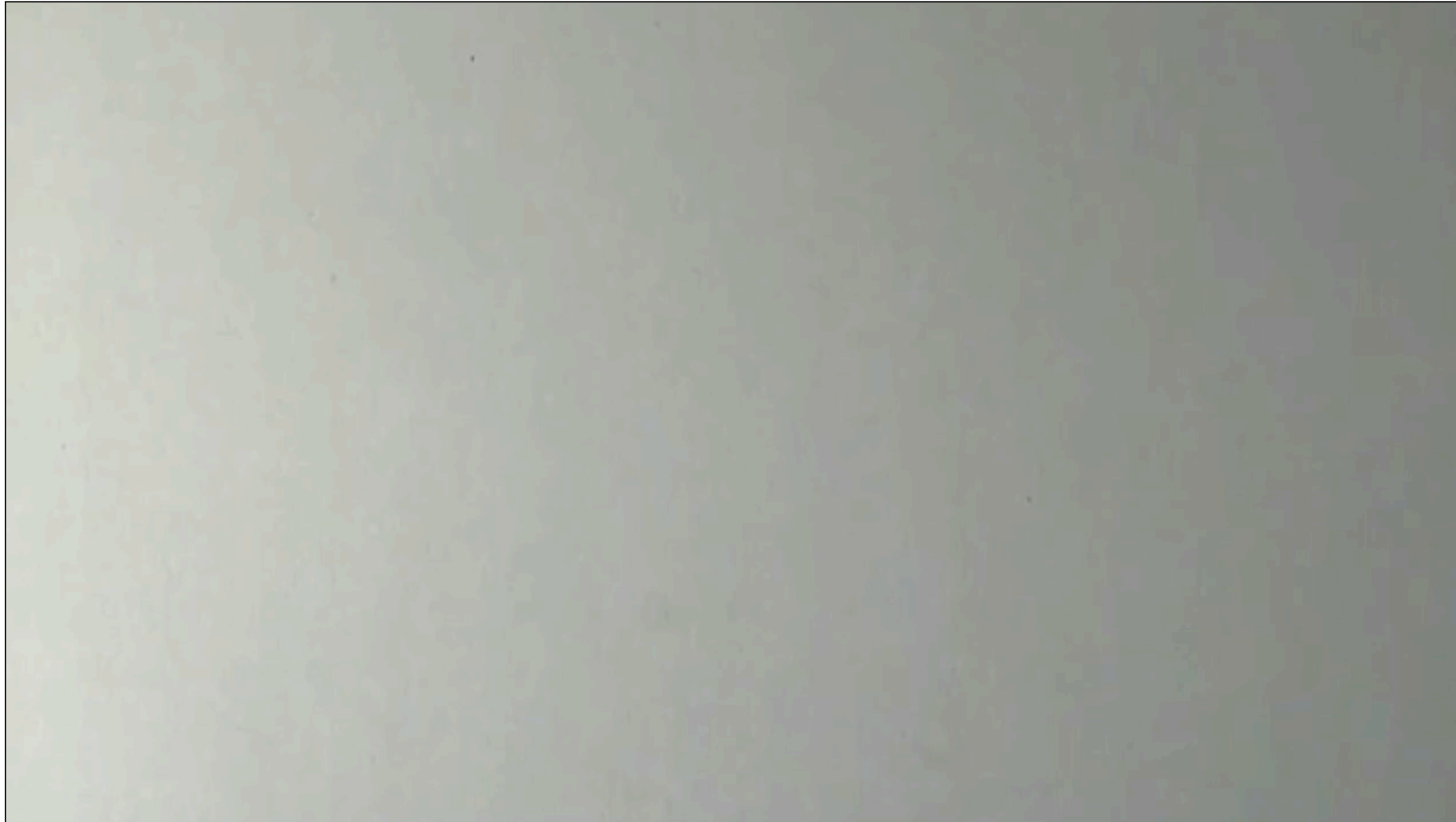


Edit

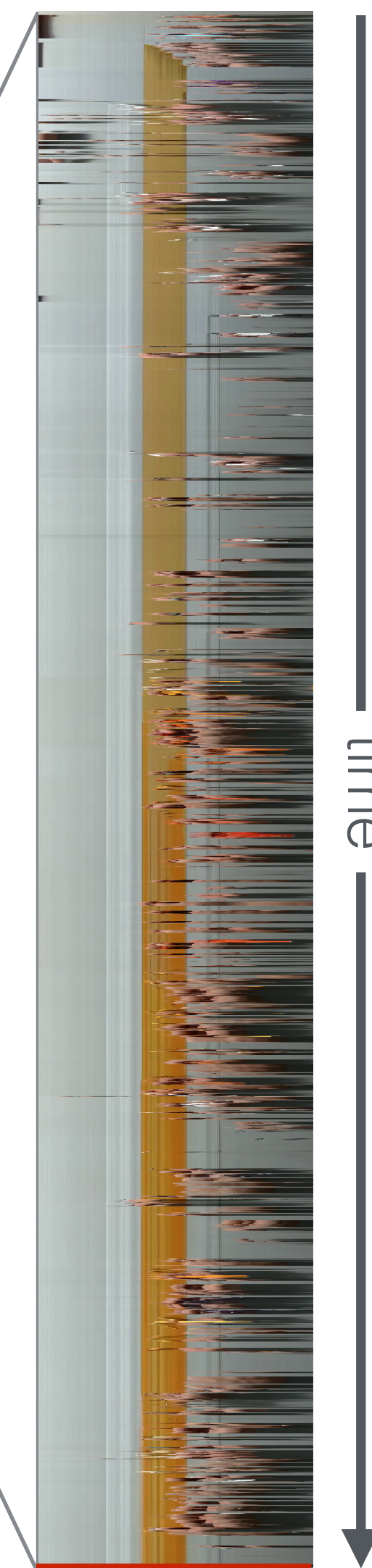
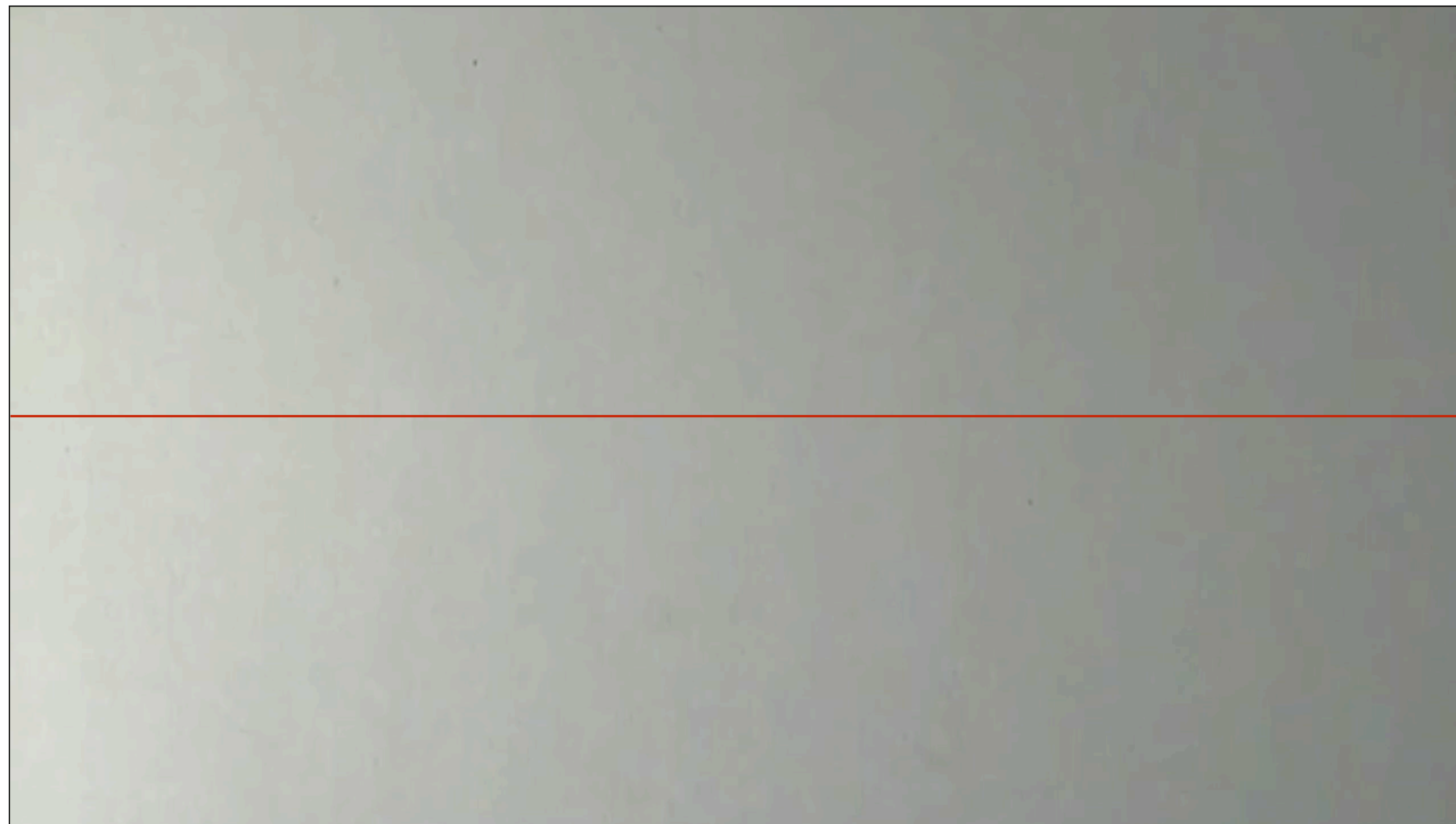
Preprocessing Overview



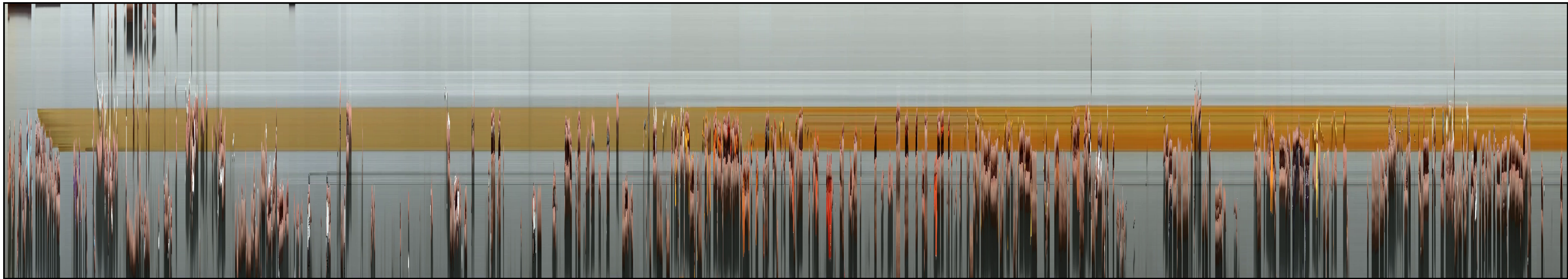
Preprocessing Overview



Preprocessing Overview



Preprocessing Overview

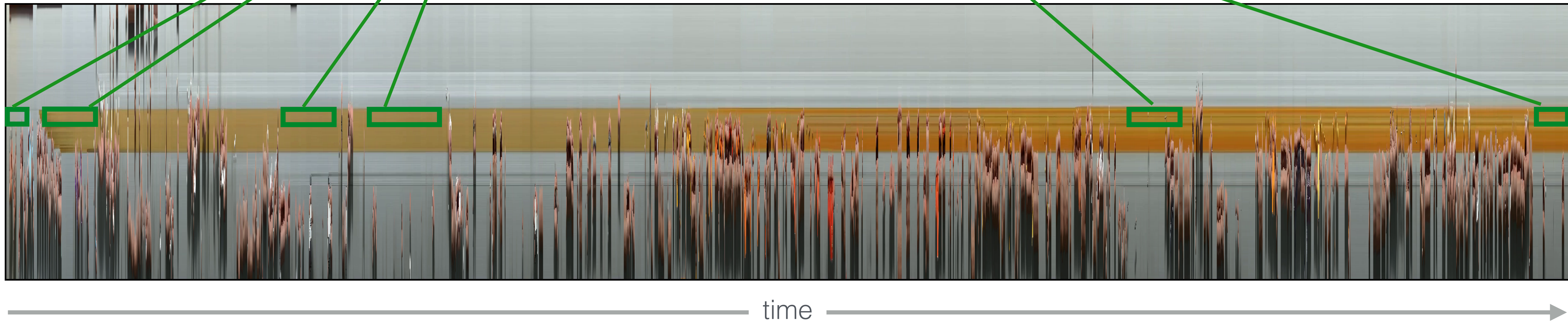


time



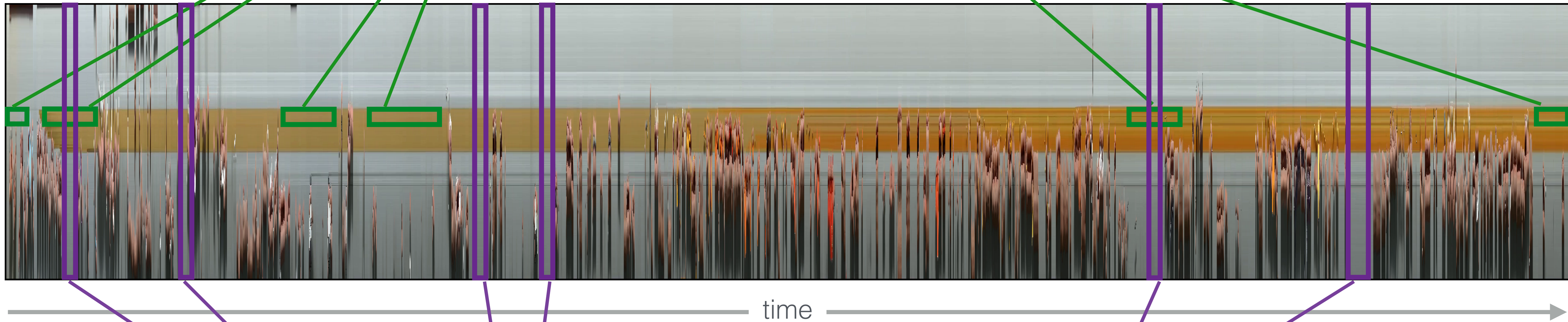
Preprocessing Overview

The value of an unblocked pixel should be piecewise constant in time (**stable**)



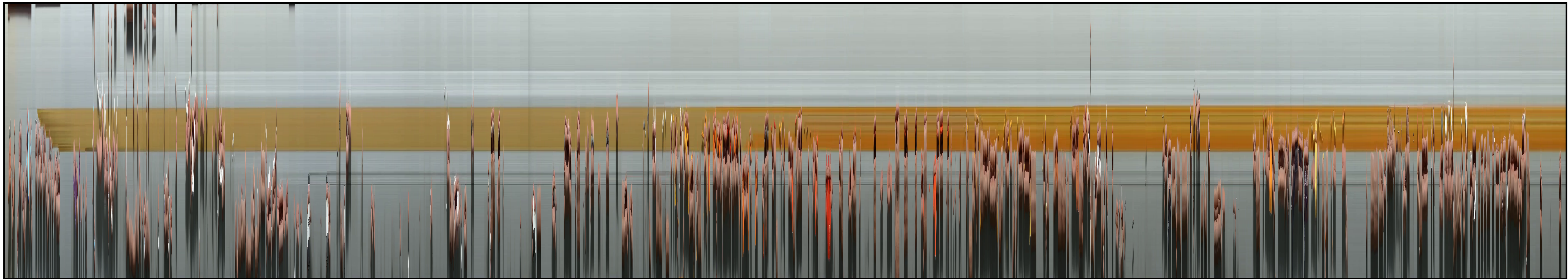
Preprocessing Overview

The value of an unblocked pixel should be piecewise constant in time (**stable**)



Identical sequences of **stable** frames provide checkpoints for the painting progress

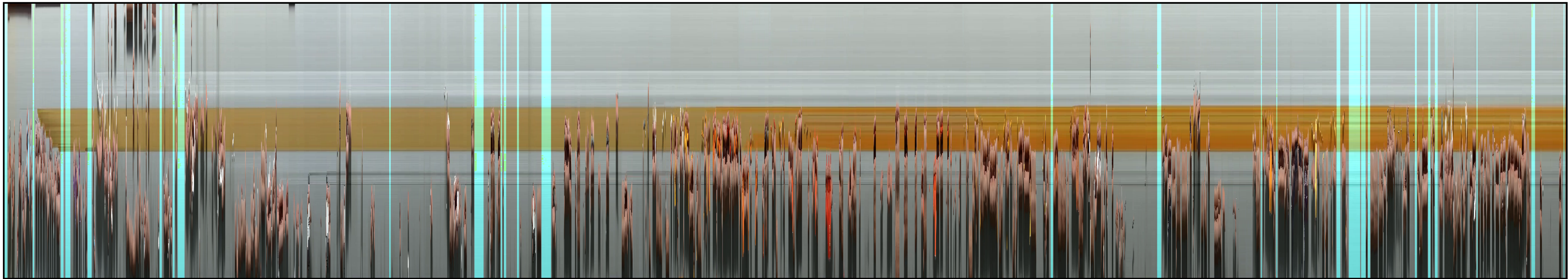
Preprocessing



time

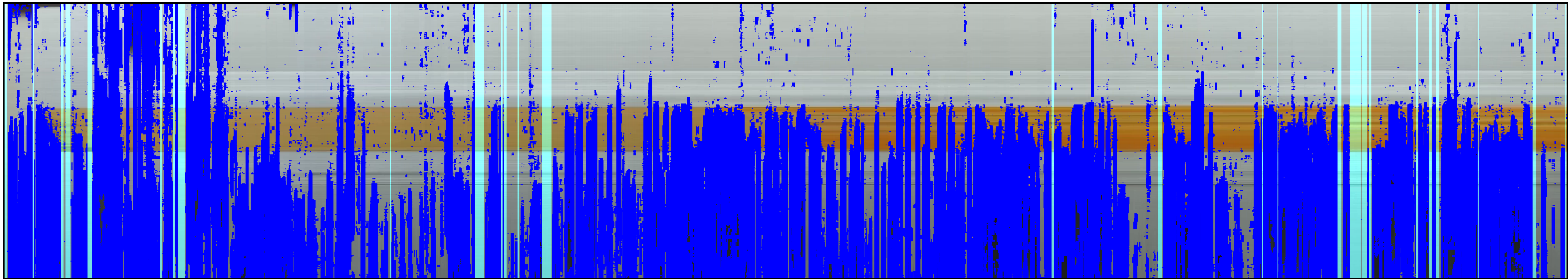


Preprocessing



time

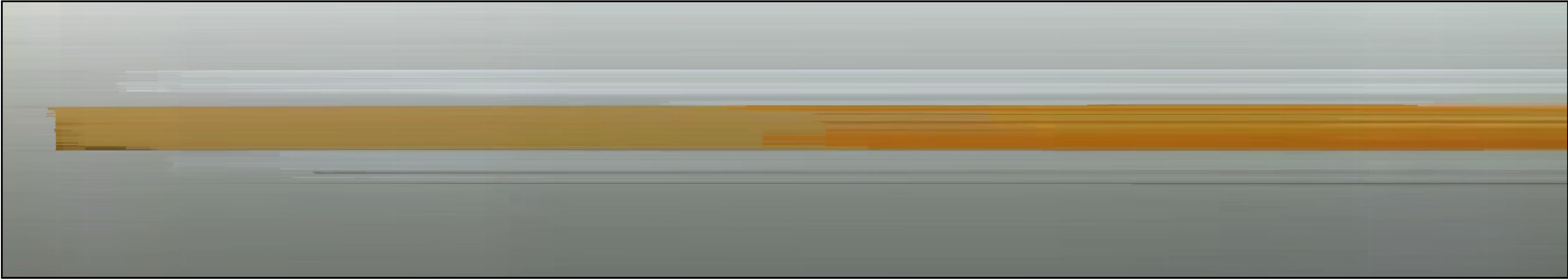
Preprocessing



time



Preprocessing



time



Preprocessing



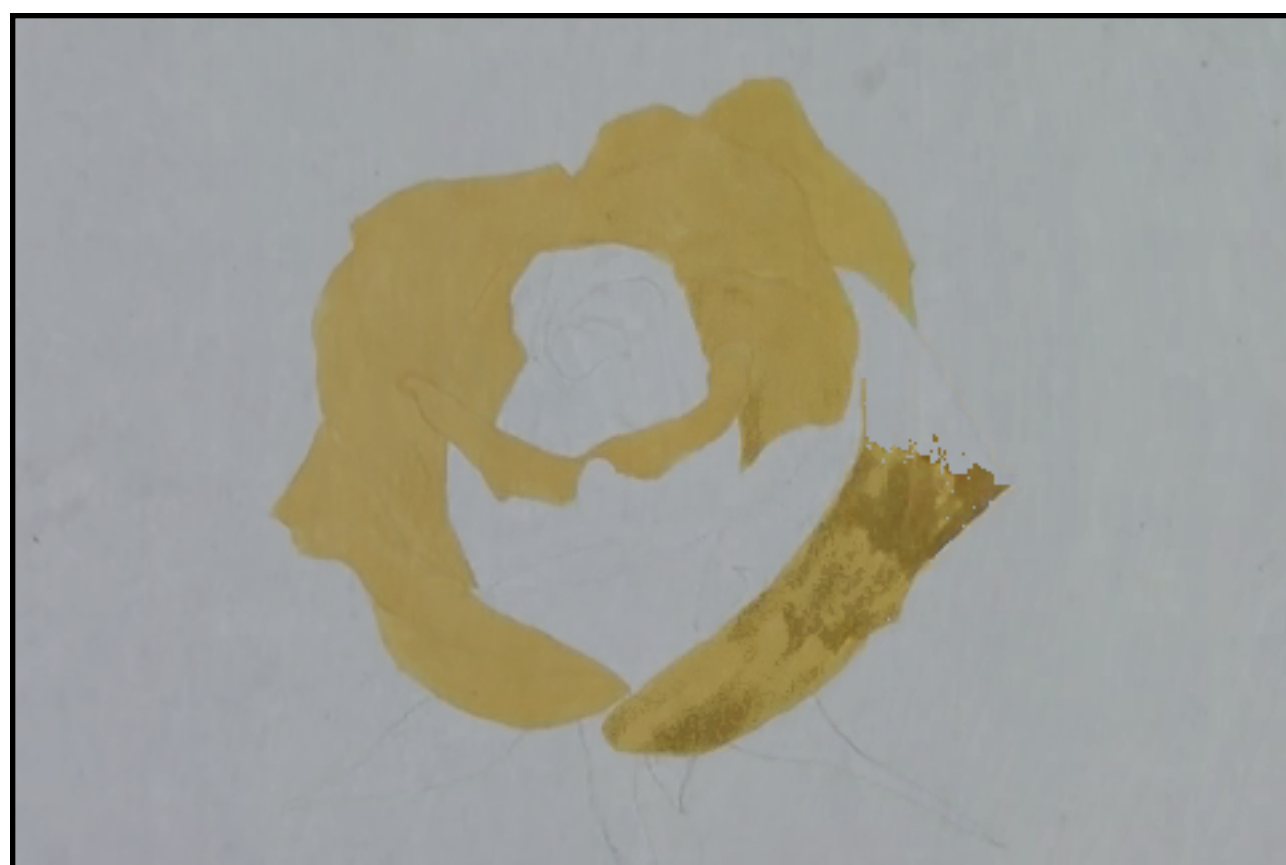
- See paper for:
 - illumination
 - color shift
 - noise removal
 - 1D L_0 smoothing and bilateral filtering

Preprocessing



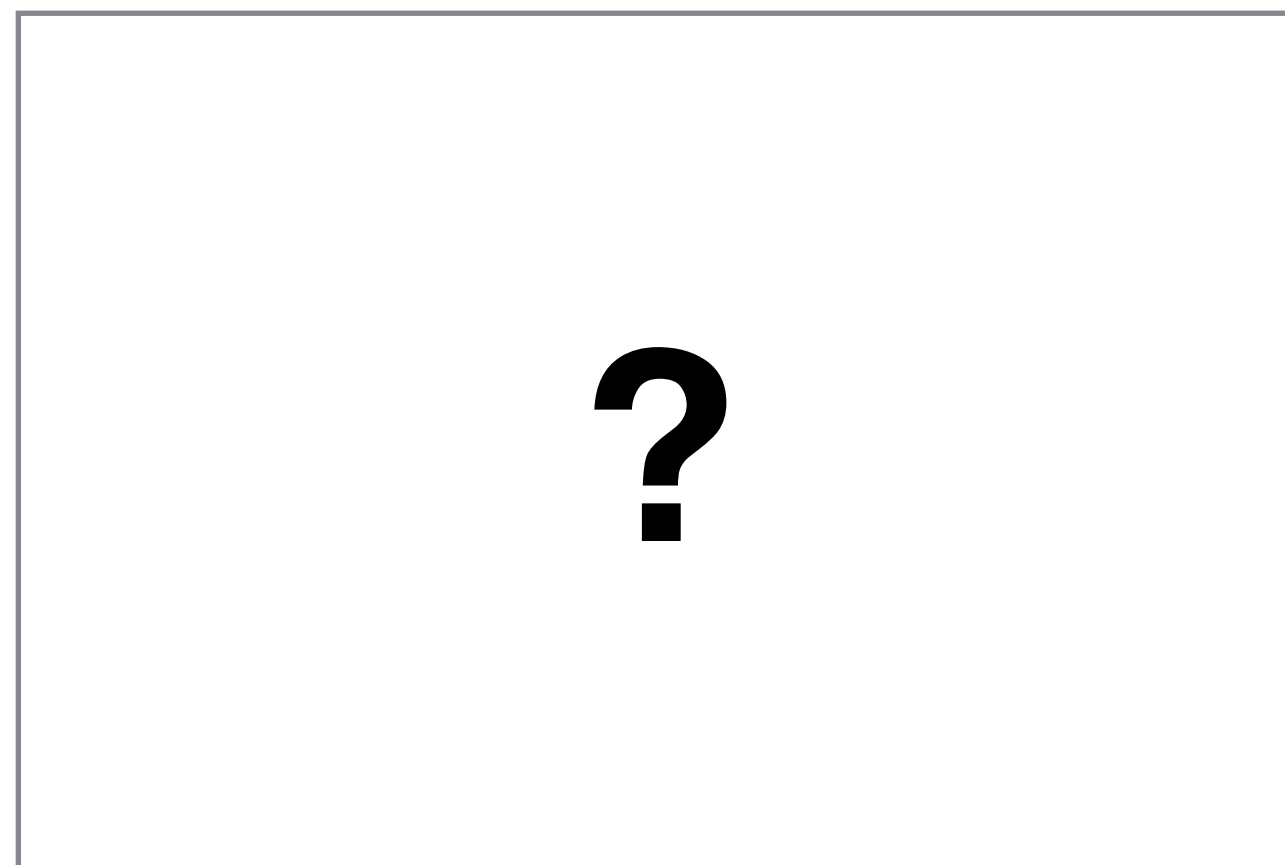
- See paper for:
 - illumination
 - color shift
 - noise removal
 - 1D L_0 smoothing and bilateral filtering

Recovering Layers

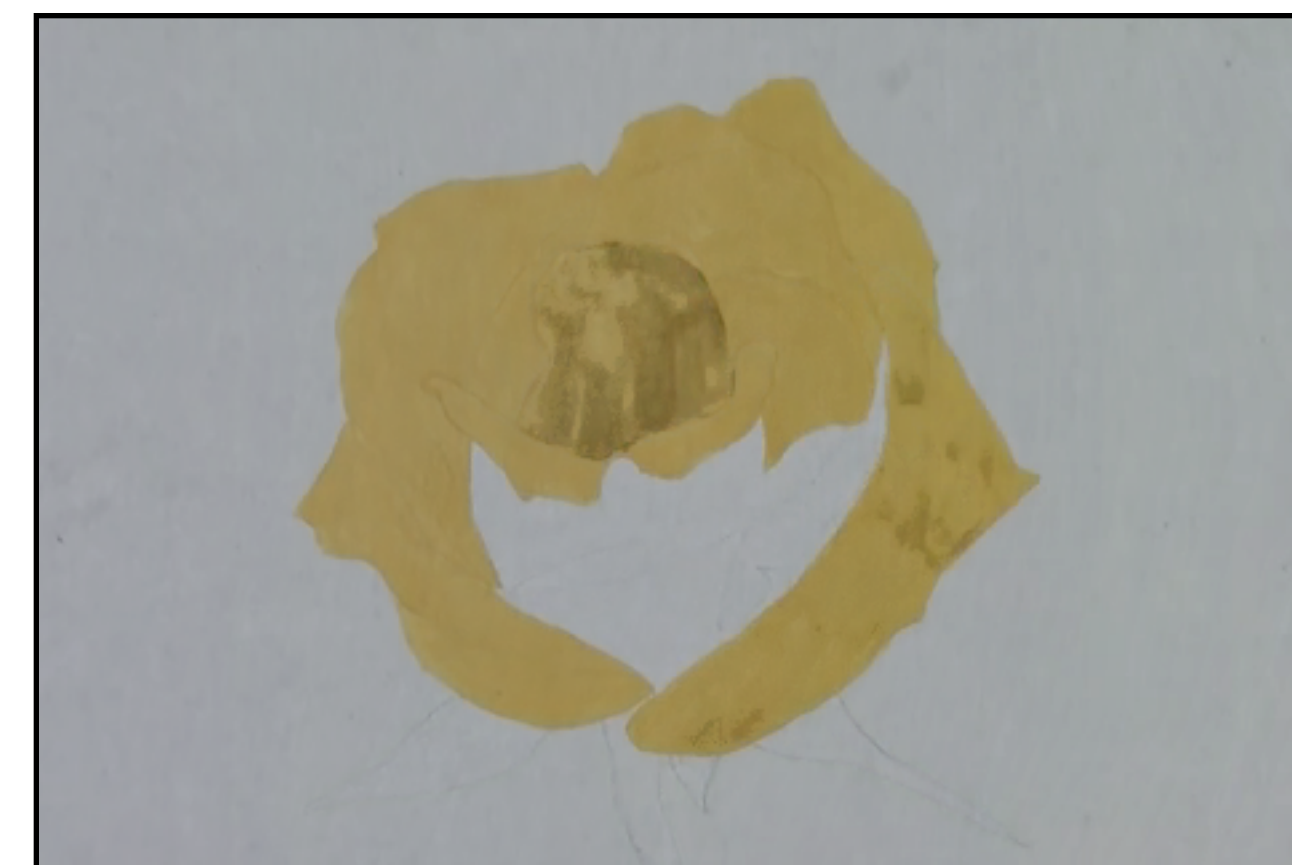


before

+

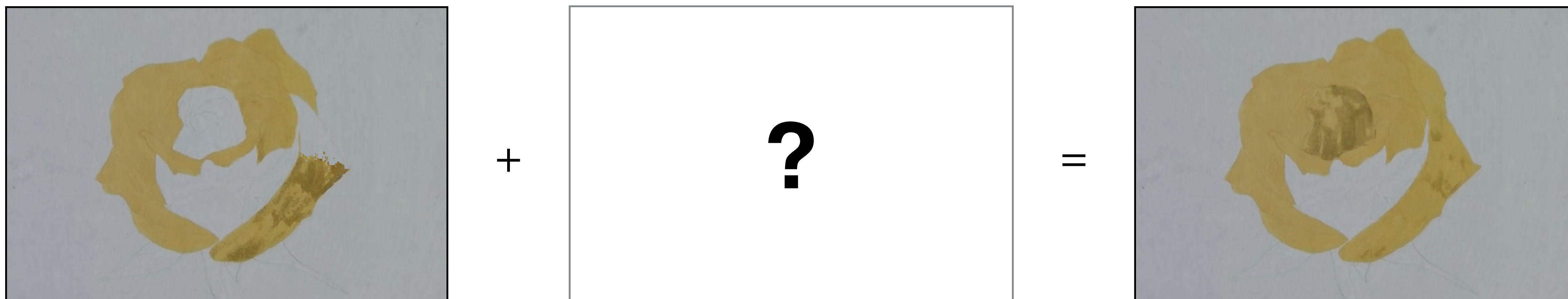


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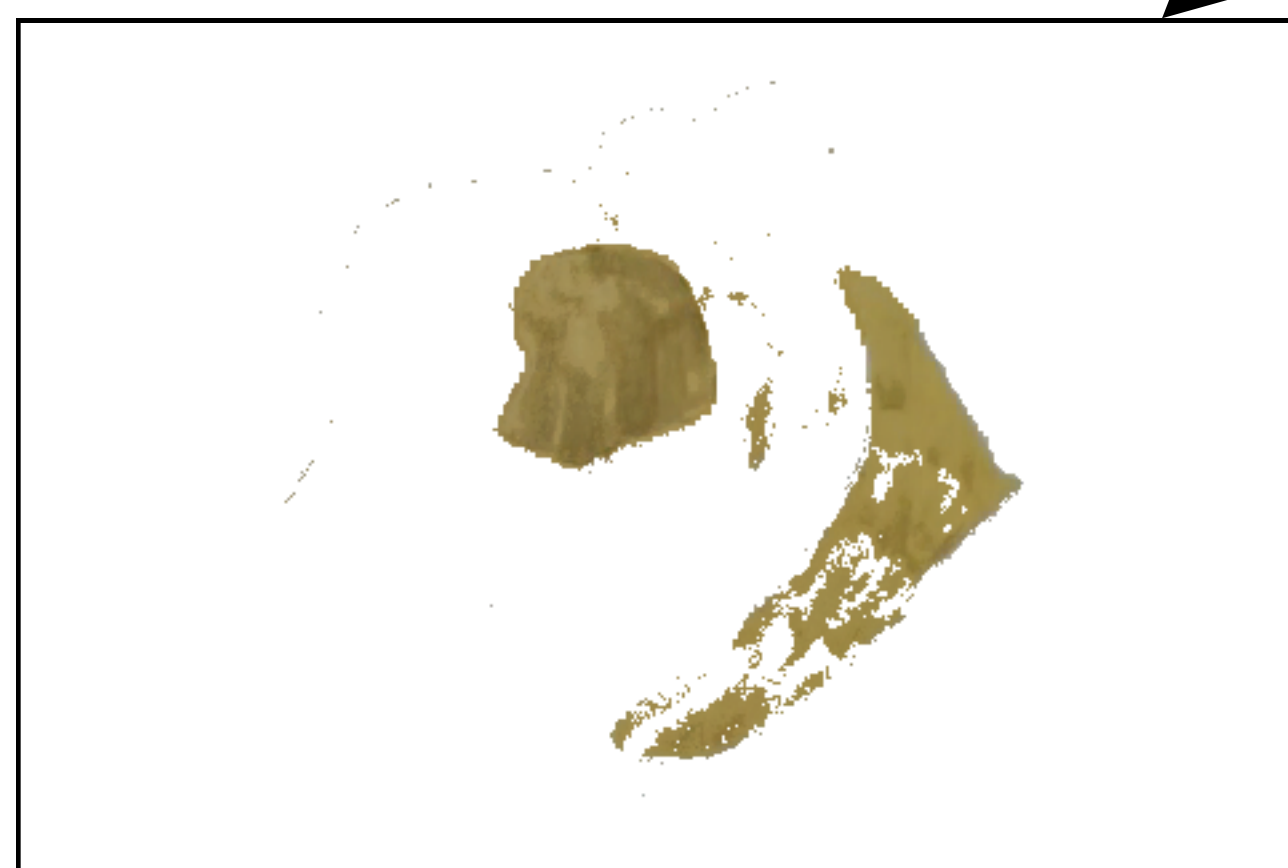
after

Recovering Layers



before

after



opaque solution



our solution

Recovering Layers

Recovering Layers

Model

Porter-Duff (1983)

Kubelka-Munk (1931)

Recovering Layers

Model

Porter-Duff (1983)

Kubelka-Munk (1931)

The standard for:

digital compositing

physical compositing

Recovering Layers

Model

Porter-Duff (1983)

Kubelka-Munk (1931)

The standard for:

digital compositing

physical compositing

Compositing operation:

Linear

Non-linear

Recovering Layers

Model

Porter-Duff (1983)

Kubelka-Munk (1931)

The standard for:

digital compositing

physical compositing

Compositing operation:

Linear

Non-linear

Used in graphics:

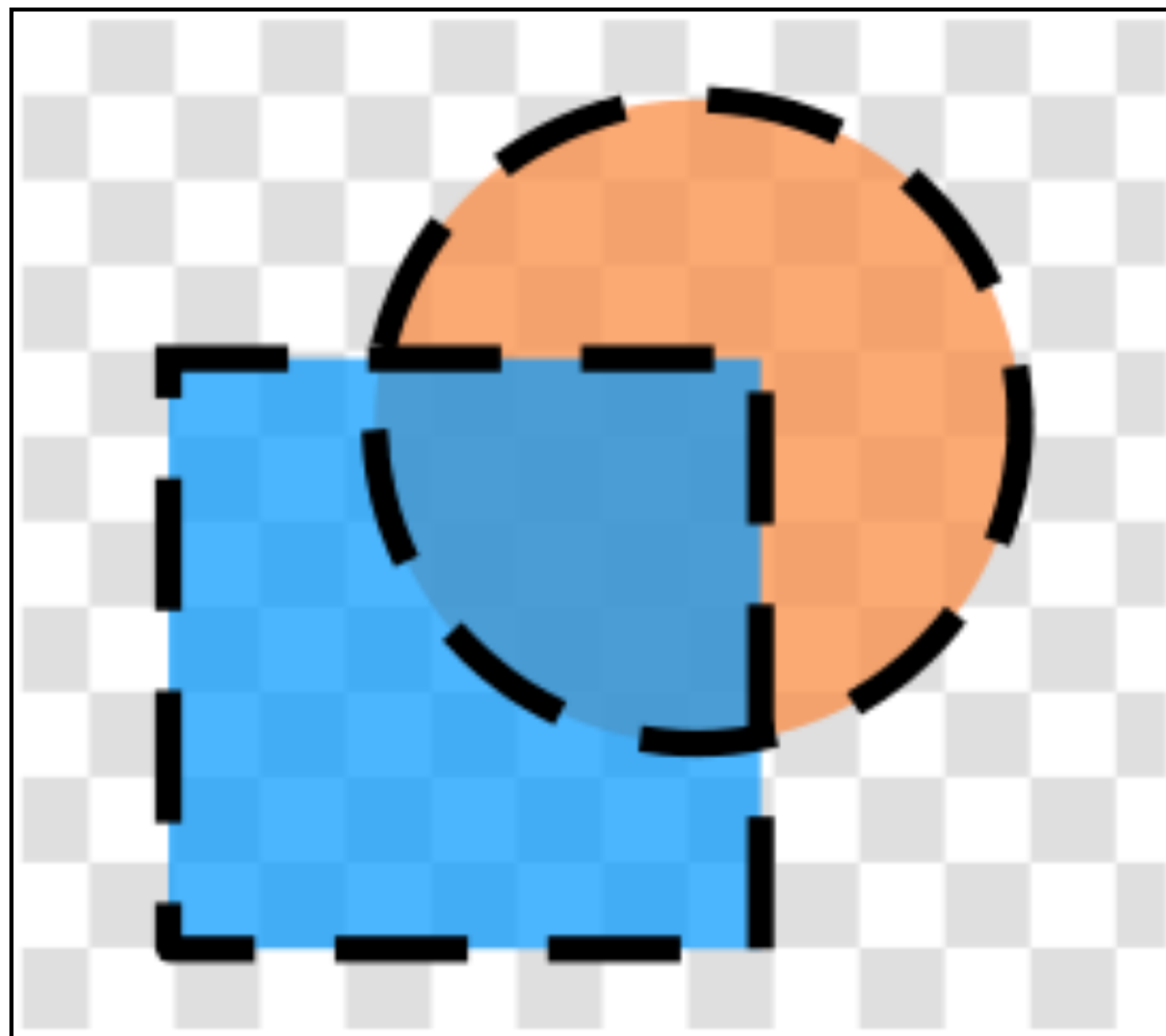
Almost everywhere

Occasionally
Lu et al. [2014], ...

Porter-Duff Model

- “Over” operator:

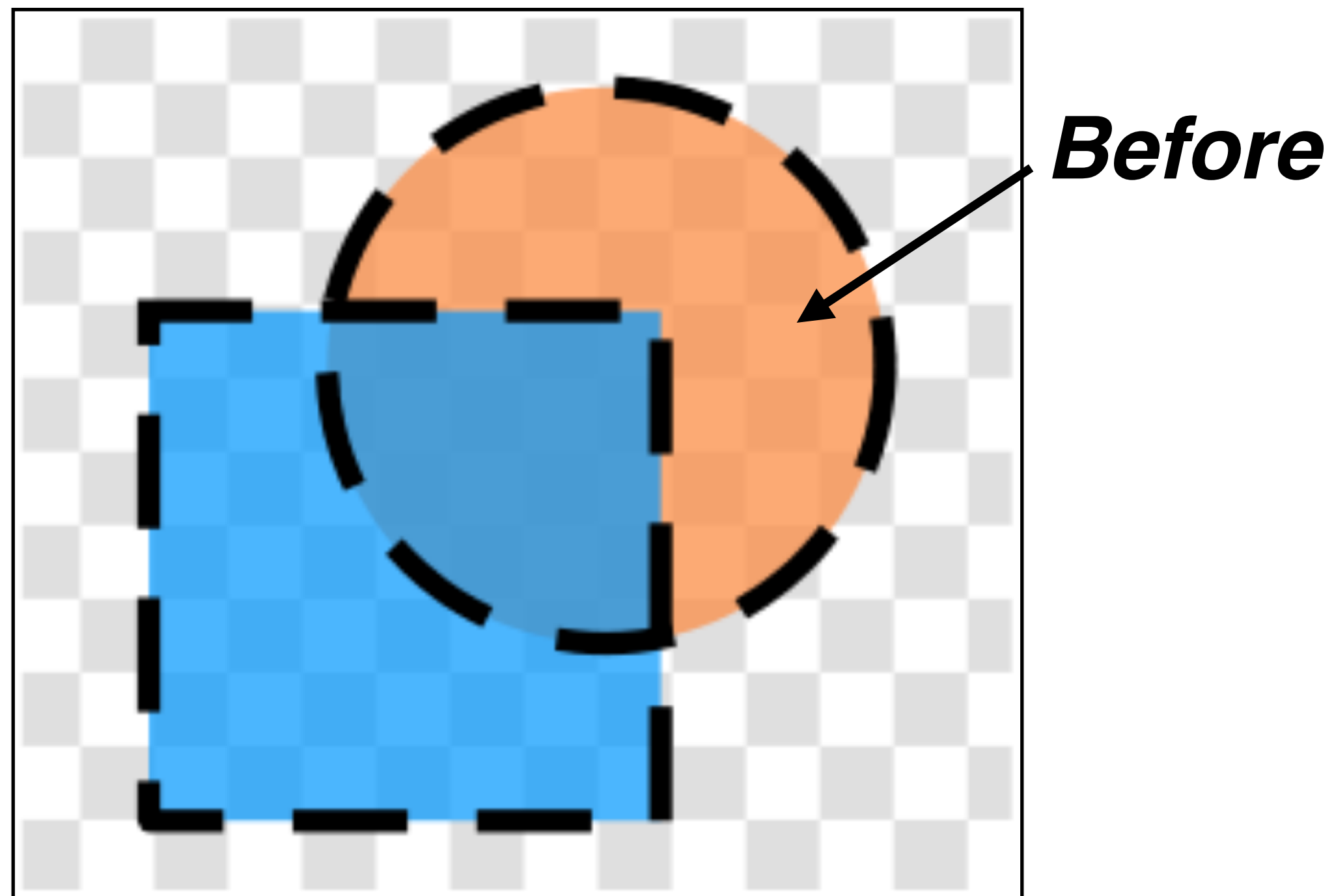
$$After = Before \cdot (1 - \alpha) + Paint \cdot \alpha$$



Porter-Duff Model

- “Over” operator:

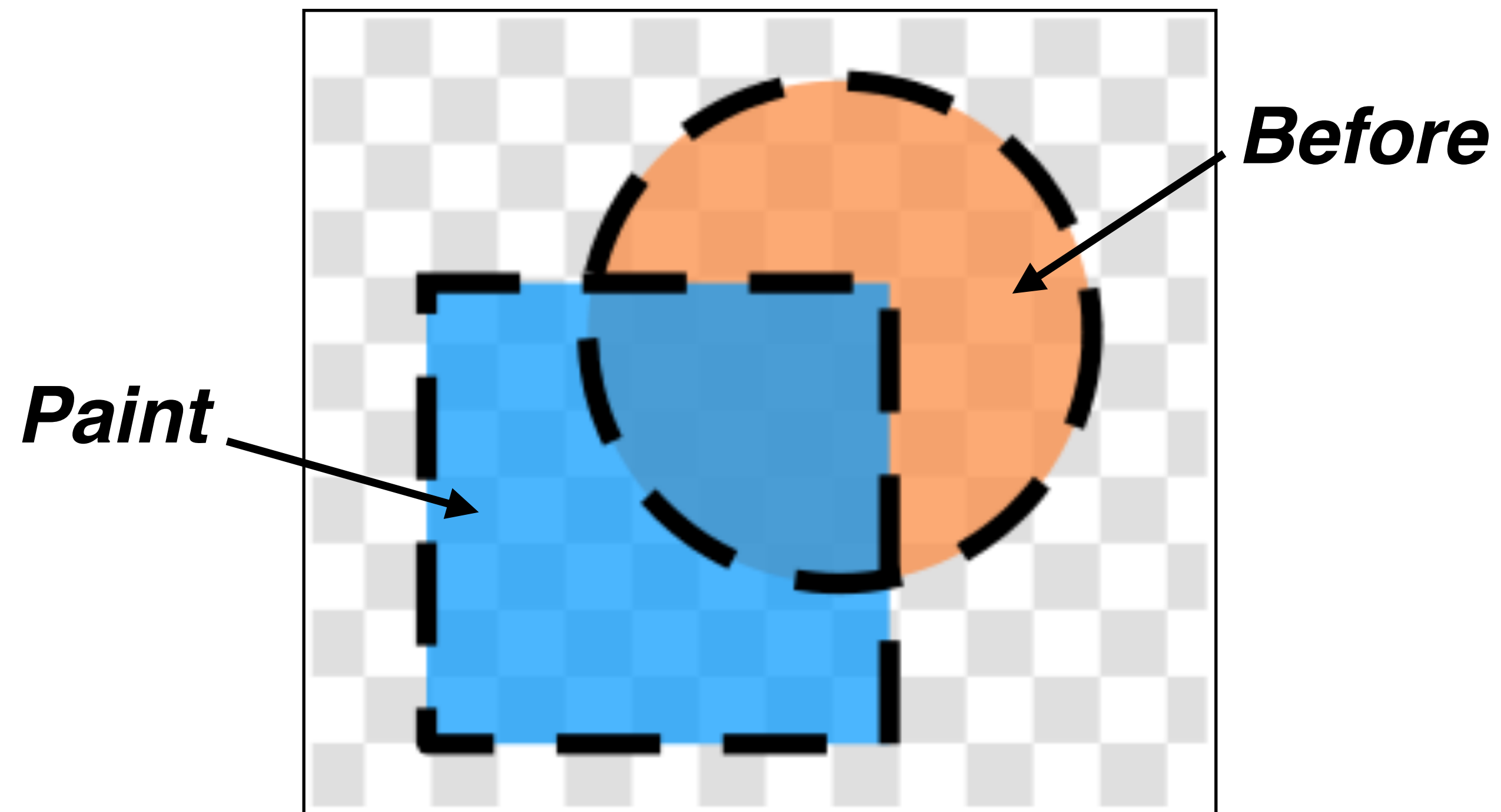
$$After = Before \cdot (1 - \alpha) + Paint \cdot \alpha$$



Porter-Duff Model

- “Over” operator:

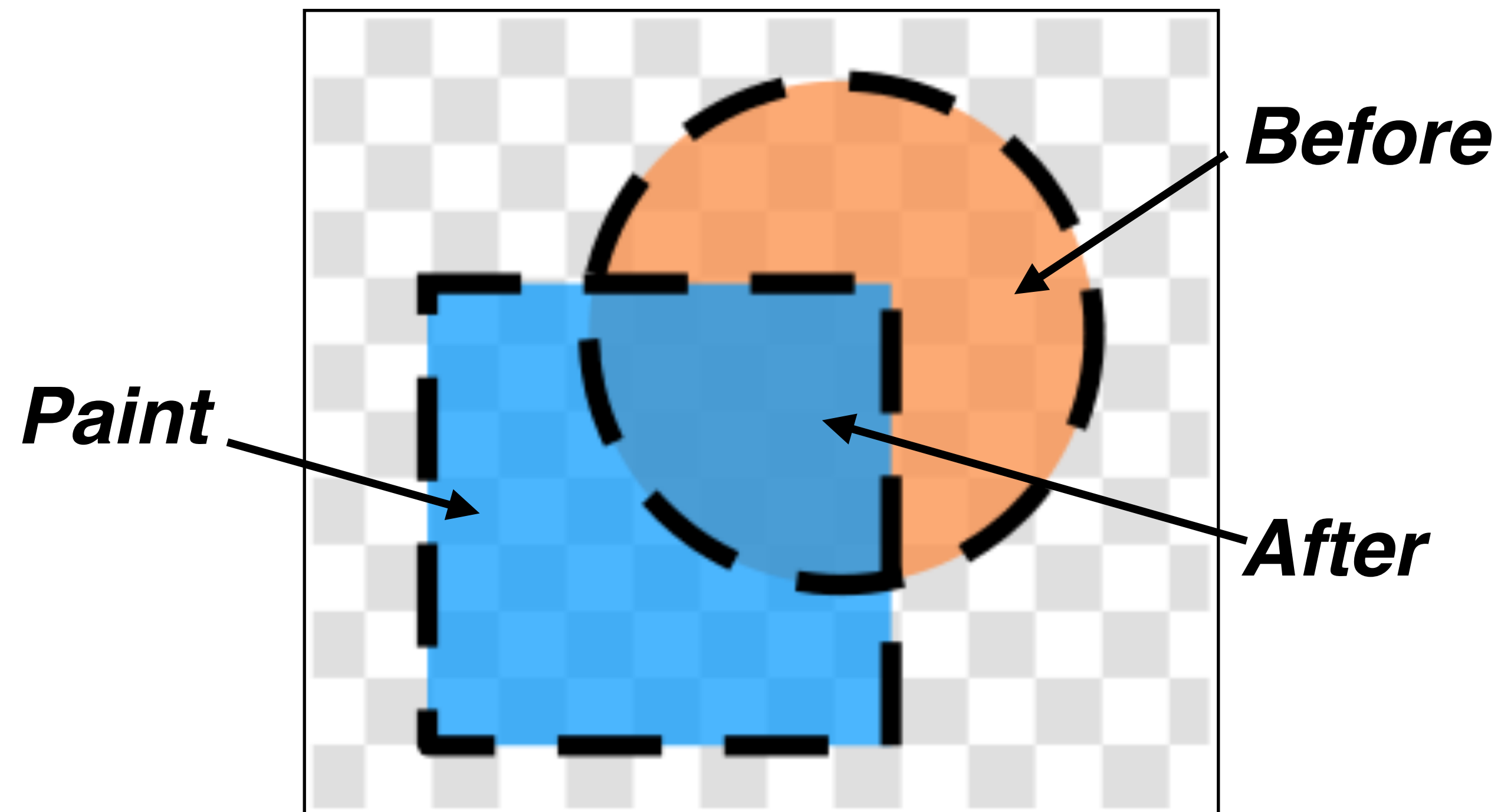
$$After = Before \cdot (1 - \alpha) + Paint \cdot \alpha$$



Porter-Duff Model

- “Over” operator:

$$After = Before \cdot (1 - \alpha) + Paint \cdot \alpha$$

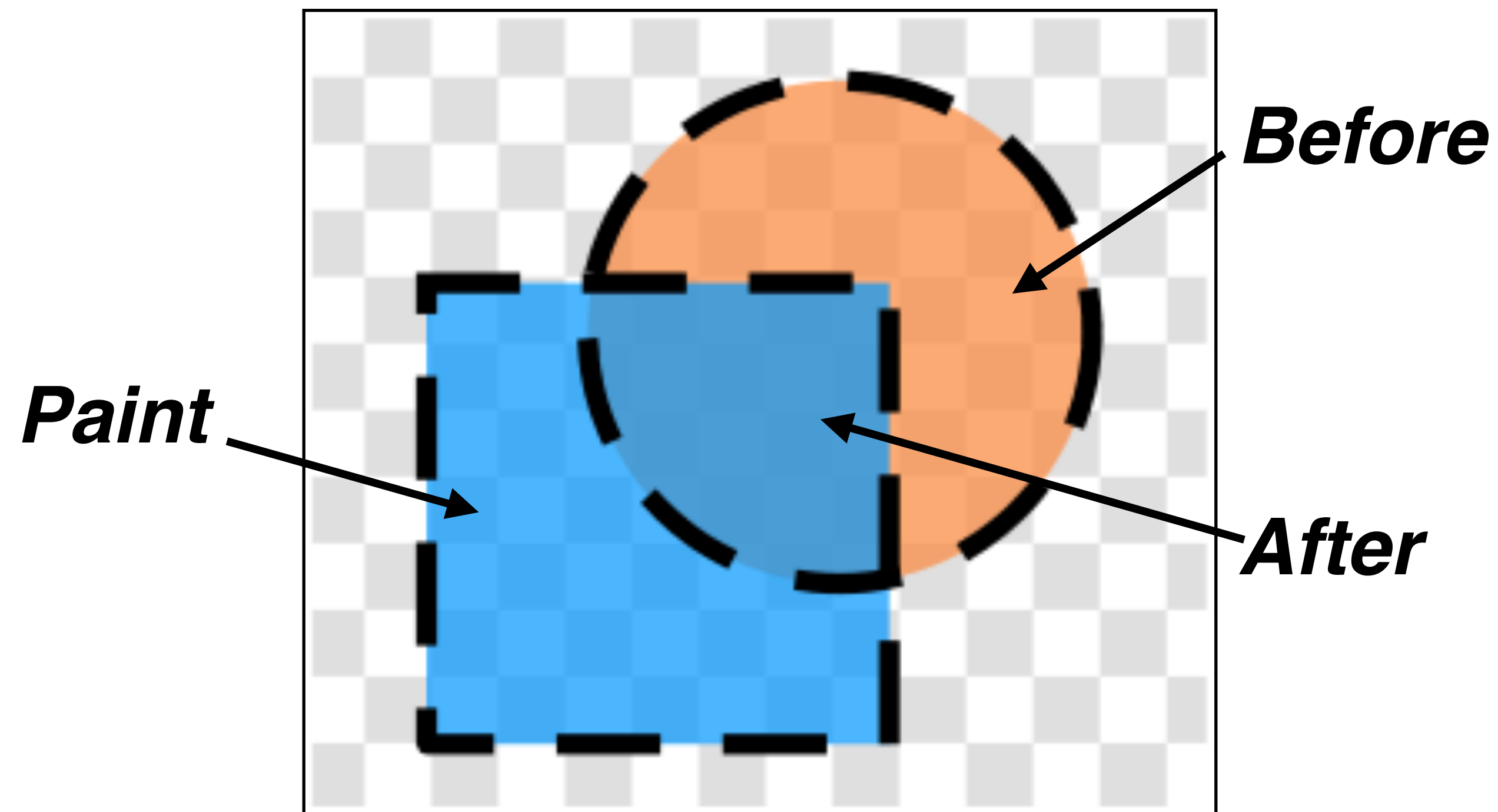


Porter-Duff Model

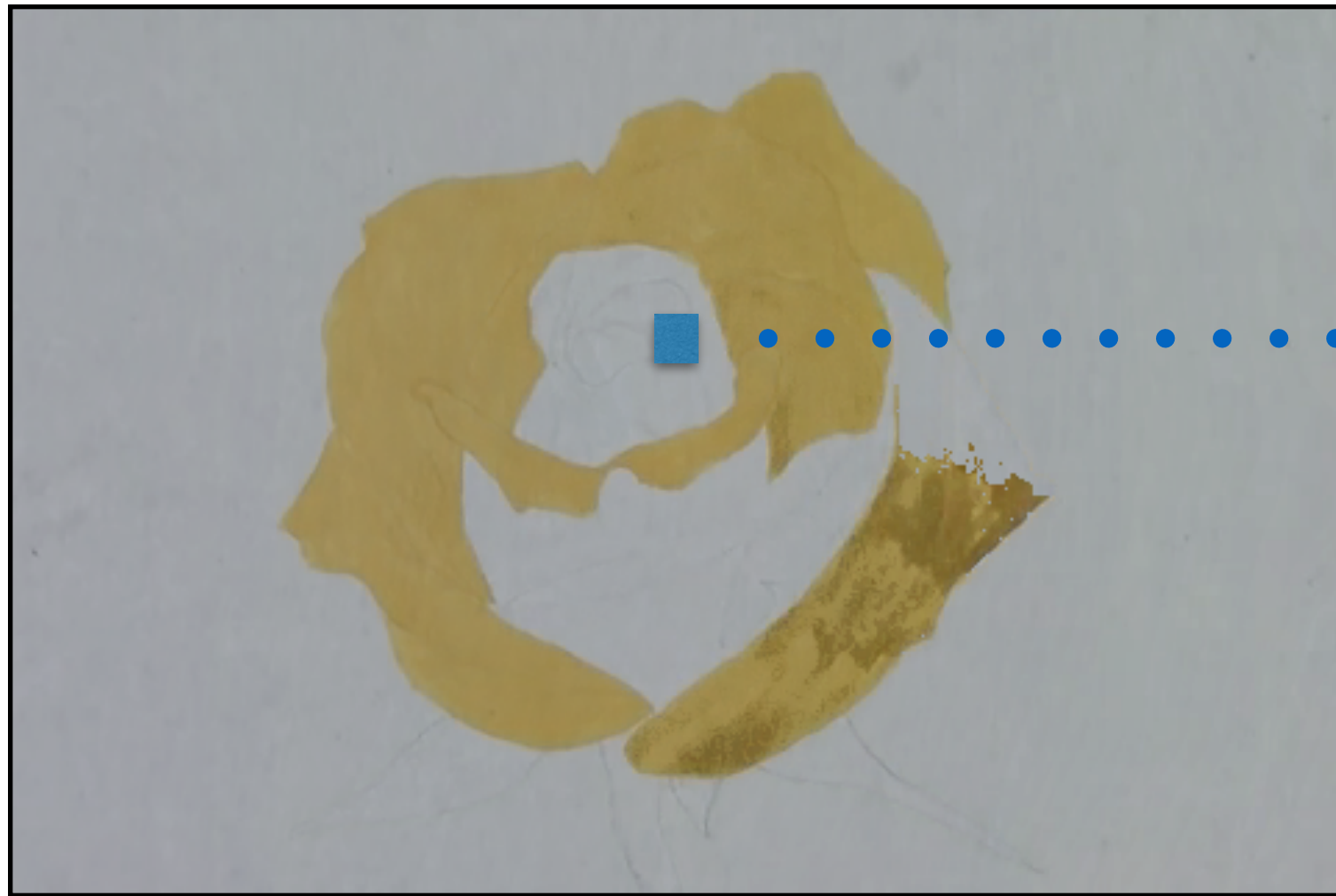
- “Over” operator:

$$After = Before \cdot (1 - \alpha) + Paint \cdot \alpha$$

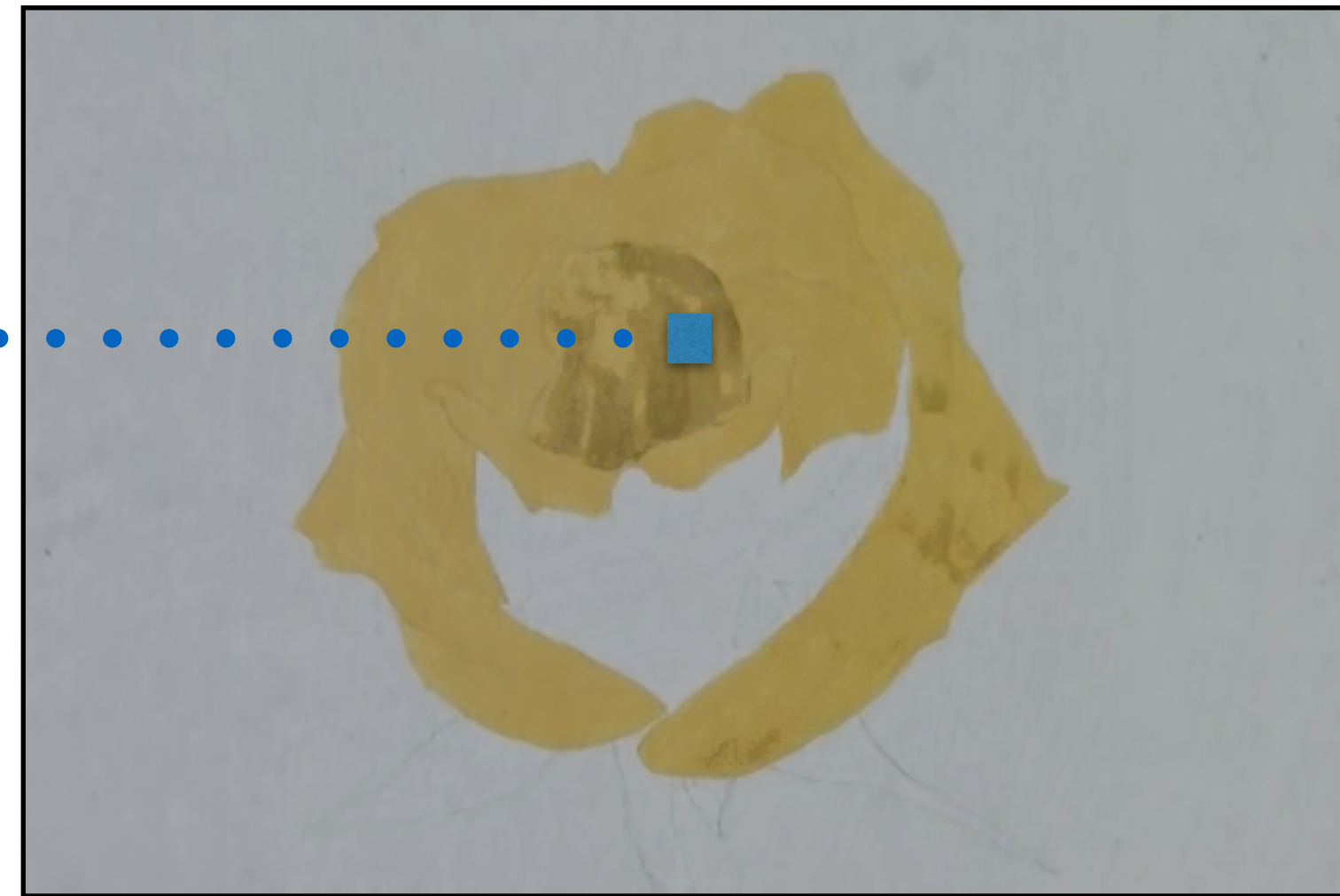
unknown



Porter-Duff Model

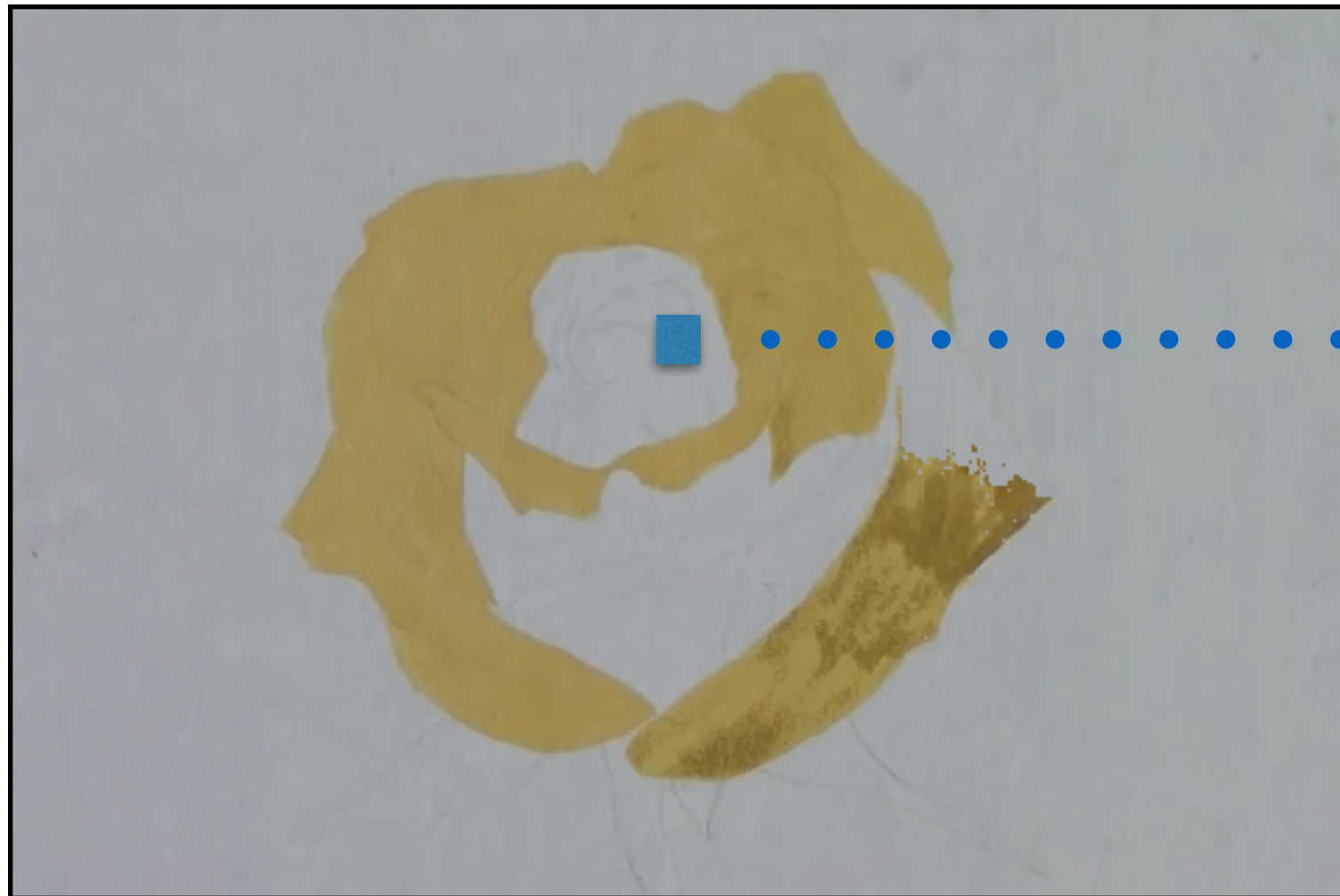


before

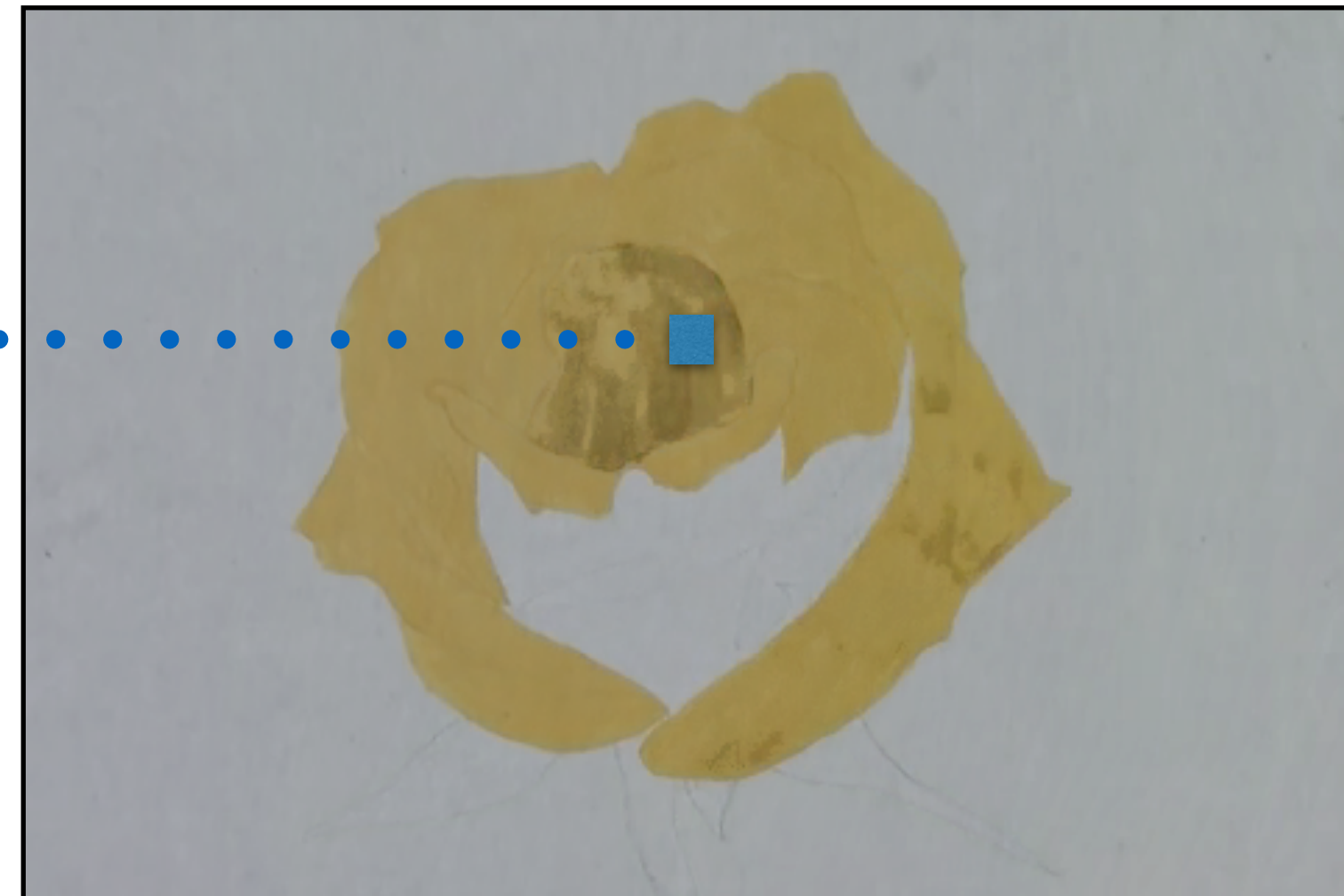


after

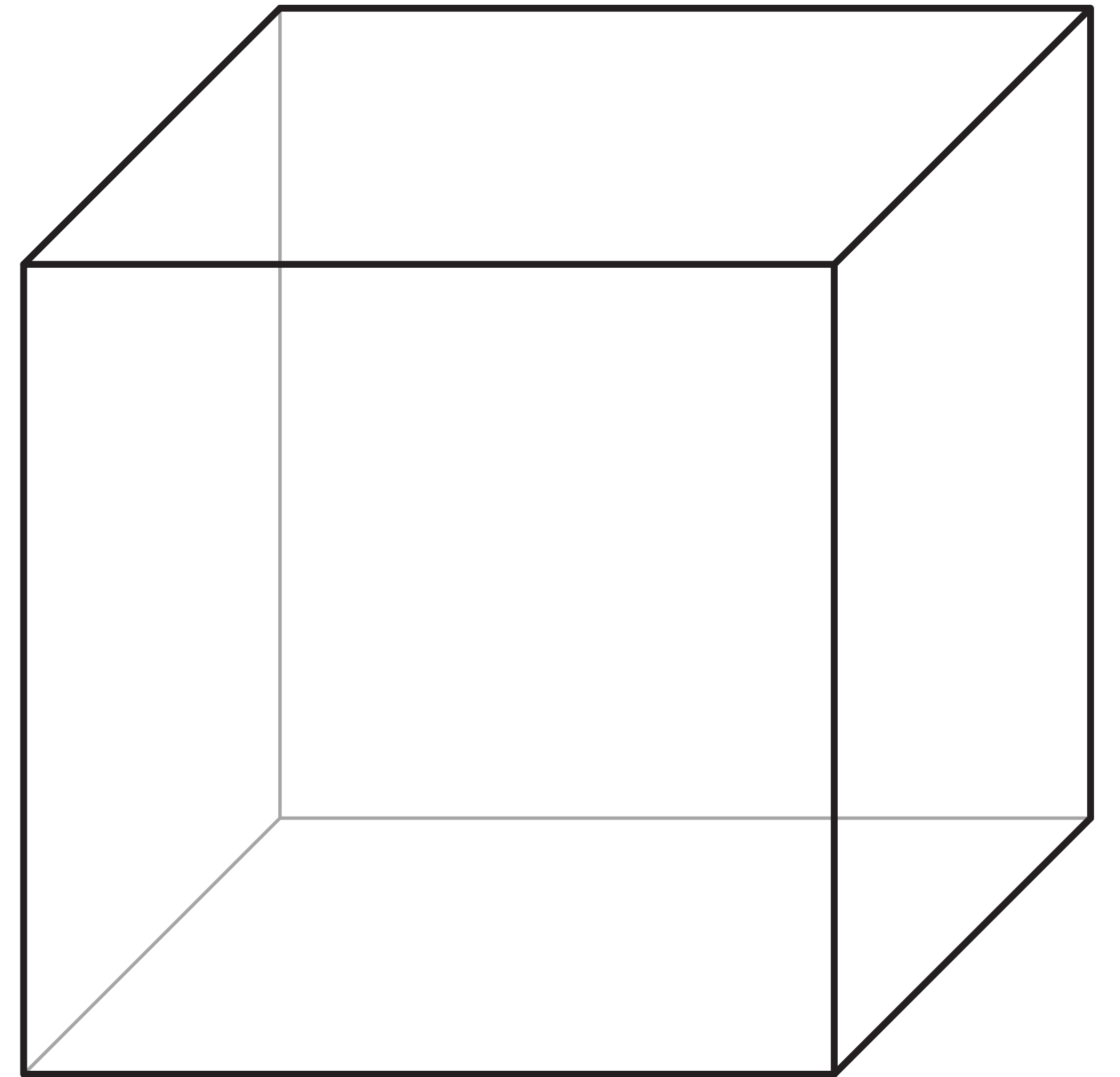
Porter-Duff Model



before

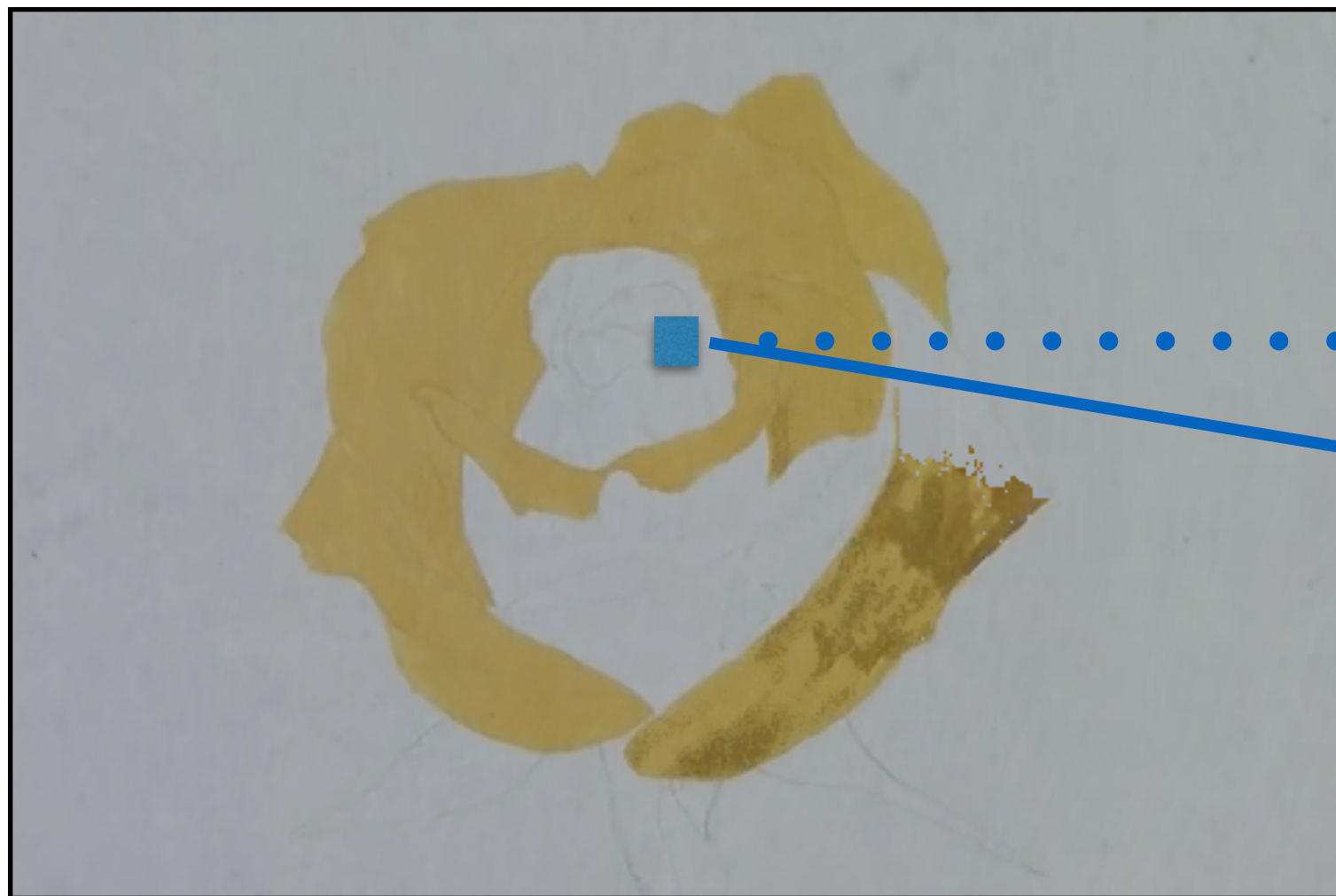


after

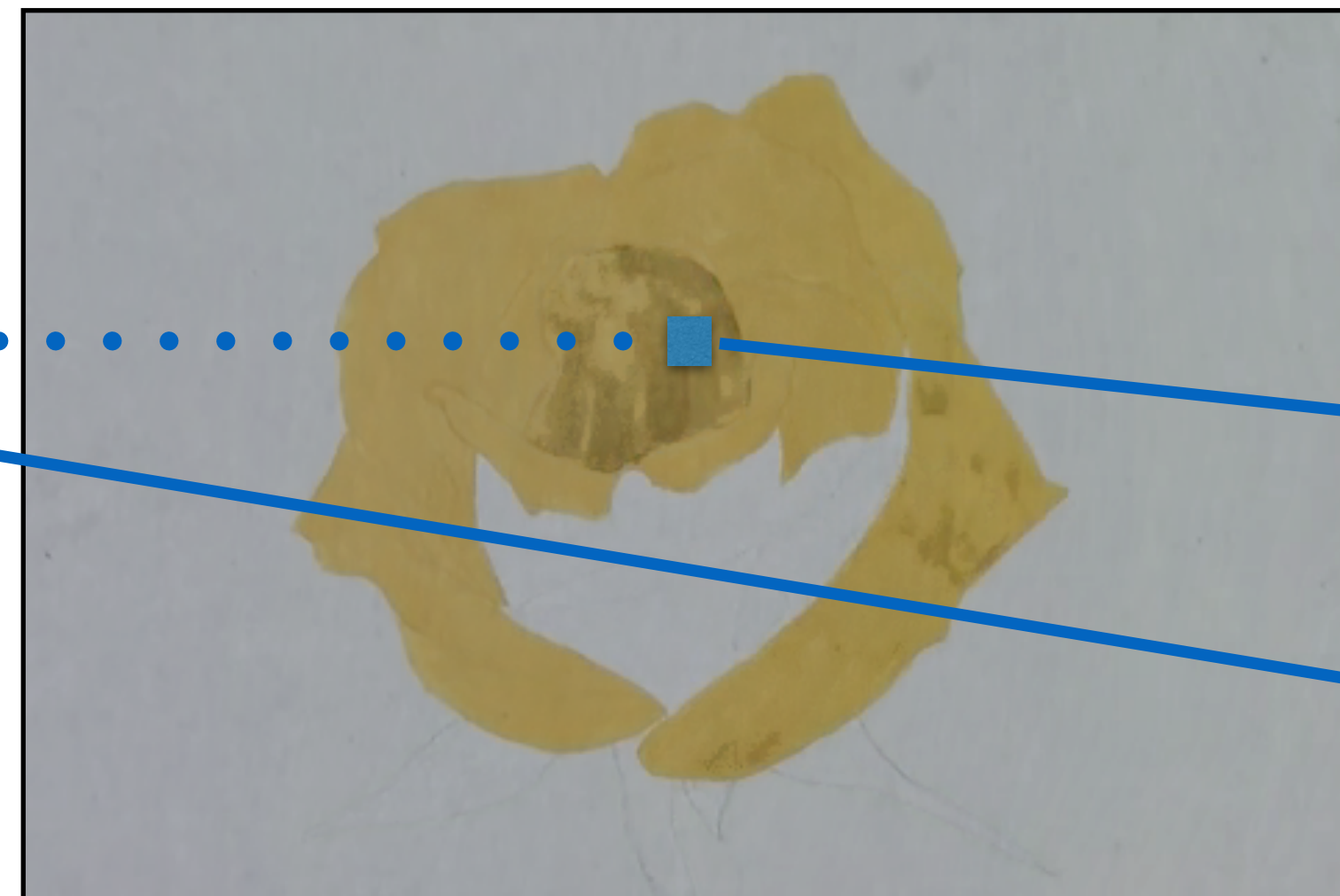


RGB Color Space

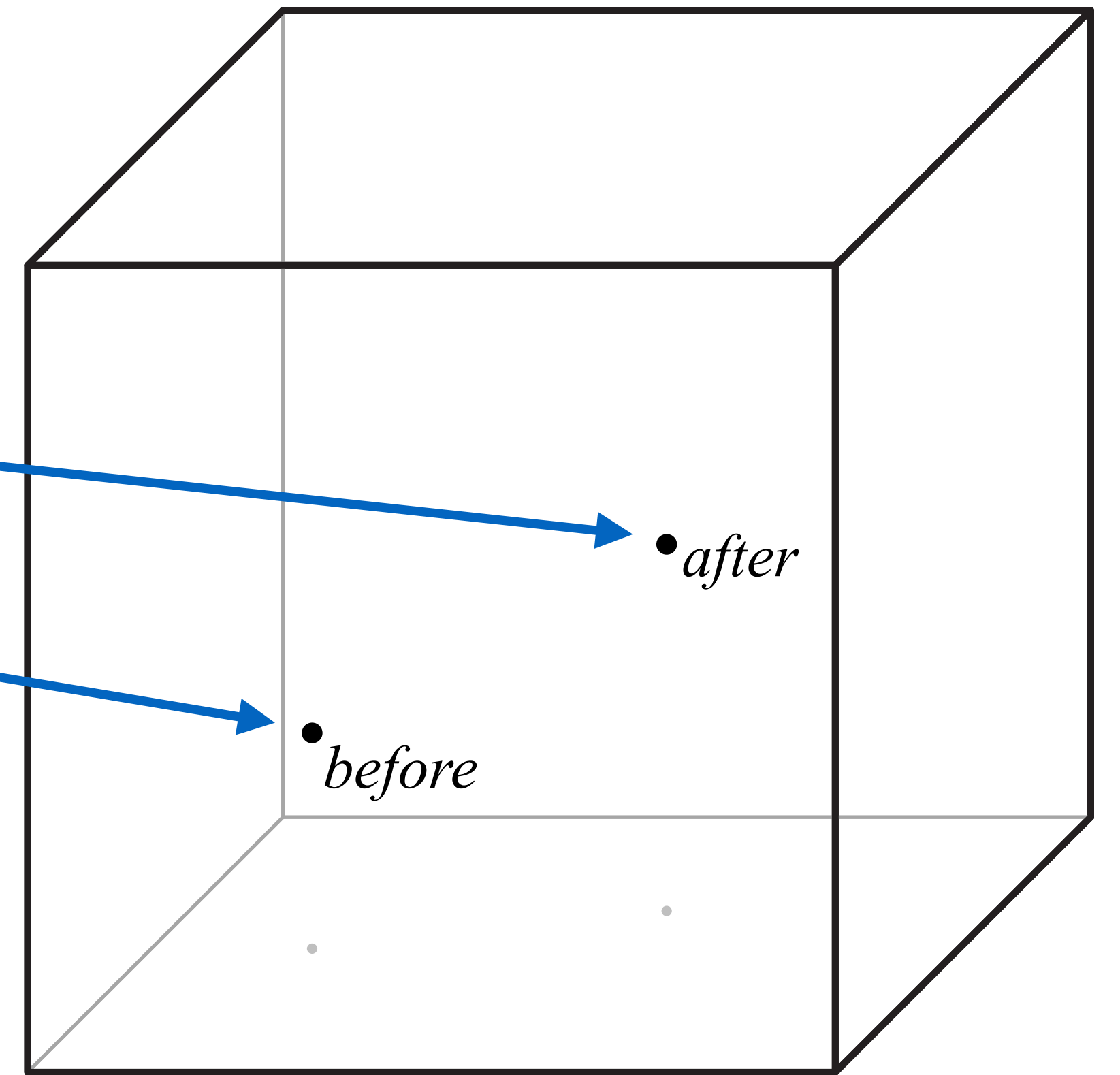
Porter-Duff Model



before

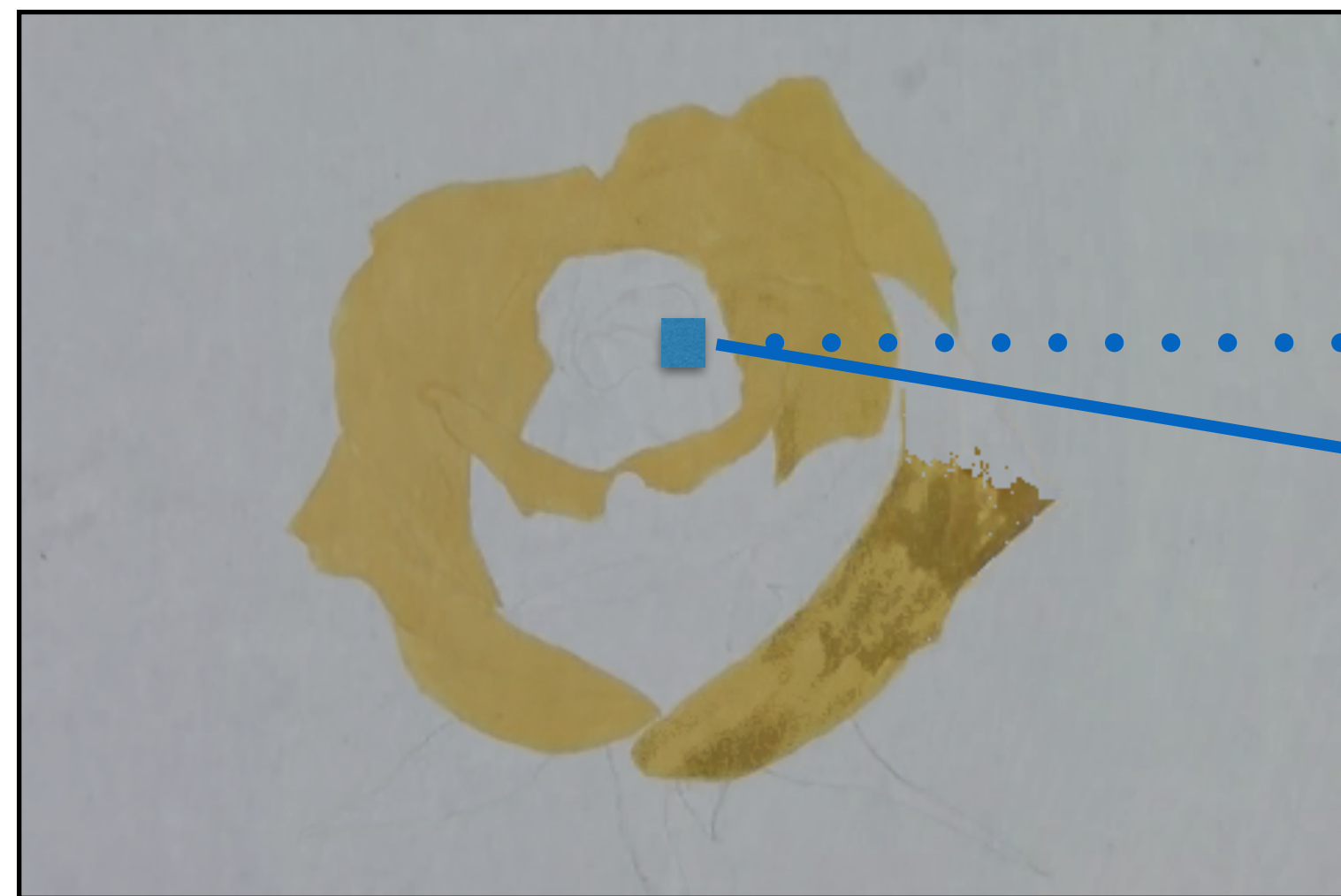


after

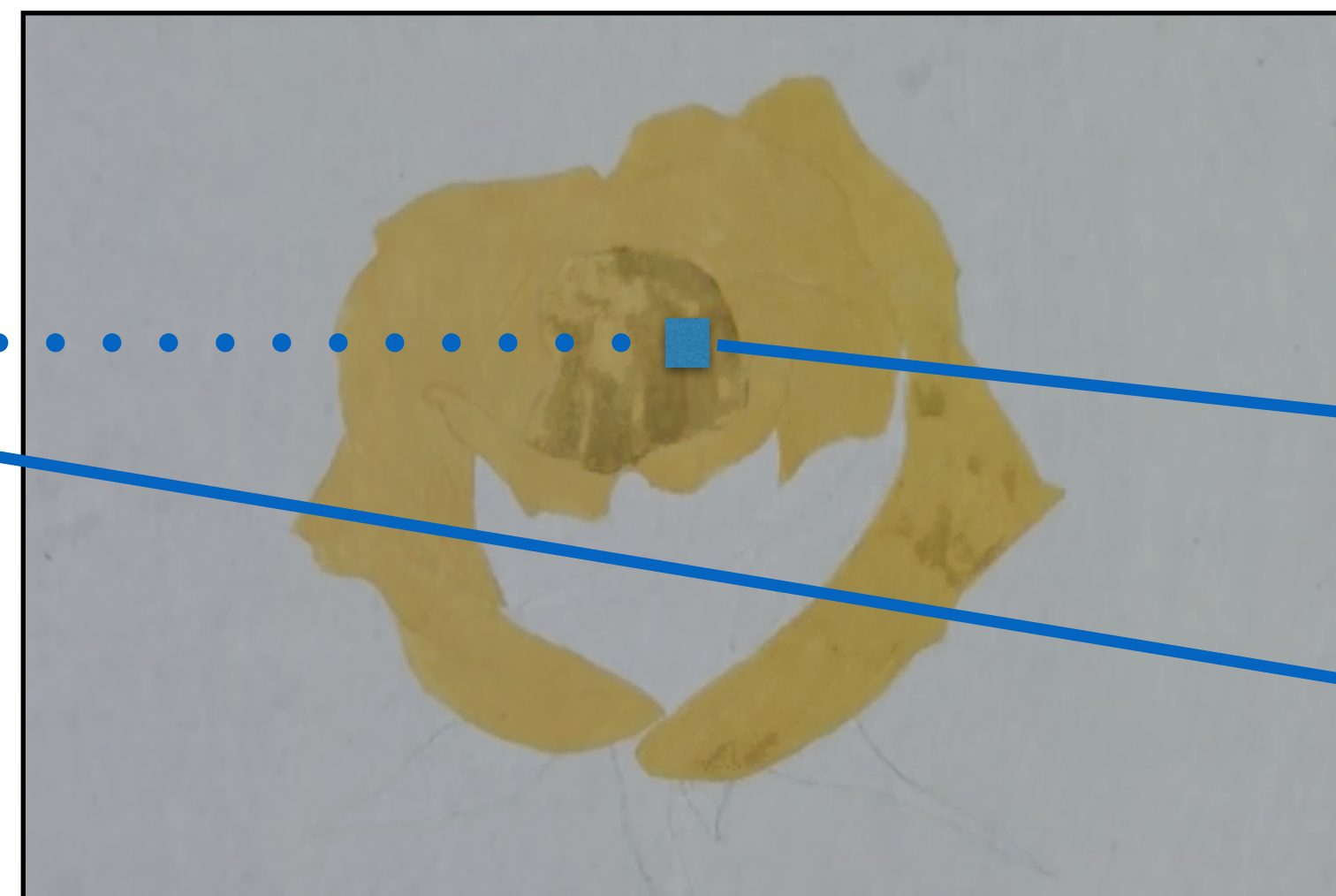


RGB Color Space

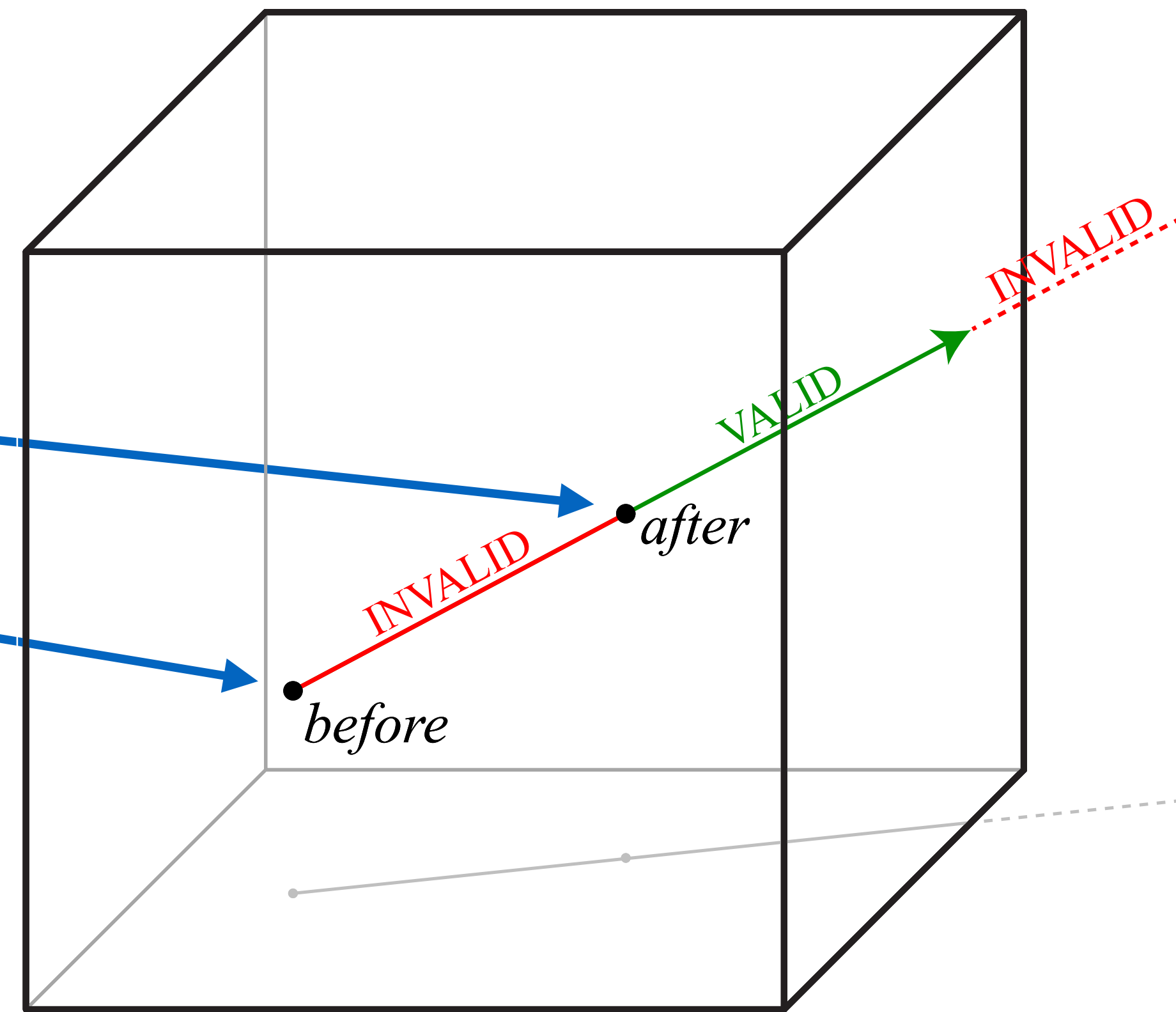
Porter-Duff Model



before

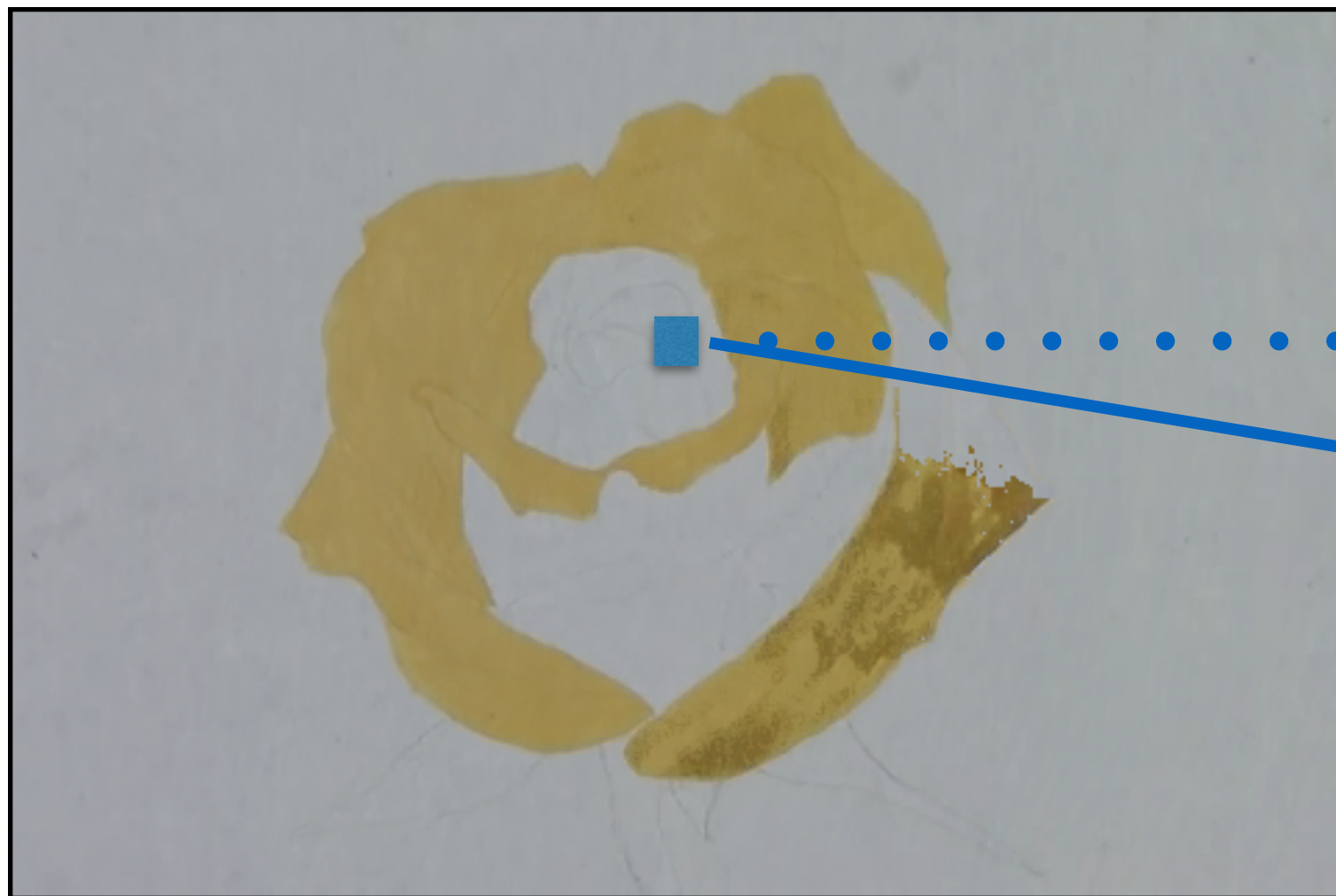


after

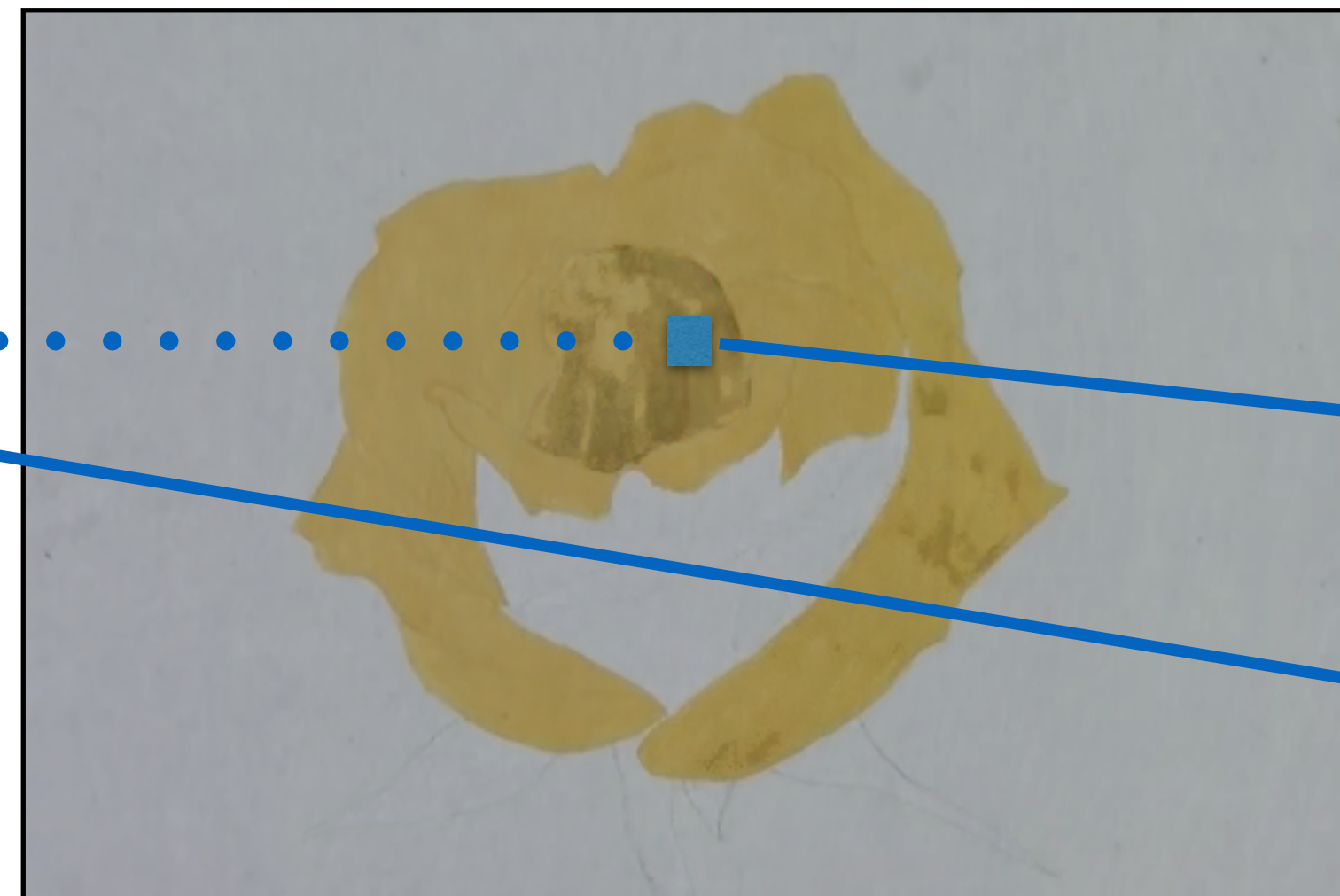


RGB Color Space

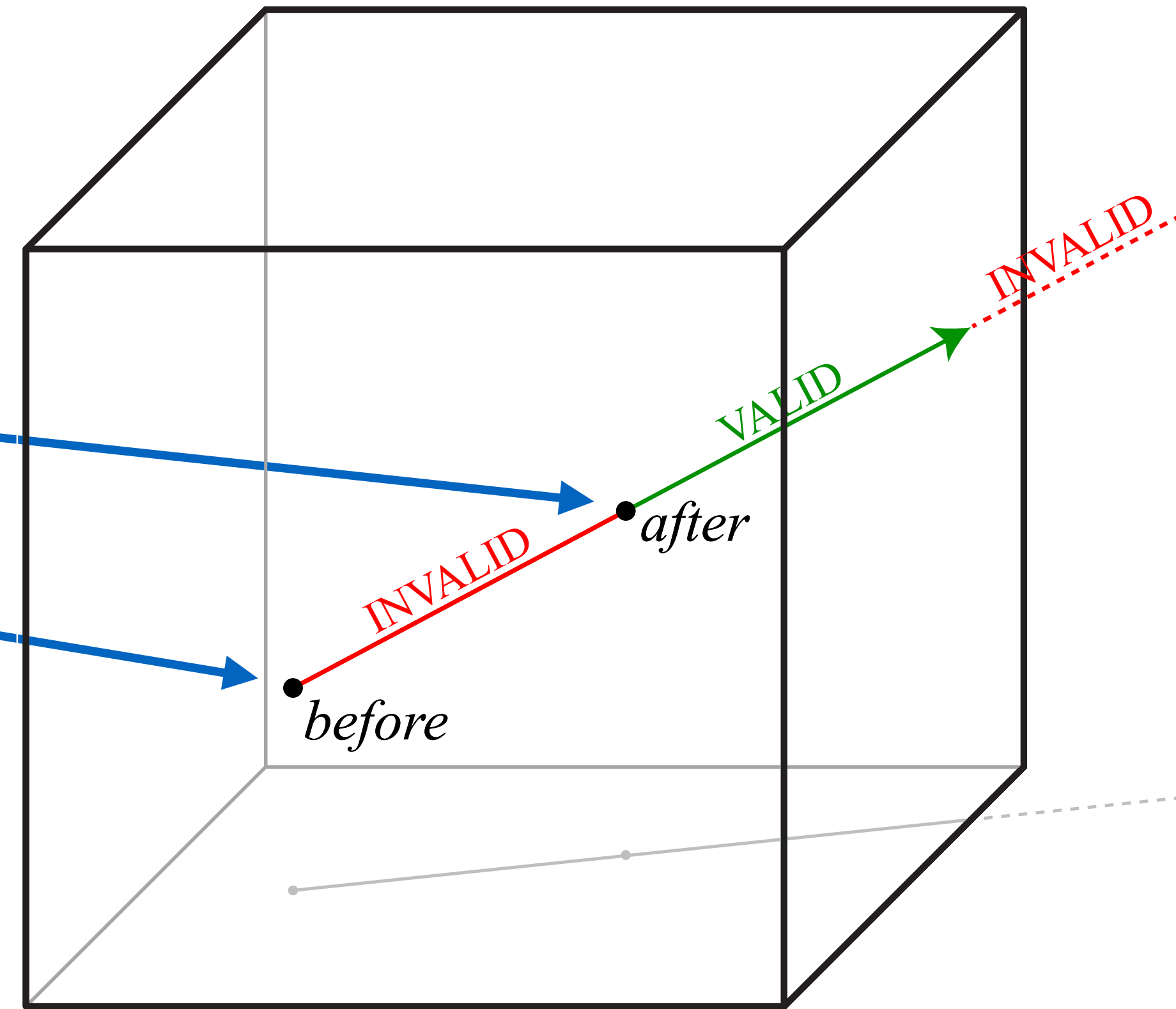
Porter-Duff Model



before



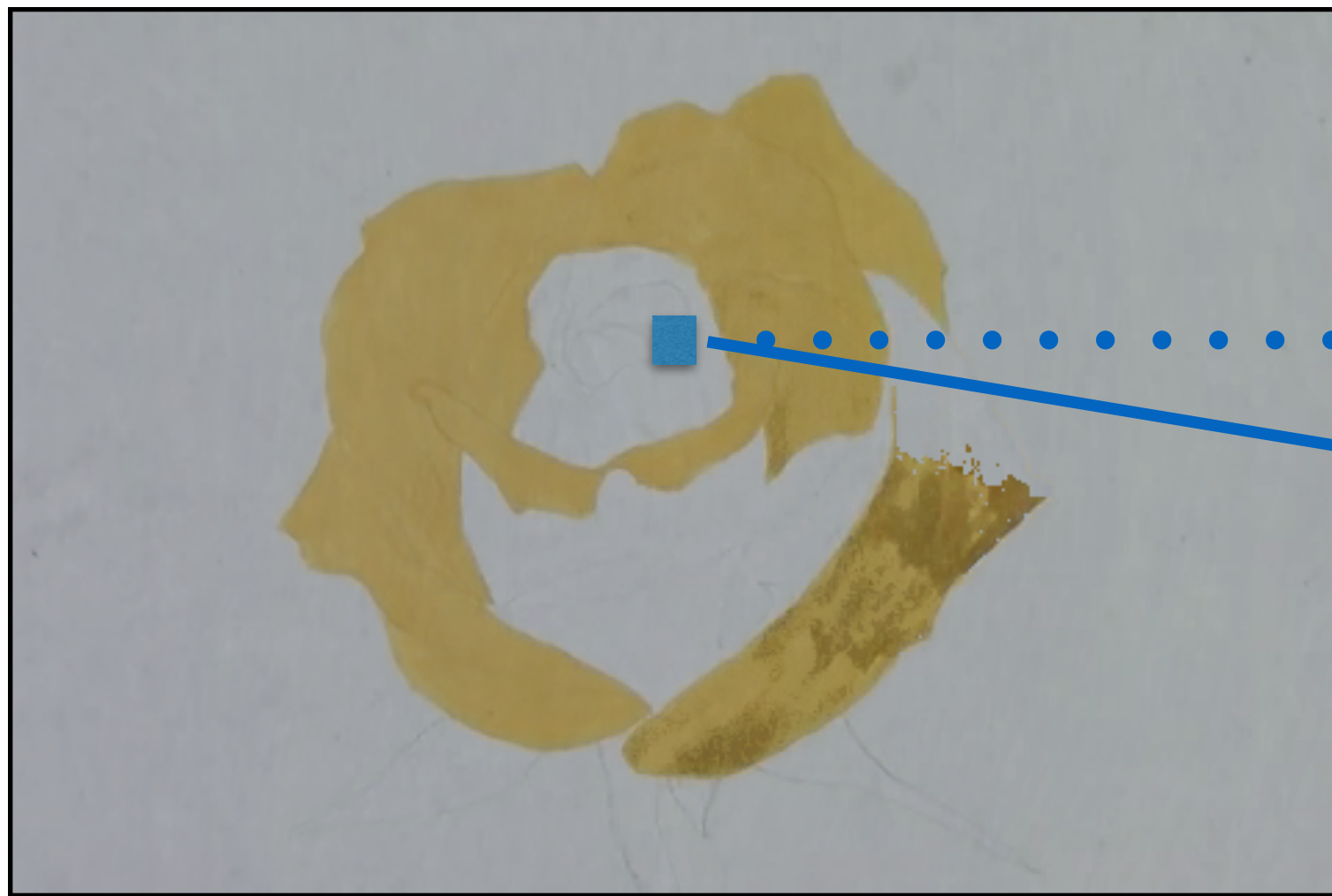
after



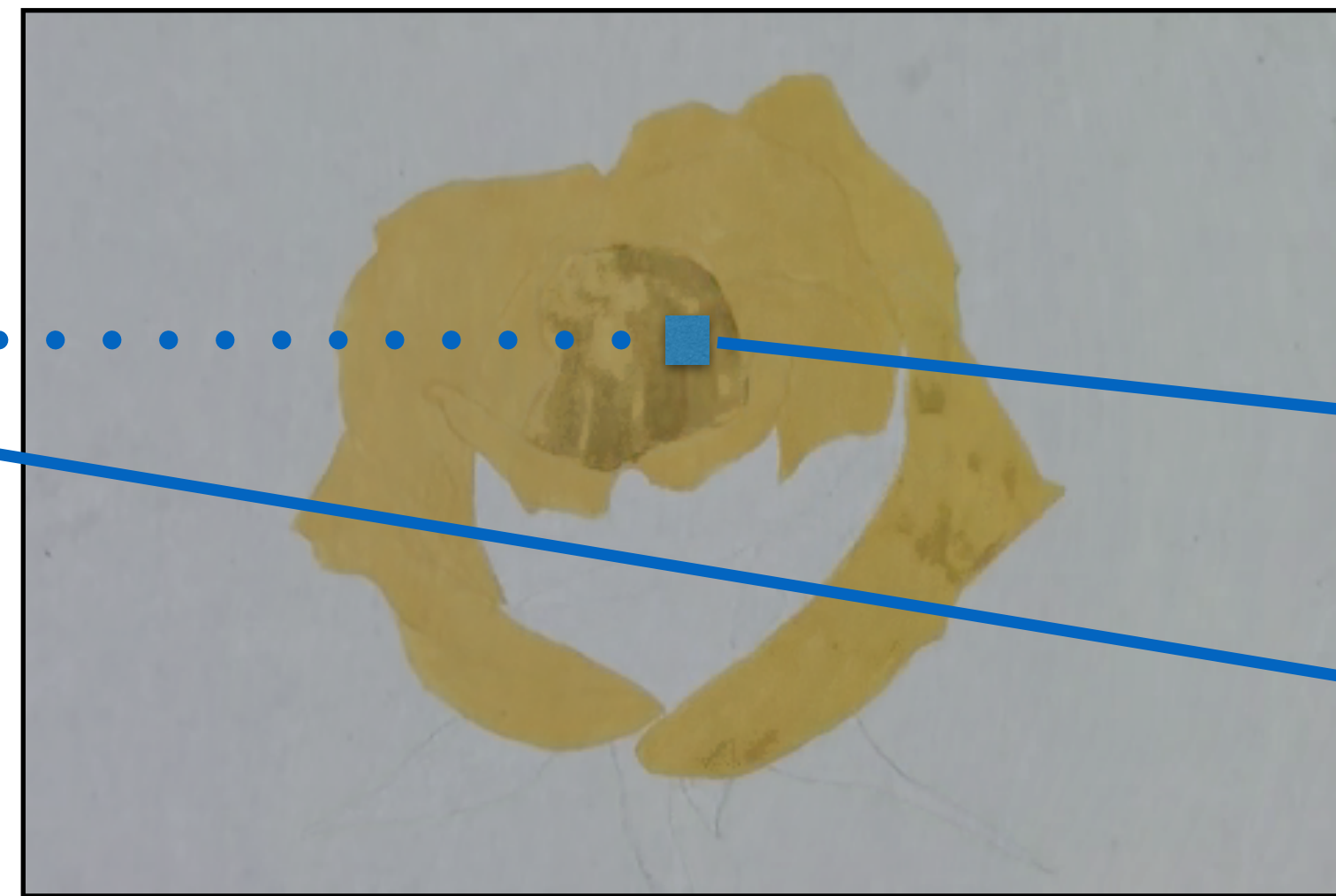
RGB Color Space

Find solution that minimizes ***alpha***

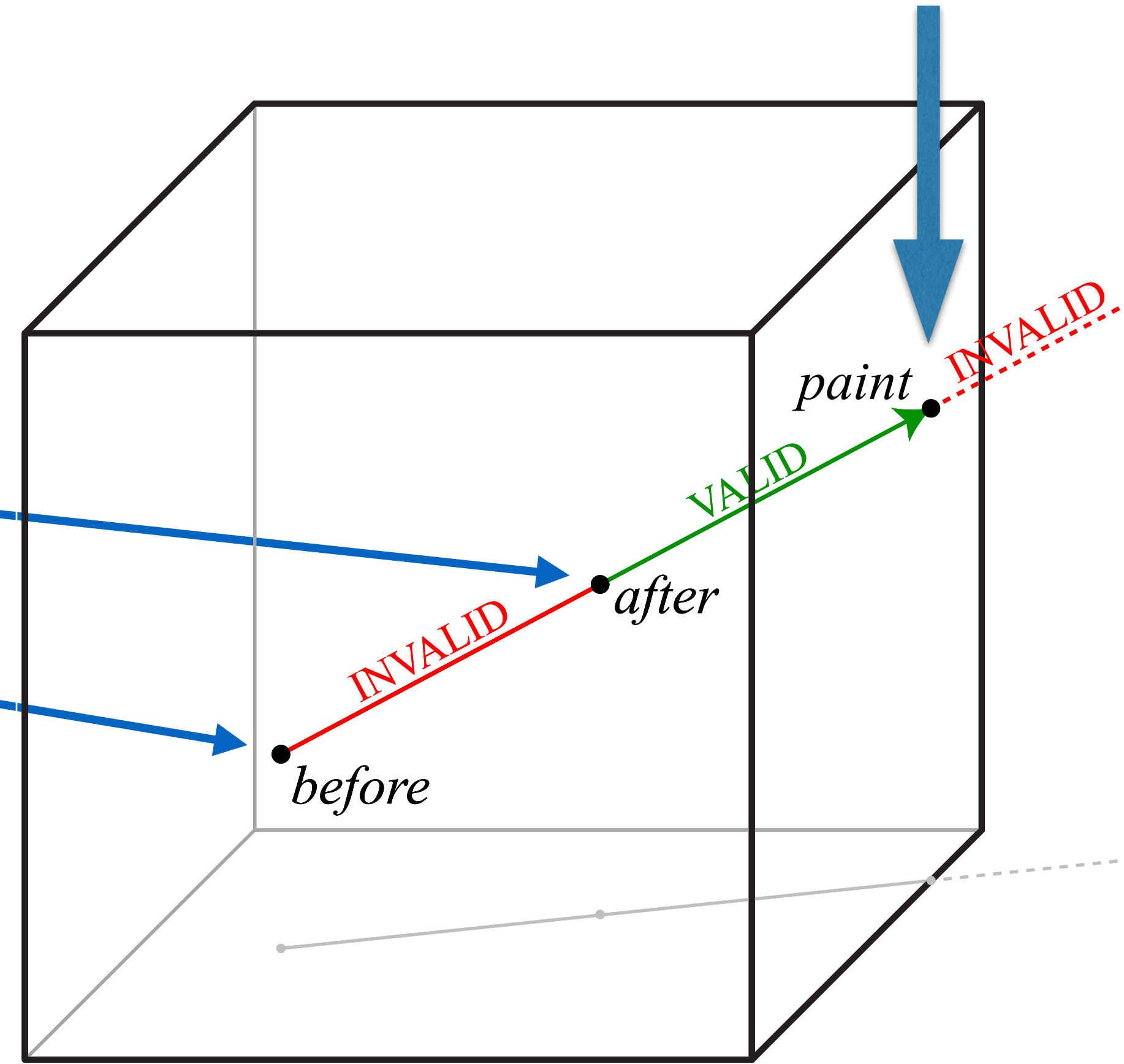
Porter-Duff Model



before



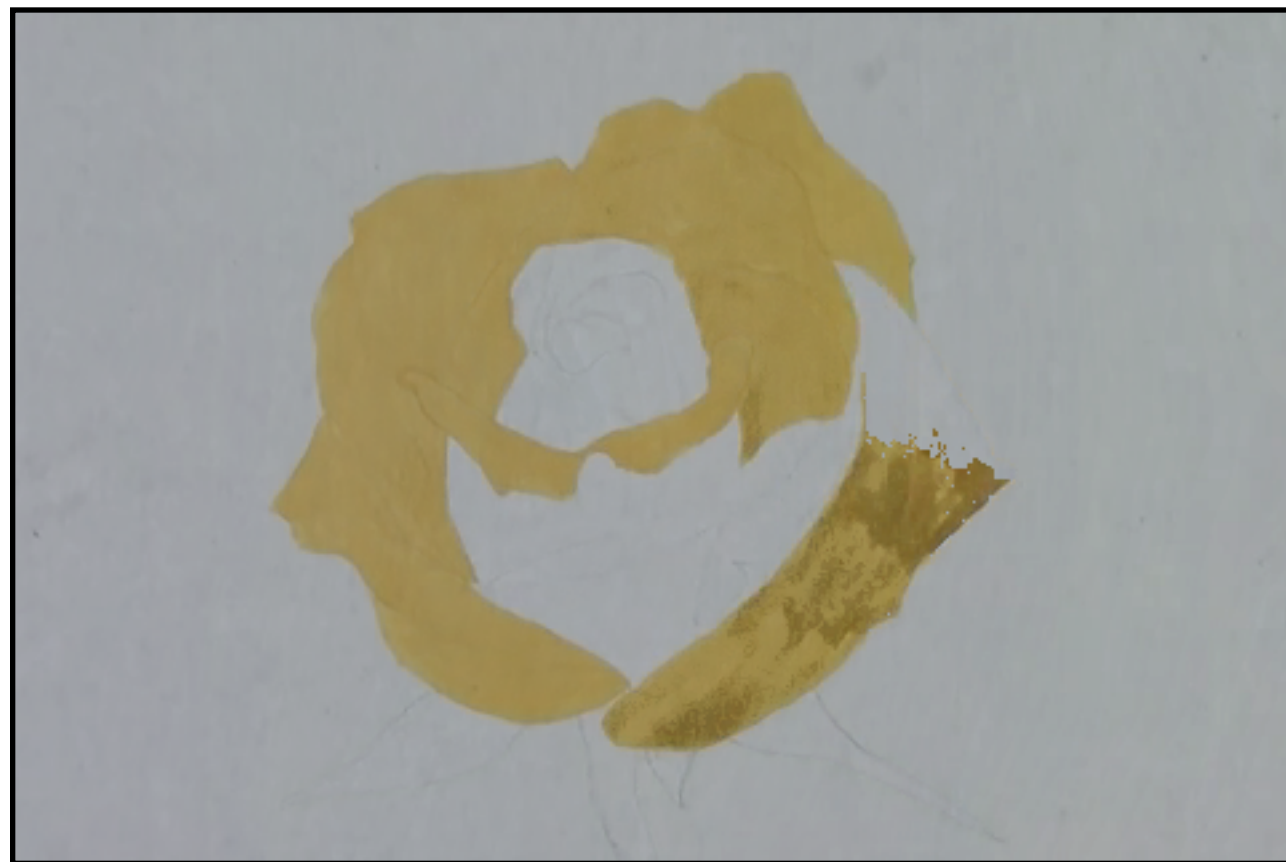
after



RGB Color Space

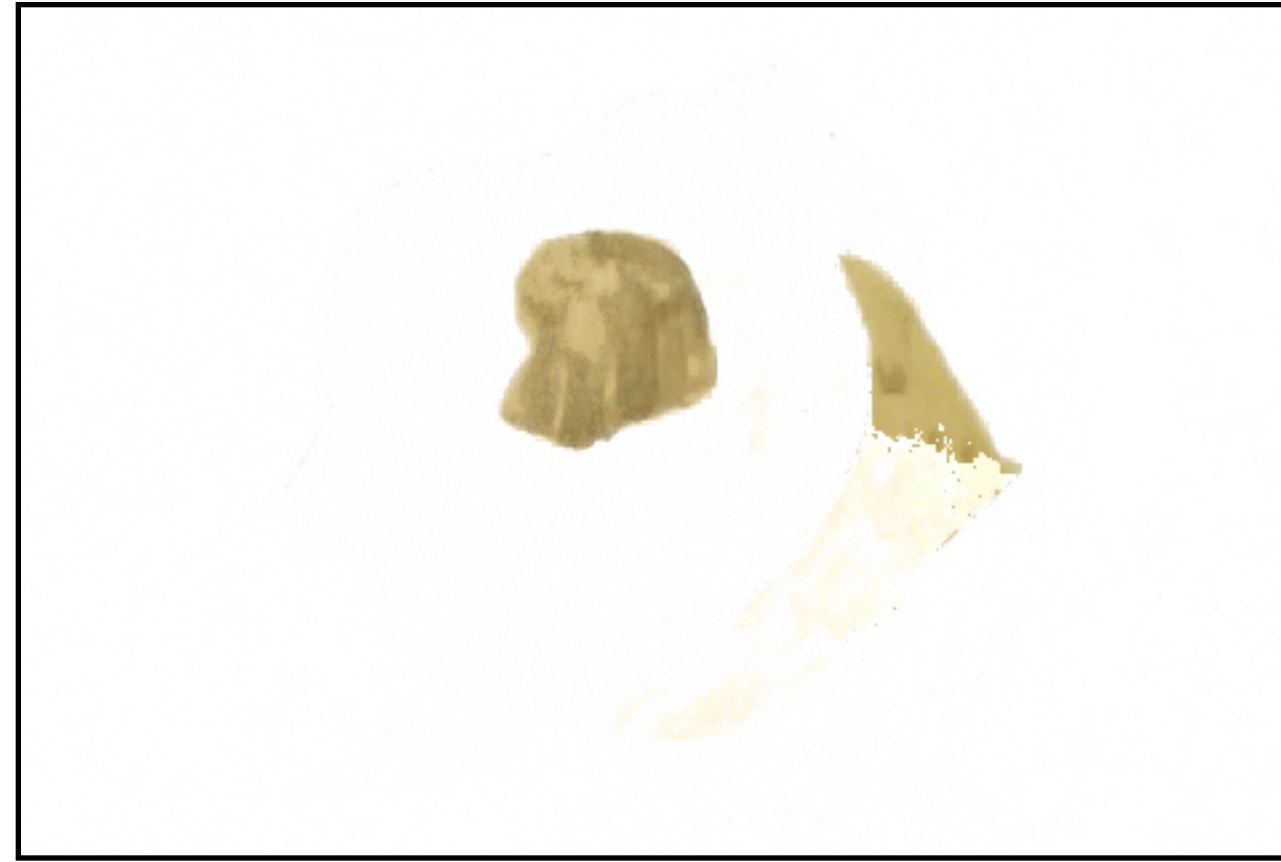
Find solution that minimizes ***alpha***

Porter-Duff Model



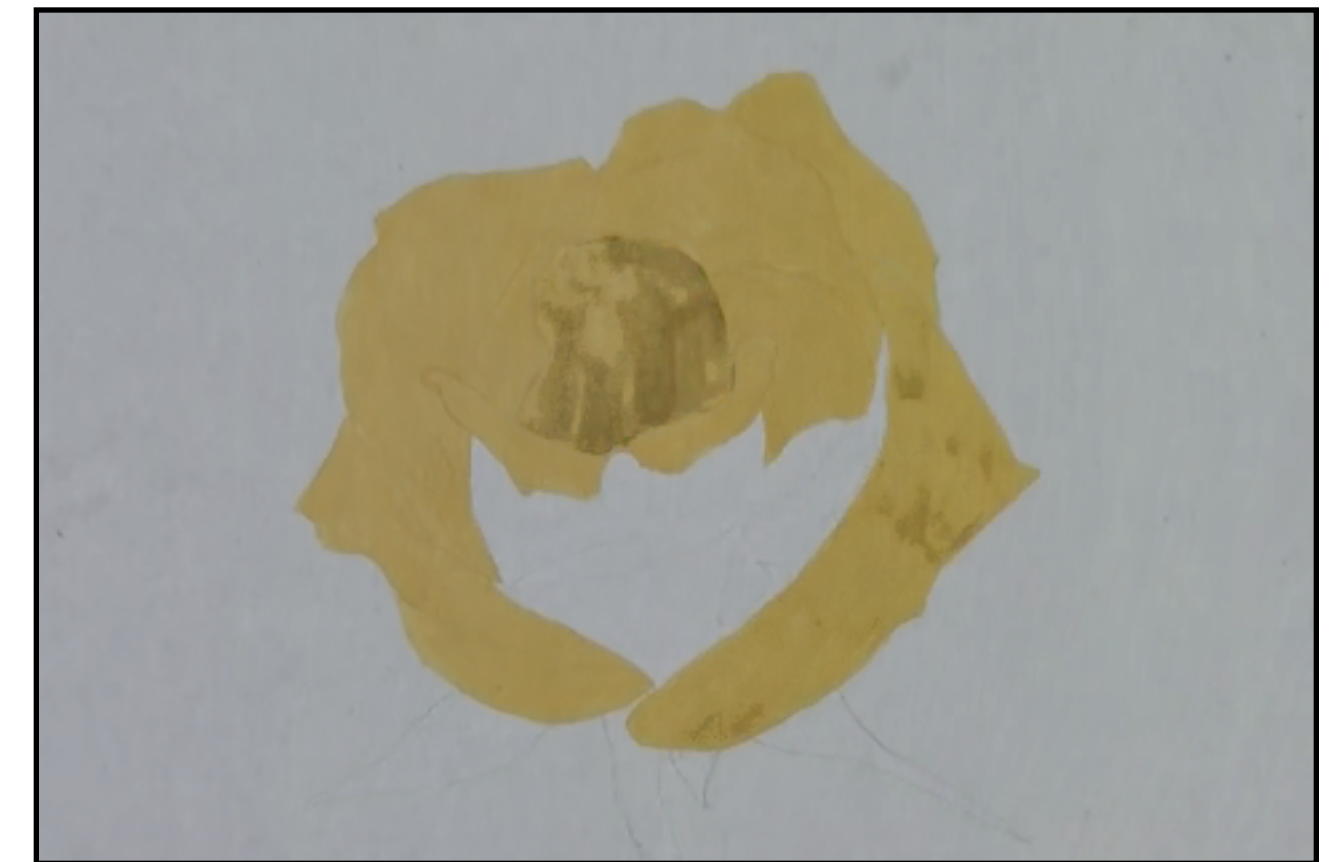
before

+



Layer (RGBA)

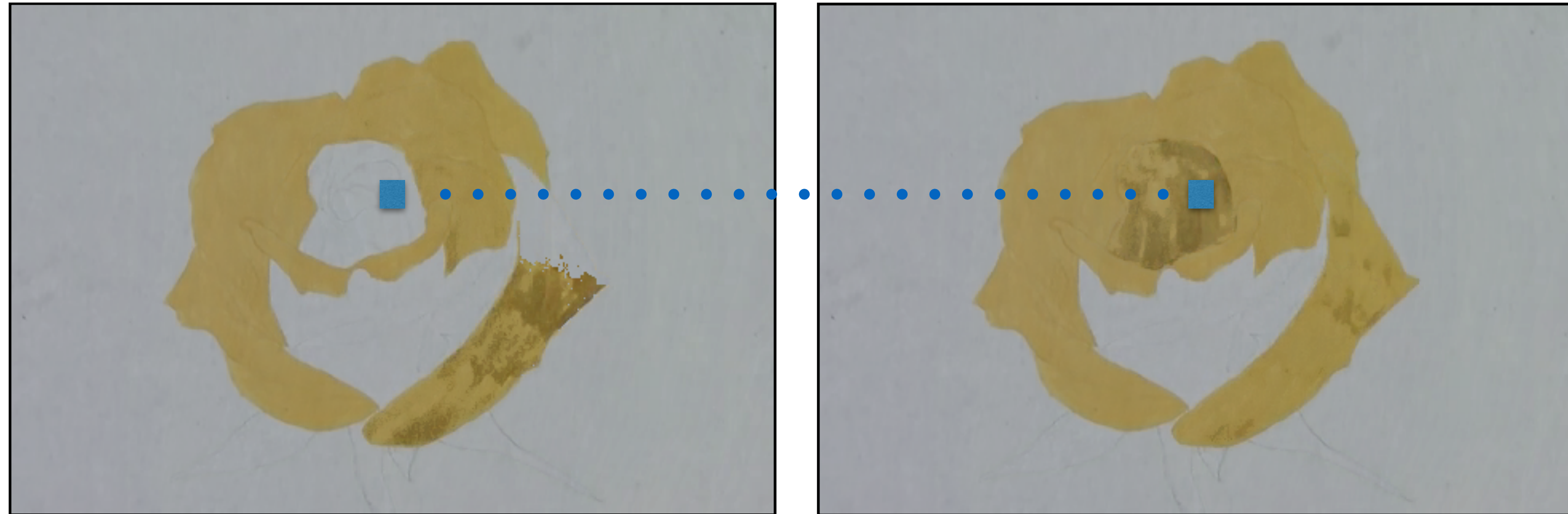
=



after

Kubelka-Munk Model

- Layer model (mixing model can be found in paper)

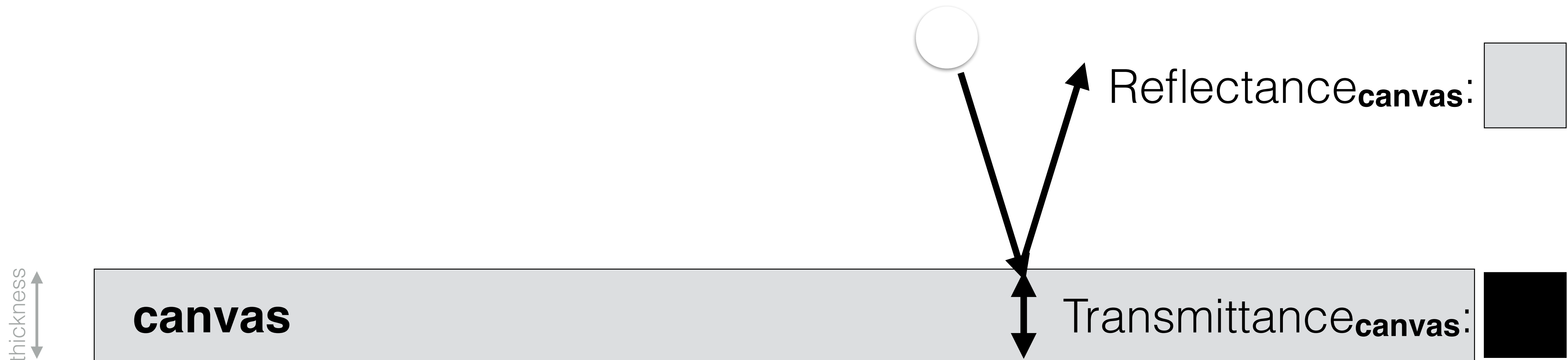


before

after

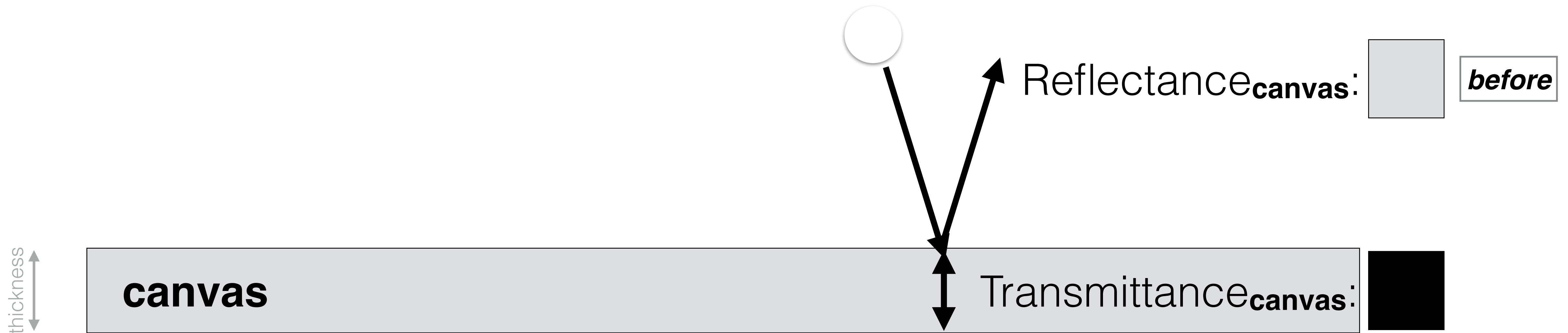
Kubelka-Munk Model

- Layer model (mixing model can be found in paper)



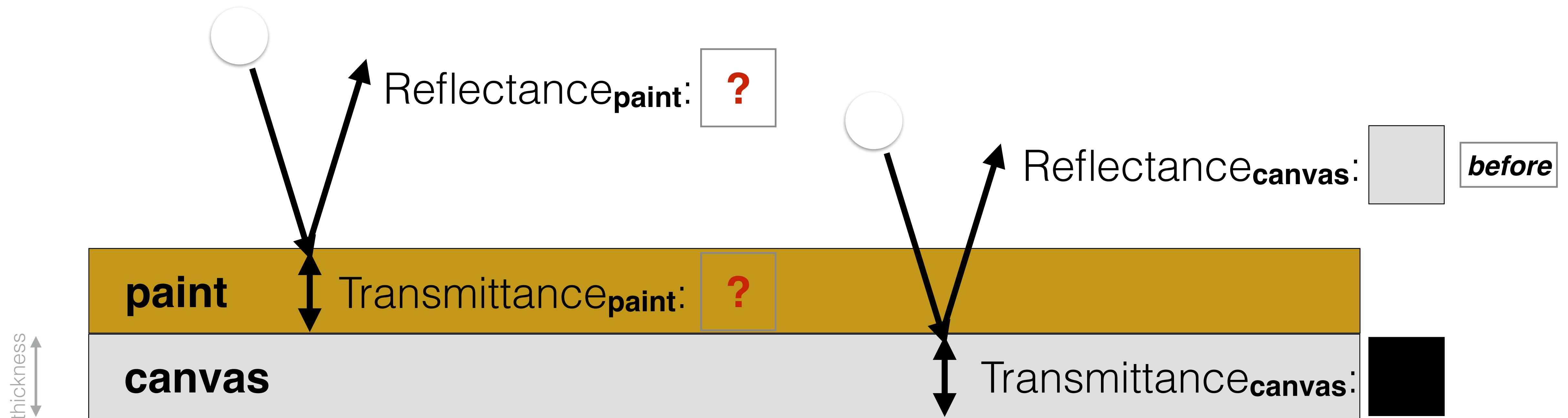
Kubelka-Munk Model

- Layer model (mixing model can be found in paper)



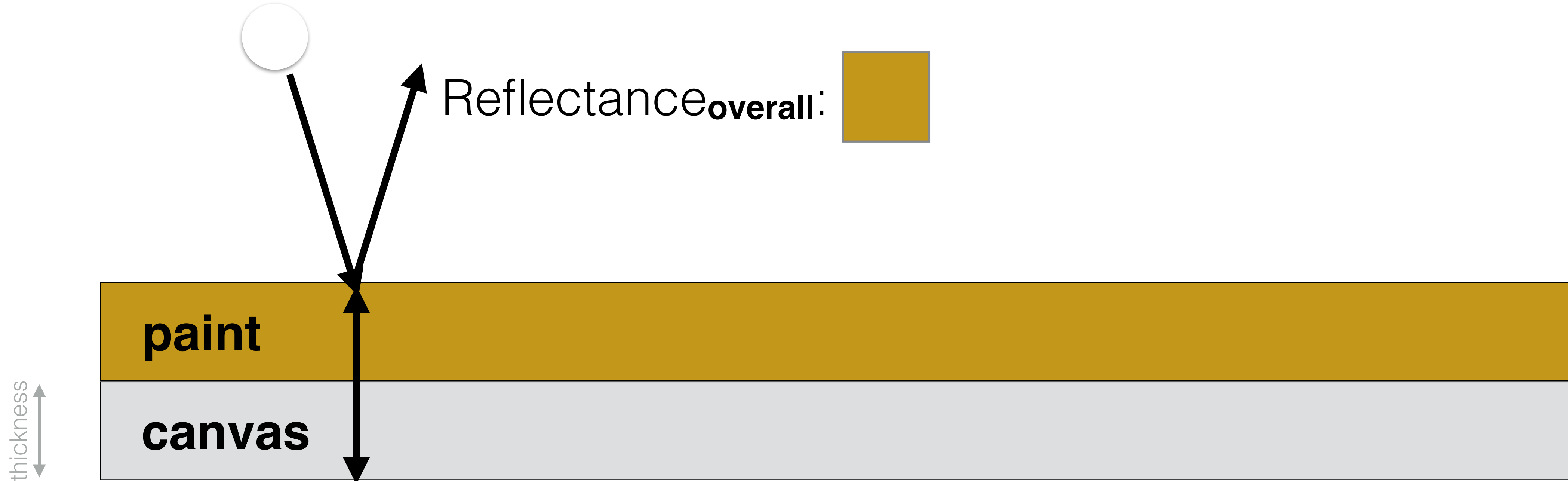
Kubelka-Munk Model

- Layer model (mixing model can be found in paper)



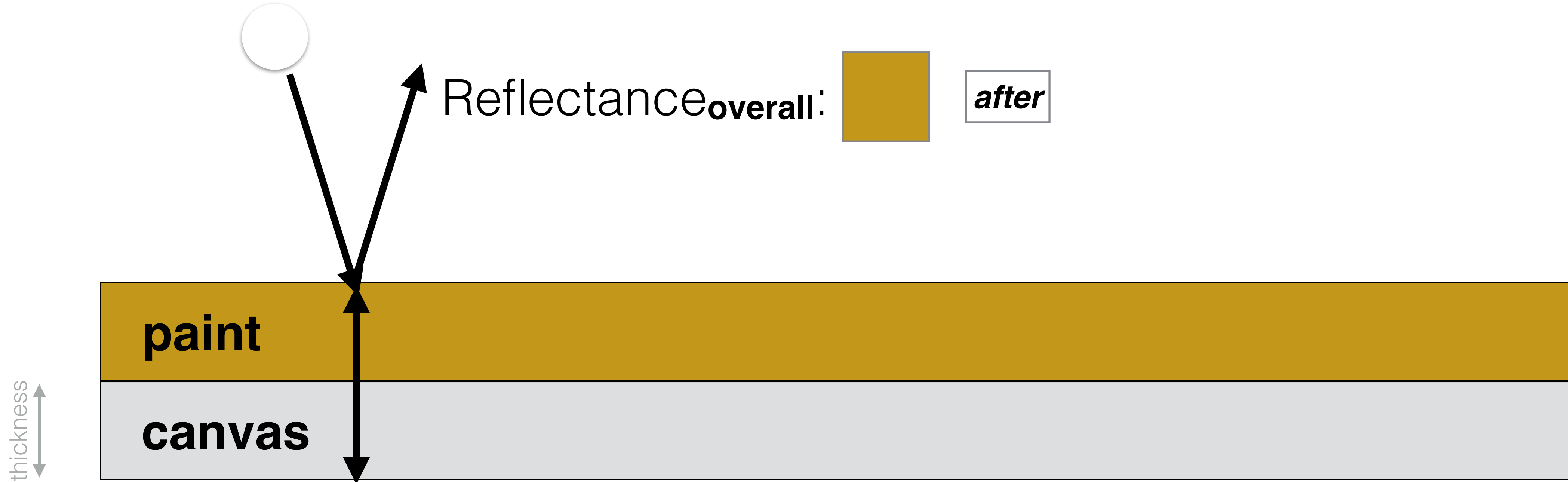
Kubelka-Munk Model

- Layer model (mixing model can be found in paper)



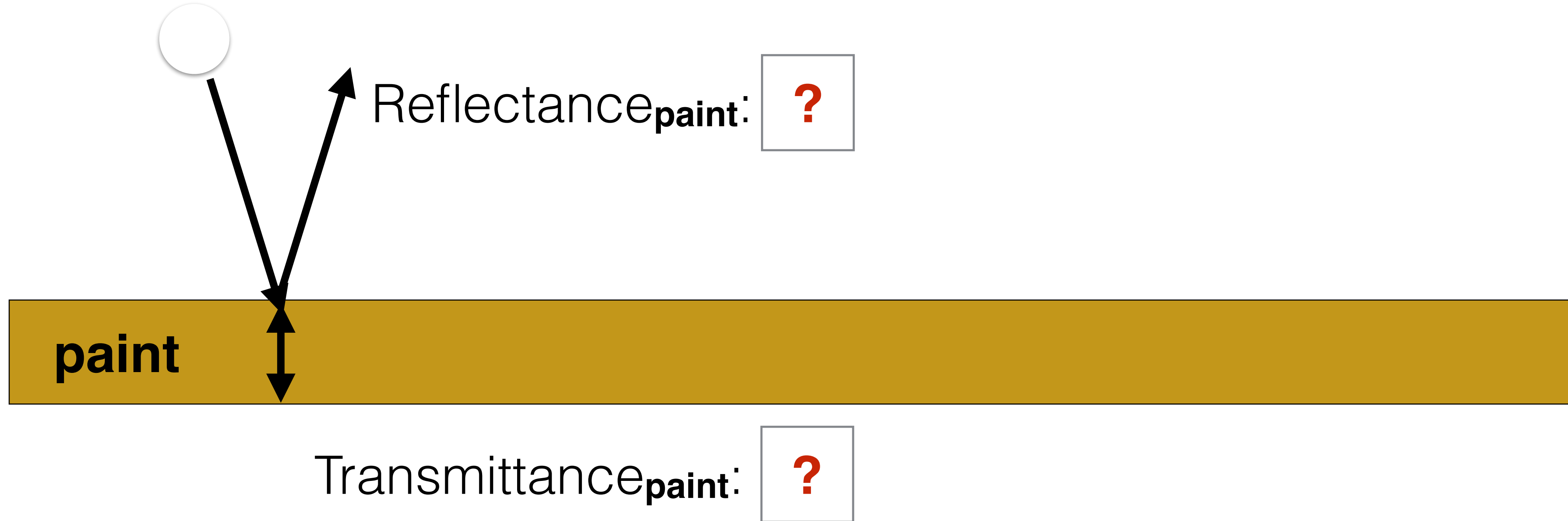
Kubelka-Munk Model

- Layer model (mixing model can be found in paper)



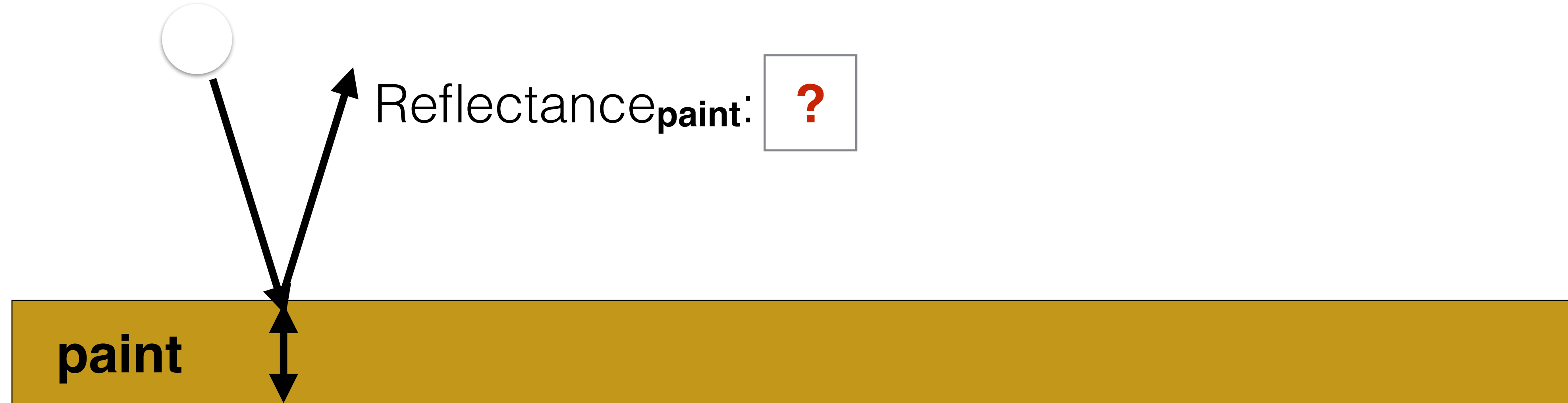
Kubelka-Munk Model

- Layer model (mixing model can be found in paper)



Kubelka-Munk Model

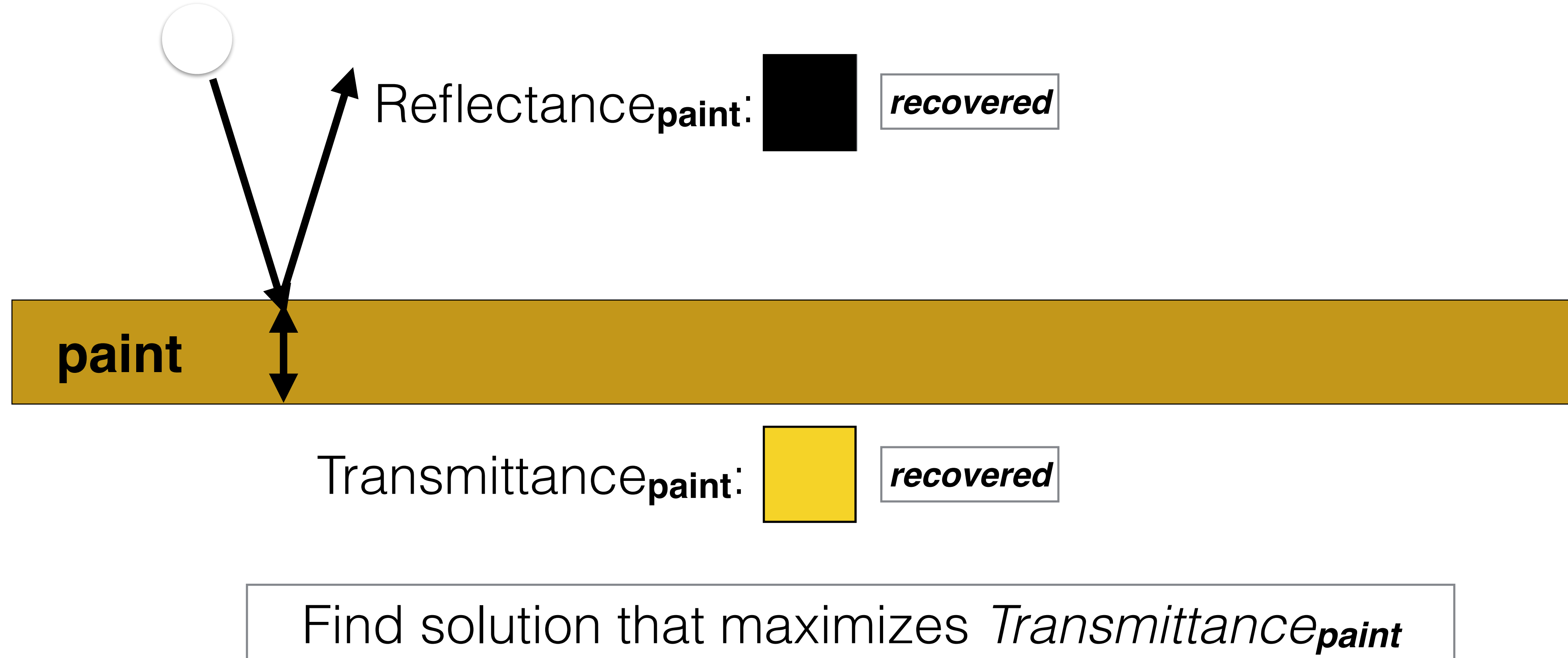
- Layer model (mixing model can be found in paper)



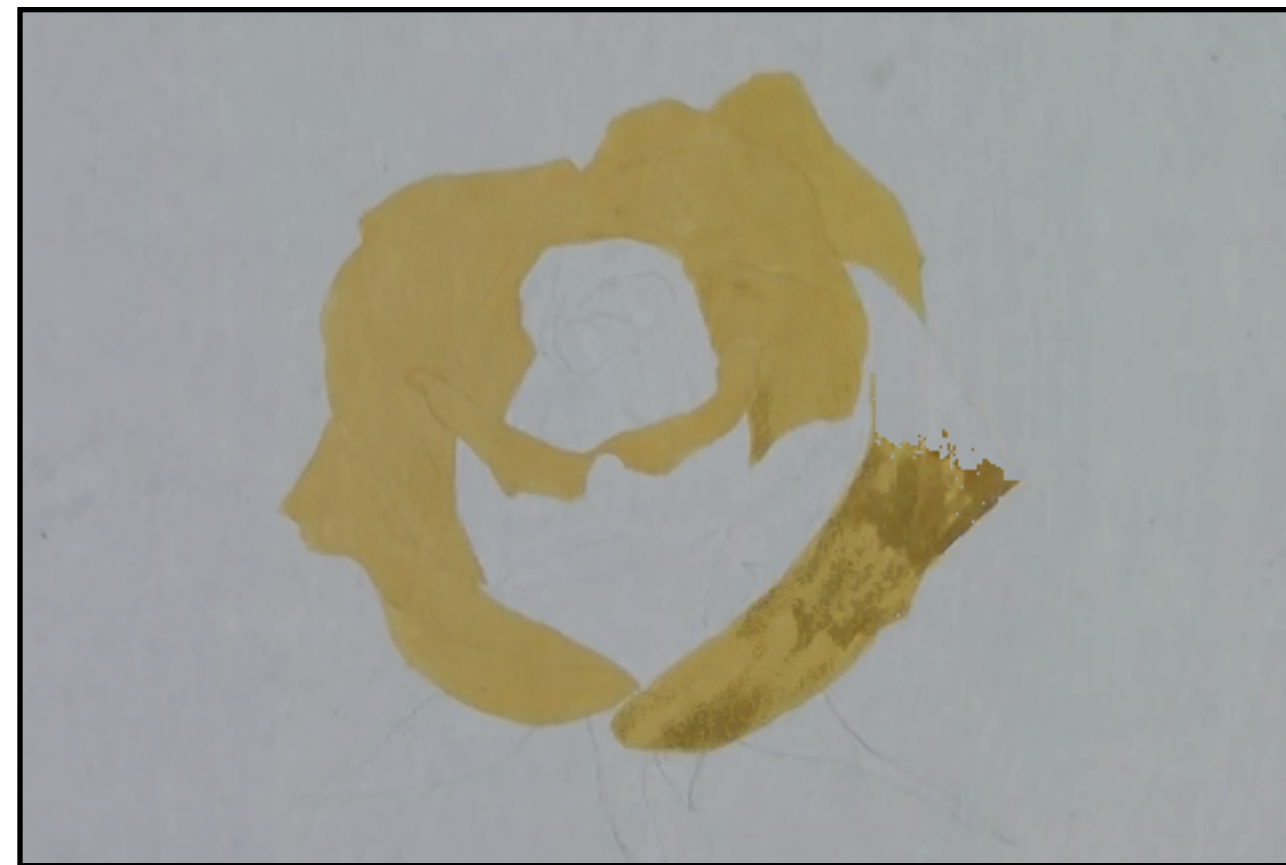
Find solution that maximizes *Transmittance_{paint}*

Kubelka-Munk Model

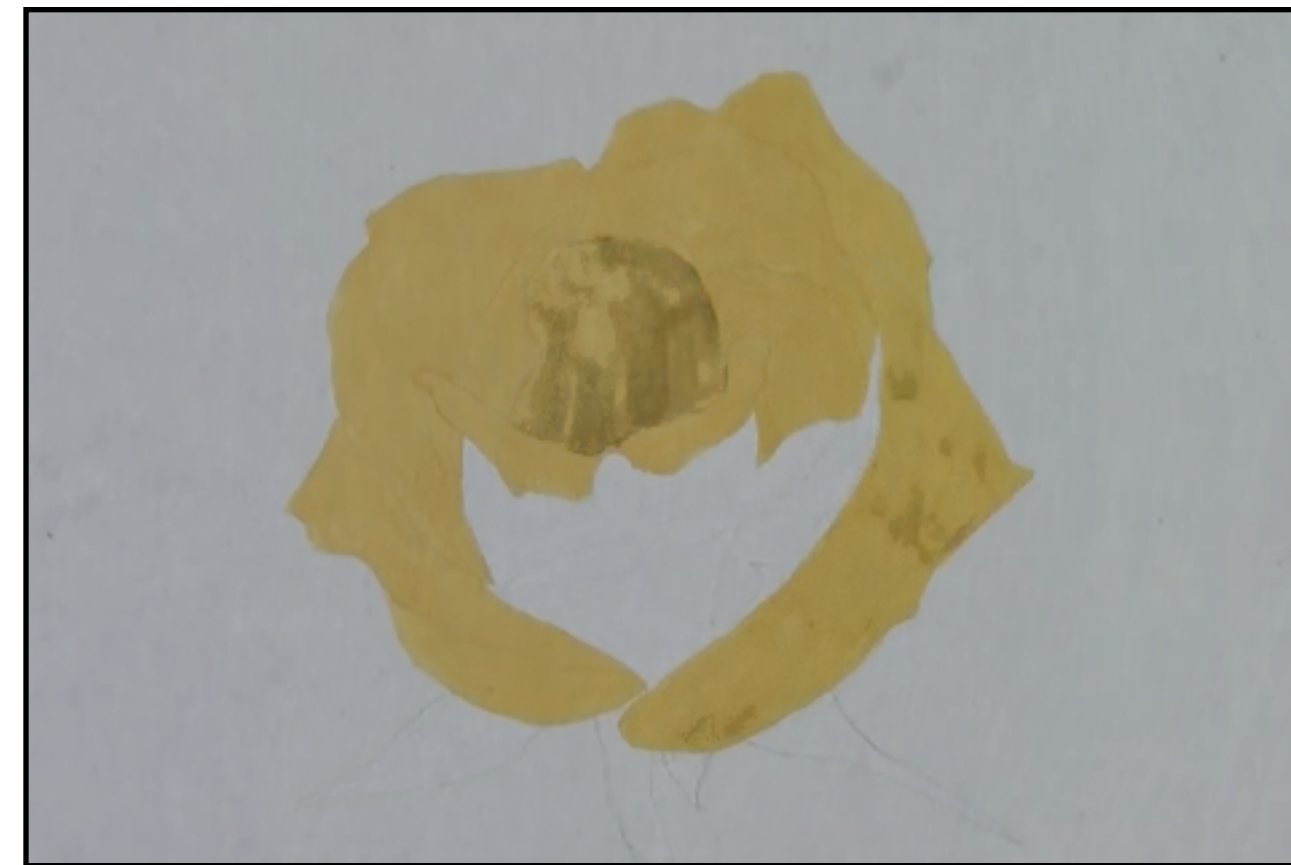
- Layer model (mixing model can be found in paper)



Kubelka-Munk Model



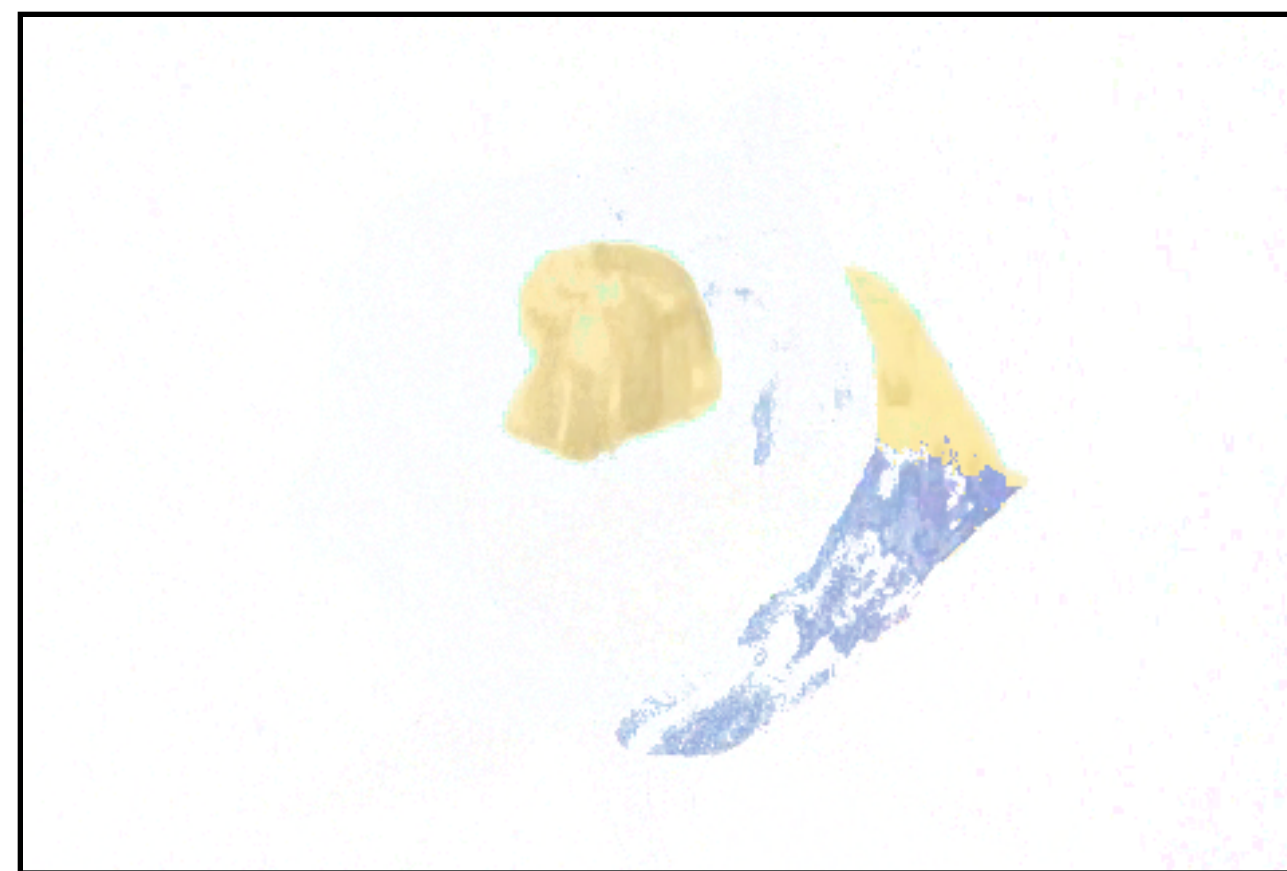
before



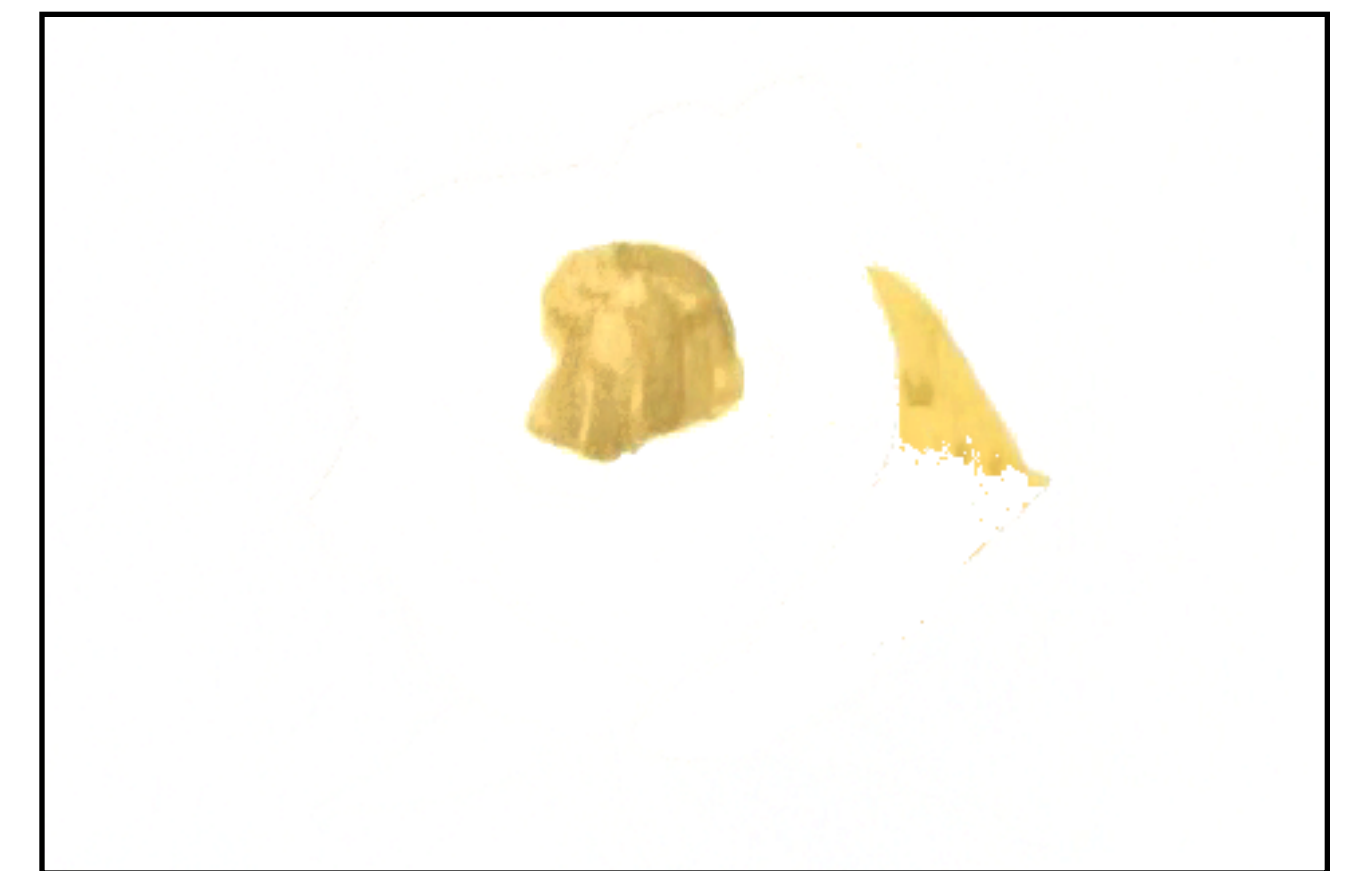
after



Reflectance



Transmittance

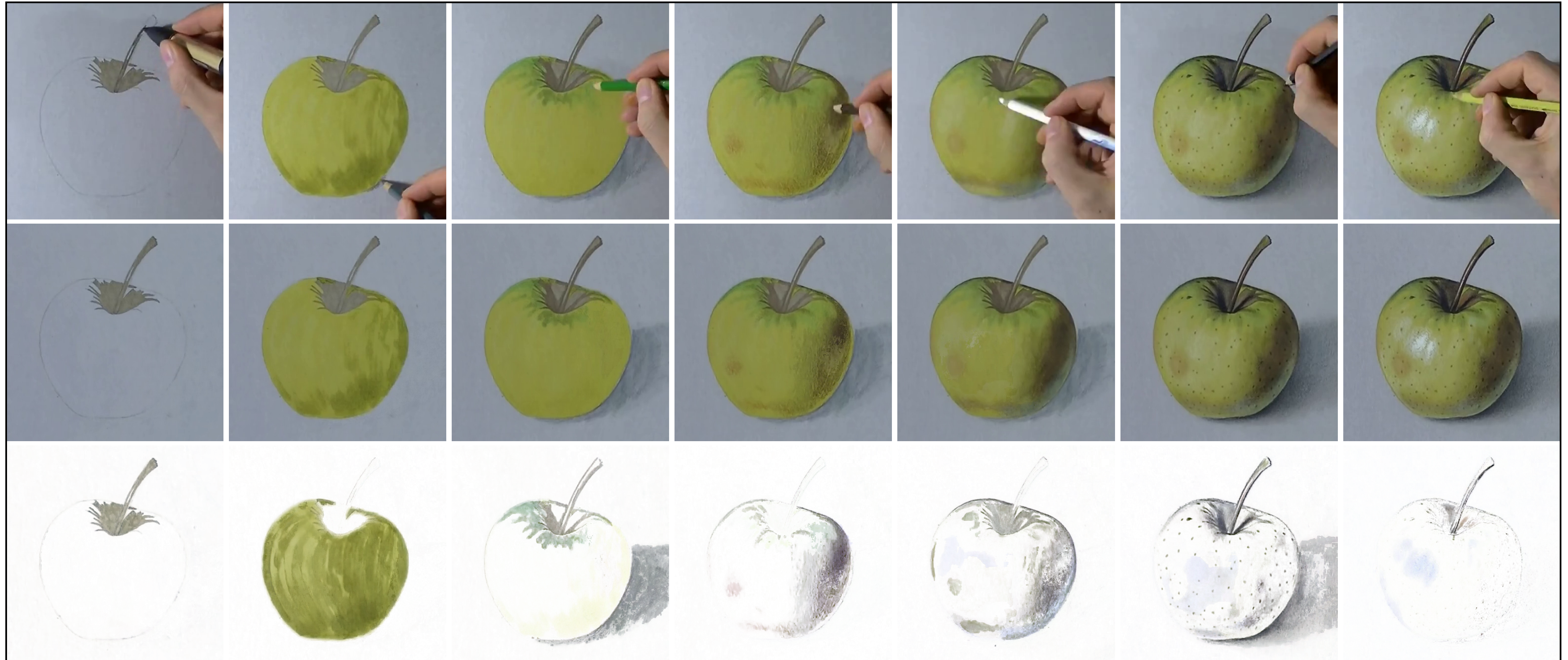


Layer (on white canvas)

Results Overview

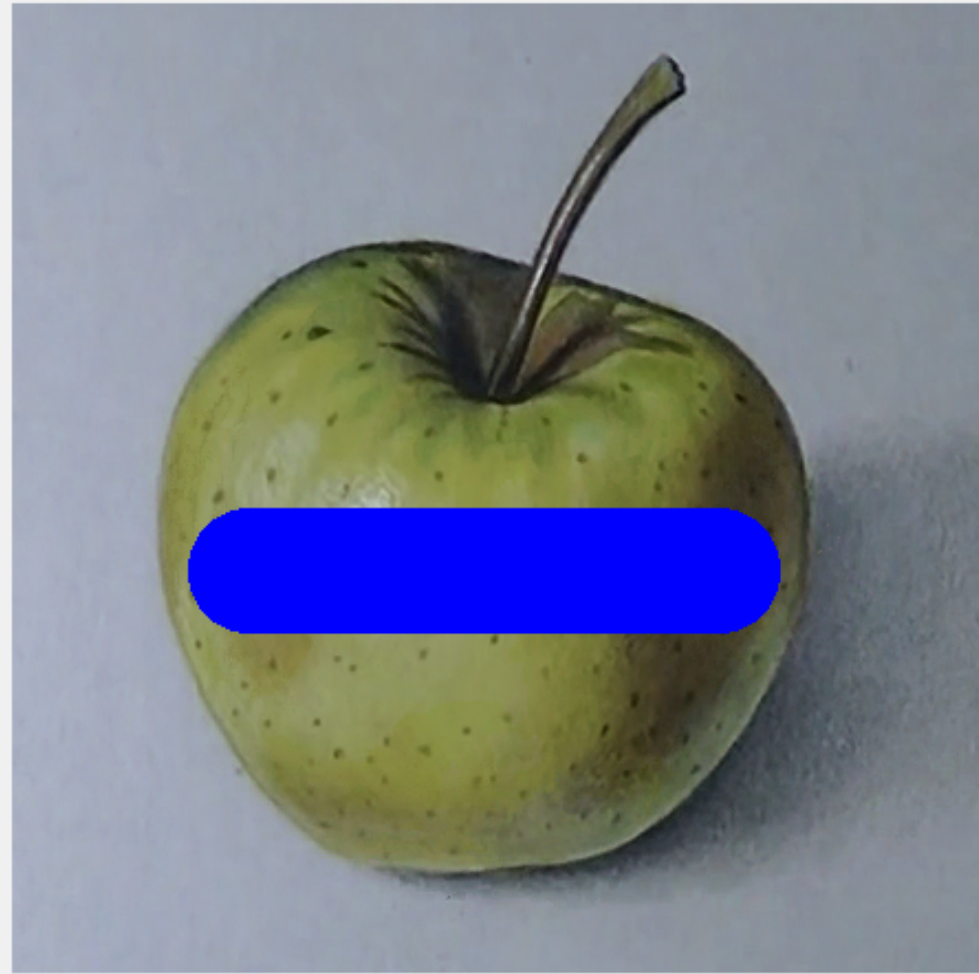


Results Overview



Editing

- Temporal-Spatial Selection:



Editing

- Coloring using Time Gradient :



Editing

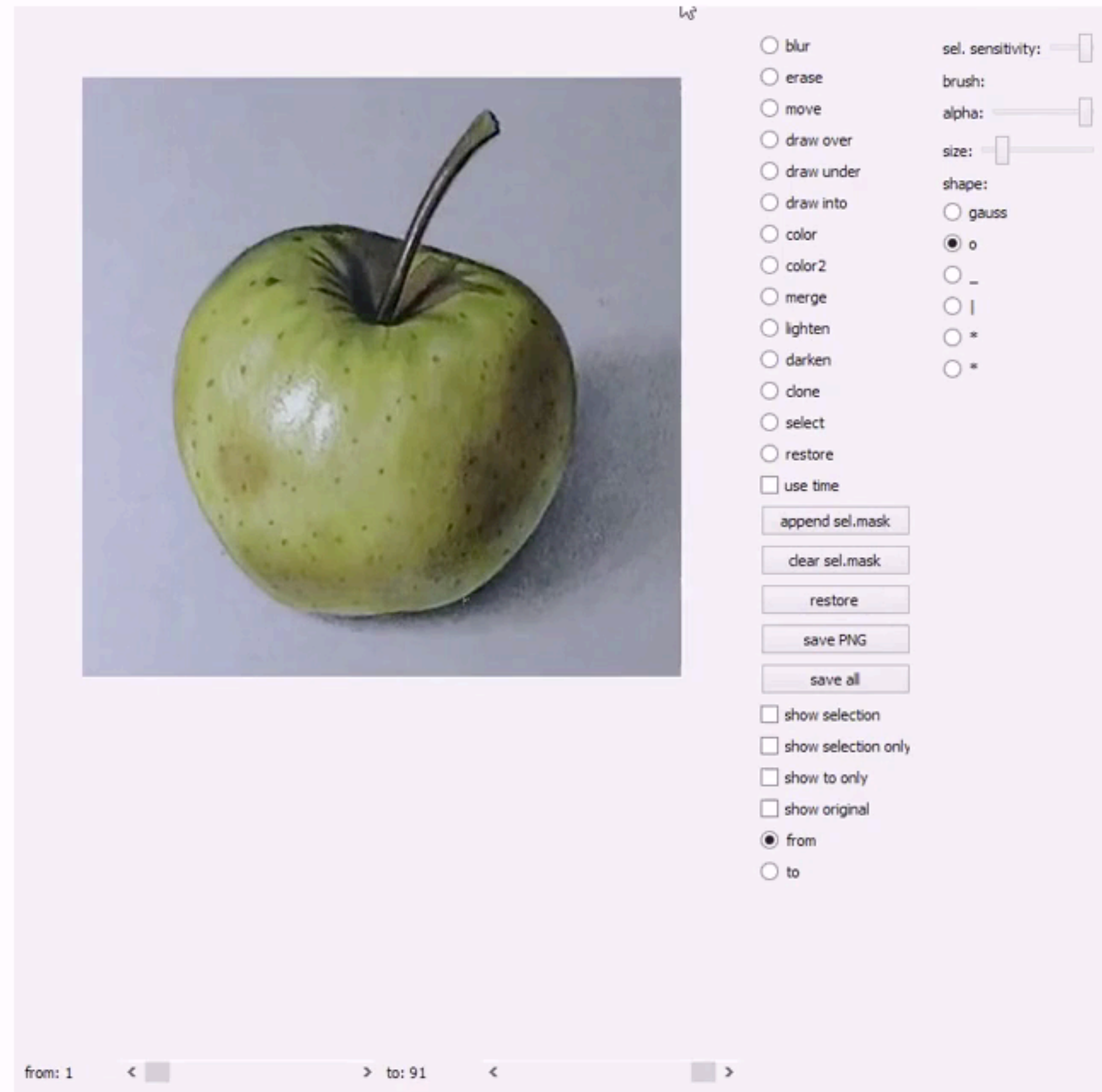
Interactive editing using our stroke decomposition

The screenshot displays an interactive editing interface for a green apple. The interface is divided into several sections:

- Central Image:** A high-quality photograph of a green apple with a stem, centered on a light gray background.
- Toolbar (Left):** A vertical list of tools, each with a radio button:
 - blur
 - erase
 - move
 - draw over
 - draw under
 - draw into
 - color
 - color2
 - merge
 - lighten
 - darken
 - clone
 - select
 - restore
 - use time
- Toolbar (Right):** A vertical list of options, each with a radio button:
 - sel. sensitivity: (with a slider)
 - brush:
 - alpha: (with a slider)
 - size: (with a slider)
 - shape:
 - gauss
 - o
 -
 - |
 - *
 - *
- Buttons (Middle):** A vertical stack of buttons:
 - append sel.mask
 - clear sel.mask
 - restore
 - save PNG
 - save all
- Checkboxes (Bottom):** A vertical list of checkboxes:
 - show selection
 - show selection only
 - show to only
 - show original
 - from
 - to
- Navigation (Bottom):** A horizontal bar with the text "from: 1" and "to: 91", and navigation arrows.

Editing

Interactive editing using our stroke decomposition



The screenshot displays an interactive editing interface for a green apple. The central part of the interface shows a photograph of a green apple with a stem. To the right of the image is a toolbar with various editing tools, each represented by a radio button:

- blur
- erase
- move
- draw over
- draw under
- draw into
- color
- color2
- merge
- lighten
- darken
- clone
- select
- restore
- use time

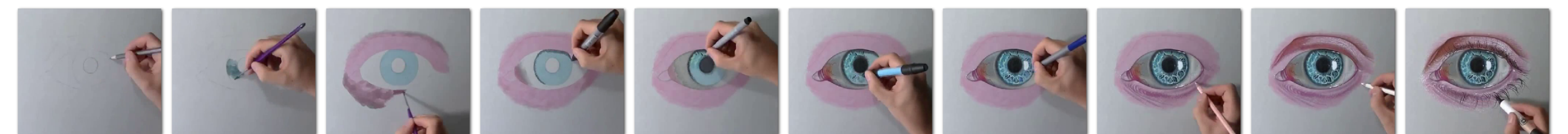
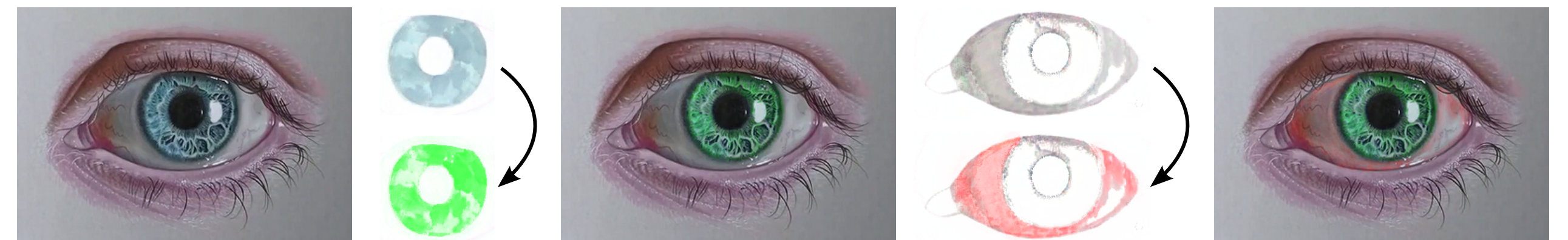
Below these tools are several buttons: "append sel.mask", "clear sel.mask", "restore", "save PNG", and "save all".

On the right side of the toolbar, there are sliders for "sel. sensitivity:", "brush:", "alpha:", and "size:". Below these are radio buttons for "shape:" with options: "gauss", "o" (selected), "-", "|", "*", and "x".

At the bottom of the interface, there are checkboxes for "show selection", "show selection only", "show to only", and "show original". Below these are radio buttons for "from" (selected) and "to".

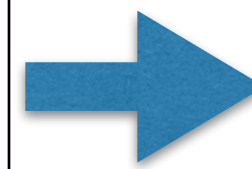
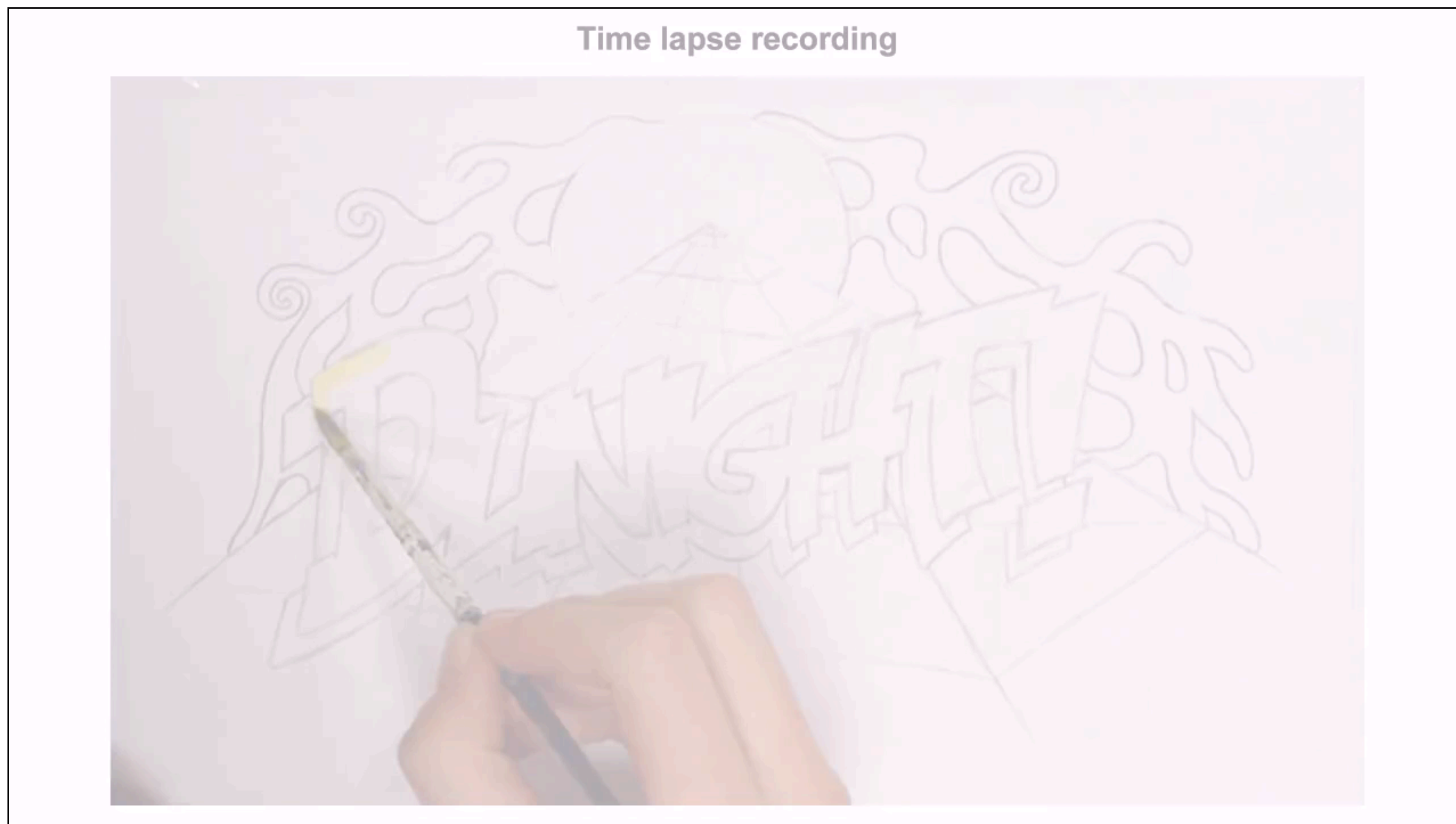
At the very bottom, there is a navigation bar with the text "from: 1" and "to: 91", and arrows indicating navigation.

Editing



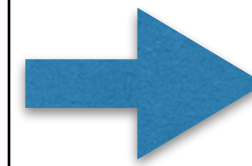
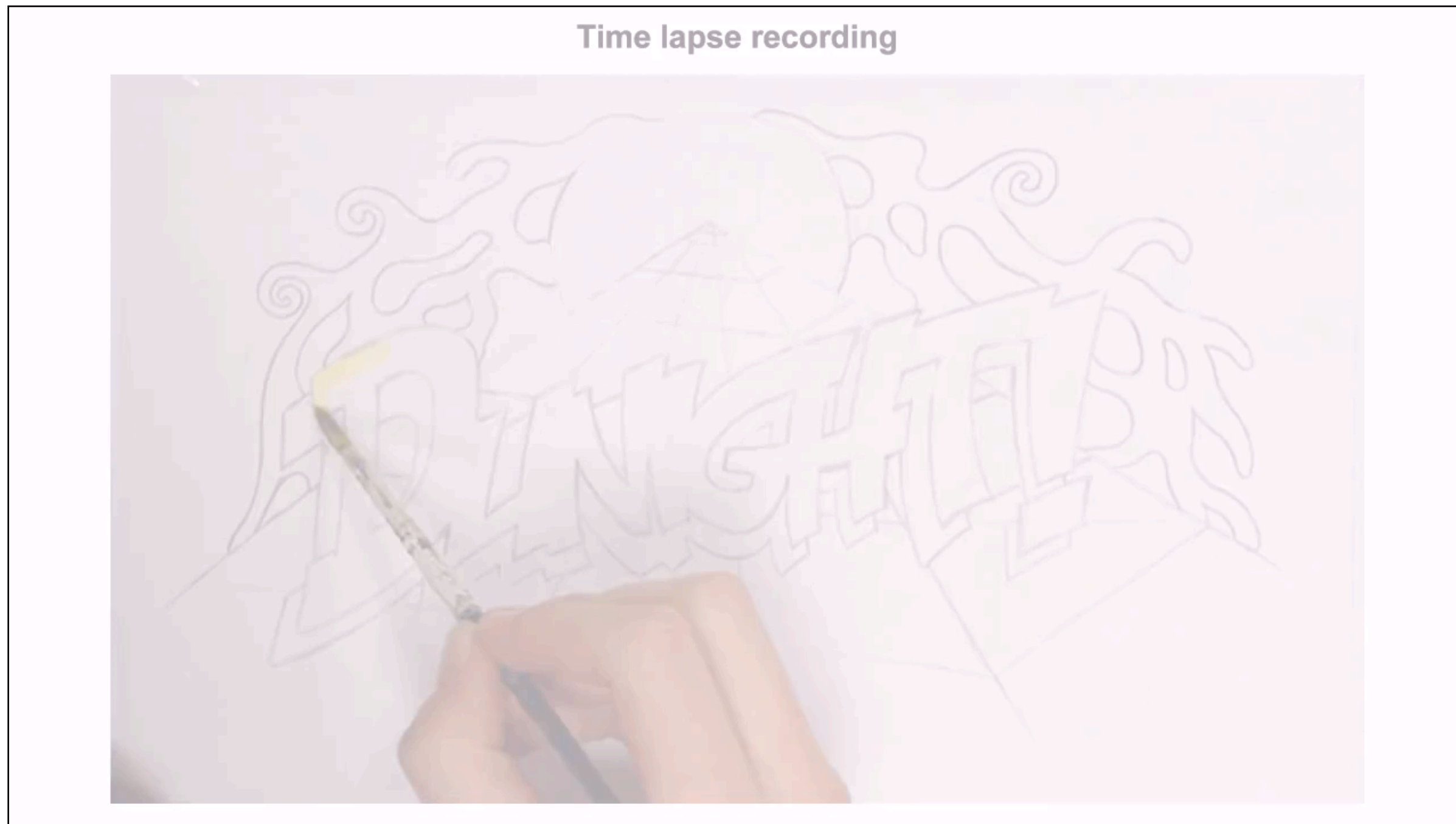
Conclusion

- A preprocessing method to get a clean, albedo video



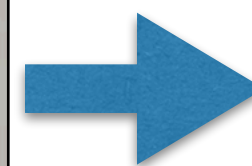
Conclusion

- A preprocessing method to get a clean, albedo video



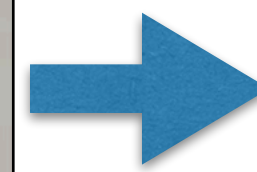
Conclusion

- Two types of solutions for extracting translucent layers



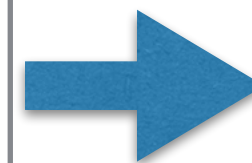
Conclusion

- Two types of solutions for extracting translucent layers



Conclusion

- Useful layers for editing



Interactive editing using our stroke decomposition

blur
 erase
 move
 draw over
 draw under
 draw into
 color
 merge
 lighten
 darken
 clone
 select
 restore
 use time

sel. sensitivity:
brush:
alpha:
size:
shape:
 gauss
 o
 _
 |
 =
 *

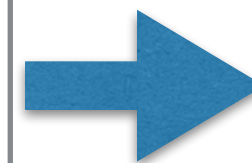
append sel.mask
clear sel.mask
restore
save PNG
save all

show selection
 show selection only
 show to only
 show original
 from
 to

from: 0 < to: 81 >

Conclusion

- Useful layers for editing



Interactive editing using our stroke decomposition

sel. sensitivity:

brush:

alpha:

size:

shape: gauss

o

_

|

*

=

*

*

*

*

*

*

use time

append sel.mask

clear sel.mask

restore

save PNG

save all

show selection

show selection only

show to only

show original

from

to

from: 0 < > to: 81 < >

Future Work

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- Camera and canvas calibration.

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Future Work

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- Single image layer extraction?



Future Work

- Camera and canvas calibration.
- Single image layer extraction?
- Apply layer data into more systems.
 - WetPaint [Bonanni et al. 2009]
 - Chronicle [Grossman et al. 2010]
 - ...



Future Work

- Camera and canvas calibration.
- Single image layer extraction?
- Apply layer data into more systems.
 - WetPaint [Bonanni et al. 2009]
 - Chronicle [Grossman et al. 2010]
 - ...
- Apply our technique to art education.



Thank You!

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 - Daniel Sýkora: sykorad@fel.cvut.cz
 - Yotam Gingold: ygingold@gmu.edu
- Project Website: <https://cs.gmu.edu/~ygingold/timemap/>
- Artists: [Marcello Barengi](#), Matyáš Veselý, [Dani Jones](#), semisecretsoftware (YouTube)
- Sponsors:
 - United States National Science Foundation, Google.
 - Technology Agency of the Czech Republic, Czech Science Foundation, Grant Agency of the Czech Technical University in Prague

P-D and K-M Comparison

Layers



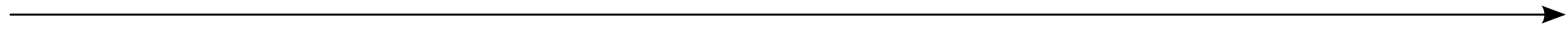
P-D



K-M



Input

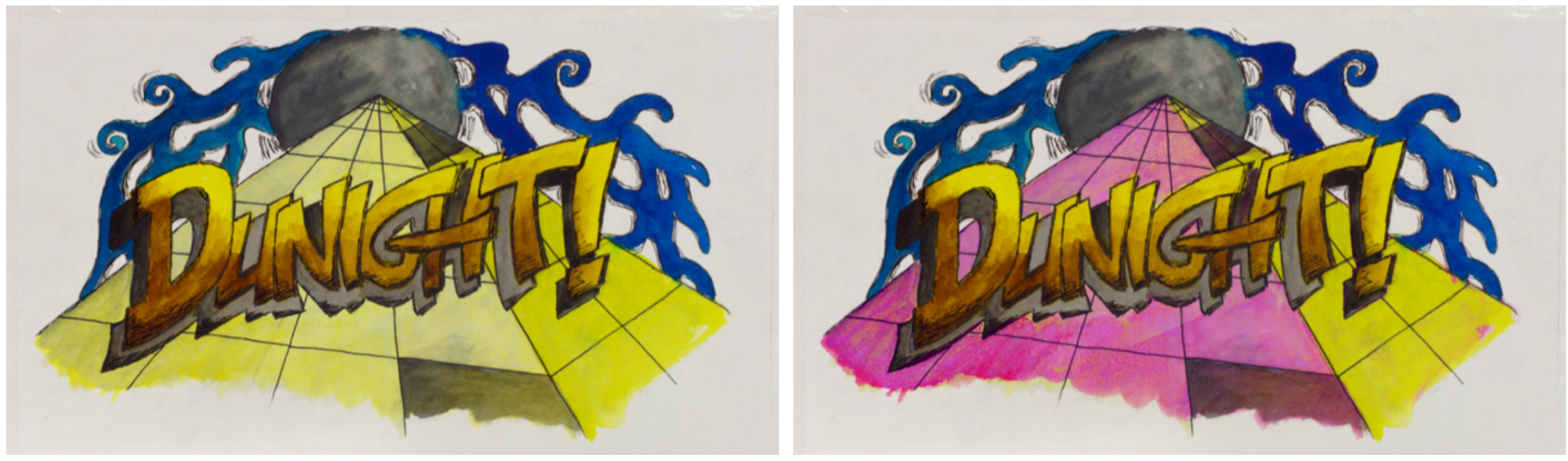


P-D and K-M Comparison



Layers

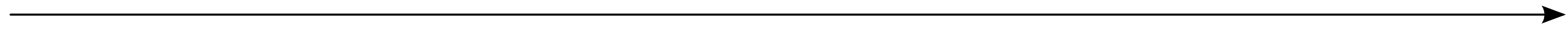
P-D



K-M

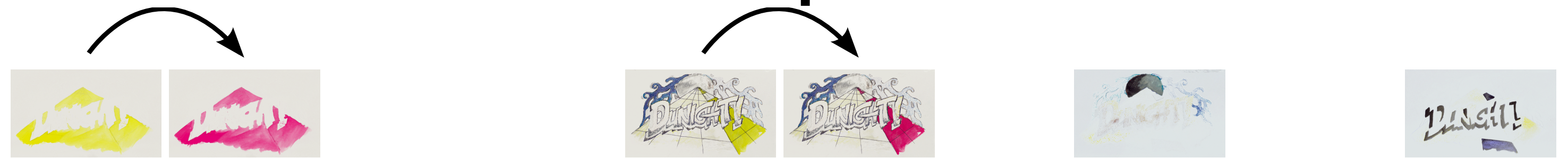


Input



P-D and K-M Comparison

Layers



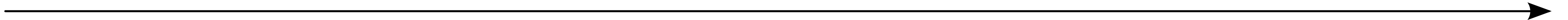
P-D



K-M

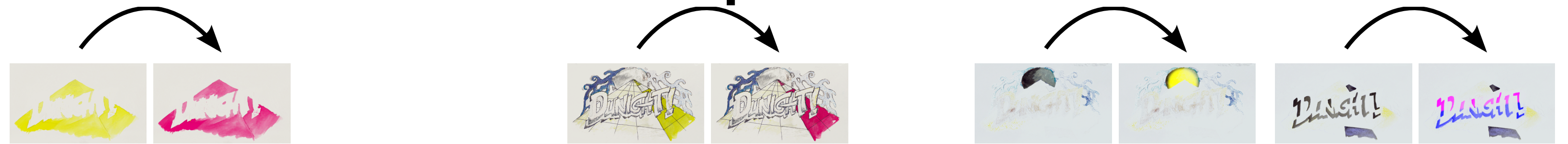


Input

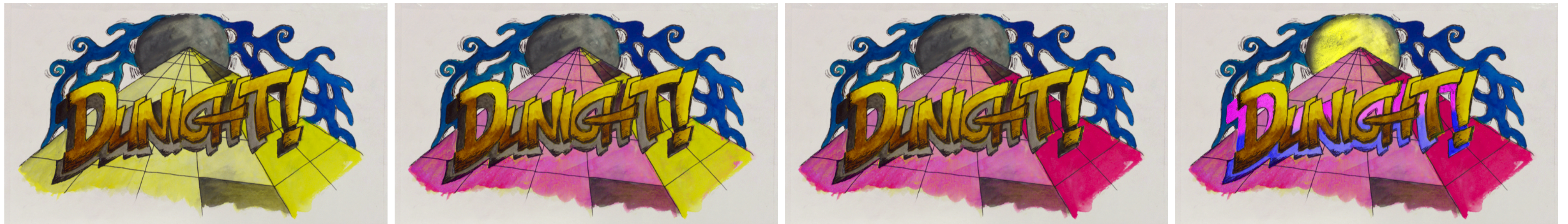


P-D and K-M Comparison

Layers



P-D



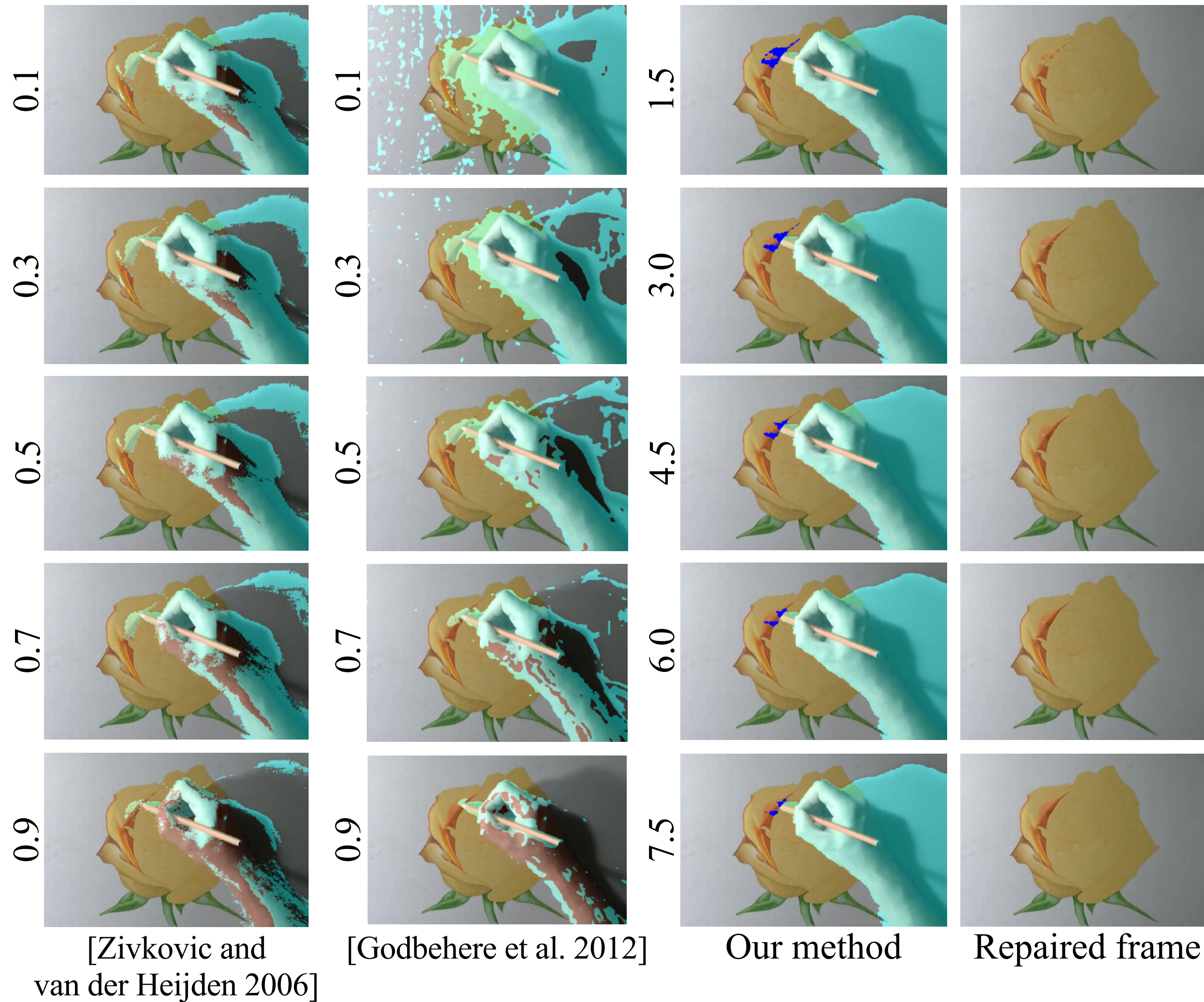
K-M



Input



Preprocessing Comparison



Closest-Point Method

