

LoCoPalettes: Local Control for Palette-based Image Editing

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Jason Klein



Jianchao Tan



Jose Echevarria



Yotam Gingold



Palette-based Image Recoloring



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Palette-based Image Recoloring

- Palette selection and image editing
 - [Chang et al. 2015], [Tan et al. 2016], [Tan et al. 2018], [Chao et al. 2021]

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Photo by Tobi

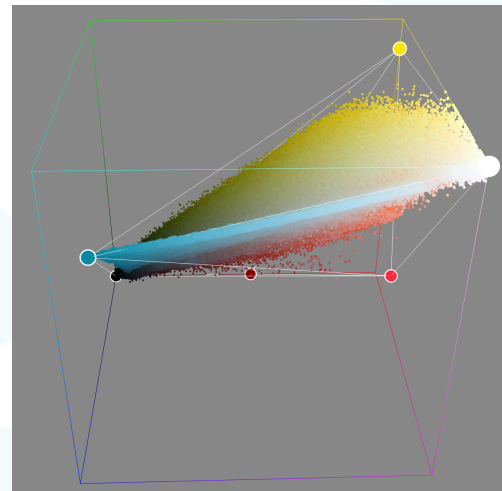
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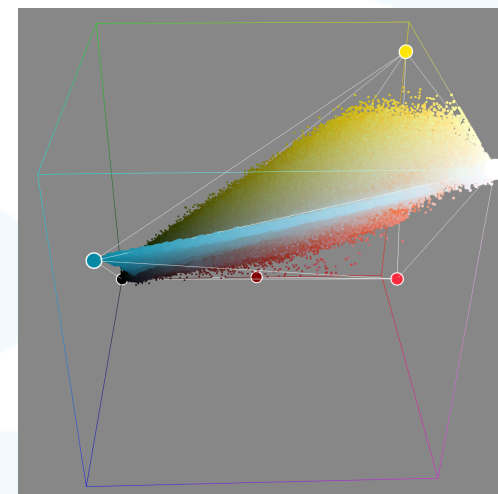
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$$I = W \cdot P$$

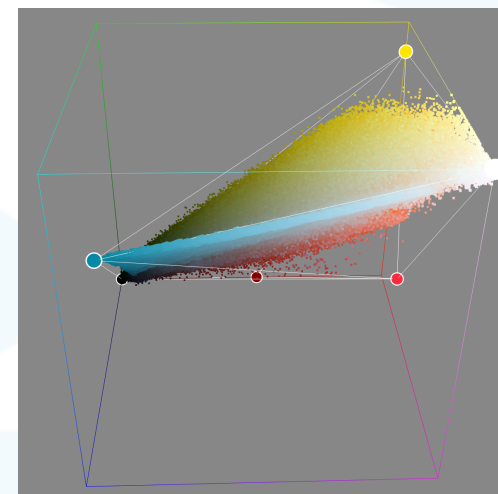
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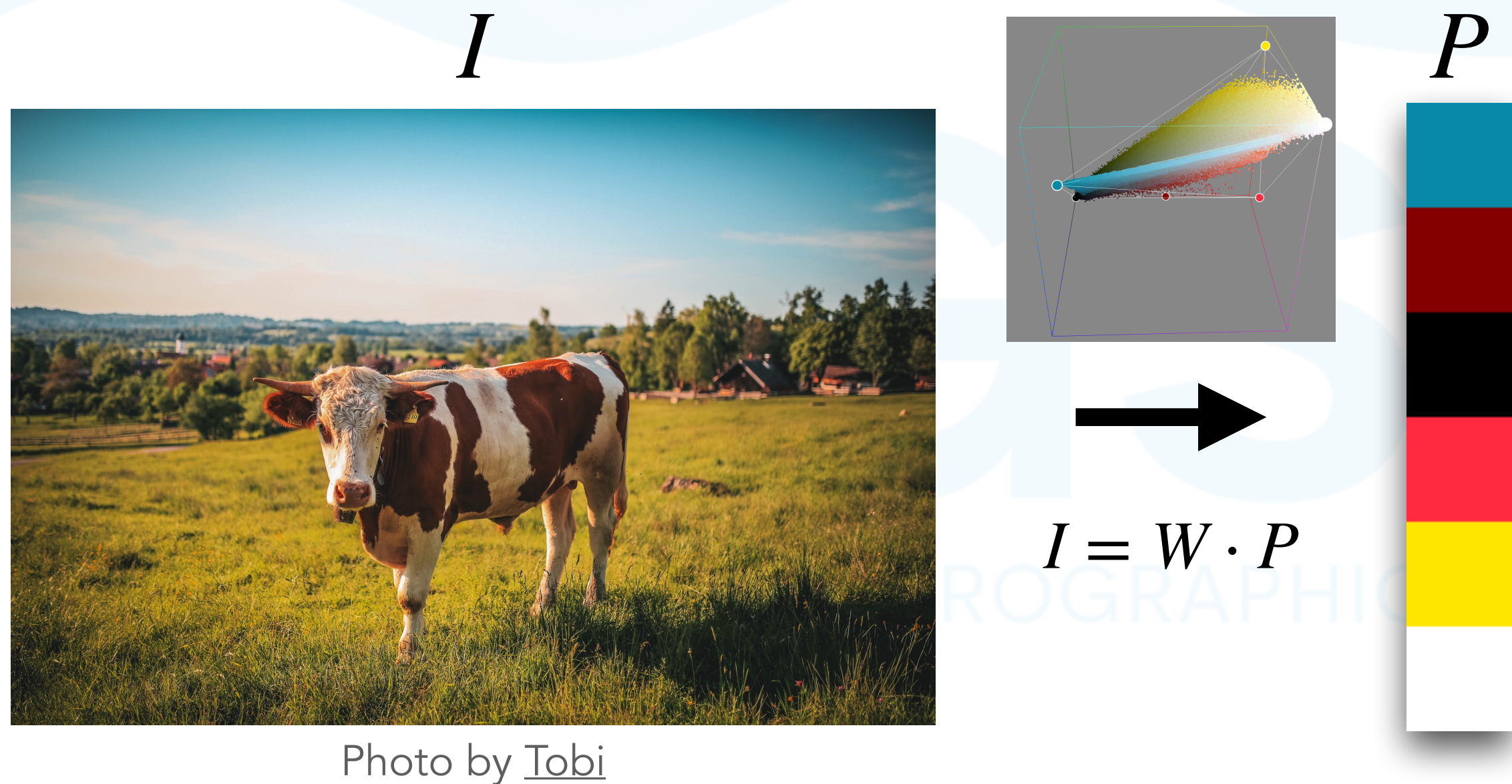
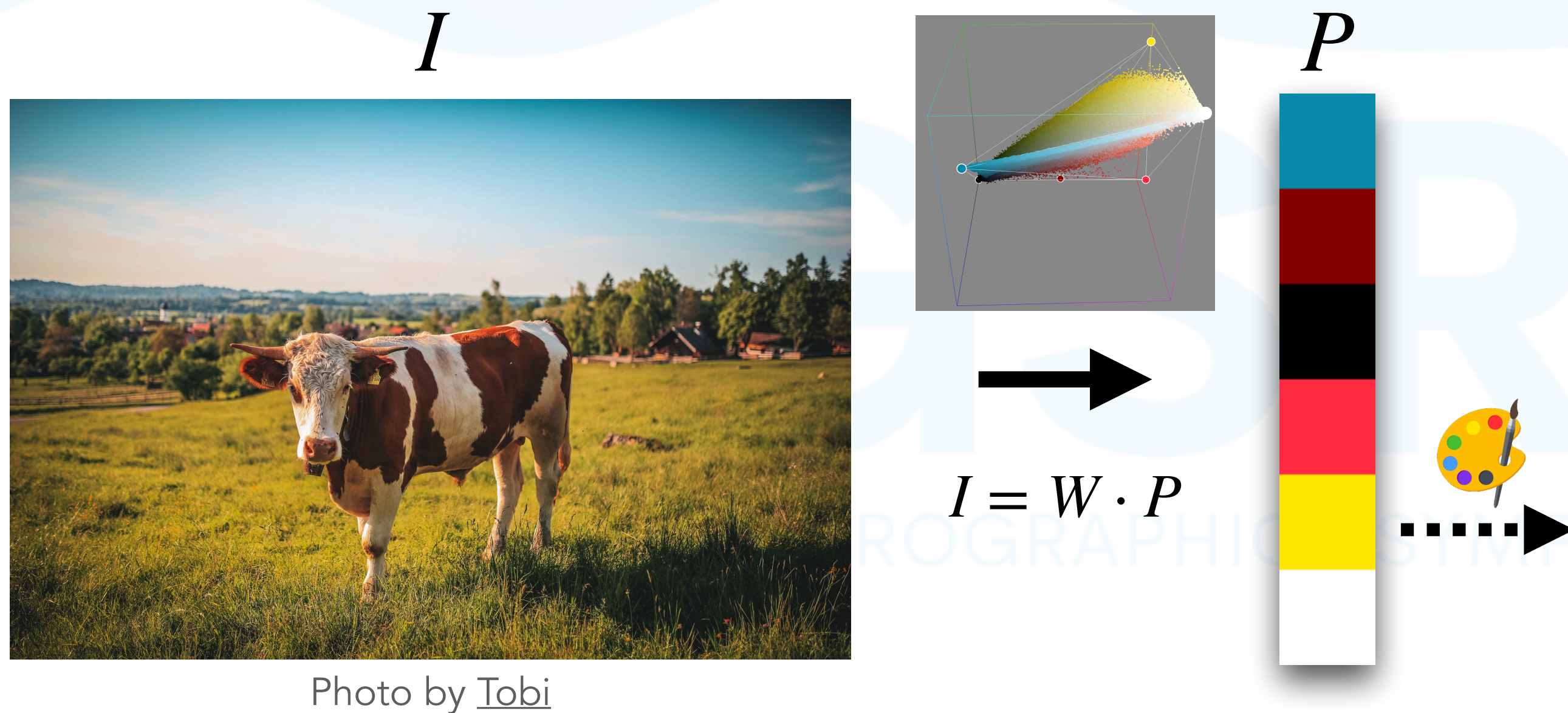


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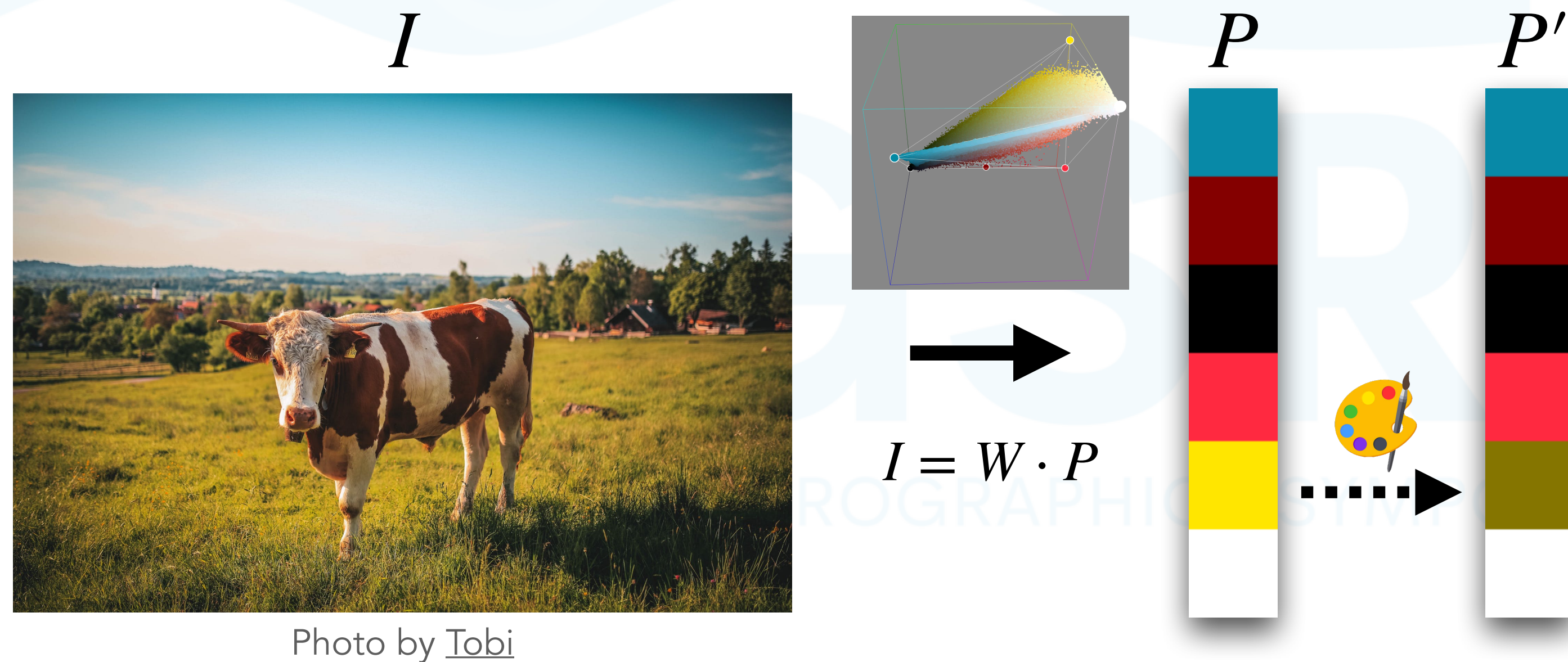
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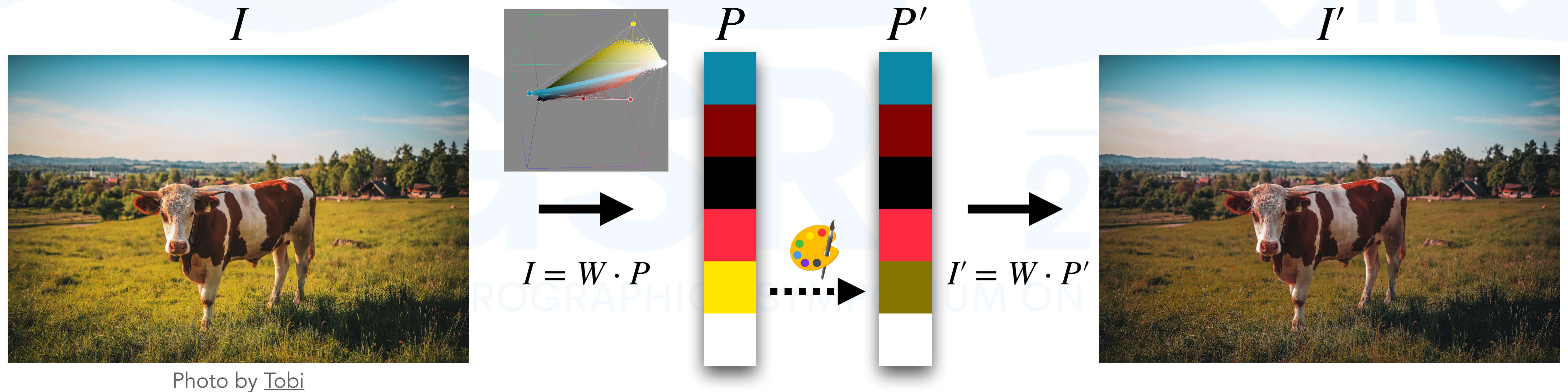


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What's the problem?



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What's the problem?

- How to change a color of a specific pixel into another color?

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- How to change a color of a specific pixel into another color?
 - It's **tedious** when the color mixture of the pixel is nonobvious

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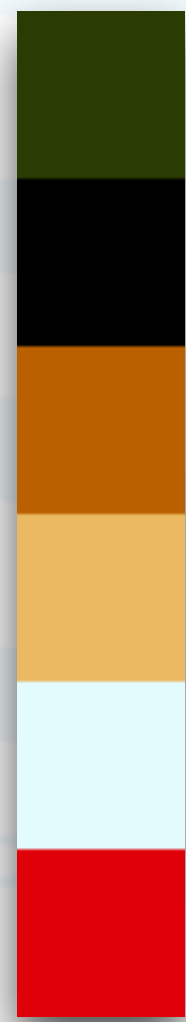
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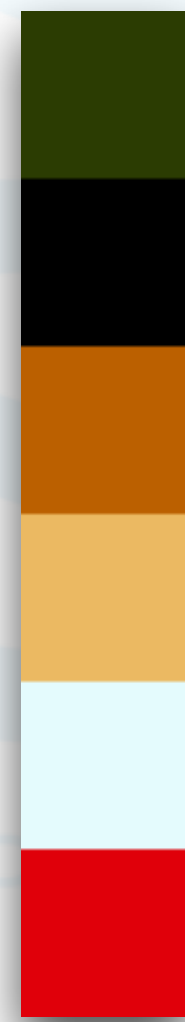
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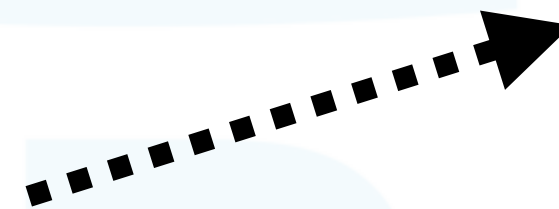
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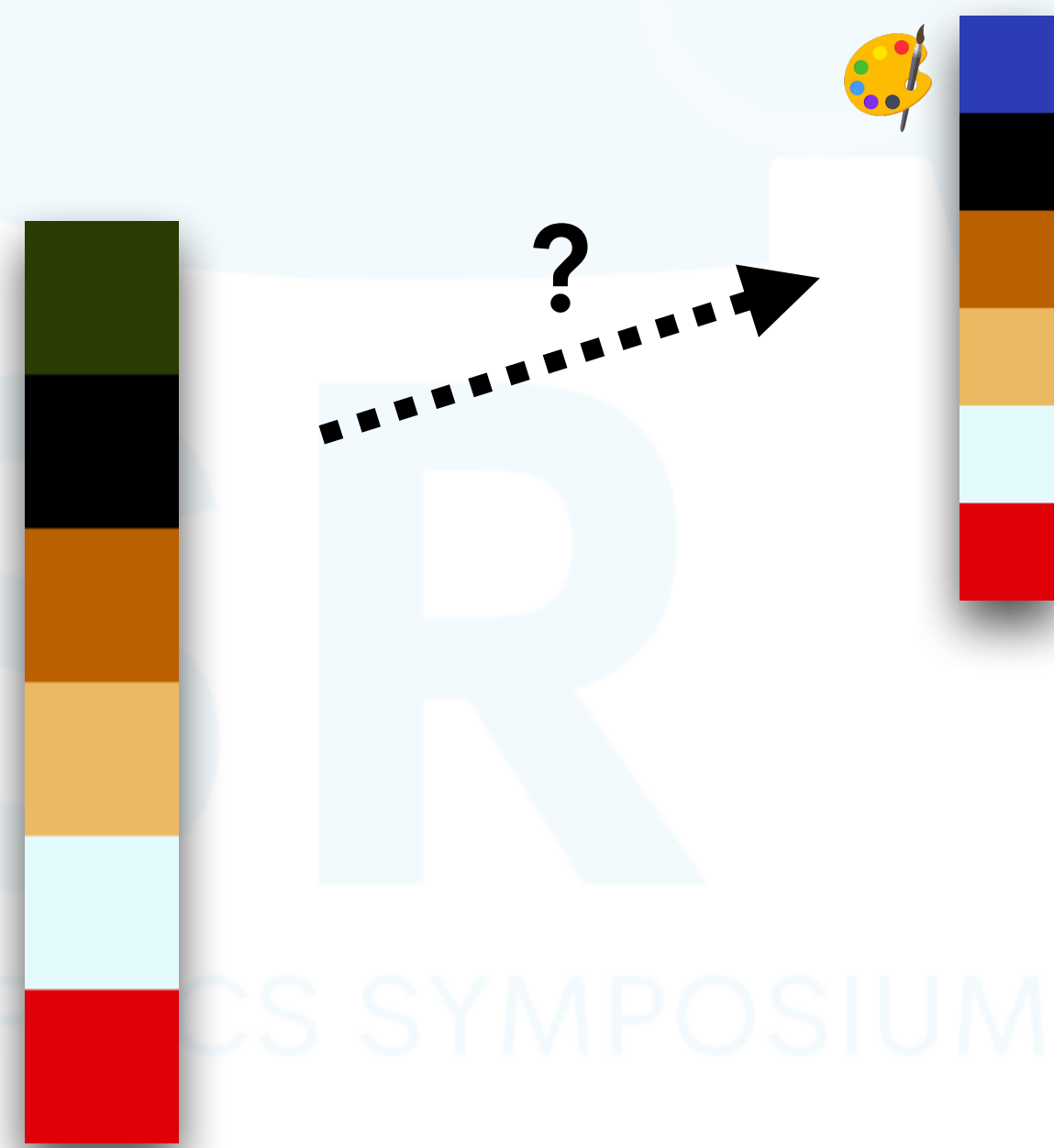
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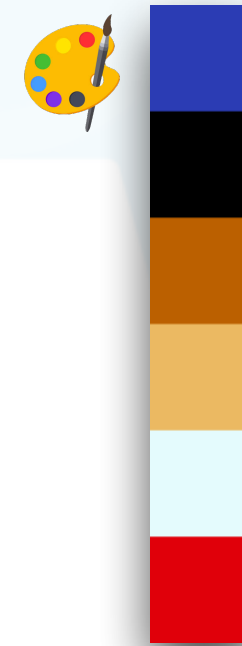
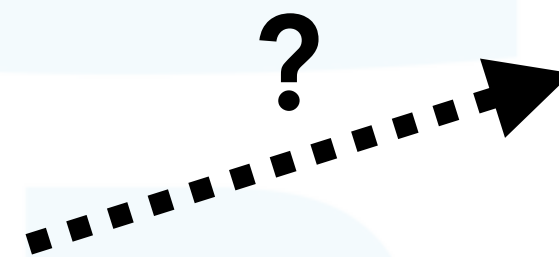
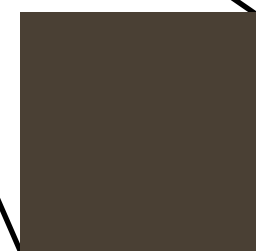
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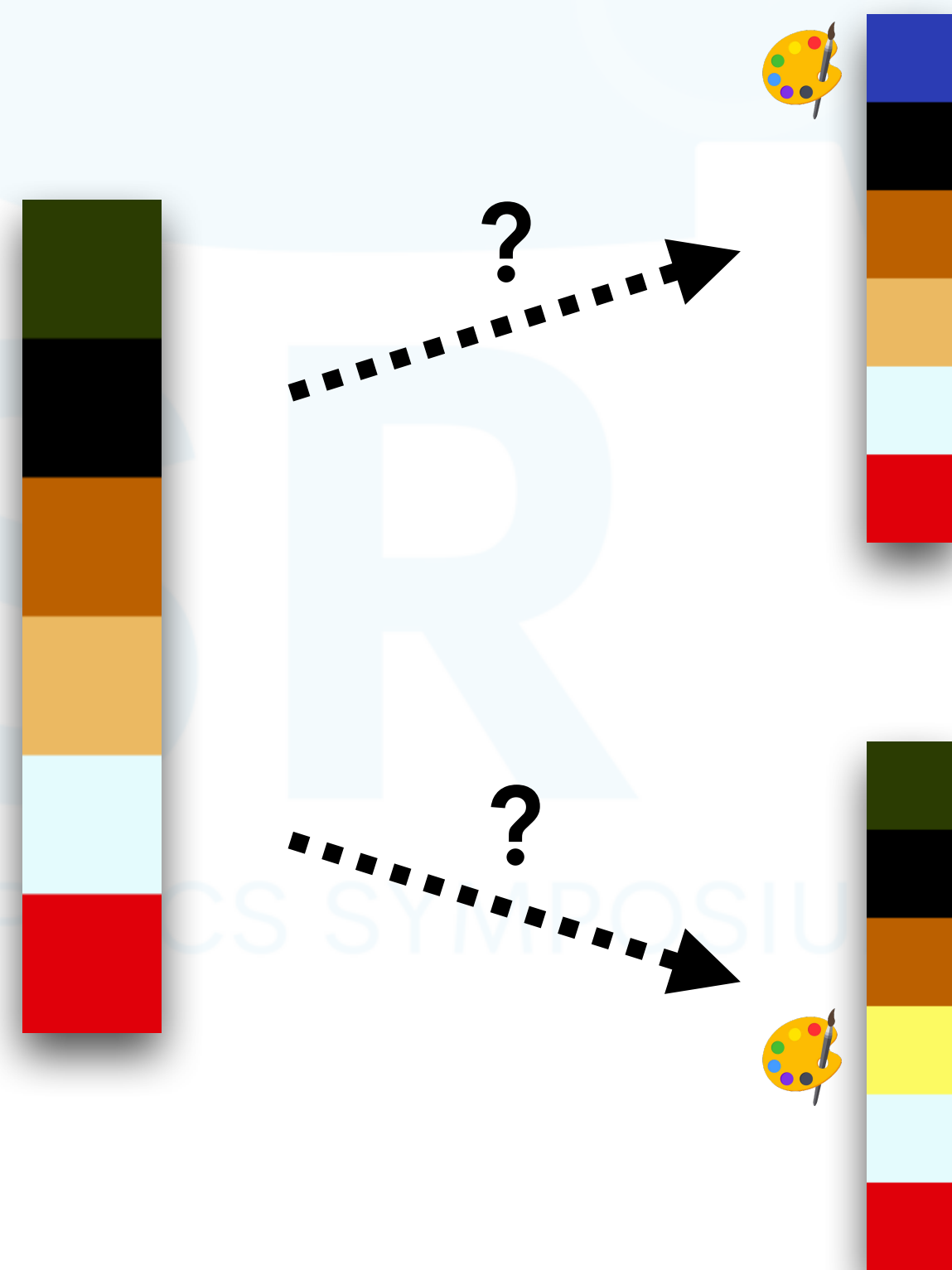
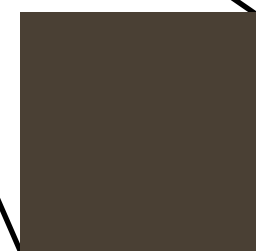
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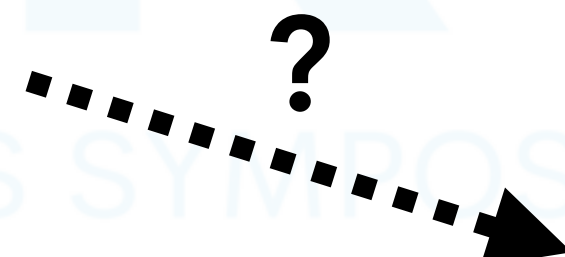
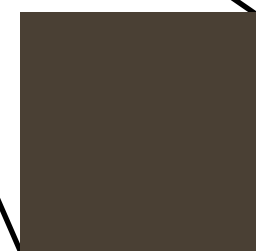
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ColorfulCurves [Chao et al. 2023]

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ColorfulCurves [Chao et al. 2023]

- The indirect editing problem can be solved by finding the **sparsest** palette change via an $L_{2,1}$ sparse optimization

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$$\min_{\Delta} \|\Delta\|_{2,1}$$



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$$\min_{\Delta} \|\Delta \text{ 🎨} \|_{2,1}$$

subject to

$$W \cdot (\text{ 🎨} + \Delta \text{ 🎨}) \Big|_{\odot} = \text{ 📏}$$

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$$I' = W \cdot (\text{palette} + \Delta \text{palette})$$

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$$I' = W \cdot (\text{ 🎨} + \Delta \text{ 🎨})$$

There are *still* problems

A stylized, light blue landscape with rolling hills and a windmill on the right side. The windmill has four blades and a small building at its base. The overall aesthetic is clean and modern.

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There are *still* problems

- The applied edits are not sparse enough

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There are *still* problems

- The applied edits are not sparse enough
 - Why is sparsity important?

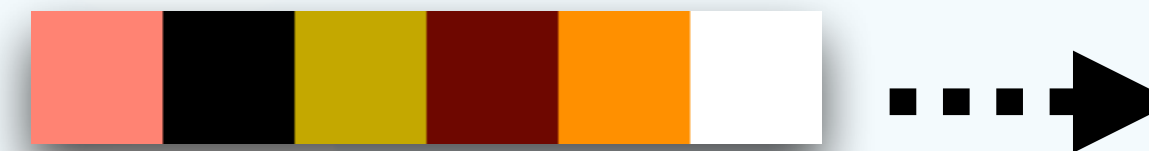
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[Tan et al. 2018]

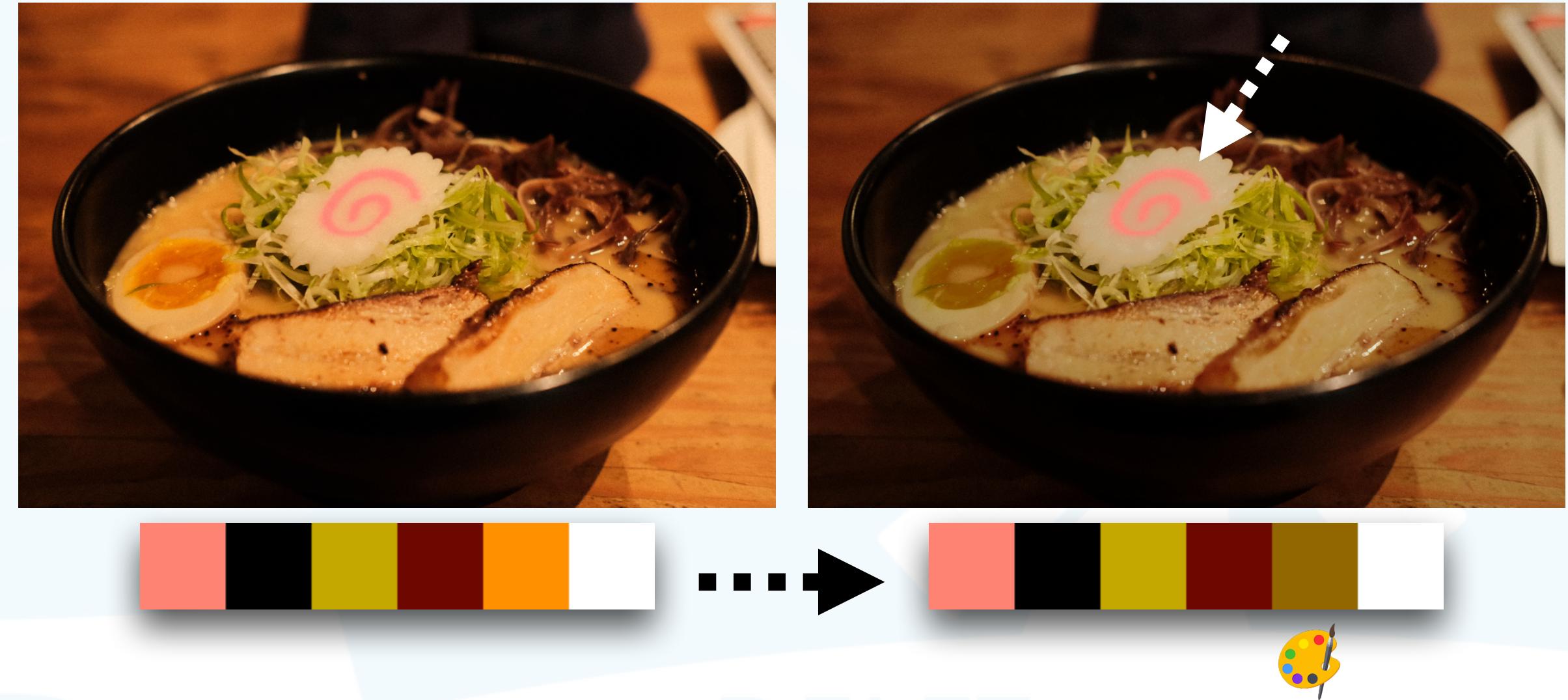
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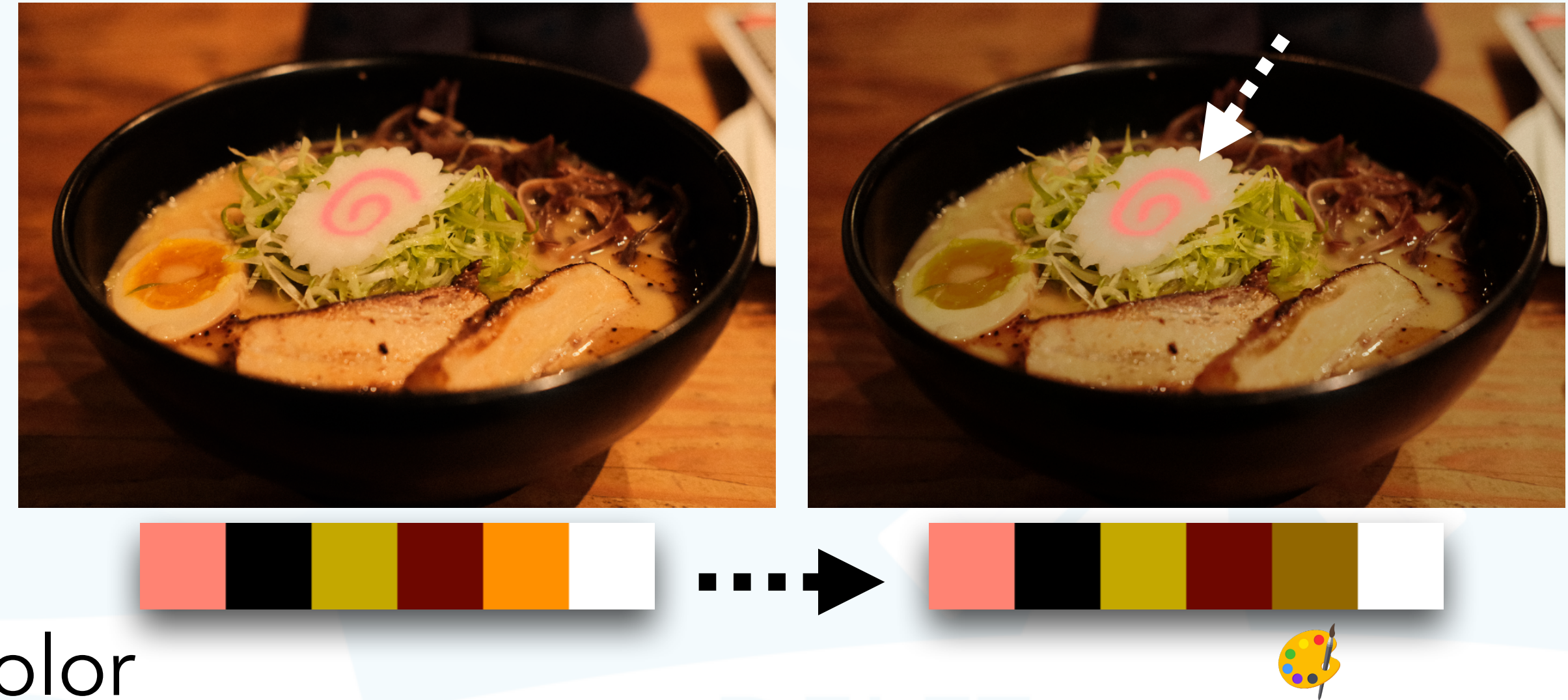
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There are *still* problems

[Tan et al. 2018]

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 - Two different objects share the same color



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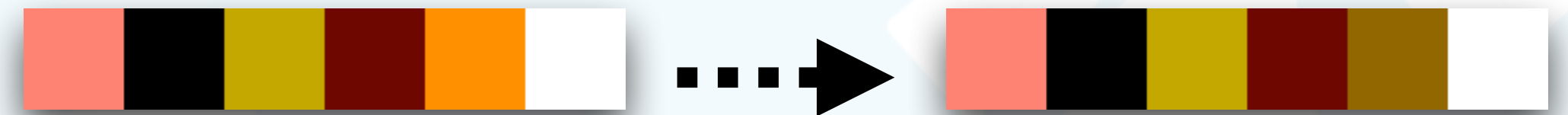
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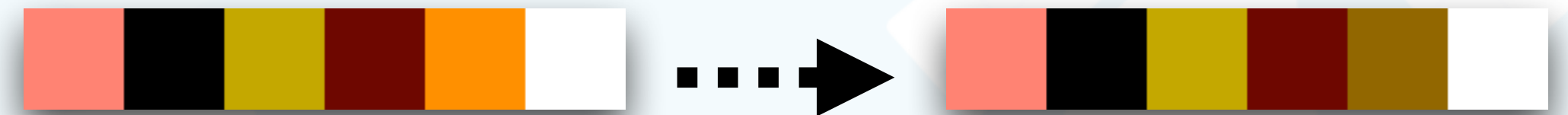
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- Two different objects share the same color



[Tan et al. 2018], [Chao et al. 2023]



Our Workflow



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Our Workflow



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Our Workflow



Our Workflow



Our Workflow



Our Workflow



Our Workflow



- Each edit needs to be applied in a sparse way

Our Workflow



- Each edit needs to be applied in a sparse way
- Each image-space constraint must be satisfied

Sparser Weights

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Geometric Palette

A stylized, light blue landscape with rolling hills and a windmill on the right side. The windmill has four blades and a small house-like base. The background is a gradient of light blue.

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Geometric Palette

- Two-level decomposition [Tan et al. 2018]

Geometric Palette

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Image *I*



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RGB palette P



Image I



Geometric Palette

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RGBXY convex hull vertices

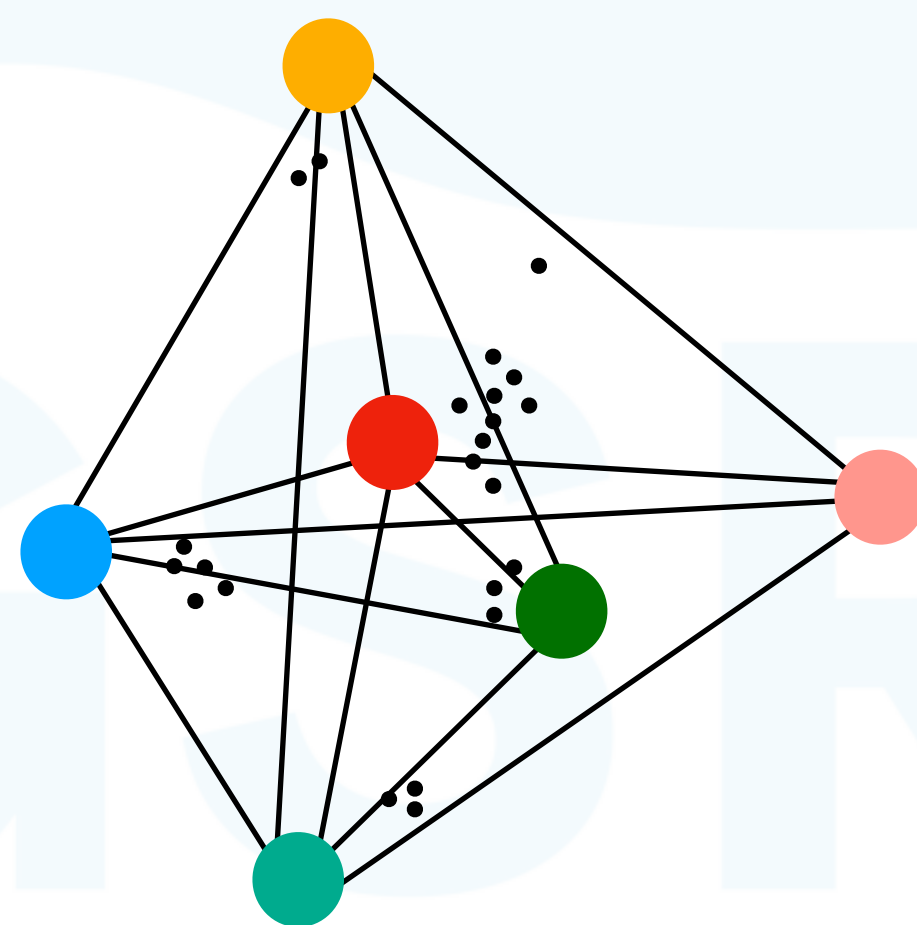


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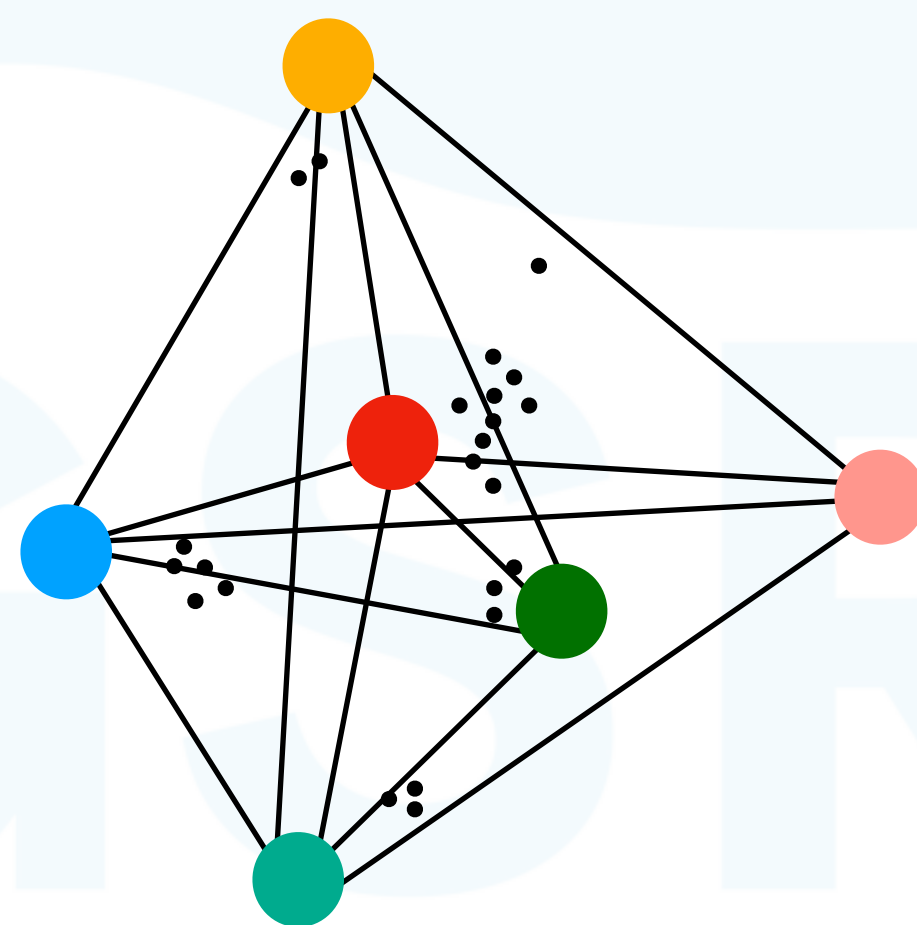


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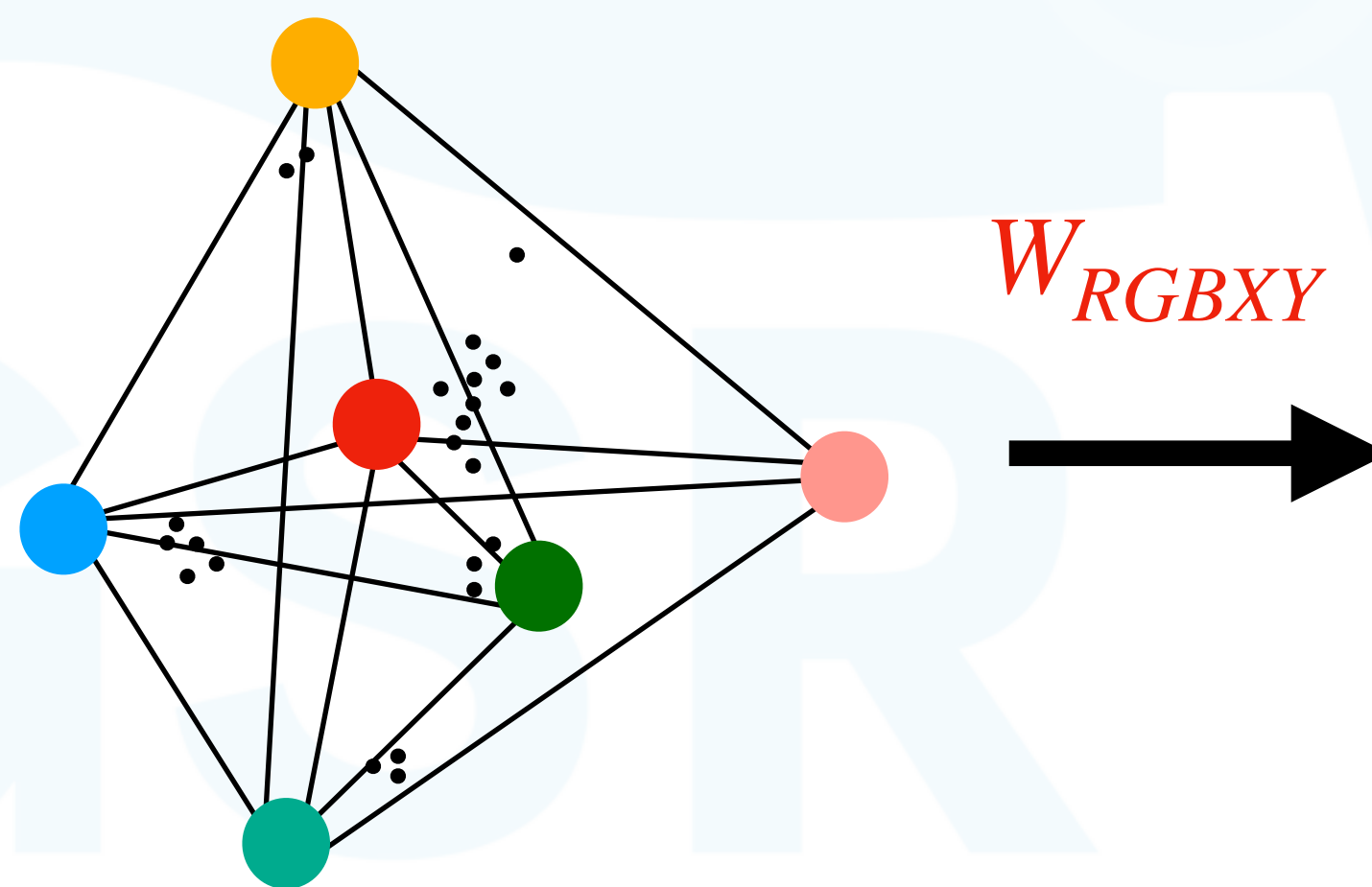


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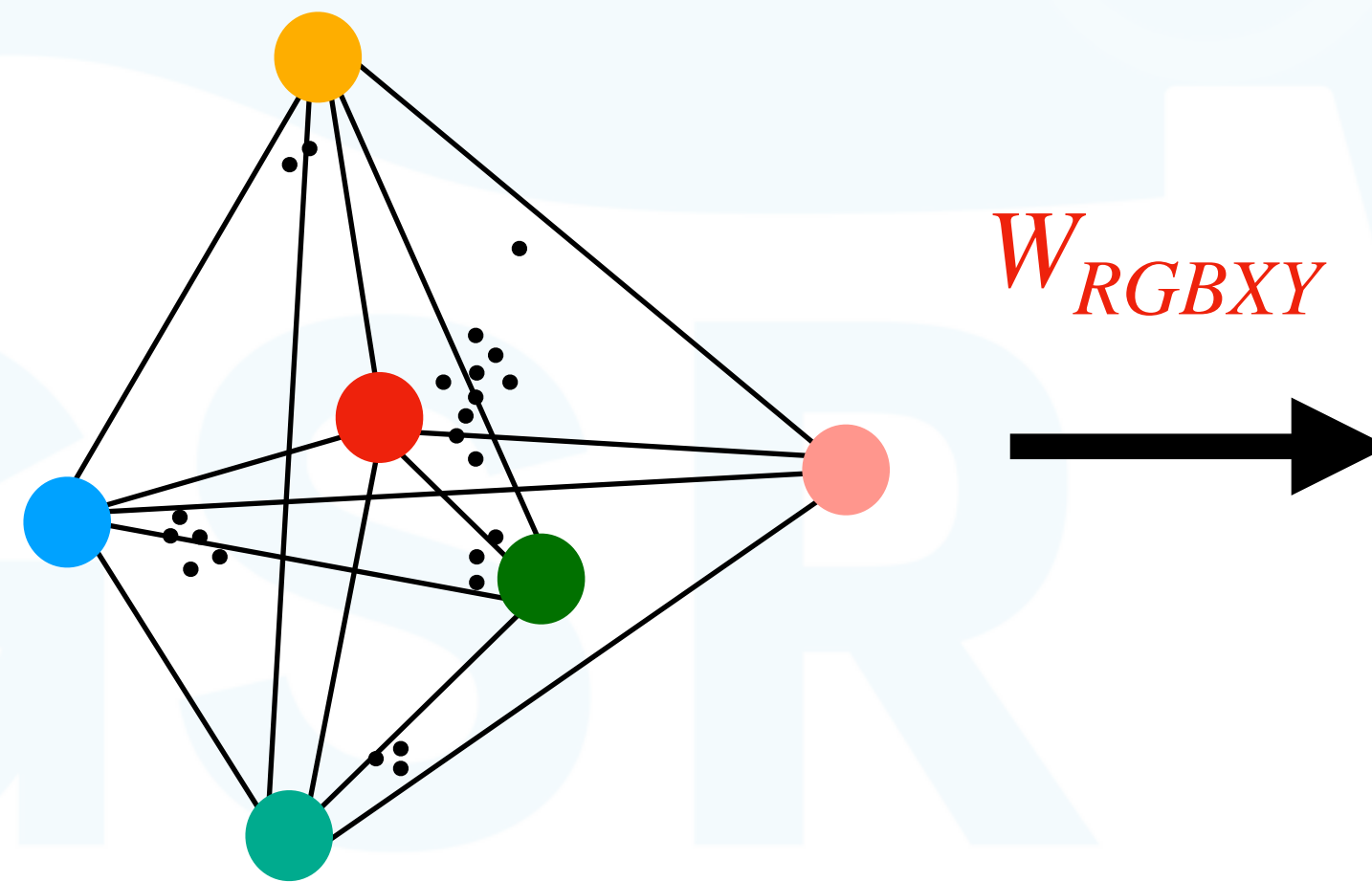


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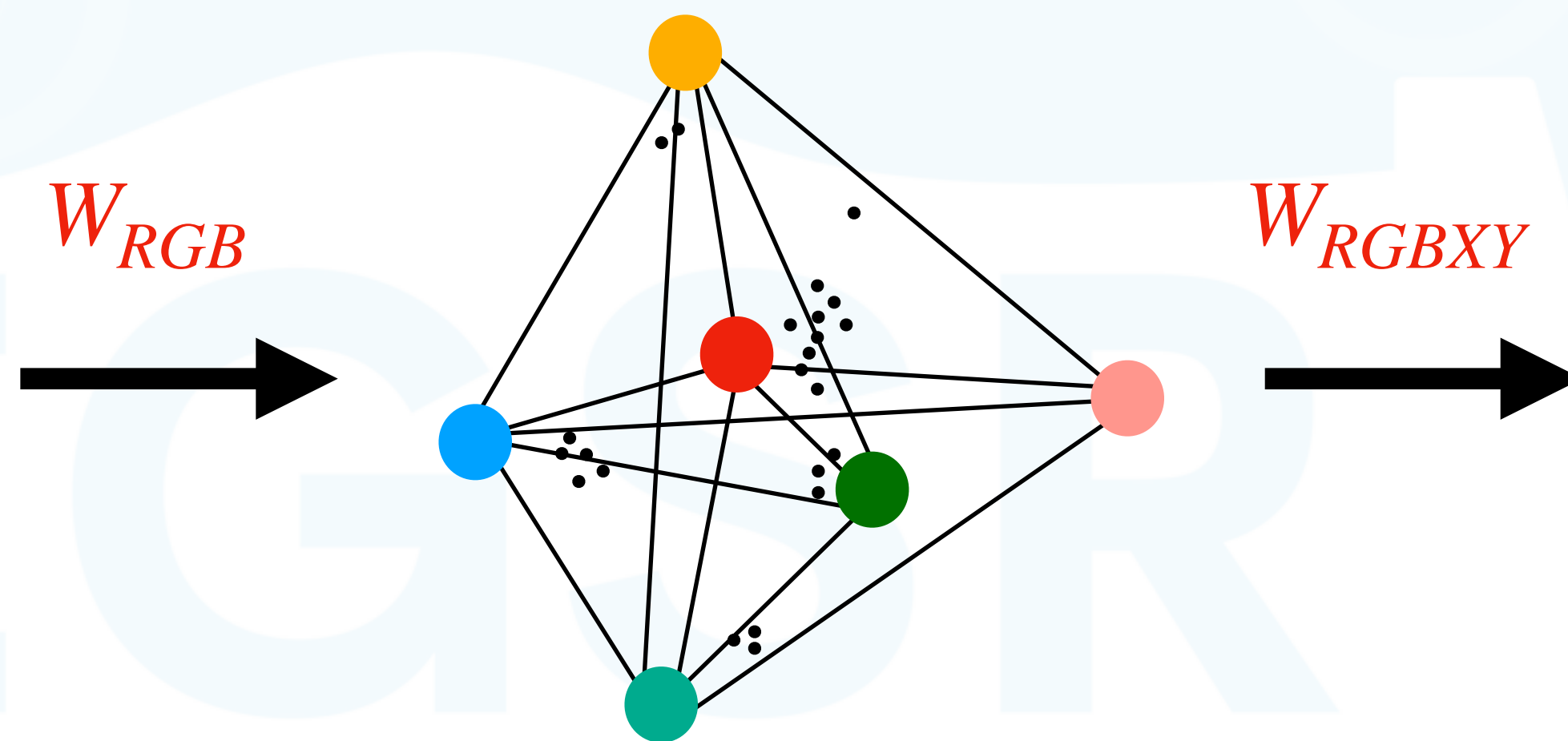


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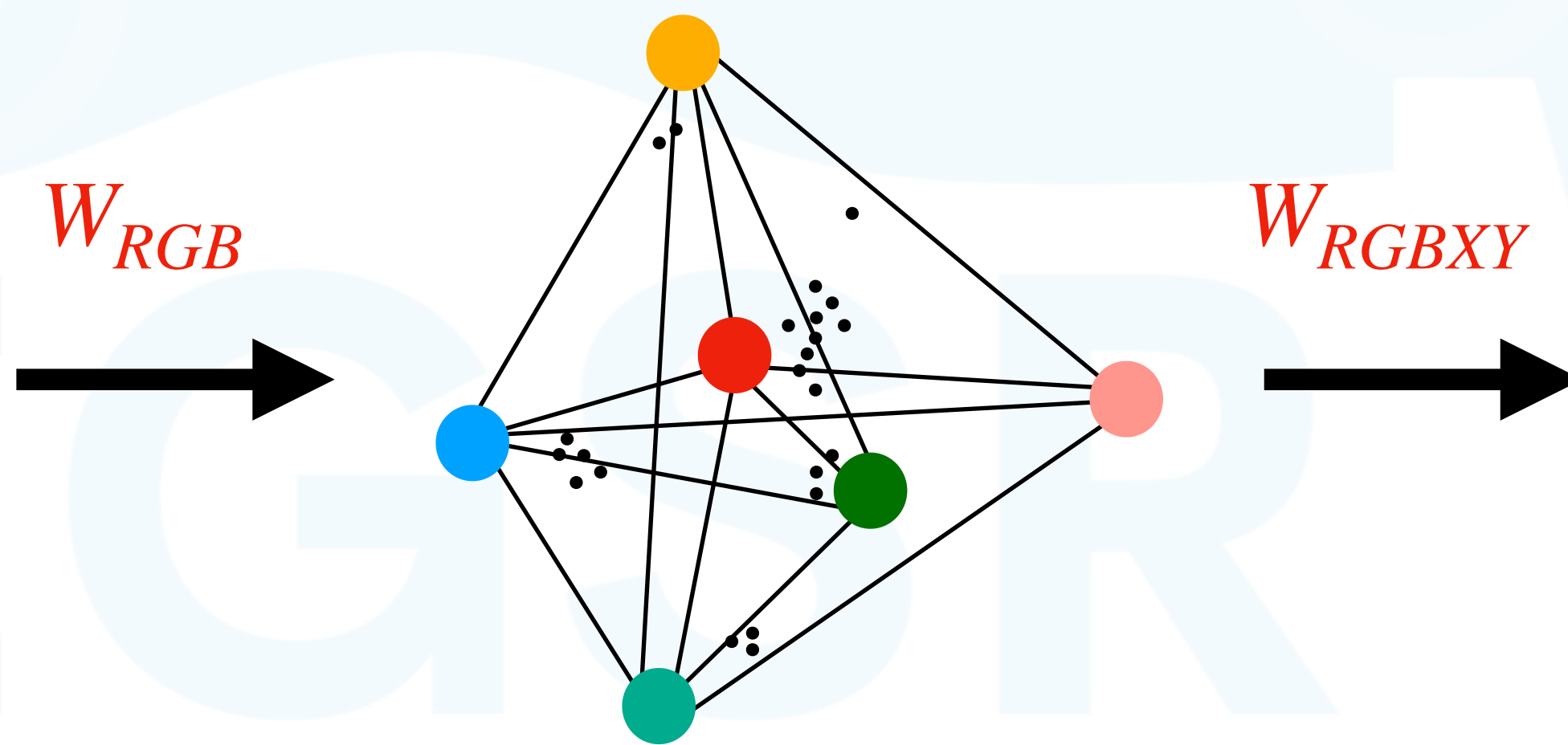


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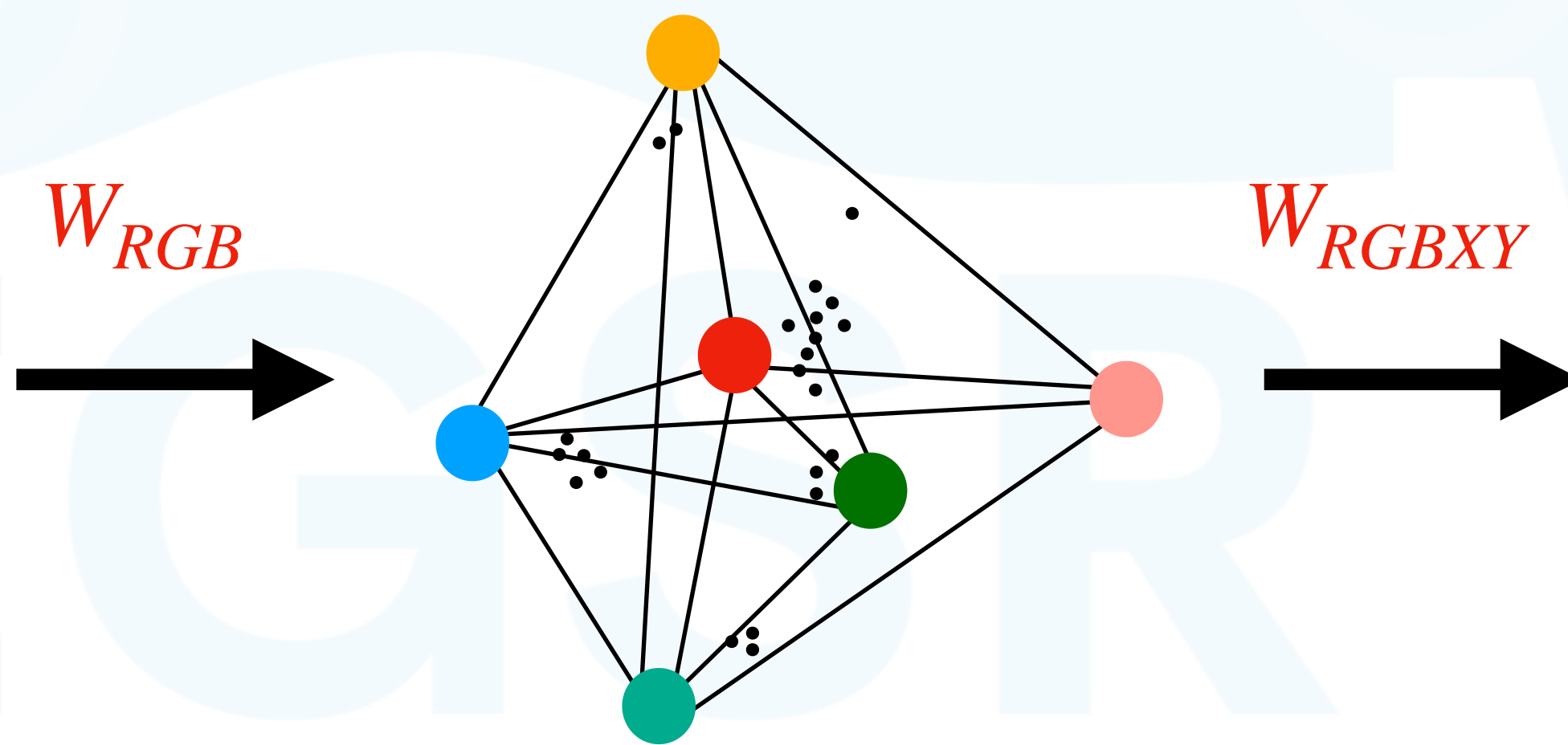


Image I



$$I = W_{RGBXY} \cdot (W_{RGB} \cdot P)$$

Sparsest Weights

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Sparsest Weights

- Observation: how to achieve maximum sparsity?

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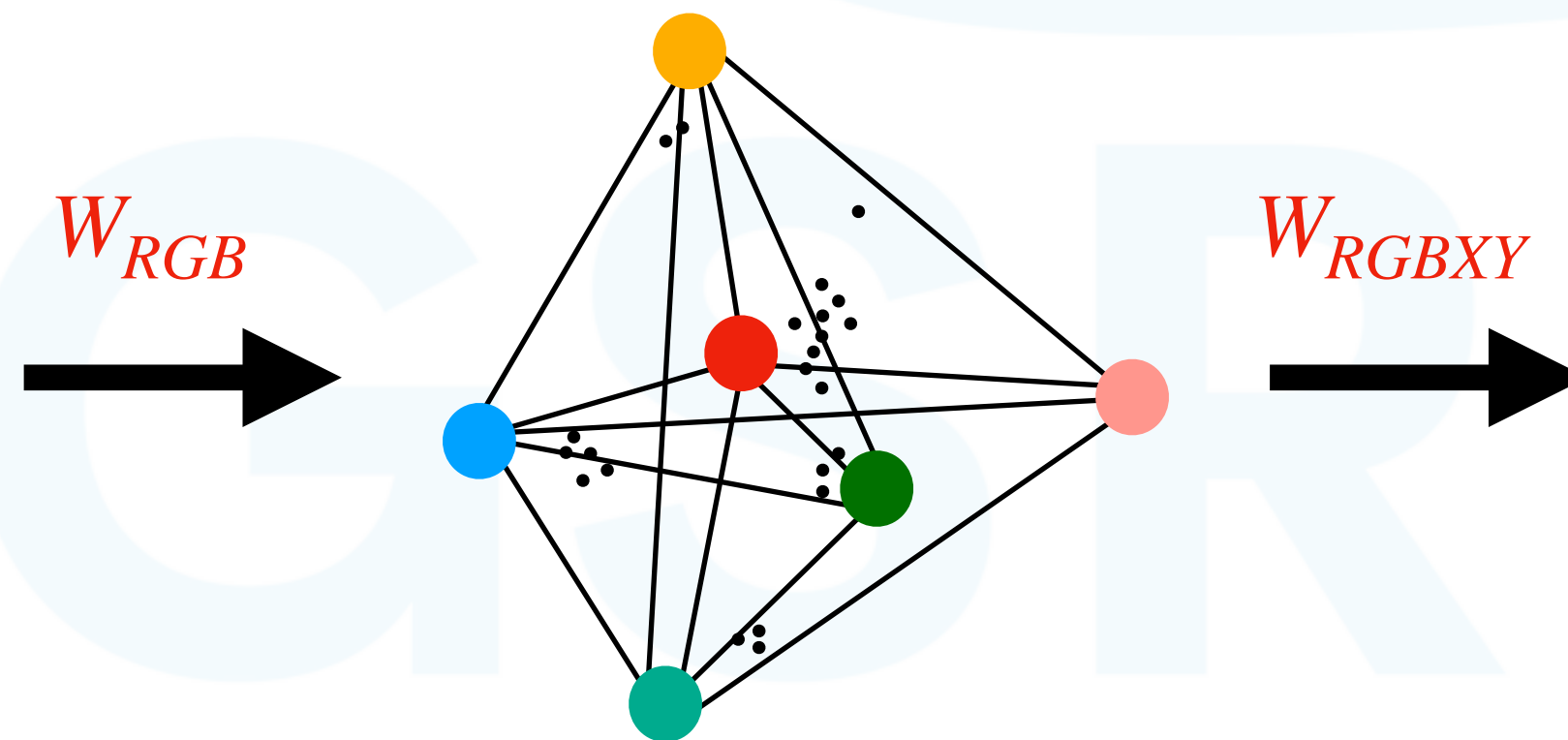


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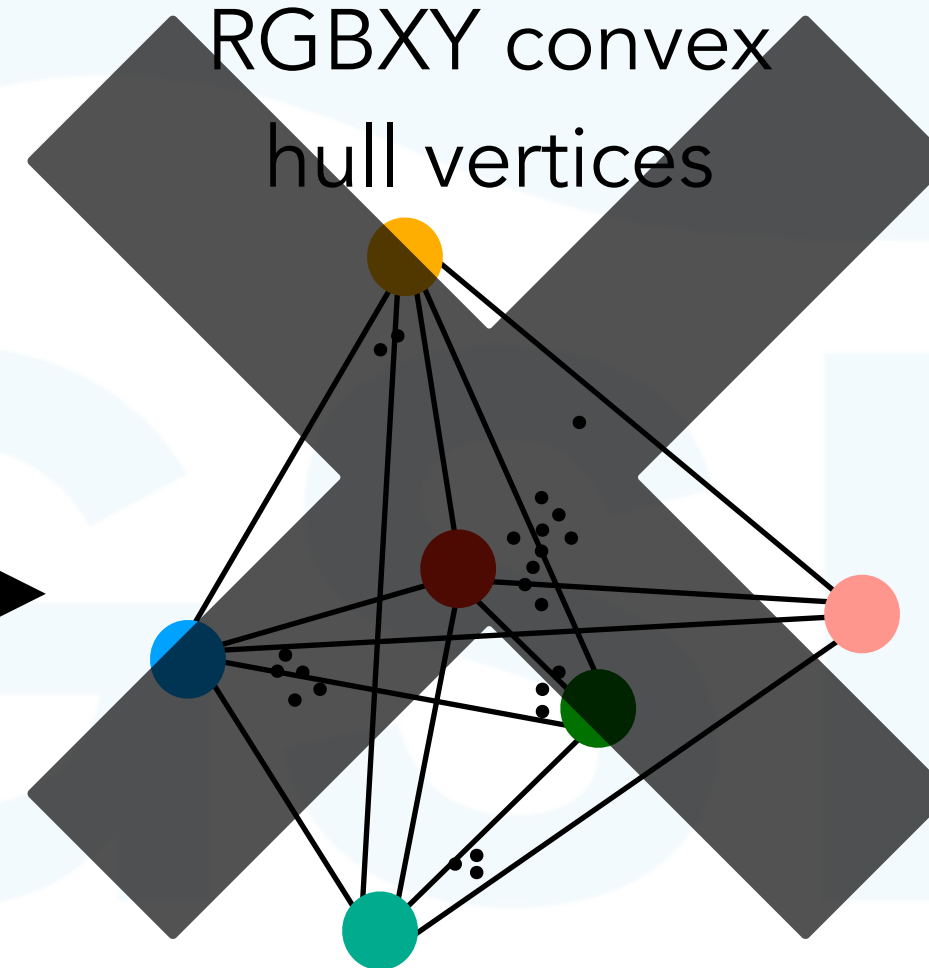
RGB palette P



W_{RGB}



RGBXY convex hull vertices



W_{RGBXY}



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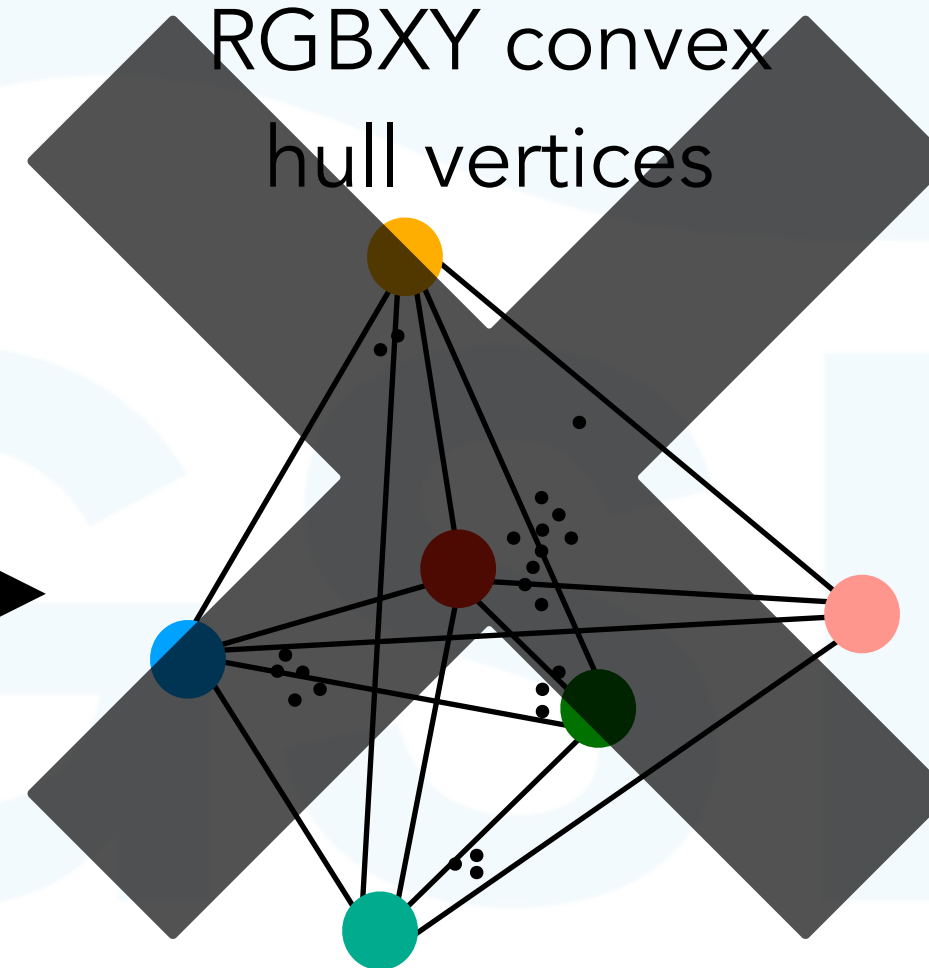
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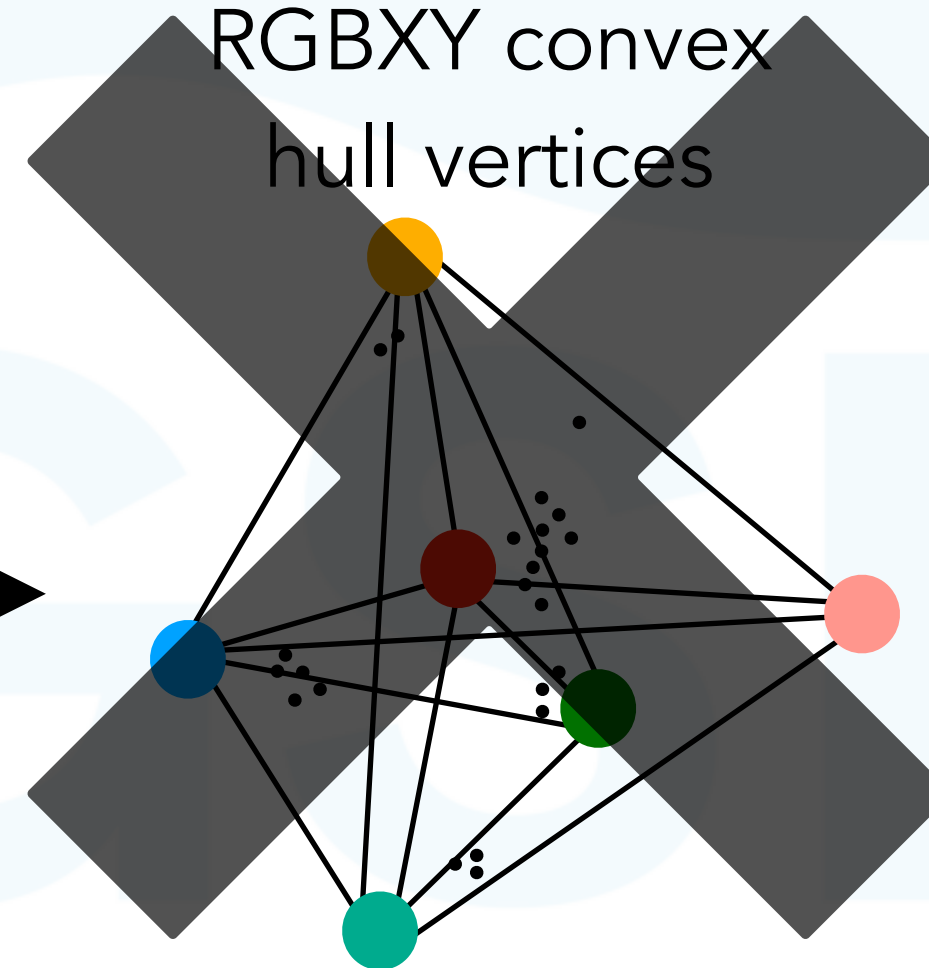
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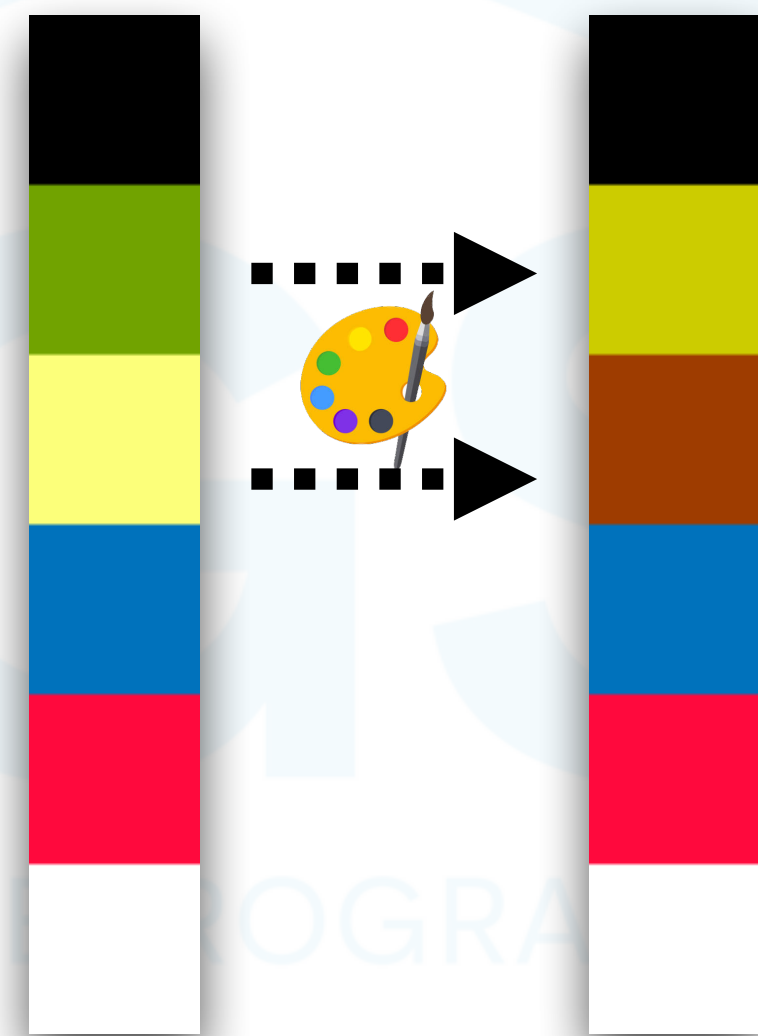
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Sparsest Weights

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Only RGB palette

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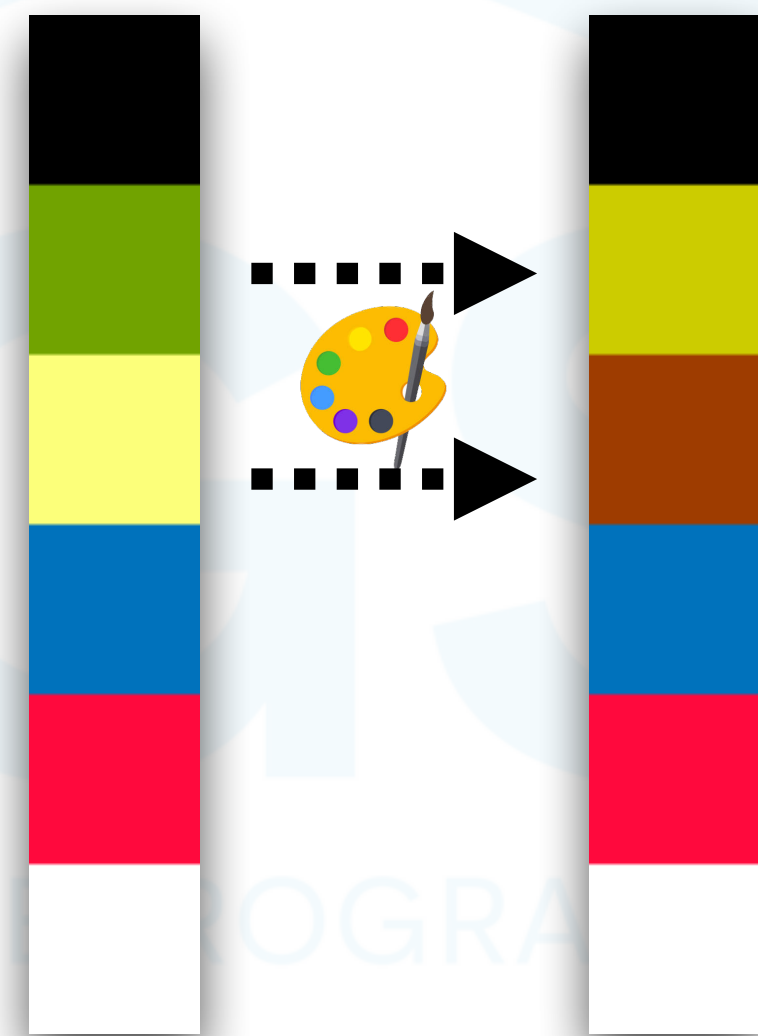
Only RGB palette



[Tan et al. 2018]

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[Tan et al. 2018]

Sparser Weights

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Sparser Weights

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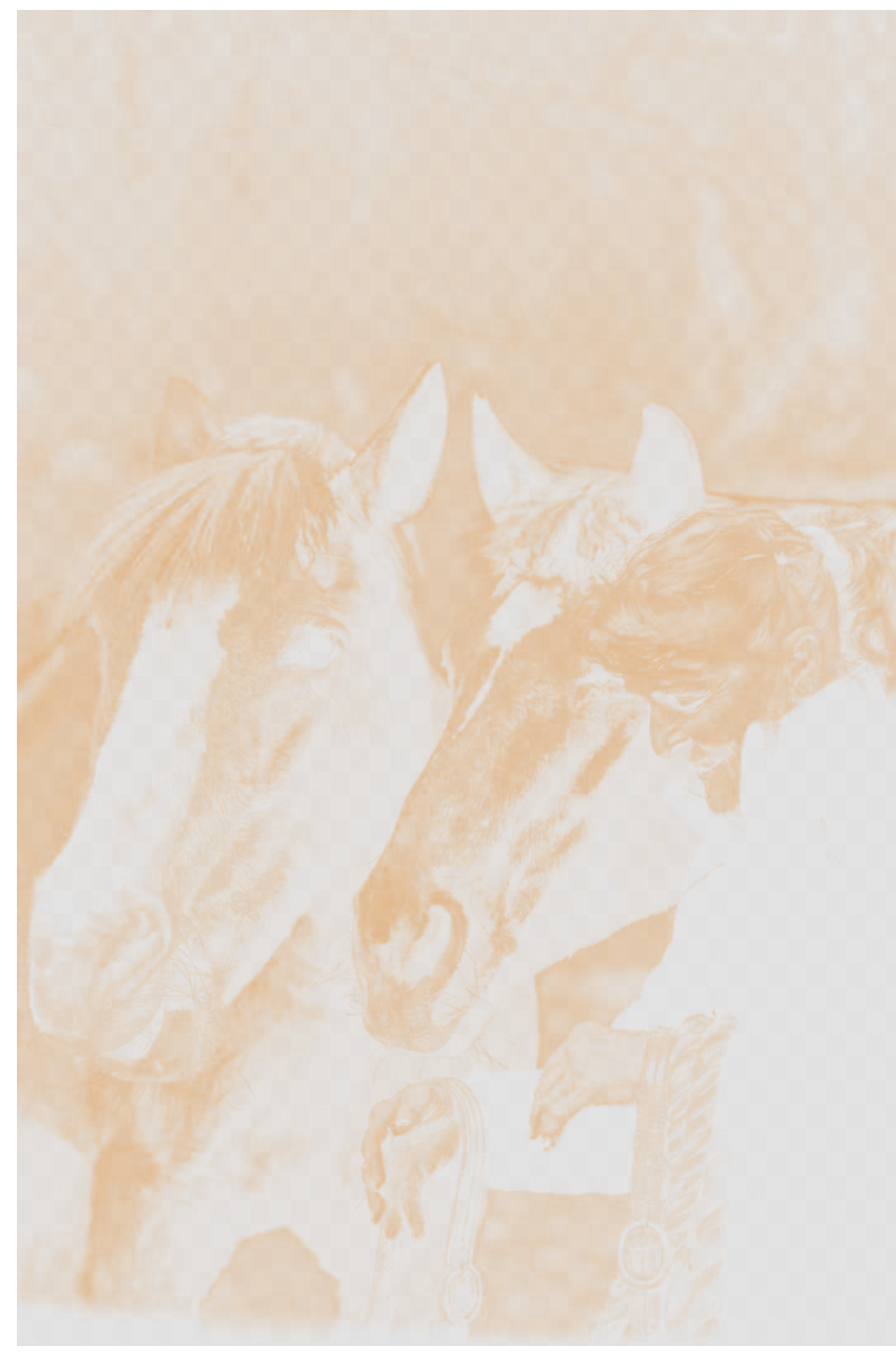
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 - Concatenate image data with feature vectors [Aksoy et al. 2018] $\rightarrow I_{RGBFEAXY}$
 - Internal vertices are $V_A = \text{ConvexHull}(\text{PCA}(I_{RGBFEAXY}, \mathbf{dim=5})) |_{RGBXY}$



Ours



[Tan et al. 2018]

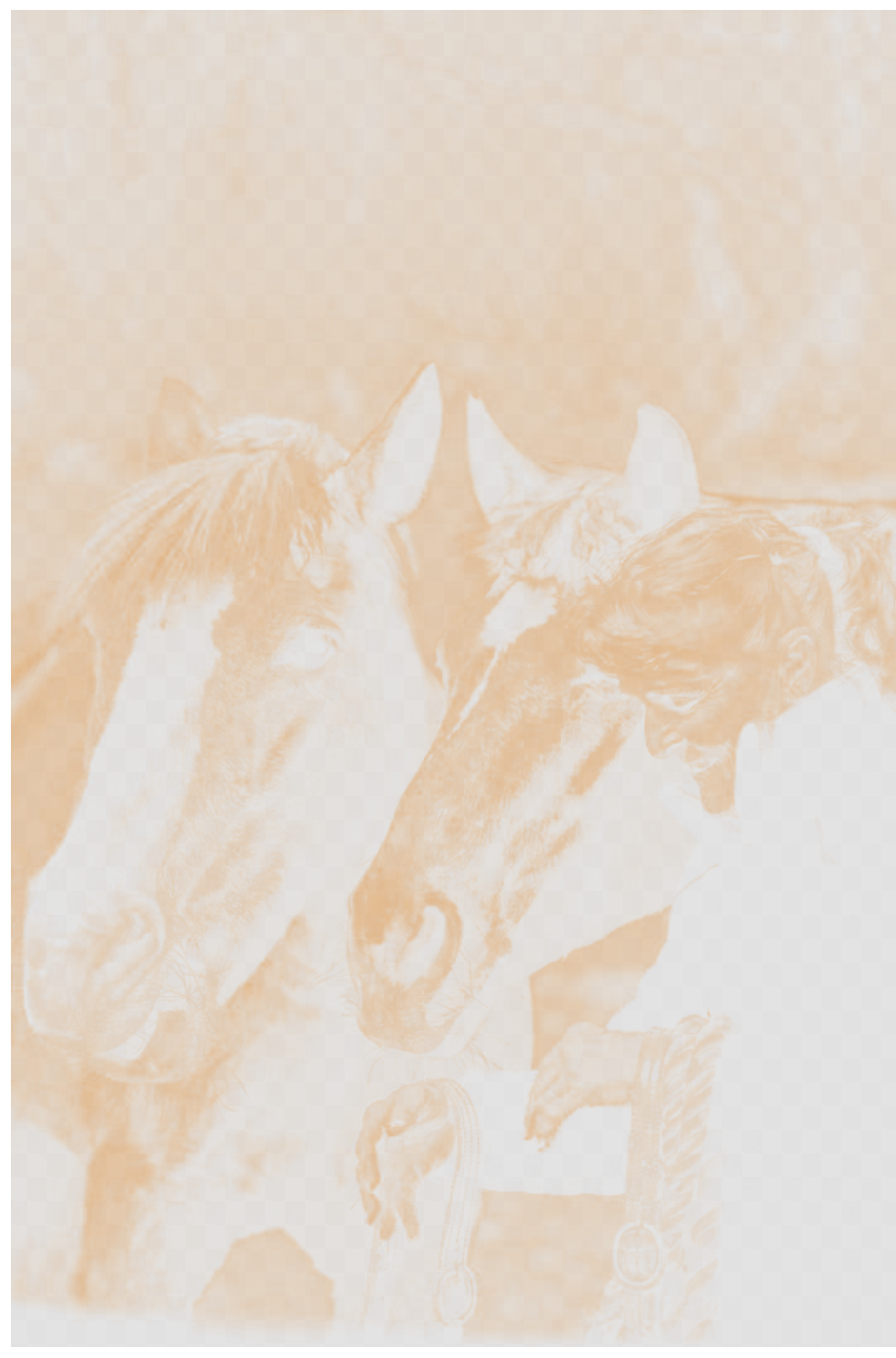




Ours



[Tan et al. 2018]





Ours



[Tan et al. 2018]



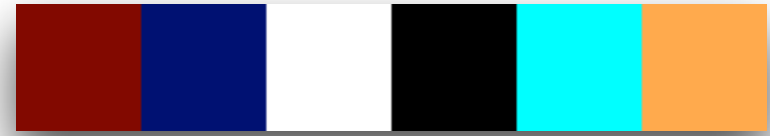


Ours



[Tan et al. 2018]





Ours

[Tan et al. 2018]





Ours

[Tan et al. 2018]





Ours



[Tan et al. 2018]



Sparse Editing

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Sparse Editing

- Follow [Chao et al. 2023]: Solve for minimum palette change

Sparse Editing

- Follow [Chao et al. 2023]: Solve for minimum palette change
- image-space constraints: $\|LAB(w_x \cdot (P + \Delta P)) - LAB(c_x)\|_2 \leq JND$

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- image-space constraints: $\| \underline{LAB}(w_x \cdot (P + \Delta P)) - \underline{LAB}(c_x) \|_2 \leq \underline{JND}$
- palette constraints: $(P + \Delta P)[j] = c_P$

Sparse Editing

- Follow [Chao et al. 2023]: Solve for minimum palette change
- image-space constraints: $\| \underline{LAB(w_x \cdot (P + \Delta P))} - \underline{LAB(c_x)} \|_2 \leq \underline{JND}$
- palette constraints: $\underline{(P + \Delta P)[j]} = c_p$

Sparse Editing

- Follow [Chao et al. 2023]: Solve for minimum palette change
- image-space constraints: $\| \underline{LAB}(w_x \cdot (P + \Delta P)) - \underline{LAB}(c_x) \|_2 \leq \underline{JND}$
- palette constraints: $\underline{(P + \Delta P)[j]} = \underline{c_P}$

Sparse Editing

- Follow [Chao et al. 2023]: Solve for minimum palette change
 - image-space constraints: $\| \underline{LAB}(w_x \cdot (P + \Delta P)) - \underline{LAB}(c_x) \|_2 \leq \underline{JND}$
 - palette constraints: $\underline{(P + \Delta P)[j]} = \underline{c_P}$
- All together:

Sparse Editing

- Follow [Chao et al. 2023]: Solve for minimum palette change
 - image-space constraints: $\| \underline{LAB}(w_x \cdot (P + \Delta P)) - \underline{LAB}(c_x) \|_2 \leq \underline{JND}$
 - palette constraints: $\underline{(P + \Delta P)[j]} = \underline{c_P}$
- All together:
 - $\min_{\Delta P} \|\Delta P\|_{2,1}$

Sparse Editing

- Follow [Chao et al. 2023]: Solve for minimum palette change
 - image-space constraints: $\| \underline{LAB(w_x \cdot (P + \Delta P))} - \underline{LAB(c_x)} \|_2 \leq \underline{JND}$
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- All together:
 - $\min_{\Delta P} \| \underline{\Delta P} \|_{2,1}$

Sparse Editing

- Follow [Chao et al. 2023]: Solve for minimum palette change
 - image-space constraints: $\| \underline{LAB}(w_x \cdot (P + \Delta P)) - \underline{LAB}(c_x) \|_2 \leq \underline{JND}$
 - palette constraints: $\underline{(P + \Delta P)[j]} = \underline{c_P}$
- All together:
 - $\min_{\Delta P} \|\Delta P\|_{2,1}$
 - Subject to $0 \leq P + \Delta P \leq 1$ and

Sparse Editing

- Follow [Chao et al. 2023]: Solve for minimum palette change

- image-space constraints: $\| \underline{LAB}(w_x \cdot (P + \Delta P)) - \underline{LAB}(c_x) \|_2 \leq \underline{JND}$ ①

- palette constraints: $\underline{(P + \Delta P)[j]} = \underline{c_P}$

- All together:

- $\min_{\Delta P} \|\underline{\Delta P}\|_{2,1}$

- Subject to $0 \leq P + \Delta P \leq 1$ and ①

Sparse Editing

- Follow [Chao et al. 2023]: Solve for minimum palette change

- image-space constraints: $\| \underline{LAB}(w_x \cdot (P + \Delta P)) - \underline{LAB}(c_x) \|_2 \leq \underline{JND}$ ①

- palette constraints: $\underline{(P + \Delta P)[j]} = \underline{c_P}$ ②

- All together:

- $\min_{\Delta P} \|\underline{\Delta P}\|_{2,1}$

- Subject to $0 \leq P + \Delta P \leq 1$ and ① ②

Input



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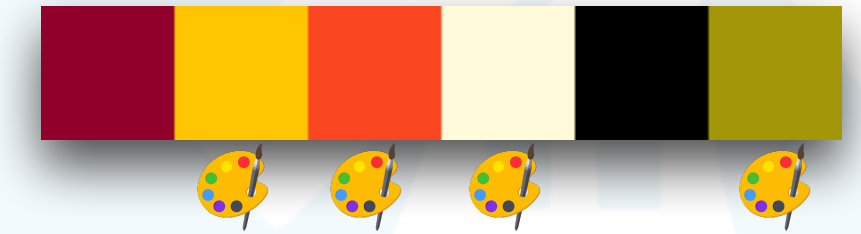
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Input



[Tan et al. 2018]

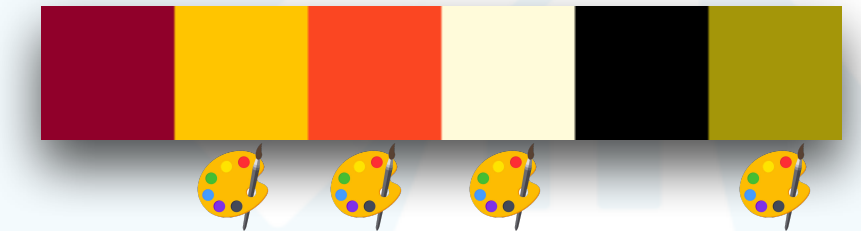


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Input

LoCoPalettes

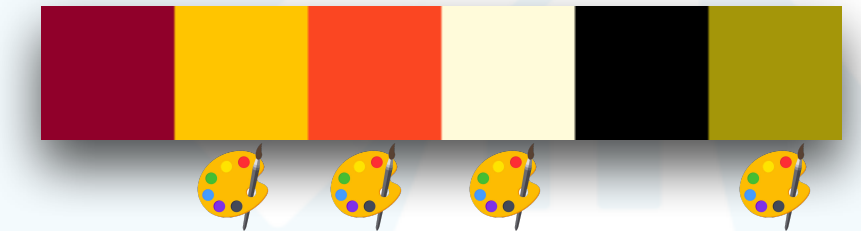
[Tan et al. 2018]



Input

LoCoPalettes

[Tan et al. 2018]



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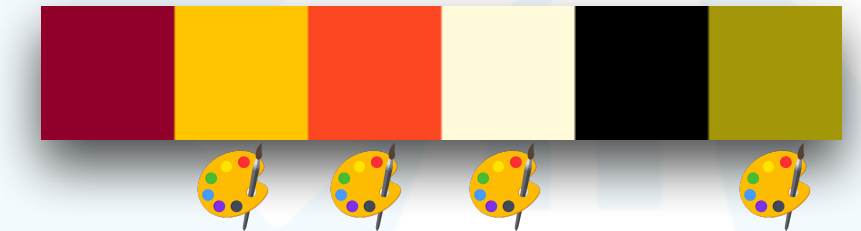
Input

LoCoPalettes

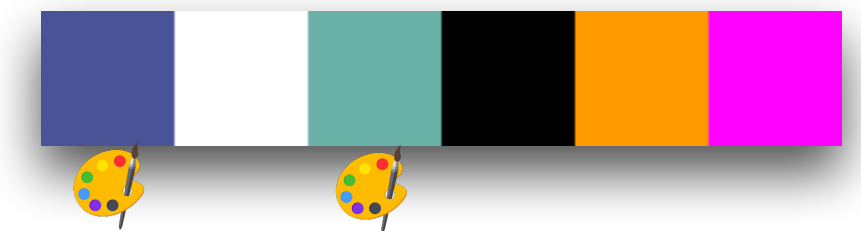
[Tan et al. 2018]



16× palette manipulations



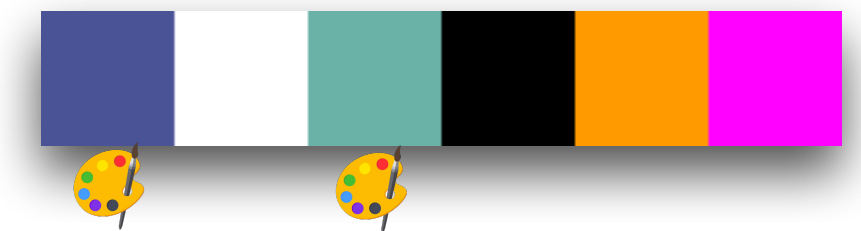
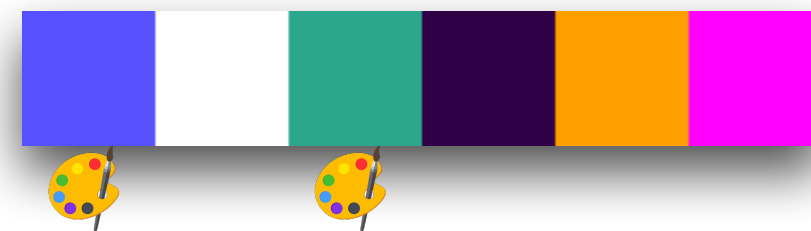
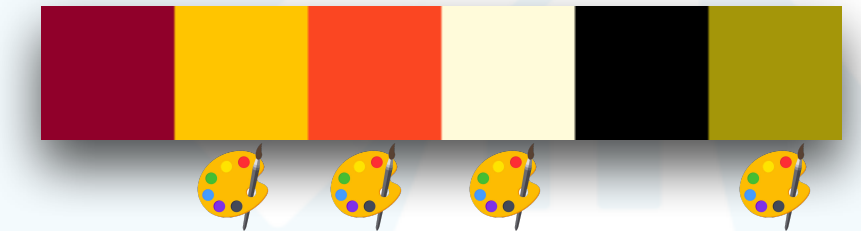
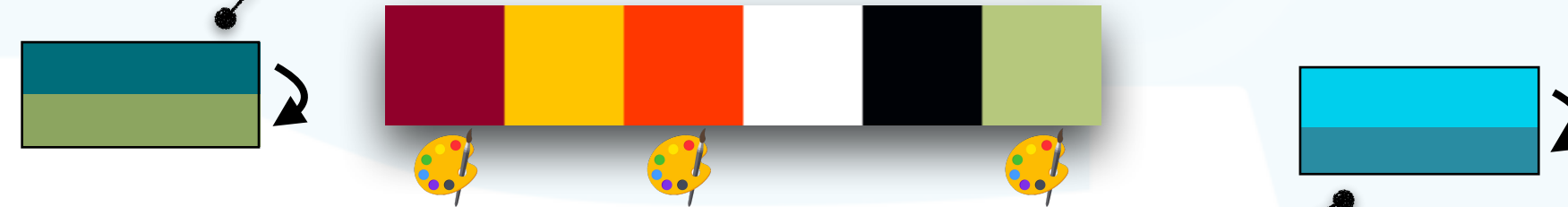
29× palette manipulations



Input

LoCoPalettes

[Tan et al. 2018]



Local Control

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Palette and Weight Hierarchy

Definition



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Palette and Weight Hierarchy

Definition

- Hierarchical data structure to support local edits

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Palette and Weight Hierarchy

Definition

- Hierarchical data structure to support local edits
 - Each node: local palette, local weights, local soft mask

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Palette and Weight Hierarchy

Definition

- Hierarchical data structure to support local edits
 - Each node: local palette, local weights, local soft mask
 - DETR [Carion et al. 2020]'s panoptic segmentation

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Palette and Weight Hierarchy

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- Hierarchical data structure to support local edits
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 - Root → Classes → Instances

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 - DETR [Carion et al. 2020]'s panoptic segmentation
 - Root \rightarrow Classes \rightarrow Instances

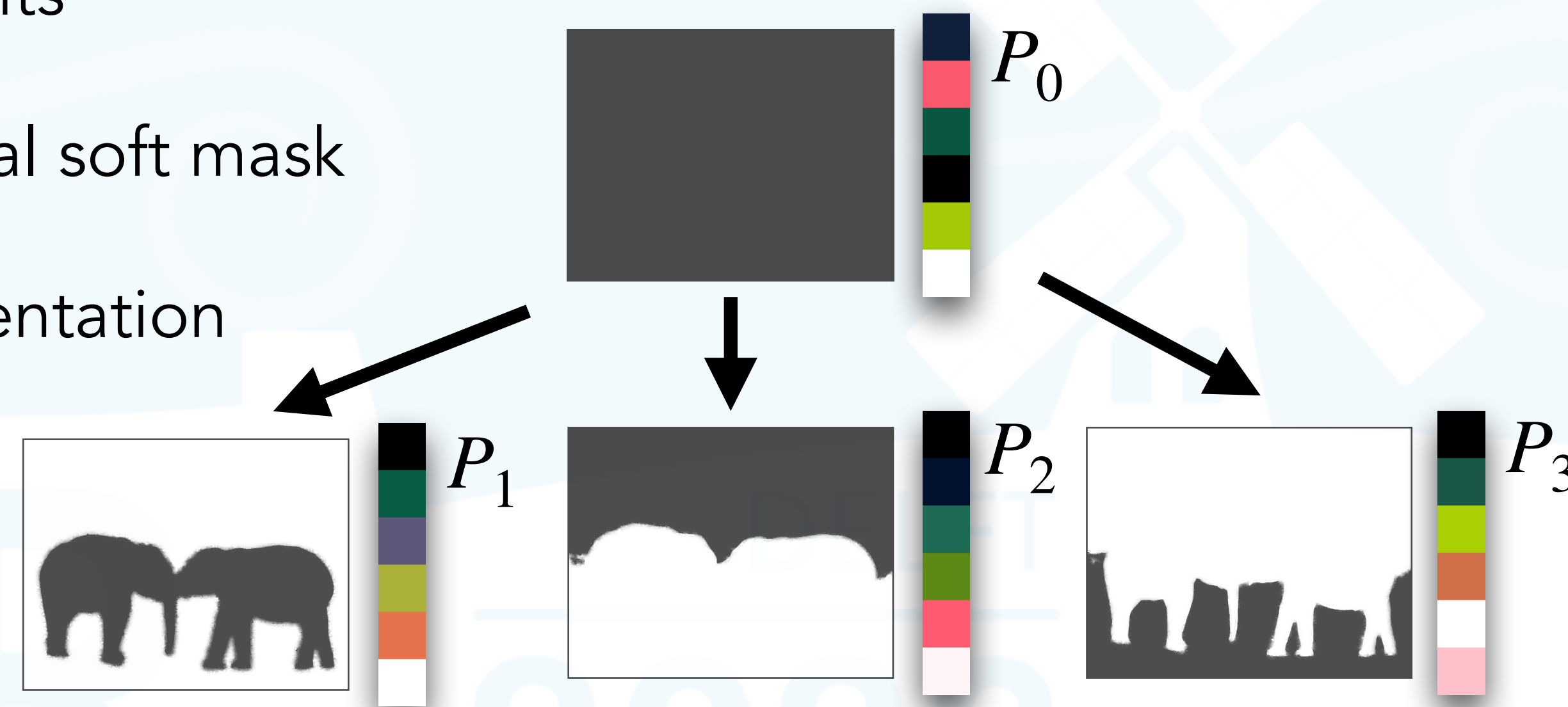


Palette and Weight Hierarchy

Definition



- Hierarchical data structure to support local edits
 - Each node: local palette, local weights, local soft mask
 - DETR [Carion et al. 2020]'s panoptic segmentation
 - Root \rightarrow Classes \rightarrow Instances

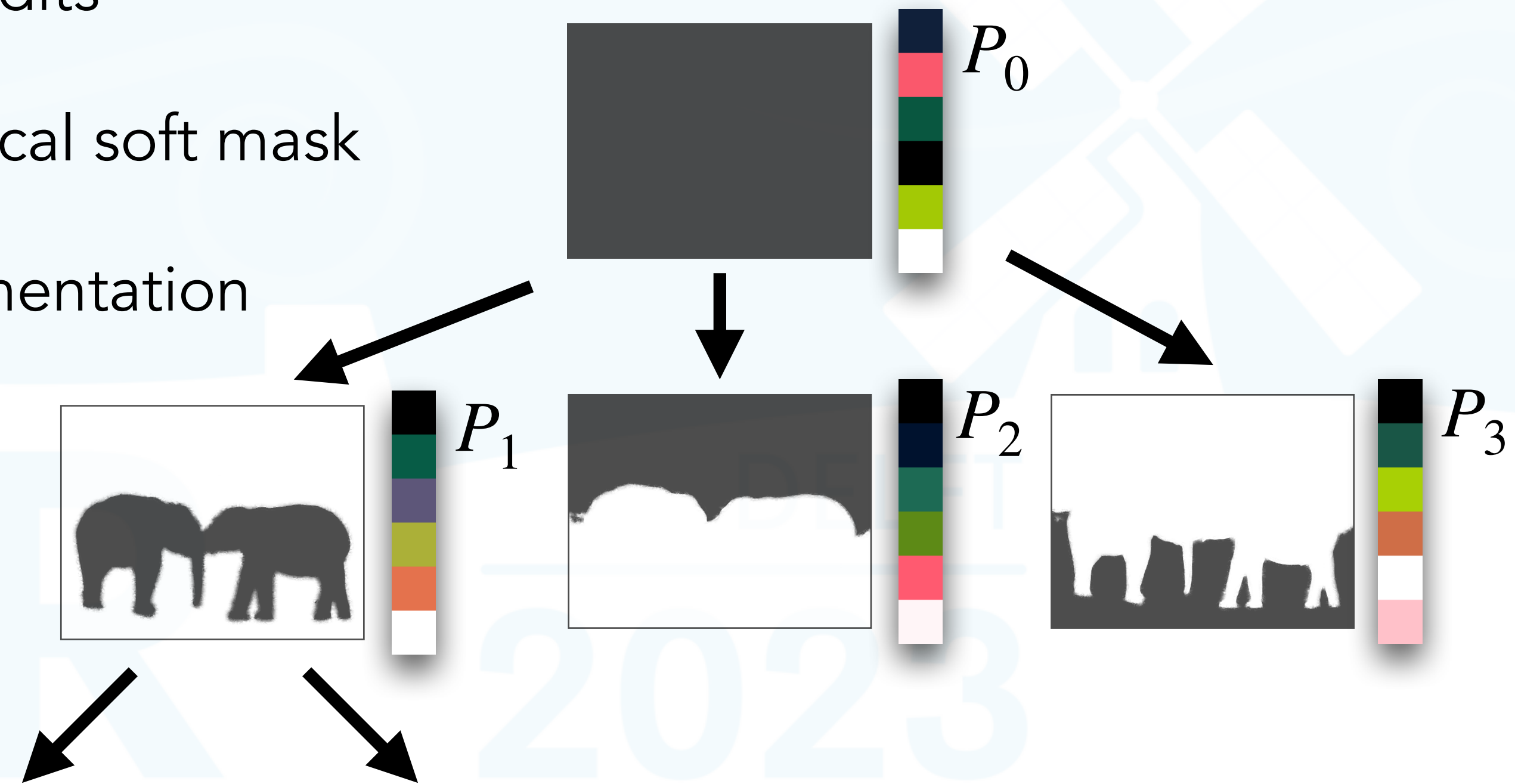


Palette and Weight Hierarchy

Definition



- Hierarchical data structure to support local edits
 - Each node: local palette, local weights, local soft mask
 - DETR [Carion et al. 2020]'s panoptic segmentation
 - Root \rightarrow Classes \rightarrow Instances

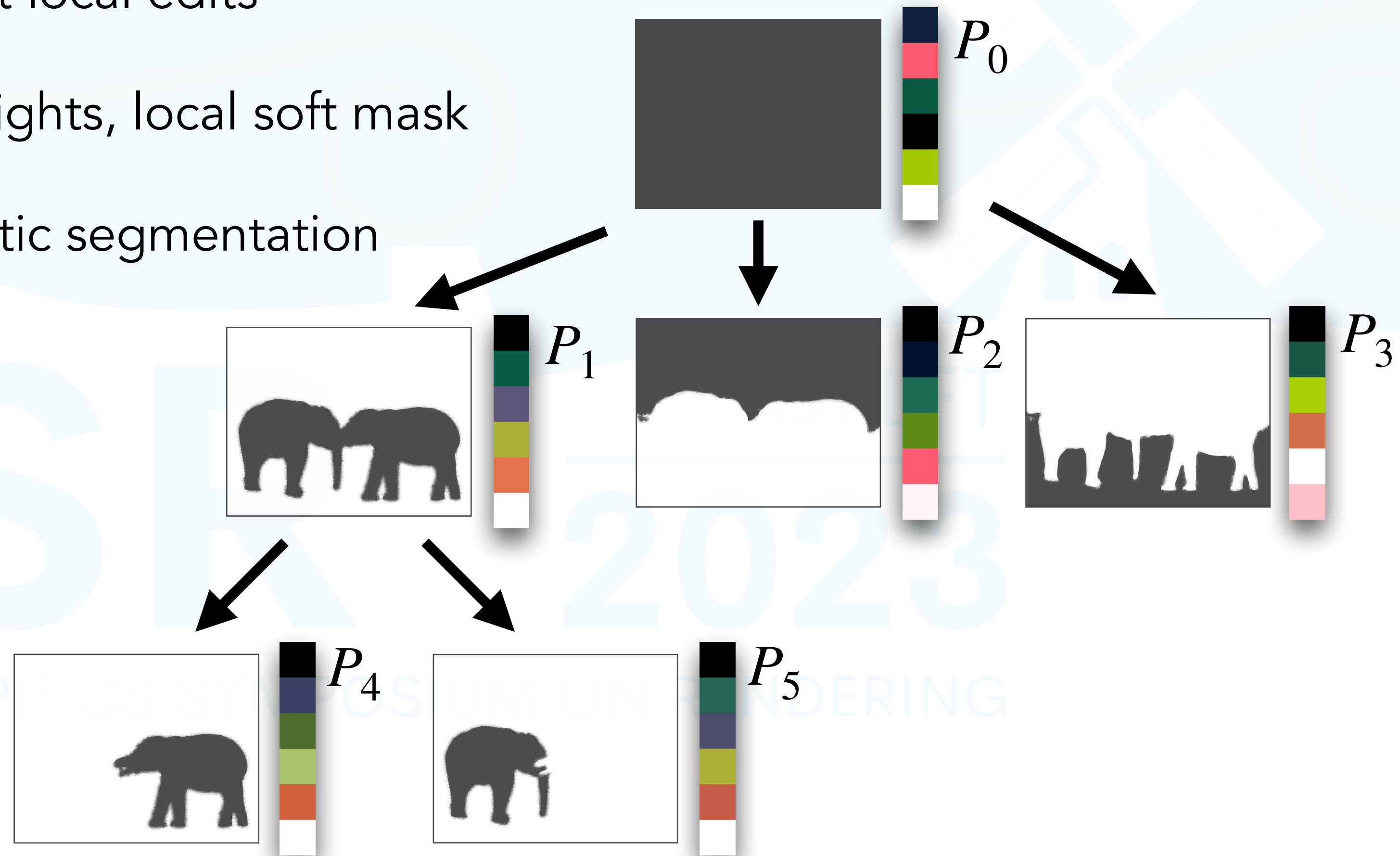


Palette and Weight Hierarchy

Definition



- Hierarchical data structure to support local edits
 - Each node: local palette, local weights, local soft mask
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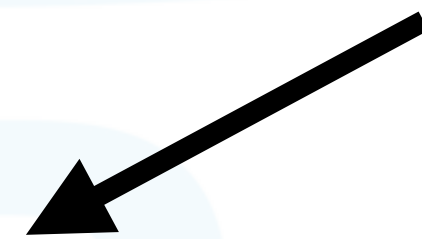
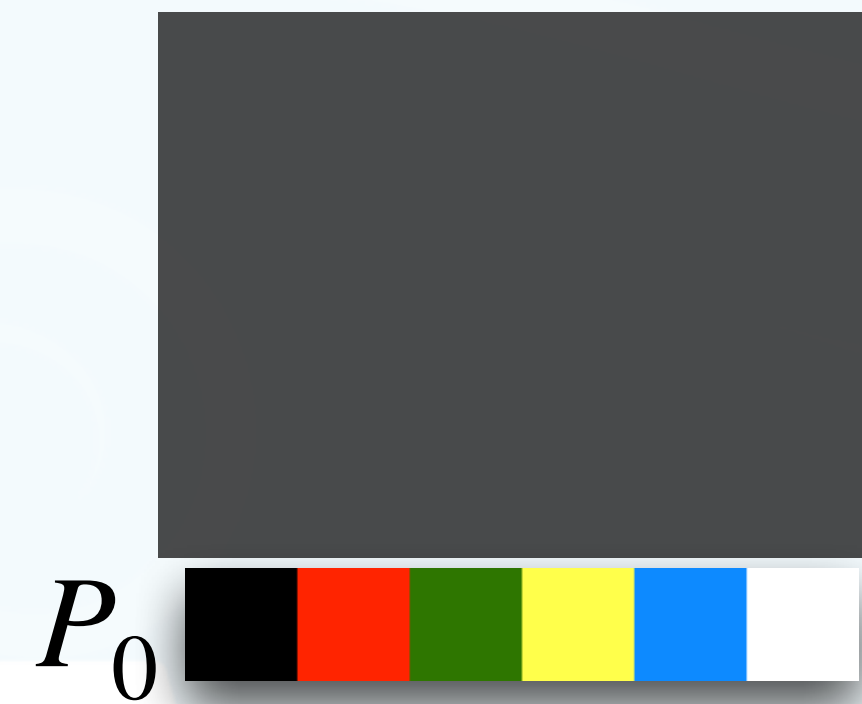
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Editing Example

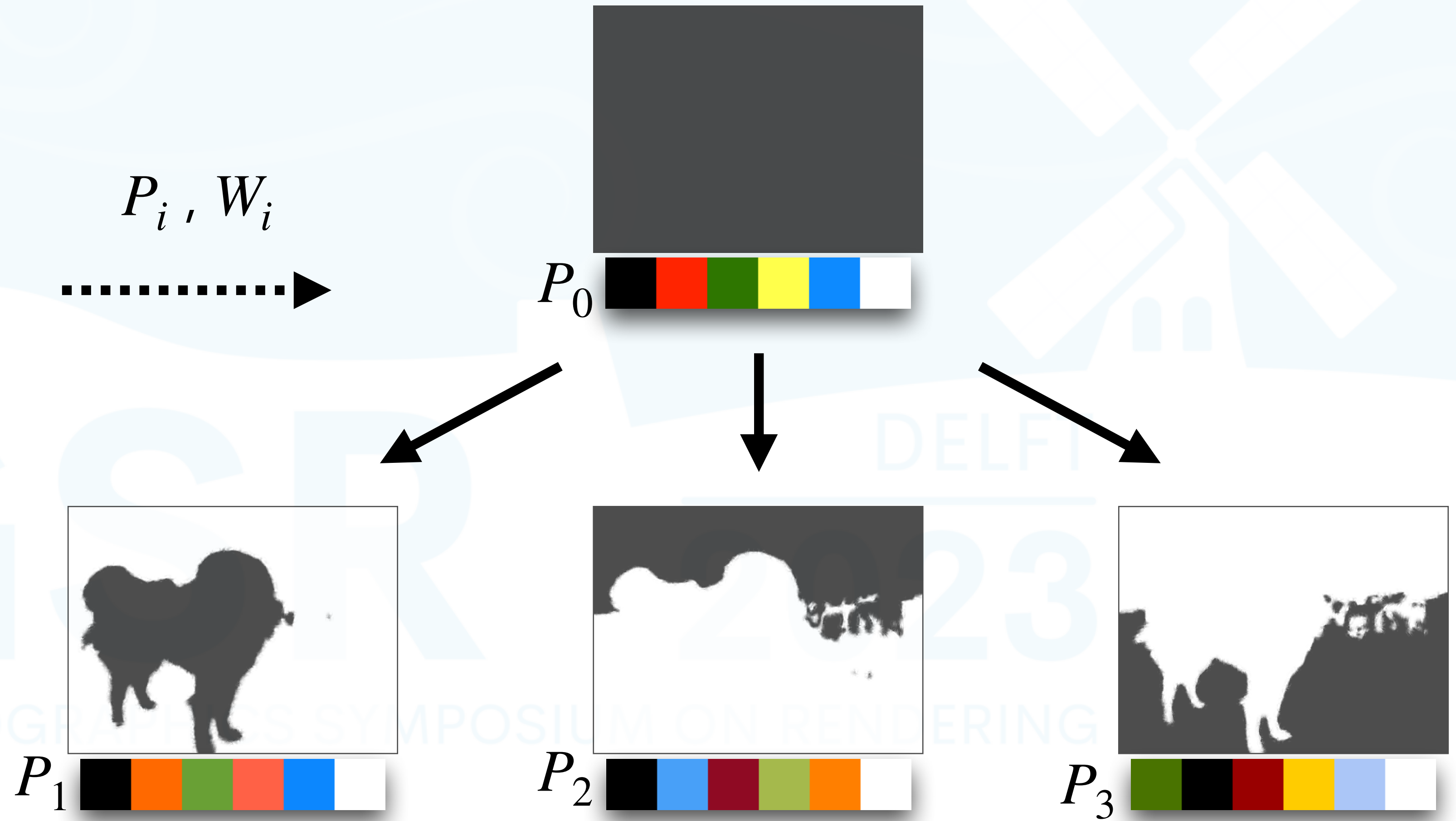
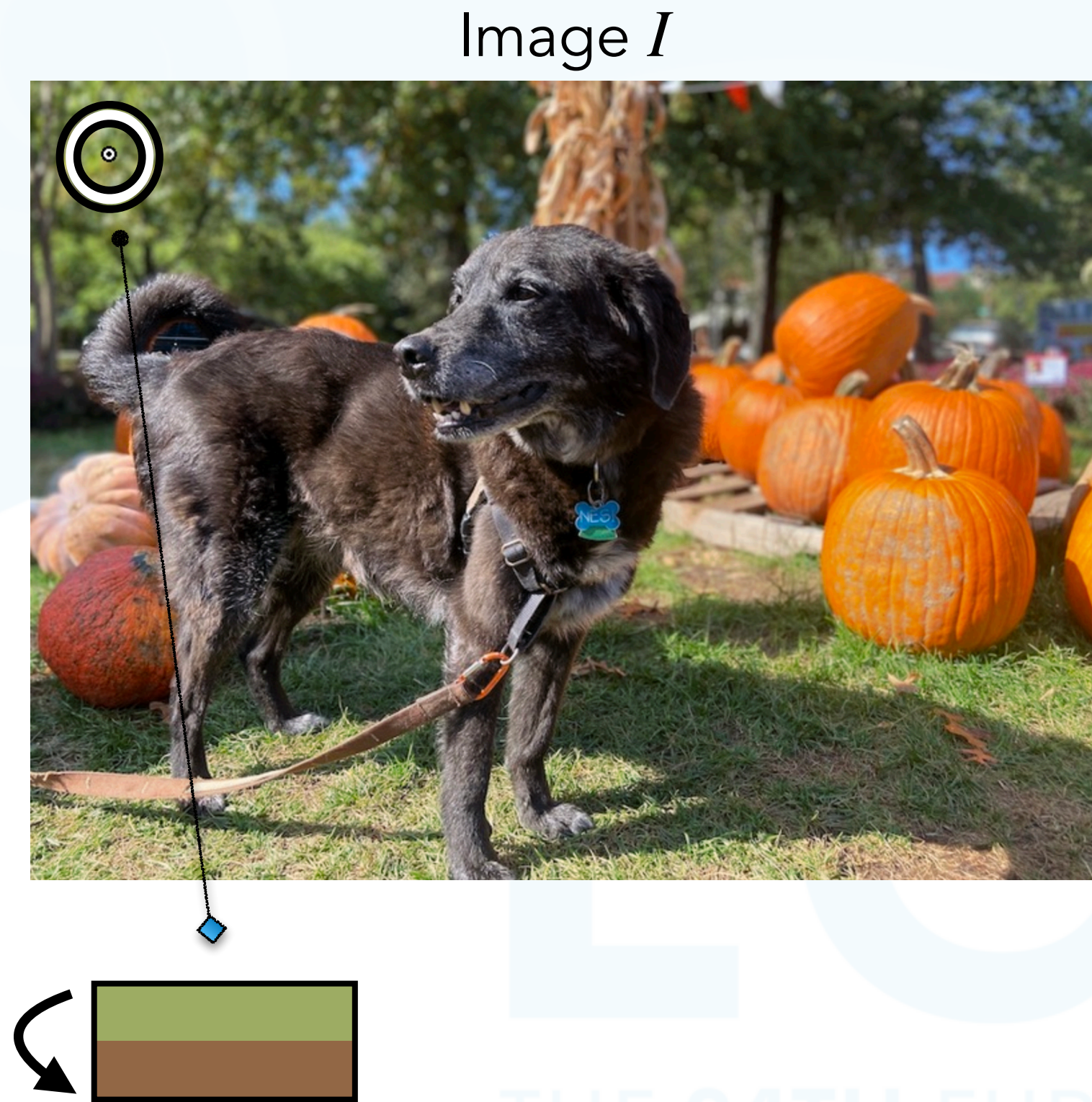
Image I



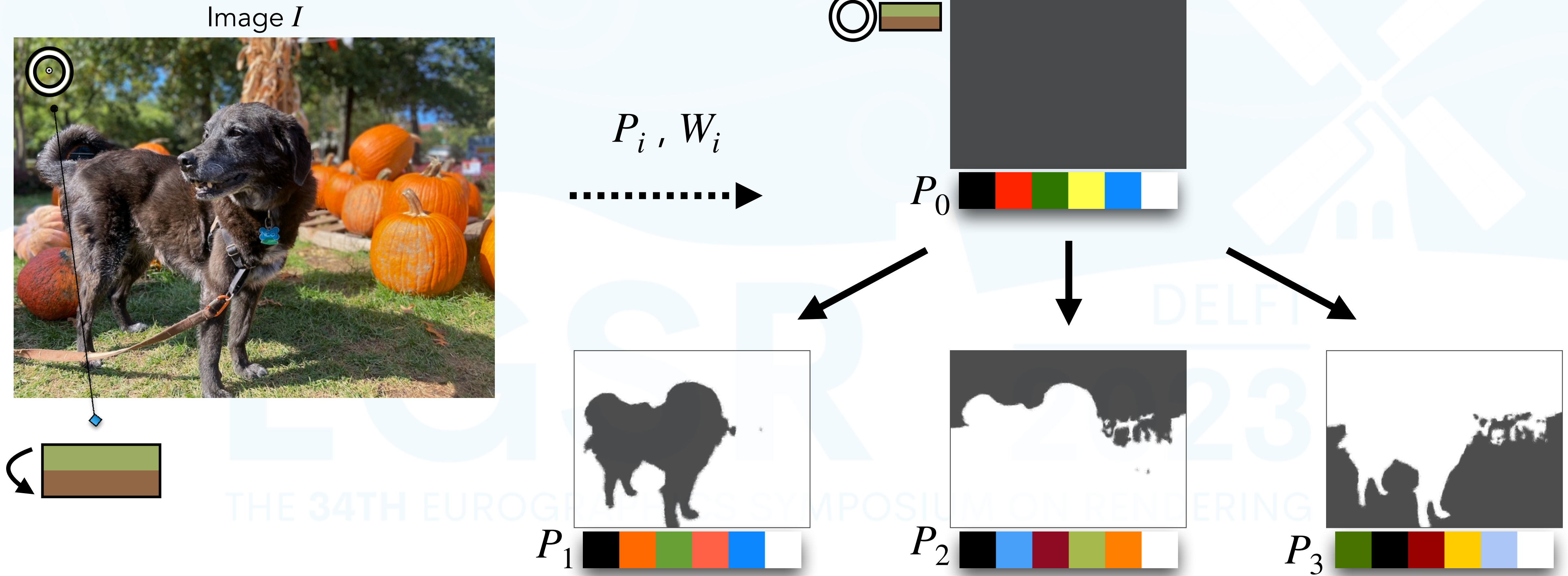
P_i, W_i



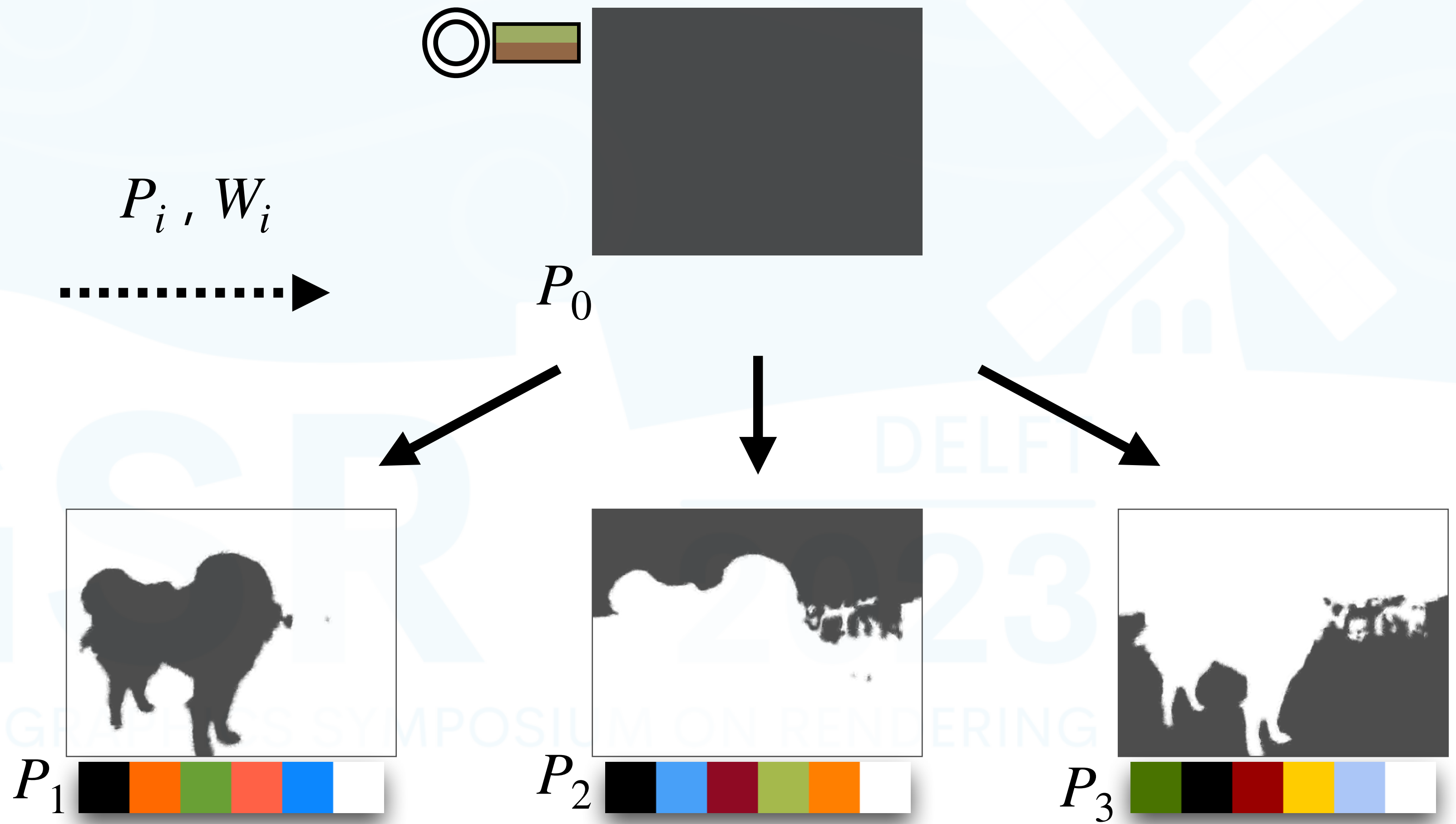
Editing Example



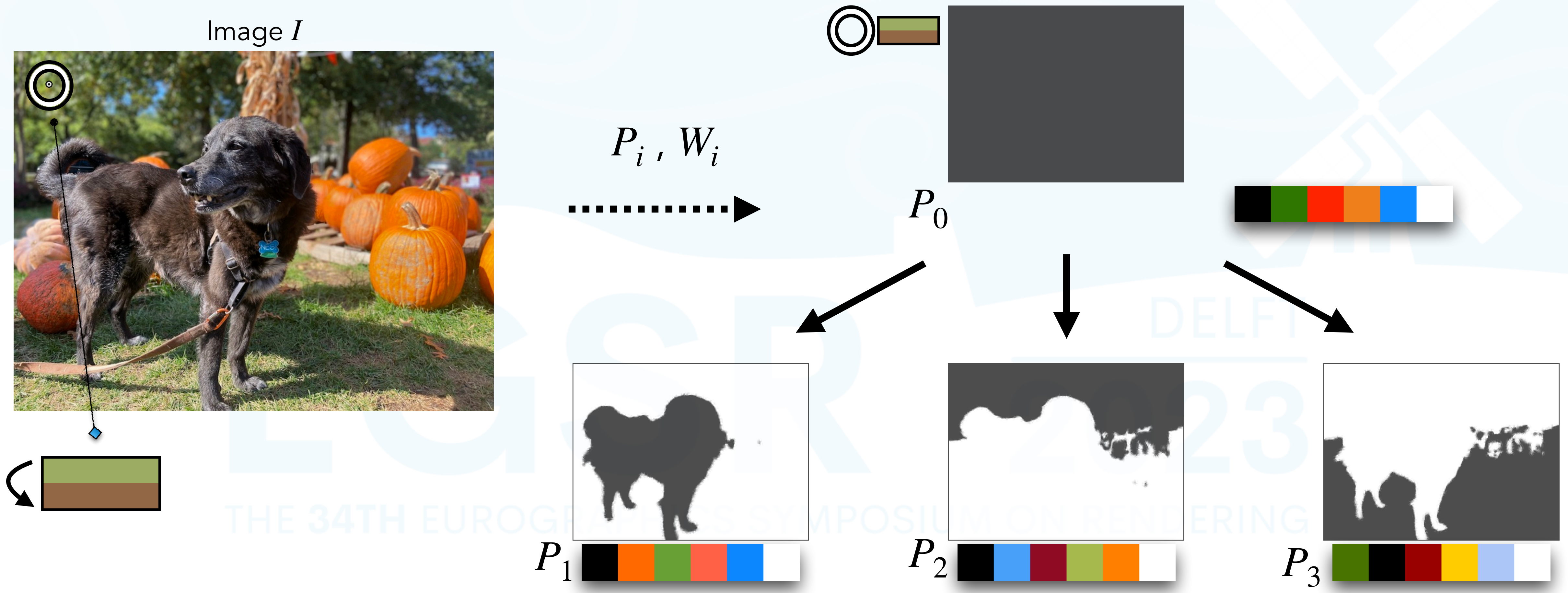
Editing Example



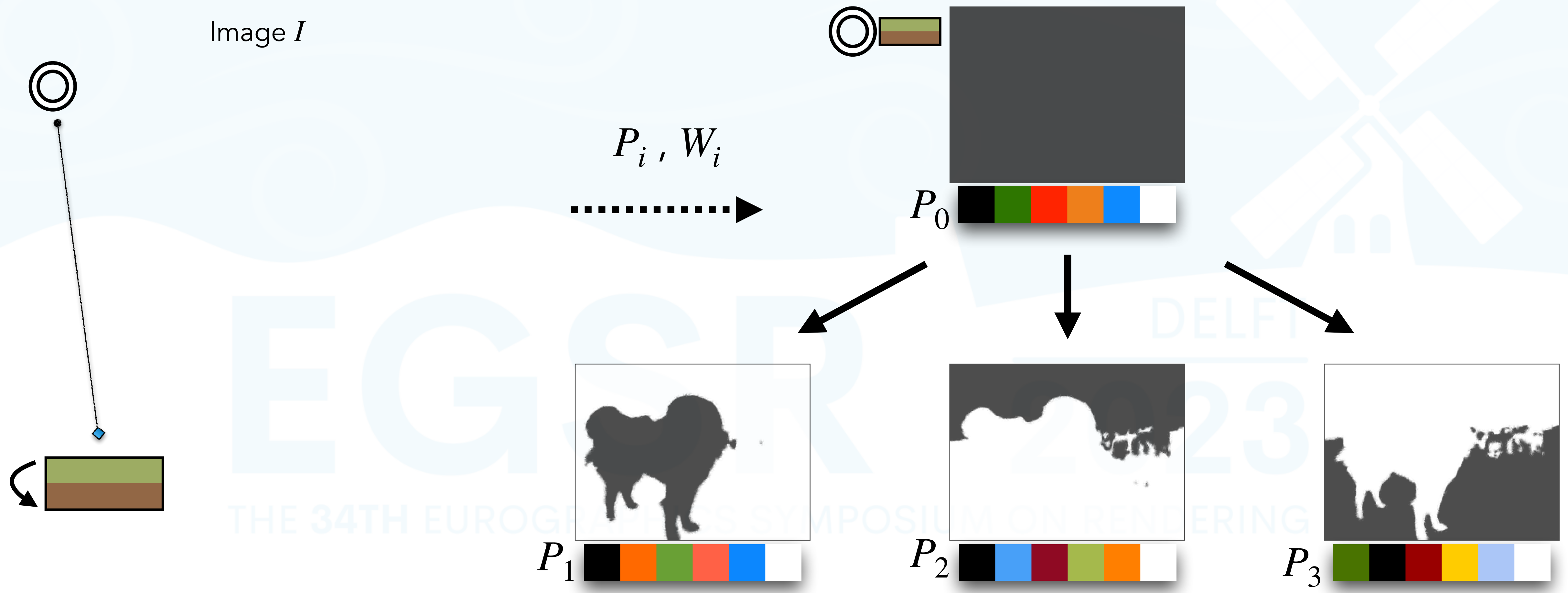
Editing Example



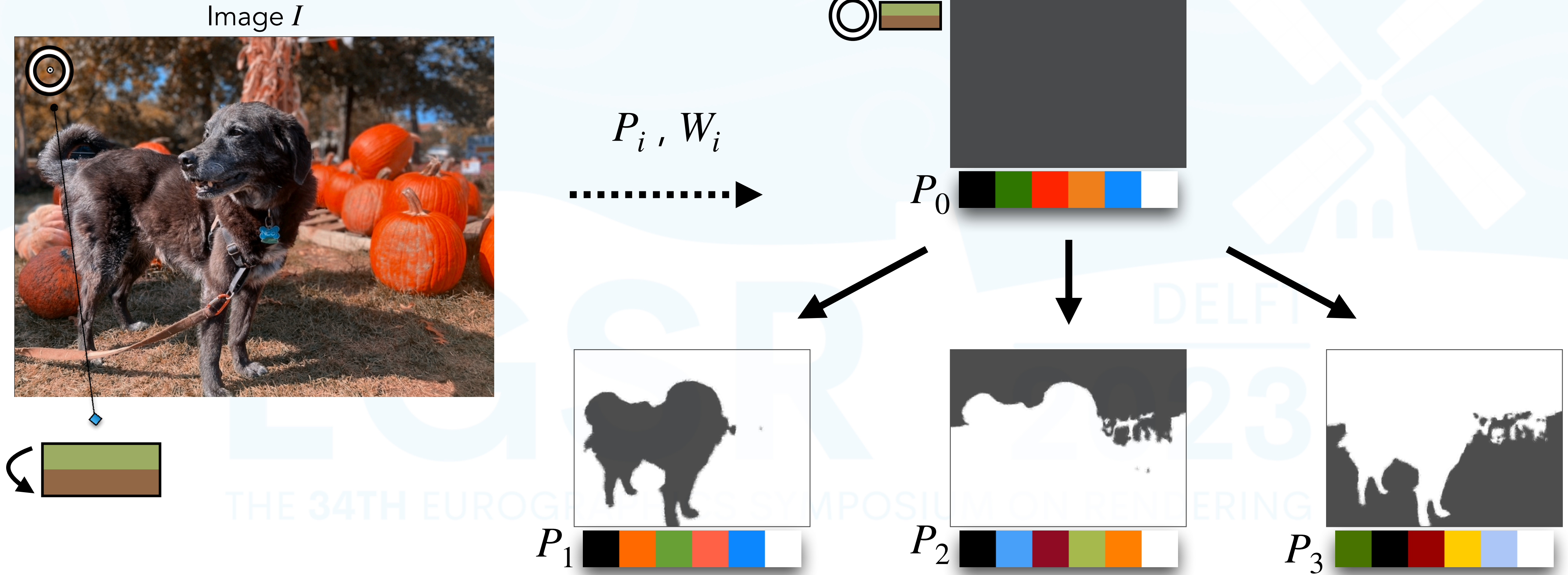
Editing Example



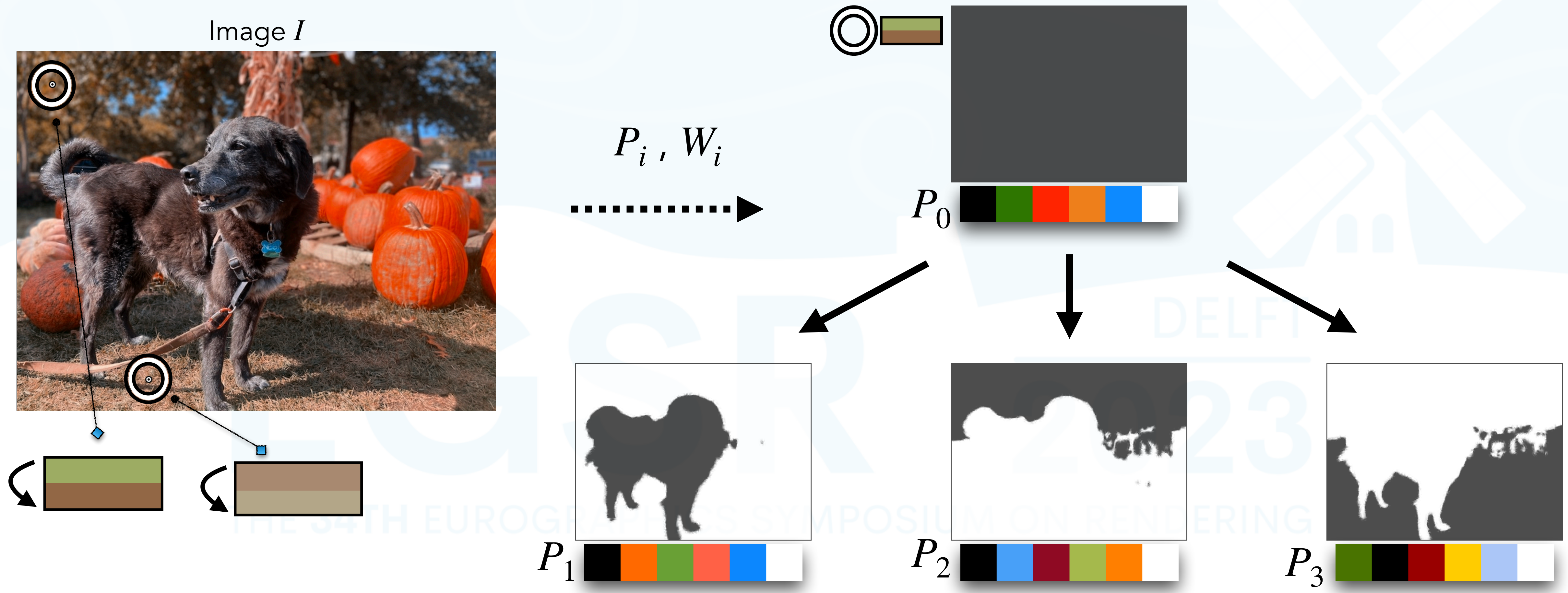
Editing Example



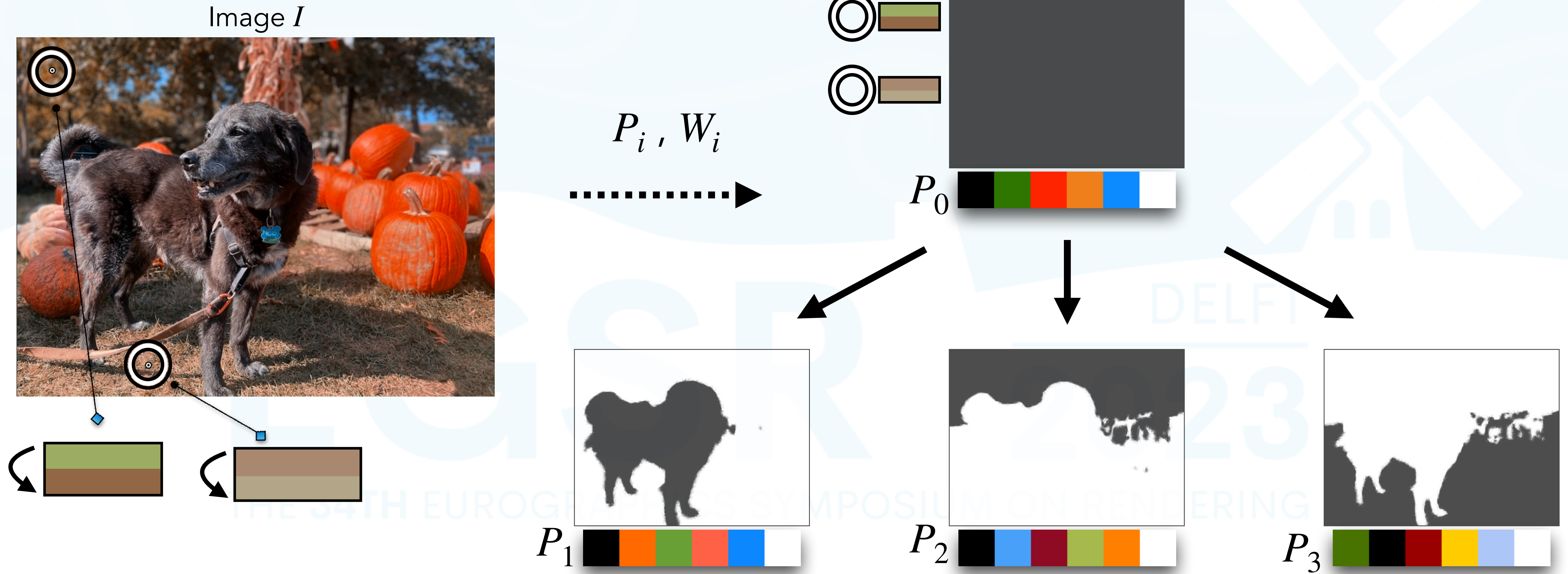
Editing Example



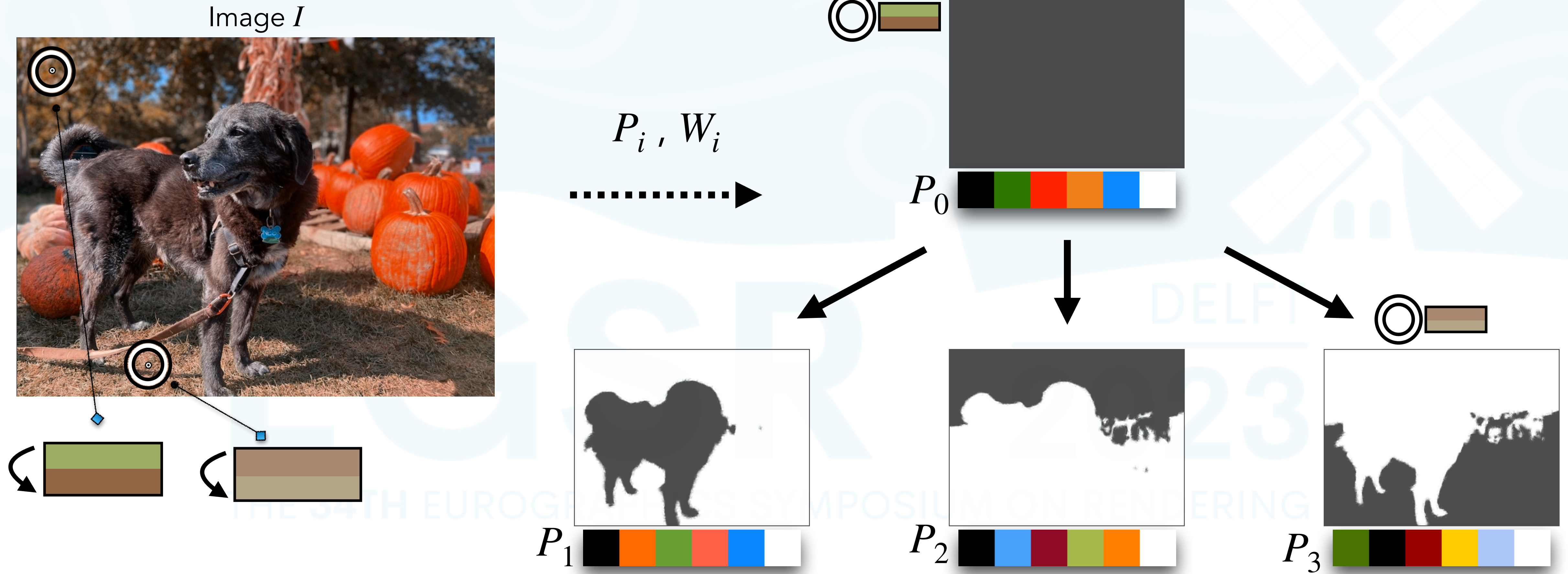
Editing Example



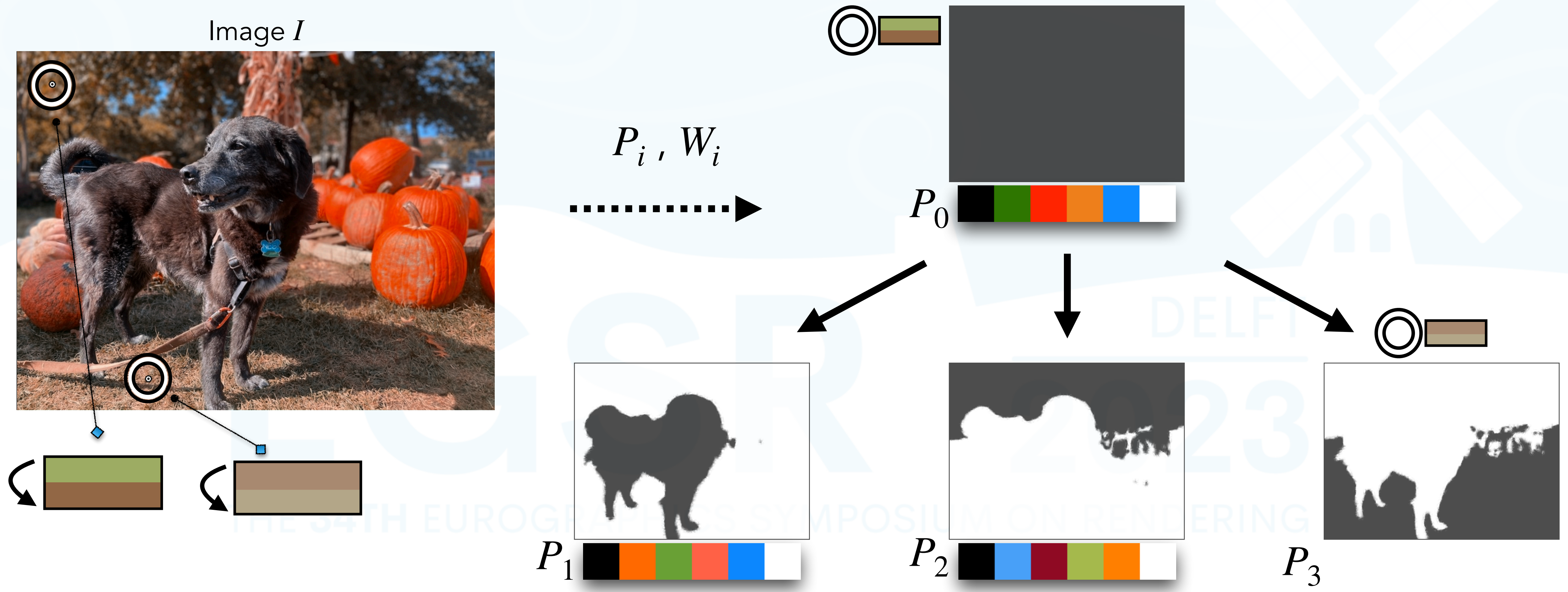
Editing Example



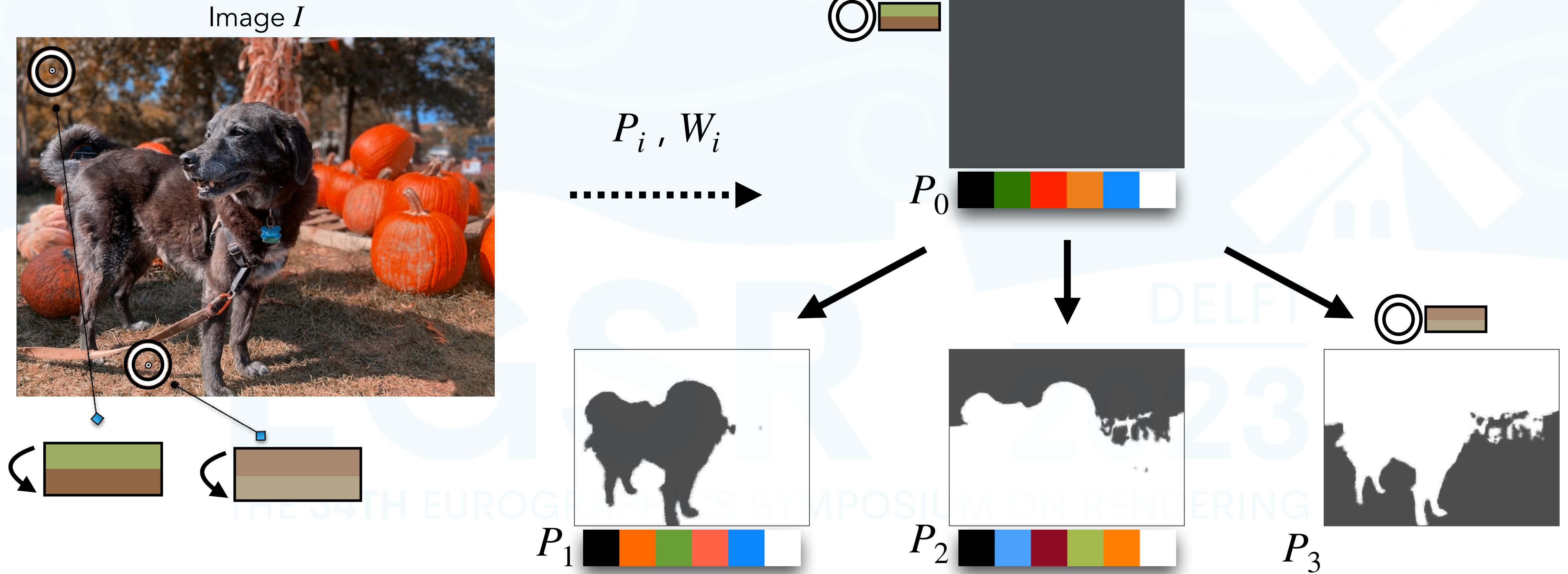
Editing Example



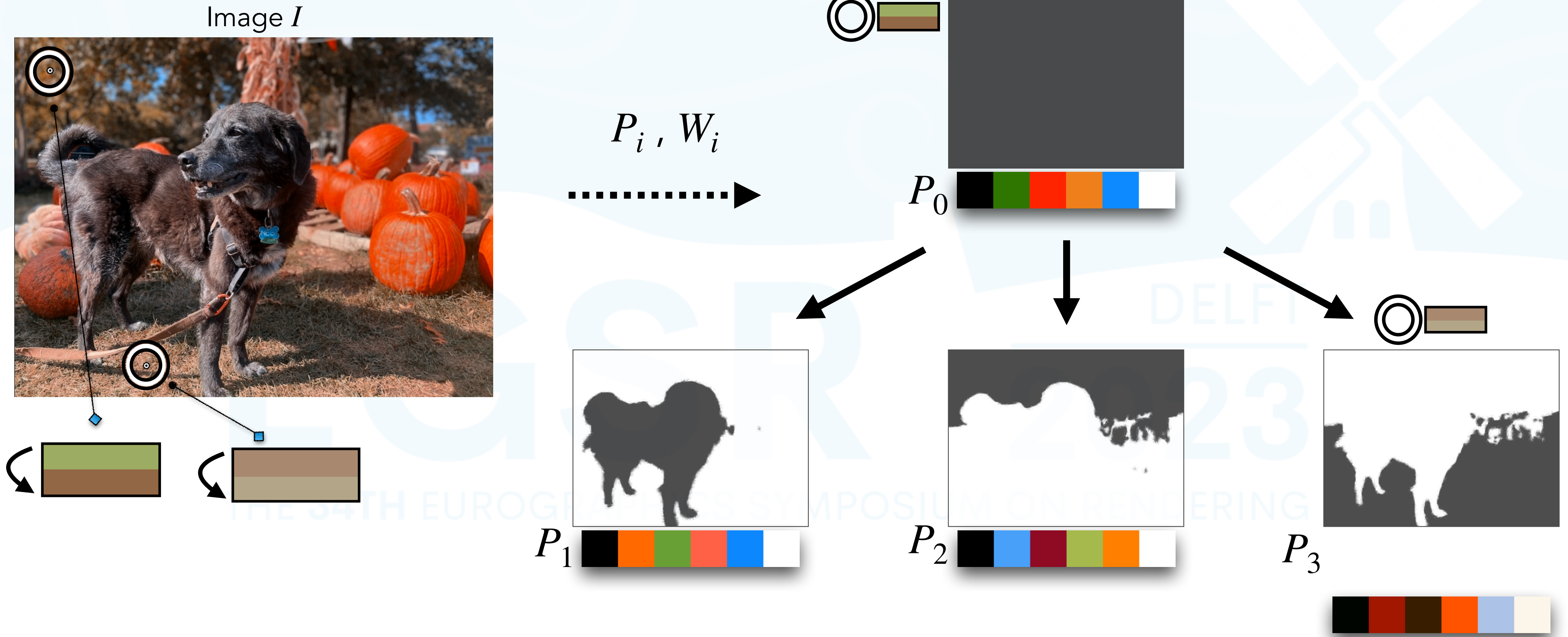
Editing Example



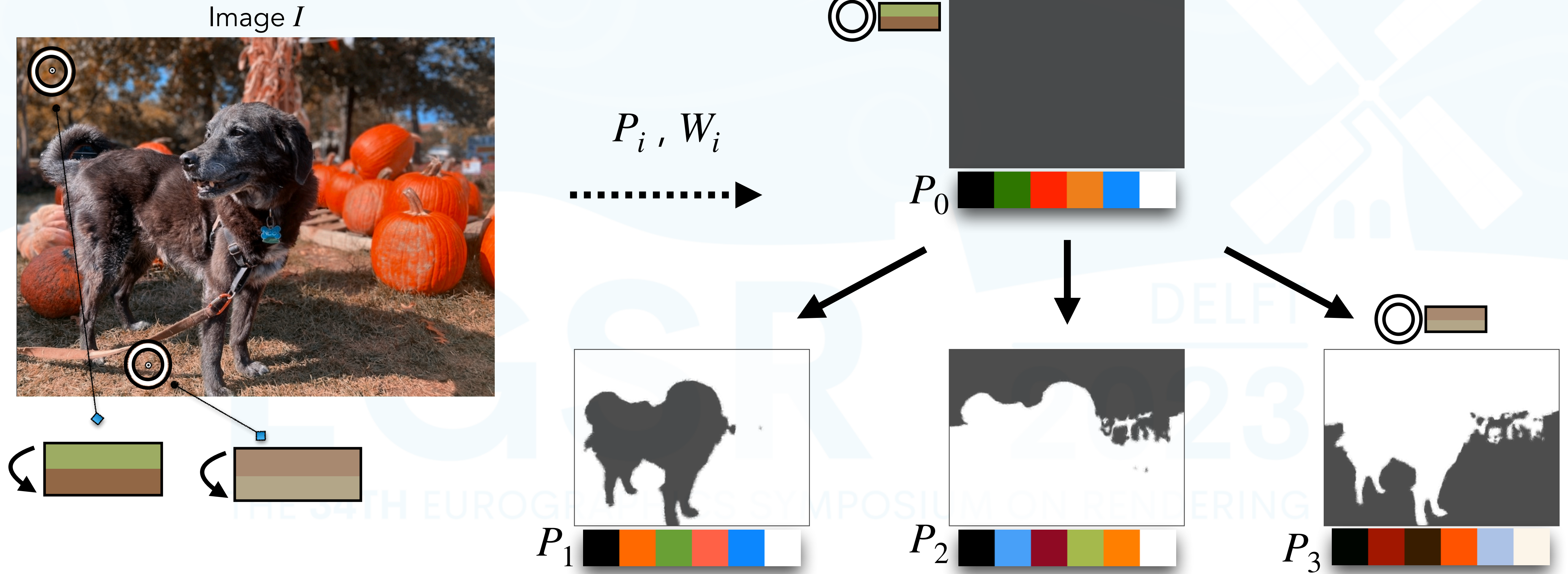
Editing Example



Editing Example

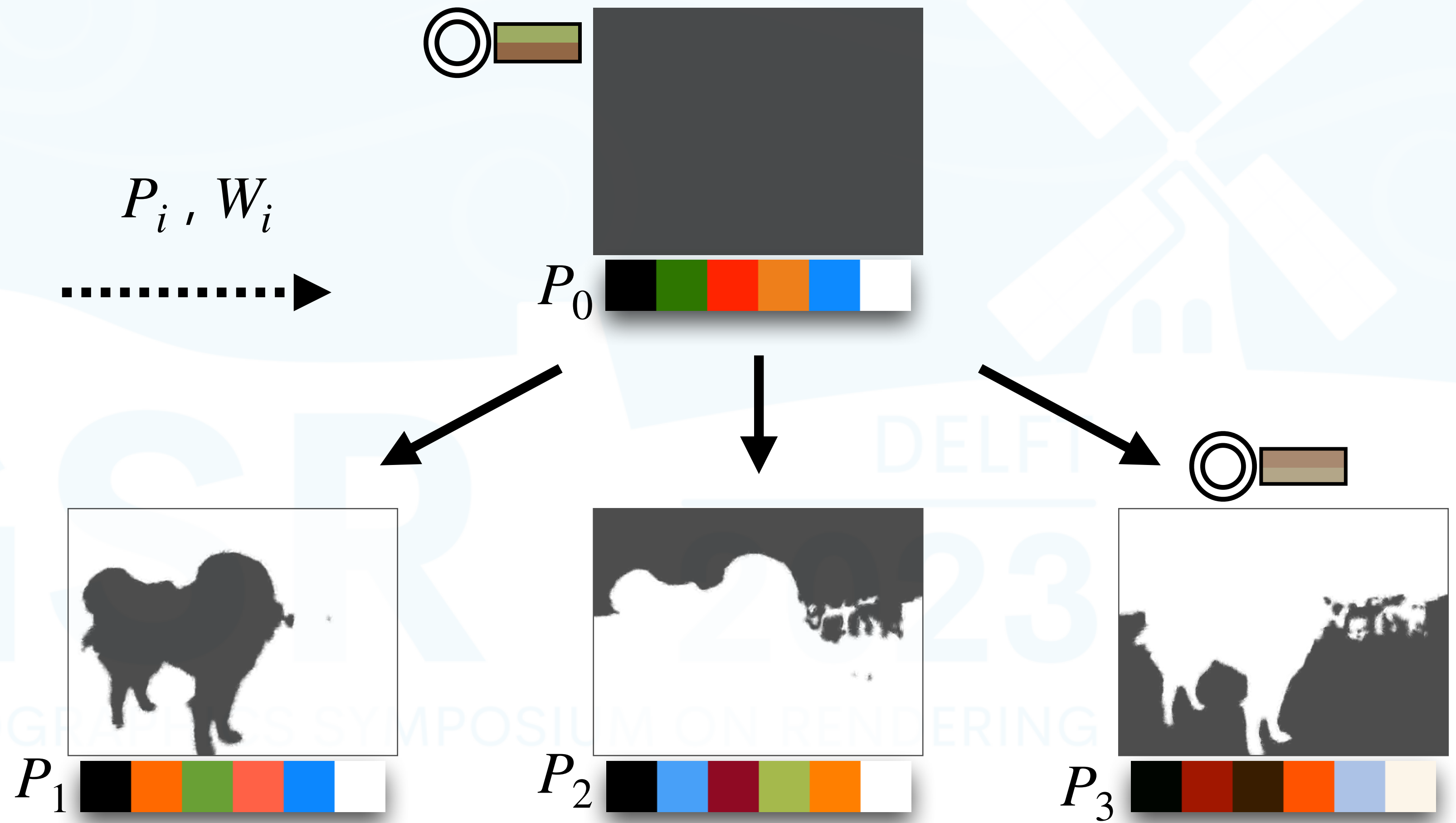


Editing Example



Editing Example

Image I

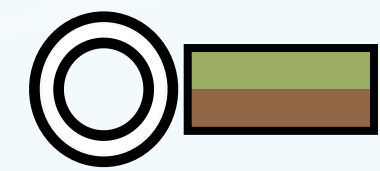


Editing Example

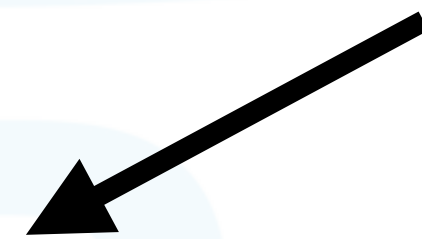
Image I



P_i, W_i



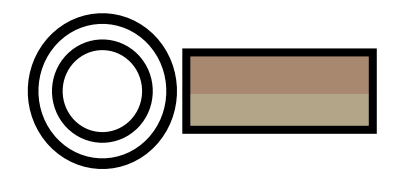
P_0



P_1



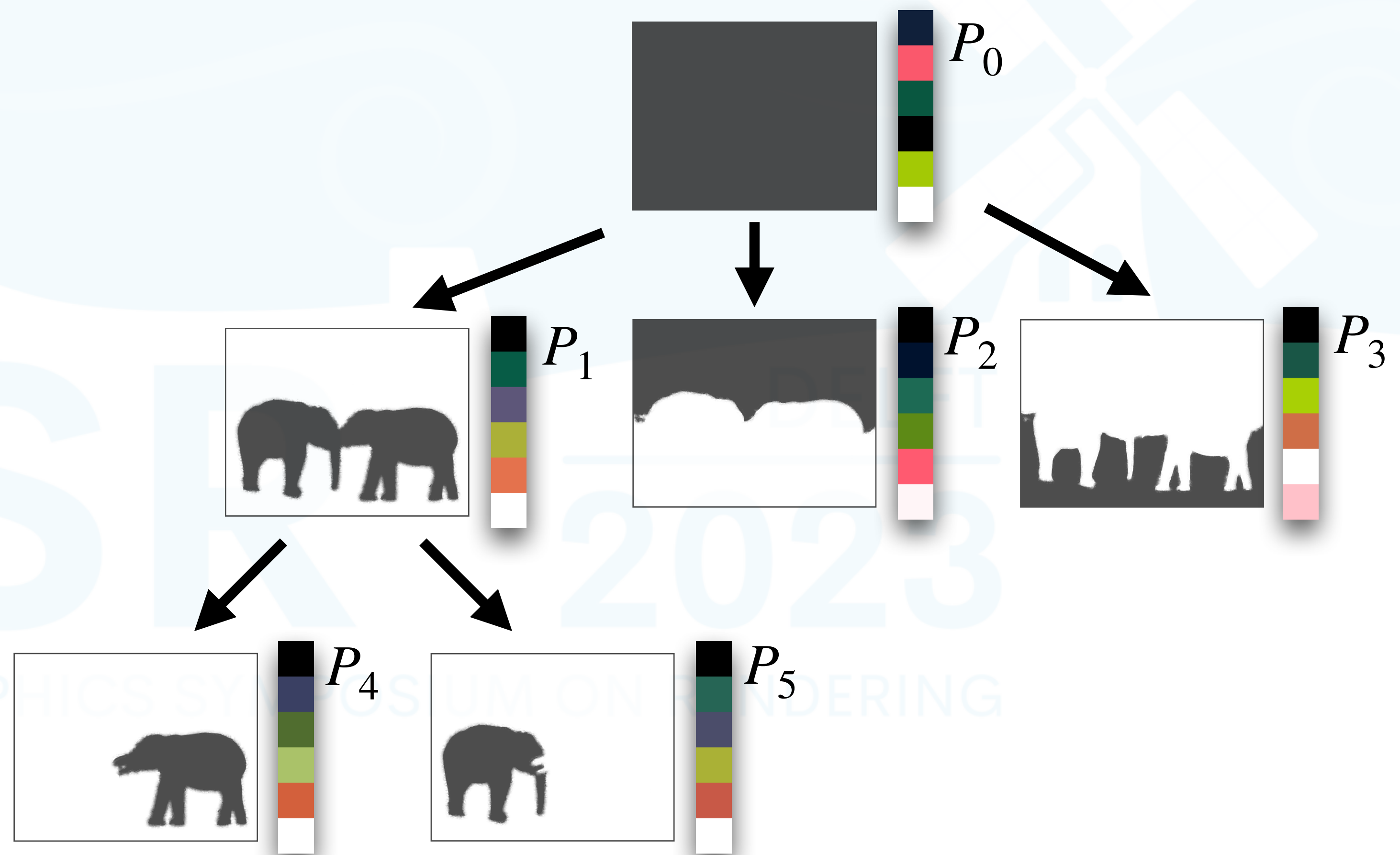
P_2



P_3

Sparse Editing *with* Hierarchy

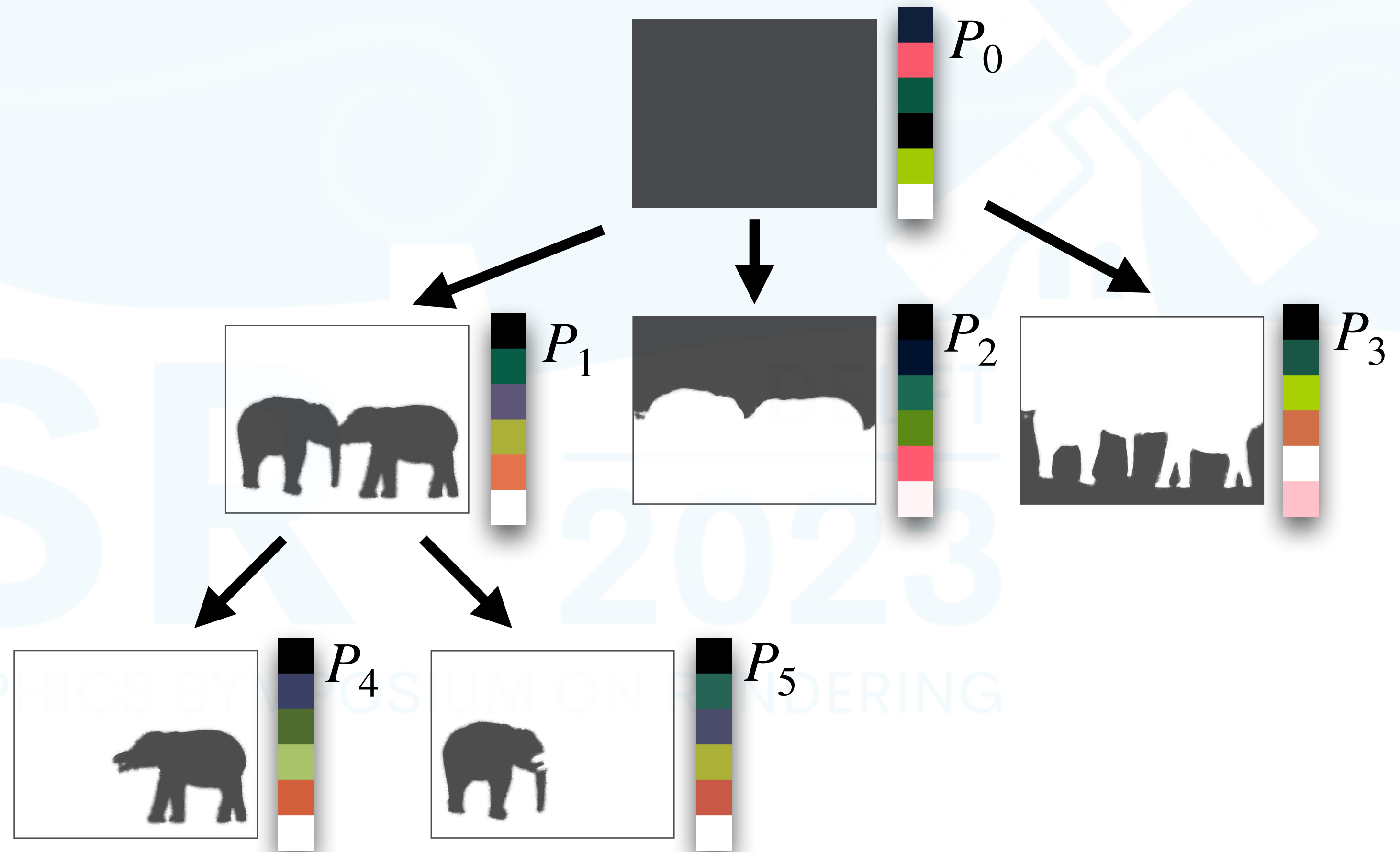
Palette splitting rules



Sparse Editing *with* Hierarchy

Palette splitting rules

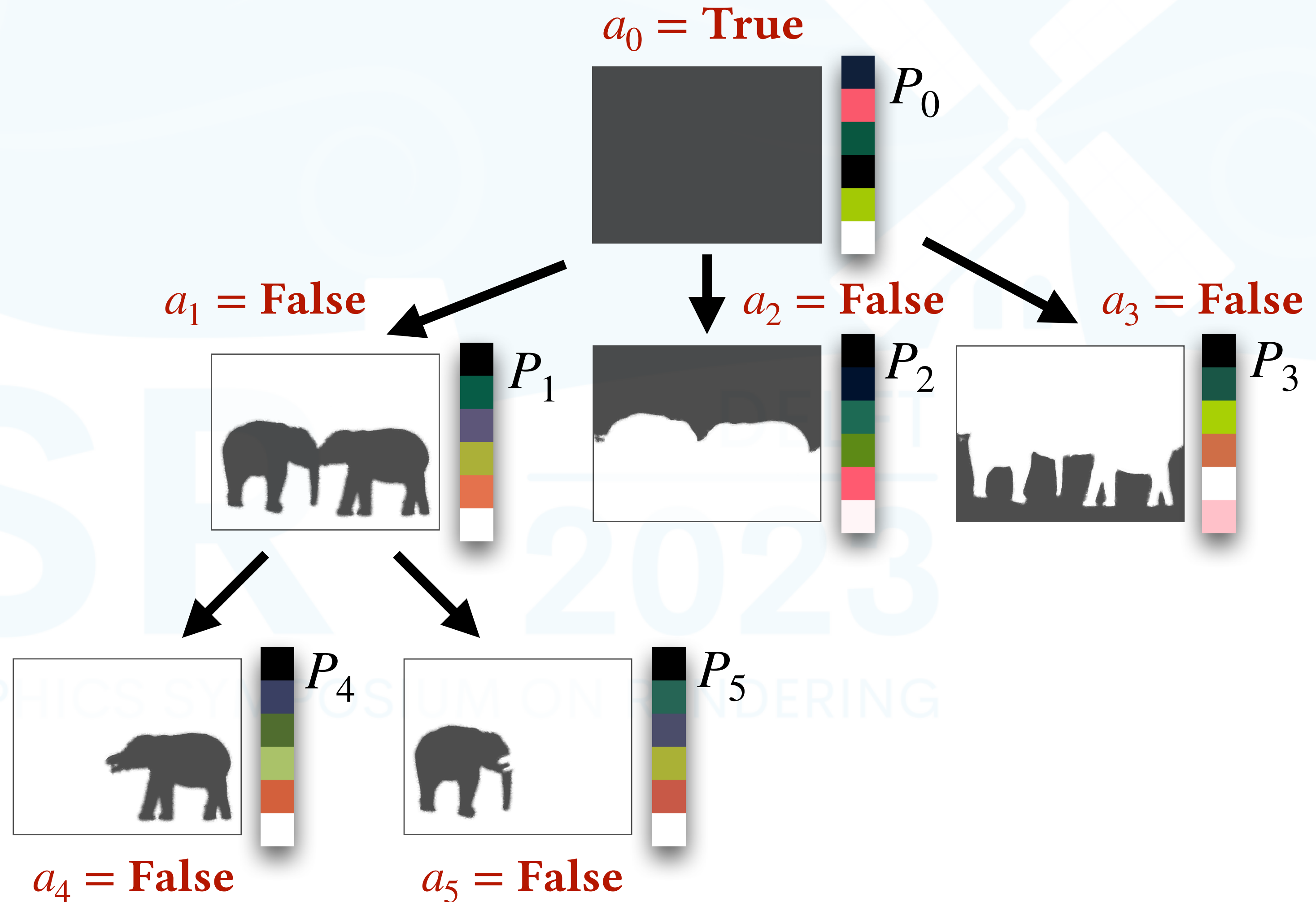
- Store booleans to track node activations



Sparse Editing *with* Hierarchy

Palette splitting rules

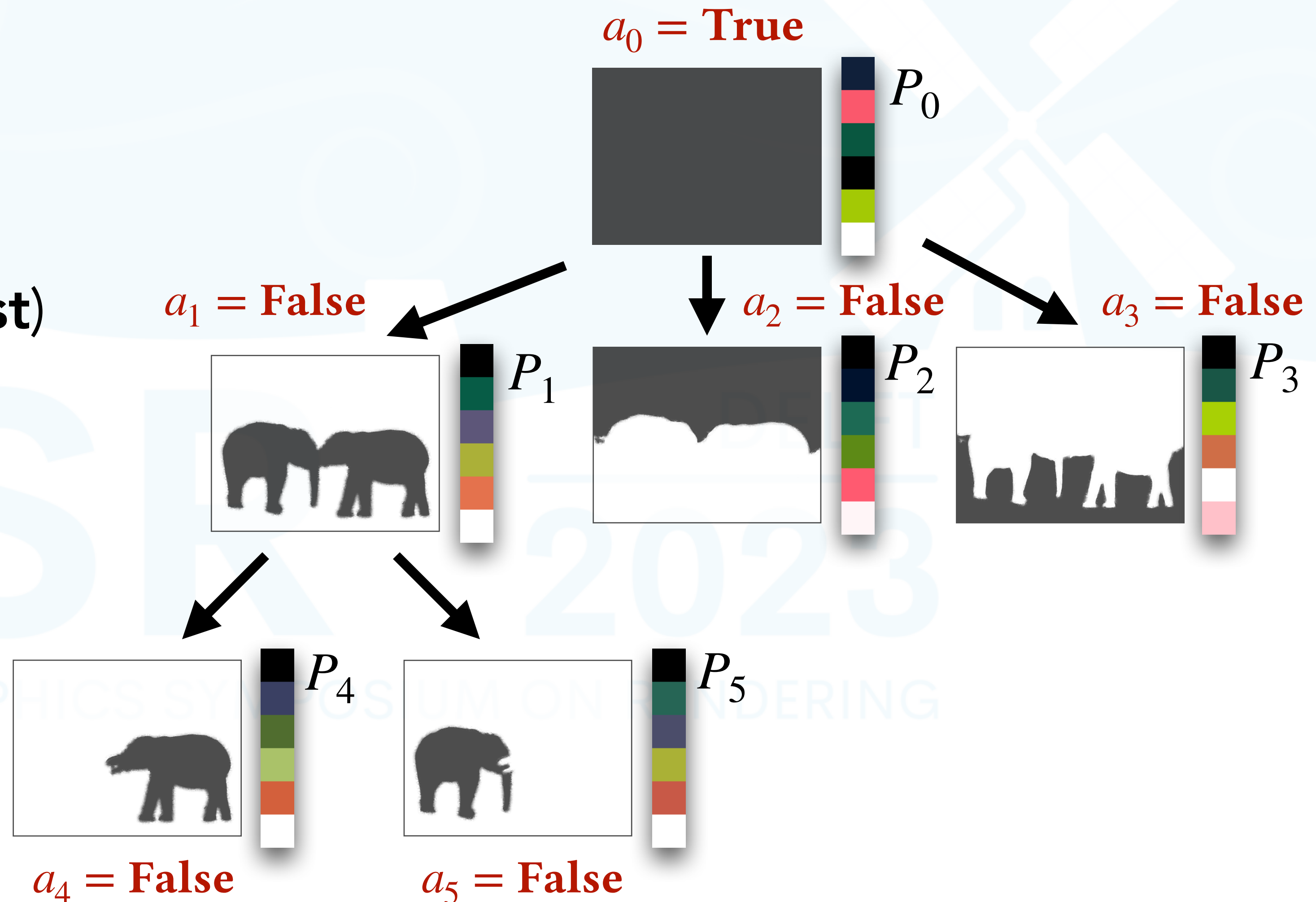
- Store booleans to track node activations



Sparse Editing *with* Hierarchy

Palette splitting rules

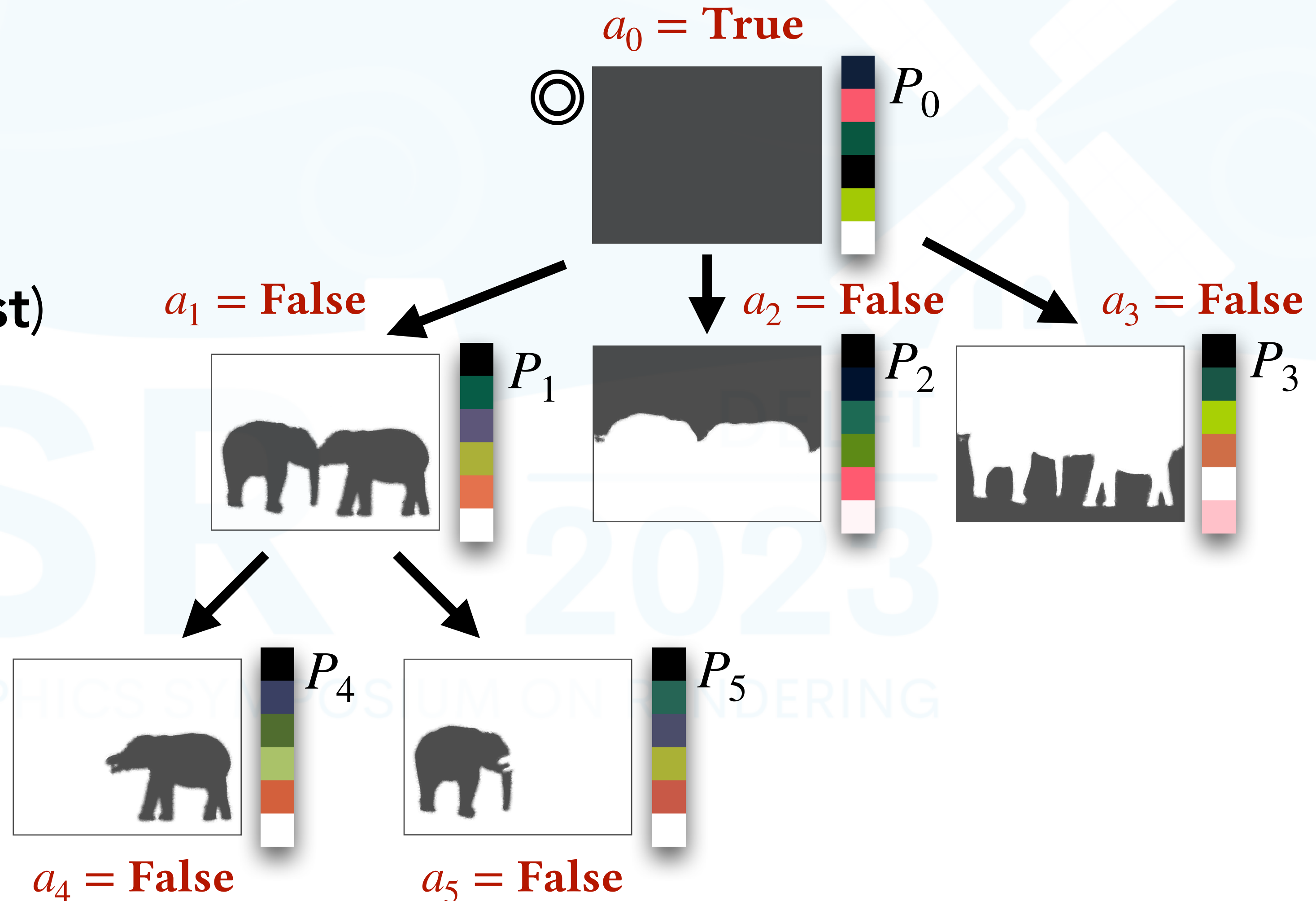
- Store booleans to track node activations
- A new image-space constraint starts at the most local (**deepest**) **active** node containing it



Sparse Editing *with* Hierarchy

Palette splitting rules

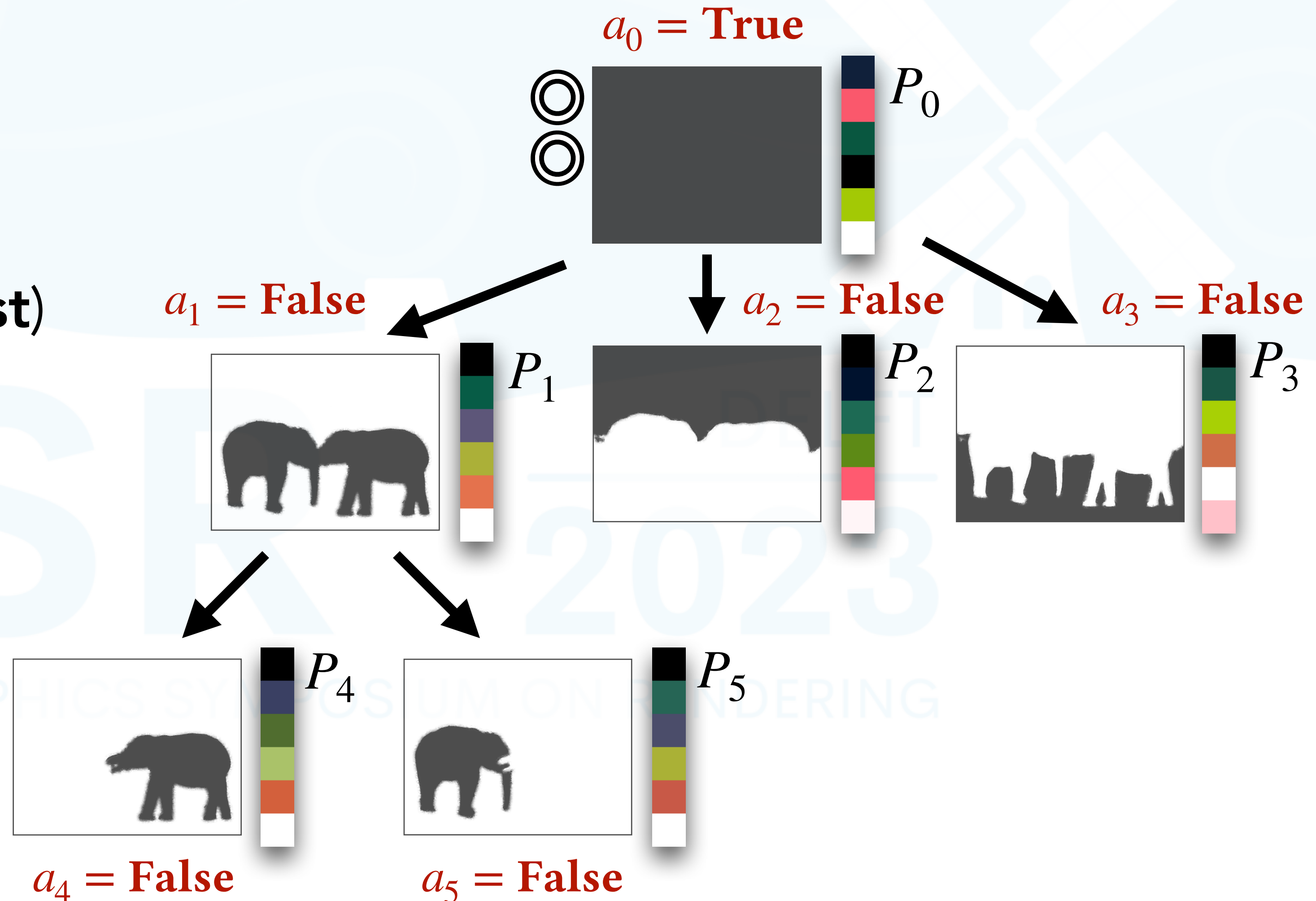
- Store booleans to track node activations
- A new image-space constraint starts at the most local (**deepest**) **active** node containing it



Sparse Editing *with* Hierarchy

Palette splitting rules

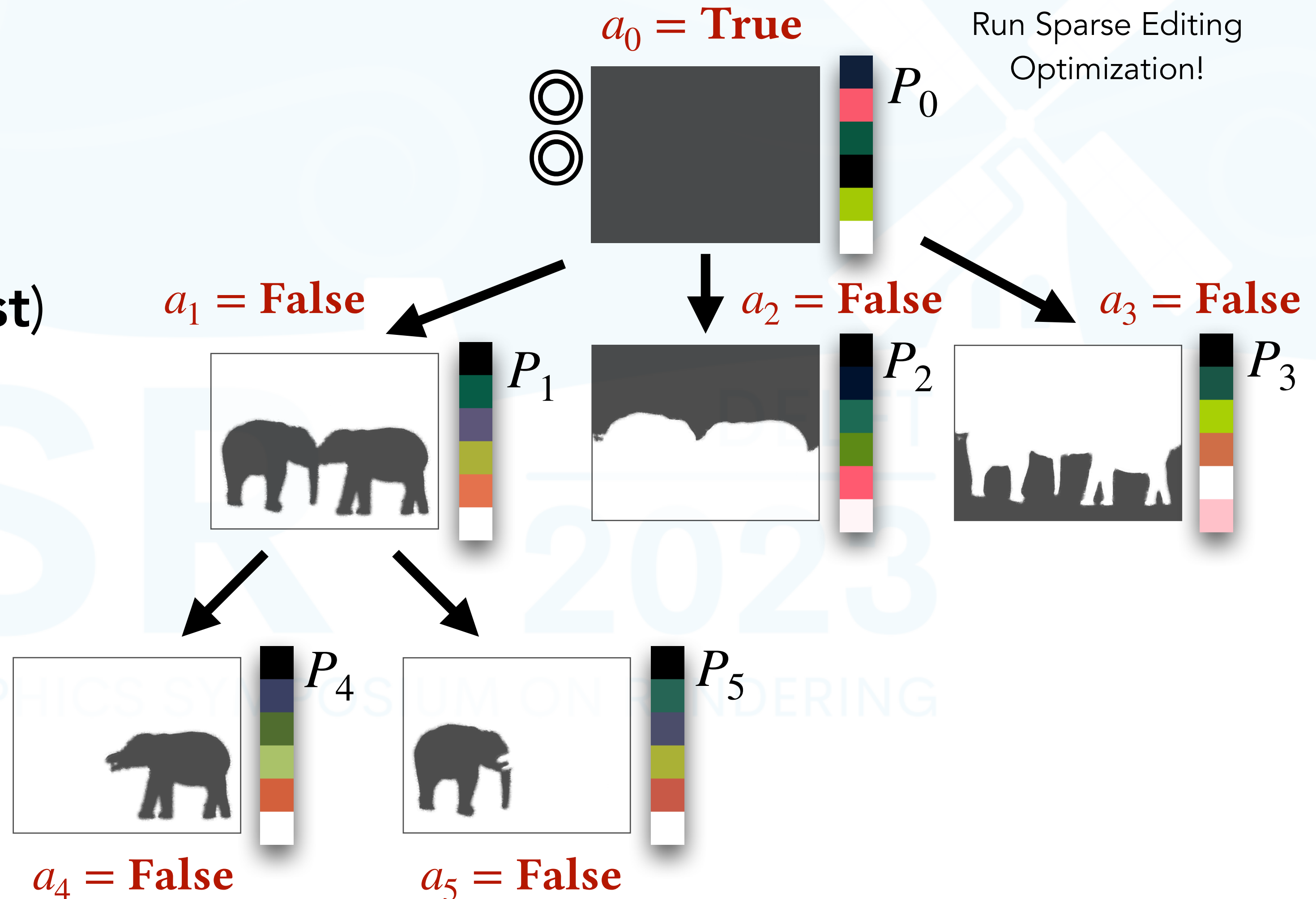
- Store booleans to track node activations
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Sparse Editing *with* Hierarchy

Palette splitting rules

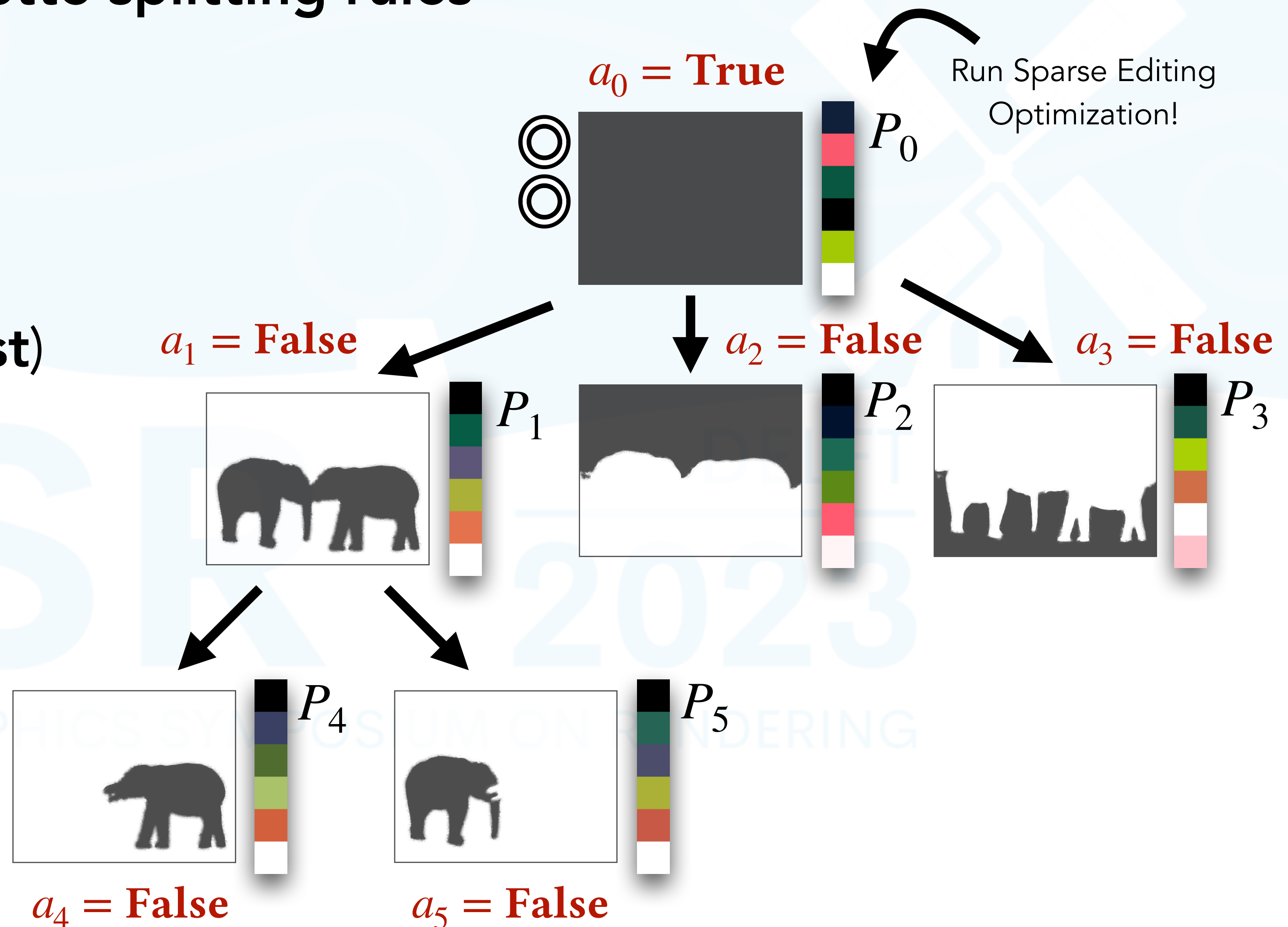
- Store booleans to track node activations
- A new image-space constraint starts at the most local (**deepest**) **active** node containing it



Sparse Editing *with* Hierarchy

Palette splitting rules

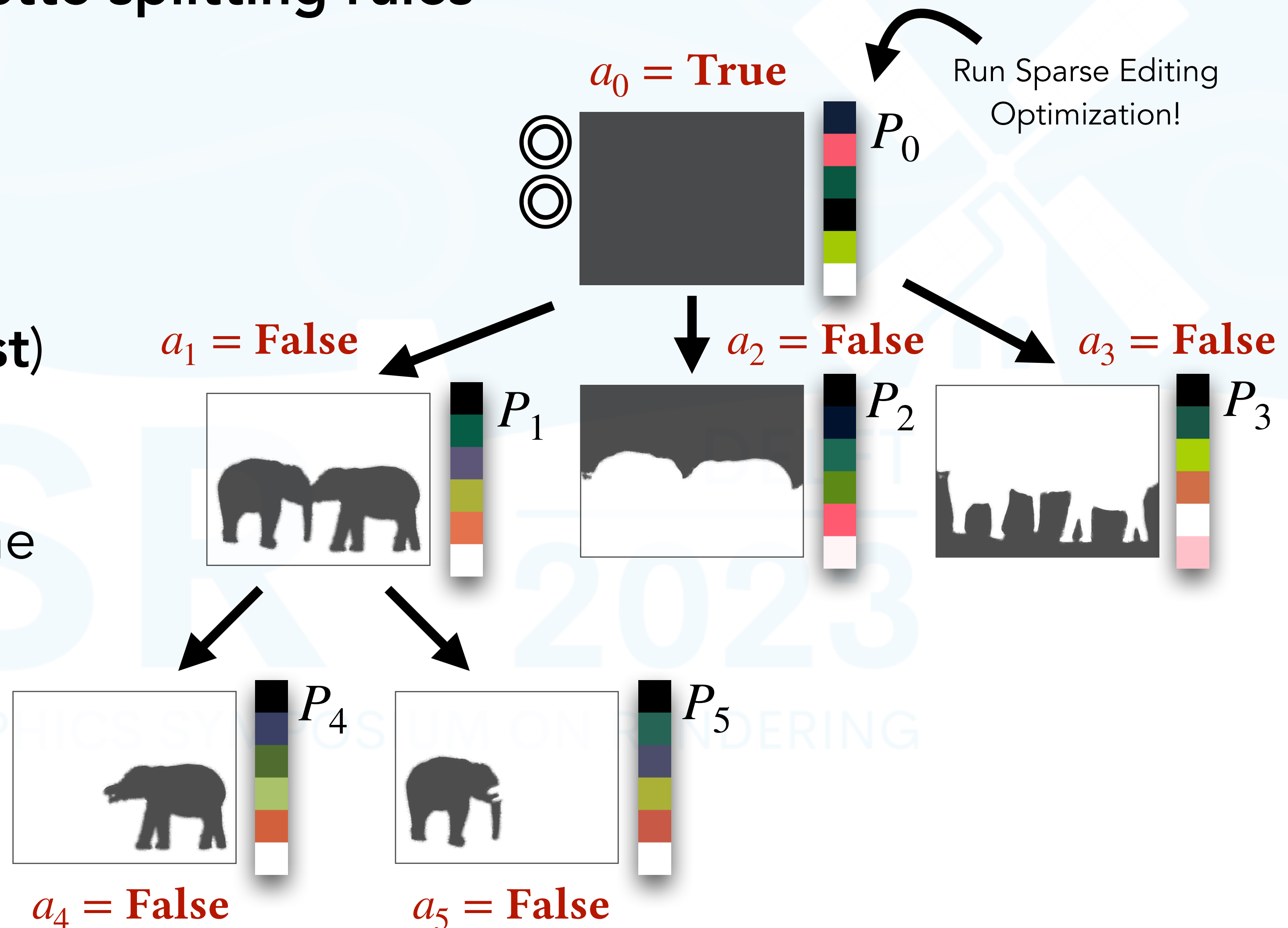
- Store booleans to track node activations
- A new image-space constraint starts at the most local (**deepest**) **active** node containing it



Sparse Editing *with* Hierarchy

Palette splitting rules

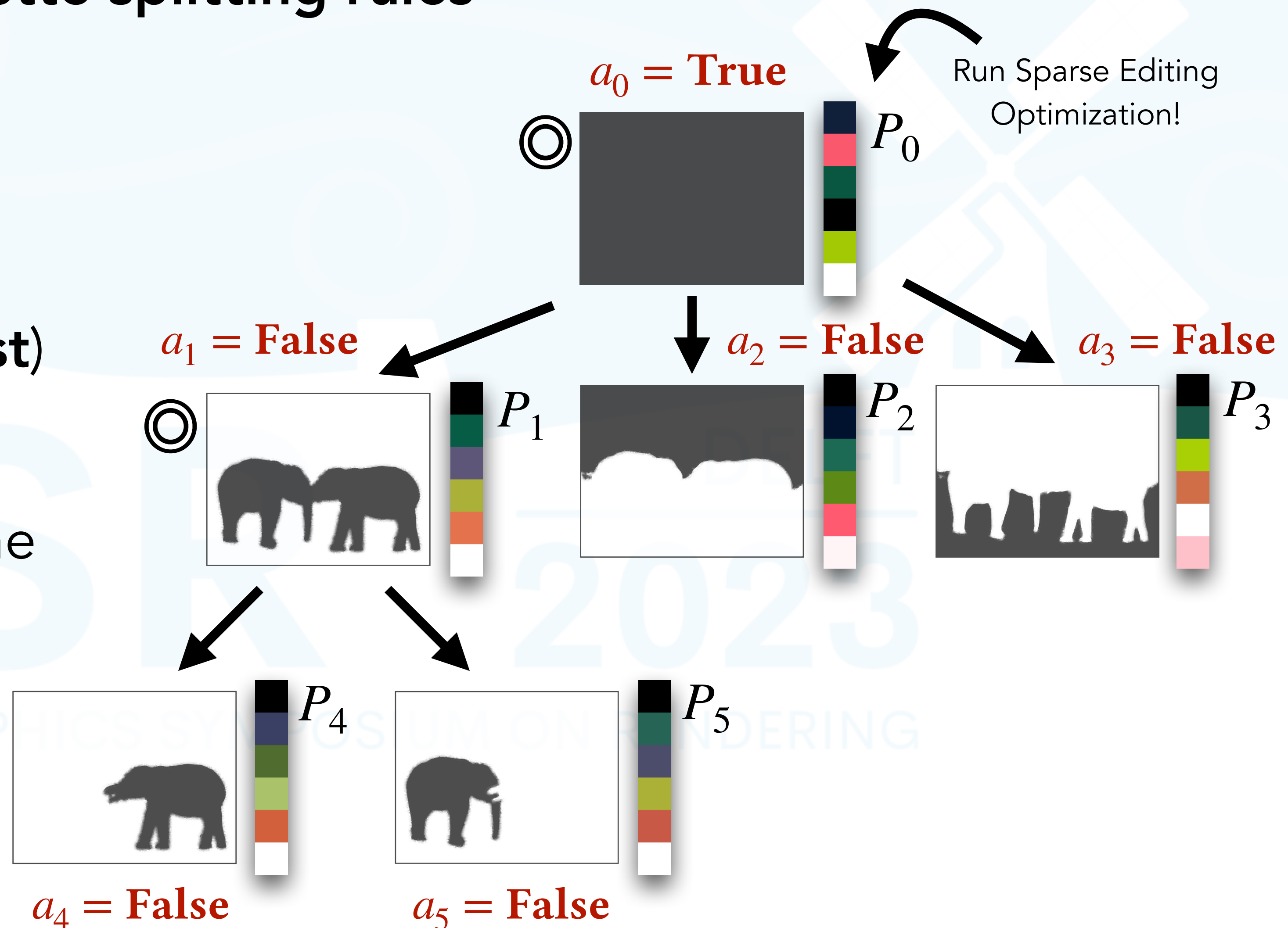
- Store booleans to track node activations
- A new image-space constraint starts at the most local (**deepest**) **active** node containing it
- Optimization fails → activate the next deeper node containing it



Sparse Editing *with* Hierarchy

Palette splitting rules

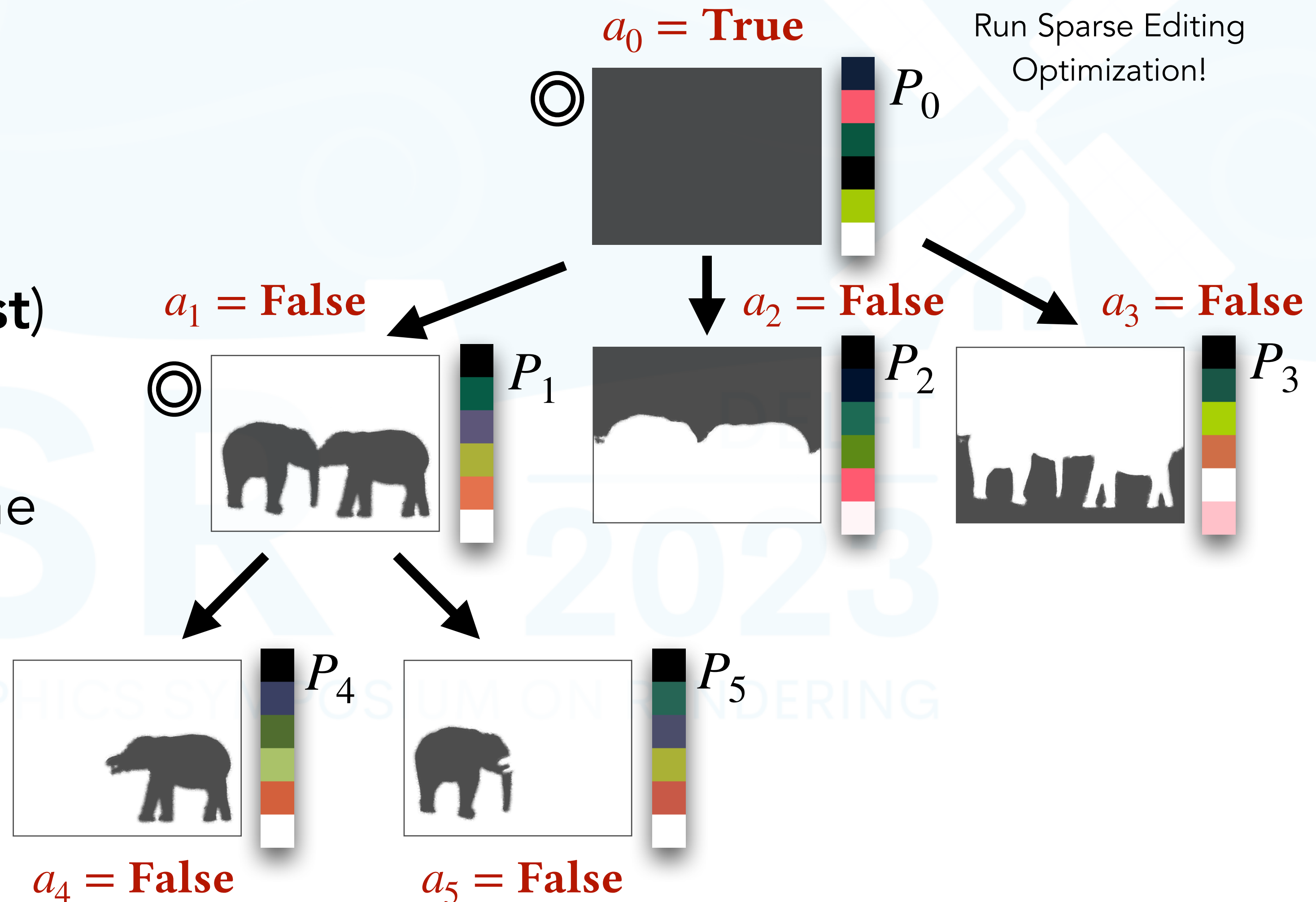
- Store booleans to track node activations
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Sparse Editing *with* Hierarchy

Palette splitting rules

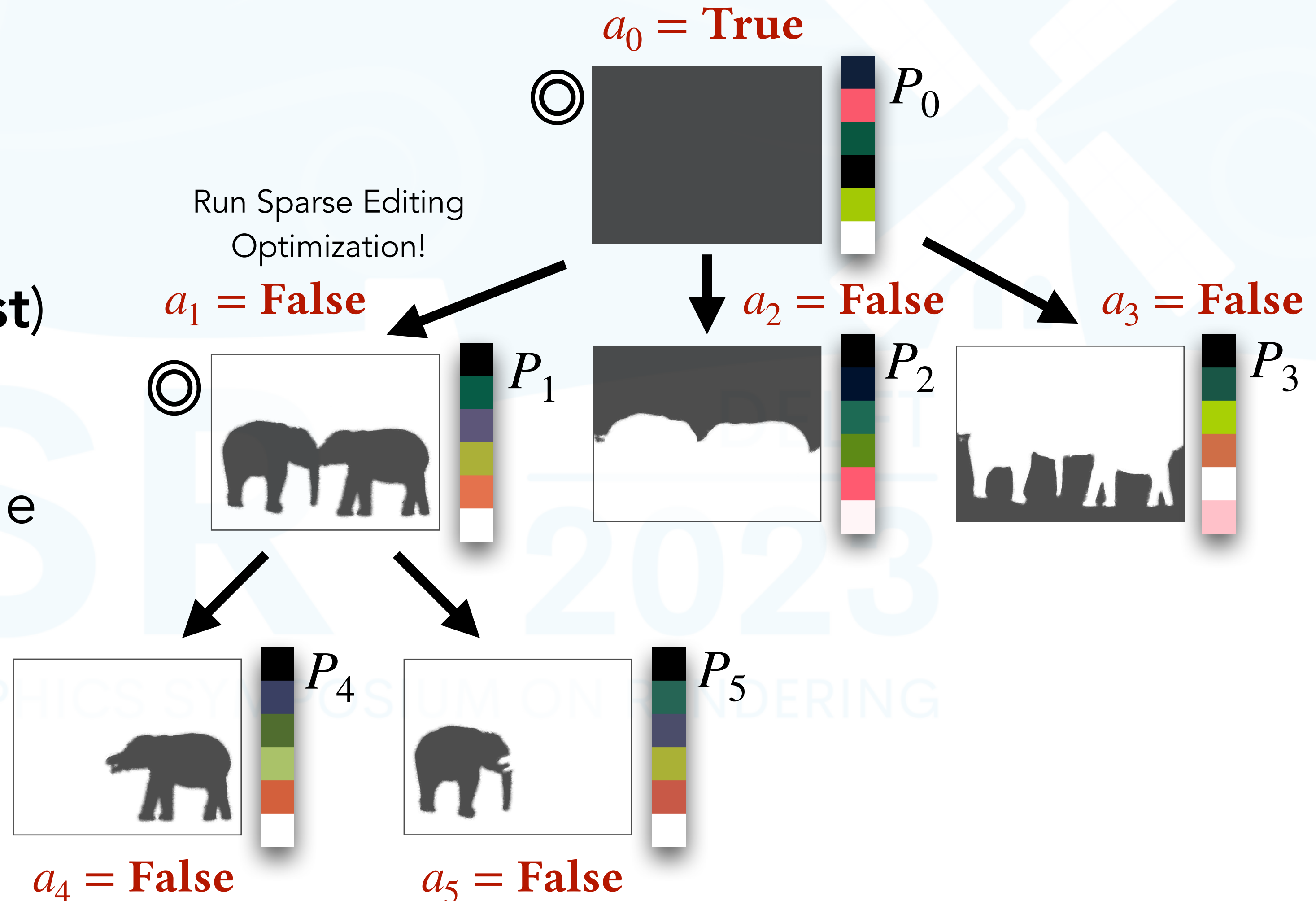
- Store booleans to track node activations
- A new image-space constraint starts at the most local (**deepest**) **active** node containing it
- Optimization fails → activate the next deeper node containing it



Sparse Editing *with* Hierarchy

Palette splitting rules

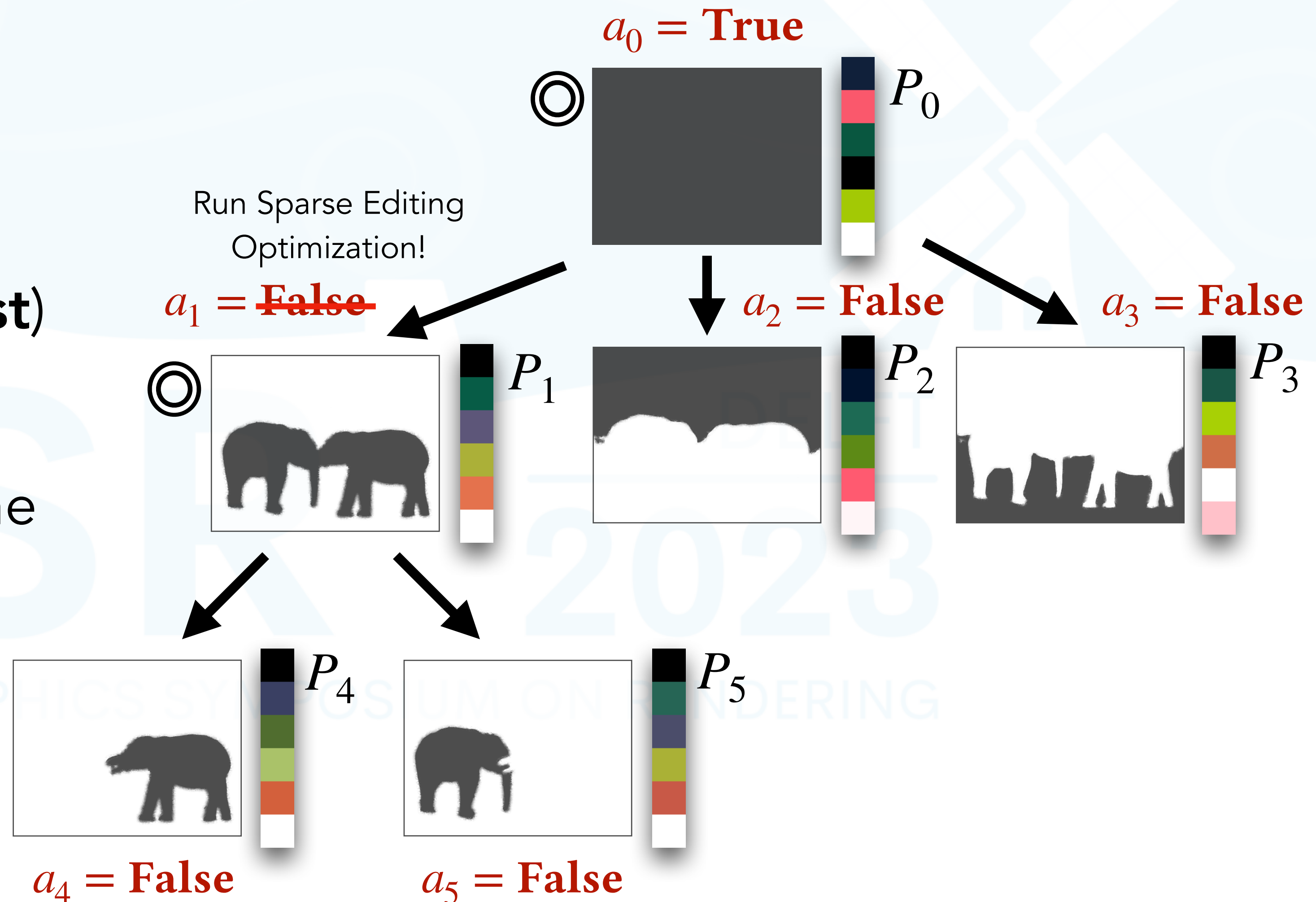
- Store booleans to track node activations
- A new image-space constraint starts at the most local (**deepest**) **active** node containing it
- Optimization fails \rightarrow activate the next deeper node containing it



Sparse Editing *with* Hierarchy

Palette splitting rules

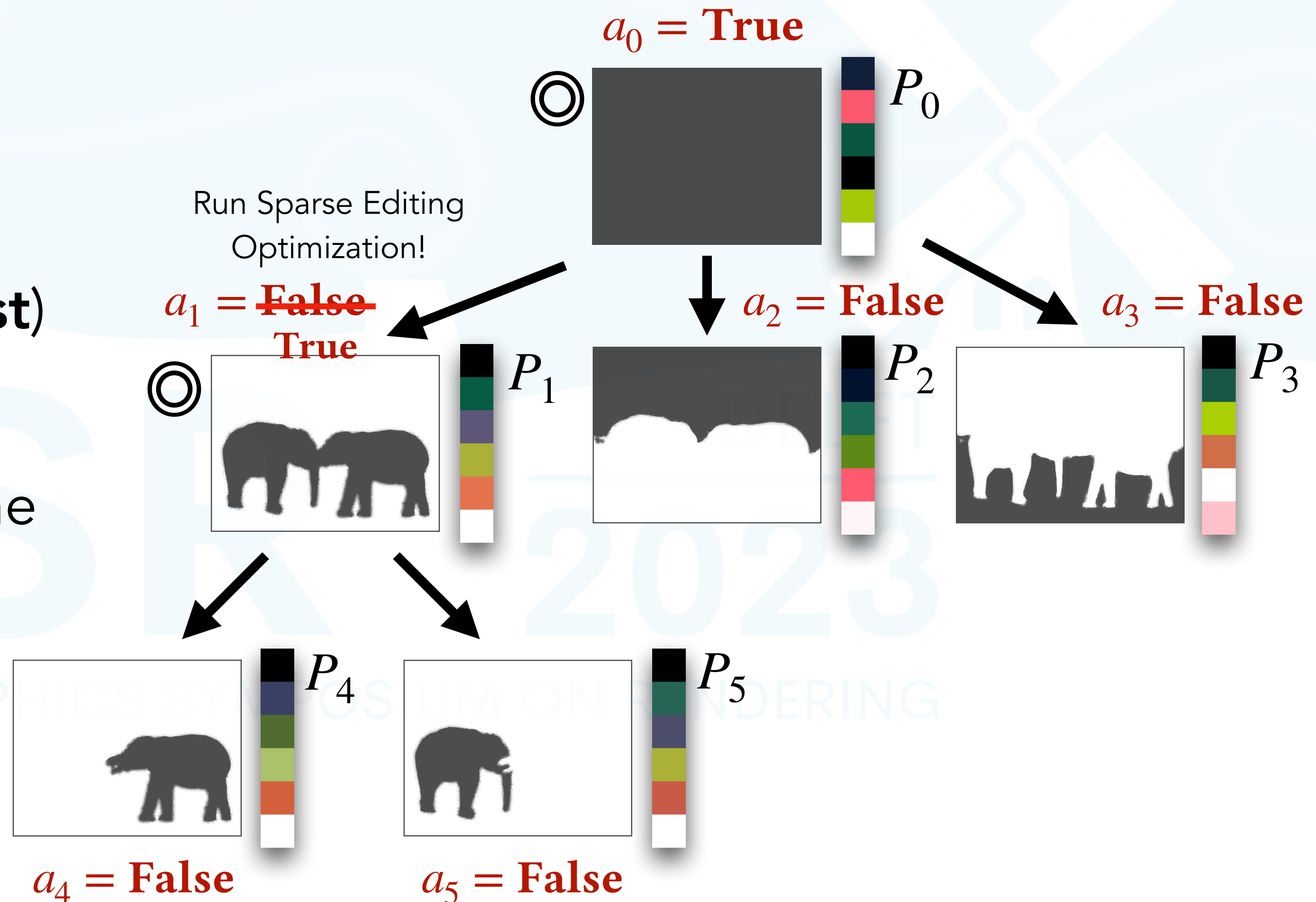
- Store booleans to track node activations
- A new image-space constraint starts at the most local (**deepest**) **active** node containing it
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Sparse Editing *with* Hierarchy

Palette splitting rules

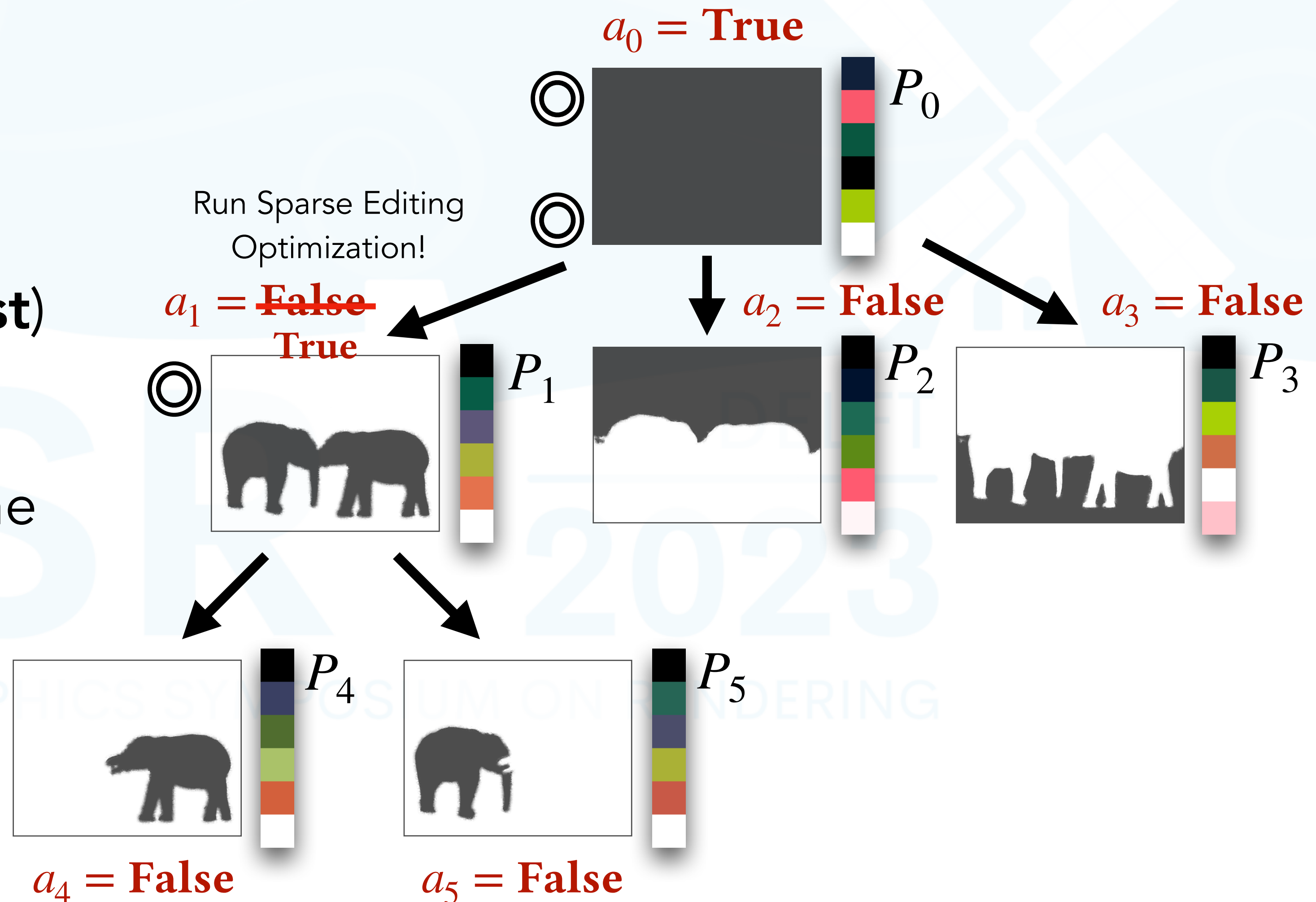
- Store booleans to track node activations
- A new image-space constraint starts at the most local (**deepest**) **active** node containing it
- Optimization fails → activate the next deeper node containing it



Sparse Editing *with* Hierarchy

Palette splitting rules

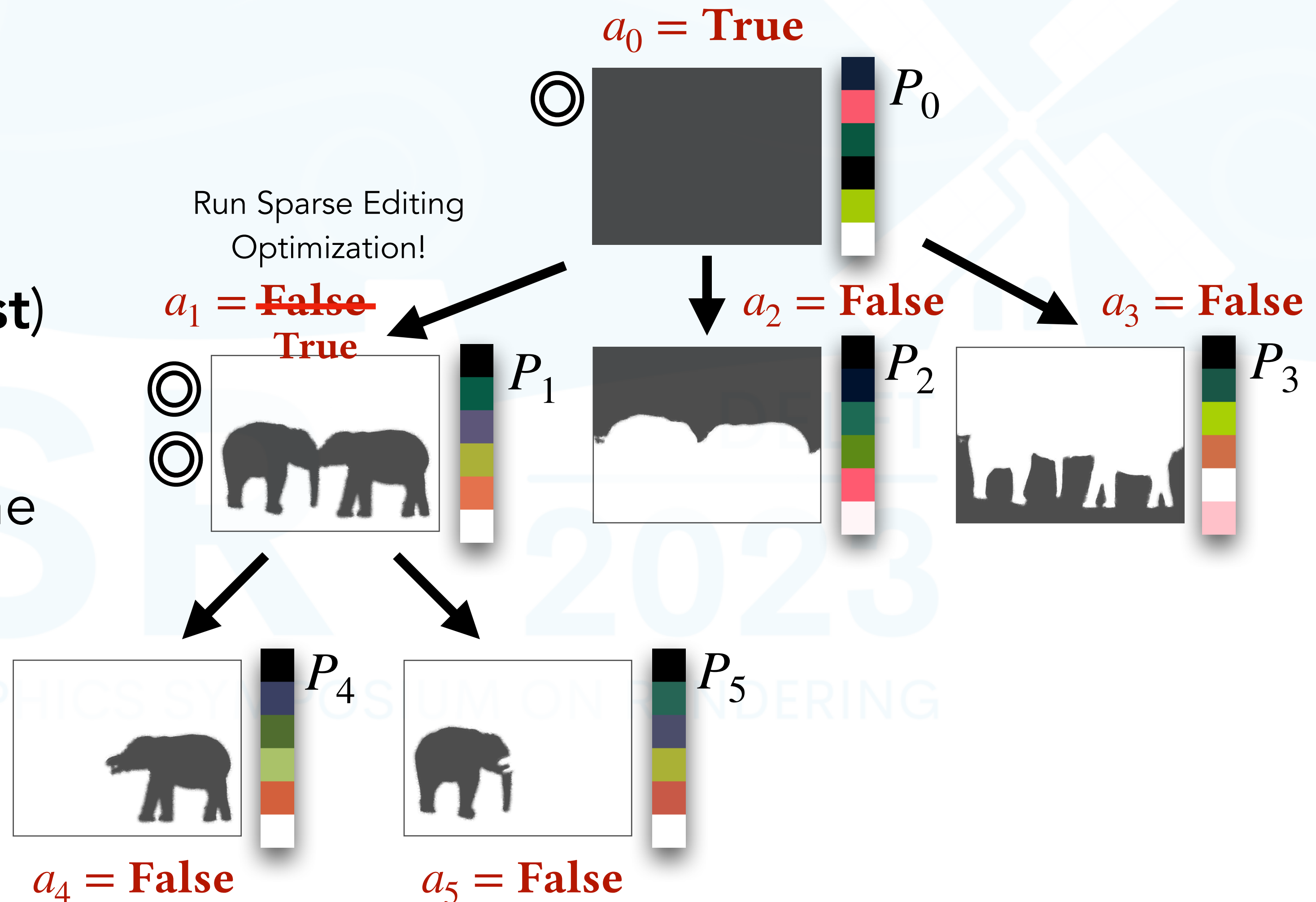
- Store booleans to track node activations
- A new image-space constraint starts at the most local (**deepest**) **active** node containing it
- Optimization fails → activate the next deeper node containing it



Sparse Editing *with* Hierarchy

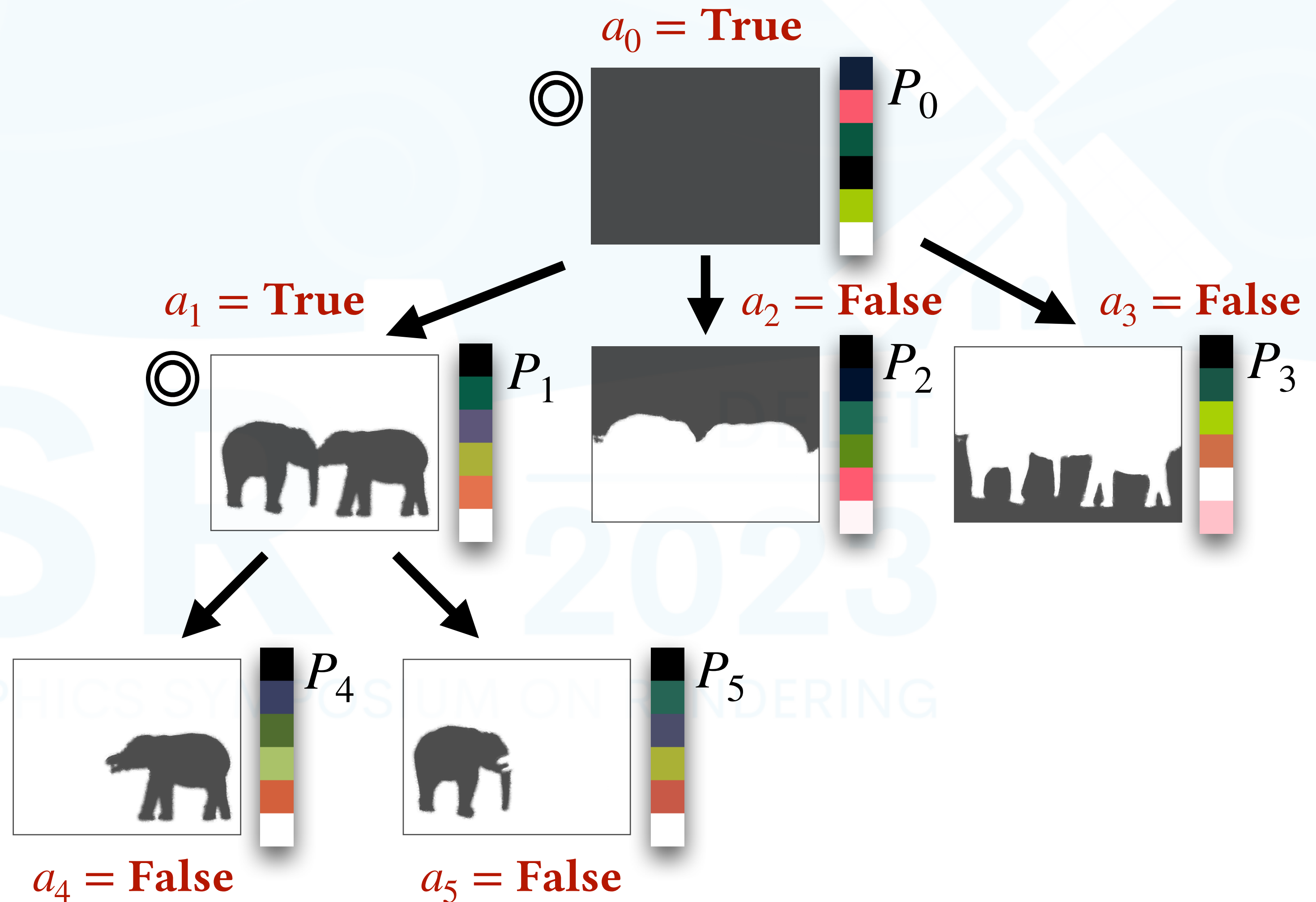
Palette splitting rules

- Store booleans to track node activations
- A new image-space constraint starts at the most local (**deepest**) **active** node containing it
- Optimization fails → activate the next deeper node containing it



Palette and Weight Hierarchy

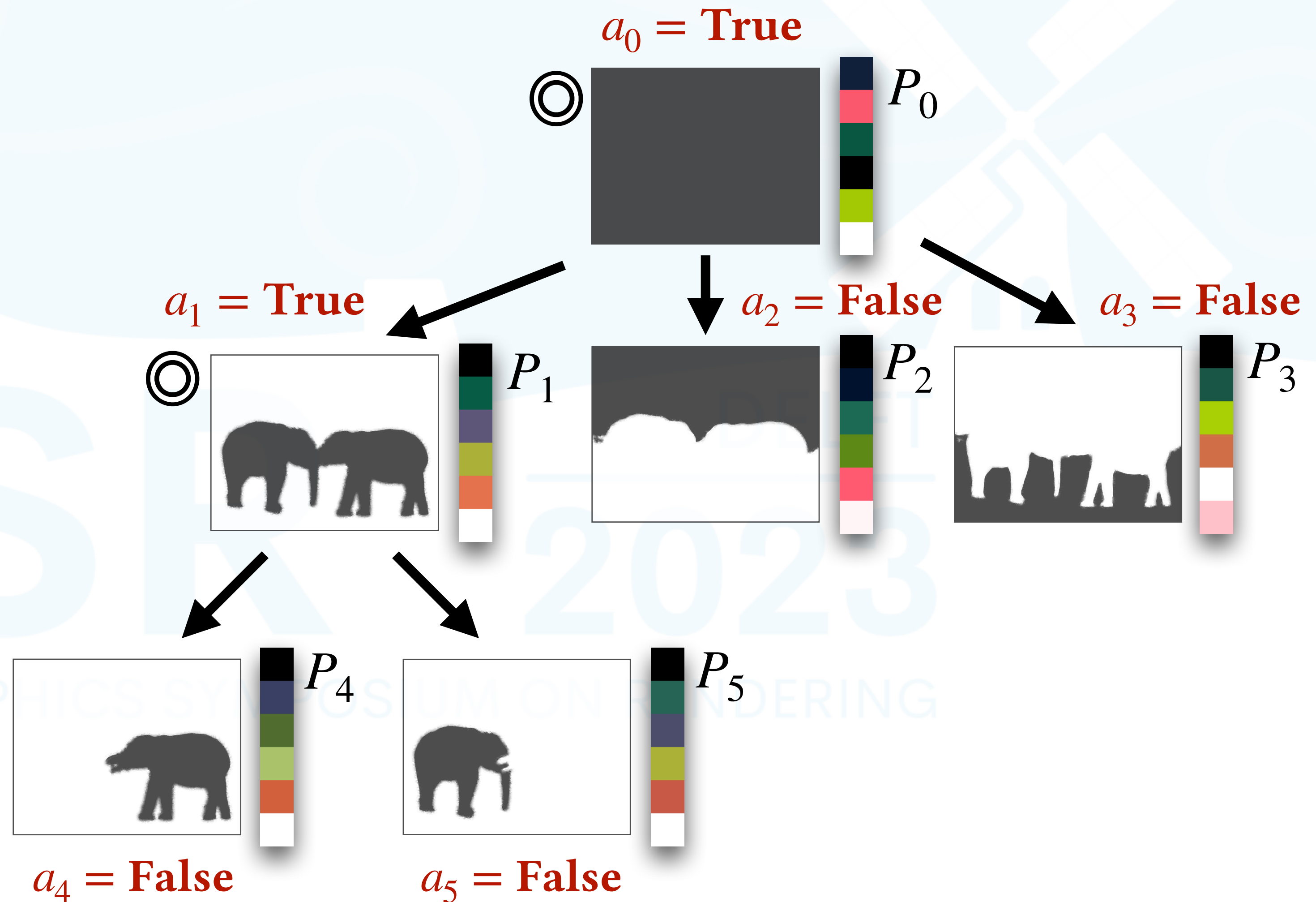
Reconstruction



Palette and Weight Hierarchy

Reconstruction

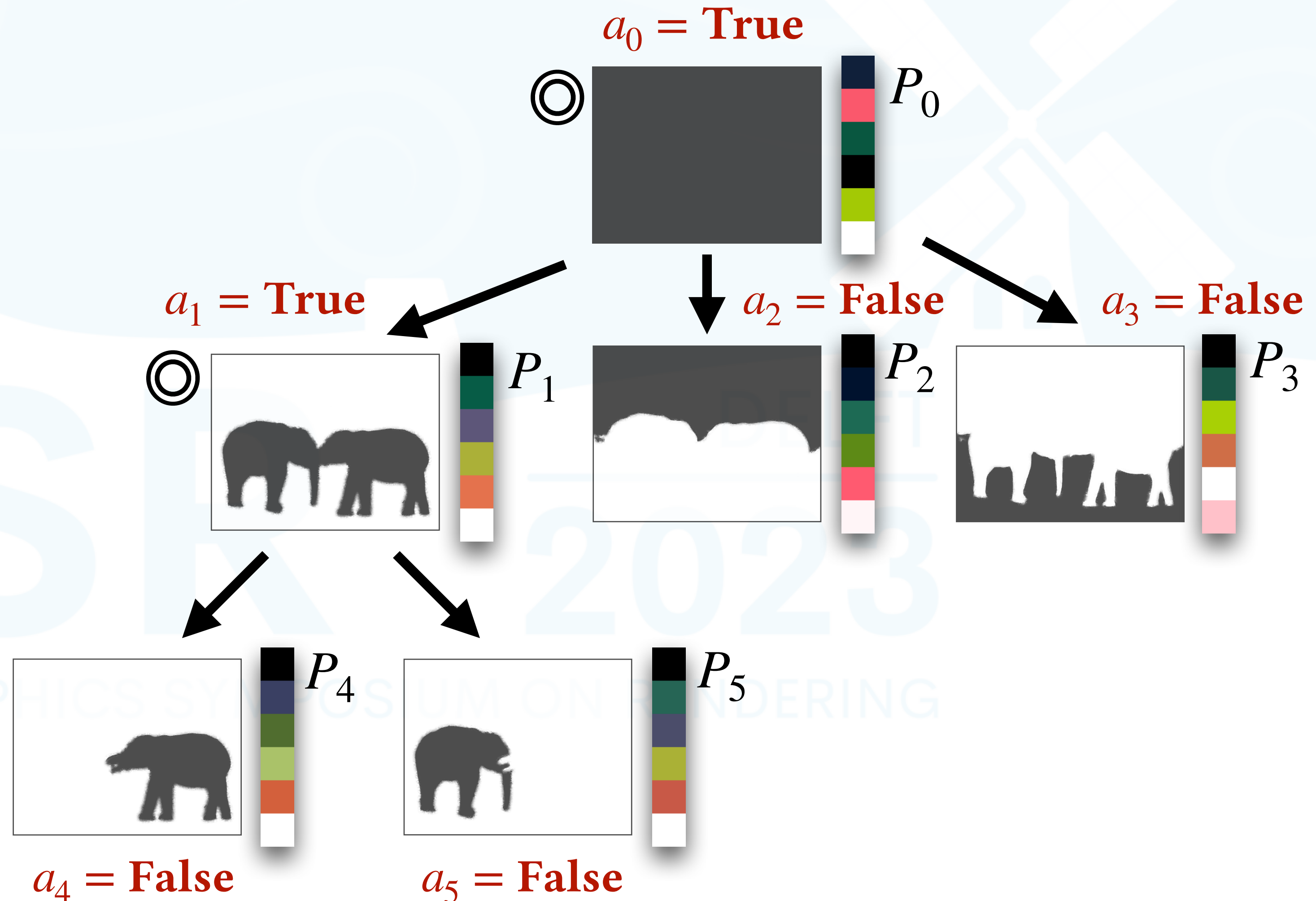
- How to reconstruct the edited image under the hierarchy?



Palette and Weight Hierarchy

Reconstruction

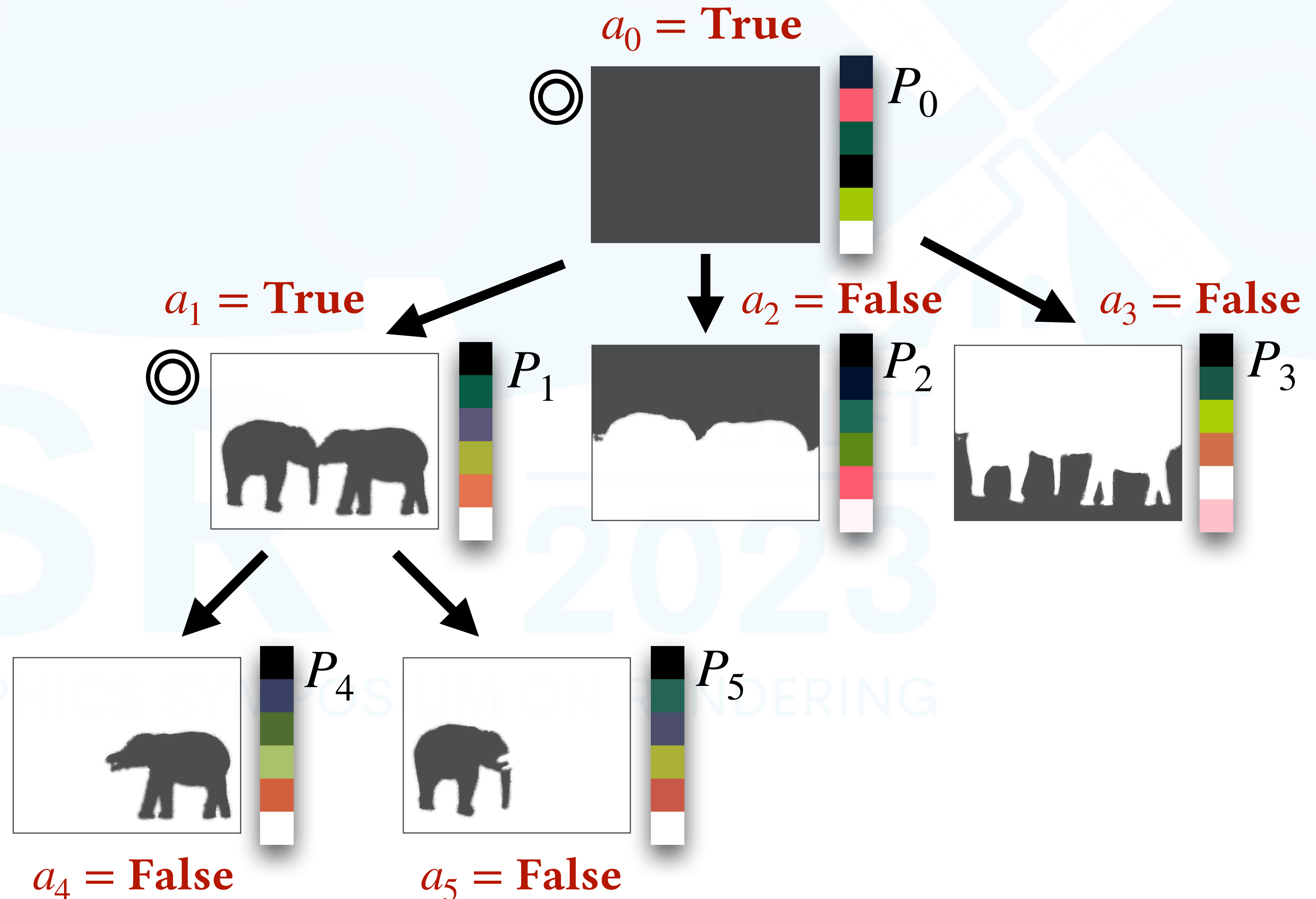
- How to reconstruct the edited image under the hierarchy?
- Alpha compositing over activated nodes



Palette and Weight Hierarchy

Reconstruction

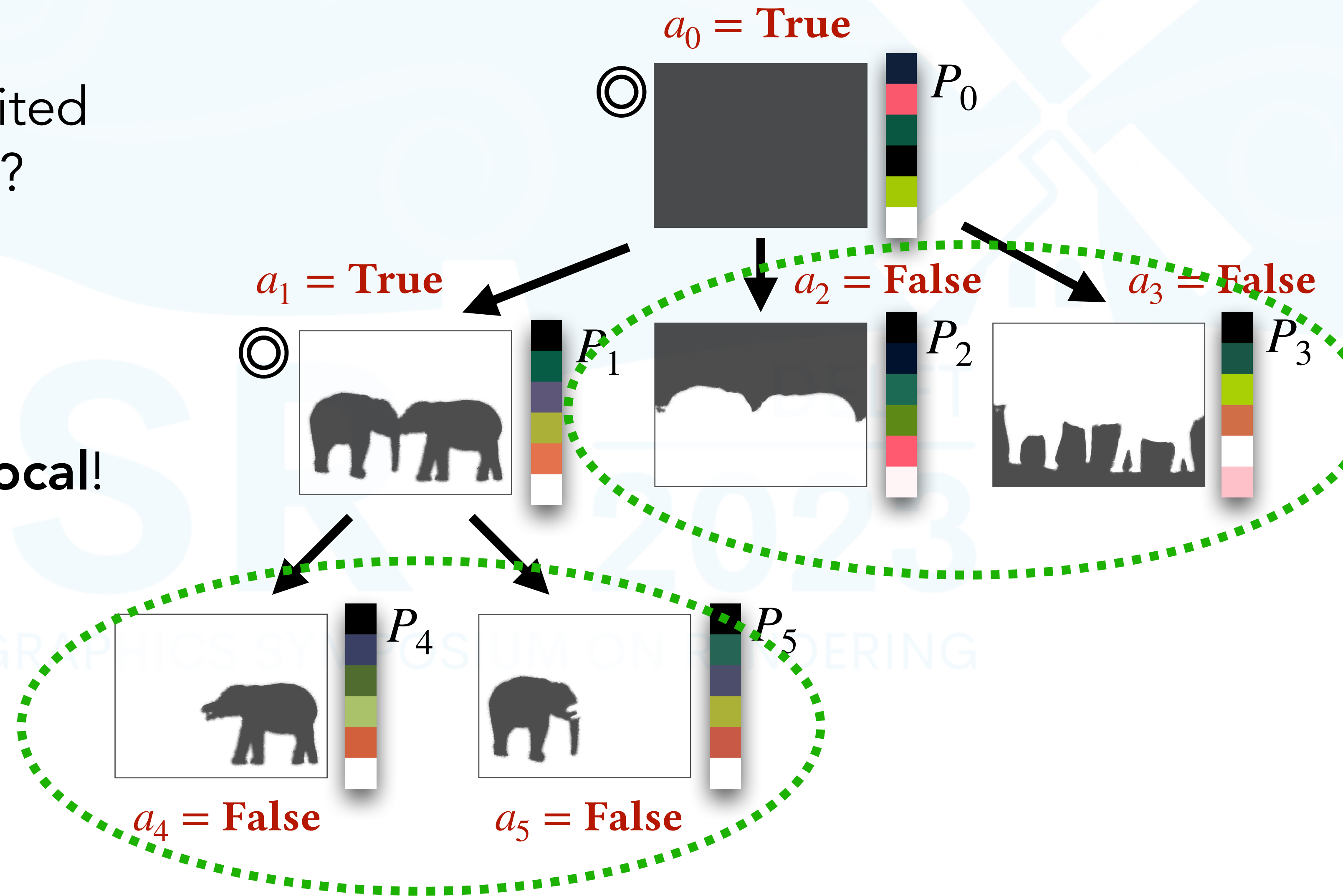
- How to reconstruct the edited image under the hierarchy?
- Alpha compositing over activated nodes
- Leaf palettes are more **local**!



Palette and Weight Hierarchy

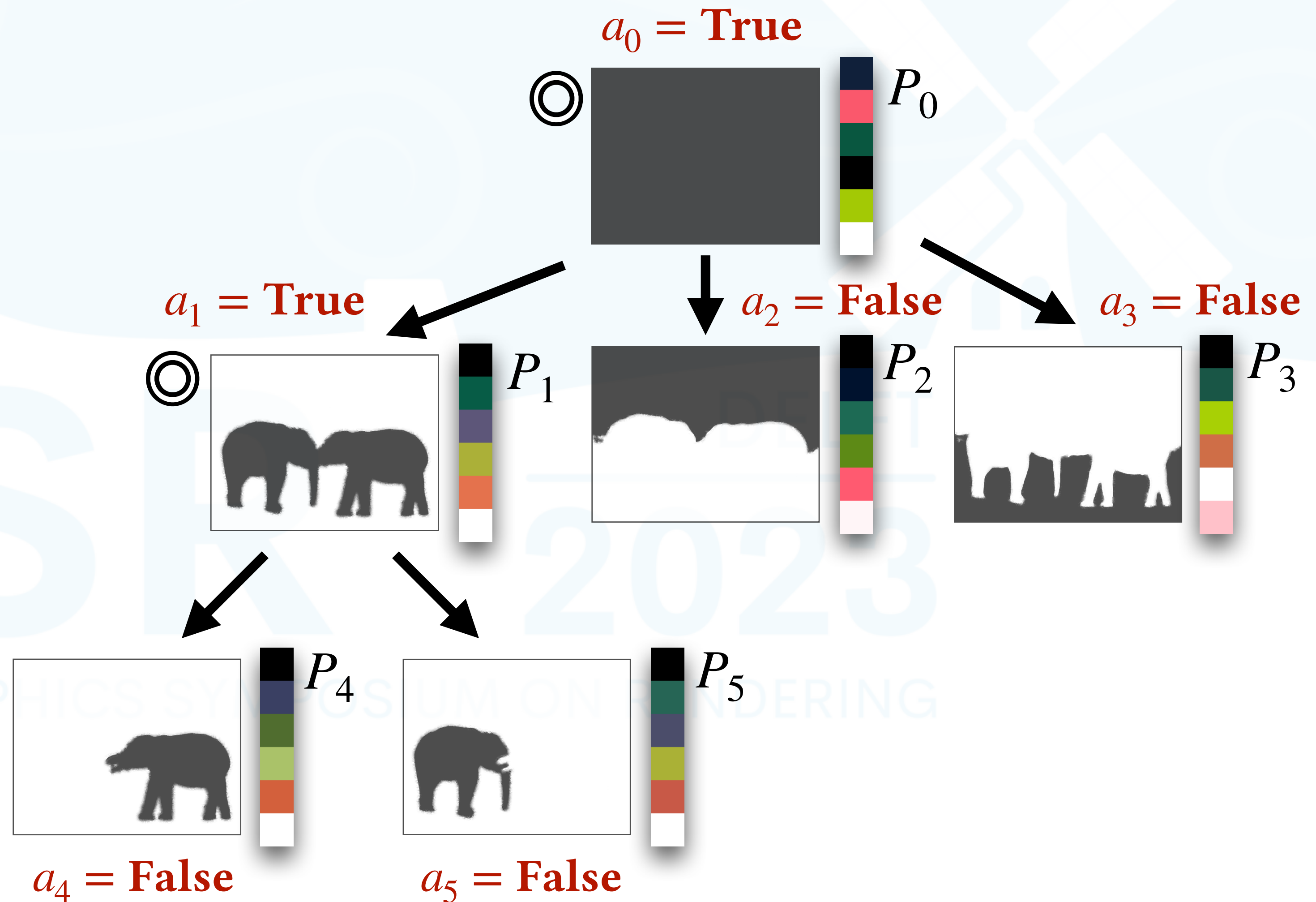
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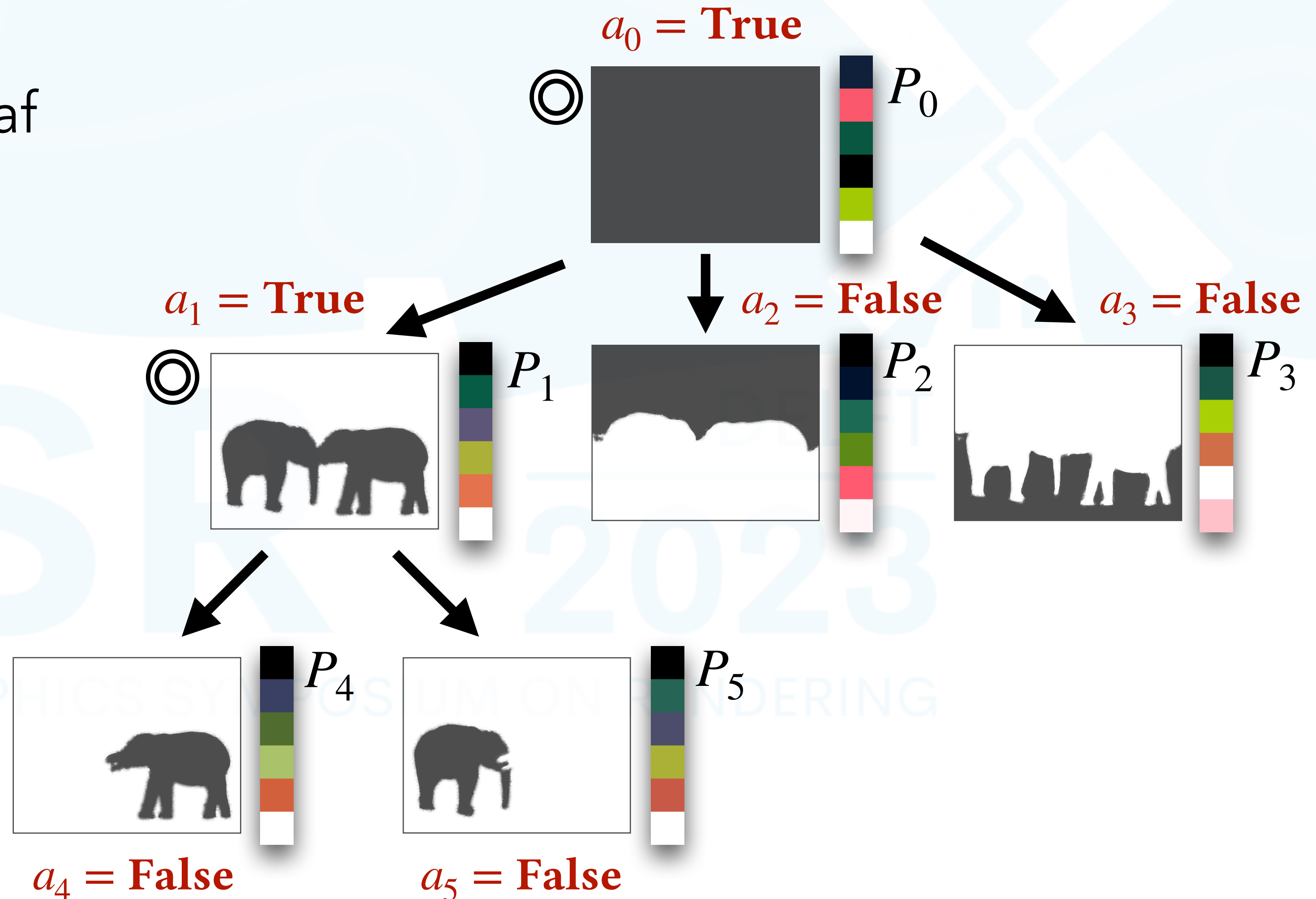
Palette Propagation



Palette and Weight Hierarchy

Palette Propagation

- Propagate changes towards leaf palettes if **not activated**

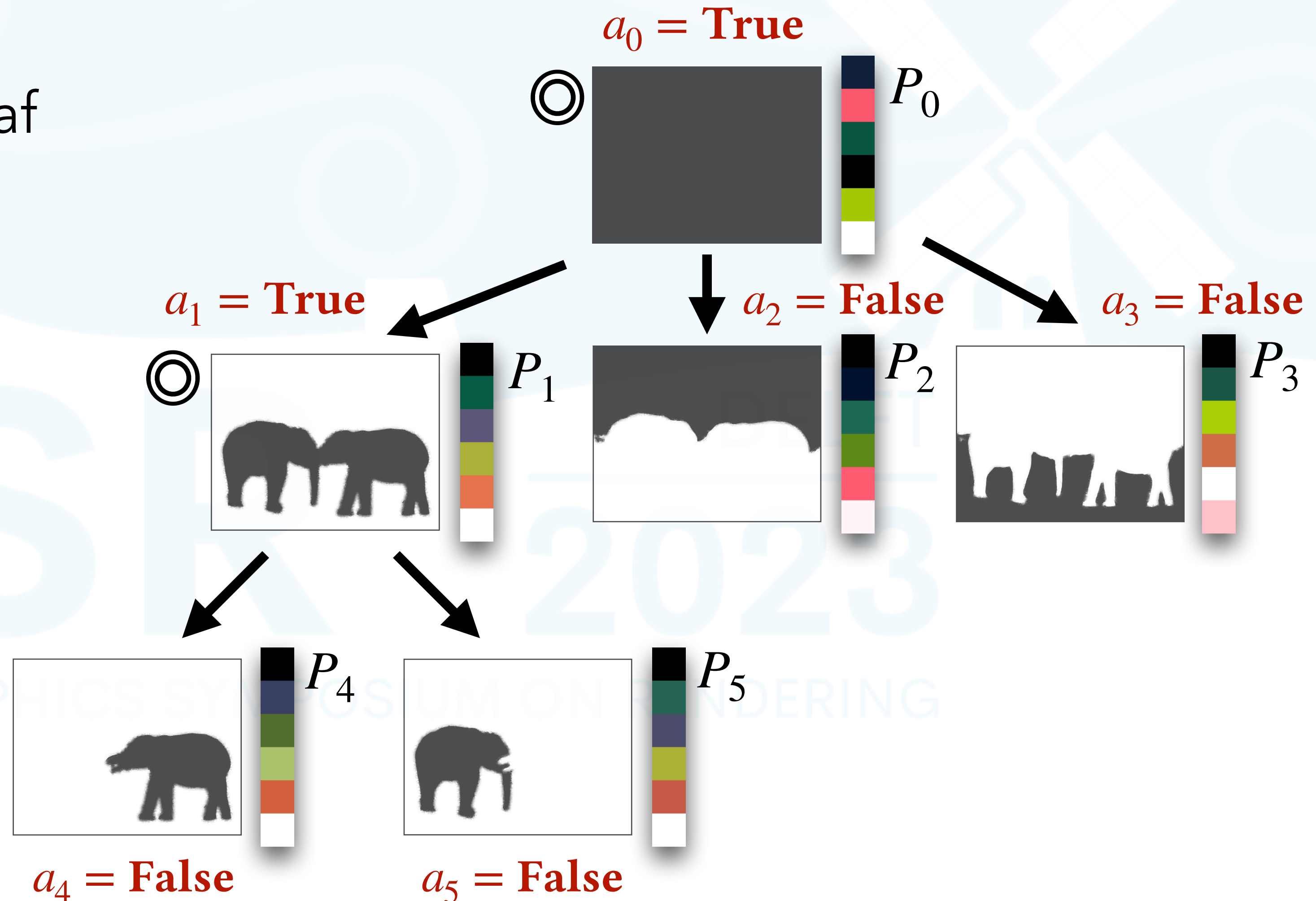


Palette and Weight Hierarchy

Palette Propagation

- Propagate changes towards leaf palettes if **not activated**

- $$\min_{P_c} \|W_c \cdot P_c - W_p \cdot P_p\|_2^2$$



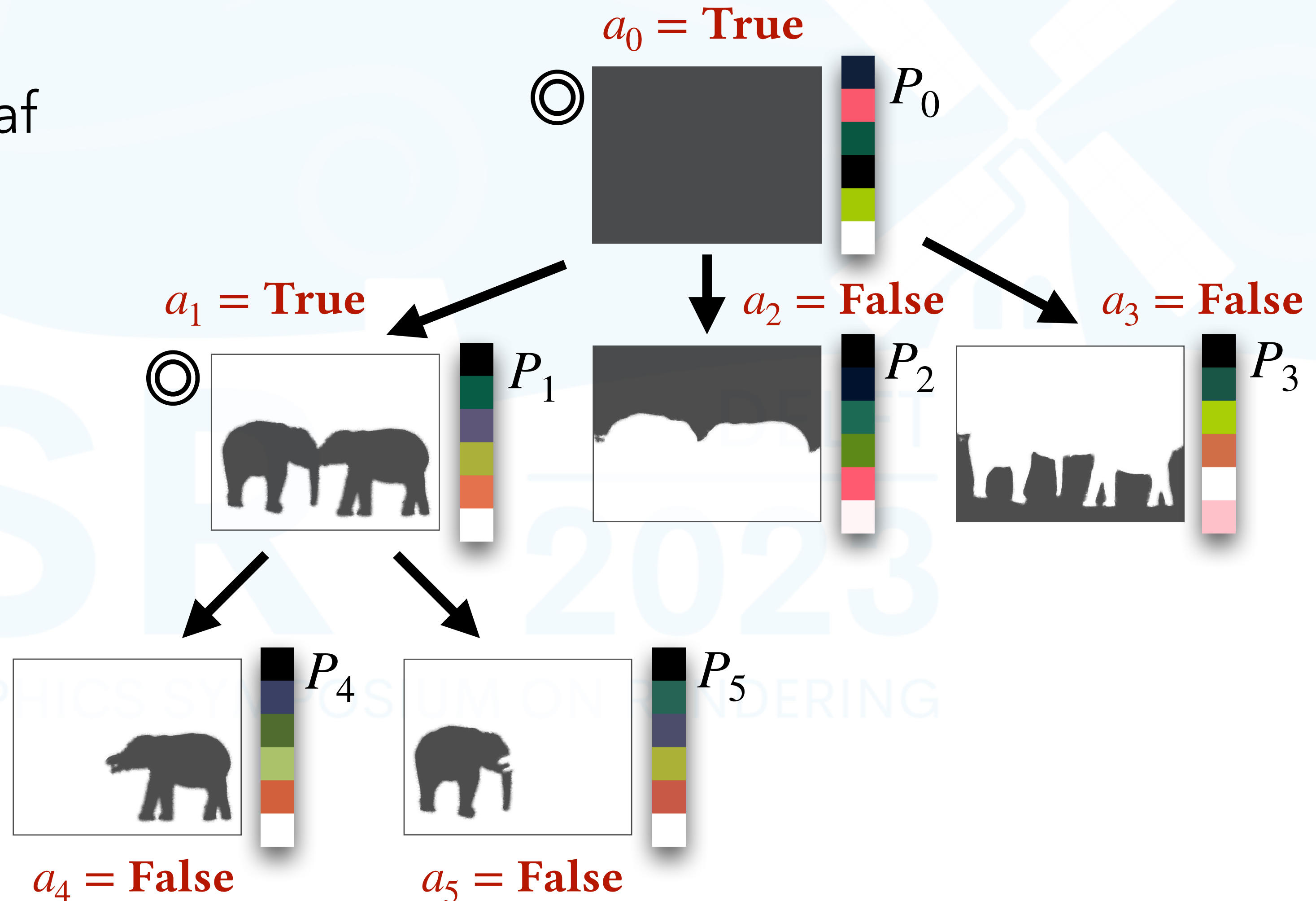
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- Propagate changes towards leaf palettes if **not activated**

- $\min_{P_c} \|W_c \cdot P_c - W_p \cdot P_p\|_2^2$

- Subject to $0 \leq P_c \leq 1$



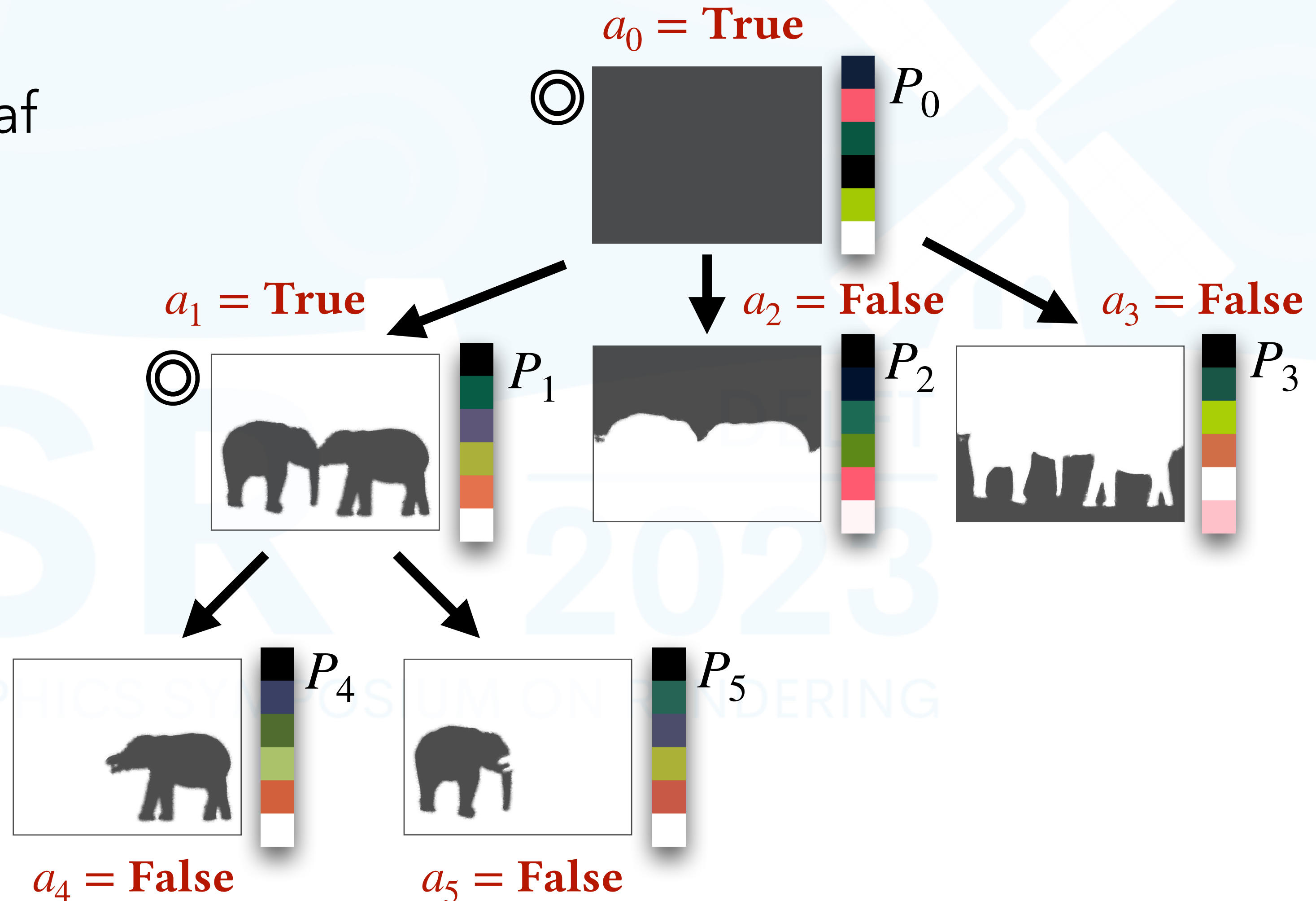
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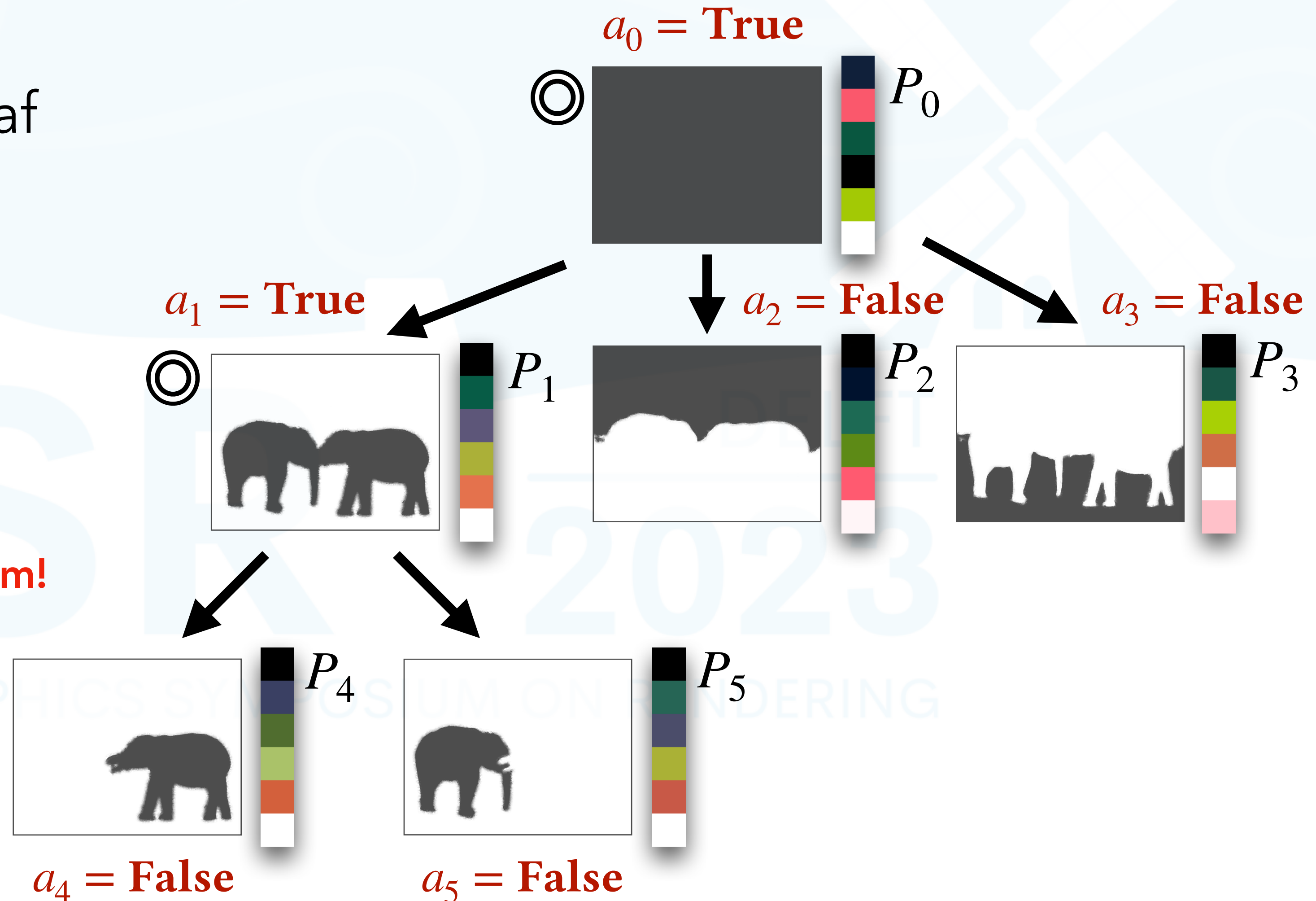
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- Subject to $0 \leq P_c \leq 1$

Small #p x #p quadratic programming problem!



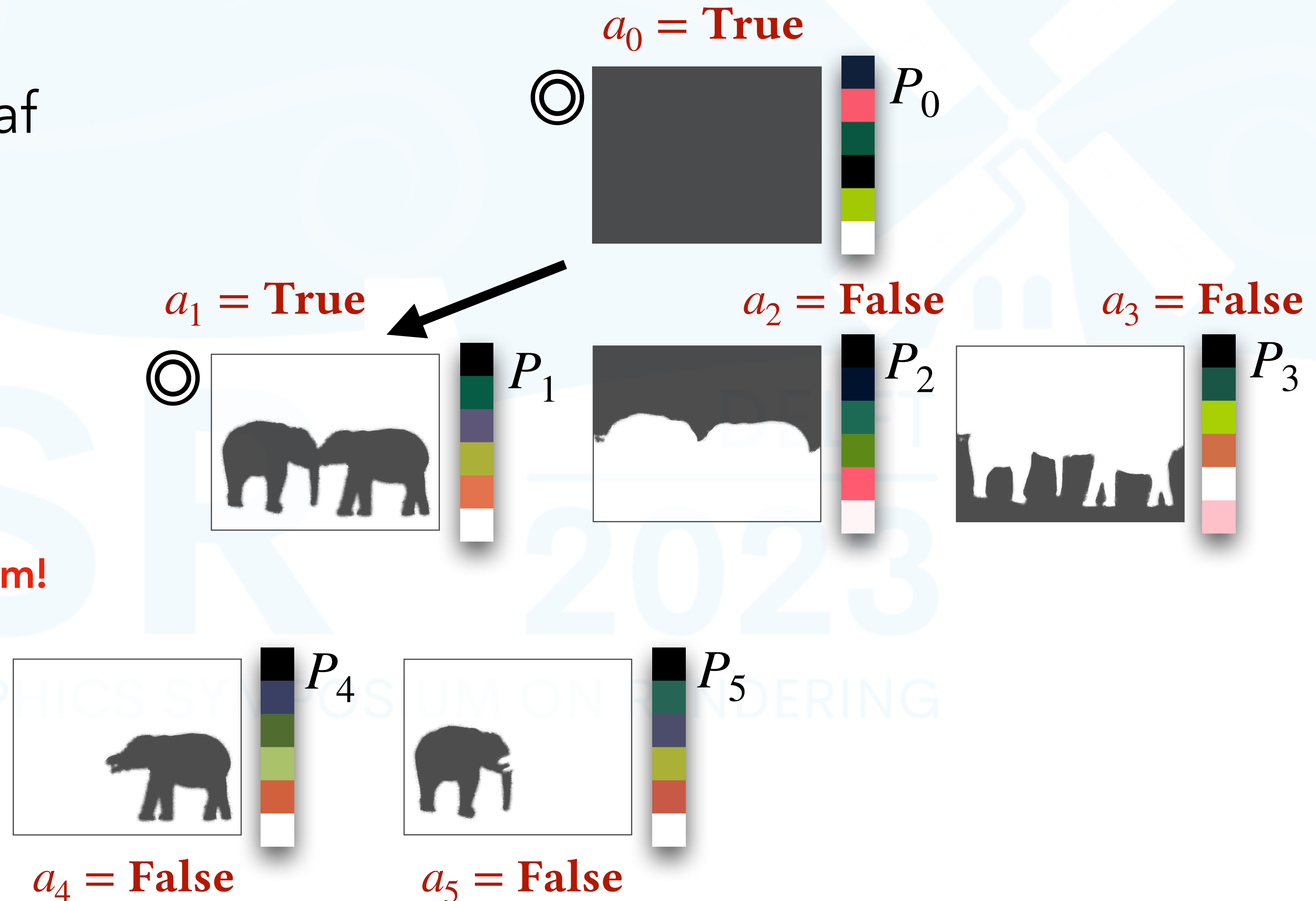
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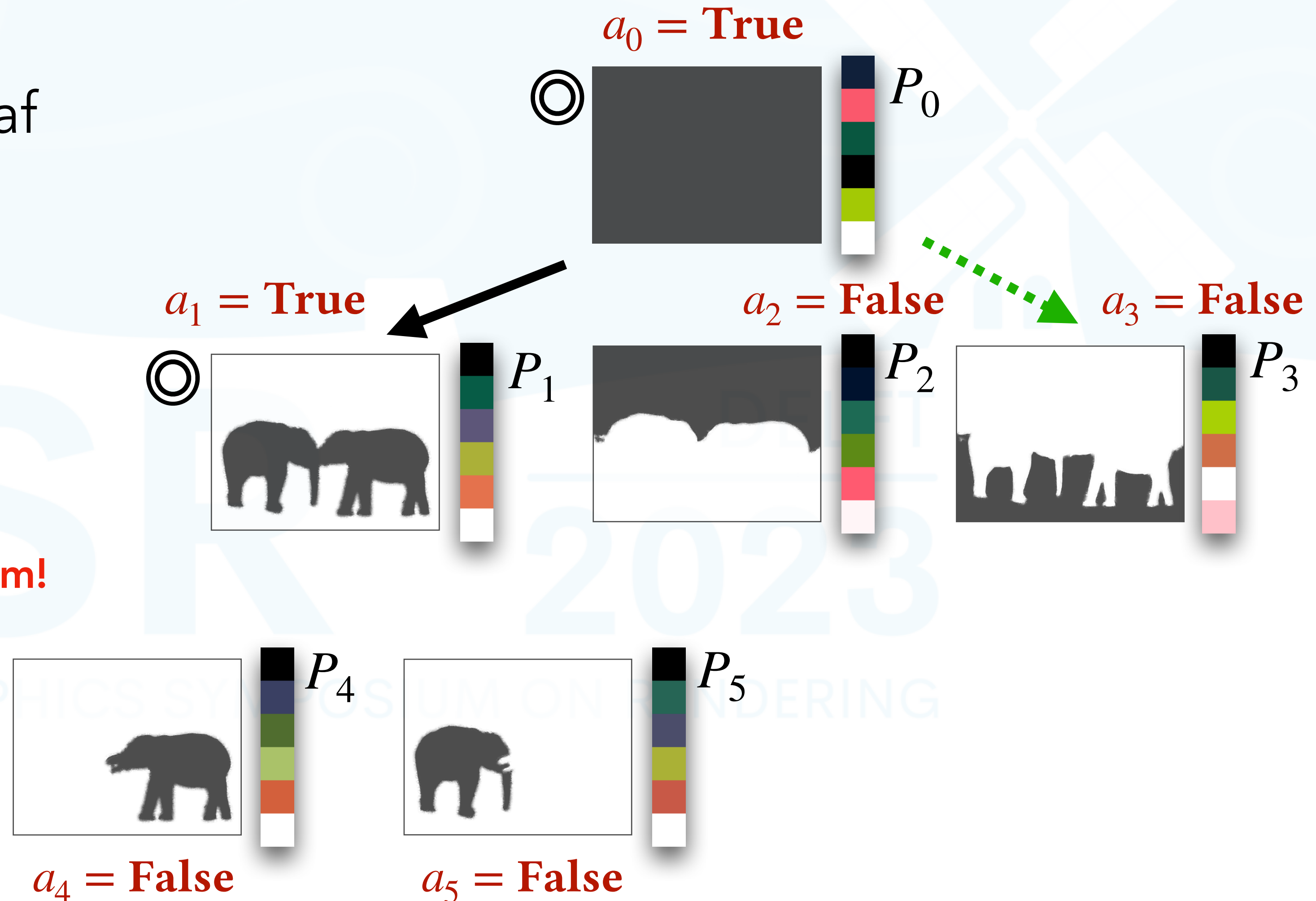
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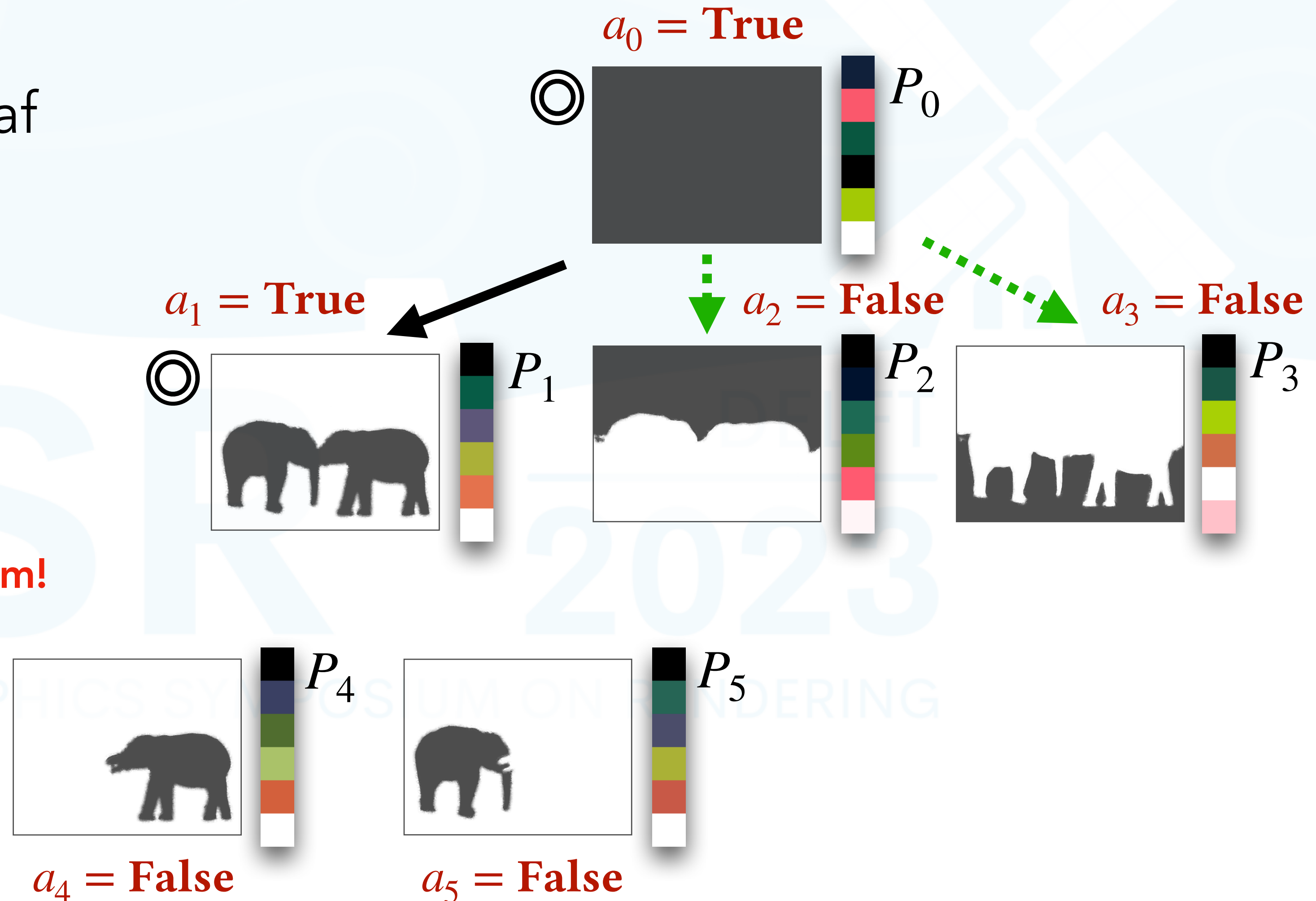
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Palette and Weight Hierarchy

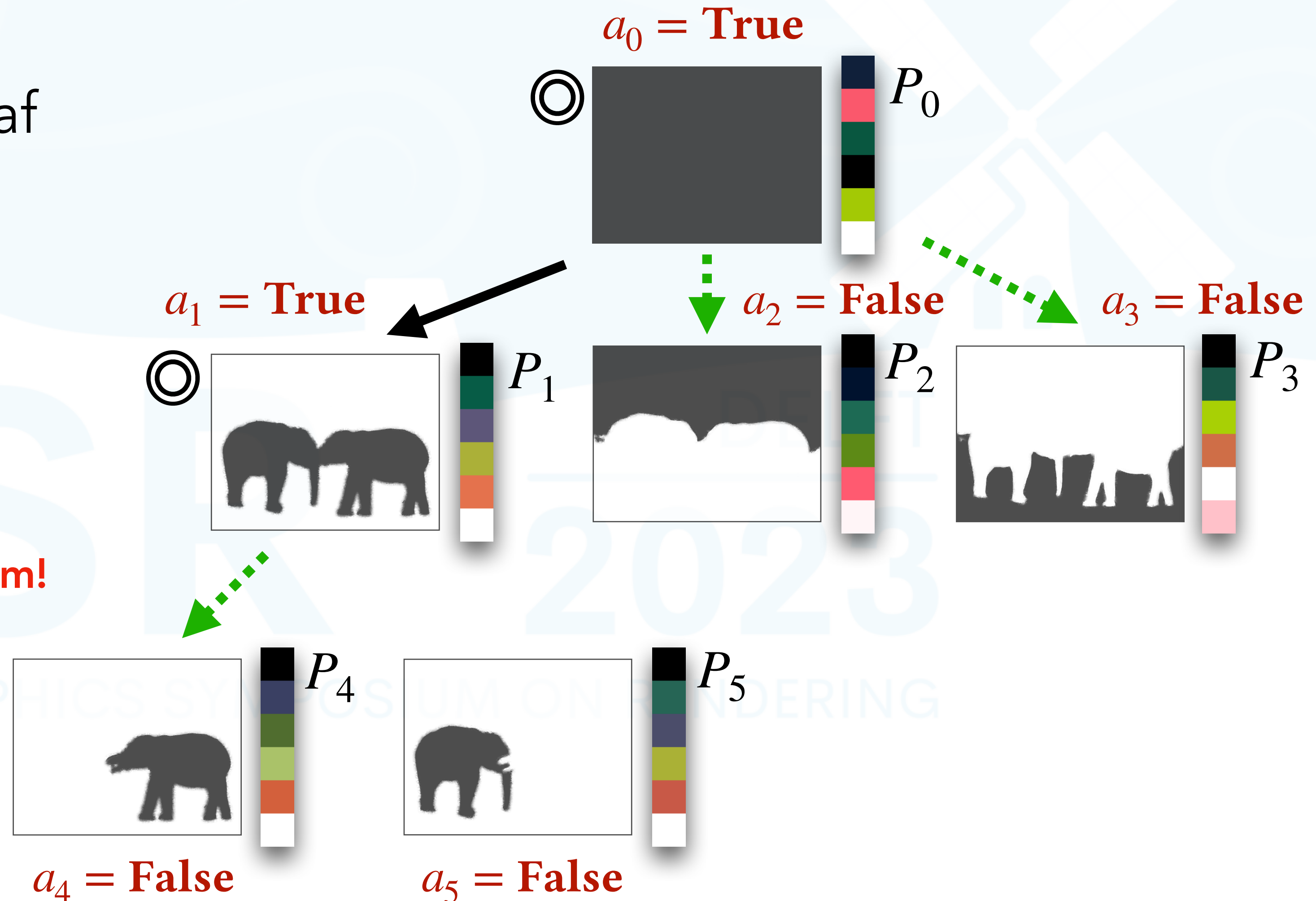
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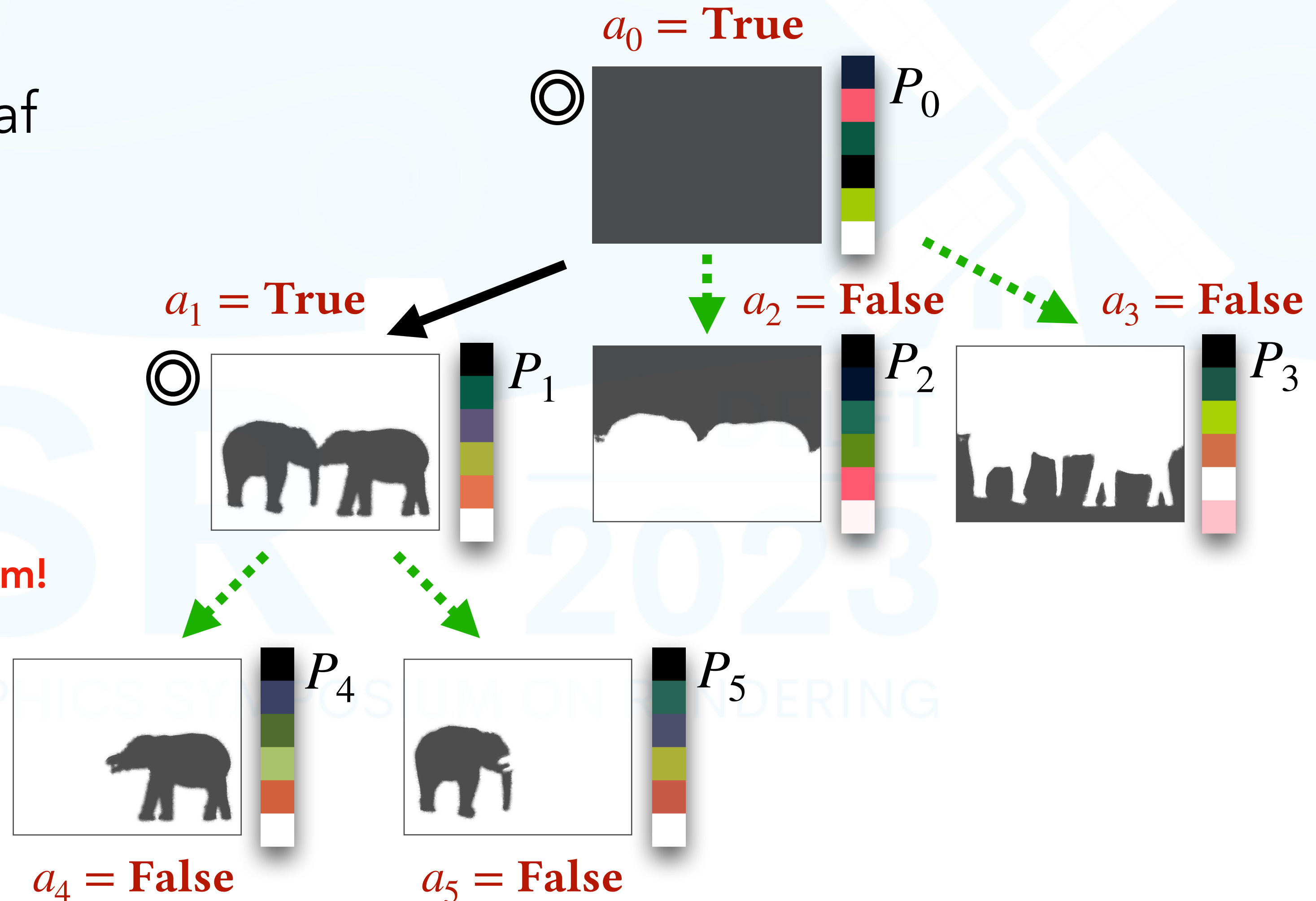
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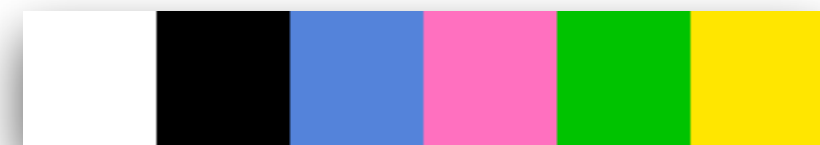
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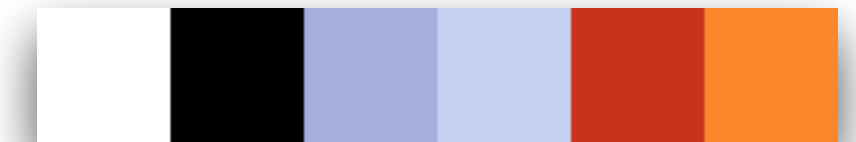
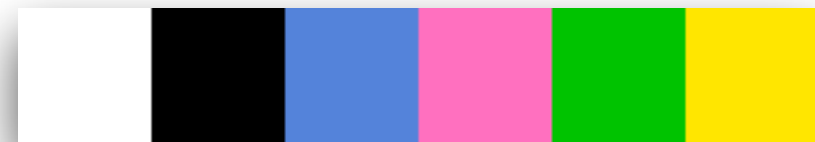


Input

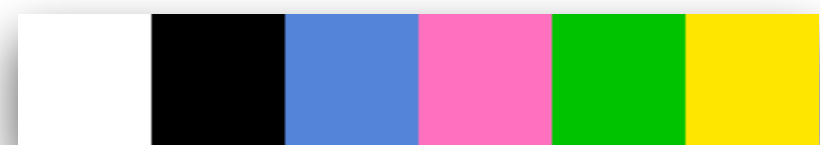


Input

[Tan et al. 2018]



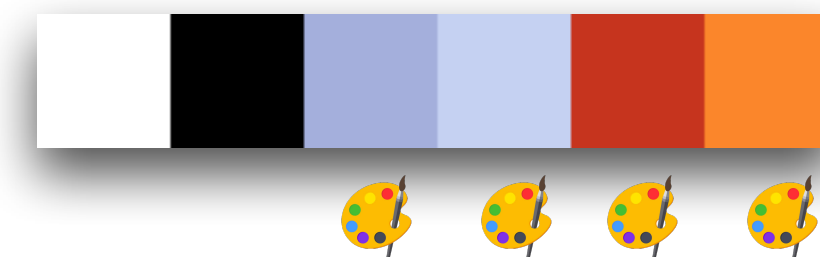
Input



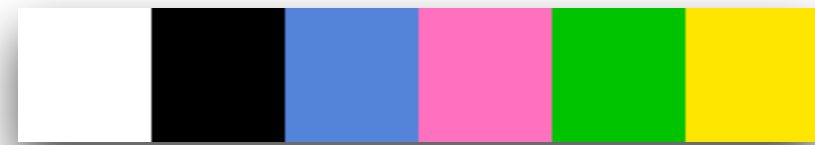
LoCoPalettes



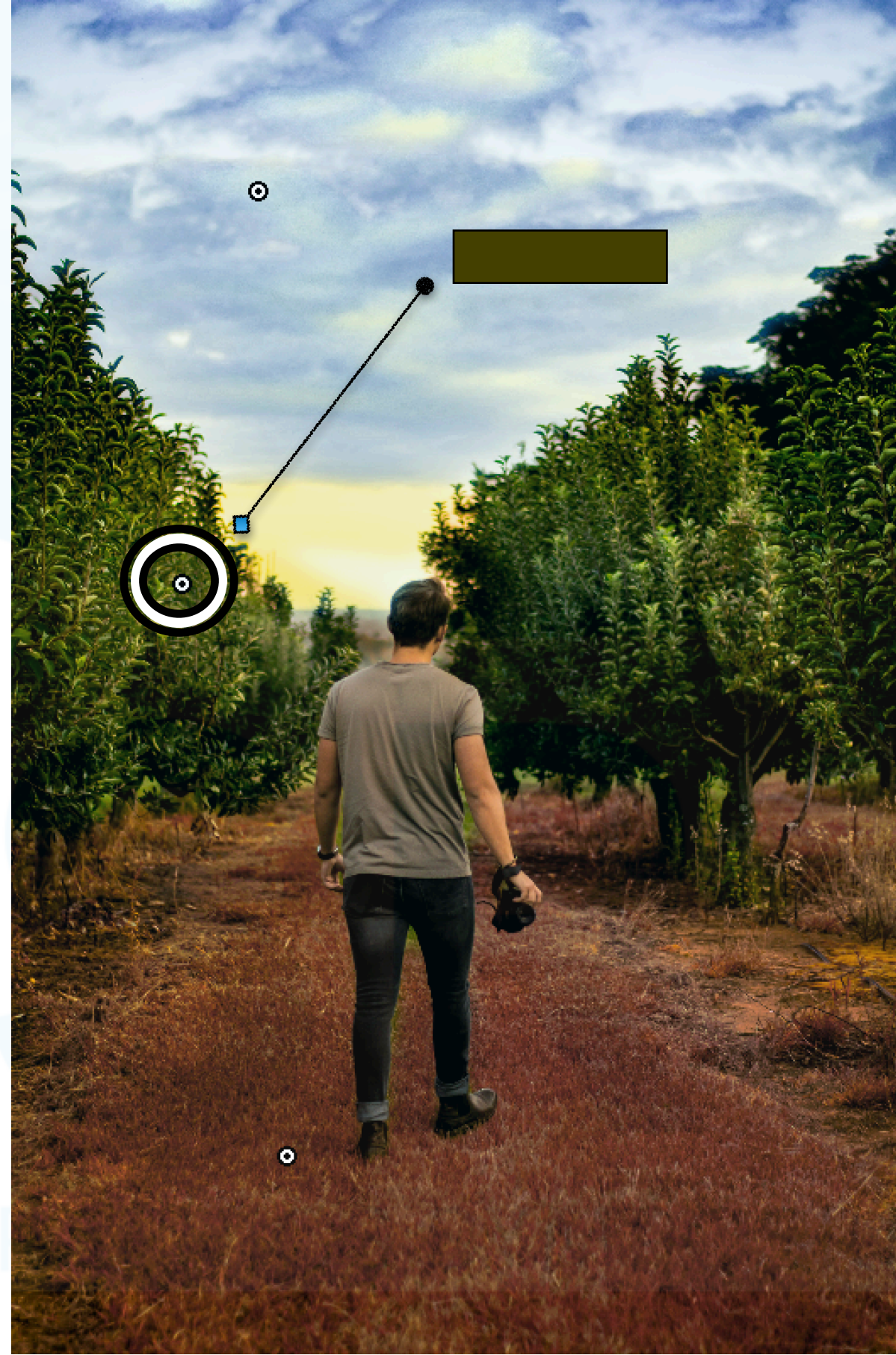
[Tan et al. 2018]



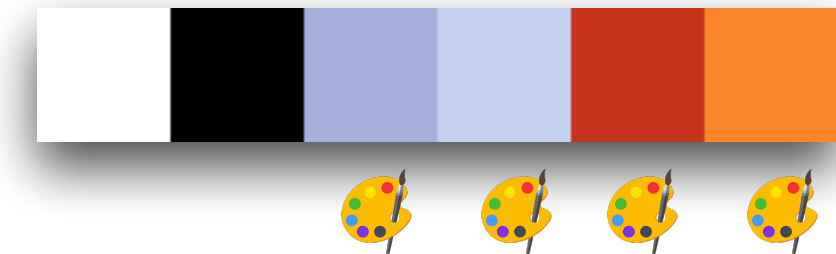
Input



LoCoPalettes



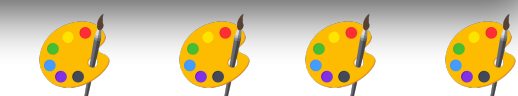
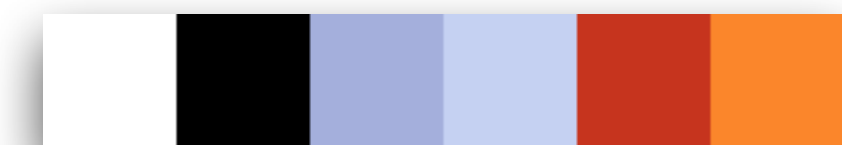
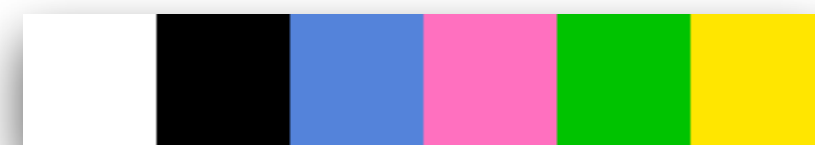
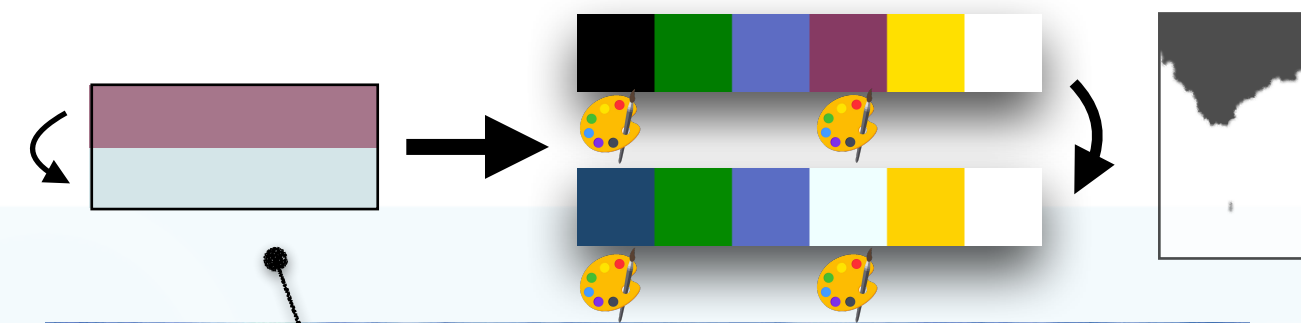
[Tan et al. 2018]



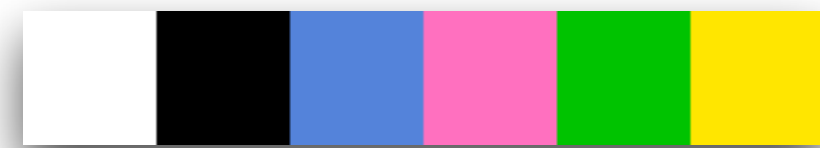
Input

LoCoPalettes

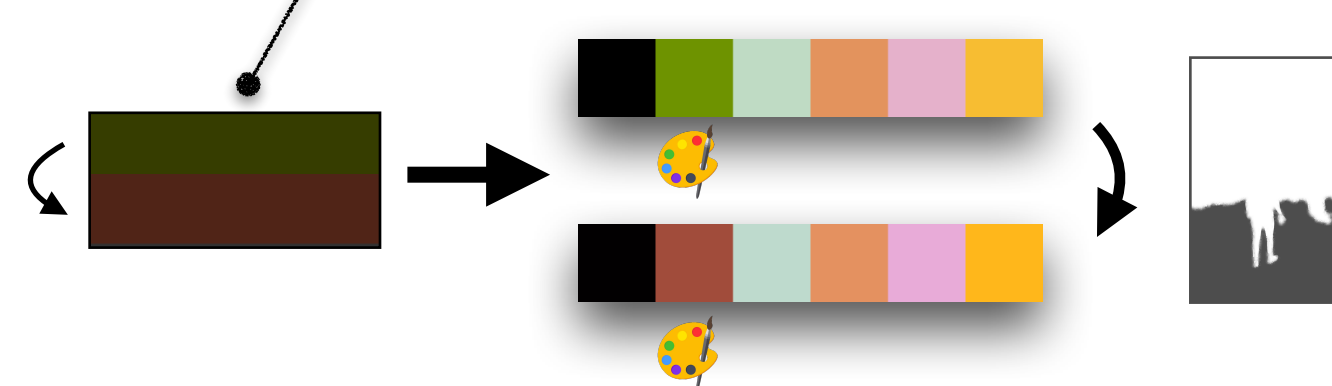
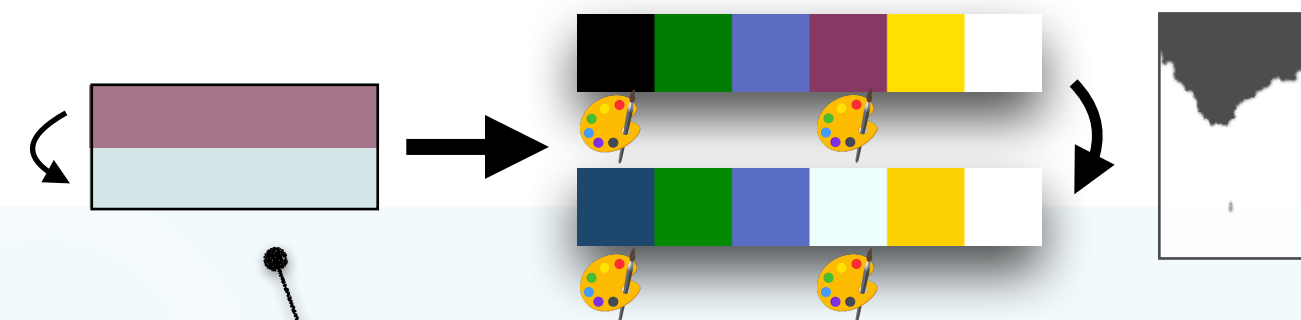
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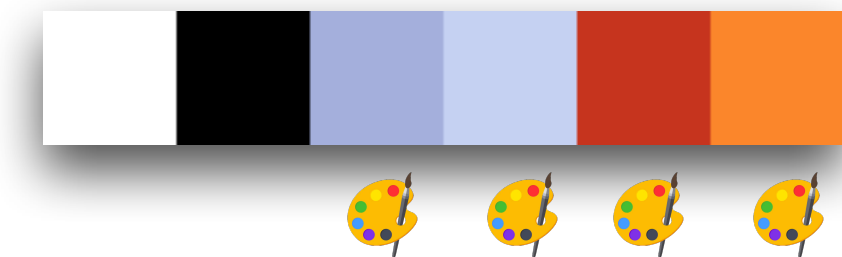
Input



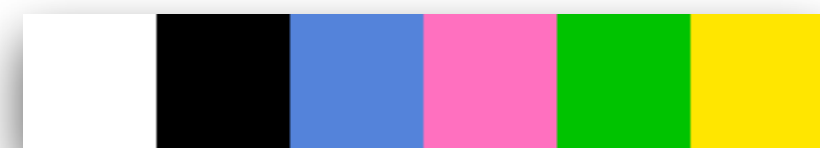
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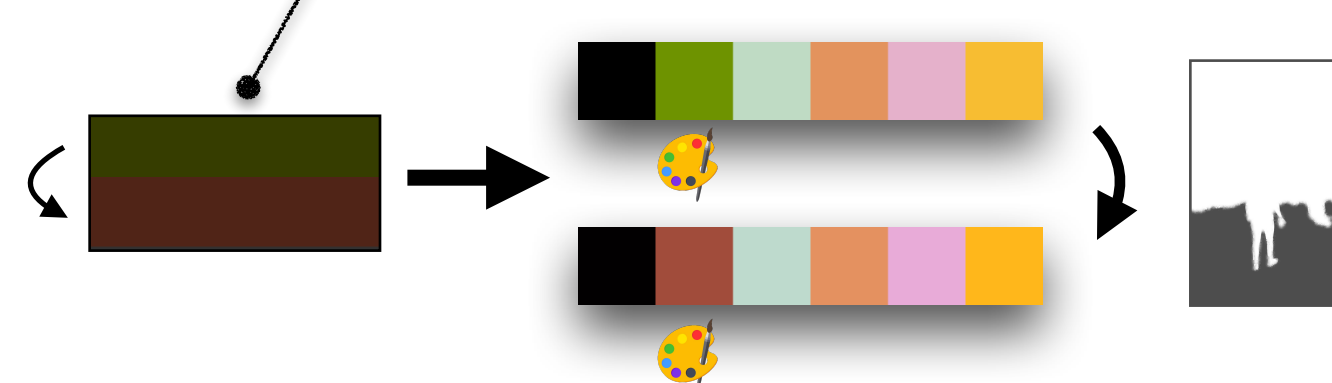
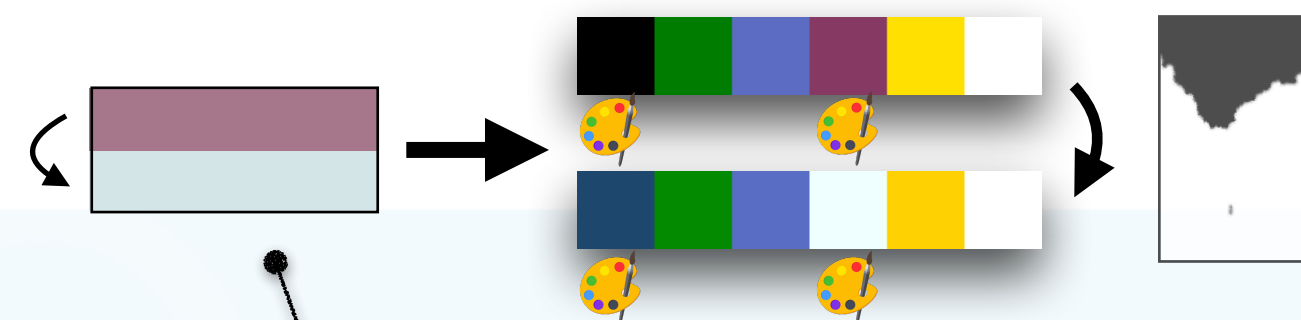
[Tan et al. 2018]



Input

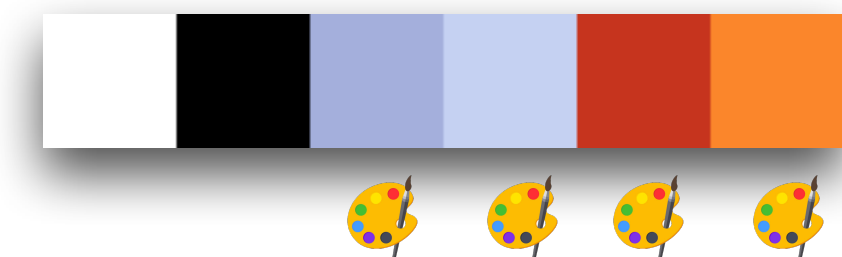


LoCoPalettes



[Tan et al. 2018]

13x palette manipulations



Input



CSR

UROGRAPHICS SYMPOSIUM ON RENDERING

DELFT

2023



Input

[Tan et al. 2018]



Input



LoCoPalettes



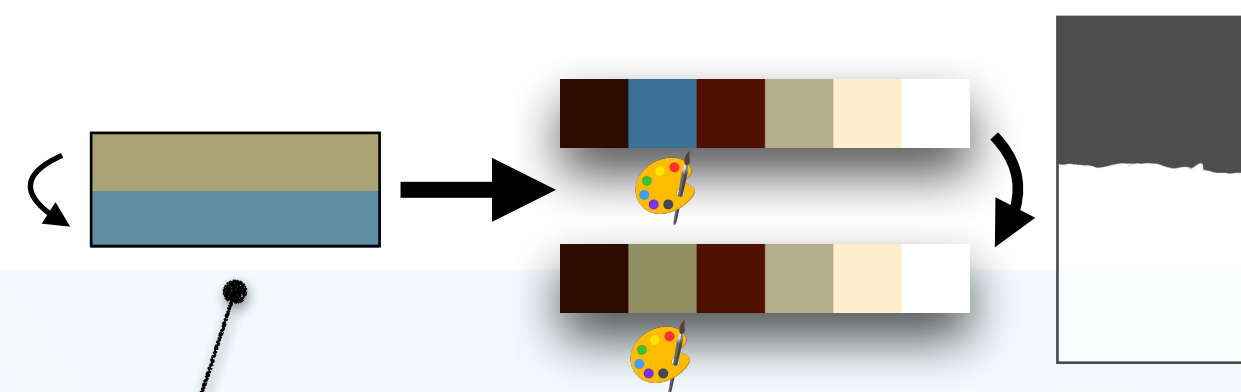
[Tan et al. 2018]



Input



LoCoPalettes



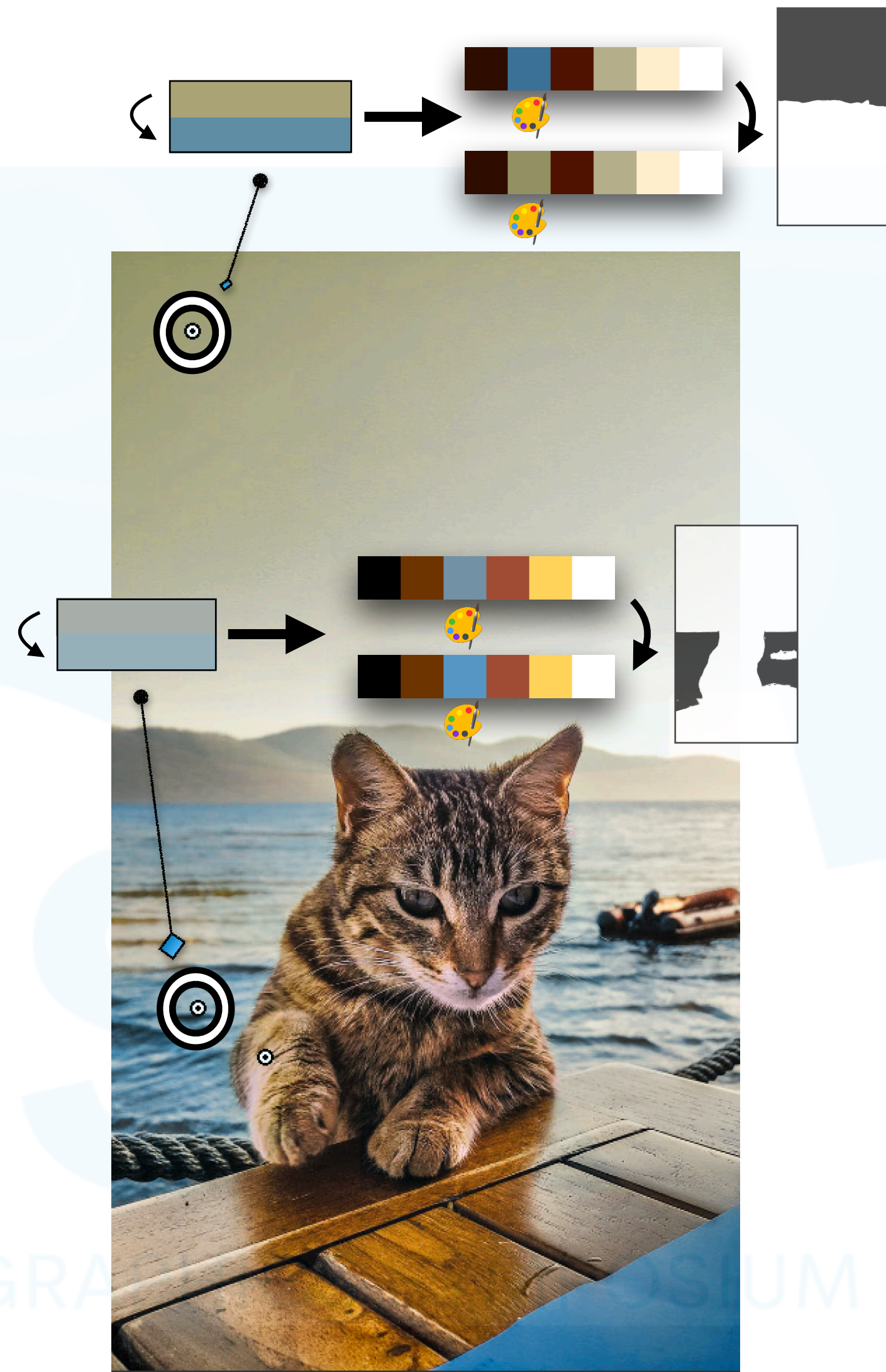
[Tan et al. 2018]



Input



LoCoPalettes



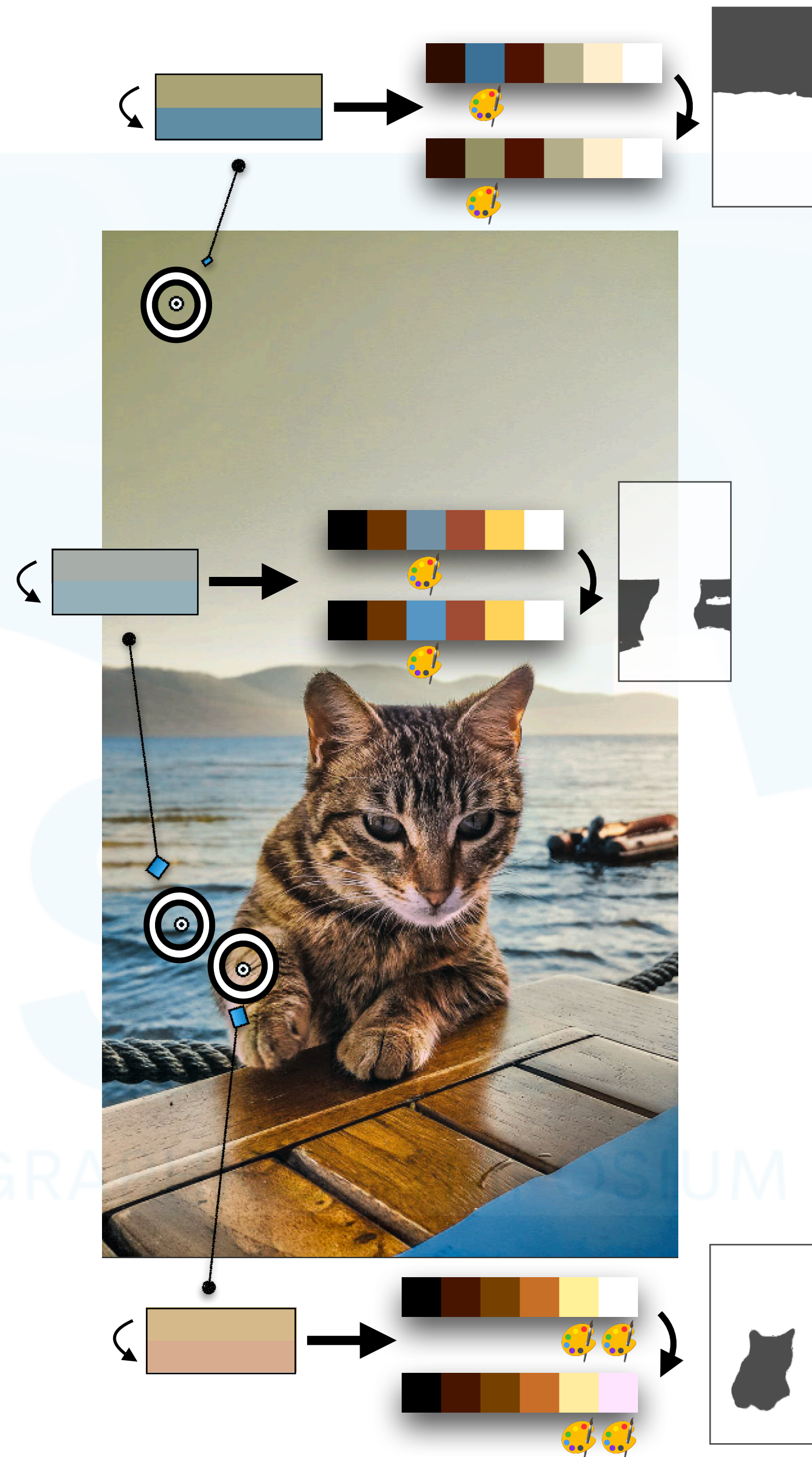
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Input



LoCoPalettes



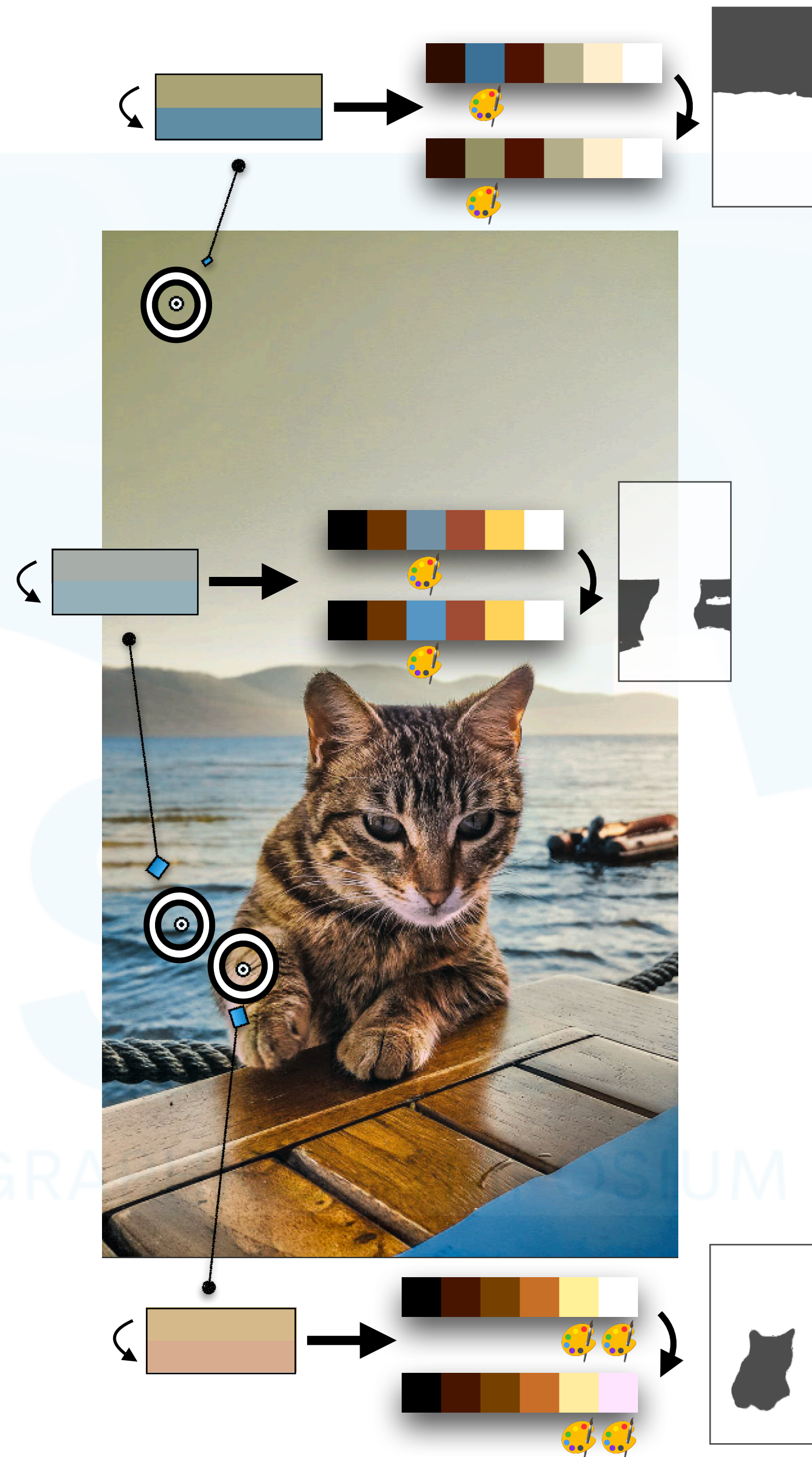
[Tan et al. 2018]



Input



LoCoPalettes



[Tan et al. 2018]

17x palette manipulations



Conclusion



EGSR

DELFT

2023

THE 34TH EUROGRAPHICS SYMPOSIUM ON RENDERING

Conclusion

- LoCoPalettes provides **local** control for palette-based editing

EGSR

DELFT

2023

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Conclusion

- LoCoPalettes provides **local** control for palette-based editing
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EGSR

DELFT

2023

THE 34TH EUROGRAPHICS SYMPOSIUM ON RENDERING

Conclusion

- LoCoPalettes provides **local** control for palette-based editing
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EGSR

DELFT

2023

THE 34TH EUROGRAPHICS SYMPOSIUM ON RENDERING

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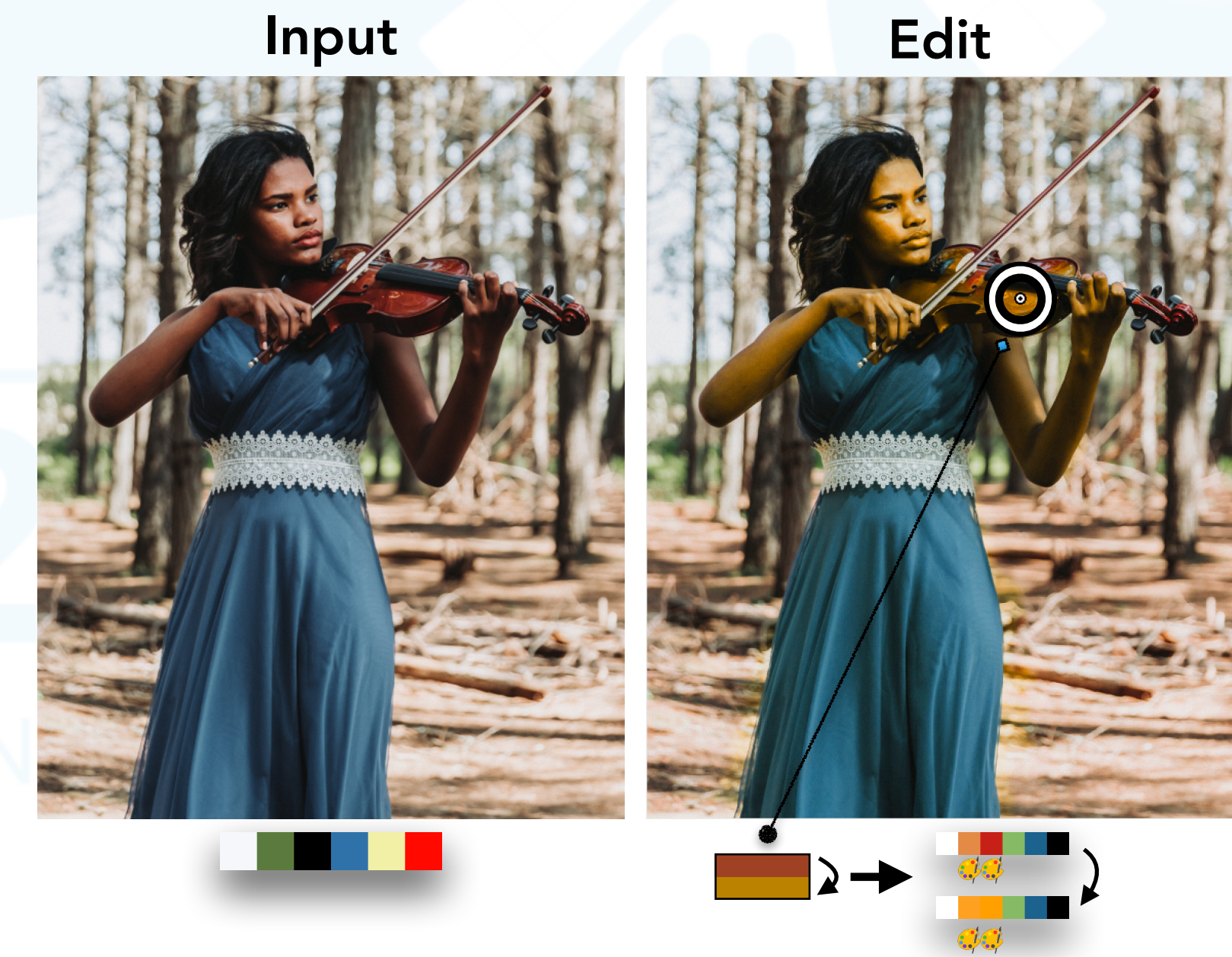
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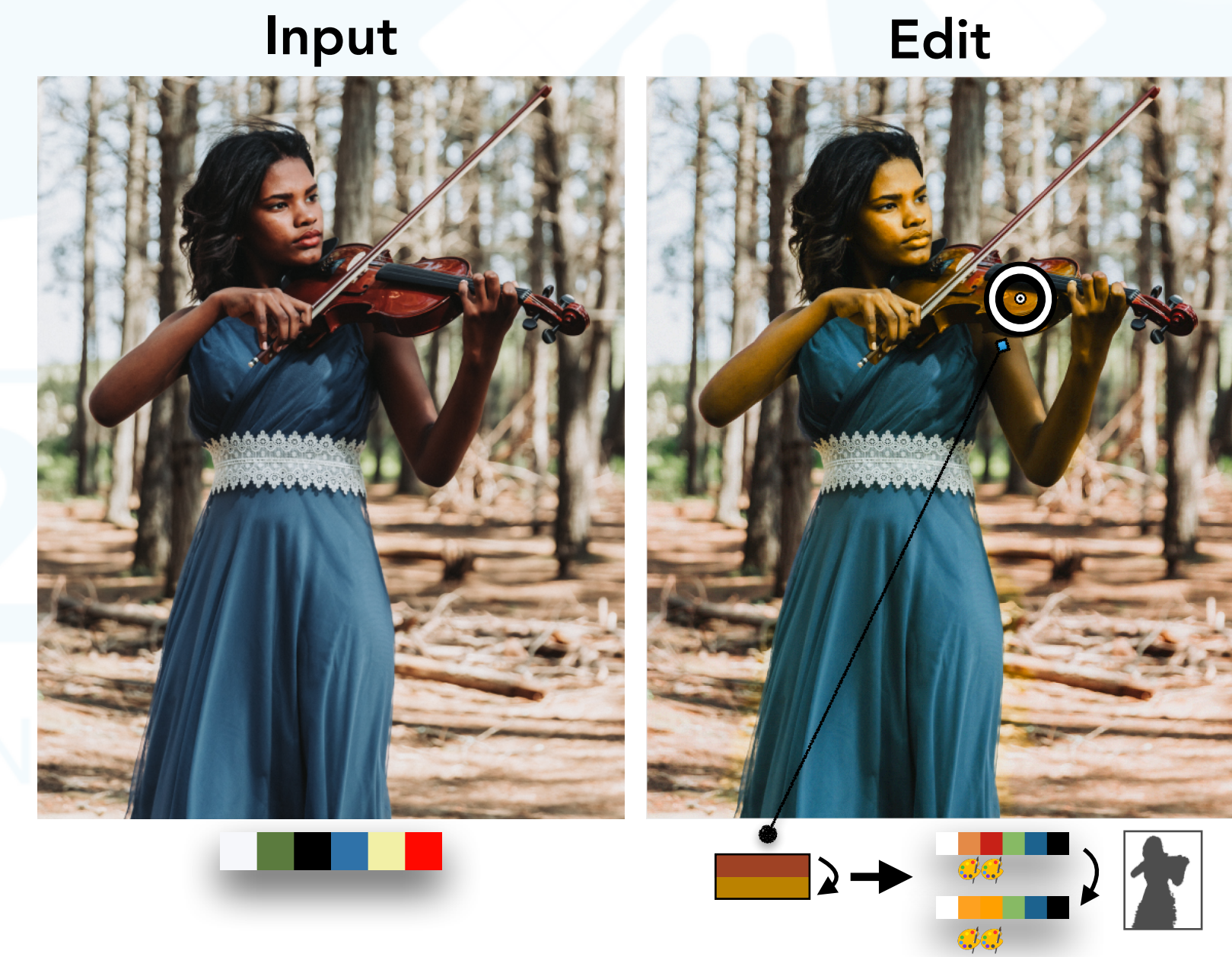
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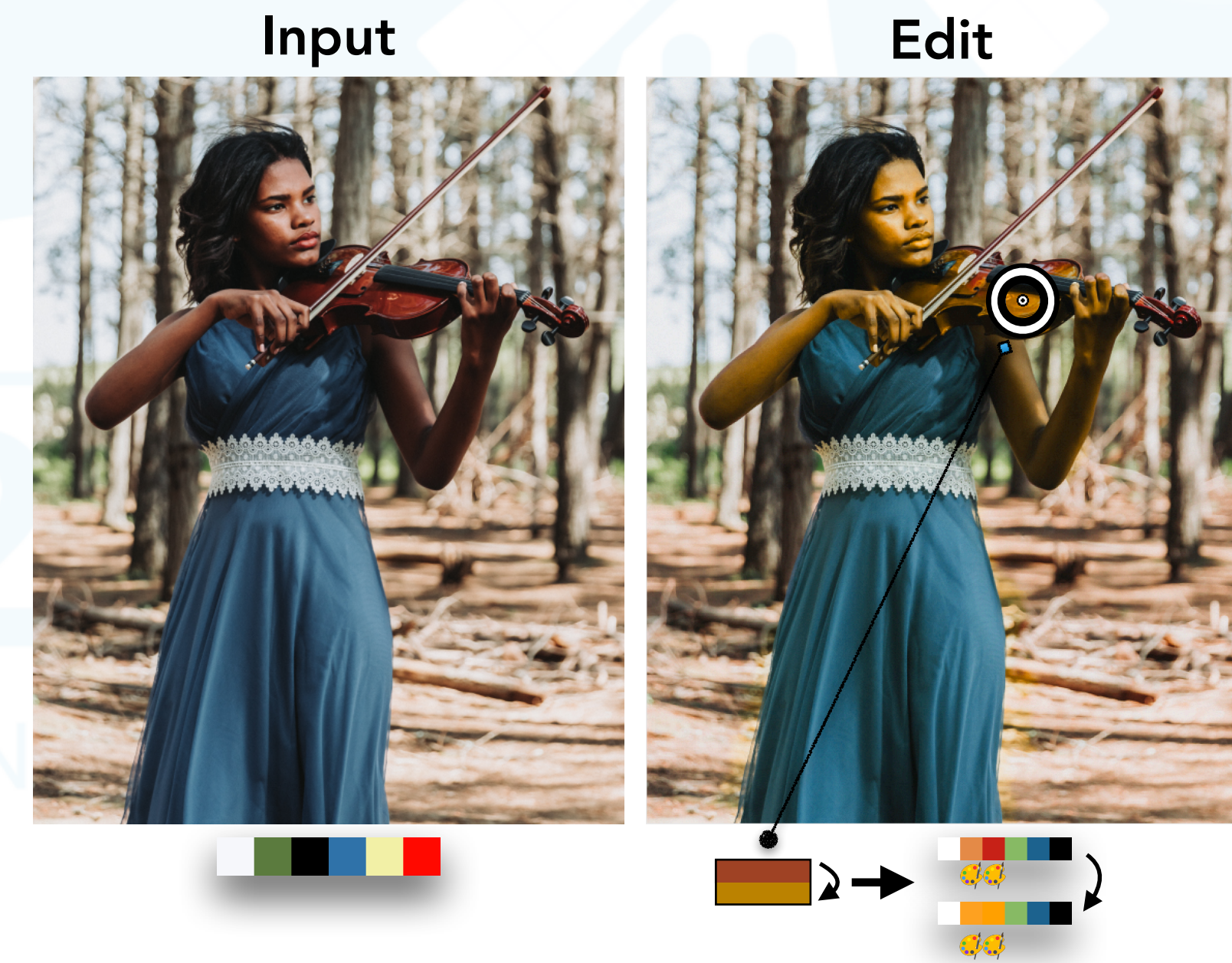
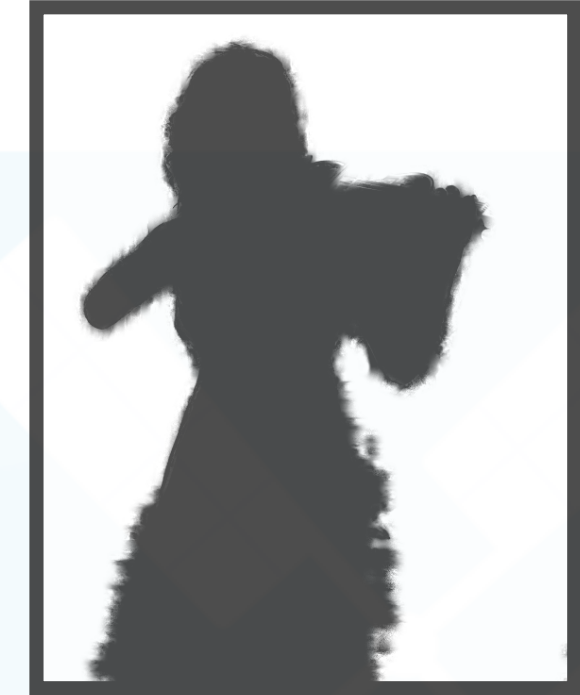
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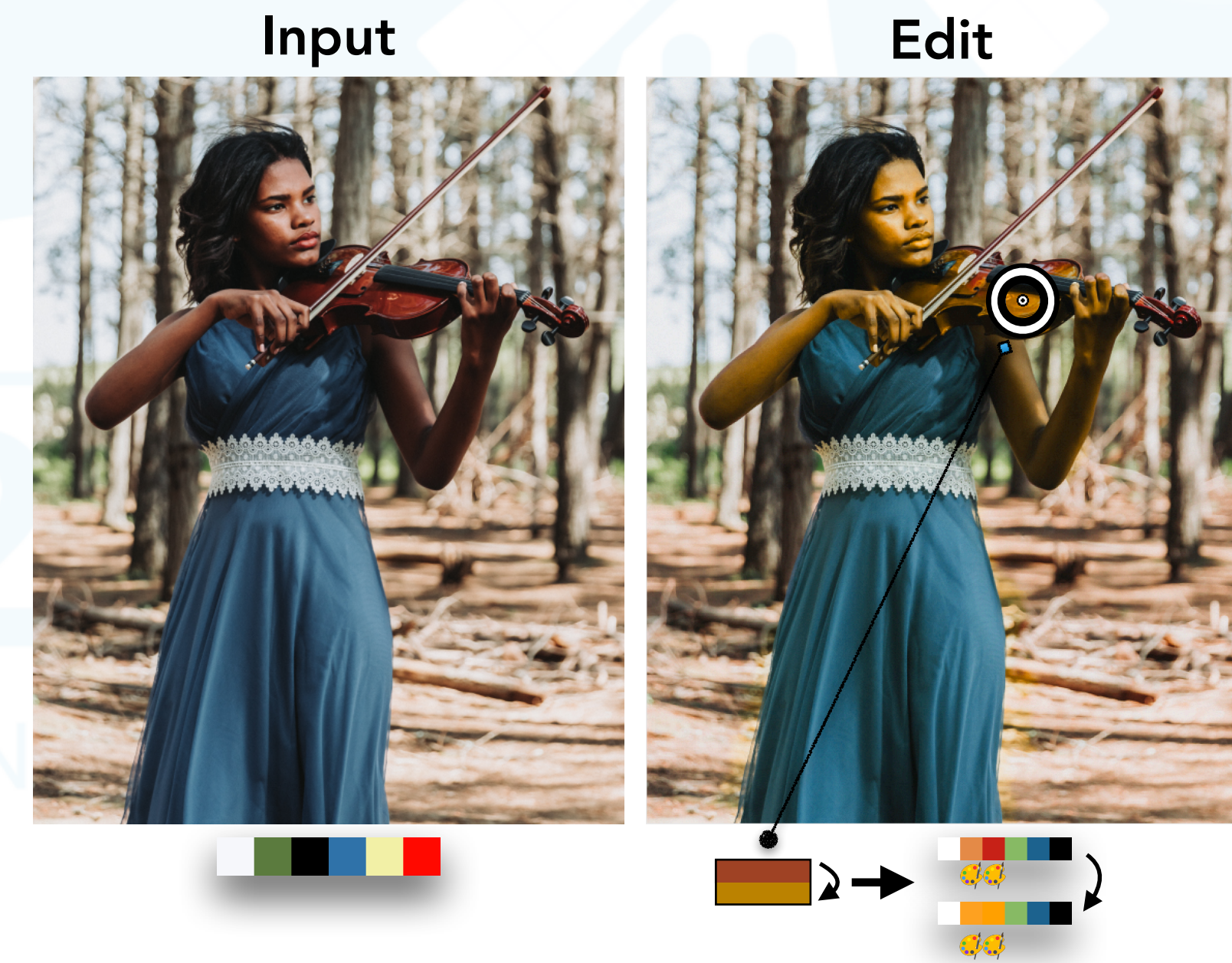
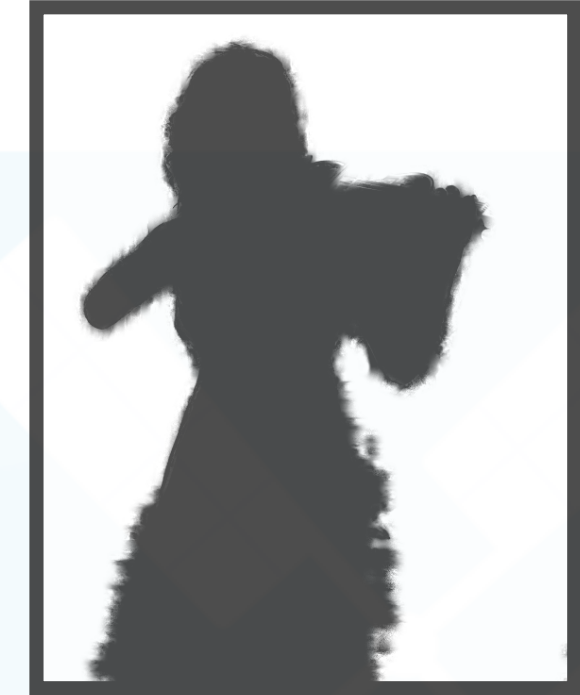
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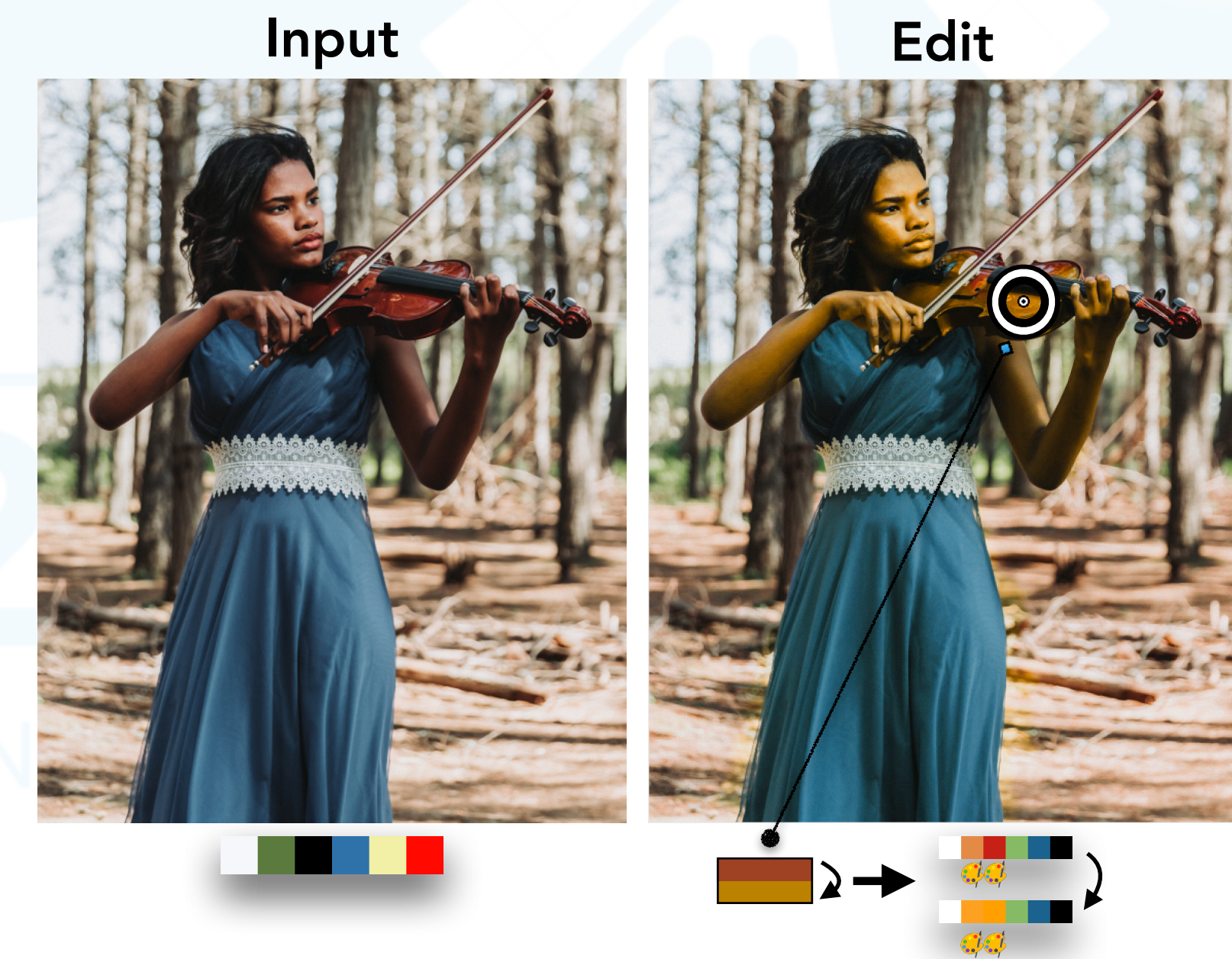
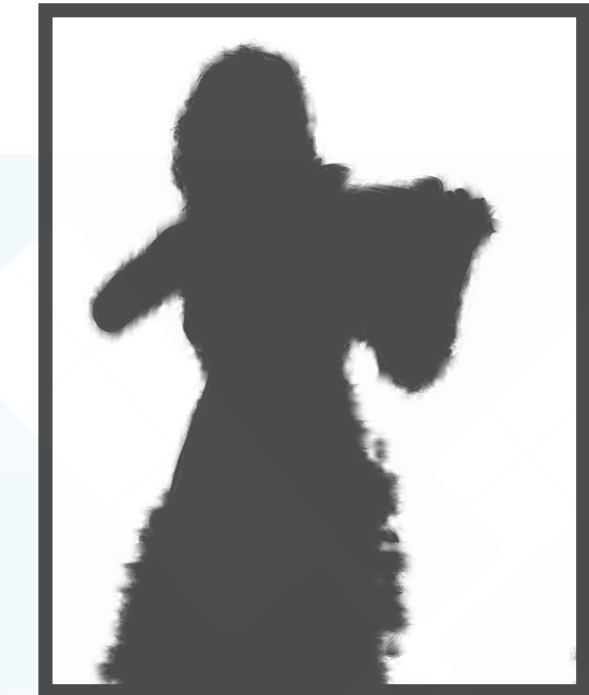
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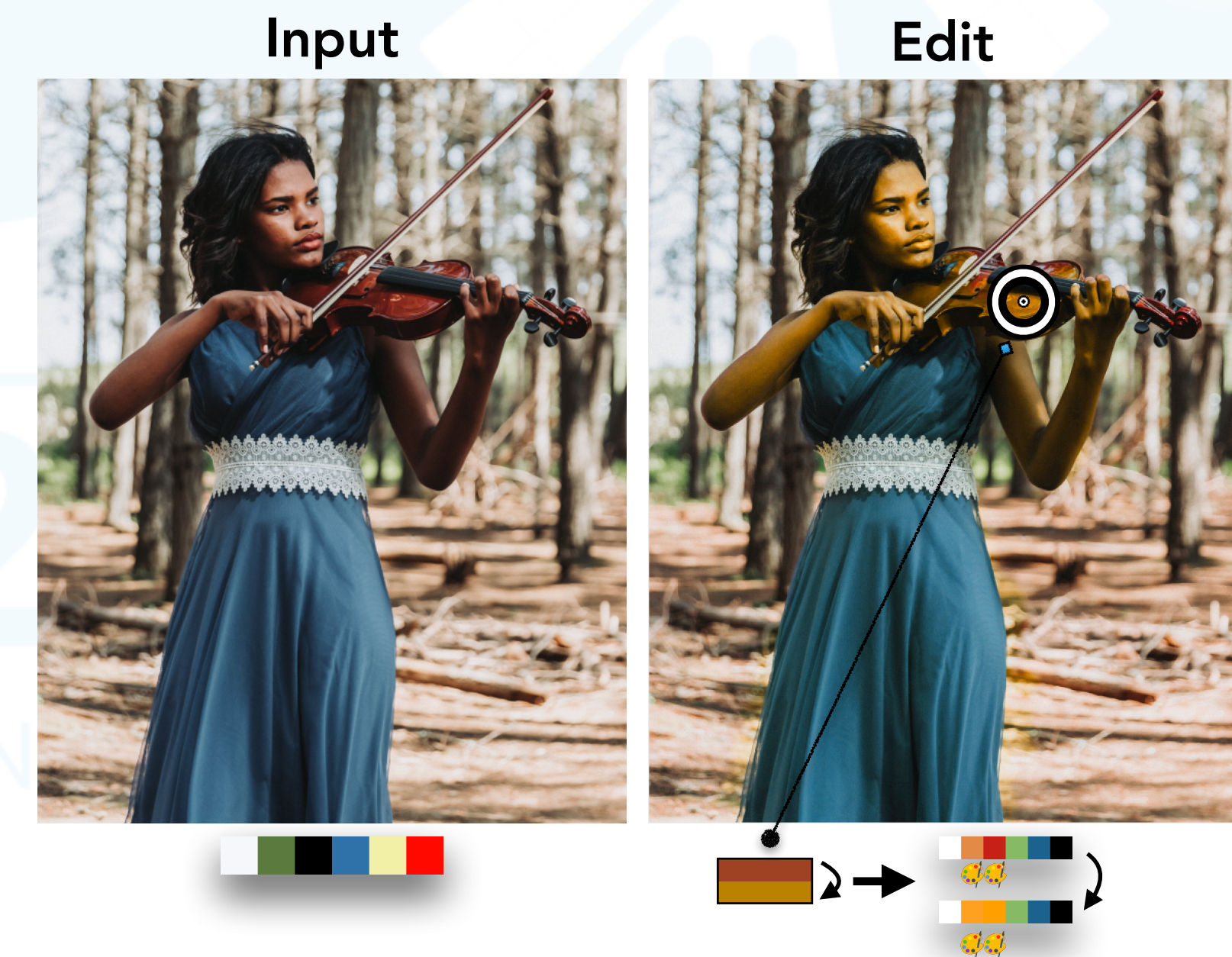
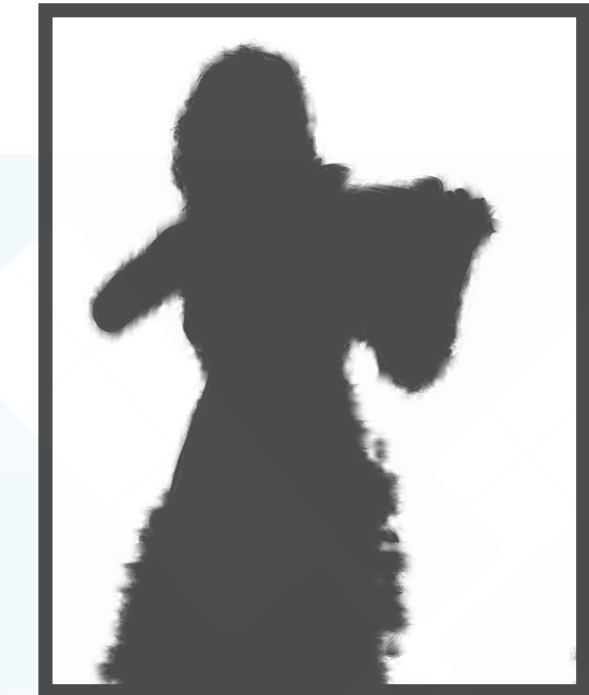
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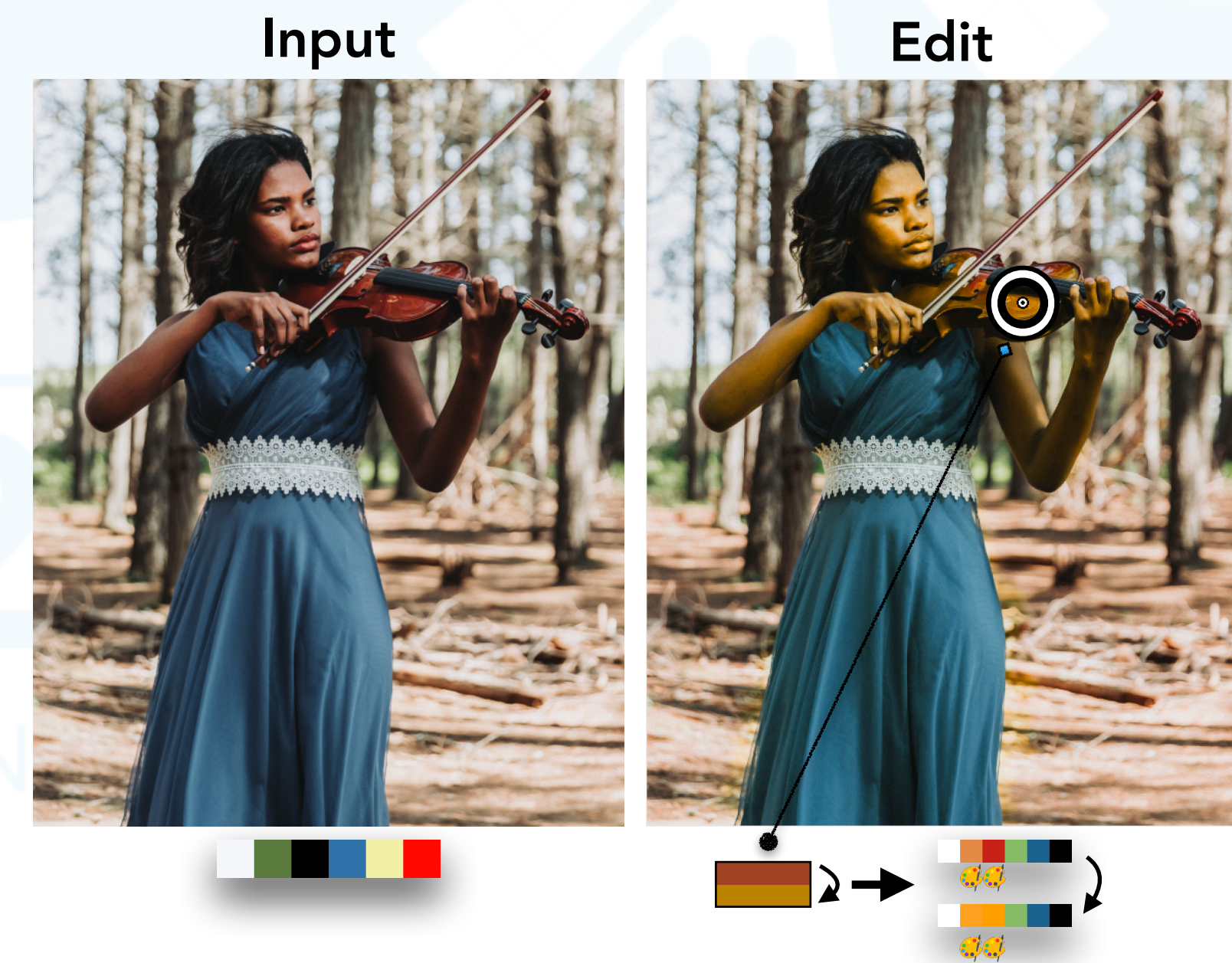
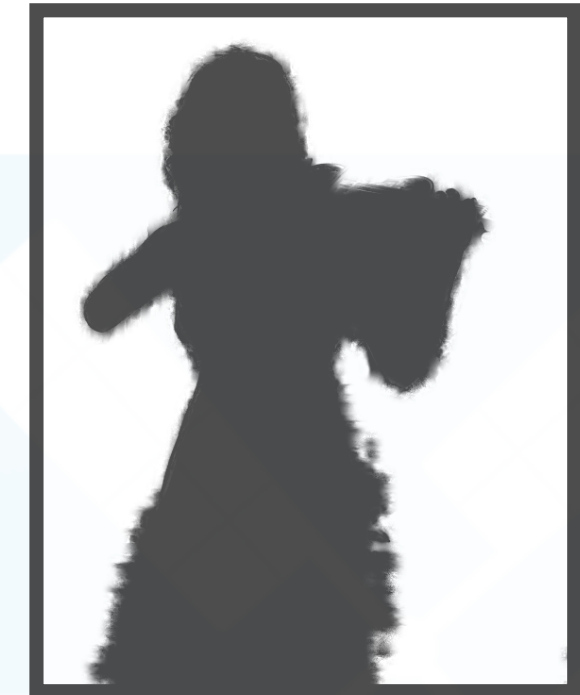
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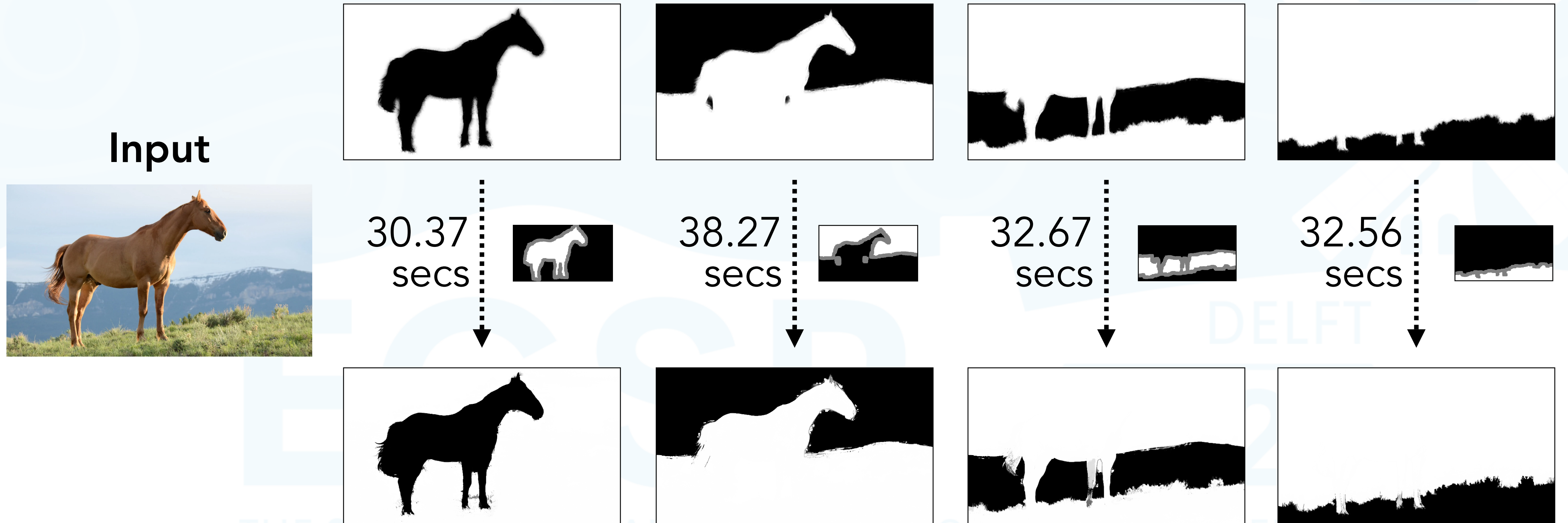
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 - Palette-based video editing, e.g. [Du et al. 2021]
 - Speed up local palette computation from a global palette
 - Text-guided color manipulations



Thank you

- **Project page:** <https://cragl.cs.gmu.edu/locopalettes/>
- **Code and data:** <https://github.com/tedchao/LoCoPalettes>
- **Financial support**
 - Adobe

Evaluation



KNN Matting [Chen et al. 2013]

Sparsity Evaluation

Sparsity Estimate:	Tan et al. [2016]		Aksoy et al. [2017]	
	Weights: Tan et al. [2018]	Ours	Tan et al. [2018]	Ours
Mountain	0.2630	0.2586	1.3679	1.2285
Birds	0.2670	0.2614	1.5114	1.3168
Colorful	0.2549	0.2511	1.1242	1.0245
Boy	0.2676	0.2638	1.5325	1.3966