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Video Recoloring via Spatial-Temporal Geometric Palettes

Zheng-Jun Du Tsinghua University, Qinghai University
Kai-Xiang Lei Tsinghua University
Kun Xu Tsinghua University
Jianchao Tan Kwai Inc.
Yotam Gingold George Mason University



清华大学
Tsinghua University



快手

GEORGE
MASON
UNIVERSITY

Motivation

- Palette-based image recoloring is intuitive and simple



- Can we extend it to recolor a video?
Input video

Palette

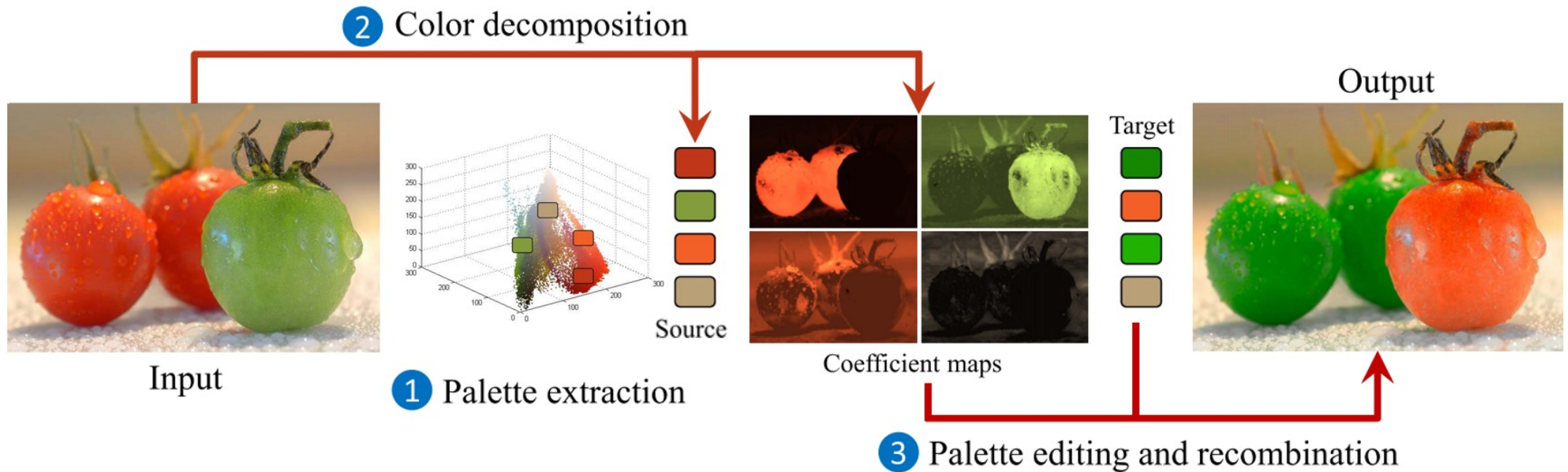
Recolored video

Challenge: The palette can change over time!

Related work

- Clustering-based methods

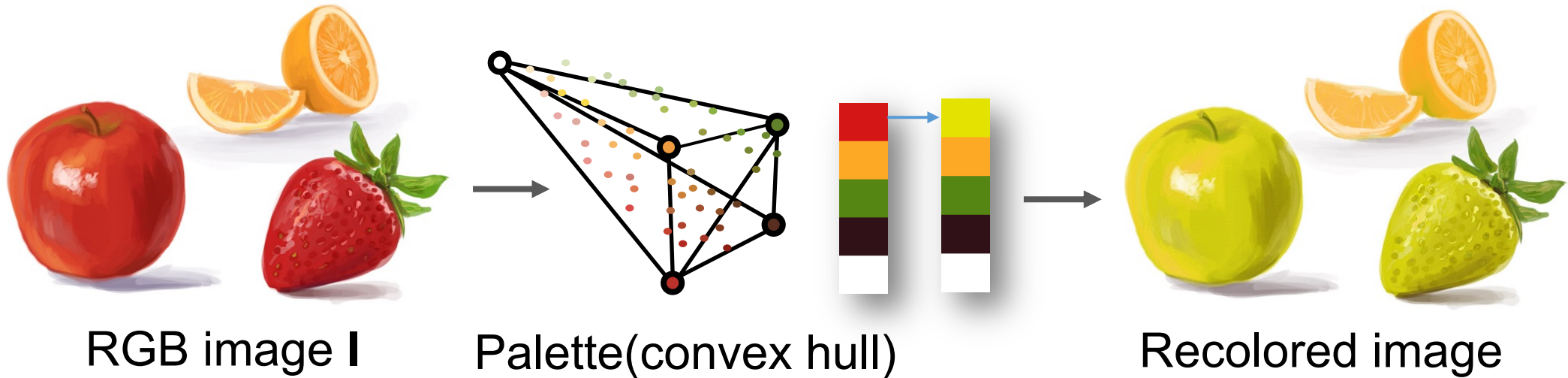
- [Chang et al. 2015; Nguyen et al. 2017; Zheng et al. 2017]



Palette-based image recoloring using color decomposition optimization [Zheng et al. 2017]

Related work

- Convex hull-based methods
 - [Tan et al. 2017; Tan et al. 2018; Wang et al. 2019]



An improved geometric approach for palette-based image decomposition and recoloring [Wang et al. 2019]

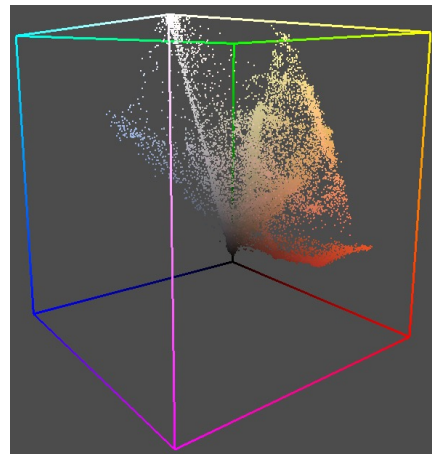
Background

- Our work is based on RGB convex hull-based palette recoloring

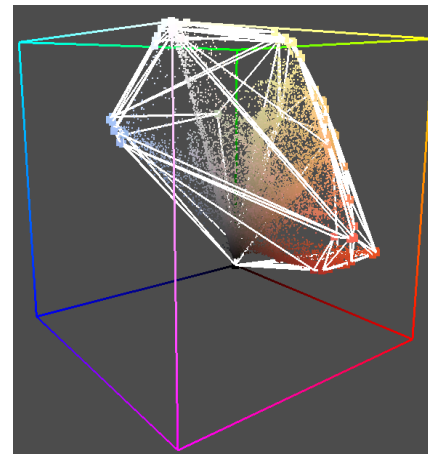
1) Palette extraction



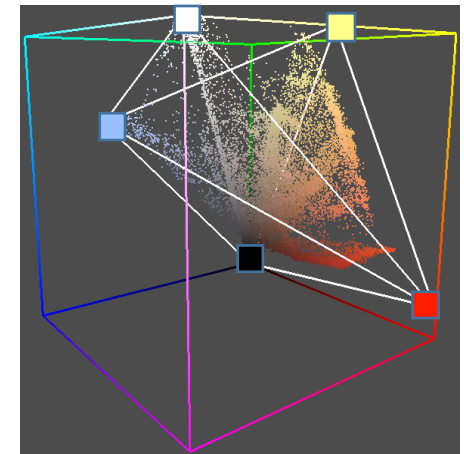
Input image



RGB point cloud



RGB convex hull



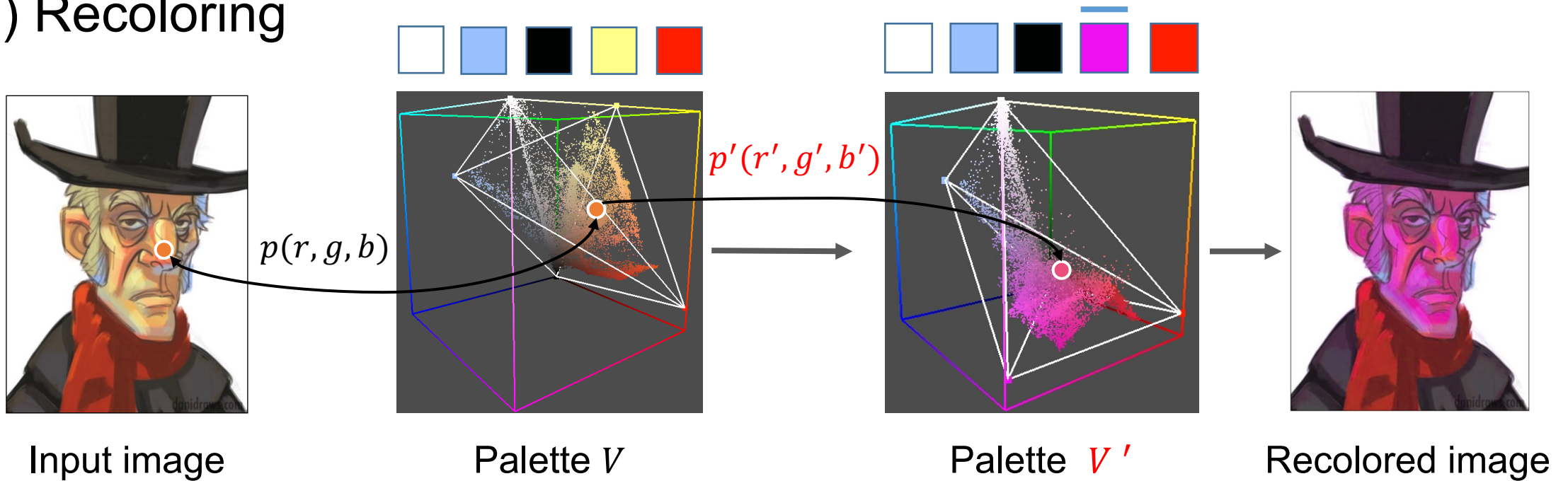
Simplified RGB convex hull

(**Palette**)

Background

- Our work is based on RGB convex hull-based palette recoloring

2) Recoloring

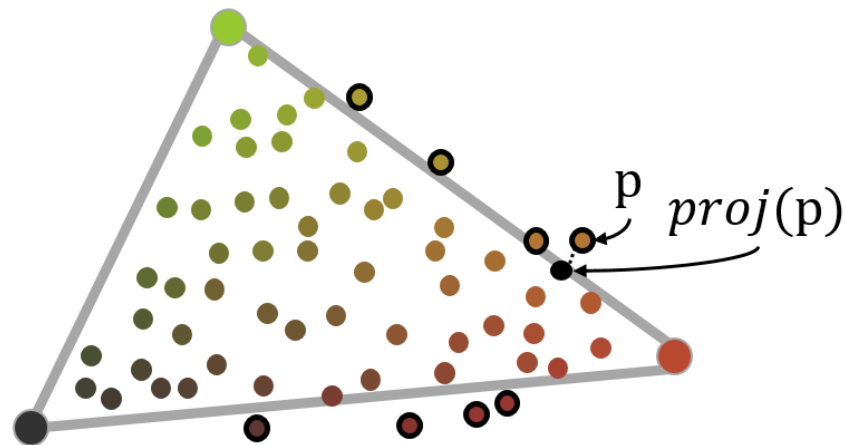


- Mixing weights: $p = \sum_{i=1}^{|V|} w_i V_i \quad 1 = \sum_{i=1}^{|V|} w_i$
- Recoloring: $p' = \sum_{i=1}^{|V|} w_i V'_i$

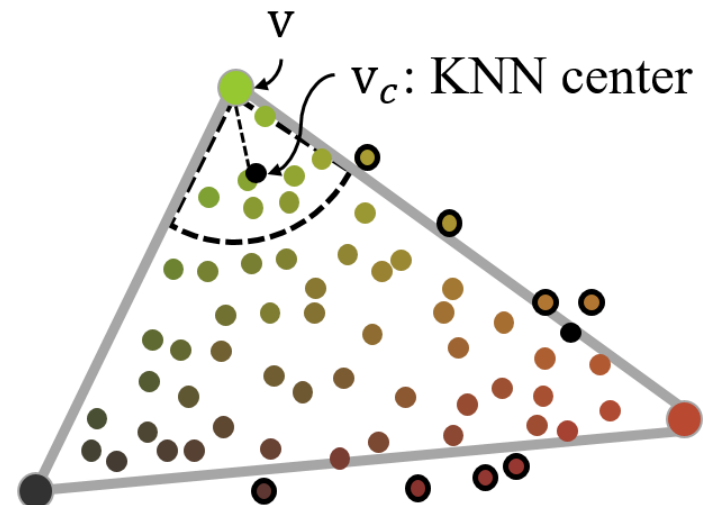
Background

- Measurement of the convex hull-based palette V
 - Reconstruction accuracy
 - Compactness

$$R(V, I) = \frac{1}{|I|} \sum_{p \in I} \|p - \text{proj}(p)\|$$



$$C(V, I) = \frac{1}{|V|} \sum_{v \in V} \|v - v_c\|$$



Background

- Measurement of the convex hull-based palette V

➤ Reconstruction accuracy

$$R(V, I) = \frac{1}{|I|} \sum_{p \in I} \|p - \text{proj}(p)\|$$

➤ Compactness

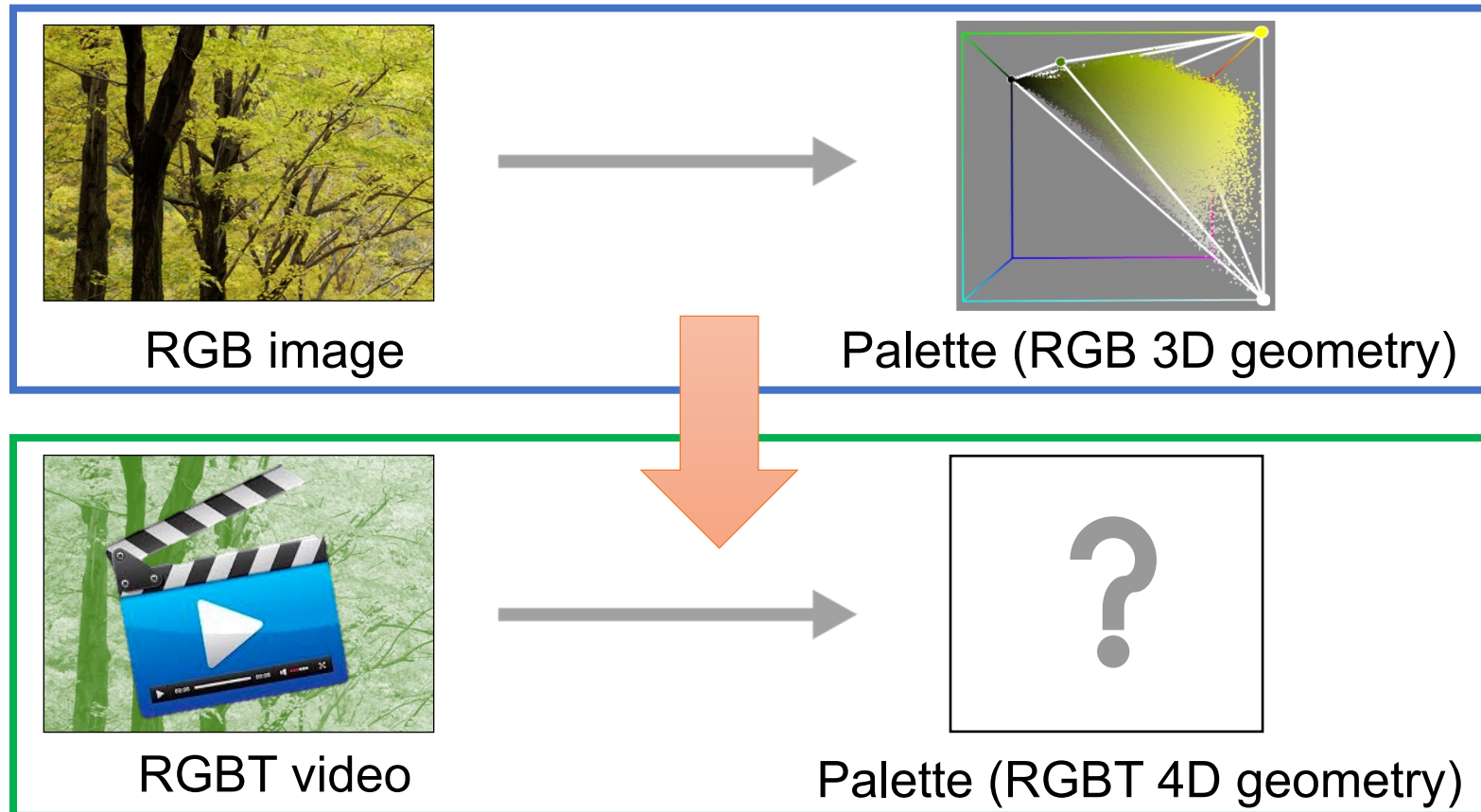
$$C(V, I) = \frac{1}{|V|} \sum_{v \in V} \|v - v_c\|$$


$$L(V, I) = \lambda R(V, I) + C(V, I)$$

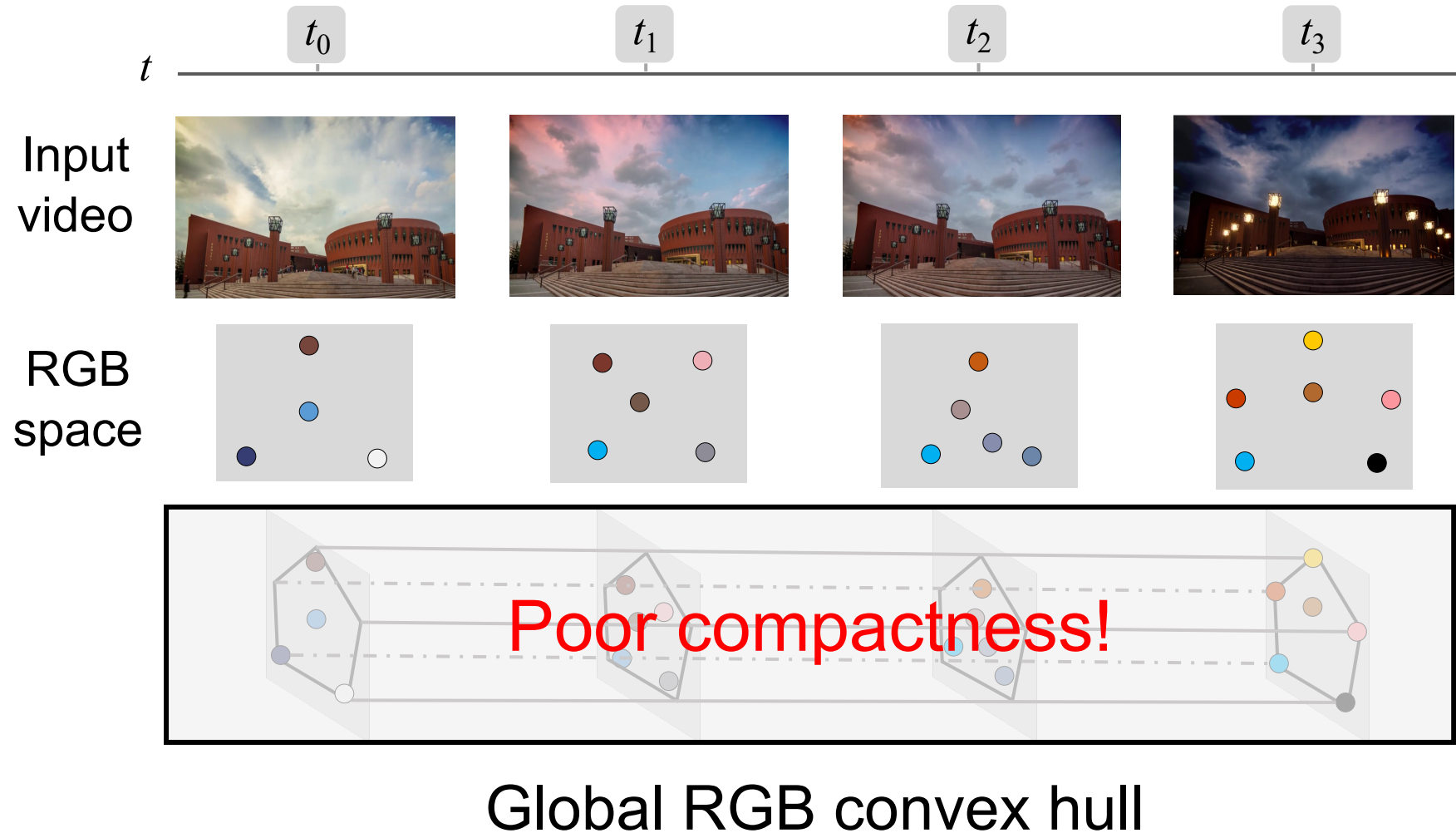
Image palette overall loss

Our main idea

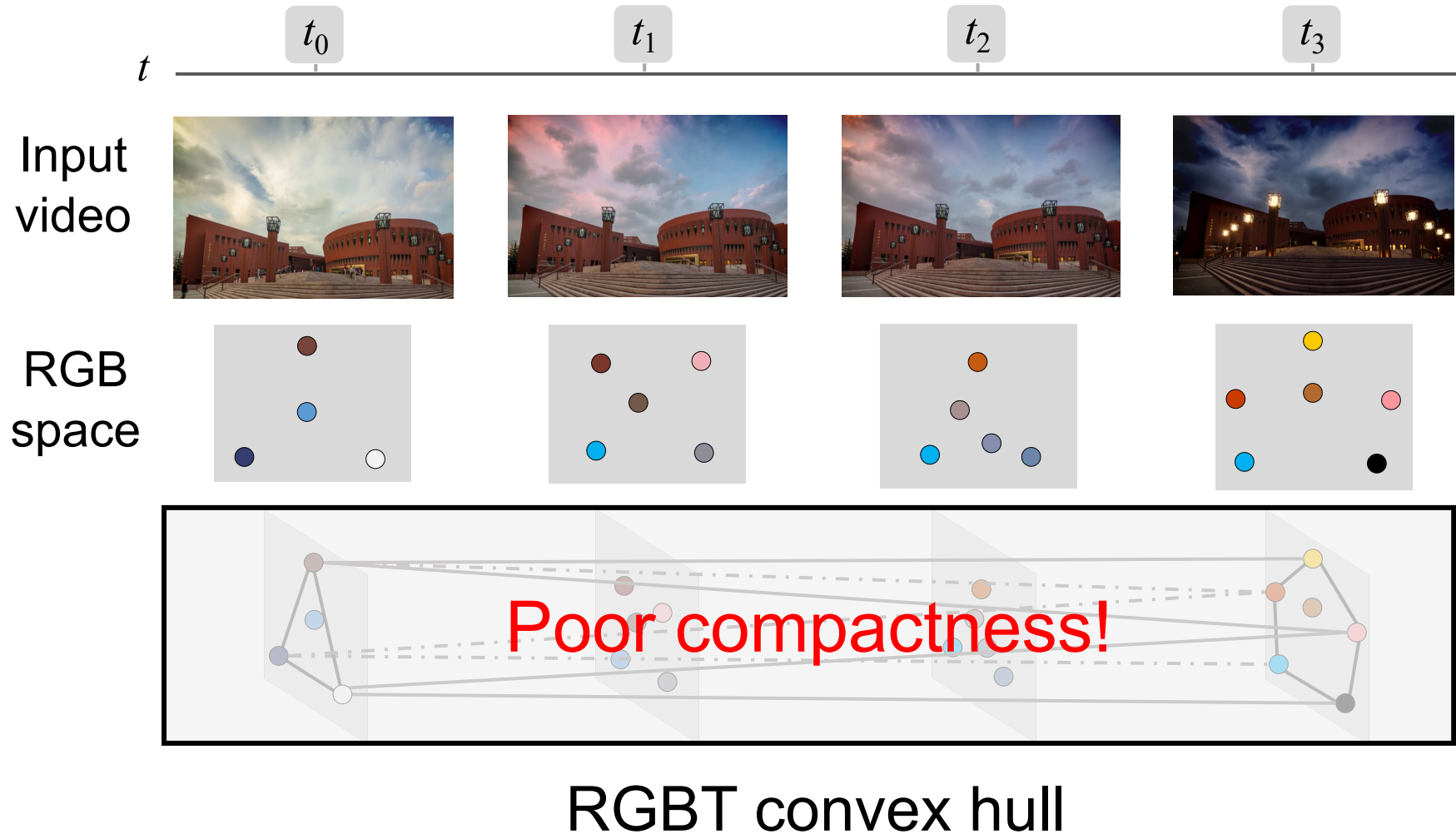
- Extend the convex hull-based image recoloring to video scenarios



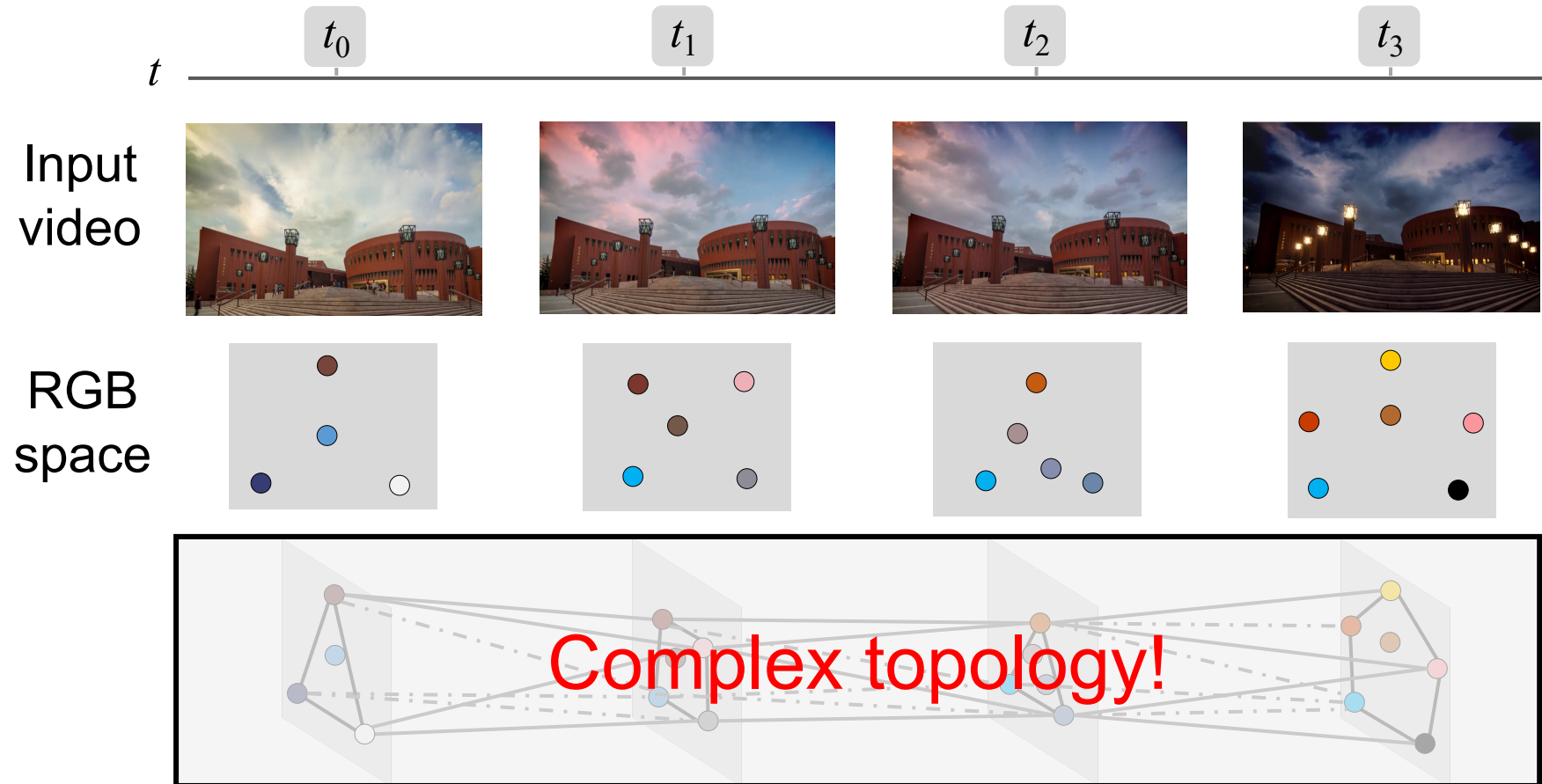
Choices of RGBT 4D geometry



Choices of RGBT 4D geometry

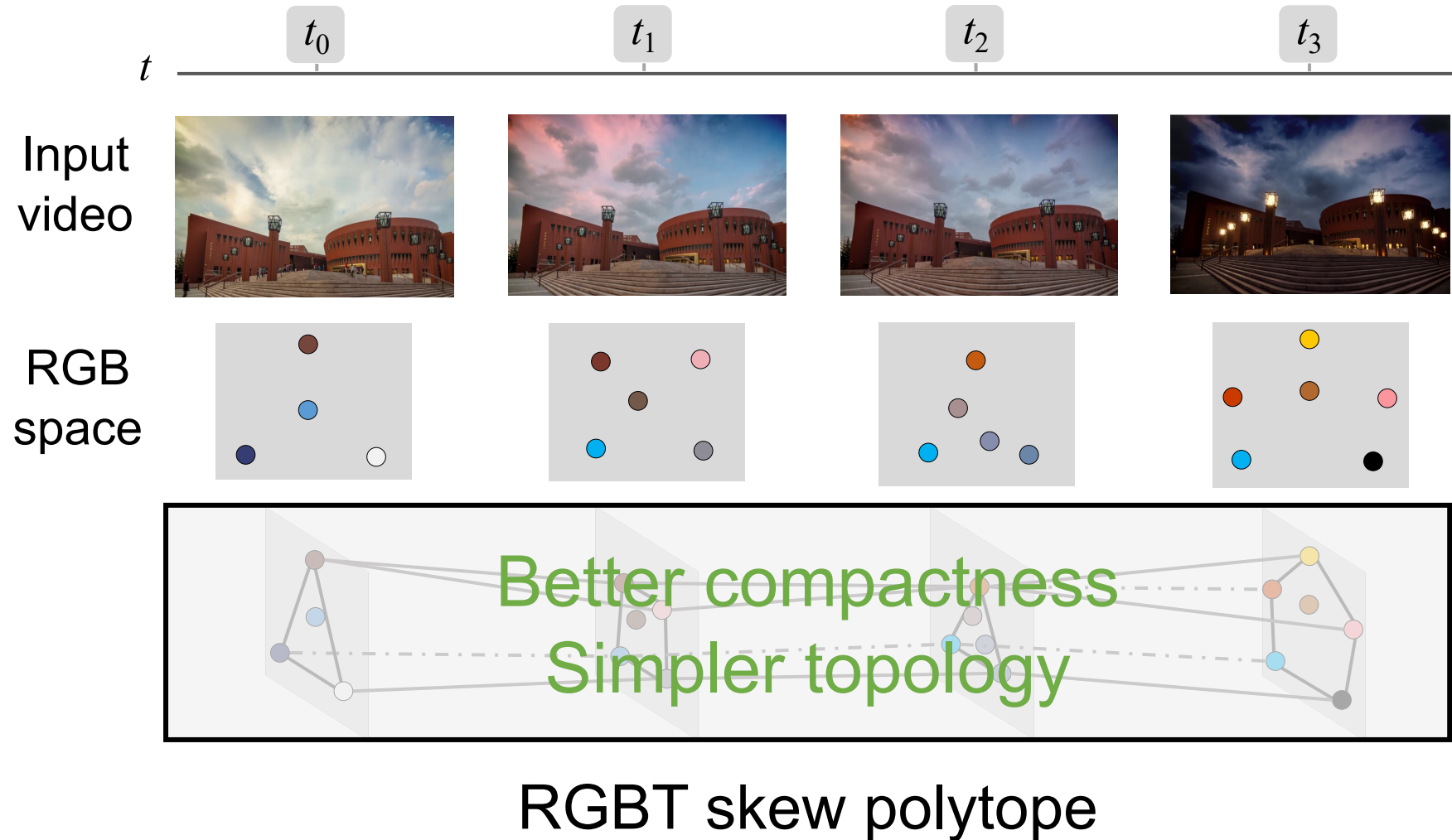


Choices of RGBT 4D geometry

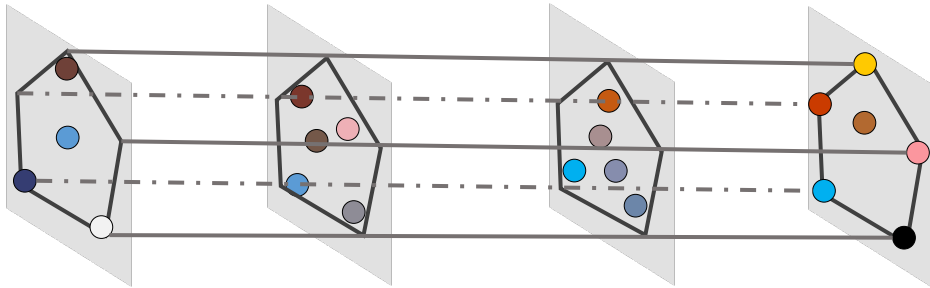


RGBT regular polytope

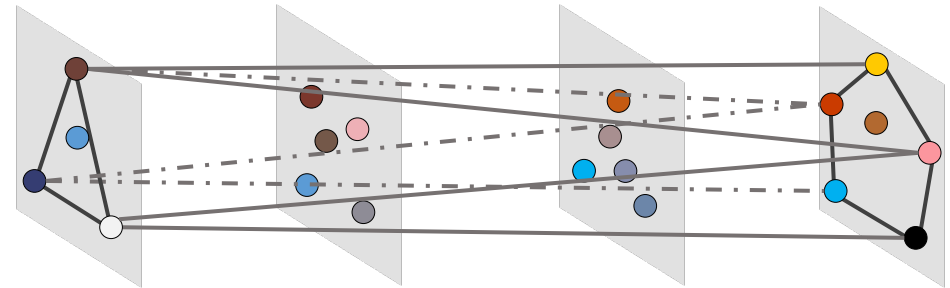
Choices of RGBT 4D geometry



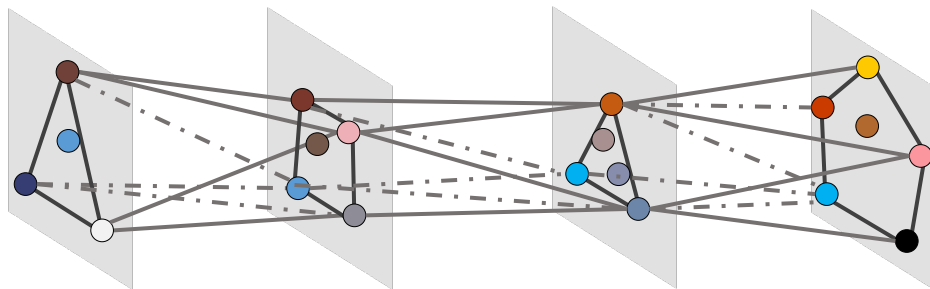
Choices of RGBT 4D geometry



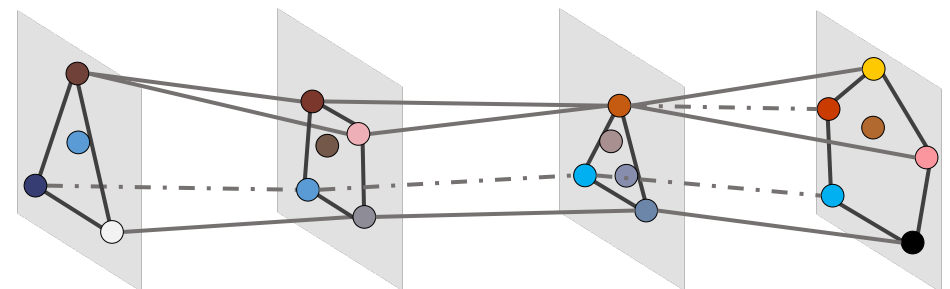
Global RGB convex hull



RGBT convex hull



RGBT regular polytope



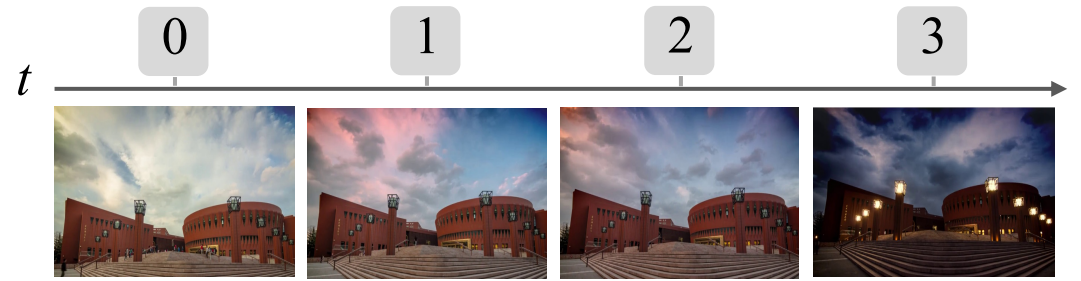
RGBT skew polytope

Geometric palette measurement

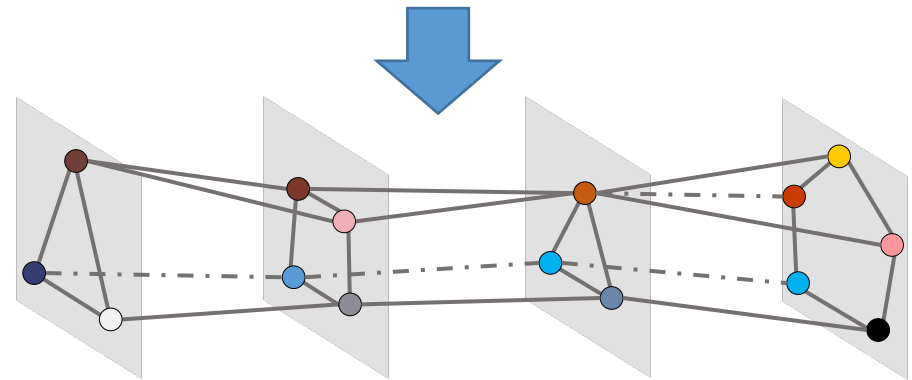
- Our loss function

$$L_V(P, I) = \underbrace{L_{frame}(P, I)}_{\text{Average polyhedral palette loss}} + \underbrace{L_{smooth}(P)}_{\text{Smooth term}}$$

Average polyhedral palette loss Smooth term



Input video I



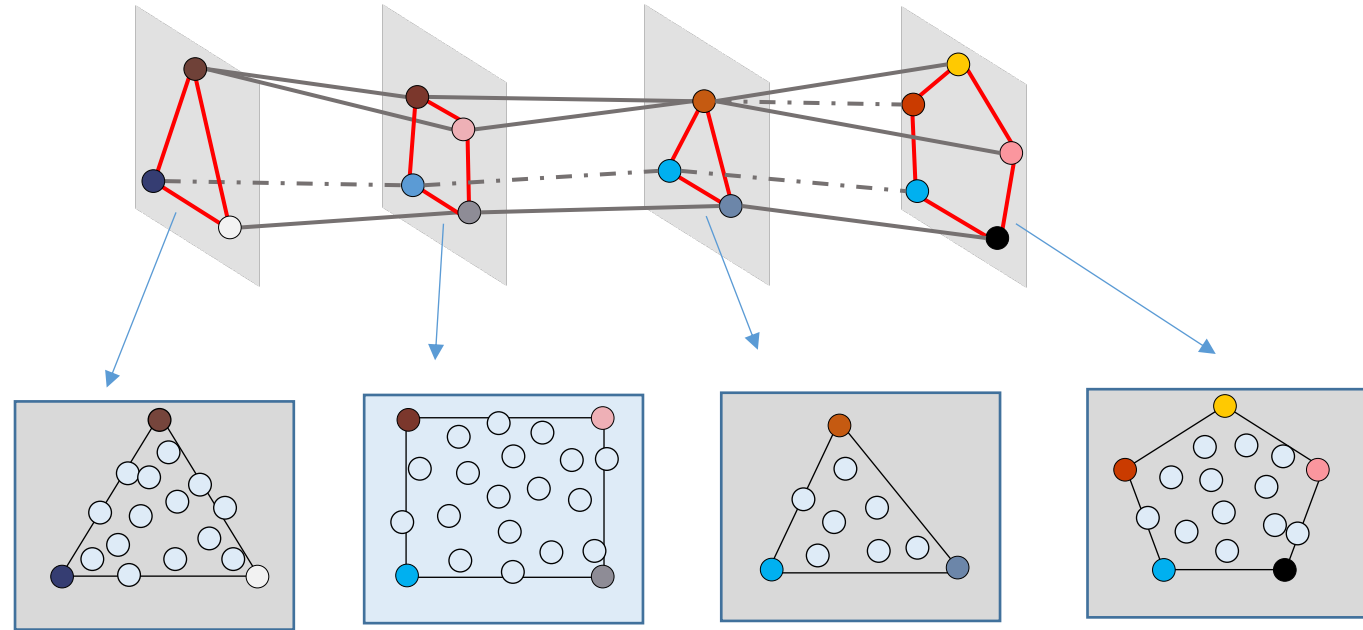
Geometric palette P

Geometric palette measurement

- Lower reconstruction loss

$$L_v(P, I) = L_{frame}(P, I) + L_{smooth}(P)$$

Polyhedral palettes

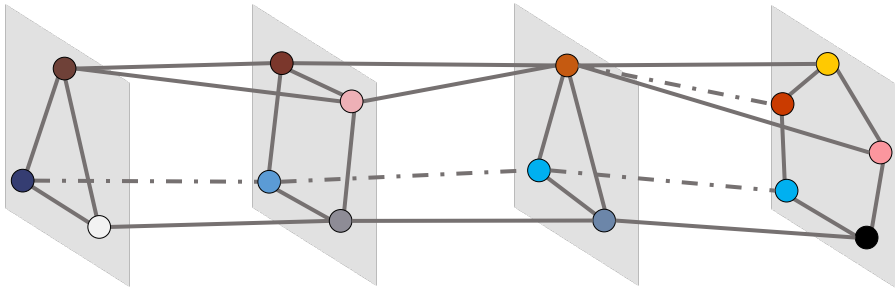


Polyhedral palettes
and video pixels

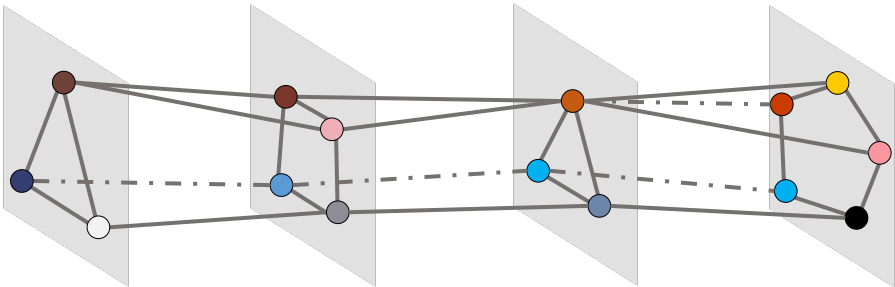
Geometric palette measurement

- Rewards compactness

$$L_v(P, I) = L_{frame}(P, I) + L_{smooth}(P)$$



Polyhedral palettes with larger volumes

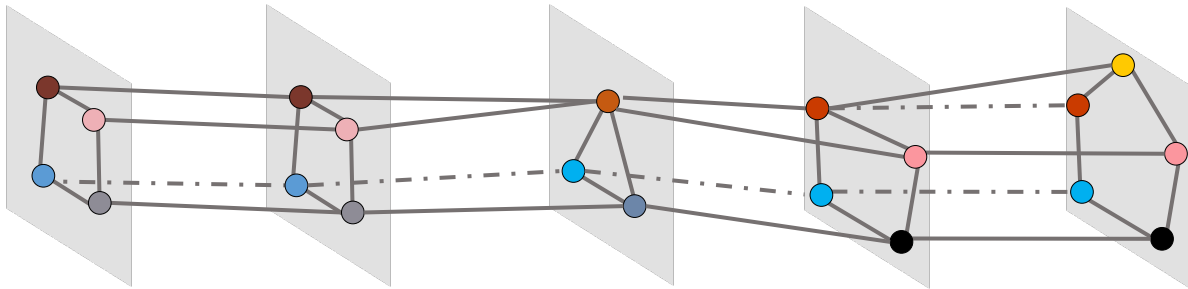


Polyhedral palettes with smaller volumes

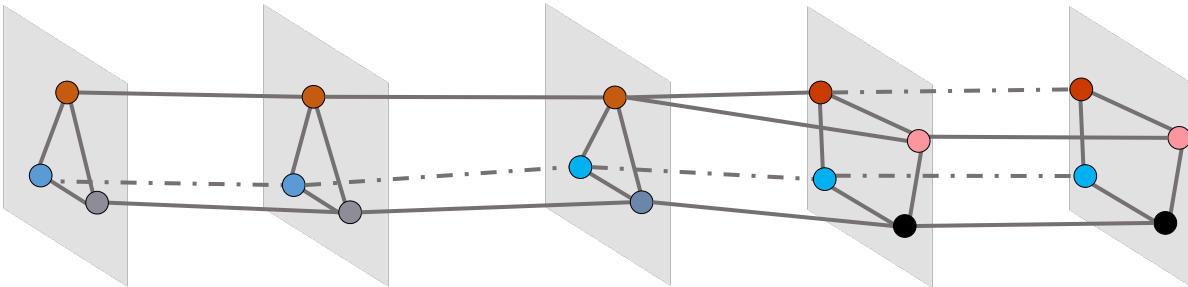
Geometric palette measurement

- Prefers palettes with simpler topologies

$$L_v(P, I) = L_{frame}(P, I) + L_{smooth}(P)$$



More vertices and edges

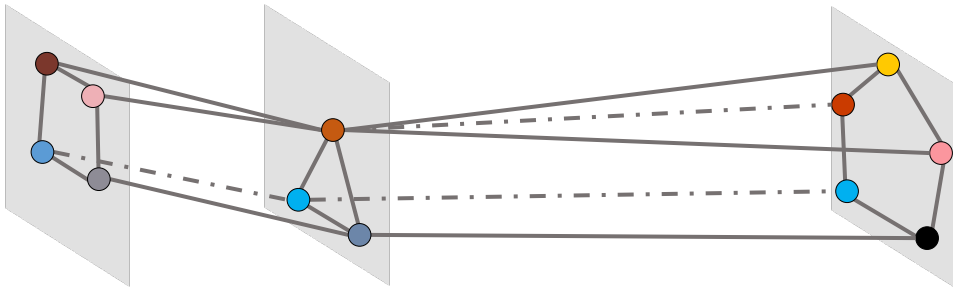


Fewer vertices and edges

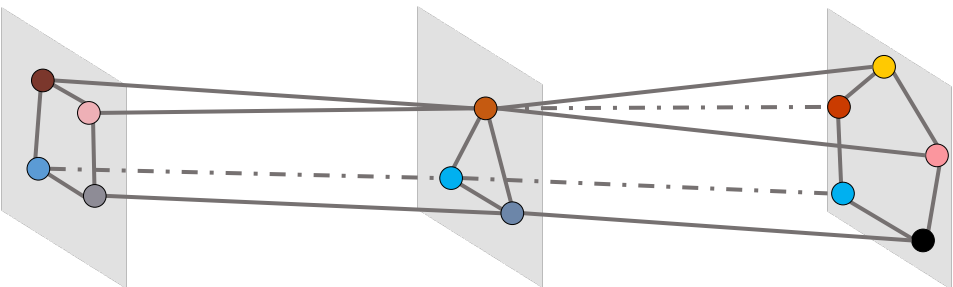
Geometric palette measurement

- Smooth change over time

$$L_v(P, I) = L_{frame}(P, I) + L_{smooth}(P)$$



Color changes sharply



Color changes smoothly

Geometric palette extraction

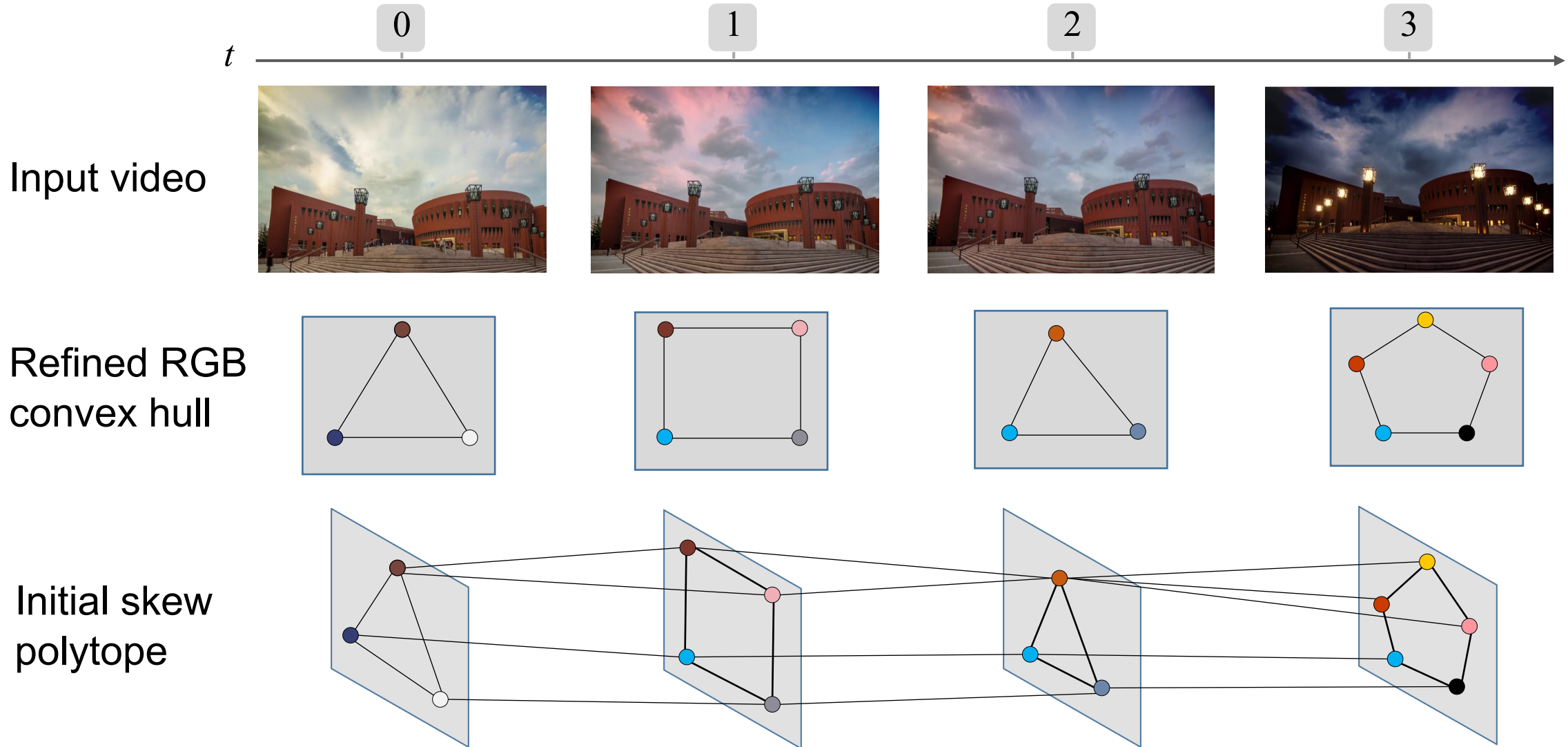
Step1 Initialization

Step2 Block Merging

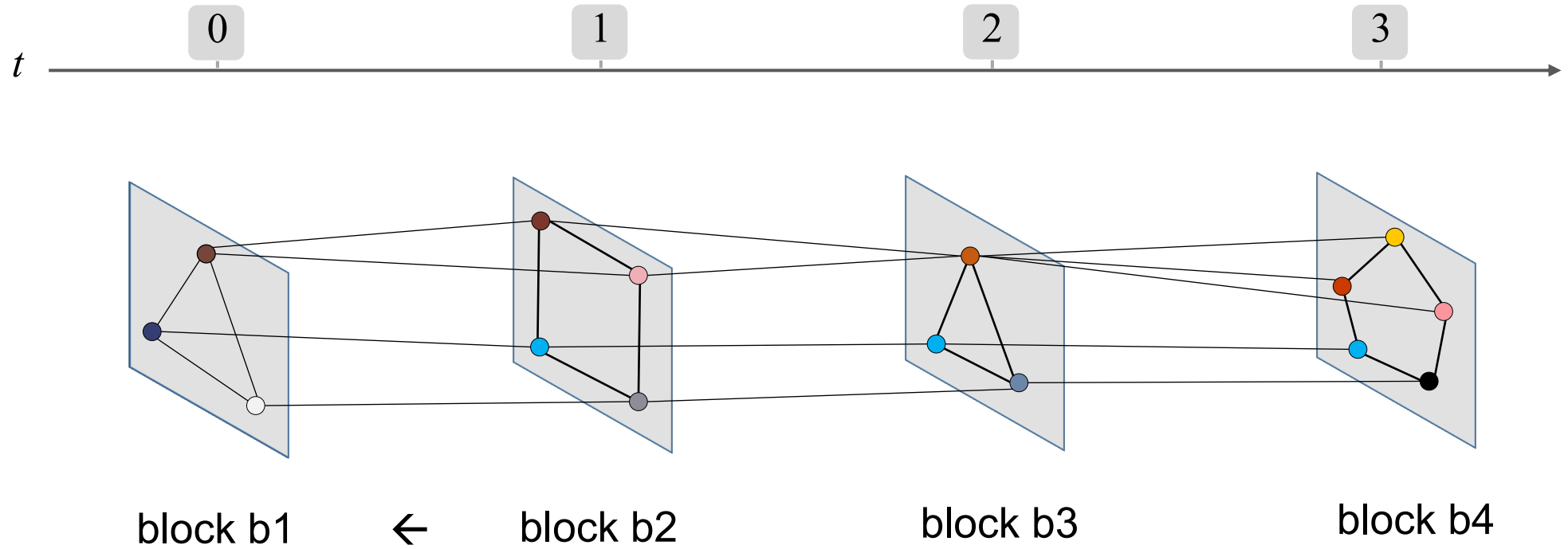
Step3 Vertex Removal

Step4 Vertex Refinement

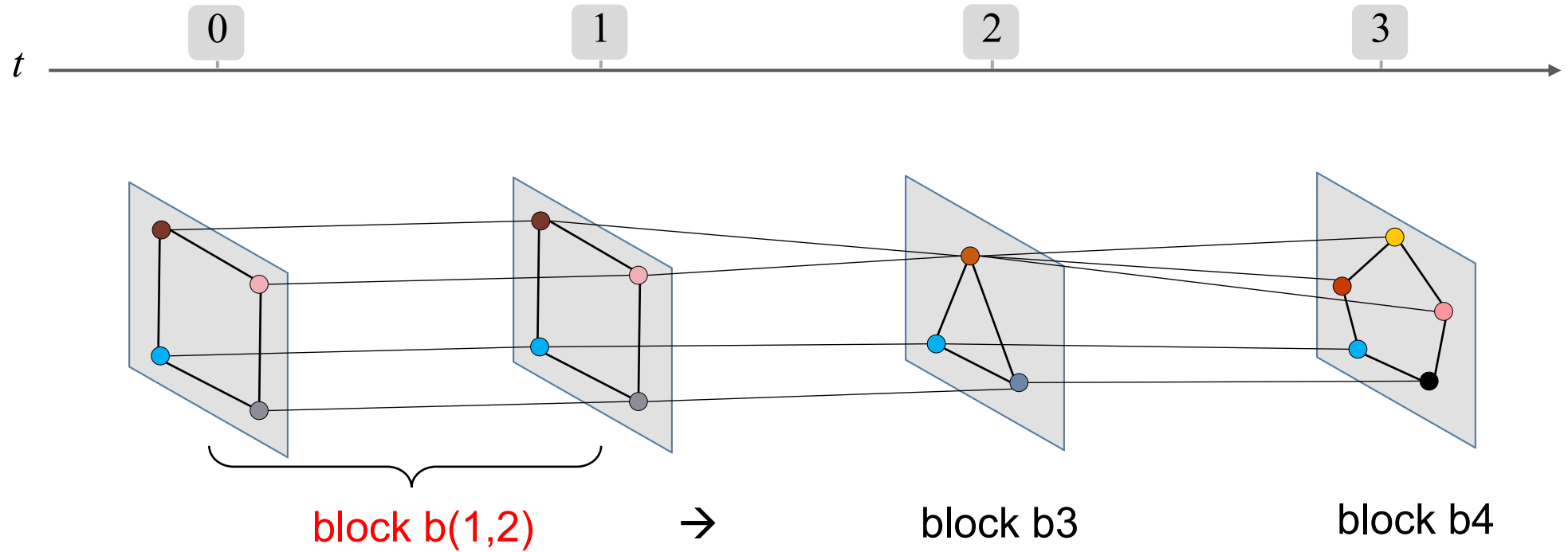
Step1 Initialization



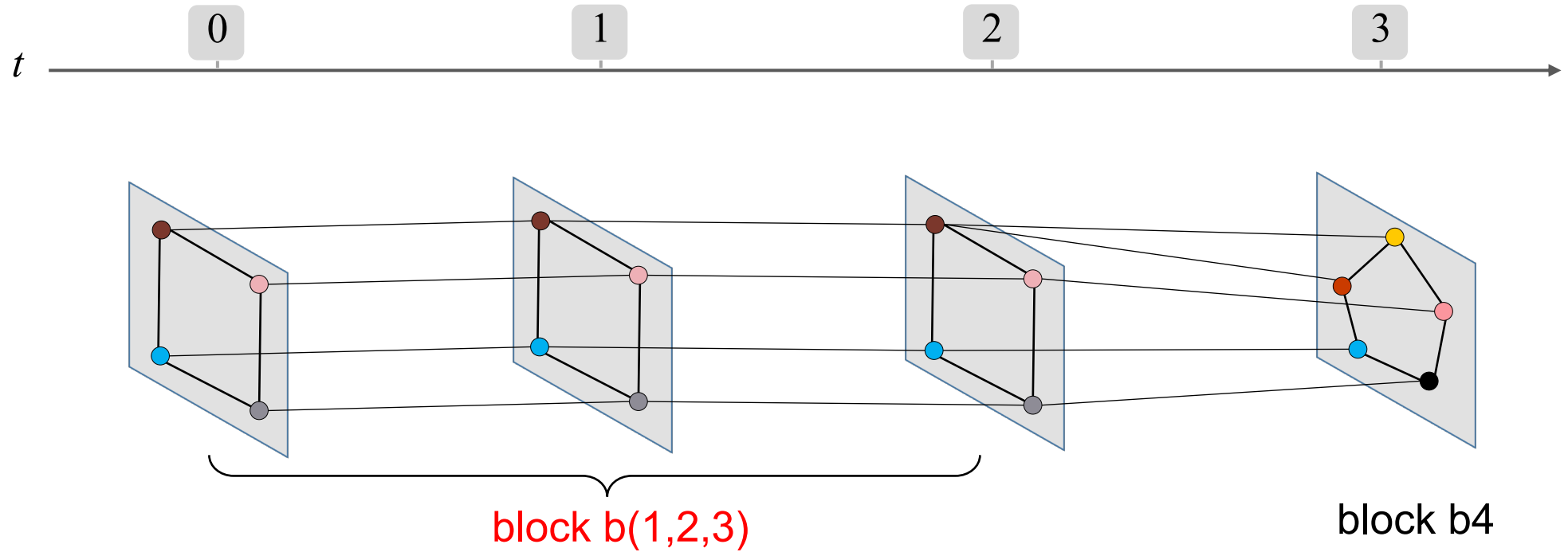
Step2 Block Merging



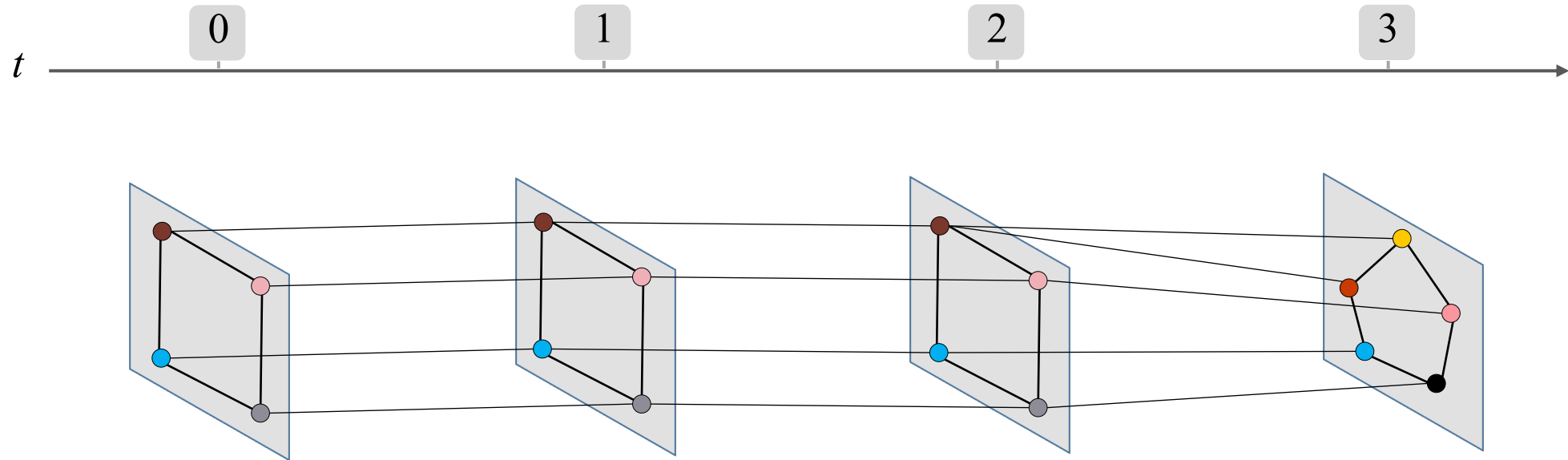
Step2 Block Merging



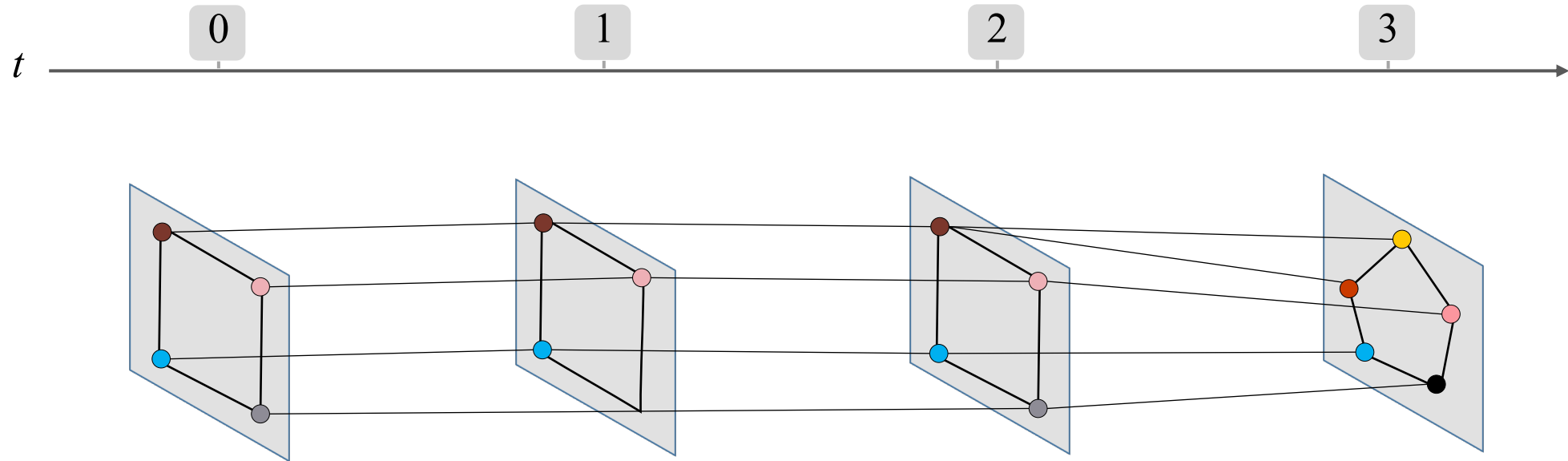
Step2 Block Merging



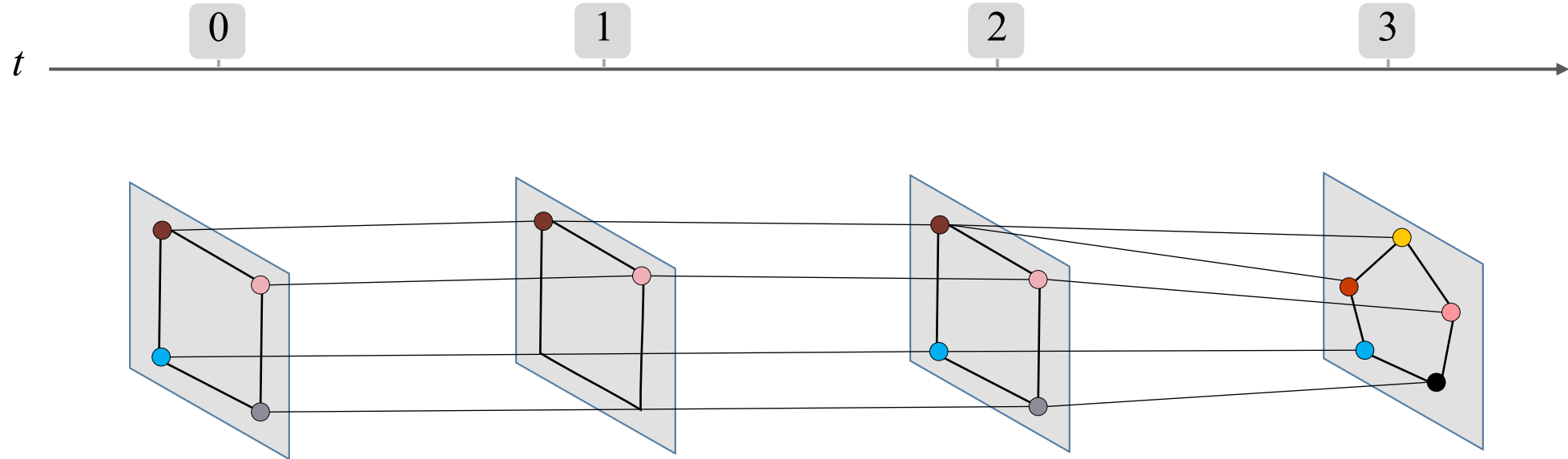
Step2 Block Merging



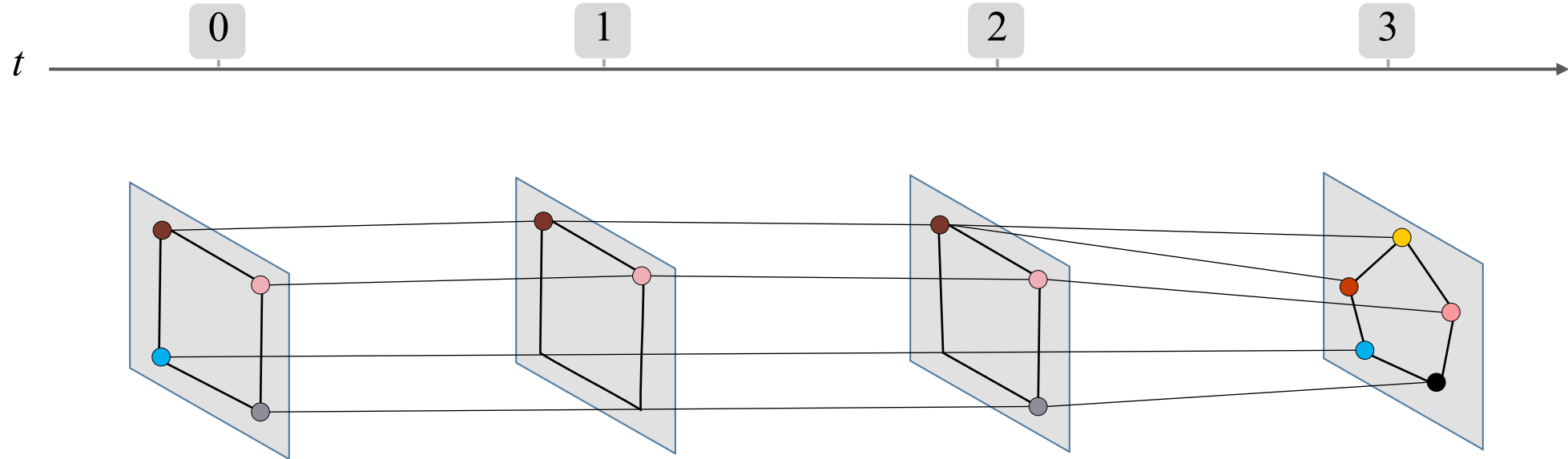
Step3 Vertex removal



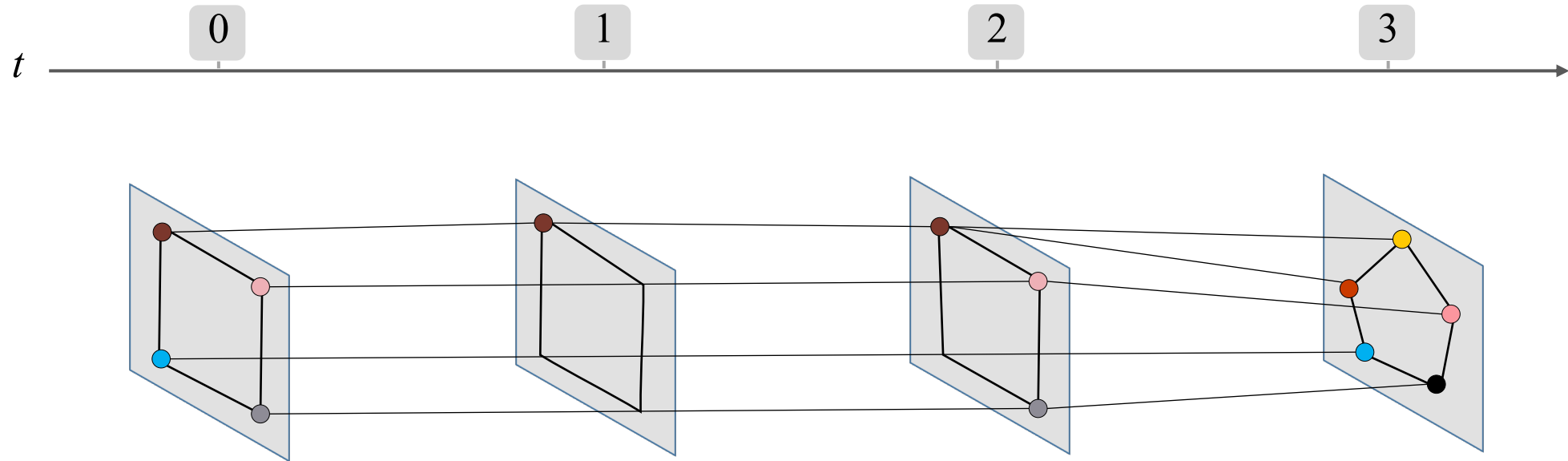
Step3 Vertex removal



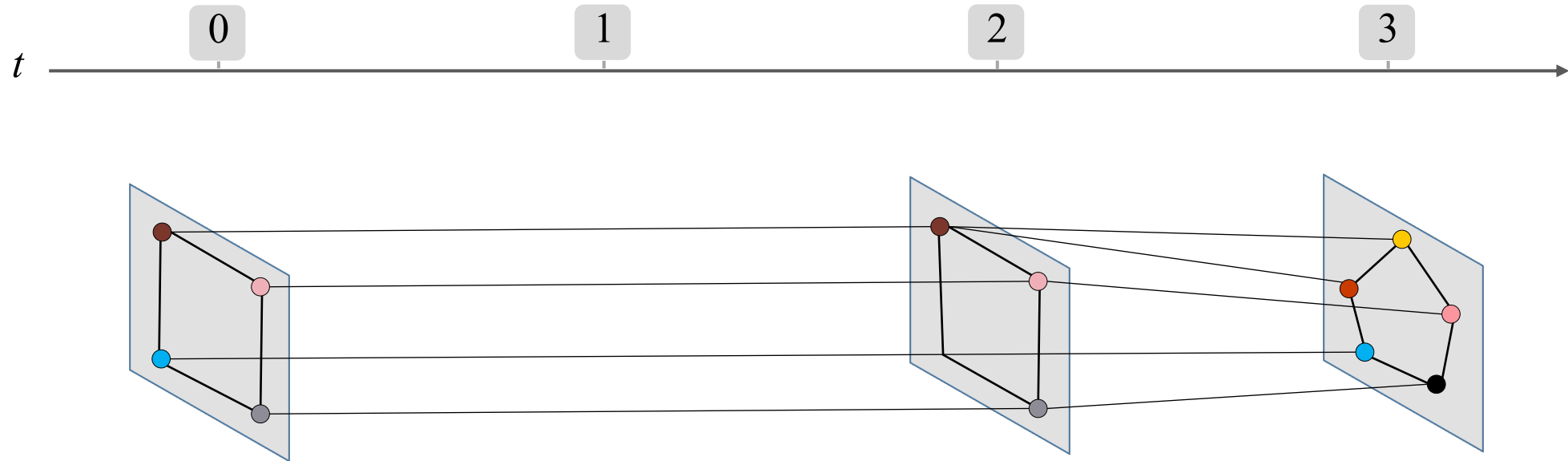
Step3 Vertex removal



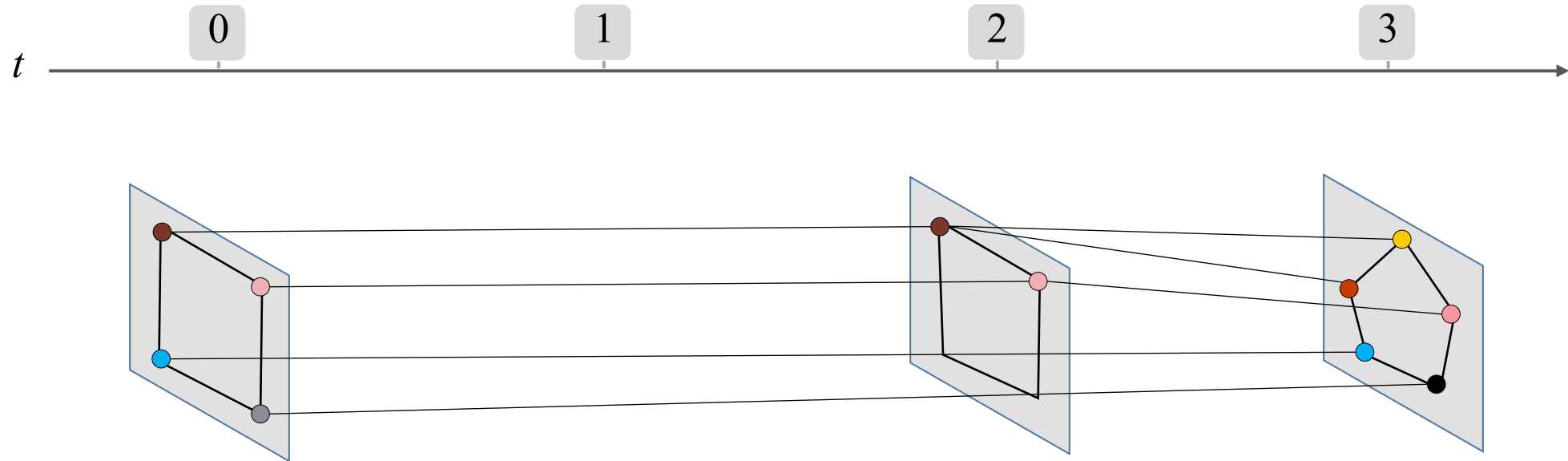
Step3 Vertex removal



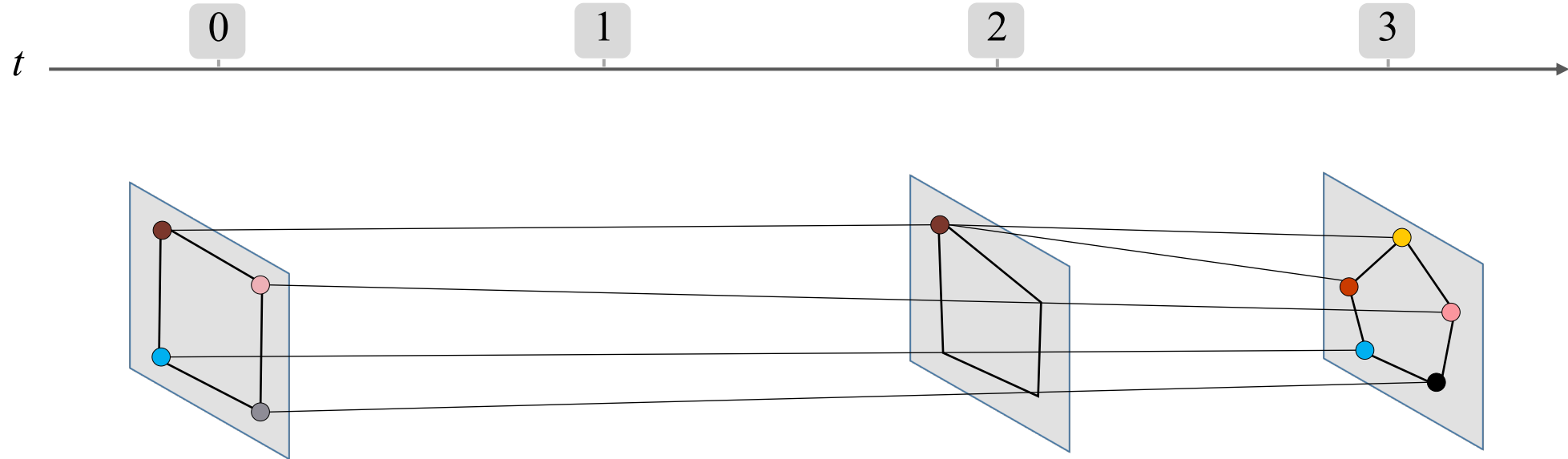
Step3 Vertex removal



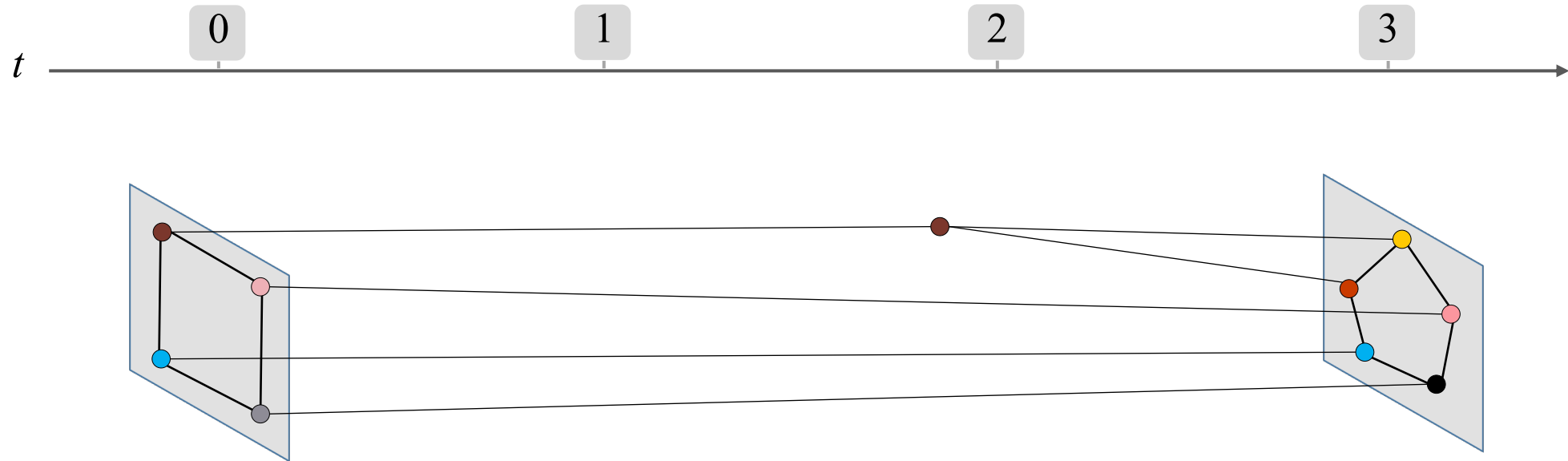
Step3 Vertex removal



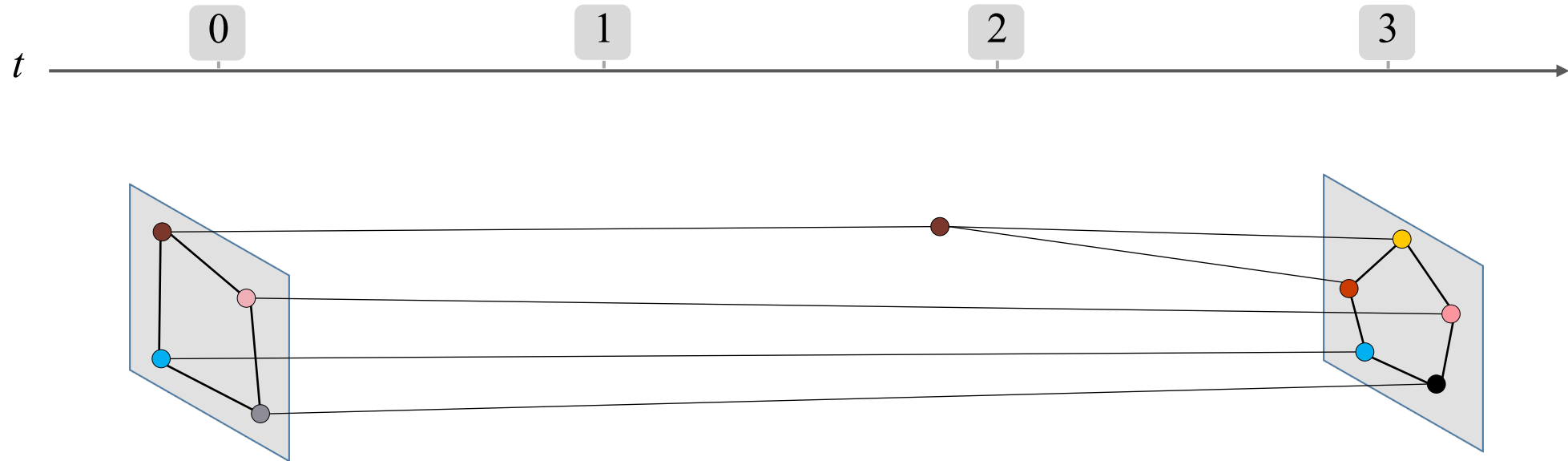
Step3 Vertex removal



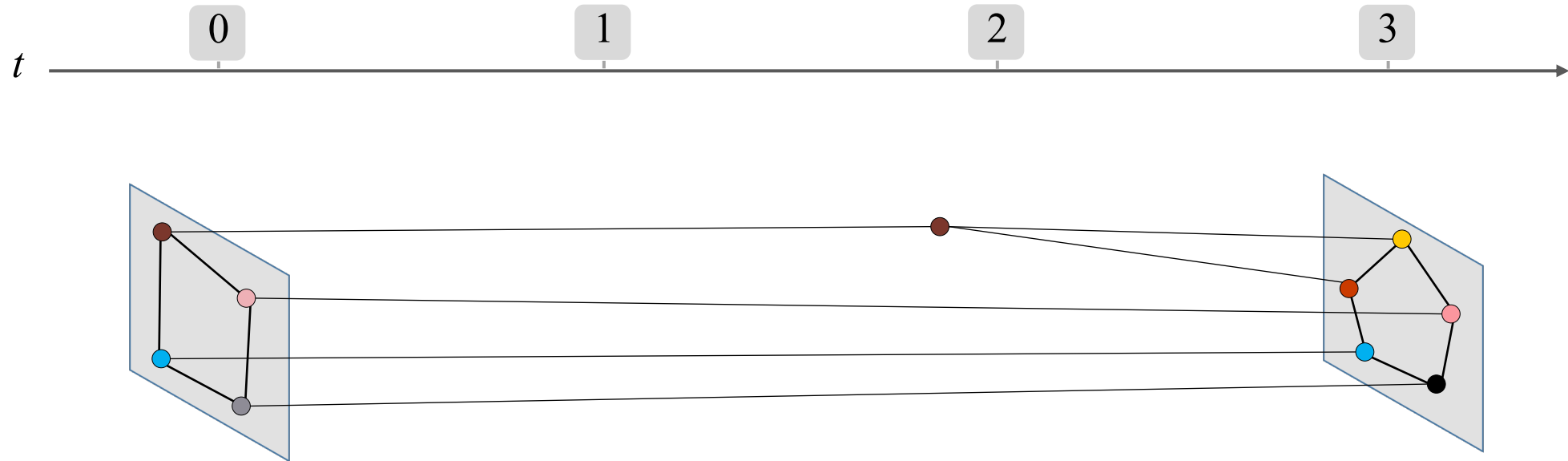
Step3 Vertex removal



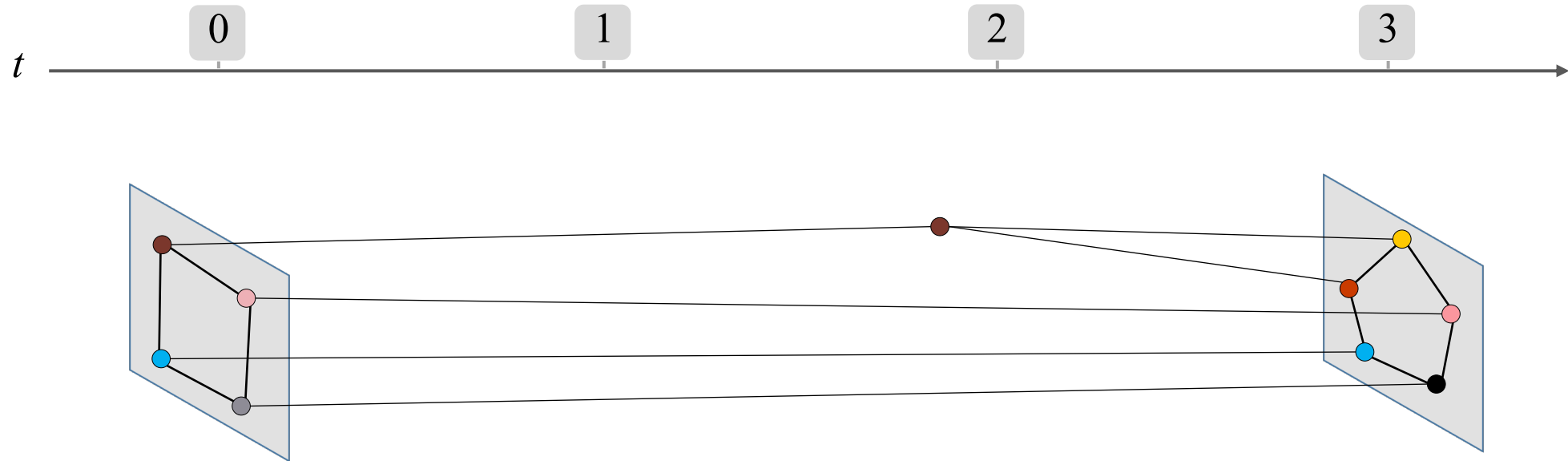
Step4 Vertex refinement



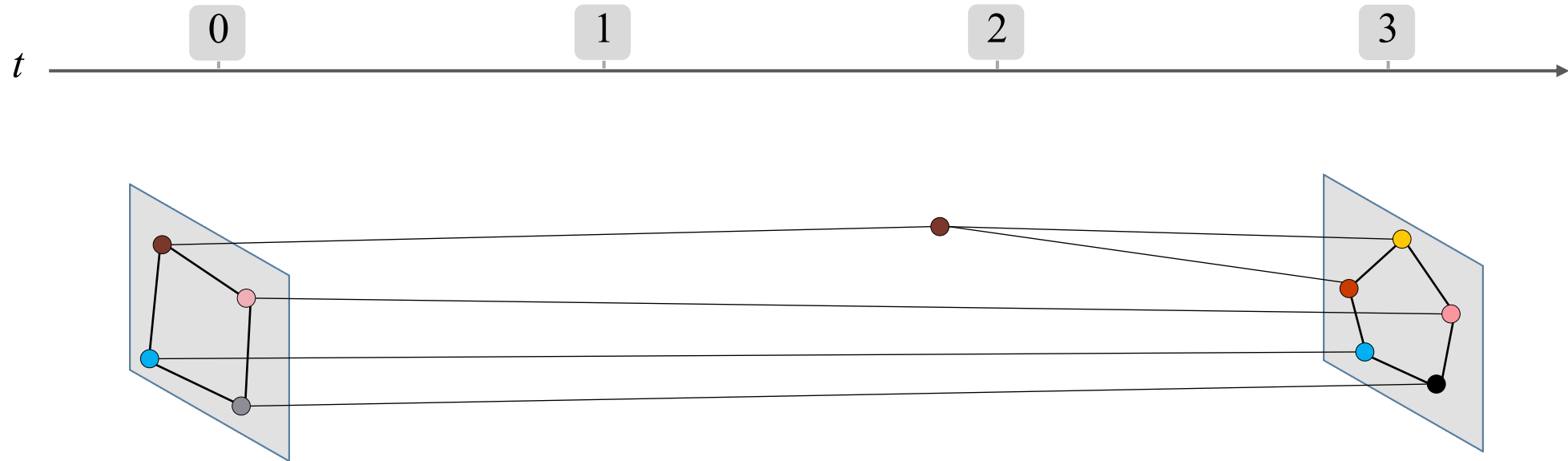
Step4 Vertex refinement



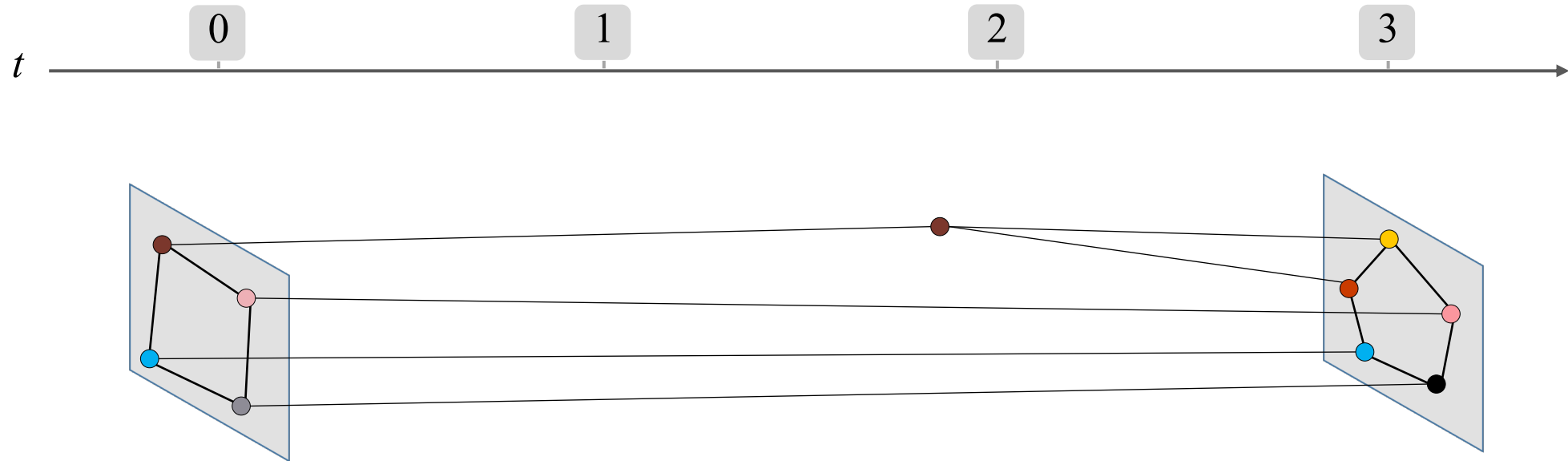
Step4 Vertex refinement



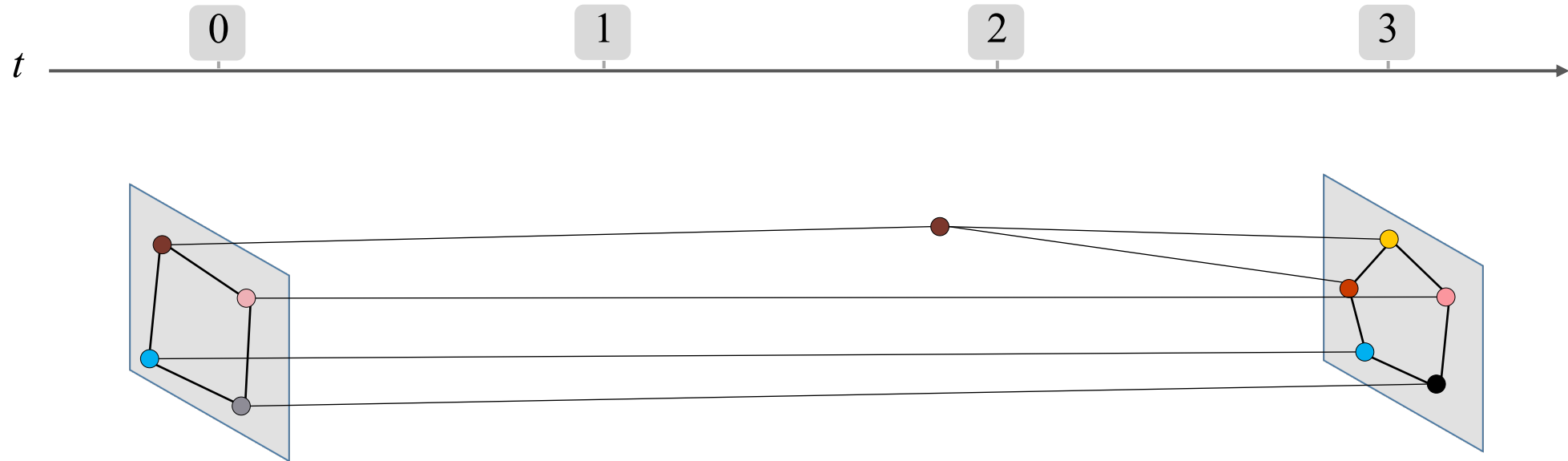
Step4 Vertex refinement



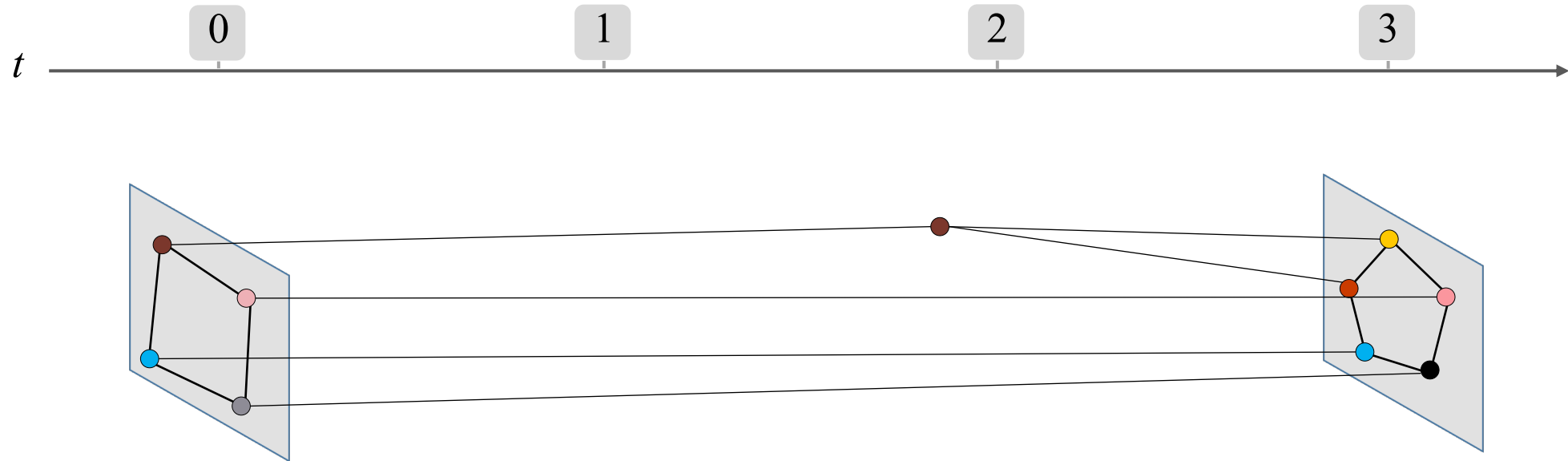
Step4 Vertex refinement



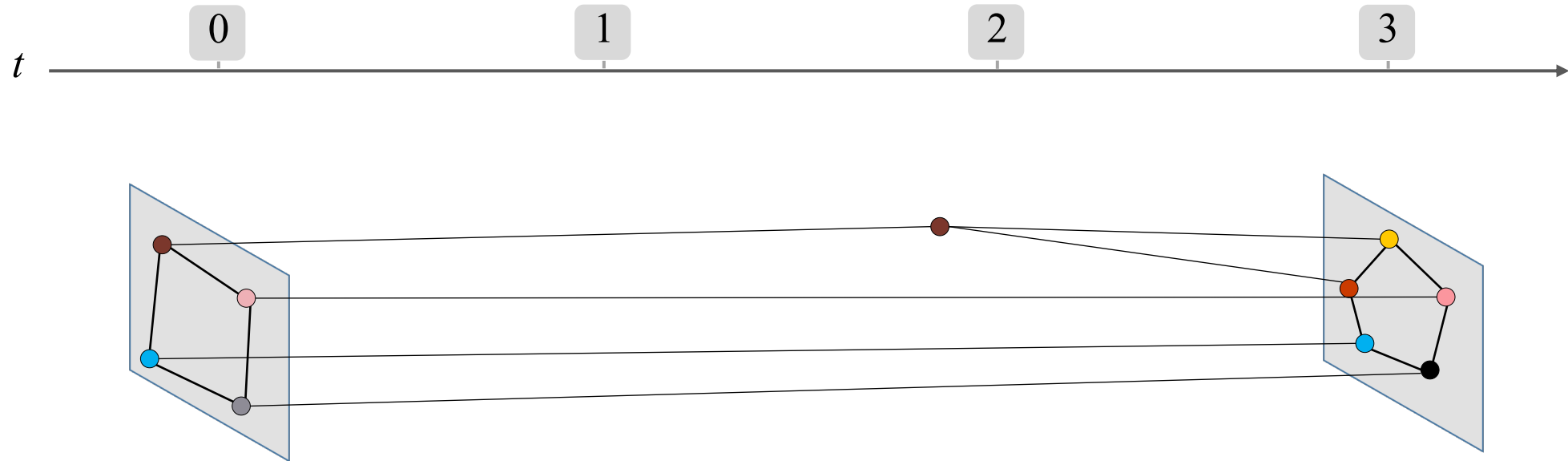
Step4 Vertex refinement



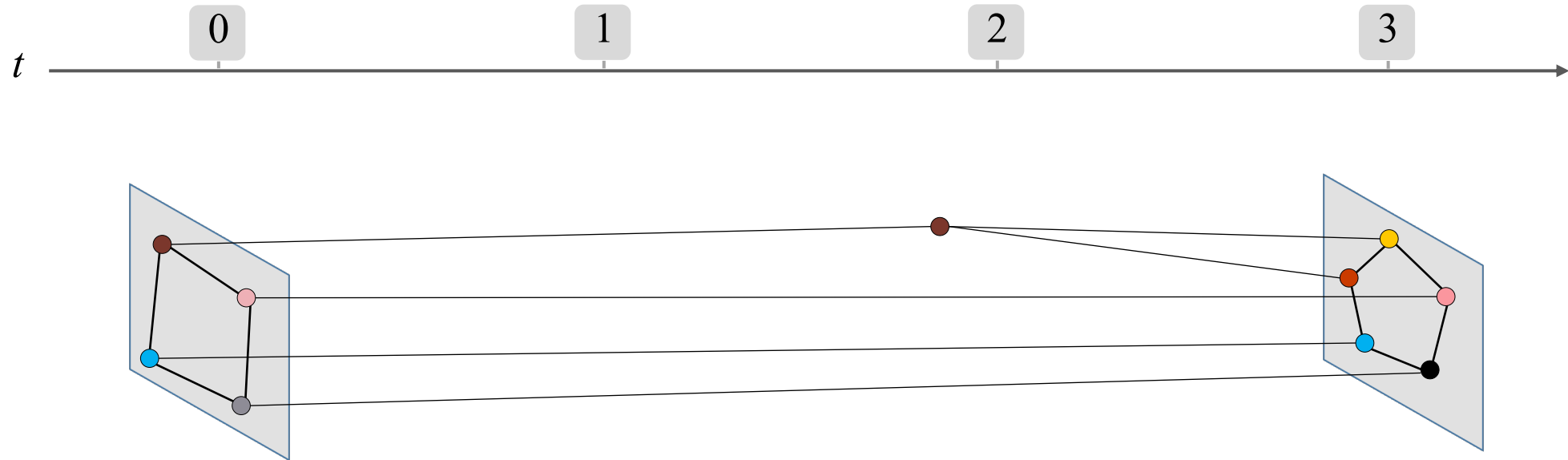
Step4 Vertex refinement



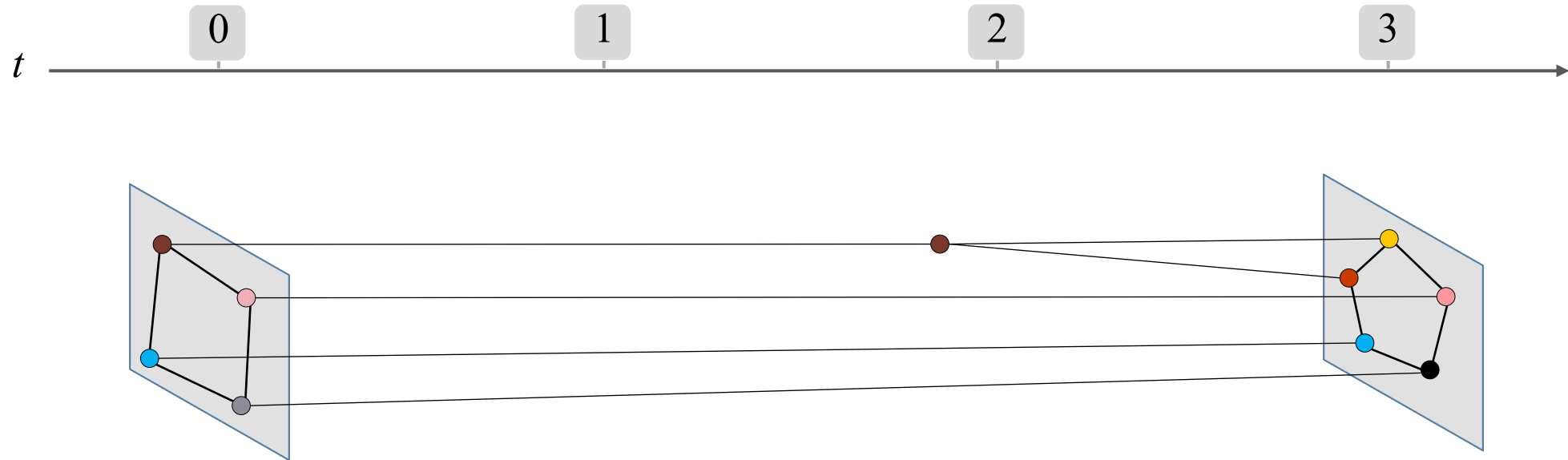
Step4 Vertex refinement



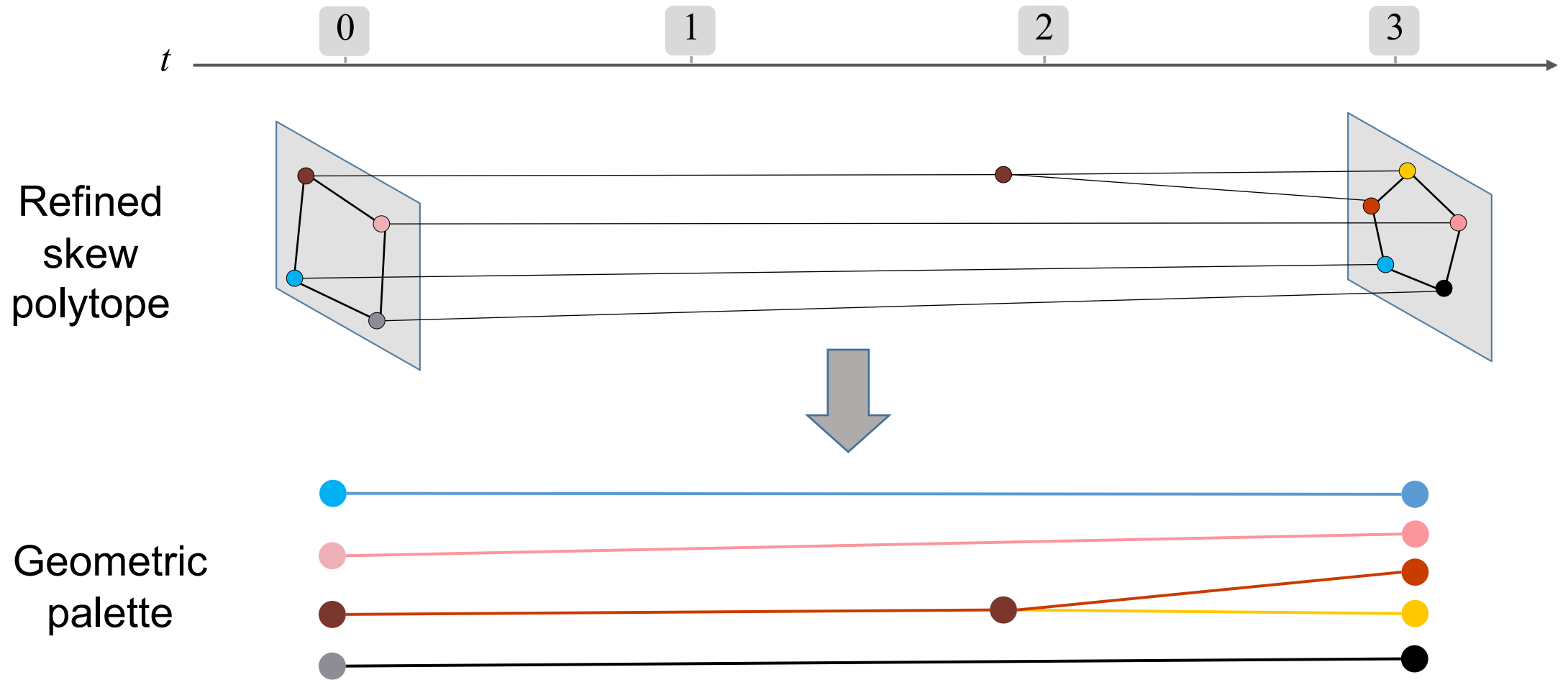
Step4 Vertex refinement



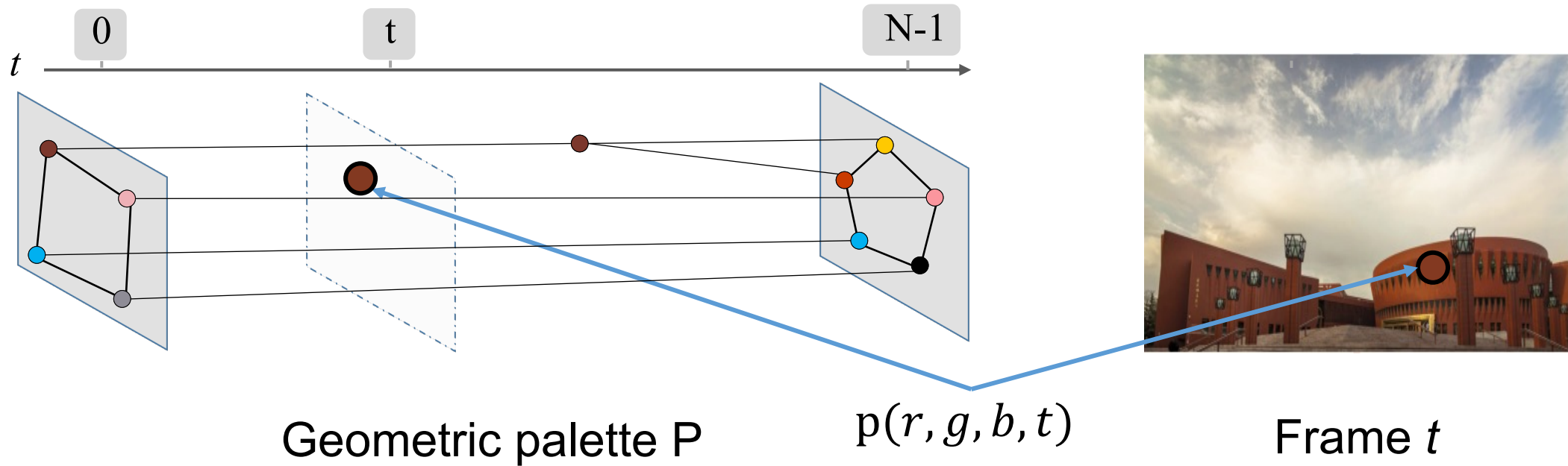
Step4 Vertex refinement



Output the geometric palette



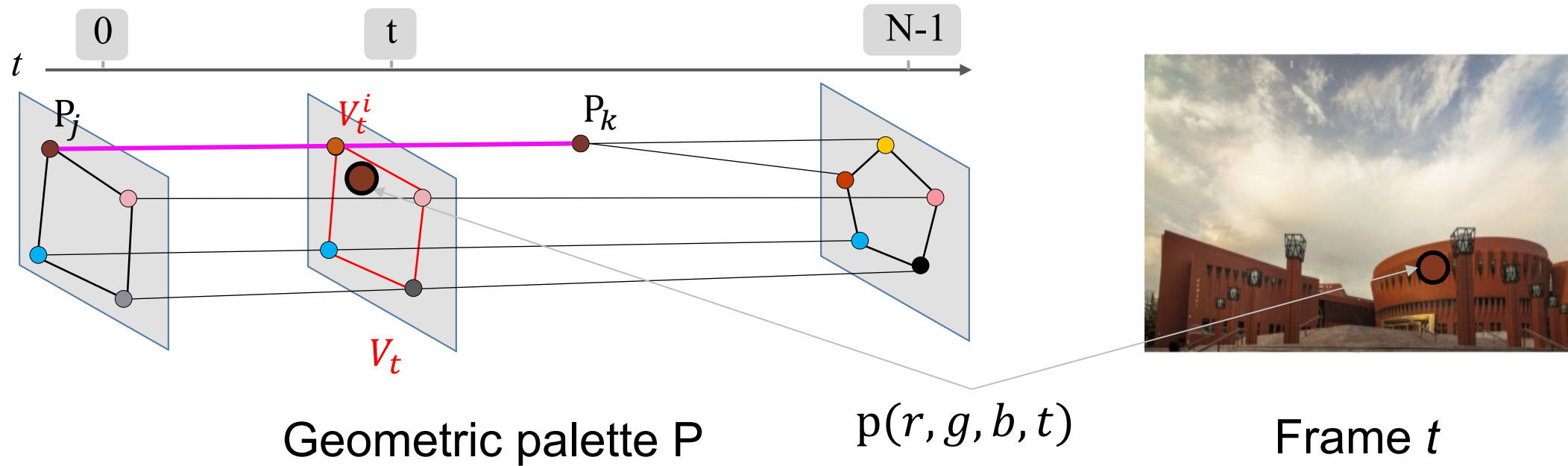
Video recoloring



$$p = \sum_{i=1}^{|V|} w_i P_i = W_{RGBT} P = W_{RGBT} \left[\begin{array}{c} \text{[Color Palette Vertices]} \end{array} \right]^T$$

Geometric palette P vertices (colors)

Video recoloring

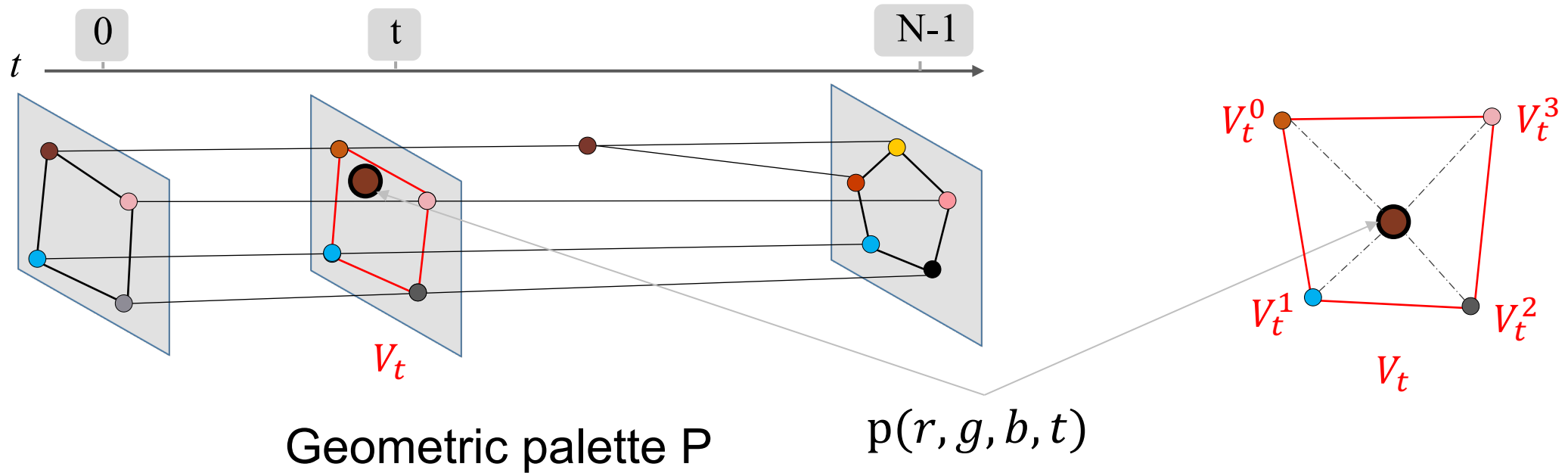


1) Get the slice (polyhedral palette) at frame t : $V_t = S(P, t)$

Each vertex of V_t lies in an edge of P , it can be linearly interpolated as:

$$V_t^i = \alpha P_j + (1 - \alpha) P_k \longrightarrow V_t = W_t P$$

Video recoloring

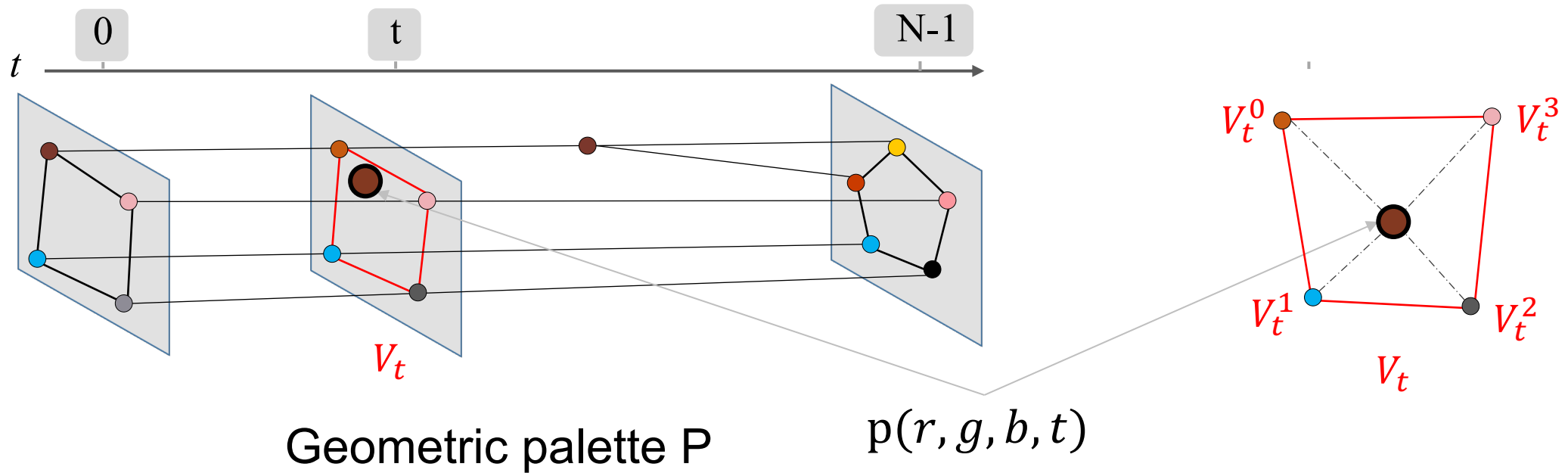


2) Inside the slice (closed polyhedron V_t), the point p can be expressed as:

$$p = \sum_i w_p^i V_t^i \longrightarrow p = W_p V_t$$

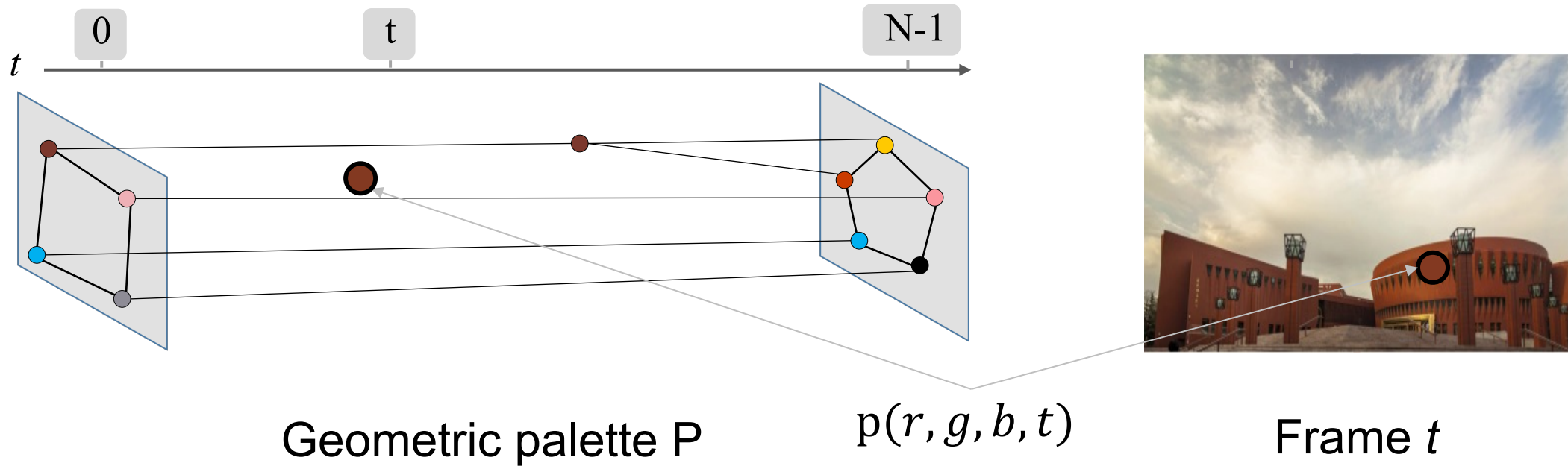
Mean value coordinates for closed triangular meshes [Ju et al. 2005]

Video recoloring



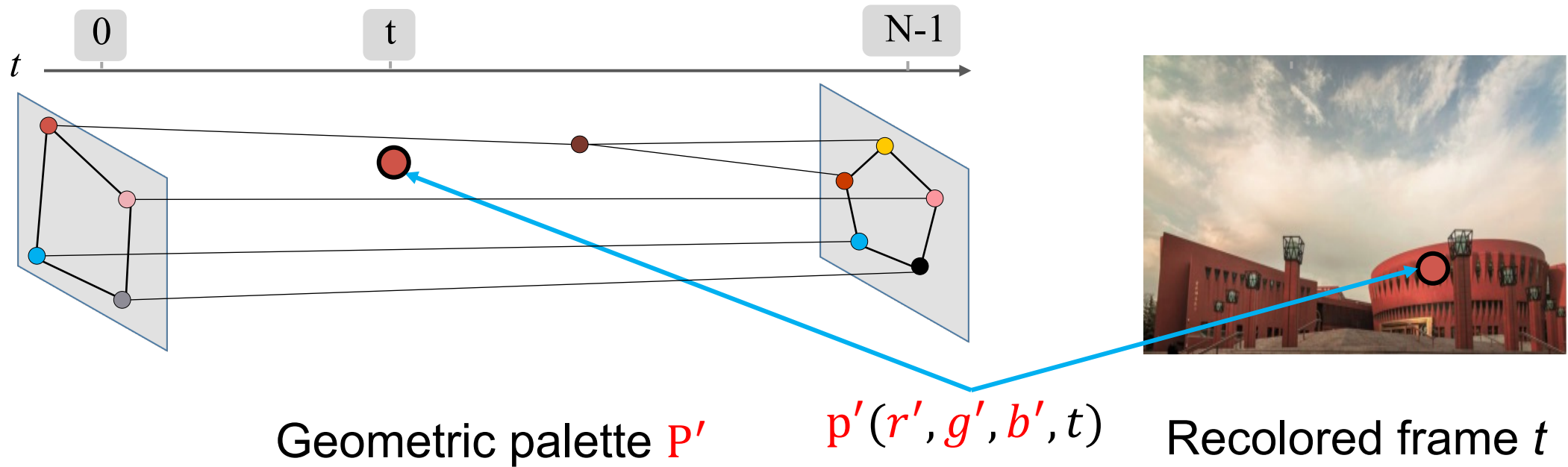
- 1) Get the slice of $p(r, g, b, t)$ in P : $V_t = W_t P$
 - 2) $p(r, g, b, t)$ is inside the slice V_t : $p = W_p V_t$
- $p = \underbrace{W_p}_{W_{RGBT}} W_t P$

Video recoloring



$$p = W_{RGBT}P$$

Video recoloring



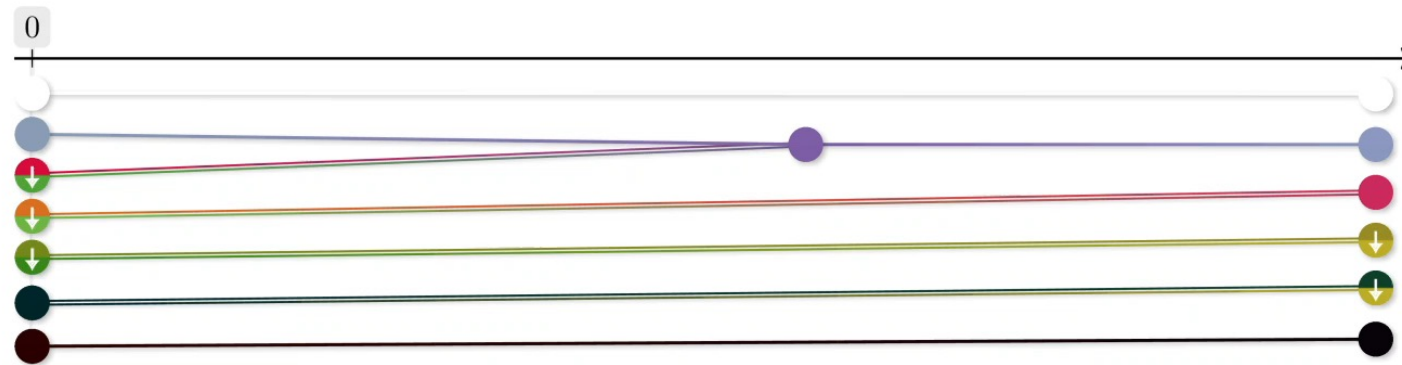
$$p = W_{RGBT} P \longrightarrow p' = W_{RGBT} P'$$

Results



Input Video

Output Video (Ours)



4D Geometric Palette

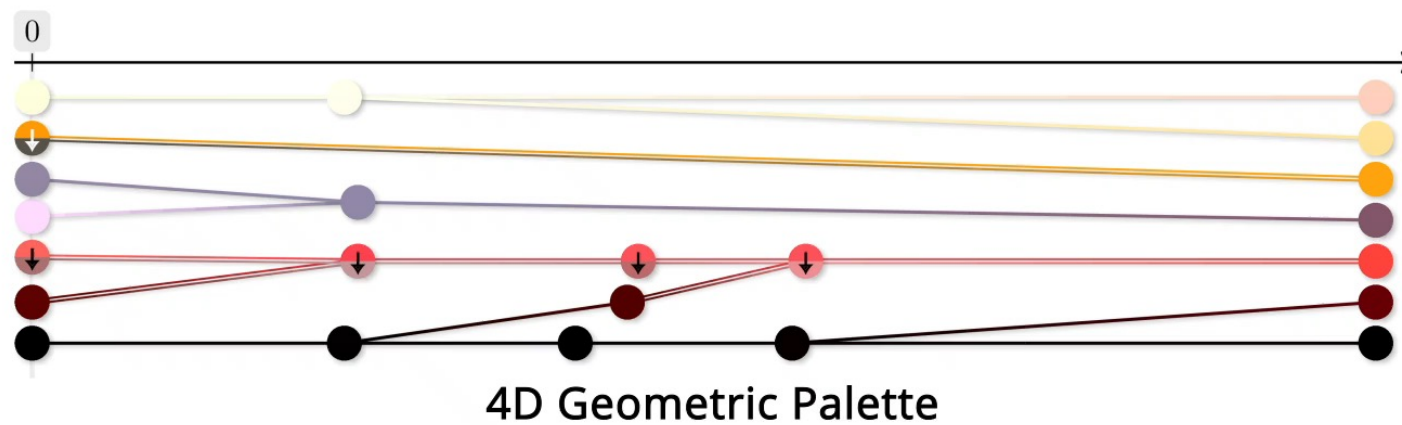
Results



Input Video



Output Video (Ours)



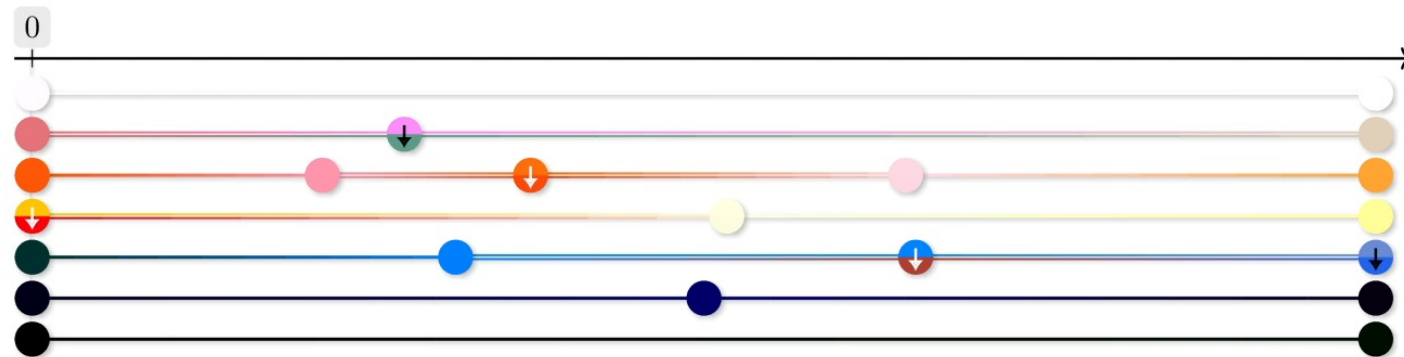
Results



Input Video



Output Video (Ours)



4D Geometric Palette

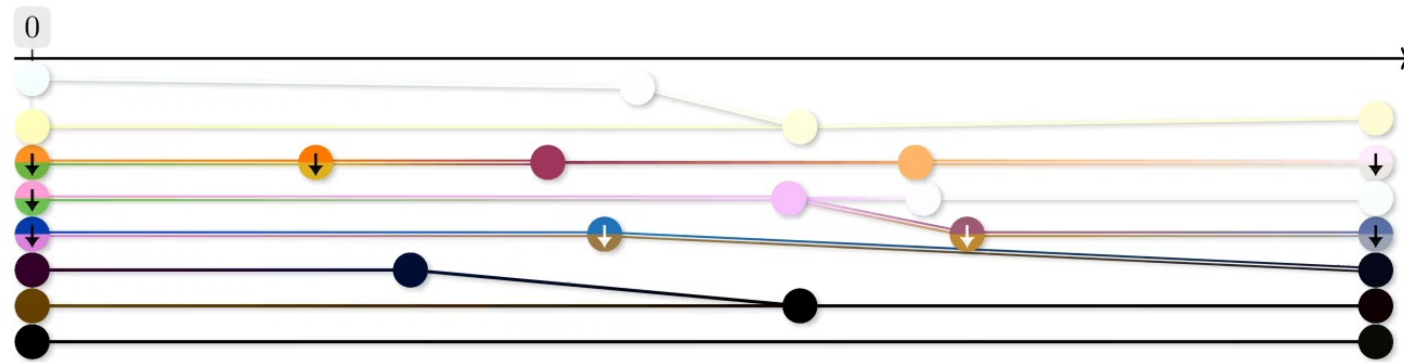
Results



Input Video



Output Video (Ours)



4D Geometric Palette

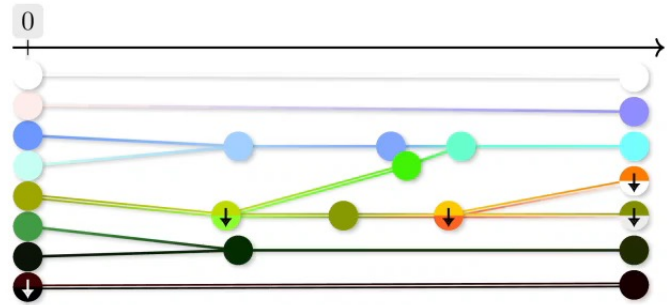
Compare to RGB convex hull



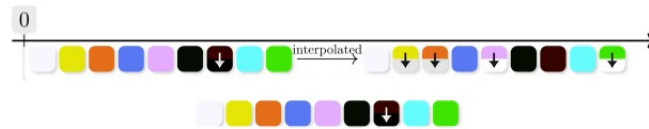
Input Video



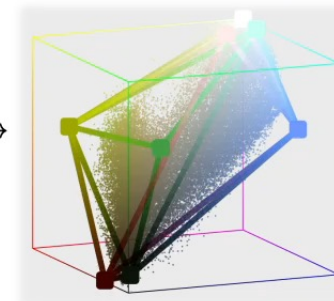
Output Video (Ours; RGB Convex Hull)



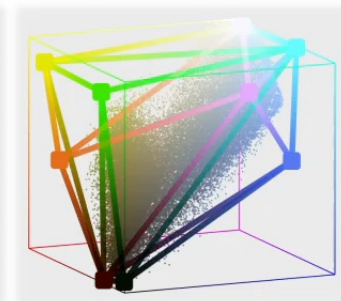
4D Geometric Palette
(Ours)



Interpolated Palette
(RGB Convex Hull)



Sliced Palette
(Ours)



Sliced Palette
(RGB Convex Hull)

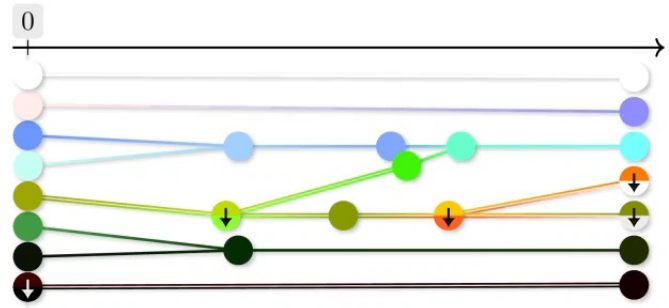
Compare to RGBT convex hull



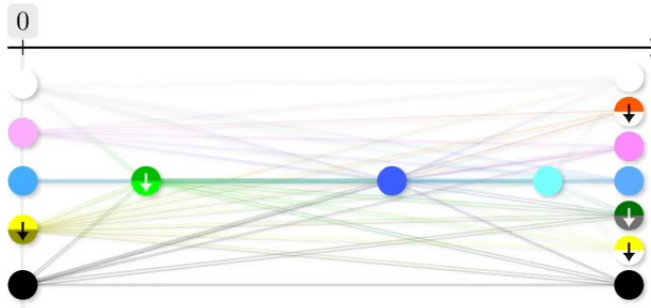
Input Video



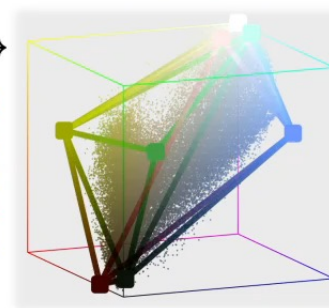
Output Video (Ours; RGBT Convex Hull)



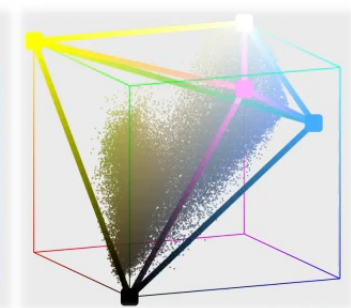
4D Geometric Palette (Ours)



4D Geometric Palette (RGBT Convex Hull)



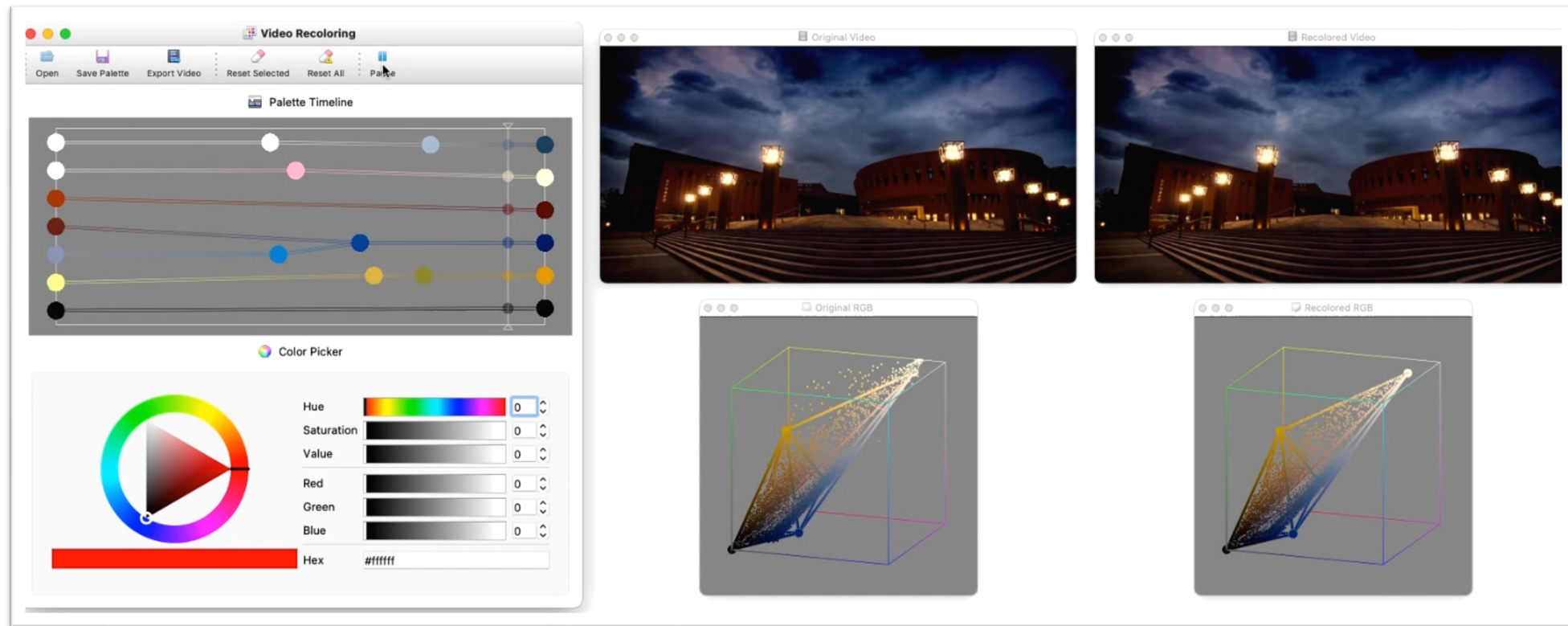
Sliced Palette (Ours)



Sliced Palette (RGBT Convex Hull)

Conclusion

- We proposed the first palette-based video recoloring
- Our method produces natural, artifact-free recoloring



Limitation

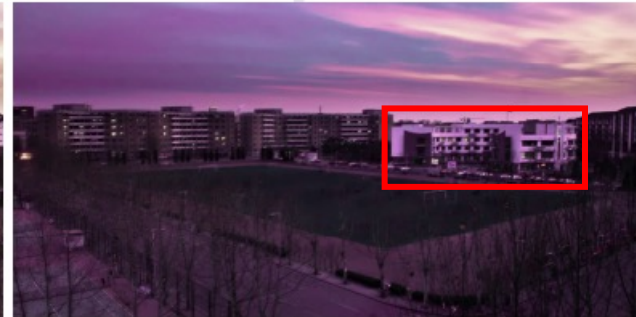
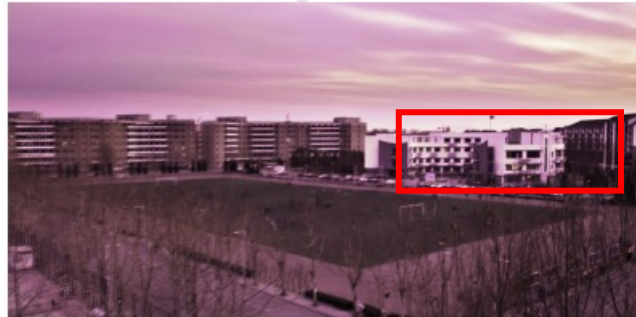
- Can not realize object aware local recoloring

Input video



The sky and building with similar blue

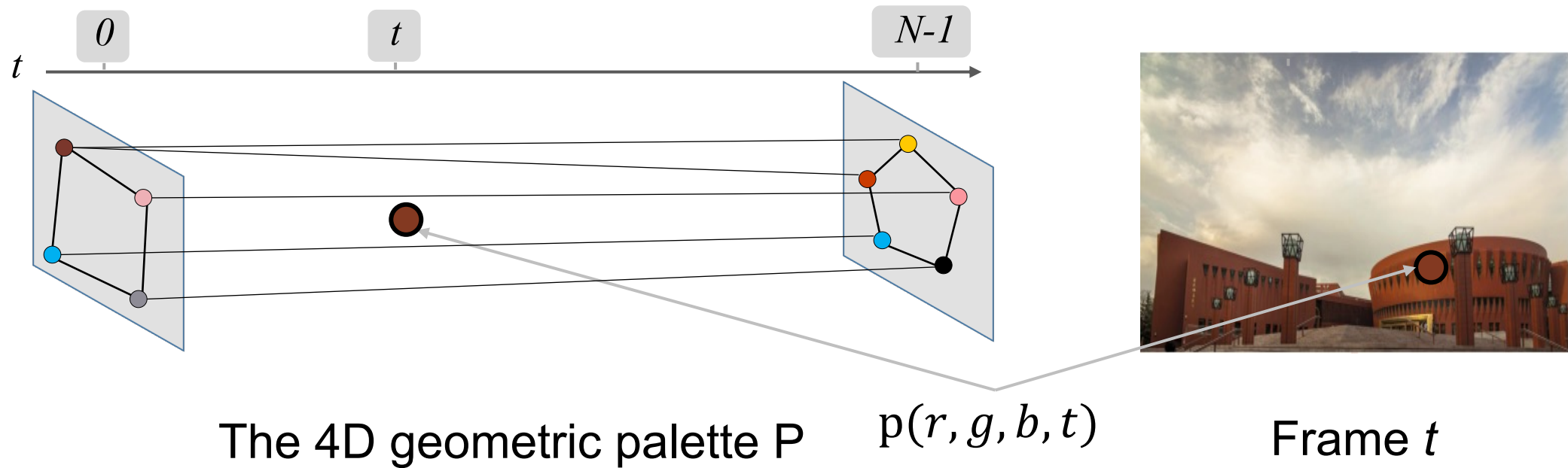
Recolored video



Different objects with similar colors will be recolored simultaneously

Limitation

- Non-linear color editing such as tone mapping is not supported



$$p = W_{RGBT} P$$

Thank You!

- **Contact Information:**

- Zheng-Jun Du: duzj19@mails.tsinghua.edu.cn
- Kai-Xiang Lei: leikx18@mails.tsinghua.edu.cn
- Kun Xu: xukun@tsinghua.edu.cn
- Jianchao Tan: tanjianchaoustc@gmail.com
- Yotam Gingold: ygingold@gmu.edu



Project page