Split and Match: Example-based Adaptive Patch Sampling for Unsupervised Style Transfer

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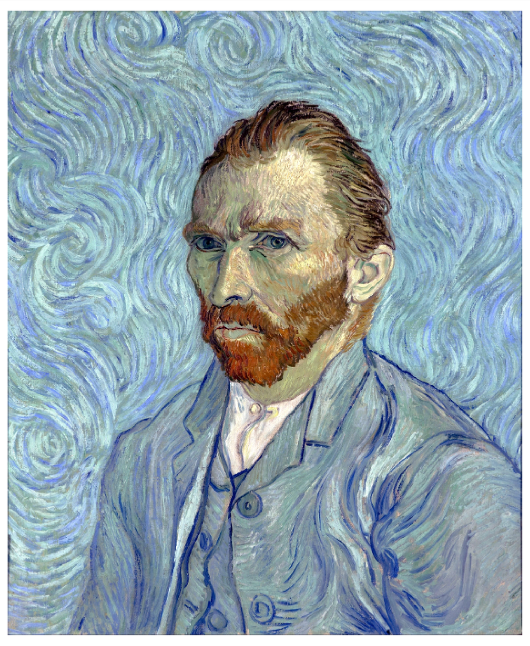
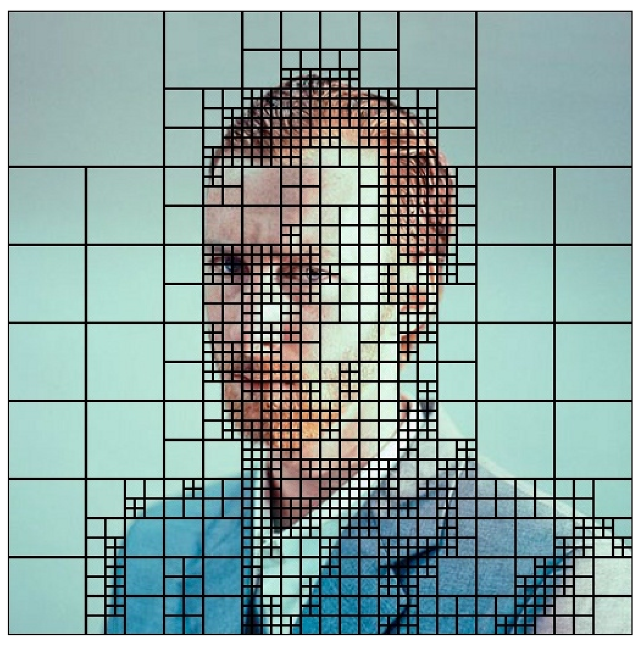
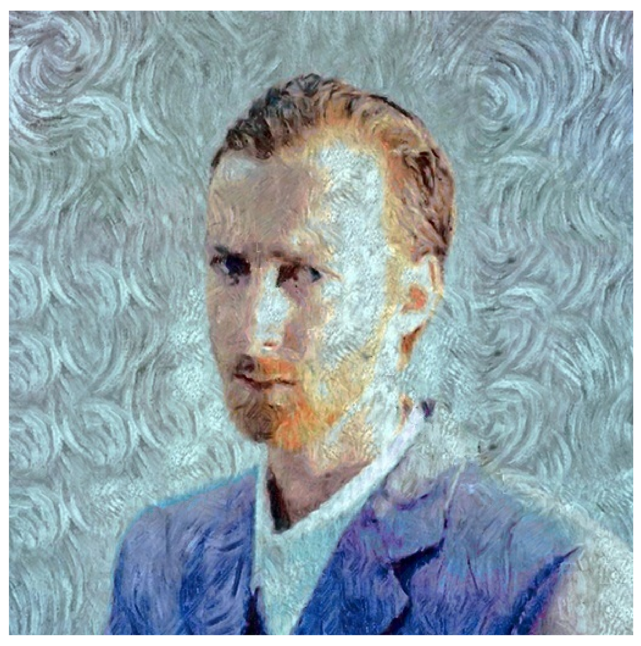
Original (u)


Example (v)


Partition ($\mathcal{R}$)


Stylization ($\hat{u}$)

Introduction

- *Example-based style transfer*: transform an image to **mimic the style** of a given example
- Style as a combination of global **color** and local **texture** transfer
- Previous patch-based texture transfer methods assume regular grid

Our Approach

- Let $u : \Omega_u \to \mathbb{R}^3$ be an input image and $v : \Omega_v \to \mathbb{R}^3$ an example style image
- Search for correspondence map $\varphi : \Omega_u \to \Omega_v$, with texture transfer defined as $\hat{u} = v(\varphi)$
- We follow the steps below to achieve style transfer:
  1. **Split and match**: compute an adaptive partition $\mathcal{R}$ of Ω_u;
  2. **Optimization**: Search for the optimal map φ;
  3. Bilinear **blending** between neighbor regions and reconstruction of $\hat{u}$;
  4. Global **color transfer** [2] and **contrast matching**.

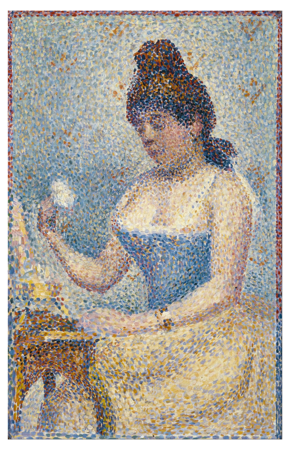
Adaptive patch partition

- Quadtree partition inspired by classic **Split and Merge**
- Region R_i is split in four regions only if

$$\left(\sigma_i + d[p^u_{x_i}, p^v_{y_i}] > \omega \;\textbf{and}\; \tau_i > \Upsilon_0\right) \;\textbf{or}\; \tau_i > \Upsilon_1$$

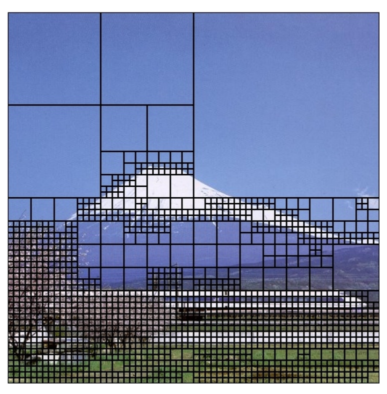
- y_i is the best match of $p^u_{x_i}$ in v, σ_i is the standard deviation of $p^u_{x_i}$
- Distance between patches $p^u_{x_i}$ and p^v_y of size τ_i^2 given by $d[p^u_{x_i}, p^v_y] = \frac{\|p^u_{x_i} - p^v_y\|^2}{\tau_i^2}$

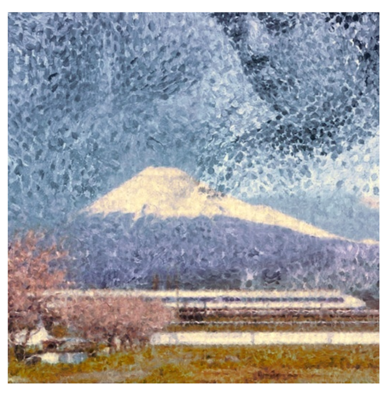

Original

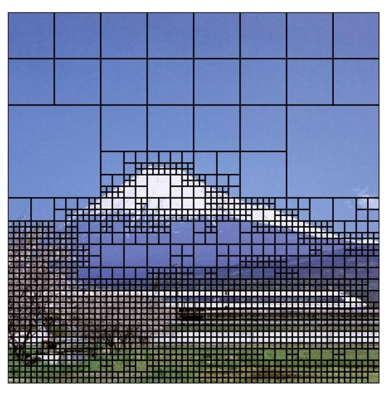

Example


Regular grid result, size 8^2


Regular grid result, size 32^2


Split and merge quadtree

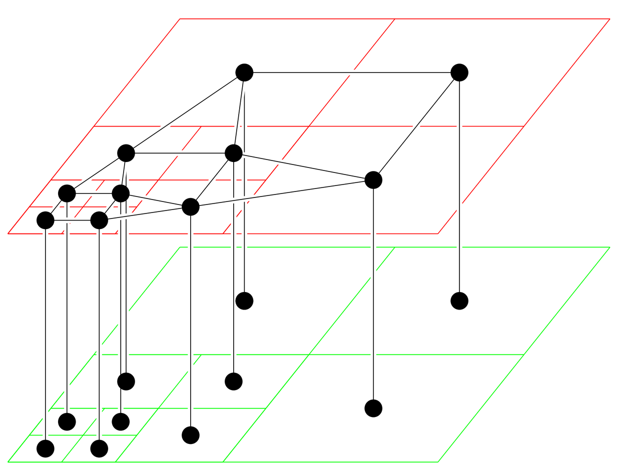

Split and merge result


Split and match quadtree


Split and match result

Optimal candidate selection

- Patch correspondences as a **labeling problem**
- Label assignments given by MAP inference from joint probability distribution on $L = \{L_i\}_{i=1}^n$
- MRF model over **non-regular grid**



- For quadtree patch $p^u_{x_i}$, K candidates $L_i = \{l_{i_k}\}_{k=1}^K$ are computed by k-nearest neighbors
- Then we search for label assignments $\hat{L} = \{\hat{l}_i\}_{i=1}^n$ maximizing

$$P(L) = \frac{1}{Z} \prod_i \phi(l_i) \prod_{(i,j)\in\mathcal{N}} \psi(l_i, l_j),$$

  - where $\phi(l_i) = \exp(-d[p^u_{x_i}, p^v_{l_i}]\lambda_d)$
  - $\psi(l_i, l_j) = \exp(-d[\tilde{p}^v_{l_i}, \tilde{p}^v_{l_j}]\lambda_s + |l_i - l_j|^2\lambda_r)$
- Approximate inference by **loopy belief propagation** [4]

Blending

- Given a a set of overlapping patches P of arbitrary sizes
- Blending as a weighted sum of all overlapping intensities:

$$\tilde{u}(x) = \sum_{s=1}^{S} \alpha_s(x)\, \tilde{p}^{\hat{u}}_{x_s}(x)\,,\ \text{where } \alpha_s(x) = \frac{\delta(x, \partial\tilde{p}^{\hat{u}}_{x_s})}{\sum_{s=1}^{S} \delta(x, \partial\tilde{p}^{\hat{u}}_{x_s})} \text{ and } \delta(x, \partial\tilde{p}^{\hat{u}}_{x_s}) = \frac{|x - \partial\tilde{p}^{\hat{u}}_{x_s}|^2}{\tau_s^2}$$

$\alpha_s(x)$ is a weight and $\delta(x, \partial\tilde{p}^{\hat{u}}_{x_s})$ is the distance between pixel x and patch border $\partial\tilde{p}^{\hat{u}}_{x_s}$

Results


Original and Example


Our method


Unsupervised Patch table [1]


Neural Artistic Style [3]


Figure: Results of our method with Monet's and Van Gogh's paintings as examples.

Conclusion

- Style transfer synthesizing **textures of different scales**
- Local texture modeling and global color transfer leads to **structure-preserving stylization**
- Future work will **extend our method to videos**

References

[1] C. Barnes, F.-L. Zhang, L. Lou, X. Wu, and S.-M. Hu. Patchtable: Efficient patch queries for large datasets and applications. In *SIGGRAPH*, Aug. 2015.

[2] O. Frigo, N. Sabater, V. Demoulin, and P. Hellier. Optimal transportation for example-guided color transfer. In *ACCV*, pages 655–670, 2014.

[3] L. A. Gatys, A. S. Ecker, and M. Bethge. A neural algorithm of artistic style. *CoRR*, abs/1508.06576, 2015.

[4] Y. Weiss. Belief propagation and revision in networks with loops. Technical report, Cambridge, MA, USA, 1997.

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