# Epitomic Image Colorization

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# Outline

# Image Colorization

- A process of adding color to grayscale images
  - Increasing the visual appeal of images
  - Information illustration in scientific images
- Manual colorization is time consuming and tedious.
- We focus on automatic image colorization that transfers color from the reference image to the grayscale target image.

# Image Colorization

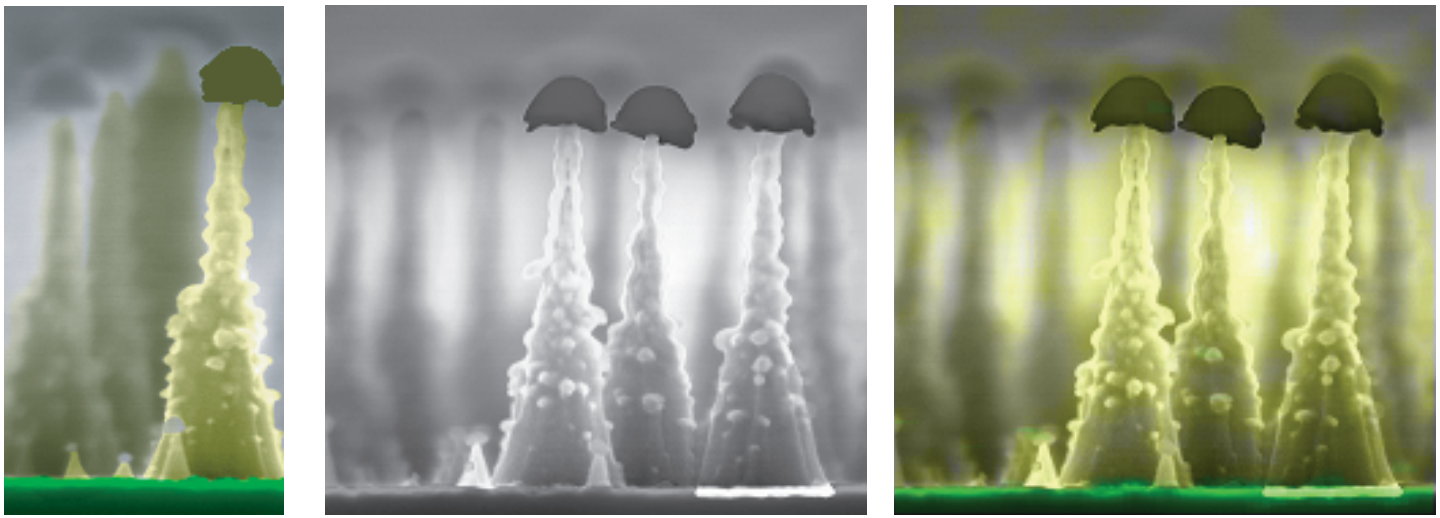


Figure 1: Colorize the Nano Mushroom-like structure by our method. From left to right: the reference image, the target image, the colorized target image.

# Related Work

- Transferring Color to Greyscale Images (Welsh et al., 2002)
  - Pixel-level matching by luminance value and neighborhood statistics
  - Suffers from spatial inconsistency
- Image Colorization Using Similar Images (Gupta et al., 2012)
  - A cascade feature matching scheme for matching the target superpixels to the reference superpixels
  - Lacks robust to change in pose or orientation

# Contribution

- We propose a new automatic image colorization method by epitome, called Epitomic Image Colorization
  - Achieve feature matching robust to both noise and the large change in the pose or orientation of the objects
  - Epitome is a generative model which summarizes raw image patches into a condensed representation.
- A new robust patch dissimilarity measure by epitome and the MRF inference.

# Introduction to Epitome

- Epitome (Jojic, Frey, & Kannan, 2003) is a generative model which summarizes raw image patches into a condensed representation similar to Gaussian Mixture Models (GMMs).
- In contrast to tradition GMMs, the Gaussian components of epitome can be overlapping with each other.

Figure 2: Examples of the learned epitome

# Introduction to Epitome

- The epitome $\mathbf{e}$ is obtained by maximizing the log likelihood function:

$$\mathbf{e} = \arg\max_{\hat{\mathbf{e}}} \log p\left(\{\mathbf{Z}_k\}_{k=1}^{Q} | \hat{\mathbf{e}}\right), \tag{1}$$

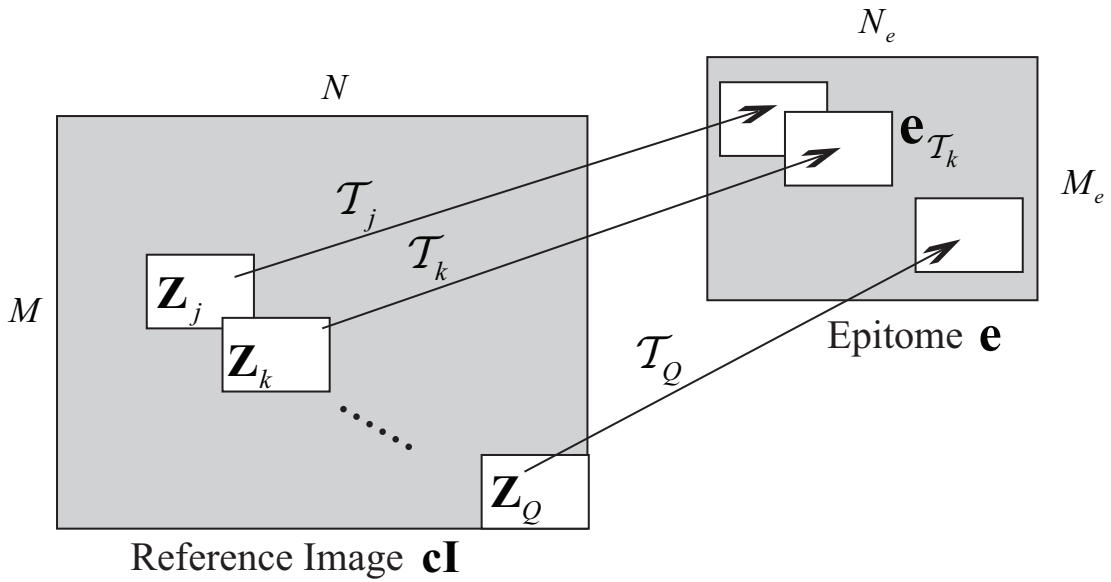



Figure 3: Learn the epitome from the reference image. $\mathbf{Z}_k$ : patch from the reference image; $\mathcal{T}_k$: hidden mappings that maps the image patch $\mathbf{Z}_k$ to the epitome patch.

# Heterogeneous Feature Epitome

- We learn the pixel epitome $\mathbf{e}^{YIQ}$, the dense SIFT epitome $\mathbf{e}^{SIFT}$ and the LBP epitome $\mathbf{e}^{LBP}$ jointly from the the raw pixel, the dense SIFT feature (Lazebnik, Schmid, & Ponce, 2006) and the rotation invariant Local Binary Pattern (LBP) (Ojala, Pietikainen, & Maenpaa, 2002) of the reference image.
- The heterogeneous feature epitome $\mathbf{e} = (\mathbf{e}^{YIQ}, \mathbf{e}^{SIFT}, \mathbf{e}^{LBP})$

# Robust Patch Dissimilarity Measure via Epitome

- In order to match the target patch to the reference patch for color transfer, we need a robust patch dissimilarity measure.
- We propose a robust dissimilarity measure between the target patch $\hat{\mathbf{Z}}_i$ and the reference patch $\mathbf{Z}_j$ with the heterogeneous feature epitome $\mathbf{e}$ learned from the reference image:

$$\mathcal{D}_{\mathbf{e}}\left(\hat{\mathbf{Z}}_i, \mathbf{Z}_j\right) = 1 - p(\hat{\mathcal{T}}_i^* | \mathbf{Z}_j, \mathbf{e}) \tag{2}$$

where $\hat{\mathcal{T}}_i^*$ is the most probable hidden mapping for $\hat{\mathbf{Z}}_i$:

$$\hat{\mathcal{T}}_i^* = \arg\max_{\hat{\mathcal{T}}_i} p\left(\hat{\mathcal{T}}_i | \hat{\mathbf{Z}}_i, \mathbf{e}\right) \tag{3}$$

# Robust Patch Dissimilarity Measure via Epitome

- This dissimilarity measure is robust to noise and the large change in the pose or orientation of the objects.

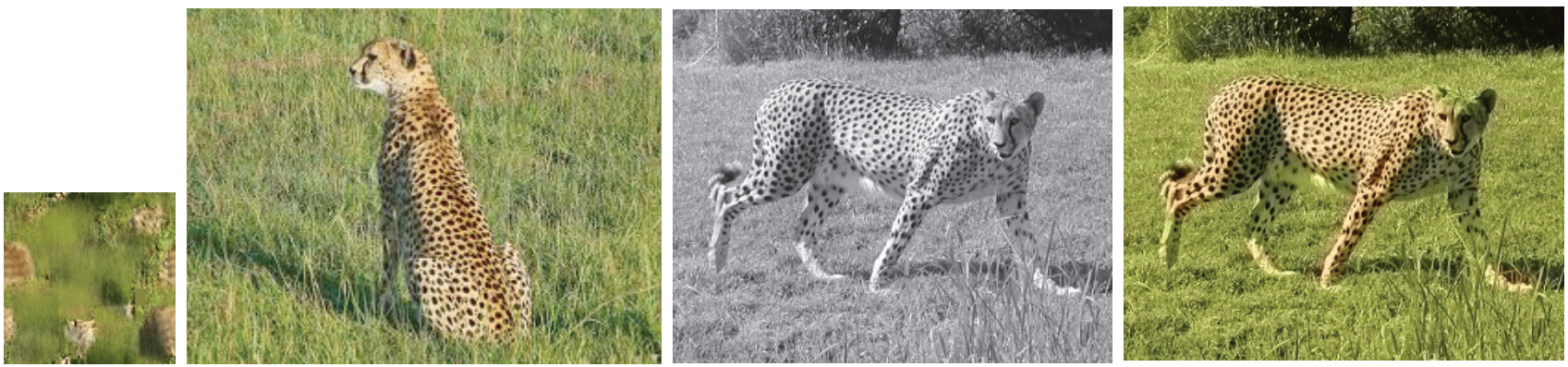


Figure 4: Colorize the cheetah

# Epitomic Image Colorization

- Use the robust patch dissimilarity measure via epitome to find similar reference patches for each target patch
- Transfer color from the similar reference patch to the target patch
- Use MRF inference to obtain a smooth colorization result

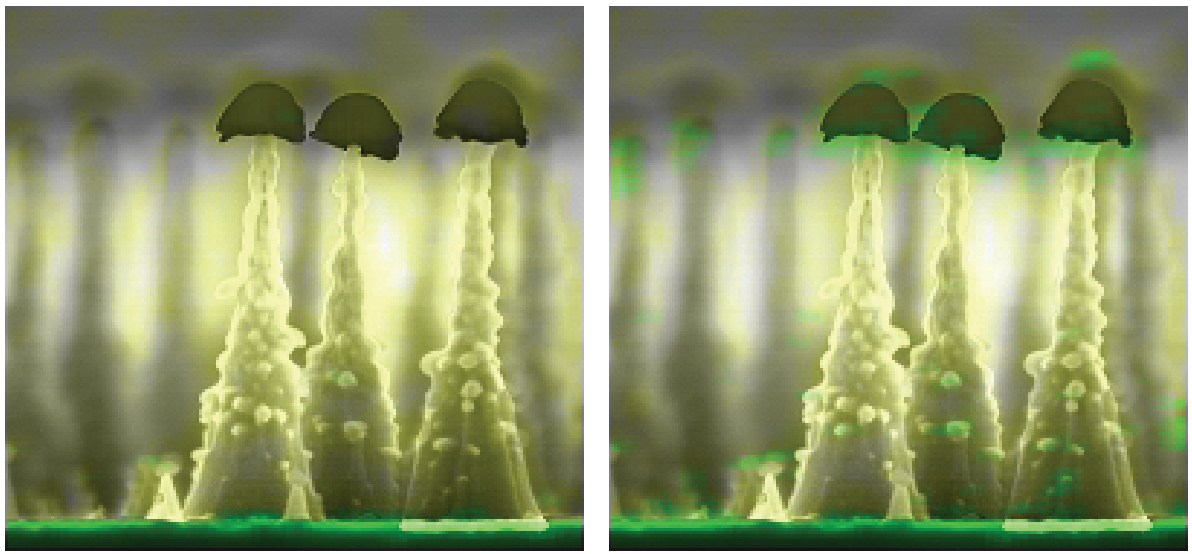
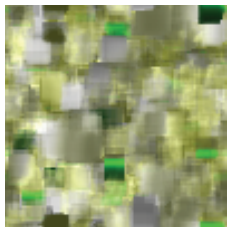


Figure 5: Comparison between colorizing the Nano image with MRF inference (left) or not (right).

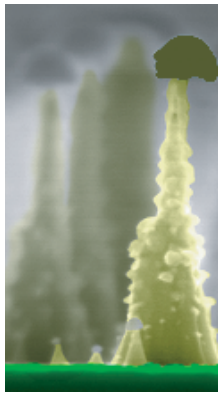
# Parameter Setting

- The area of the heterogeneous feature epitome is no more than $\frac{1}{4}$ of that of the reference images.
- The patch size is $9 \times 9$ or $12 \times 12$.

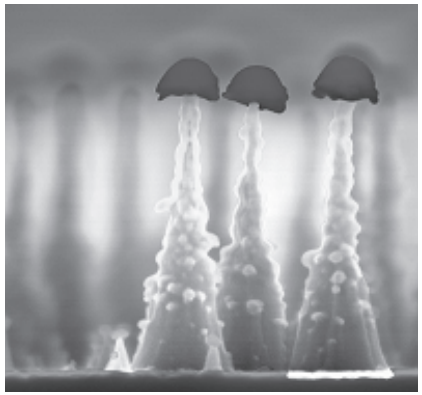
# Colorization Results



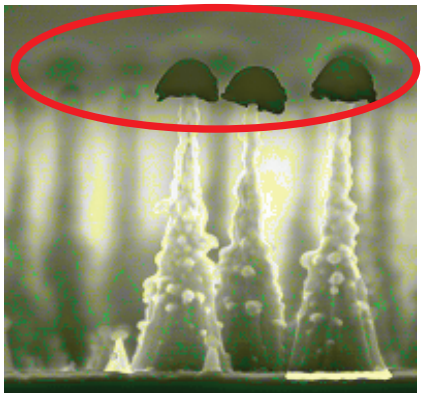
learned epitome



reference image

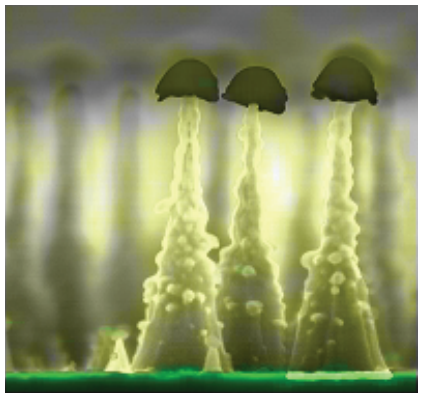


target image



Welsh et al.

Gupta et al.



our result.

# Colorization Results Cont.

learned epitome

reference image

target image

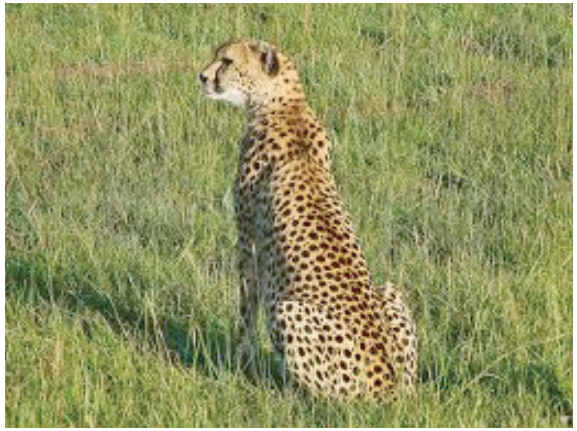
Welsh et al.

Gupta et al.

our result.

# Colorization Results Cont.

learned epitome



reference image

target image

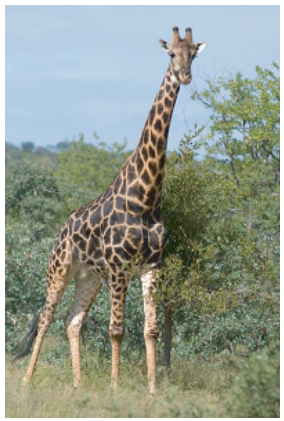
Welsh et al.

Gupta et al.

our result.

# Colorization Results Cont.

learned epitome



reference image

target image

Welsh et al.

Gupta et al.

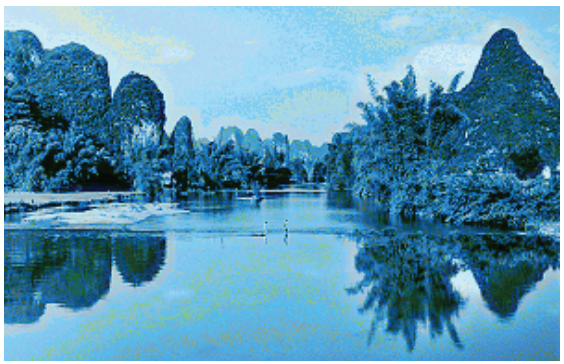
our result.

# Colorization Results Cont.

learned epitome

reference image

target image

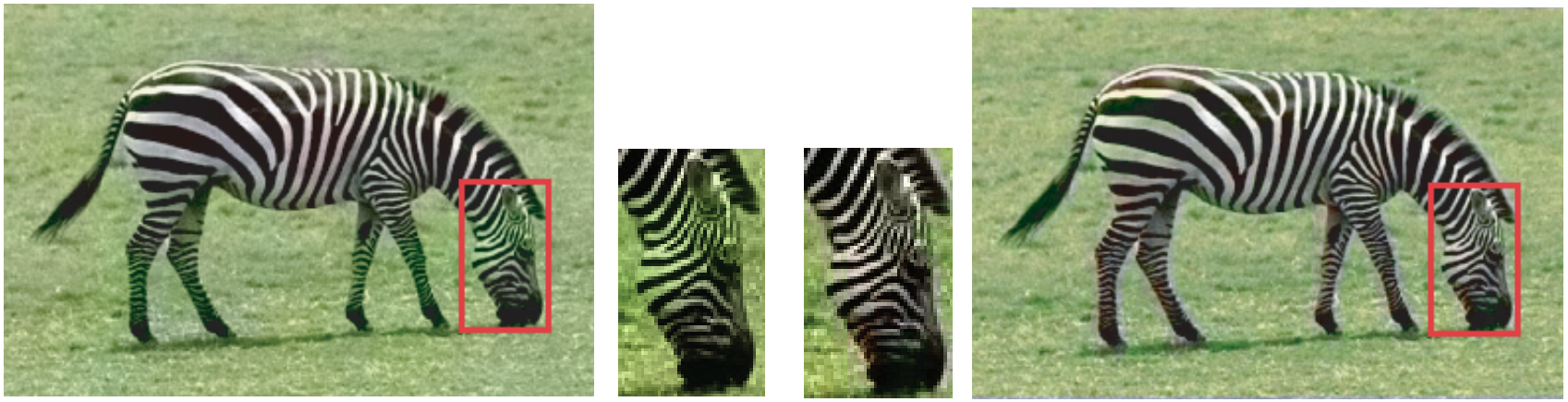


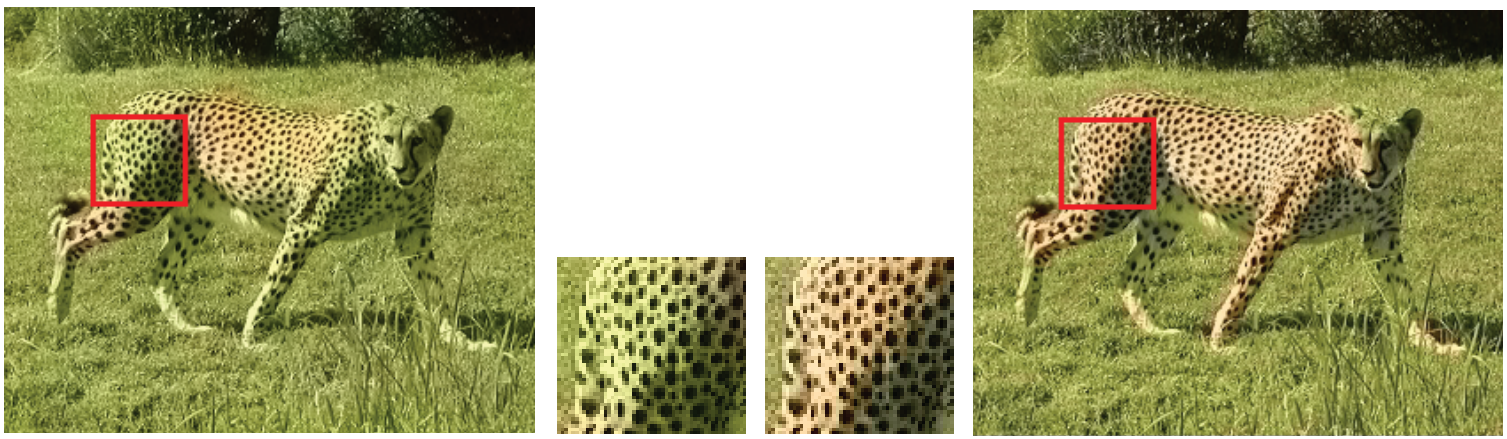
Welsh et al.

Gupta et al.

our result.

# Colorization Results Cont.





# End

Thank you!

# Reference I

Gupta, R. K., Chia, A. Y. S., Rajan, D., Ng, E. S., & Huang, Z. (2012). Image colorization using similar images. In *Acm multimedia* (p. 369-378).

Jojic, N., Frey, B. J., & Kannan, A. (2003). Epitomic analysis of appearance and shape. In *Iccv* (p. 34-43).

Lazebnik, S., Schmid, C., & Ponce, J. (2006). Beyond bags of features: Spatial pyramid matching for recognizing natural scene categories. In *Computer vision and pattern recognition, 2006 ieee computer society conference on* (Vol. 2, p. 2169 - 2178).

# Reference II

Ojala, T., Pietikainen, M., & Maenpaa, T. (2002, jul). Multiresolution gray-scale and rotation invariant texture classification with local binary patterns. *Pattern Analysis and Machine Intelligence, IEEE Transactions on*, *24*(7), 971 -987.

Welsh, T., Ashikhmin, M., & Mueller, K. (2002). Transferring color to greyscale images. *ACM Trans. Graph.*, *21*(3), 277-280.