From Grayscale to Color:

Digital Image Colorization using Machine Learning

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Problem Definition

Input: Grayscale photo and color photo of similar content

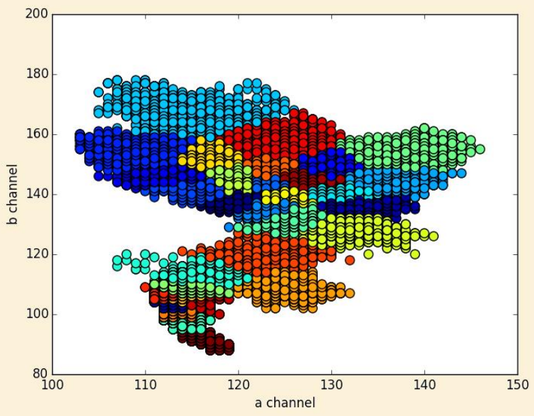
Output: Colorized version of the grayscale image

Challenges

- Want fully automated colorization
- Output has higher dimension than input
- Colorization solution is not uniquely defined

Training

Input Color Image



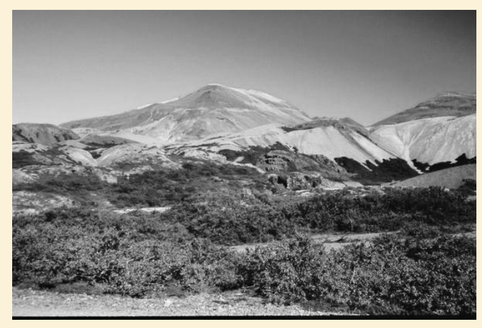
Discretized αβ Color Space

"Grass" SVM Margin Heat Map

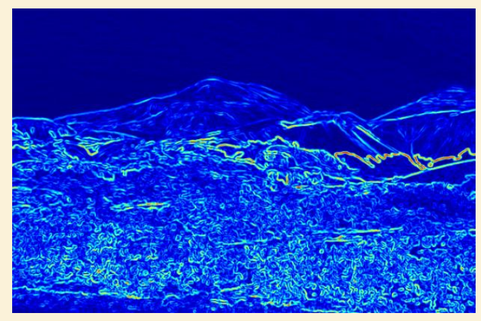
1. Input a color image
2. Separate the luminance from the color (αβ) channels
3. Discretize the color space using K-means (32 colors)
4. Compute luminance SURF texture features and FFT for a square neighborhood around every pixel (556 features)
5. Perform PCA to reduce dimensionality (30 features)
6. Train a collection of SVMs, one per discrete color

Testing

1. Input a grayscale image
2. Compute texture features using the same steps as in training (SURF + FFT)
3. Project the data into the subspace chosen by PCA in the training step
4. Compute the margin each SVM assigns to each test pixel
5. Detect edges in the grayscale image using the Sobel filter
6. Solve an energy minimization problem with the above objective function (includes label cost and spatial coherency terms). Use Graph Cut algorithm to solve for optimal color labels



Input Grayscale Image

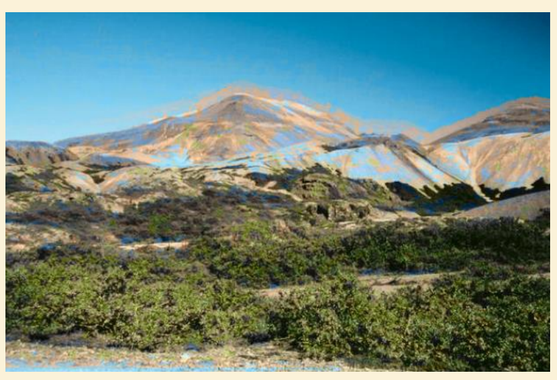


Sobel Edge Detection

$$\alpha \sum_{p} -s_{c(p)}(p) + \sum_{p,q \in \mathcal{N}(p)} \frac{1(c(p) \neq c(q)}{w(p)w(q)}$$

The output when trained and tested on the same landscape image. Almost perfect colorization is achieved.

The output when trained and tested on different images. The algorithm has trouble differentiating sky from flat mountain faces, two areas with similar luminance.



Another colorization using images from the Pasadena Houses dataset. Challenging due to the presence of areas with little texture.

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Conclusions / Future Work

- Has minimum input from user
- Incorporates spatial coherency into predictions
- Future Work: Improving weights to "snap" to edges

References

- Charpiat, G. et al. "Machine Learning for Automatic Image Colorization," *Computational Photography: Methods and Applications*, 2010
- Boykov, Y. et al. "Fast Approximate Energy Minimization with Label Costs," *Computer Vision and Pattern Recognition,* San Francisco, 2010