Principal Noiseless Color Component Extraction by Linear Color Composition with Optimal Coefficients

T. Sugimoto, K. Fujimori, K. Shirai, H. Miyao, M. Maruyama

Faculty of Engineering, Shinshu University, Japan

Background

Character reading support system from ancient wooden tablets

Main Focus

Character extraction

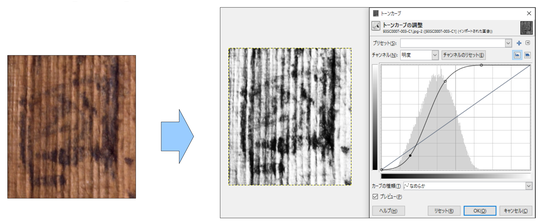
Character recognition

Characters suggestion

The difficulty of generating clear input image

• Although query images should be clean, they consist of faint characters and noisy wood grain textures.

• Manual adjustment requires parameters to control luminance and chrominance contrast.



Original Editing process

Purpose

• Using a single color image automatically generates an image with the distinction between characters and background.

• Our method operates fastly.

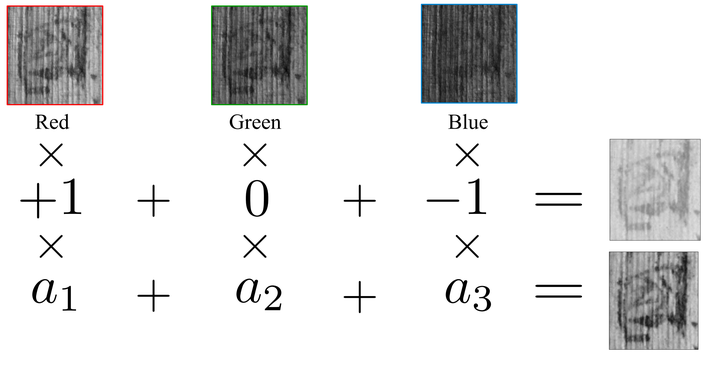
Main Idea

・The variation is calculated by inner product calculation of an axis $[a_1, a_2, a_3]^T$and color coordinates (R, G, B).

・Since characters written with black ink absorb red component, characters tend to emphasize when subtracting blue component.

・Visibility changes with addition and subtraction of color components.

More appropriate composite coefficients should exist.



Proposed method (PCA with TV minimization)

• Characters are difficult to see unless the range of change in value is appropriate, i.e., normalization is required.

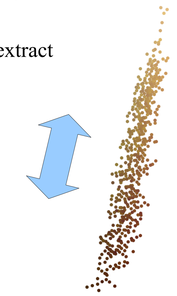
• In an RGB color distribution of pixel colors, the variation along each principal axis usually corresponds to luminance and chrominance components.

• Automatic extraction of an axis is desired since proper principal axis can extract characters in color space.

Estimation of the principal axis by PCA

• PCA is often used to analyze the principal axes of colors distribution.

• Principal component axes are necessary to improve the contrast of the luminance of characters and background.



Noise removal by TV minimization

• To reduce noise and wood grain and flattening intensity values, we apply smoothing.

result in

Our model

$$\arg\min_{\bar{\mathbf{a}}} \|\mathrm{D}\mathrm{X}\bar{\mathbf{a}}\|_1 \quad \text{s.t. } \bar{\mathbf{a}} \in \{\mathbf{a} : \|\mathbf{a}\|_2 = 1\}$$

$\Leftrightarrow$

PCA

$$\arg\min_{\bar{\mathbf{a}}} \|\mathrm{X}\bar{\mathbf{a}}\|_2^2 \quad \text{s.t. } \bar{\mathbf{a}} \in \{\mathbf{a} : \|\mathbf{a}\|_2 = 1\}$$

N : number of pixels

$\bar{\mathbf{a}} := [a_1, a_2, a_3]^T$: coefficient vector

$\mathbf{X} := [\mathbf{r}, \mathbf{g}, \mathbf{b}] \in \mathbb{R}^{N\times 3}$: data matrix (whitened)

$\mathbf{D} := [\mathbf{D}_\mathrm{h}^\mathrm{T}, \mathbf{D}_\mathrm{v}^\mathrm{T}]^\mathrm{T} \in \mathbb{R}^{2N\times 3}$: a set of differential matrices for the horizontal and the vertical direction

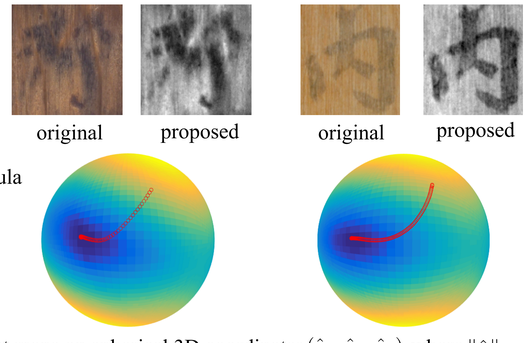
Solution by ADMM

• Although the problem comes down to {*the minimization of least absolute deviations (*LAD*) on a spherical manifold*}, i.e., non-convex problem, it can be solved (converged to the global solution) by ADMM for convex optimization.

Cost map

• Dark blue region :
the minimum cost of the above formula

• Red dots :
the trajectory of convergence



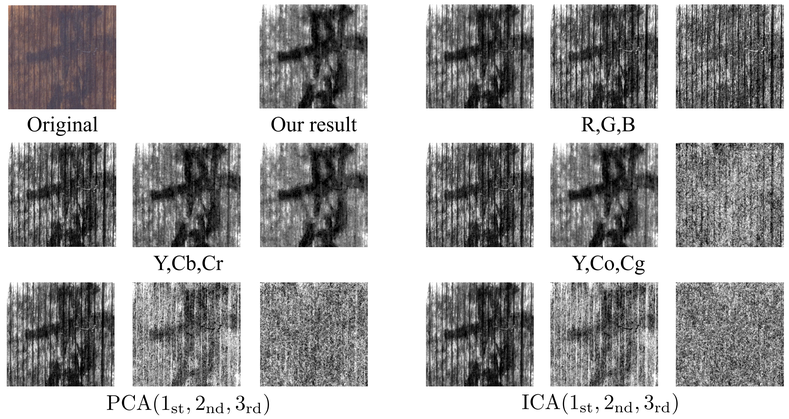
Cost maps on spherical 3D coordinates $(\hat{a}_r, \hat{a}_g, \hat{a}_b)$ where $\|\hat{\mathbf{a}}\|_2 = 1$

Experiments

Comparison1 : Color transformation and Decomposition methods

• The result of ICA becomes nearly similar to that of PCA.

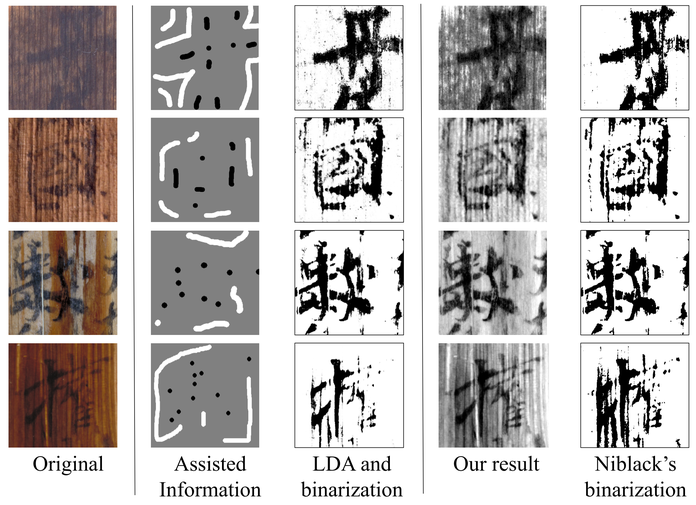
• Our result is better extracted than other representative color transformation methods.



Comparison2 : LDA method with user-assisted information

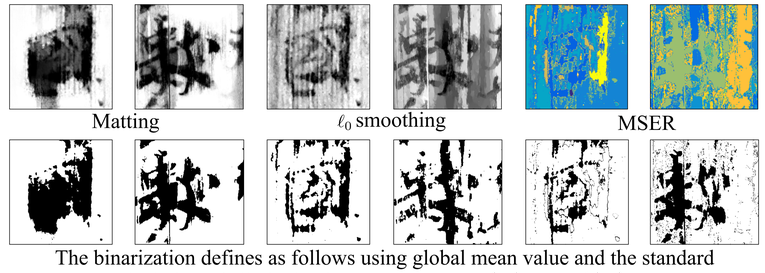
• We used tri-color map for Linear Discriminant Analysis (LDA) method.

• Burdensome pixel color selection is not required in our method.



Comparison3 : Standard methods

• The following methods are not better than comparison2's methods.



The binarization defines as follows using global mean value and the standard deviation of all pixel values. $x_i \leq \mathrm{mean}(x_i) - \gamma\mathrm{std}(x_i)$

Conclusion

• We proposed a color component extraction method regarded as a PCA method in combination with TV minimization.

• Our method doesn't require user assisted information but has performance equivalent to a LDA method with assisted information.