Inpainting The Colors

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Spring 2012

Contents

Colorization Background

- **Colorization** is any process that adds color to black-and-white or monochrome still/moving images.
- Application:
  - Image Editing
  - Image compression
- Computerized colorization began in the 1970s with a process developed by Wilson Markle
- Problem: soft contrast and fairly pale, flat, washed out images

Colorization Background

- Colorization
  - Based on Segmentation
    - Fuzzy edges segmentation
    - Object tracking (Foreground/Background Method)
  - Base on scribble

Colorization Background

- ❖ Example-based methods
- ✓ Transferring color to grayscale images (Welsh et al. 2002)

Shortcoming: spatial coherence

Convert source image to decorrelated *l*αβ color space

– *l*: luminance

– α, β: chromatic channels (yellow/blue and red/green)

• Perform luminance remapping (histogram matching)

• Take ~200 color samples from the source image

• For each pixel in the target image (in scanline order):

– Find best matching source pixel (compare luminance and std. dev. of luminance values in neighborhood)

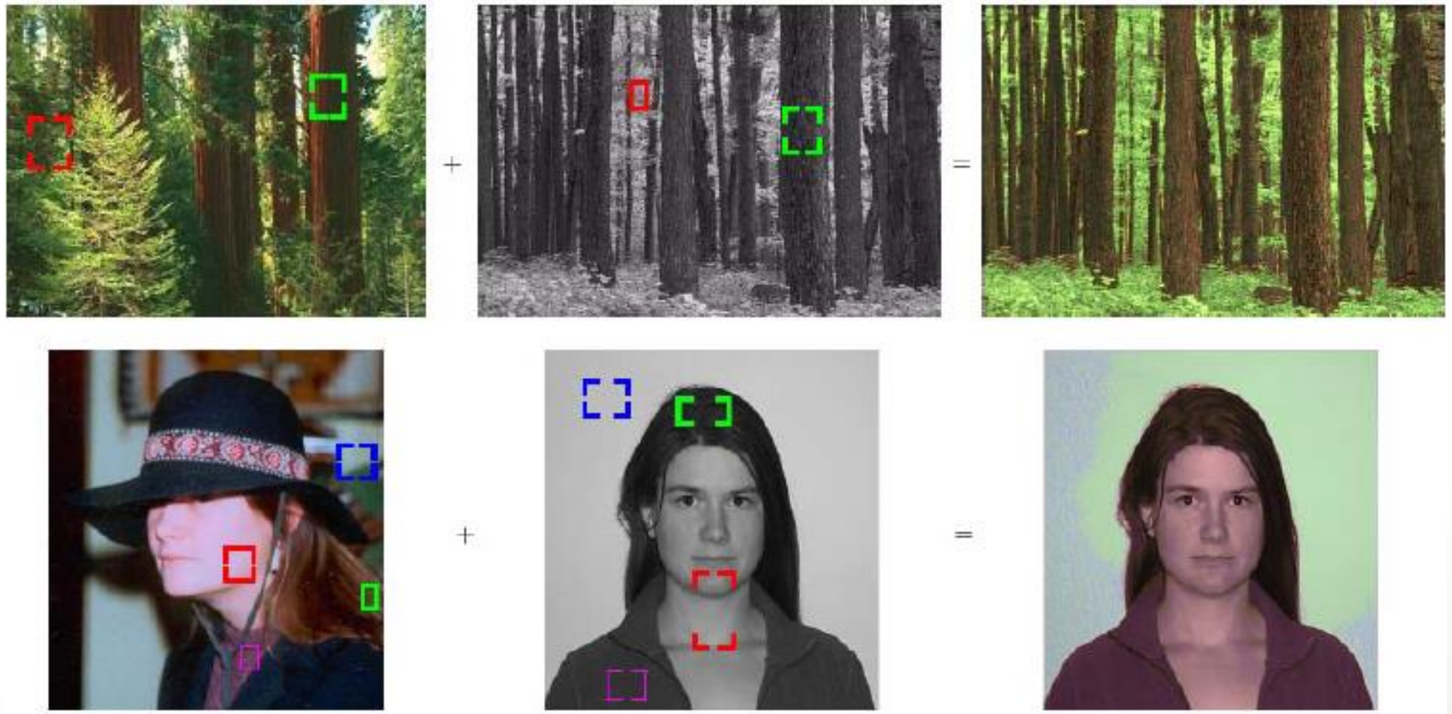
– Transfer color from source pixel to target pixel

Colorization Background

- Global procedure fails when corresponding colors don't have corresponding luminance values

Colorization Background

- ✓ Colorization by example (Irony et al. 2005)



Colorization Background

Stroke-based methods

- ✓ Colorization using optimization (Levin et al. 2004)

- Shortcomings: color leaking, too many strokes required for textured images

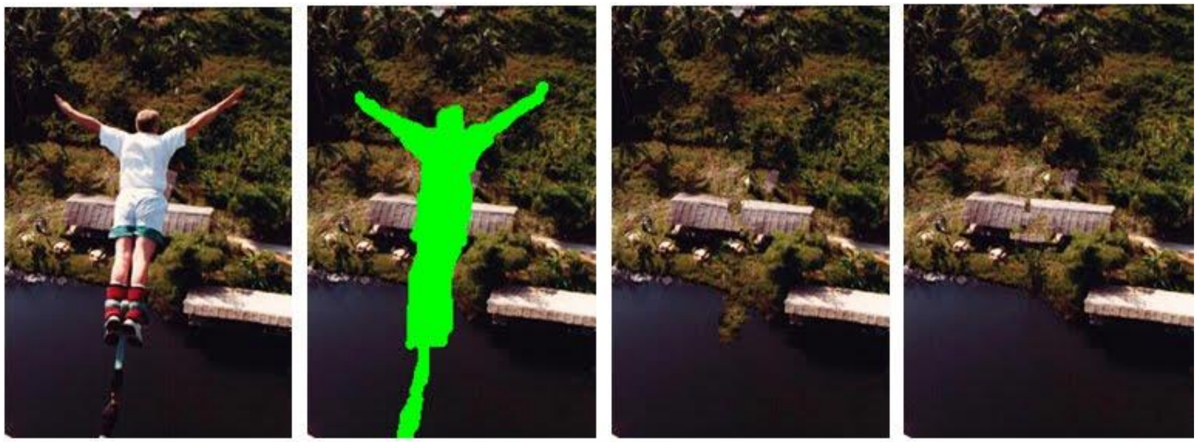
Colorization Background

- Natural image colorization (Qing et al. 2007)
  - Handle images with non-contiguous textures
  - The user draws strokes indicating regions that (roughly)share the same color
  - Strokes are used for automatic texture segmentation
  - The user selects color for a few pixels in each region
  - Color is transferred automatically based on segmentation and selected colors

Colorization Background

Inpainting Background

- Inpainting is the process of reconstructing lost or deteriorated parts of images and videos.
  - Restoration
  - Editing/Image Blending



Inpainting Methods

- Optimization base methods
  - Smooth propagation

$$\theta = \text{normalized gradient} \Rightarrow \theta \bullet \nabla I = \|\nabla I\|$$

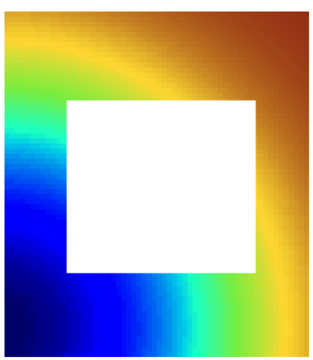
$$\min(I) \int_{\Omega \cup Band} | \|\nabla I\| - \theta \bullet \nabla I | \, d\Omega$$

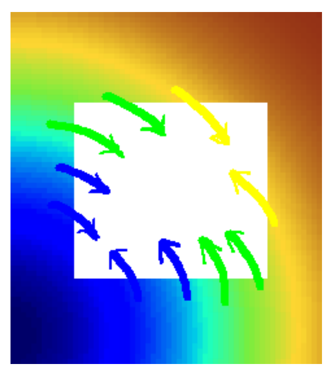
- Propagation information

$$\nabla L \bullet \vec{N} = 0$$

- Evalutionary form

$$\frac{\partial I}{\partial t} = \nabla L \bullet \vec{N}$$





Inpainting The Colors

- Main Idea is looking at colorization as an inpainting problem
- Chung and Sapiro have shown that the (scalar) luminance channel faithfully represents the geometry of the whole (vectorial) color image.(Edges)
- We work in Y Cb Cr
  - Y represented By intensity levels of grayscale image.
  - Changes in Cb and Cr will prepare

    the correct color.

Inpainting The Colors

$$Y(x,y) : \Omega \rightarrow \mathbb{R}^+$$

$$Cb(x,y) : \Omega \rightarrow \mathbb{R}^+$$

$$Cr(x,y) : \Omega \rightarrow \mathbb{R}^+$$

$$|\Omega_c| << |\Omega|$$

$$\min_{Cb} \int_{\Omega} \rho(\| \nabla Y - \nabla Cb \|) d\Omega$$

$$\Delta Cb = \Delta Y$$

$$\Delta := \left(\frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2} \right) \quad \nabla := \left(\frac{\partial}{\partial x}, \frac{\partial}{\partial y} \right)$$

Poisson Eq. Dif./Sol.

Poisson Equation: $$\Delta\varphi = f$$

In Euclidean space: $$\nabla^2\varphi = f$$

Cartesian space: $$\left(\frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2} + \frac{\partial^2}{\partial z^2}\right)\varphi(x,y,z) = f(x,y,z)$$

Discrete Poisson: $$(\nabla^2 u)_{ij} = \frac{1}{dx^2}(u_{i+1,j} + u_{i-1,j} + u_{i,j+1} + u_{i,j-1} - 4u_{ij}) = g_{ij}$$

$$2 \le i \le m-1 \text{ and } 2 \le j \le n-1$$

Poisson Eq. Matrix: $$[A]\,[U] = [b]$$

$$[U] = [u_{11}, u_{21}, \ldots, u_{m1}, u_{12}, u_{22}, \ldots, u_{m2}, \ldots, u_{mn}]^T$$

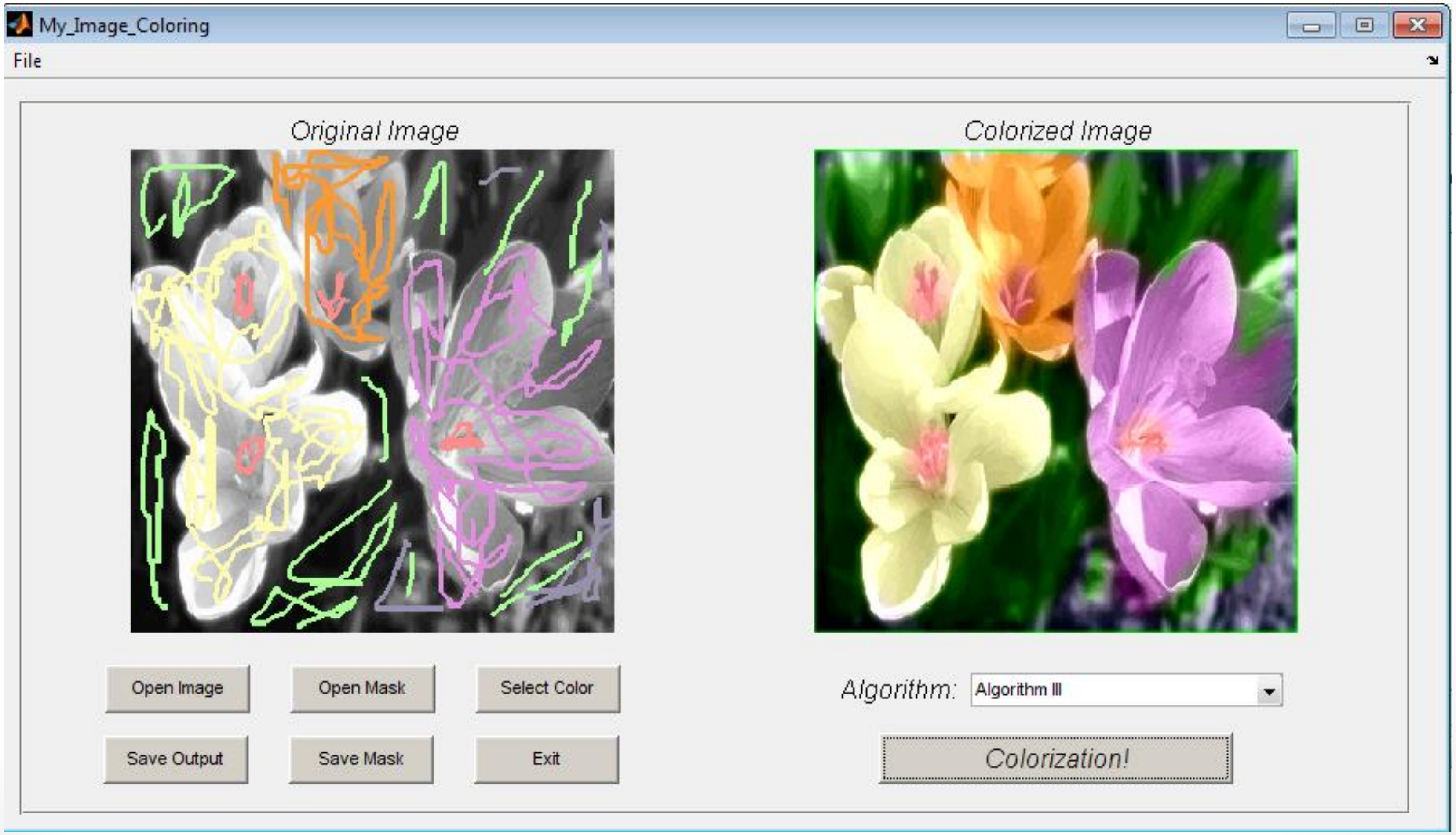
Poisson Eq. Dif./Sol.

$$A = \begin{bmatrix} D & -I & 0 & 0 & 0 & \dots & 0 \\ -I & D & -I & 0 & 0 & \dots & 0 \\ 0 & -I & D & -I & 0 & \dots & 0 \\ \vdots & \ddots & \ddots & \ddots & \ddots & \ddots & \vdots \\ 0 & \dots & 0 & -I & D & -I & 0 \\ 0 & \dots & \dots & 0 & -I & D & -I \\ 0 & \dots & \dots & \dots & 0 & -I & D \end{bmatrix}_{mn \times mn} \quad D = \begin{bmatrix} 4 & -1 & 0 & 0 & 0 & \dots & 0 \\ -1 & 4 & -1 & 0 & 0 & \dots & 0 \\ 0 & -1 & 4 & -1 & 0 & \dots & 0 \\ \vdots & \ddots & \ddots & \ddots & \ddots & \ddots & \vdots \\ 0 & \dots & 0 & -1 & 4 & -1 & 0 \\ 0 & \dots & \dots & 0 & -1 & 4 & -1 \\ 0 & \dots & \dots & \dots & 0 & -1 & 4 \end{bmatrix}_{m \times m}$$

U=b/A

- **Scribbles are our Dirichlet boundaries.**

Results


My_Image_Coloring
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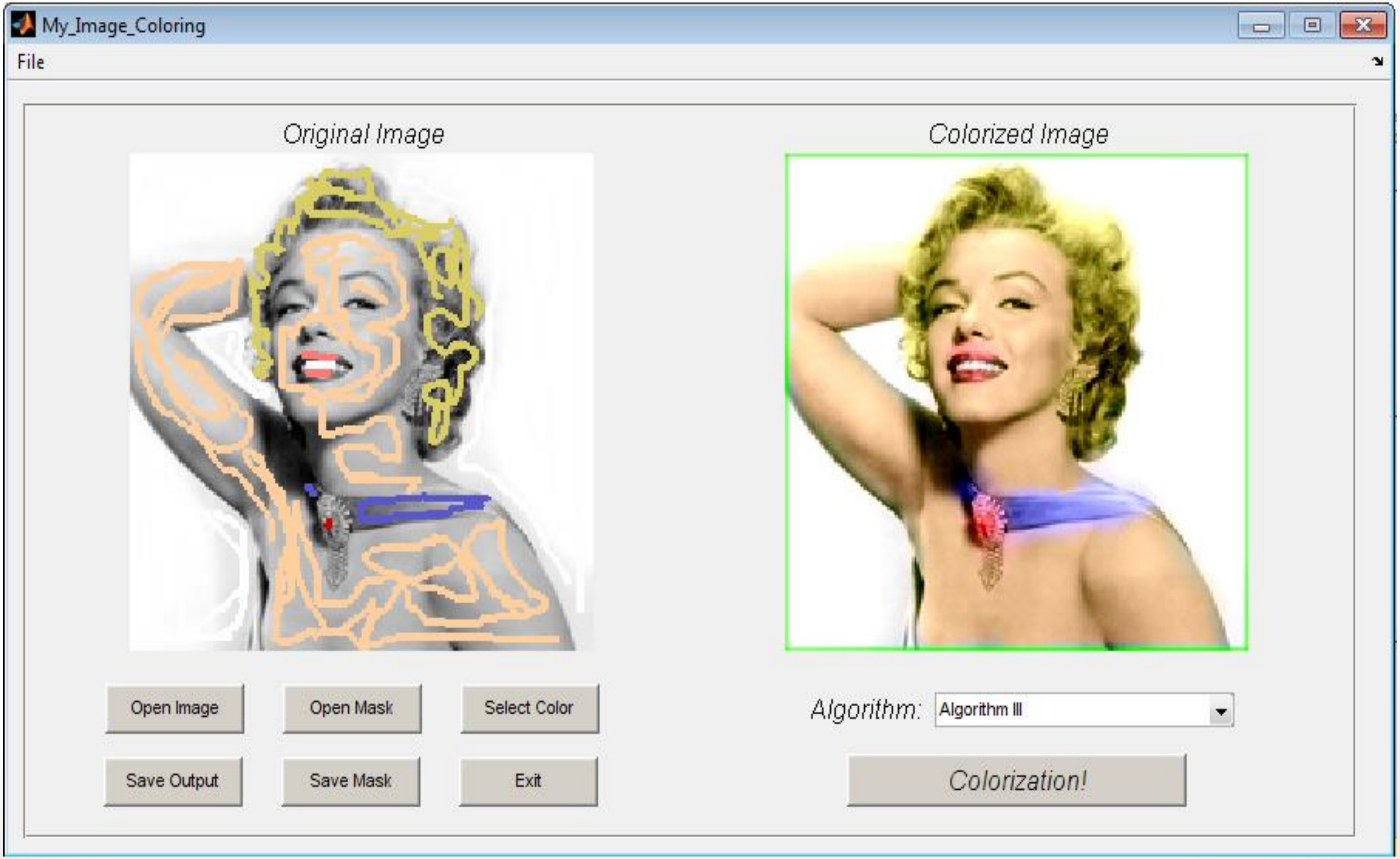
Original Image
Colorized Image
Open Image
Open Mask
Select Color
Save Output
Save Mask
Exit
Algorithm:
Algorithm III
Colorization!

Results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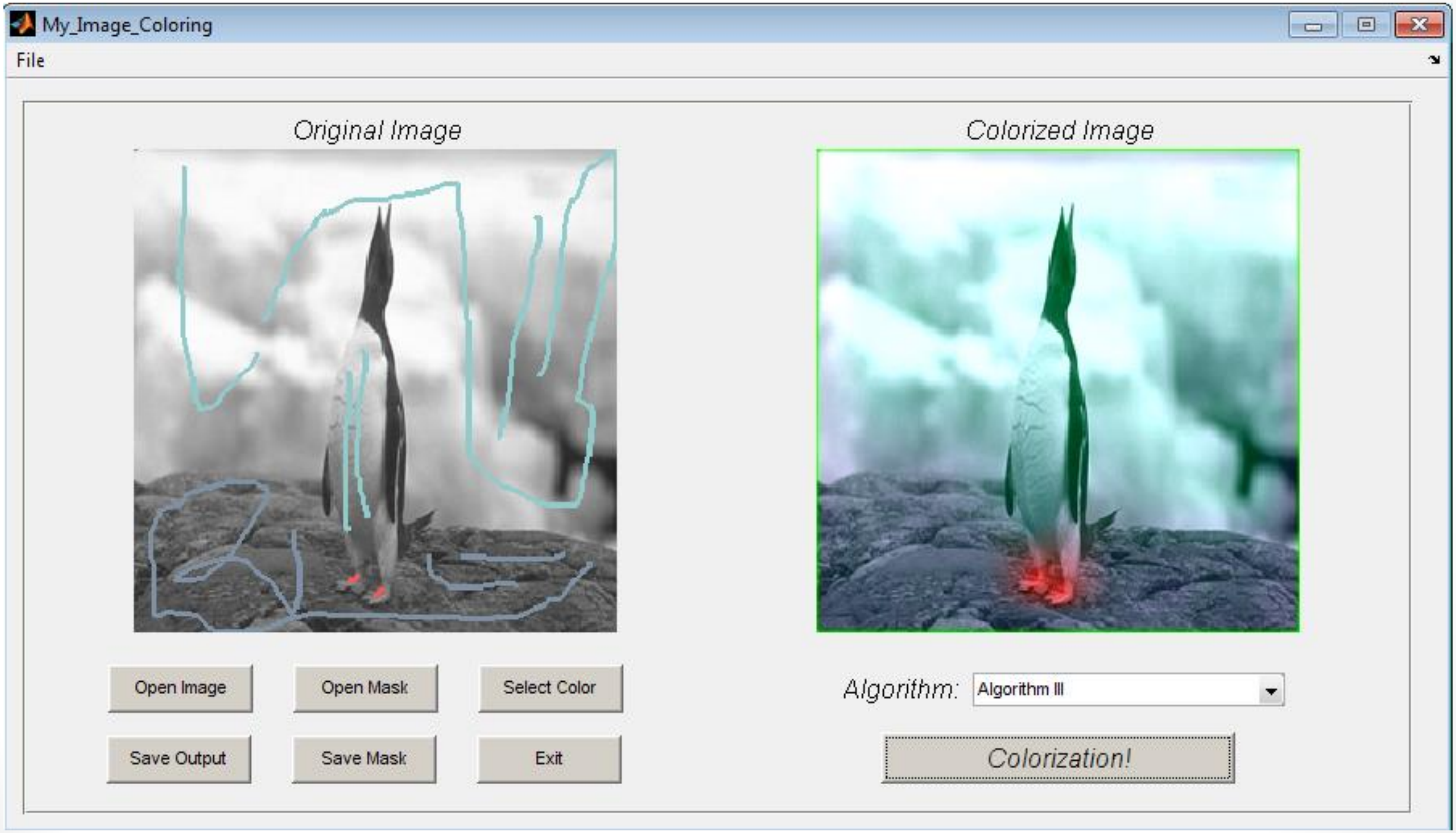
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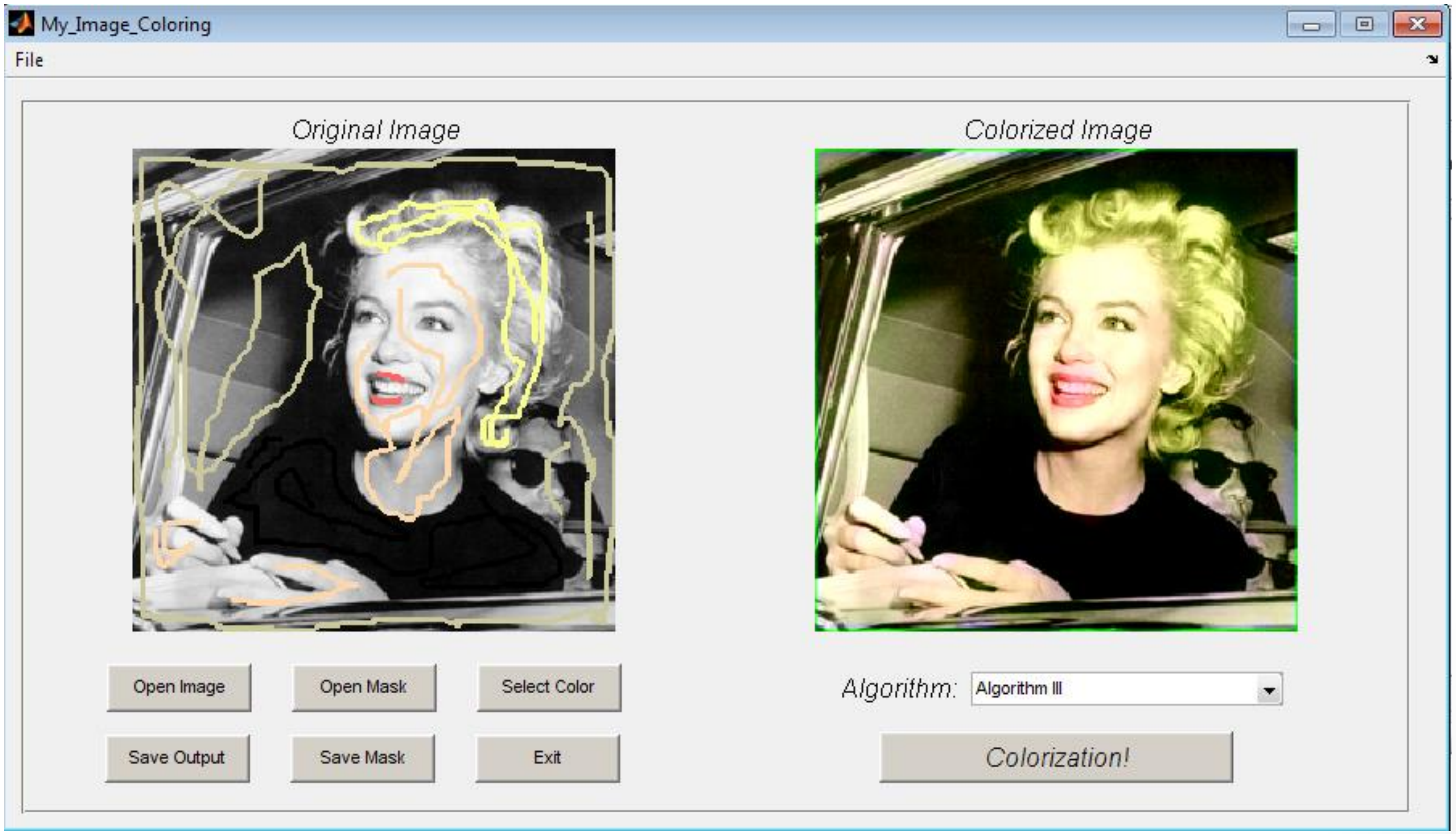

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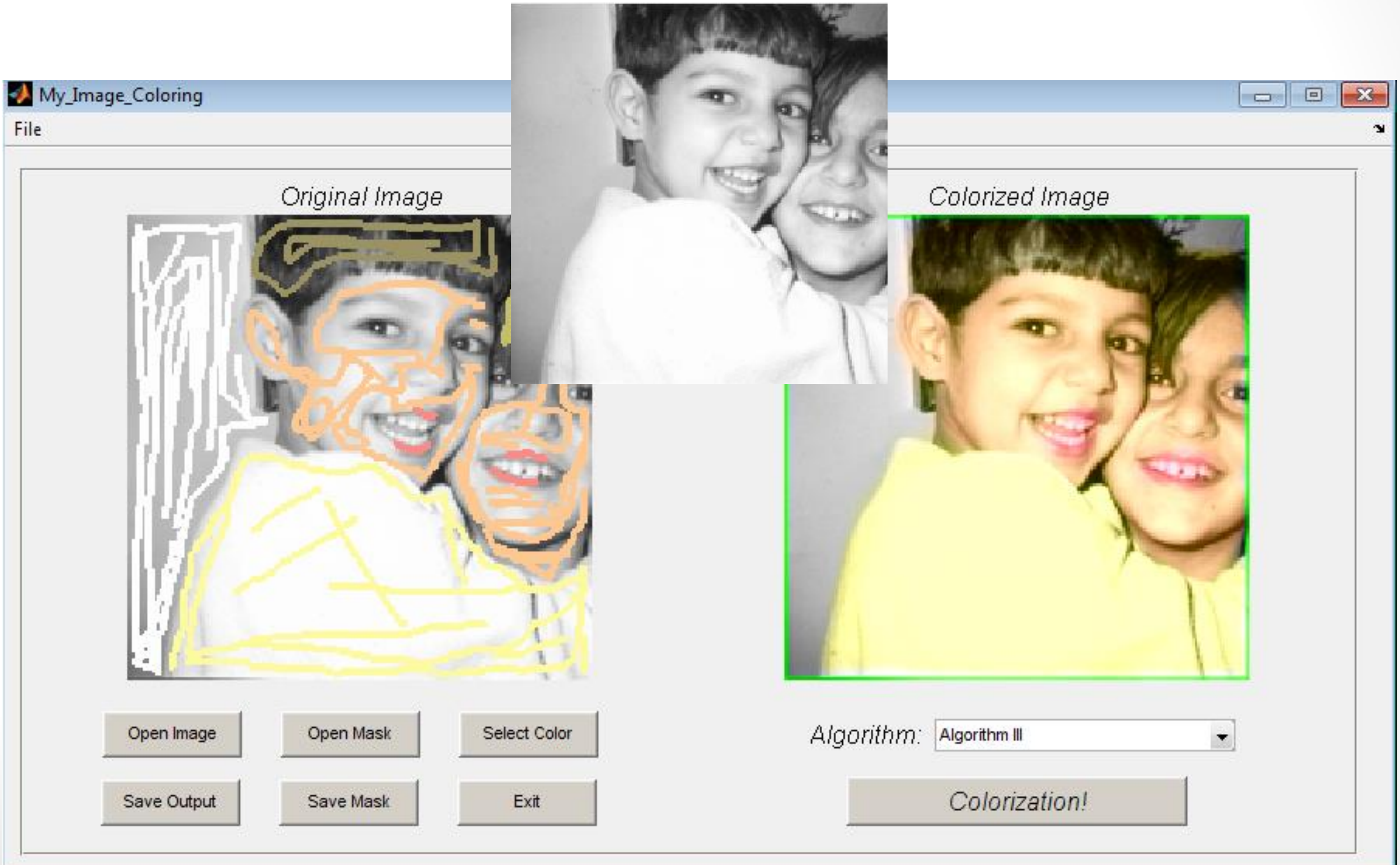
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