Cartoon Transformation

Jake Garrison

EE 440 Final Project - 12/5/2015

Features

The core of the program relies on a gradient minimization algorithm based the *g*radient minimization concept. This filter generally flattens the color content and removes high frequency noise while still retaining the edges and primary color change. In my experience, the gradient minimization algorithm I implemented preforms better than 'cartoon filters' and 'bilateral filters' found online which simply combing a blurring filter or bilateral filter with and edge detection. After the gradient minimization, the edges of the original image are extracted and altered using a customizable morphological transformation that serves to thicken the edges and display them in a more 'hand drawn stroke' form. After applying the modified edges to the gradient minimization output, the final output is formed after a simple color quantization is applied, reducing the color depth to better represent a cartoon. These stroke and color settings, as well as the gradient minimization parameters are customizable through the GUI.

An additional mode inspired by old newspaper cartoons and the pop art style is also available in the GUI. This mode performs binary operations and color masking to output a simple, binary representation of the input that emphasizes the features present in the input image. As in the cartoon mode, this mode has morphological operations to better simulate human strokes, but the true elegance of this effect comes from its ability to accurately emphasize borders rather than all edges. The border is extracted with a function that scores all edges based off continuity and density to identify possible borders, then gaps in edges are filled in and the resulting fully closed edges are added to the output effectively emphasizing the borders.

Figure 1: GUI Wireframe

The GUI provides a simple, but powerful interface for working with the effects outlined above. It is resizable (responsive design) and allows the user to load an image of choice and save the output to disk. There are also some radio buttons allowing a user to apply addition transformations like inverting or toggle controls such as the morphological transform.

Functions

The GUI has many functions and parameters that can be set via sliders. There are also different selectable modes which influence the direct behavior of the sliders.

Global Controls

The global parameters are located along the bottom row and are made up of global controls for working with the effects. The functionality is summarized below.

Mode

Toggles between the `Color` and `Binary` modes. `Color` is meant to transform the image into a color, hand drawn cartoon. All color information in the original image is retained and gradient minimization is used along with other edge related effects to produce the output. See Figure 2: Color Mode

In `Binary` mode, the output is meant to resemble that of a black and white newspaper graphic, or pop art from the '60s. Color information is lost, however, color masks can be applied using the `Color Tweak` slider. See Figure 3: Binary Mode with BW selected

Color Representation

In addition to the mode selection, the output color representation can be further modified with the `Invert` and `BW` radio buttons. These toggles are fairly straightforward and work in all modes. In color, `BW` converts to grayscale, and in `binary`, removes the colored mask. The `Invert` option inverts the colors. In `binary` mode, this essentially exposes the edges, but seems to have buggy results depending on the other slider positions.

Load

Prompts the user to load a local image file.

Apply

Applies the current parameters to the image and displays the output.

Reset

Clears the input and output images

Save

Prompts the user to save the output to file

Figure 2: Color Mode

Figure 3: Binary Mode with BW selected

Effect Parameters

There are a number of effect sliders that can parameterize the overall transformation applied to the output.

Color Tweak

In `Color` mode, this adjusts the color *quantization*, spanning from 1 to 255. Lowering this reduces the color gradients and available colors in the display palette.
In `Binary` mode, this adjusts the *hue* of the mask, spanning from 0 to 255. In `BW` mode, this slider has no effect.

Dither Toggle

Adds dithering to the output image. Only works in `Color` mode.

Smoothness

This is the main parameter for the *gradient minimization*. Increasing this will consequently produce a smoother image with less detail and color gradient, and also require fewer iterations in processing.

Detail

Decreasing this parameter will remove finer details from the output creating a simpler output. Features that don't meet the minimum area defined by this parameter are removed.

Morph Toggle

Toggles whether the morphological transformations are applied to the output. The sliders below this are enabled or disabled based on the toggle. The transformation attempts to add a more human style to the extracted borders using erosion for line border thickness, and dilation with a customizable line structuring element.

Stroke Thickness

Controls the thickness of the extracted borders using erosion with a disk structuring element.

Stroke Length

Modulates the length of the line segment used in the dilation process

Stroke Angle

Modulates the angle of the line segment used in the dilation process; from 0 to 360 deg.

Implementation

The general implementation strategy is covered first, then the discussion is split into a section for both modes.

All code is developed in Matlab, and it has been tested on version 2015bfor OSX. Some of the functionality relies on the Image Processing Toolbox. The *input* image must be of the form `*.bmp, *.tif *.jpg, *.png *.hdf.` The *output* is saved as `file.png`.

The processing time is mainly dependent on the input image size. In general, the `Color` mode takes between 3 to 8 seconds due to the `FFT` and `IFFT` required and the gradient optimization process. In `Binary` mode, processing typically takes less than 5 seconds. While this code isn't optimized for speed, many considerations were accounted for in the implementation to help speed it up. For example, a simple `Sobel` edge detection is used rather than a slower more accurate `Canny` detection. Operations were vectorized as well to avoid loops as much as possible. Both modes rely on processing a binary representation of the input through the same `Area Filter` fed into the `Morphological Transform` block.

Area Filter

The area takes binary input and computes the pixel density of the black pixels. If the density for a cluster, or feature is below the value specified in the `Detail` parameter, that feature is erased. This effectively removes small details that frequently occur in nature, but are usually not included in a cartoon. In Matlab this is achieved with the `bwareaopen` command.

Morphological Transform

The morphological transform block aims to add human artifacts to the output such as stroke simulation and variable edge thickness. The thickness is achieved by applying `erosion` with a disc structuring element that takes user input for radius. This effectively thickens all black pixels of the binary input. The stroke pattern and variable thickness is achieved by using `dilation` with

a line structuring element to erase black pixels. Depending on the angle and length specified by the user, the patter can have a variable effect. Often it adds stroke patterns that may happen when an artist has their hand at a constant angle. It also produces interesting variable thickness, especially on rounded edges.

Color Mode

Gradient Smoothing and Sharpening

The gradient minimization method is effective for sharpening major edges by increasing the steepness of transition while eliminating a significant degree of low-amplitude structures. The result is strengthened edges and flattened color gradient with high frequency details attenuated. This contradictory effect relies on an optimization routine that utilizes gradient minimization, which controls how many non-zero gradients are rejected in the transformation process.

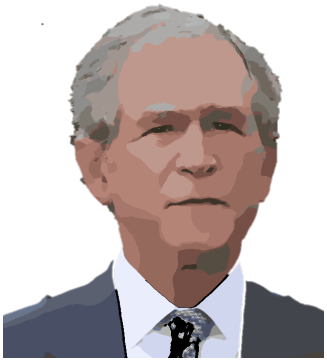


Figure 4: Color

The runtime can be controlled by lowering the `max_beta` since the `while` loop executes until the `max_beta` value is reach. A larger `max_beta`, however is a more optimized result.

Sobel Edge

Simple Sobel edge detection is used to extract some of the defining edges to thicken and add strokes to. Other methods could be used, but Sobel is ideal for speed. The Matlab command used is `edge(Img, 'Sobel')`.

Quantization

Color quantization is used to reduce the color palette to be closer to what an artist may have. This effectively eliminates color gradients and instead has more abrupt color shifts. The Matlab command used is `rgb2ind(Img,colordepth,'nodither')`. The dither option produces mixed results and often adds dot or fuzziness.

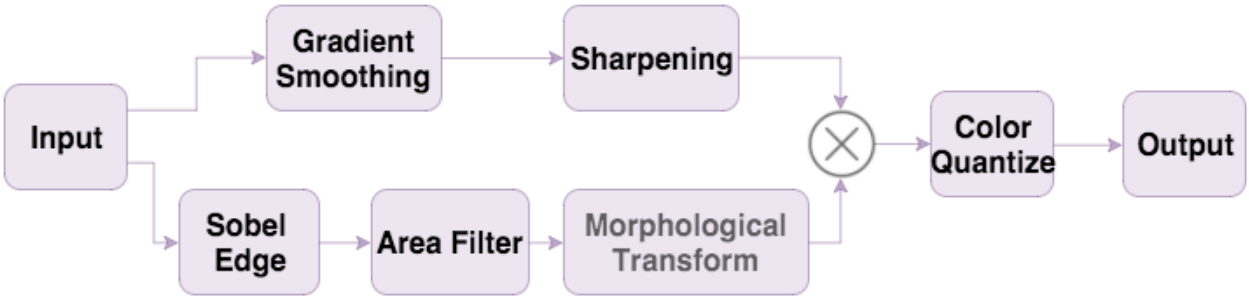


Figure 5: Block diagram for Color Mode

Binary Mode

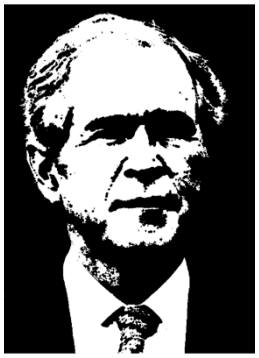


Figure 6: Binary

Binary

The first step here is to convert the input to binary. The binary threshold is specified with the `graythresh(Img)` command which uses Otsu's method.

Hue

A colored mask is created based off the *hue* user input. This mask is multiplied by the binary image to fill in the white pixels with the color mask.

Boundary Emphasis

Using the command `bwboundaries(Img)`, the exterior boundaries of objects is traced, as well as boundaries of holes inside these objects. Due to the Area Filter applied before, most holes inside boundaries are removed, but any remaining ones are removed in this process. Only the exterior boundaries are kept and added to the image. This approach offers much more control over which edges are included.

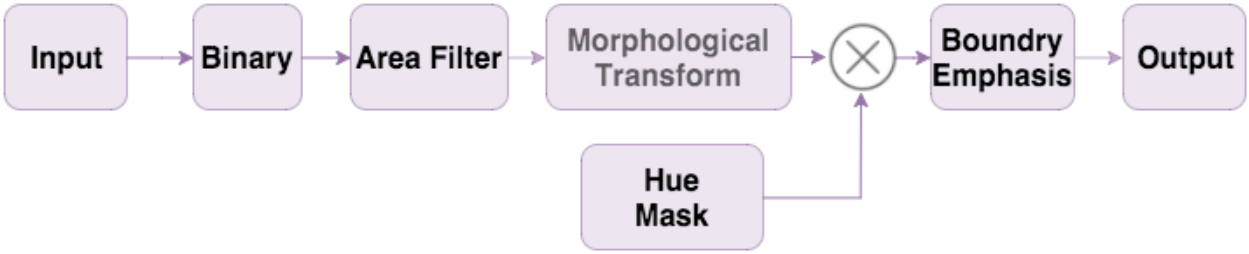


Figure 7: Block diagram for Binary Mode

User Guide

Usage is pretty straight forward. Refer to **Error! Reference source not found.** for GUI layout information

1. Open the `gui.m` function
2. Load the image by pressing the `Load` button
3. Choose the mode of interest (`Color` or `Binary`)
4. Select the buttons of interest (`Invert`, `BW`, or `Morph`). See Functions for more information.
5. Adjust the sliders as necessary. Note some may have no effect depending on the mode
6. Apply the effect to the image by pressing the `Apply` button
7. The result will appear in the output figure. Note it may take up to 10 seconds depending on the settings and input size
8. Save the image to the hard drive by pressing the `Save` button. It will save the file as `output.jpg`
9. To try another image, press `Reset` and restart the steps, otherwise, simply close the window

Comments

My original project was to to implement Google's deep dreaming set of algorithms and in the GUI offer additional editing options. I got this started, but realized it would require a lot of drivers and special libraries to distribute and effectively run, so I will just work on this on my own time. One thing that came out of this project was a useful executable python script that downloads several similar pictures to the input by searching Google and using correlation to return matches. I was thinking maybe this could go towards extra credit. Since the main code is Matlab, I didn't go through the effort of having the Matlab script run the python code to generate a series of images, however it could be done. I will include the OSX executable in the submission.

Once I decided to settle on Matlab, I ended up finding information on the gradient minimization method which formed the foundation for my project. I also was interested in pop art effect, but this was pretty basic, so I didn't devote my project to it. Instead I sort of included it in the `Binary` mode. In addition, I spent a lot of time trying to access the webcam in Matlab, but it requires the Image Acquisition Toolbox which is not available to UW students as far as I know.

I am not sure what the bonus credit criteria is, but I tried to go above and beyond with my cartoon effect by using an alterative, more complex algorithm compared to the bilateral filter method. I also spent a lot of time making the GUI functions much more complicated then in the given demos. All in all, I probably would not use Matlab in the future for GUI design since it was not very intuitive to me and doesn't look very modern. I would have liked to use JavaScript to make a web GUI, but I didn't want to figure out how to link it to Matlab.

See the Appendix for example of the output.

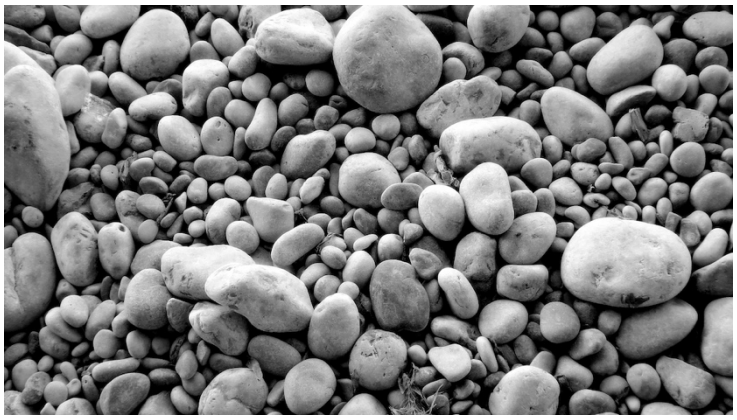
Future Research

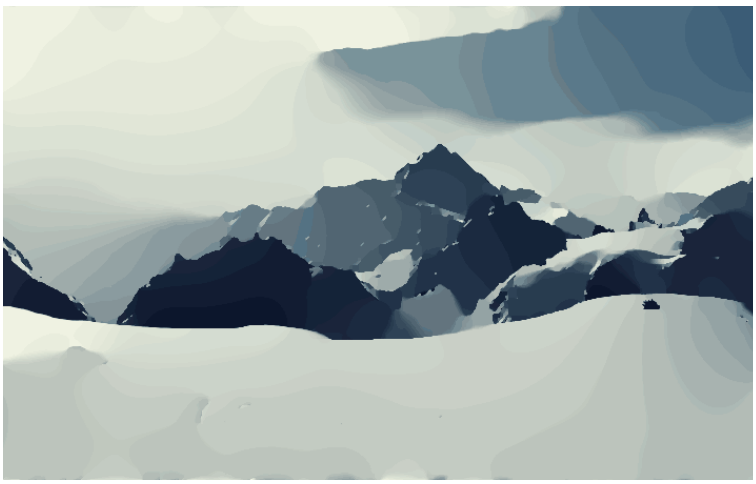
I am very interested in porting some of this functionality to Node.js or Python so that I can make a web app out of it. I also am interested in further developing my python image scraper app explained in Comments. I think it is a cool utility that doesn't really exist. Its core relies on Google's reverse image search, which as far as I know is proprietary, but it is treated like a black box in my implementation. I am also interested in working more with the deep dreaming concept as it results and very interesting, artistic renderings.

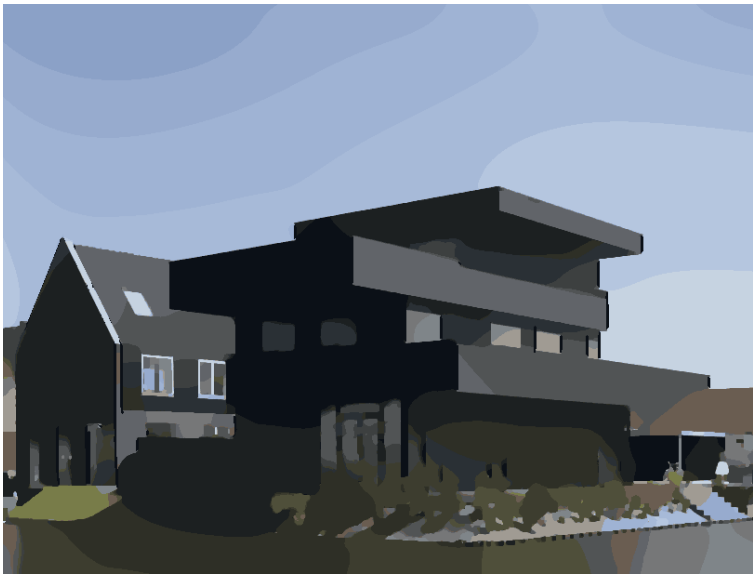
Appendix

Original

Effect







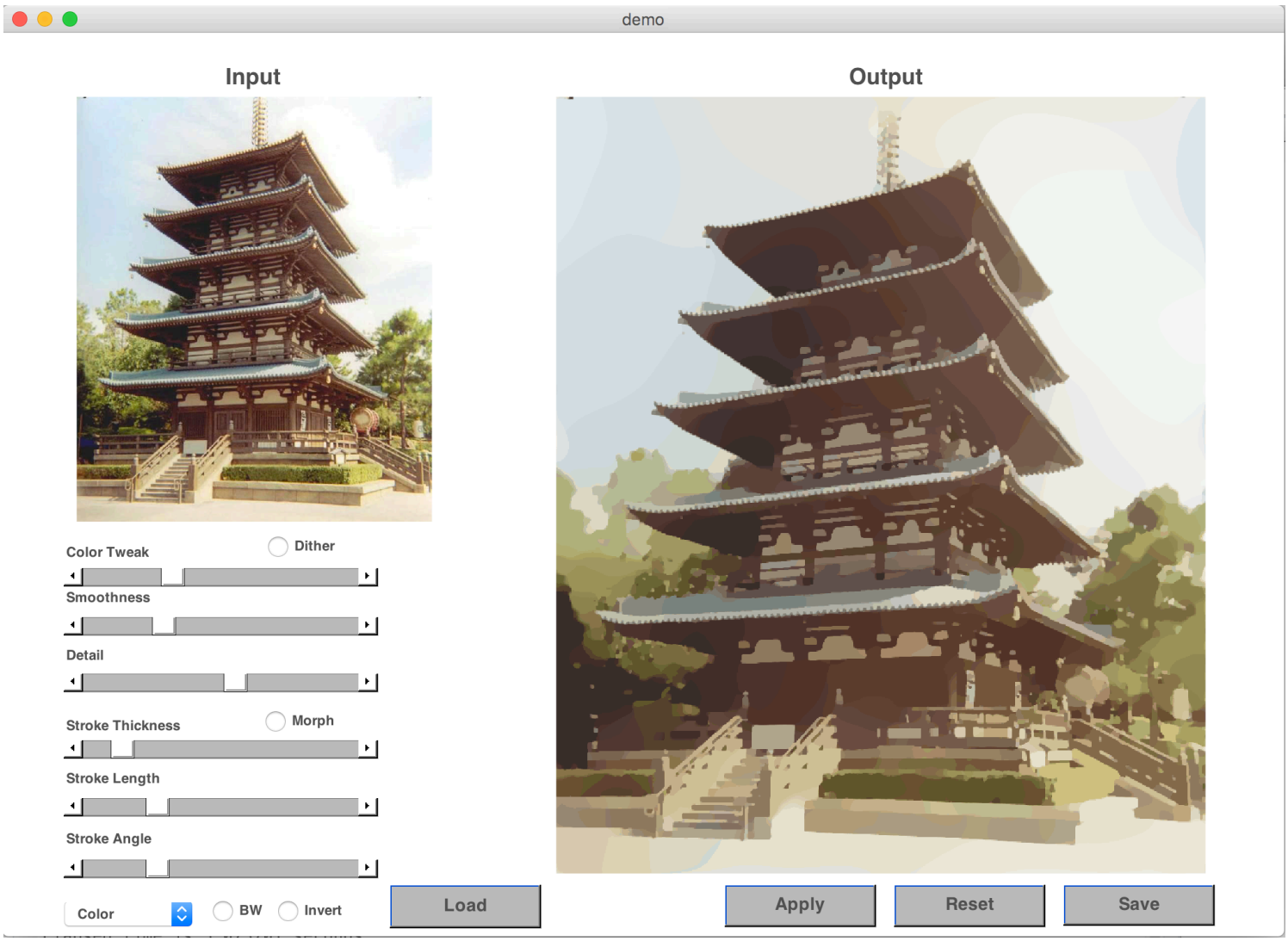


Figure 8: GUI Instance