Computer Vision Project
Manga Colorization

Nilabja Bhattacharya
2018201036

Devesh Tiwari
2018201039

Arpit Gupta
2018201048

Abstract

Manga colorization technique is used to automate the process of coloring manga comic books which are mostly available in black and white colors. Here we have implemented a novel colorization technique that propagates color over regions exhibiting pattern-continuity as well as intensity-continuity. Our implemented method works effectively on colorizing black-and-white manga which contains intensive amount of strokes, hatching, halftoning and screening. With the segmented regions, various colorization techniques have been applied like, replace colors, colorize with stroke preservation, or even convert pattern to shading. Several results are shown to demonstrate the effectiveness and convenience of the proposed method.

Introduction

The manga (comic books in Japanese) are mostly black and white in color. Since, coloring them can be time consuming and labor intensive thus, automating this task is necessary. The proposed technique starts by scribbling the desired color on the interested regions. Our method then automatically propagates the color within the pattern-continuous regions. The propagation stops accurately at the boundary where the pattern exhibits abrupt change, even if there is no apparent outline. The segmentation is achieved by applying a novel texture-based level set method which propagates boundary curves over regions with similar but not necessarily homogeneous patterns.

Implementation

Implementation of our method has following steps -

1. The user scribbles different colors on different areas in the image.
2. The image is segmented, either using intensity continuity or pattern continuity.
3. The segmented parts are colorized using three different methods, specified later.

Step 1: User Input

The whole process begins by a user scribbling on regions of interest. Our system processes the user input incrementally. This provides the user with full control of modification and refinement. In each incremental step, the user enters one or more scribbles to segment the desired regions.

Step 2: Segmentation

Our system provides two modes of propagations for segmentation, pattern-continuous and intensity-continuous propagations. It is up to the user to decide which mode of propagation should be employed in the current step. The pattern-continuous and intensity-continuous propagations are designed for hatched/screened region and intensity-continuous region with/without unclosed outlines, respectively.

For segmenting required region from the whole image *Level Set* method is used.

<u>Level Set</u>

Since, there are only two colors black and white, changes in the gray level is abrupt. This introduces difficulties to traditional color transfer techniques that mainly rely on the continuity or similarity of gray levels.

The fundamental idea of level set method is to raise the modeling of boundaries from a two-dimensional planar curve into a three-dimensional curved surface, by embedding the propagating curves as the zero level set of a higher dimensional surface.

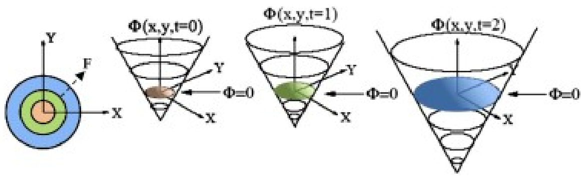

Fig.1 : Level set transforms the front propagation into an initial value problem into a space of one higher dimension.

The level set method tracks the evolution of a front that is moving normal to the boundary with a speed F(x, y).

Mathematically,

$$\frac{\partial \phi}{\partial t} = F|\nabla \phi| \qquad (1)$$

Traditional level set method proposed in the given paper has certain drwbacks which makes the segmentation step more complex. Thus, we have used an upgraded and more stable version called as *Distance Regularized LSE (DRLSE)* method. Above equation changes to,

$$\frac{\partial \phi}{\partial t} = \mu \operatorname{div}\left(d_p(|\nabla \phi|)\nabla \phi\right) + \lambda \delta_\varepsilon(\phi) \operatorname{div}\left(g \frac{\nabla \phi}{|\nabla \phi|}\right) + \alpha g \delta_\varepsilon(\phi) \qquad (2)$$

<u>Pattern Continuos Regions</u>

In order to evolve the boundary over pattern-continuous regions as in, the key is to measure the change of pattern instead of the ordinary change of intensity.

$$h_P(x,y) = \frac{1}{1 + |D(T_{\text{user}}, T_{\text{front}}(x,y))|}. \qquad (3)$$

Above equation defines the *Halting* term for the pattern continuos regions. As the name suggests, it tries to halt the evolution of the front curve at the boundary of the pattern continuos region. The term D(T_{user} , T_{front}(x,y)) is the distance between feature vector generated for the pixels at scibbled region (T_{user}) and features of the pixels at front (current boundary) region (T_{front}(x,y)).

More the distance, lesser will be halting term and thus will slow down the evolution curve eventually stopping it.

Now to calculate feature, Gabor Wavelet transform is used. Given the user scribble, we compute the pattern features at k points
sampled uniformly on the scribble. We then perform clustering on these feature patterns, identify the major cluster, and compute the
average of this cluster. This average is regarded as the representative feature pattern, Tuser.

Intensity Continuos Regions

Intensity continuos regions can also be segemnted using the same method as above but, we need to define a new halting term for such regions.

$$h_I(x,y) = \frac{1}{1 + |\nabla(G_\sigma \otimes I(x,y))|} \tag{4}$$

Here instead of calculating features we convolute images region with gaussian filters. Calculating features will not give any interpretable output as whole region is constant in terms of pattern and intensity.

Step 3: Colorization

Once the segmented regions are obtained, we can colorize them using various methods. We have implemented three ways to colorize these segmented areas. These are stroke-preserving colorization, pattern-to-shading, and multi-color transtion, based on the user decision.

Color Replacement

For the intensity-continuous region, filling color can be trivially done by replacing the black or white color by the user color on the scribble. But, this may also overcolor the strokes on the intensity continuos regions. Thus, instead of directly floodfilling the region we have preserved the strokes.

Stroke-Preserving Colorization

In the pattern continuos regions we cannot naively replace the region eith color as we also need to preserve the pattern (strokes) used by the artists to retain the meaning of that region. Therefore, such regions are colorized by bleeding colors out of the strokes/patterns. The user color is multiplied with the halting term h_I in the YUV space.

$$Y_{\text{new}}(x,y) = Y_{\text{user}} \otimes |1 - h_I(x,y)|^2, \quad (U,V)_{\text{new}} = (U,V)_{\text{user}} \tag{5}$$

Pattern to Shading

Sometimes, we want color filling to be like shading ,i.e, it should vary and not remain constant at all places. As color can readily reproduce such shading effect, we can convert the pattern to smooth color shading.

$$Y_{\text{new}} = sY_{\text{user}}, \quad (U,V)_{\text{new}} = (U,V)_{\text{user}}$$

Where, $s = f \otimes Y_{\text{image}}.$

Results