Manga Colorization

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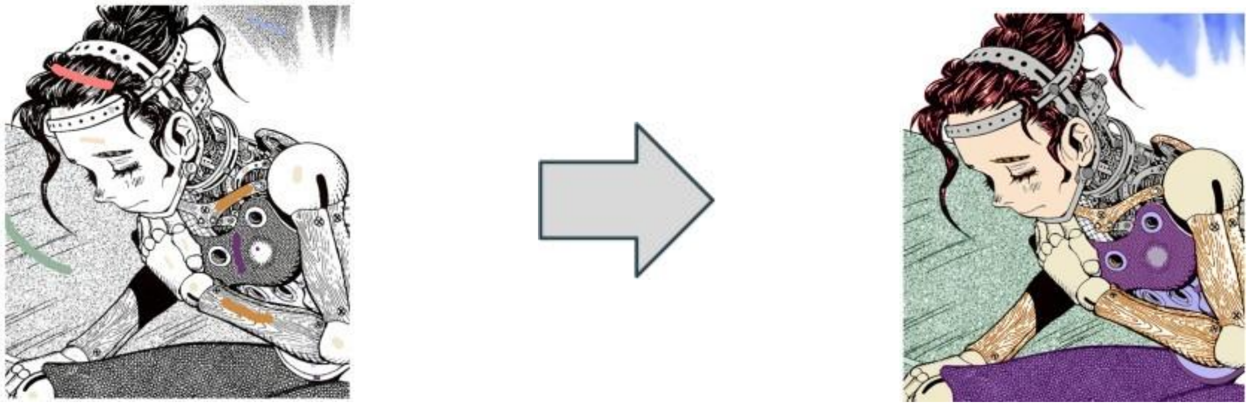
Repo: https://github.com/Digital-Image-Processing-IIITH/project-haripraveen_subramanian_cool_boss

MANGA COLORIZATION

- Manga (Japanese comic books) are usually in black and white and heavily rely upon hatching and screening, which makes colorization of these black and white comics difficult.
- We aim to implement colorization of the sort shown below.



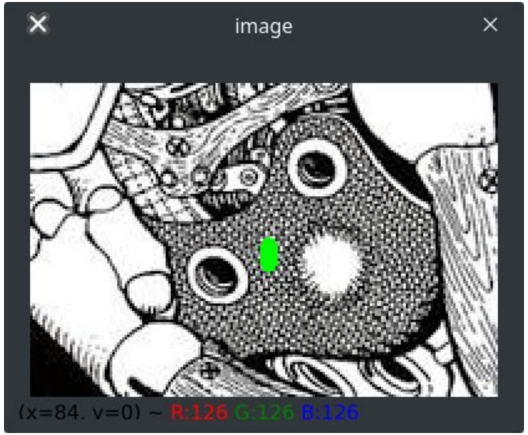
BASIC STEPS:

In short, the process is highlighted below

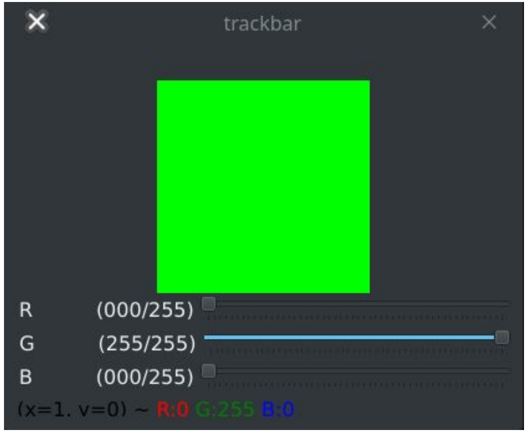
- The user first selects a region of interest and scribbles the color of choice in that region.
- The boundaries of the region selected by the user are decided and the region is segmented out
- The segmented region is then colored using one of the methods described in the paper:
  - Pattern/Intensity continuous segmentation
  - Stroke preservation
  - Pattern to shading

STEP 1: TAKING INPUT

The application provides the user with a trackbar to select an RGB value, and allows the user to make a scribble on the input image. Segmentation then happens on the basis of this scribble.



(x=84, y=0) ~ R:126 G:126 B:126



R (000/255)
G (255/255)
B (000/255)
(x=1, y=0) ~ R:0 G:255 B:0

STEP 2: IMAGE SEGMENTATION

Usually, to express detail in the lack of color, manga artists make use of the following techniques to convey artistic details.

- Hatching
- Screening
- Half-toning

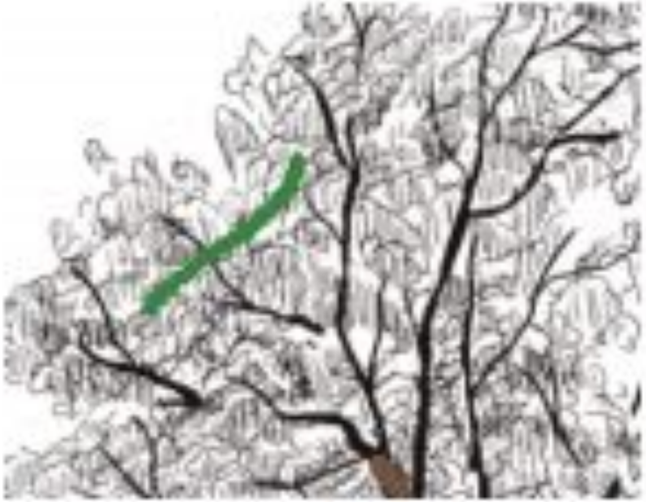
These regions have pattern continuity which we have exploited in order to segment these regions. Similarly, images can also have intensity continuity.

STEP 2: IMAGE SEGMENTATION

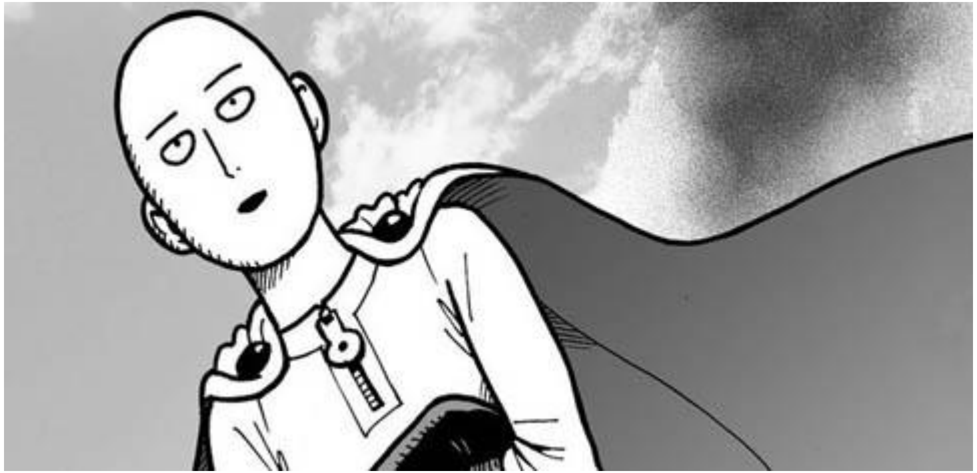
There can be two types of regions in manga:

- Intensity continuous regions
- Pattern continuous regions

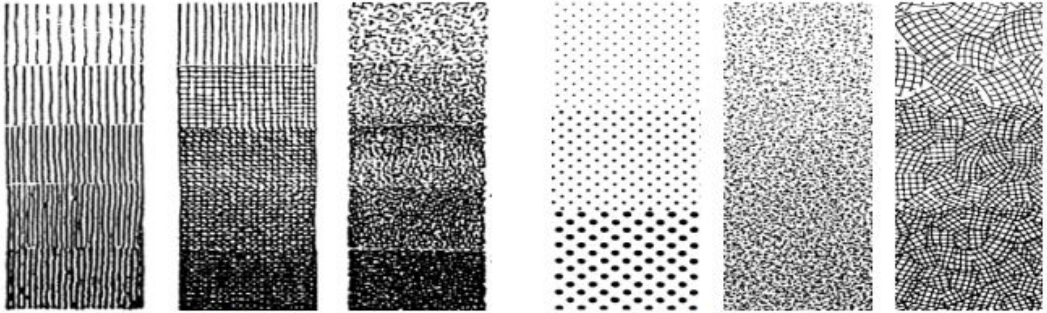
The segmentation and colorization of the image depends on the type of region you wish to do colorization on.



A Pattern Continuous Region



An Intensity Continuous region



(a) Hatching

(b) Screening

Examples of Hatching and Sc

LEVEL SETS

For finding the boundary of the region scribbled on by the user (to carry out image segmentation), we use the concept of level set propagation.
According to the paper, level set propagation can be done by solving the following PDE:

$$\frac{\partial \Phi}{\partial t} = h \cdot (F_A + F_G)|\nabla \Phi|$$

However, due to this method had quite a few disadvantages, and the outputs after implementing this method were nowhere as clean as we wanted them to be.

To overcome this, we used the Distance Regularized Level Set Method (DRLSE).
The DRLSE method avoids the difficulties of level set method by introducing a regularization term.

DRLSE

1) The distance regularization term is defined with a potential function
2) We provide a double-well potential for the distance regularization term, T
3) The level set evolution is derived as a gradient flow that minimizes this energy functional.
4) The regularity of the LSF is maintained by a forward-and-backward (FAB) diffusion derived from the distance regularization term
5) Thus distance regularization completely eliminates the need for reinitialization in a principled way, and avoids the undesirable side effect introduced by the penalty term.

DRLSE

The DRLSE PDE is given by:

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

PATTERN CONTINUOUS REGIONS

To detect changes in pattern in the image, we exploit pattern continuity. We measure the changes in pattern features at the level set boundary and at the scribble region to estimate when changes in pattern have taken place.

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

‘Gabor Wavelet Transform’ is used to obtain these features.

When there is a sudden change in pattern, the filter stops the propagation.

PATTERN CONTINUOUS REGIONS

To generate the pattern features,

$$W_{m,n}(u,v) = \int_{\Omega} I(x,y) g^{*}_{m,n}(u-x, v-y)\, dxdy,$$

$$\begin{aligned} \mu_{m,n} &= \int\int |W_{m,n}(x,y)|\, dxdy, \\ \sigma_{m,n} &= \sqrt{\int\int (|W_{m,n}(x,y)| - \mu_{m,n})^2\, dxdy}. \end{aligned}$$

$$T = [\mu_{0,0}\ \sigma_{0,0}\ \mu_{0,1}\ \ldots\ \mu_{3,5}\ \sigma_{3,5}].$$

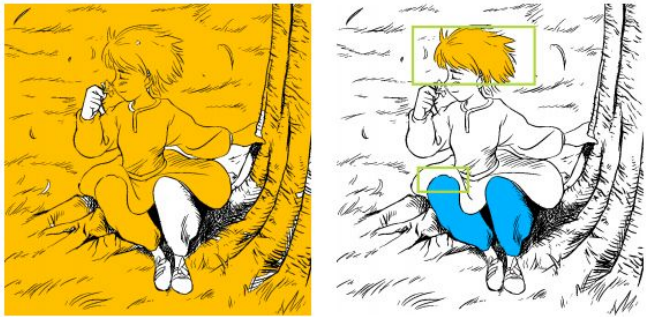
INTENSITY CONTINUOUS REGIONS

Segmenting such regions is fairly easy as compared to pattern continuous regions. Halting coefficient defined for such regions depend on the smoothing of the image with a gaussian filter.

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

In order to implement leak proofing, we add another term to the speed function F:

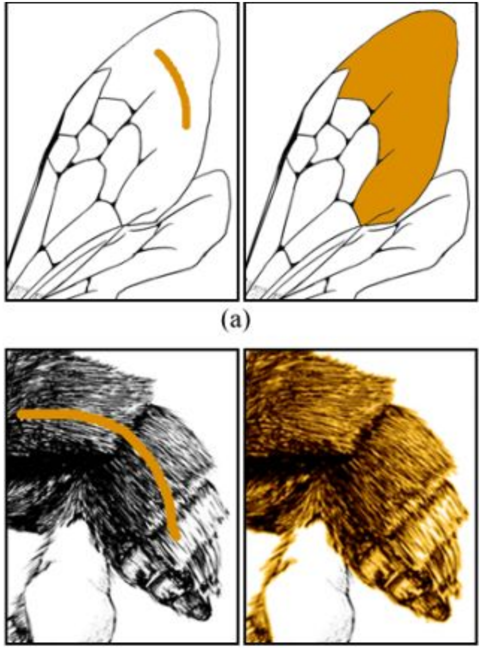
$$F_I(x,y) = -F_A R\left(\frac{|\nabla G_\sigma \otimes I(x,y)| - M_2}{M_1 - M_2 - \delta}\right),$$



STEP 3: COLORIZATION

We have implemented following three methods of colorization after the region is segmented

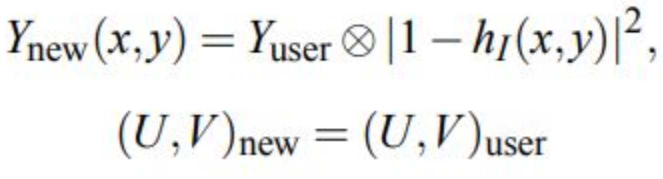
- Color replacement
  - This is a simple flood fill-type algorithm, used for intensity continuous regions. For such regions, filling color can be trivially done by replacing the black or white color by the user color on the scribble.
- Stroke preserving
- Pattern to shading



An example of intensity continuous vs. pattern continuous colorization (with stroke preserving)

STROKE PRESERVING

Pattern continuous regions are colorized by bleeding colors out of the strokes/patterns and filling it across the regions which have pattern matching to the part where user scribbles. This is done by converting the image to YUV spcae and:



$$Y_{\text{new}}(x,y) = Y_{\text{user}} \otimes |1 - h_I(x,y)|^2,$$

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

PATTERN TO SHADING

This method allow us to fill color as if we are shading, i.e., it fills color according to density of pattern in pattern continuous regions. Mathematics behind it,

$$Y_{\text{new}} = sY_{\text{user}},$$

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

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

RESULTS

RESULTS

RESULTS

DIVISION OF WORK

Loay, Rishabh

- Understanding implementation specifics
- Searching for alternative implementations of level set , understanding and implementing DRLSE propagation
- Intensity continuous propagation, stroke preservation, pattern to shading
- Making the presentation

Hari, Jayant:

- Level set propogation implementation
- Pattern Continuous propogation, floodfill algorithm
- Implementing the GUI for the application for scribbling on image using mouse
- Writing the readme