**Abstract**

I investigate the processes and uses of Convolutional Neural Networks (CNN), with the goal of applying the techniques to image colorization problems. To accomplish this, I selected three papers that had been published in a peer-reviewed journal or conference proceeding within the last three years to gain a greater understanding of modern image colorization techniques, along with familiarizing myself the current challenges researchers face with these problems. An issue with current image colorization techniques is that it cannot reliably colorize sequential frames in a video or bitmap, since previous implementations only provide a possible colorization out of several possible choices. This approach implements a Recurrent Convolutional Neural Network (RCNN) that generates a plausible image colorization for an input gray-scale image. By implementing it as a recurrent network instead of a feed-forward network, the network can retain some amount of data to use when colorizing sequential images, reducing random color-shifts between different frames and context shifts. The network was trained on roughly ten-thousand color images, and the results were evaluated with a visual test to determine their level of realism. Furthermore, the implementation can be generalized to perform several tasks when answering other problems.

**Introduction**

The problem of colorizing gray-scaled images is generally under-constrained, since most solutions don’t attempt to re-create the ground-truth RGB values in an image. Most algorithms that have been proposed to this point offer solutions that generate possible colorizations. The way these implementations differed are in the way they acquire the data, as well as deciding whether to use the data parametrically or non-parametrically. For non-parametric algorithms, a set of one or more images are defined as references, then corresponding colors in analogous regions are mapped to the input gray-scale images to produce a colorization. These methods tended to have problems with unique images, since it could prove difficult to find images that closely corresponded to the gray-scale image and would often result in skewed colorizations. Meanwhile, parametric algorithms would be trained on datasets of color images and viewed the problem through the approach of regression or classification. With these, most of the improvements came from modifying the network architecture or the loss function. By addressing the problem with an algorithm that uses regression, the networks would generate fairly monotone or “brown” images (SEE EXAMPLE) that mostly blended together. Classifiers, on the other hand, had similar issues with “browning” or “graying”, and would often create unlikely colorizations.

**Colorful Image Colorization**

Overview

This paper delineates an approach to the problem of hallucinate a plausible color version of an inputted grayscale photograph. It accomplishes this by treating the problem as a classification task and using class-rebalancing to decrease the desaturation and provide more contrasting colors.

Approach

A trained CNN maps a 256x256x1 lightness channel to a distribution of *ab* color space values, that can be applied to an outputted color image. Firstly, the approach determines the magnitude of The CNN has 8 blocks of 2 to 3 repeated convolutional or rectifier layers, followed by a batch normalization layer to re-distribute the values.

By themselves, the distribution of ab values in images trend towards lower ab values, due to the background of images containing fairly monotonic constructs such as clouds, dirt, or pavement. To account for this, the loss of each pixel at training time is re-weighted, based on pixel-color rarity. Each pixel is weighted.

Results

x

**Densely Connected Convolutional Networks**

Overview

Minimize amount of layers, feature maps

Approach

x

Results

No red

**Image-to-Image Translation with Conditional Adversarial Networks**

Overview

X

Approach

x

Results

x

**Implementation**

Overview

The network I implemented attempted to recreate the network architecture described in Colorful Image Colorization, but using a recurrent network instead of a strictly feed-forward network, so that final feature maps and ab color spaces would be available when colorizing sequential images. The values could then be merged with the ones that come afterwards, before they are re-weighted, so that the colors would be more consistent.

Approach

x

Results

x

**Conclusions**

x