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Comparative Analysis Of Gans And CNN For Image Colorization

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Abstract: Image Colorization involves colorizing grayscale image and giving the image a deeper meaning. This is a sophisticated task that requires prior knowledge of image content. Also, since the objects in the image may have several colors, it consists of numerous possible techniques to add colors to the pixels of the image, which shows there is no distinctive solution to this problem. Deep Learning techniques like Convolutional Neural Networks (CNN) and General Adversarial Networks (GANs) have been used to colorize grayscale images. This paper delves into analyzing and comparing the effectiveness of the two approaches (i.e., Convolutional Neural Networks and General Adversarial Networks) to colorize grayscale images. First, a dataset of images was created, which was subsequently converted to a dataset of grayscale images in the initial dataset. The grayscale images were then colorized using the two deep learning techniques of CNN (Convolutional Neural Networks) and GANs (Generative Adversarial Networks). The resultant colorized images were compared and analyzed with the original colorized images with their corresponding image histograms using comparison methods like 'Chi-Squared test' and 'Correlation distance'. The results obtained were then explained in the paper.

Index Terms - **Comparative study, colorization, CNN, GANs**

I. Introduction

Converting a black-and-white/gray image to a colored one has recently been researched by many researchers. It is utilized to increase the visual appeal of images such as old black and white photos, movies or scientific illustrations [1]. The ability to colorize grayscale images is one of deep learning's most intriguing uses. Years ago, this work needed significant human intervention, but with the help of deep learning, the full procedure can now be automated [7]. One of them can be employing the use of General Adversarial Networks (GANs) and another may be by using Convolutional Neural networks. There are many ways of achieving this. This paper illustrates why one method is superior to another.

II. RECENT WORK

Deep learning has been used to colorize images, and a variety of methods have been suggested over the last few years[8]. In the paper Colorful Image Colorization [2], the problem was approached as a classification task, and the authors took into account the problem's uncertainty (for example, a car in the image can appear in a variety of valid colors, and we cannot be certain about any color for it); however, another paper [7] approached the problem as a regression task (with some additional adjustments).

III. THE MODELS

A. *IMAGE COLORIZATION USING CNN*

In this approach of image colorization, an autoencoder model is used. Autoencoders consist of to major modules encoder and decoder. First a number of convolutional layers were applied to the image to encode it to a lower dimensional entity. Then to decode and upscale it, a number of deconvolution layers were applied on it. Fig. 1 represents this approach where x is the input grayscale image and y represents resultant colored image.

For the encoder part of the model, a ResNet-18 is used. ResNet-18 is a 18 layers deep pretrained CNN model. The dimensions of the first layer are changed, so as to make it accept grayscale images.

To evaluate performance of colorization, original image is compared with colored image. A loss function of the model is used for this. The metric used for the loss function is the Mean Squared Error (equation 1). This metric will attempt to minimize the difference between the predicted ($\hat{y}_i$) and the actual pixel values (y_i).

$$\text{MSE} = \frac{1}{N}\sum_{i=1}^{N}(y_i - \hat{y}_i)^2 \qquad (1)$$

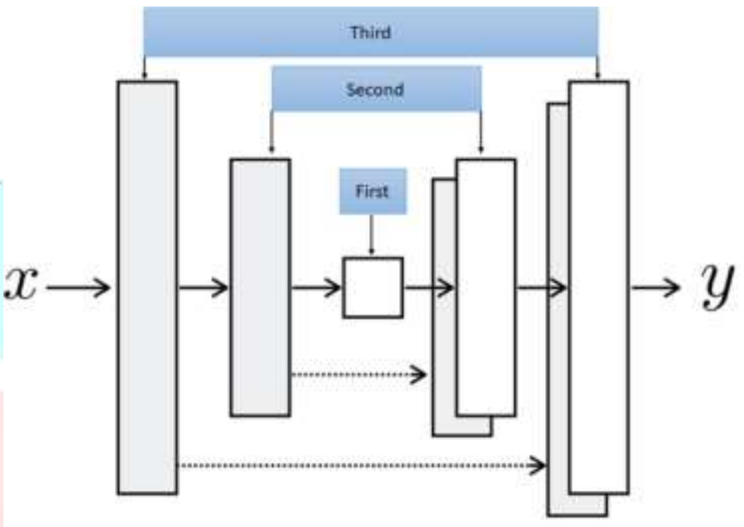

Fig. 1 Auto-encoders used in CNN model

B. *IMAGE COLORIZATION USING GANs*

A GAN consists of two components, a generator and a discriminator like encoder and decoder in autoencoders [3]. Generator in GAN follows the architecture same as that of CNN which is depicted in fig. 1. In our scenario, the generator transforms a grayscale image into a 2-channel image with channels for *a and *b (LAB color space). By joining the two created channels with the input grayscale image, the discriminator assesses whether this new 3-channel image is real or fake [4]. The discriminator also needs to be trained using some real images that are not generated by the generator and it should be trained to predict whether they are real or not.

$$\mathcal{L}_{cGAN}(G,D) = \mathbb{E}_{x,y}[\log D(x,y)] + \mathbb{E}_{x,z}[\log(1 - D(x, G(x,z))] \qquad (2)$$

The loss function equation 2 helps in generating colorful, realistic images. To further assist the model, the loss function is combined with L1 loss (same as mean absolute error, equation 3), which measures how well the predictive colors match as actual colors.

$$\mathcal{L}_{L1}(G) = \mathbb{E}_{x,y,z}[\|y - G(x,z)\|_1] \qquad (3)$$

The model will continue to learn to colorize the images if we only use L1 loss, but it will generally use colors like "grey" or "brown" because when it is unsure of the color it will take the mean of the cooler values to minimize the L1 loss. Furthermore, the tendency to produce greyish images is minimized by choosing the L1 loss. Equation 4 is the overall loss function for our system.:

$$G^* = \arg\min_G \max_D \mathcal{L}_{cGAN}(G, D) + \lambda \mathcal{L}_{L1}(G) \quad (4)$$

IV. METHODOLOGY

To compare these two colorization approaches, viz. images colorized with CNN and the images colorized with GANs the following steps were undertaken.

A. *Creating a Dataset*

A dataset of 100 images (selected at random) was created which would be used to evaluate image colorization with CNN and GANs later. The dataset was initially split into 2 datasets, one which consisted of the colorized images and the other which consisted of the grayscale images corresponding to the colorized images in the other dataset. After creating the dataset, all the images were converted from the RGB channel to the LAB channel. The images used by CNN and GANs were in the LAB color space (Lightness, A, and B), rather than the common RGB format. The information in this color space is identical to that in RGB, but it is simpler for the CNN and GANs models to distinguish between the lightness channel and the other two i.e. A and B.

B. *Colorizing the images using CNN and GANs*

The grayscale images stored in the dataset were selected and passed in the CNN model and GANs model as an input. The output images obtained from the CNN and GANs models were stored separately. These images were used for the comparative analysis.

C. *Creating image histograms*

To compare the accuracy of the colorized images numerically and statistically, the images were first converted into image histograms.

For each of the images colorized using CNN and GANs, an image histogram was created. To calculate the image histograms the 'calcHist()' function of openCV was used. The function returns an array of histogram points of dtype float32. The image histograms for the images colorized using CNN and GANs were stored separately. Image histograms of the initial dataset with color images were also calculated and stored. These histograms would further be compared and analyzed with the image histograms of the colorized CNN and GANs images.

D. *Comparison using Chi-Squared Distance*

The Chi-squared histogram distance was used to find dissimilarity between two image histograms[5]. The Chi- Squared Distance $d(H_1, H_2)$ was calculated with the formula as shown in equation 5.

$$d(H_1, H_2) = \sum_I \frac{(H_1(I) - H_2(I))^2}{H_1(I)} \quad (5)$$

Where $H_1(I)$ represents histogram of image 1 and $H_2(I)$ represents histogram of image 2

The chi-squared distances were calculated for the image histogram of the original colored images along with that of the image histograms of the respective associated image colorized using CNN and GANs. The chi-squared distance of the original colored image histogram and the image histogram of the corresponding image colorized using CNN could be compared to that of the chi-squared distance of the original colored image histogram and the image histogram of the corresponding image colorized using GANs. Higher chi-squared distances denote greater dissimilarity.

E. Comparison using Correlation Distance

Correlation Distance between two paired random vectors of any dimension, measures how dependent they are on one another. If and only if the random vectors are independent, the value of the correlation distance is 0. Correlation Distance evaluates the linear and nonlinear relationship between two random variables or random vectors. Thecorrelation distance $d(H_1, H_2)$ is calculated using the formula depicted in equation 6 and equation 7.

$$d(H_1, H_2) = \frac{\sum_I (H_1(I) - \bar{H}_1)(H_2(I) - \bar{H}_2)}{\sqrt{\sum_I (H_1(I) - \bar{H}_1)^2 \sum_I (H_2(I) - \bar{H}_2)^2}}$$ ---equation 6

$$\bar{H}_k = \frac{1}{N} \sum_J H_k(J)$$ ---equation 7

The correlation distances were calculated for the image histogram of the original images along with that of the image histograms of the corresponding image colorized using CNN and GANs. The correlation distance of the original image histogram and the image histogram of thecorresponding image colorized using CNN could be compared to that of the correlation distance of the originalimage histogram and the image histogram of thecorresponding image colorized using GANs.

V. RESULTS AND DISCUSSION

The output images obtained after colorizing the grayscale images using CNN and GANs were compared to their respective original images by comparing the image histograms of each image using histogram comparison metrics like chi- squared distance and correlation distance. These comparison metrics were used to evaluate and analyze all the 100 imagesthat were being tested.

The figure 2 shows the chi-squared distance for four of theimages tested from the dataset. Larger chi square values indicate greater dissimilarity between the images. It shows results obtained from both the model where column 1 displays the original image, column 2 and 3 are images obtained from the two image colorization models. For images in (a), (b) and (c) parts the chi-squared distance of the GANs output image is less than that of the CNN output images indicating that there is greater dissimilarity in the CNN output images with the original images. This is opposite, however for image (d).

Ground truth colored image
colored image obtained by GAN
colored image obtained by CNN

a

d)

Fig 2. Comparing GANs and CNN model sing Chi-square

Ground truth colored image colored image

colored image obtained by CNN obtained by GAN

a)

b)

c)

d)

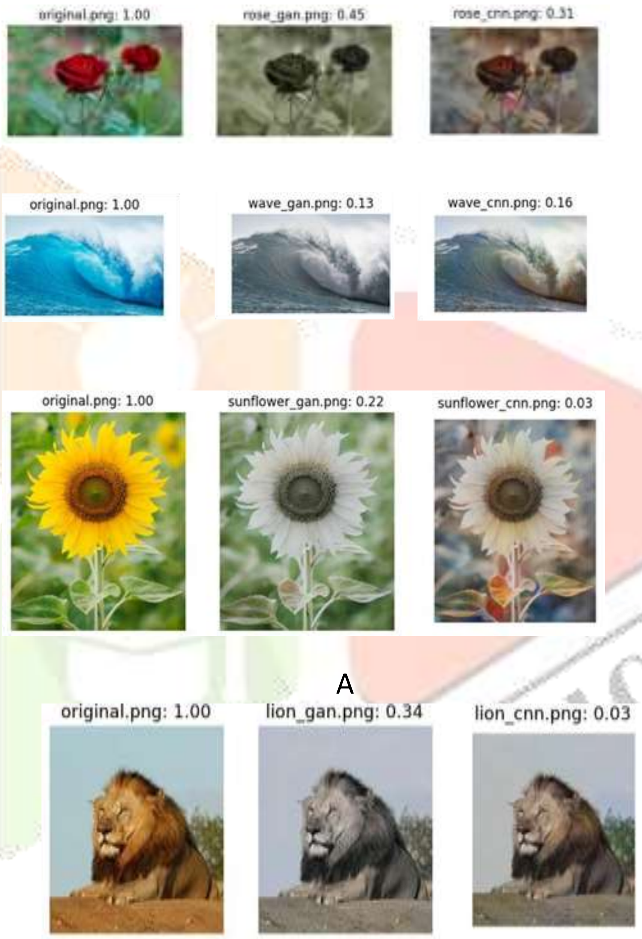

Fig 3. Comparing GANS and CNN using correlation distance

Figure 3 shows results obtained from both the model where column 1 shows the original image, column 2 and 3 are images obtained from the two image colorization models. It shows the correlation distance for four of the images tested from the dataset. Higher correlation values indicate more similarity between the images. The correlationvalue 1 indicates that the image histograms are same, i.e., theimages are same.

For images in (a), (c) and (d) the correlation distance of the GANs output image is more than that of the CNN output images indicating that there is greater similarity in the GANs output images with the original images. This is opposite, however, for figure 2.

For the 100 images that were evaluated and analyzed using the chi-square distance metric between the image histograms, 93 of the images showed that the CNN output image had higher chi- squared distance values with the original image than that ofthe chi-squared distance values of the GANs output images withthe original image. This clearly showed that colorizing images by CNN produces more dissimilarity than colorizing images by GANs

For the 100 images evaluated and analyzed by the Correlationdistance metric between the image histograms, 85 of the images showed that the CNN output image had lower correlation distance values with the original image than that of the correlation distance values of the GANs output image withthe original image. This clearly showed that colorizing imagesby GANs is more accurate than that colorizing images by CNN produces more dissimilarity while colorizing the image to that of the actual image.

VI. CONCLUSION

The study compared two image colorizing techniques CNN (Convolution Neural Networks) and GANs (Generative Adversarial Networks) by re-colorizing images that wereconverted to grayscale images at first. The comparison was then made between the image histograms of the original images and the re-colorized images using metrics like chi- square distance and correlation to measure the dissimilarity and similarity of the colorized images respectively.

In conclusion, the outcomes of this comparative analysis clearly indicate that image colorization using GANs is more accurate in comparison to that using CNN in most cases.

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