PUNE INSTITUTE OF COMPUTER TECHNOLOGY,
DHANKAWADI PUNE-43.

A Seminar Report

On

Automatic Colorization of Black and White Images Using CNNs (Convolutional Neural Networks)

SUBMITTED BY

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CERTIFICATE

ISO 9001 : 2008 Certified

This is to certify that Mr. Niranjan Rathod , Roll No. 3447 a student of T.E. (Computer Engineering Department) Batch 2016-2017, has satisfactorily completed a seminar report on "Automatic Colorization of Black and White Images Using CNNs (Convolutional Neural Networks)" under the guidance of

Prof. P. S.Vidap towards the partial fulfillment of the third year Computer Engineering Semester II of Pune University.

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Automatic Colorization of Black and White Images Using CNNs

(Convolutional Neural Networks)

Contents

Abstract:

This seminar explains colorization problem which converts a gray-scale image to a colourful version of it. This is a very difficult problem and normally requires manual adjustment to achieve good quality. Previously, it required to colour image manually using any graphics editing software or algorithms which use human-labelled colour scribbles on the gray-scale target image or a careful selection of large database of colourful reference images. Inspired by the recent success in deep learning techniques which provide amazing modelling of large-scale data, this seminar aims at explaining a high-quality fully-automatic colorization methods. State-of-art techniques like CNNs are being used to solve this problem. Different CNN models used by researchers will be explained and compared on the basis of quality and speed of algorithms.

Keywords*: Colorization, Computer Vision for Graphics, CNNs, Self-supervised learning, Machine learning, Expert systems*

1 INTRODUCTION

There has been a growing interest in recoloring gray-scale images. A preliminary search reveals many interested parties working on completing this task. The traditional approach for realistically colorizing gray-scale images is for an artist to directly color it using digital photo editing tools. Image colorization assigns a color to each pixel of a target grayscale image. Colorization methods can be roughly divided into two categories: scribble-based colorization and example-based colorization. The scribble-based methods typically require substantial efforts from the user to provide considerable scribbles on the target grayscale images. It is thus time-consuming to colorize a grayscale image with finescale structures, especially for a rookie user. To reduce the effort of user an example based methods were proposed. The example-based method typically transfers the color information from a similar reference image to the target grayscale image. However, finding a suitable reference image becomes an obstacle for a user. This problem was simplified by utilizing the image data on the Internet and propose filtering schemes to select suitable reference images. However, they both have additional constraints.

A fully-automatic colorization method is proposed to address this limitation. Intuitively, one reference image cannot include all possible scenarios in the target grayscale image.

1.1 Motivation

The first cameras were produced in the early 1800s and could only produce images in black and white. Black and white photograph persisted well into the 1900s and is surprisingly making a comeback even in the modern day. Colored photography and film did not really exist until the early 1900s and did not become economically feasible for people until even later. Because of this, there are a large amount of black and white images and videos that people would like to see colored. This problem has sparked dedicated subreddits (/r/colorization, /r/ColorizedHistory, /r/ColorizationRequests) for people who have interest in coloring black and white images. The people who use these subreddits typically put in a lot of time and effort using expensive high-end photo editing platforms in order to complete the colorization task. In addition to these subreddits, numerous online tools and guides exist for the purpose of assisting in the colorization of black and white images. We ask to what extent can this process be automated? What trade-off space exists relating quality of output and human effort?

Deep learning techniques have achieved amazing success in modeling large-scale data recently. It has shown powerful learning ability that even outperforms human to some extent and deep learning techniques have been demonstrated to be very effective on various computer vision and image processing applications including image classification, pedestrian detection , image super-resolution, photo adjustment etc. The success of deep learning techniques motivates us to explore its potential application in our context.

With the rise of machine learning and Convolutional Neural Networks,it seems plausible to be able to automate or semi-automate this task. If there exists a system that can colorize gray-scale images well enough for certain applications, then it is possible to construct a scenario in which one could compress data transfer to only a single gray-scale image instead of the typical 3 channel RGB or YUV images. For example low-quality always-on cameras are typically black and white. It might be useful to be able to convert chunks of this video feed into colored images without needing the entire stream to be saved as colored images.

1.2 History

This section gives a brief overview of the previous colorization methods.

Scribble-based colorization: Levin et al. propose an effective approach that requires the user to provide colorful scribbles on the grayscale target image. The color information on the scribbles are then propagated to the rest of the target image using least-square optimization. Huang et al. develop an adaptive edge detection algorithm to reduce the color bleeding artifact around the region boundaries. Yatziv et al. colorize the pixels using a weighted combination of user scribbles. Qu et al. and Luan et al. utilize the texture feature to reduce the amount of required scribbles.

Example-based colorization: Unlike scribble-based colorization methods, the example-based methods transfer the color information from a reference image to the target grayscale image. The example-based colorization methods can be further separated into two categories according to the source of reference images: (1) Colorization using user-supplied example(s). This type of methods requires the user to provide a suitable reference image. Inspired by image analogies and the color transfer technology, Welsh et al. employ the pixel intensity and neighborhood statistics to find a similar pixel in the reference image and then transfer the color of the matched pixel to the target pixel. It is later improved in by taking into account the texture feature. Charpiat et al. propose a global optimization algorithm to colorize a pixel. Gupta et al. develop an colorization method based on superpixel to improve the spatial coherency. These methods share the limitation that the colorization quality relies heavily on example image(s) provided by the user. However,there is not a standard criteria on the example image(s) and thus finding a suitable reference image is a difficult task.

1.3 Literature Survey:

1.3.1 YUV Color Space and Leveled Features

This paper talks about colorizing grey-scale image using 3-layered CNN architecture**.** This method uses YUV color space to work upon. Concept of four different types of features i.e. Low-level patch features, Mid-level DAISY features, High-level semantic features and Global features is described. This was published in 2015 and had good improvements over prior implementations. [1]

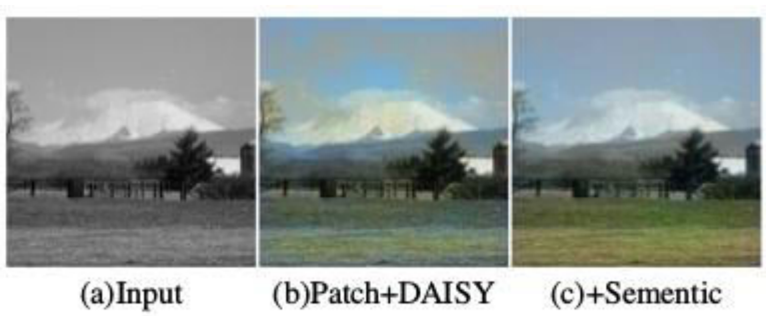


Figure 1(Results [1])

1.3.2 CIE lab color space and class rebalancing

[2] was presented in ECCV (European conference on Computer vision) in 2016.

This approach takes prior approaches a step further by improving quality of images by applying image processing after prediction by network. It uses class rebalancing technique to remove biasing of prediction towards ab channel. This approach is based on CIE LAB color space. Class rebalancing depends on temperature parameter of image.

Figure 2(Results [2])

1.3.3 VGG-16 based approach

.[3]was also presented in ECCV (European conference on Computer vision) in 2016

This approach uses popular ILSVRC -2014 runner up model (VGG-16). This model has total number of 16 layers. Typically all the approaches try to give luminous channel as input and get Chroma channel as output. Then upon merging these three channels one can get predicted color image.

1.4 Applications

1.4.1 Colorization of old movies:

There are lots of movies that were filmed before 1900s .But until 1900s there were no color cameras present. It would be nice to see those images in colored format. Manually doing this will take lot of time and efforts. Automatic colorization can help overcome this problem. Using this program automatic colorization of movies will take no time. Thus all the good content in history can be seen in vibrant colors.

1.4.2 Image Compression:

This approach, if properly used, then it can be used for image compression. In this application image can be transferred as one channel greyscale image and receiver will colorize it.

1.4.3 Assistance to Graphics editors:

This can help vast amount of people working in graphics industry and can provide innovative ideas about colorizing. In future it is possible to keep a button in graphics editing software which will automatically suggest different combination for given images.

1.5 Challenges

1.5.1 Needs large dataset

As every deep learning problem this problem also requires large amount of dataset .But fortunately for this problem any colored image can be used as training data.

1.5.2 Needs Good GPUs for training

Again as every deep learning problem this problems also requires goo quality GPUs for parallel training of model. NVIDIA Tesla architecture seems good choice for this.

1.5.3 Averaging problem

After training the model on large dataset it might lead to averaging problem. For example if we show it many images having sky in different colors like blue, orange or pink it then may get confuse in what color should it give to sky in new input image. This is most challenging problem and needs to find solution for it.

2 PROPOSED MATHEMATICAL MODEL

Let S be solution perspective of image colorization problem.
S = {St, E, X, Y, I, Fm, DD, NDD, Su, Fl}
St = Start State
E = End State
I = Image
= $(I)_{h, w, d}$ is a matrix $[W_{111}, W_{112}, ..., W_{11d}, W211, W_{212}, ..., W_{21d}, ..., W_{hwd}]$
Where,
h=height
w=width
d=depth
$W_{h,w,d} = [0\text{-}255]$

X = Input Set
= {Training Image, Input image} $\in I$
Y= expected output
Fm = {Fconv, Frelu, Fmaxpool, Floss,Fpredict}
Fconv( ):
$Fconv(X_{h,h}, K , S) = Y_z$ …(1)
Where
z=H-K/S+1
H=height or width
K=kernel height
S=stride
$Frelu(W_{h,w})$:
$$Frelu(W_{h,w}) = \begin{cases} W if W > 0 \\ 0 otherwise \end{cases}$$
$Fmaxpool(X_{h,h}, K , S)$:
$Fmaxpool(X_{h,h}, K , S) \sim Fconv$
$Foutput = Fpredict + L_I$
Where,
$Fpredict=Y_z$ … from (1)

Floss = mean $(Fpredict-Y)^2$
DD = Deterministic Data
= {Input data}
NDD = Non-Deterministic Data
= {Image output}

Su= Success case ={Image colored satisfactorily }

Fl=Failure case={Image not colored satisfactorily}

3 DESIGN AND ANALYSIS OF SYSTEM

3.1 Model 1 (Inspired from VGGnet ILSVRC 2nd place 2014)

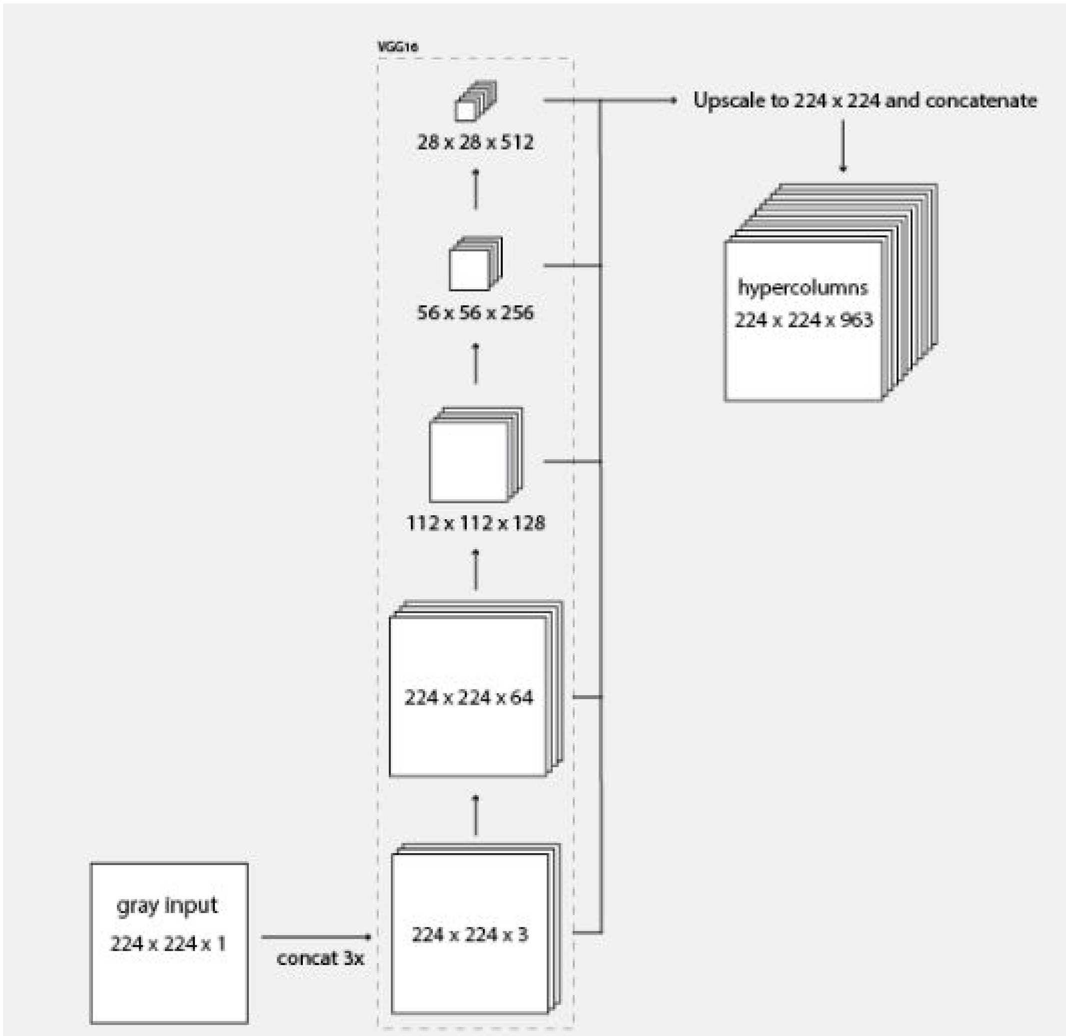


Figure 3: Model 1 (Inspired from VGGnet)[6]

3.2 Model 2 (Inspired from ResNet)

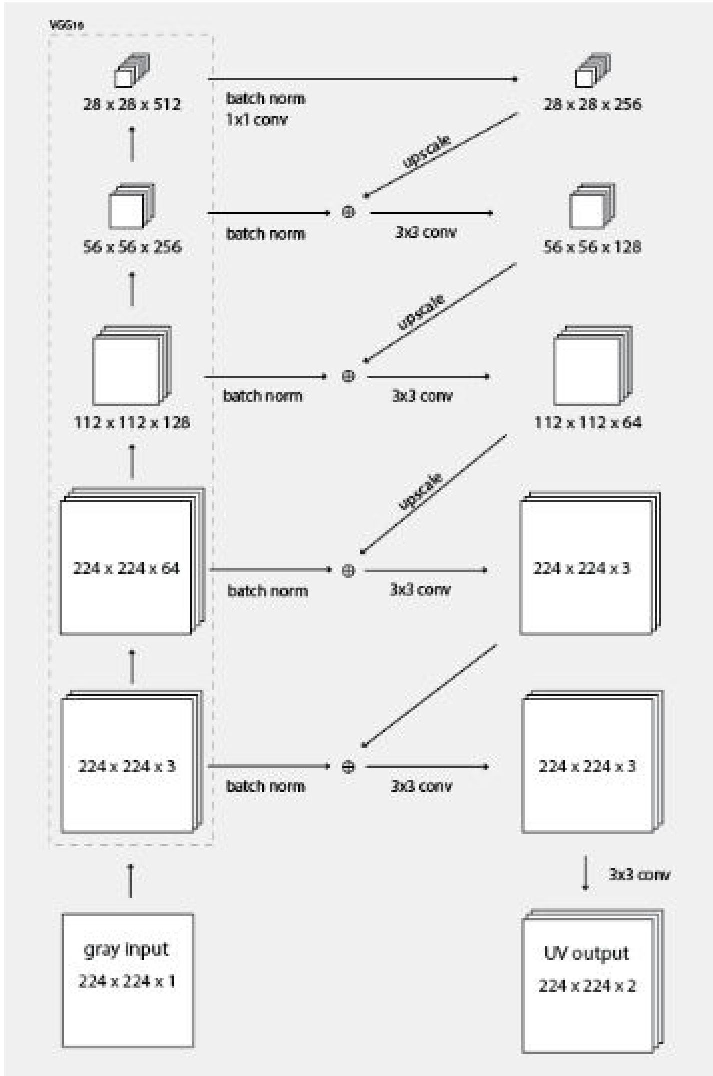


Figure 4: (Model 2 Inspired from ResNet) [6]

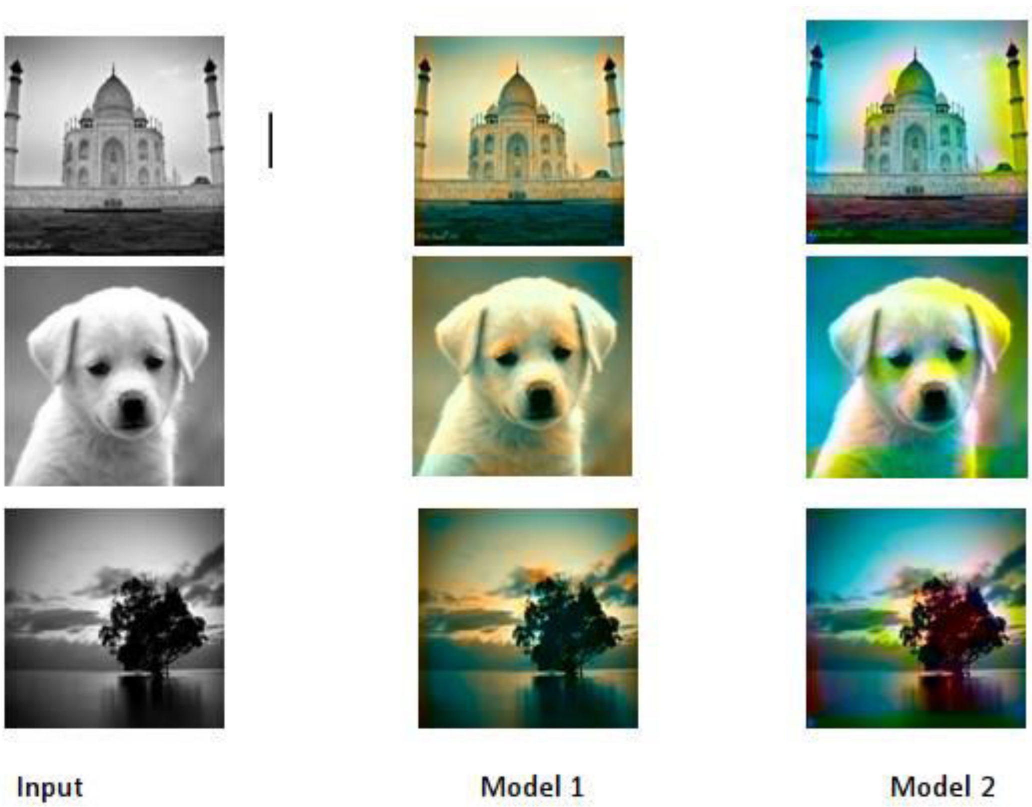
4 DISCUSSION ON IMPLEMENTATION RESULTS

Above models were implemented in python using Tensorflow library.

Due to unavailability of hardware resources like GPU both the models were trained on only one image and it is observed that model learns to colorize images based on only single image. Results are shown below.

Input Predicted Ground truth

Results on trained image



Results on unseen images

5 CONCLUSION AND FUTURE ENHANCEMENT

5.1 Conclusion

As we can see above even if model is trained on a single image it gives sensible output for unseen images. It knows to color sky as blue and tree as green.

5.2 Future Enhancements

Although results are satisfactory there a big scope for improvement in this problem.

- Training on large dataset can improve accuracy and model can be generalized.
- Present results have some patches overlay on images that can be removed by training.
- Data loss can be minimized using more efficient architecture.
- Model can be modified for image compression problem.

6 REFERENCES

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[6] www.tinyclouds.org/colorize

APPENDIX – D

Log Book

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Name of the Student:- Niranjan Rathod
Name of the Guide :- Prof. P.S.Vidap
Seminar Title :- Automatic Colorization of black and white images using CNNs

Sr. No.	Date	Details of Discussion/ Remark	Signature of Guide/ Seminar In charge
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