A PROJECT REPORT

On

"Convolutional Neural Network based Image and Video Colorization using OpenCV"

Submitted to
KIIT DEEMED TO BE UNIVERSITY

In Partial Fulfilment of the Requirement for the Award of

BACHELOR'S DEGREE IN

COMPUTER SCIENCE AND COMMUNICATION ENGINEERING

BY

Amrit Ghosh	1729009
Arpan Roy Chowdhury	1729016
Avirupa Saha	1729021
Krishnendu Kundu	1729030
Ritwik Das	1729054

UNDER THE GUIDANCE OF

PROF. RAJDEEP CHATTERJEE

SCHOOL OF COMPUTER ENGINEERING

KALINGA INSTITUTE OF INDUSTRIAL TECHNOLOGY

BHUBANESWAR, ODISHA – 751024

May 2021

A PROJECT REPORT

On

"**Convolutional Neural Network based Image and Video Colorization using OpenCV**"

Submitted to
KIIT DEEMED TO BE UNIVERSITY

In Partial Fulfilment of the Requirement for the Award of

BACHELOR'S DEGREE IN

COMPUTER SCIENCE AND COMMUNICATION ENGINEERING

BY

Amrit Ghosh	1729009
Arpan Roy Chowdhury	1729016
Avirupa Saha	1729021
Krishnendu Kundu	1729030
Ritwik Das	1729054

UNDER THE GUIDANCE OF

PROF. RAJDEEP CHATTERJEE

SCHOOL OF COMPUTER ENGINEERING

KALINGA INSTITUTE OF INDUSTRIAL TECHNOLOGY

BHUBANESWAR, ODISHA – 751024

May 2021

KIIT Deemed to be University

School of Computer Engineering
Bhubaneswar, ODISHA 751024

CERTIFICATE

This is certify that the project entitled

"Convolutional Neural Network based Image Colorization using OpenCV""

submitted by

Amrit Ghosh	1729009
Arpan Roy Chowdhury	1729016
Avirupa Saha	1729021
Krishnendu Kundu	1729030
Ritwik Das	1729054

is a record of bonafide work carried out by them, in the partial fulfilment of the requirement for the award of Degree of Bachelor of Engineering (Computer Science & Engineering OR Information Technology) at KIIT Deemed to be university, Bhubaneswar. This work is done during year 2019-2020, under our guidance.

Date: / /

(Prof. Rajdeep Chatterjee)

Project Guide

Acknowledgements

We are profoundly grateful to Prof. Rajdeep Chatterjee for his expert guidance and continuous encouragement throughout to see that this project rights its target since its commencement to its completion. We are highly obliged and thankful to KIIT Deemed to be University for giving us such fruitful opportunities which helped us to build a good base of knowledge. We are also very thankful to all the teammates for the high cooperation and contribution.

Amrit Ghosh
Arpan Roy Chowdhury
Avirupa Saha
Krishnendu Kundu
Ritwik Das

Index

List of Figures

ABSTRACT

Historians,filmographers, archaeologists etc have long searched for methods for colourising old black and white photographs. Although various colorisation techniques have been invented since, none of them have been able to provide efficient and accurate real time colourisation.

The Convolutional Neural Network based image colorisation model not only provides a rich colorisation but also by using the potential of the enormous computing capacity of deep learning, it tries to observe the minute details and hue changes that might be present in a photograph due to corners, shadows or uneven lighting. This provides a far more precise conversion of greyscale images into coloured ones.

By utilizing a pre-trained convolutional neural network, which is originally designed for image classification, we are able to separate content and style of different images and recombine them into a single image. We then propose a method that can add colors to a grayscale image by combining its content with style of a color image having semantic similarity with the grayscale one.

Keywords: Convolutional Neural Networks, Deep Learning, Machine Learning, OpenCV, Image Colorization.

Chapter 1

Introduction

Image colorization is the process of taking an input grayscale (black and white) image and then producing an output colorized image that represents the semantic colors and tones of the input.Colorizing black and white films and photographs is a very old idea dating back to 1902. For decades many movie creators opposed the idea of colorizing their black and white movies.Today it is accepted as an enhancement to the art form and is applied over grayscale image to make it more aesthetically appealing and perceptually meaningful. This is known to be a sophisticated task that often requires prior knowledge about the image content and manual adjustments in order to achieve artefact free quality.

Recently, deep learning has gained increasing attention among researchers in the field of computer vision and image processing. As a typical technique, convolutional neural networks (CNNs) have been well-studied and successfully applied to several tasks such as image recognition, image reconstruction, image generation.A Convolutional Neural Network (ConvNet/CNN) is a Deep Learning algorithm which can take in an input image, assign importance (learnable weights and biases) to various aspects/objects in the image and be able to differentiate one from the other. The pre-processing required in a ConvNet is much lower as compared to other classification algorithms.

These amazing successes of CNNs have motivated us to further investigate and explore their potential in the aforementioned image colorization problem.

1.1. Mission Statement

Automated colorization of black and white images has been subject to much research within the computer vision and machine learning communities. Beyond simply being fascinating from an aesthetics and artificial intelligence perspective, such capability has broad practical applications ranging from video restoration to image enhancement for improved interpretability. We present a

convolutional-neural-network-based system that faithfully colorizes black and white photographic images without direct human assistance. We explore various network architectures, objectives, color spaces, and problem formulations. The final classification-based model we build generates colorized images that are significantly more aesthetically-pleasing than those created by the baseline regression-based model, demonstrating the viability of our methodology and revealing promising avenues for future work.

1.2. Mission Objective

Our aim is to build a complete self-adaptive model that interprets with several features of an image together without manual interference. Using all sub-layers integrated in a single CNN based model will make it more robust and efficient both in terms of technology and pre-proccesing time. The auto-correlated model we aim to build provides a solution by taking output of a pre-trained model as an input to the other one to get a precise and accurate output.

1.3. Project Goal

- ➢ To provide rich colorisation of images in a fast and efficient manner
- ➢ To build a model which can work on different formats and qualities of images
- ➢ To provide accurate and consistent results every time
- ➢ To lower the pre-proccesing time of the deep learning model to allow faster colorisation without compromising on quality

1.4. Features

1. Completely self-adapted model.
2. Accurate and real time colorisation of images

3. Precise and reliable.
4. Reliable tools and platforms are used to get consistent and accurate results every time.
5. Low pre-proccesing time
6. Works on various formats and qualities of images

Chapter 2

Literature Survey

In recent years, CNNs have emerged as the de facto standard for solving image classification problems, achieving error rates lower than 4% in the ImageNet challenge [12]. CNNs owe much of their success to their ability to learn and discern colors, patterns, and shapes within images and associate them with object classes. These characteristics naturally lend themselves well to colorizing images since object classes, patterns, and shapes generally correlate with color choice.

A statistical-learning-driven approach is taken towards for implementing the colorisation project. A convolutional neural network (CNN) is being designed and bulit that accepts a black-and-white image as an input and generates a colorized version of the image as its output; Figure 1 shows an example of such a pair of input and output images. The system generates its output based solely on images it has "learned from" in the past, with no further human intervention.

Summary

From all the surveyed past works and visualizing workflow of a convolutional neural network provided a clear view of image colorisation and how it can be useful for real life implementation.

Chapter 3

Software Requirements Specification

3.1. System Requirements

Jupyter Notebook Version

The jupyter notebook is a tool which we can use for our machine learning project and statistical analysis.We can download anaconda from the web sourse and within it Jupyter notebook and Spyder are pre-installed.Spyder is another usefull tool for machine learning purpose.

Version 5.7.8 is used in our Project.

Python Version

Python is a very useful programming language.It is object oriented and interpreted.It is a high level language.There are lots of in-built libraries in Python for machine learning purpose which we can use easily.

Python 3.7 is used for this project.

Windows OS

Jupyter notebook and python 3 can be used is all the operating systems including Windows, iOS and Linux.

It is best usefull in Linux but can be used in windows as well. It can be run on windows xp,vista,7,8 and the latest version windows 10 as well.

About Python Language

Python was developed by Van Rossum.It was first released on 1991.It is a general purpuse programming language.It can be used for GUI developed,Web developed, web application,machine learning etc. It has object oriented features also. The basic data types in python is integer,char,float,list,tuple and dictionary.

Generally programming with python is very simple and time saving because it has lots of in-built functions and libraries.

It also has predefined libraries only for machine learning like numpy,pandas,matplotlib etc.

3.2. Tools Used

OpenCV	*Google colab*	*Sypder*
ImageNet	*Linux Kernel*	*Anaconda IDE*
Jupyter	*Git Bash*	*VSCode IDE*

Chapter 4

Basic Concepts/ Technology Used

4.1. Deep learning

Deep Learning is a subfield of machine learning concerned with algorithms inspired by the structure and function of the brain called **artificial neural networks**. Artificial Intelligence is a general term that refers to techniques that enable computers to mimic human behavior. Machine Learning represents a set of algorithms trained on data that make all of this possible. Deep Learning, on the other hand, is just a type of Machine Learning, inspired by the structure of a human brain. Deep learning algorithms attempt to draw similar conclusions as humans would by continually analyzing data with a given logical structure. To achieve this, deep learning uses a multi-layered structure of algorithms called neural networks.

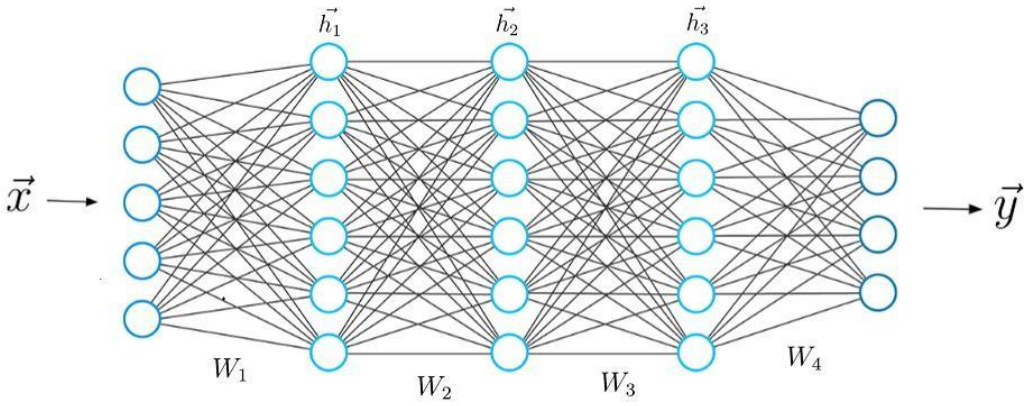


Fig 1: Neural Networks

Neural networks enable us to perform many tasks, such as clustering, classification or regression. With neural networks, we can group or sort unlabeled data according to similarities among the samples in this data. Or in the case of classification, we can train the network on a labeled dataset in order to classify the samples in this dataset into different categories.

Features of Deep Learning:-

1) Maximum utilization of unstructured data

2) Elimination of the need for feature engineering

3) Ability to deliver high-quality results

4) Elimination of unnecessary costs

5) Elimination of the need for data labeling

4.2 Convolutional Neural Network:

A **Convolutional Neural Network (ConvNet/CNN)** is a Deep Learning algorithm which can take in an input image, assign importance (learnable weights and biases) to various aspects/objects in the image and be able to differentiate one from the other. The pre-processing required in a ConvNet is much lower as compared to other classification algorithms. While in primitive methods filters are hand-engineered, with enough training, ConvNets have the ability to learn these filters/characteristics.

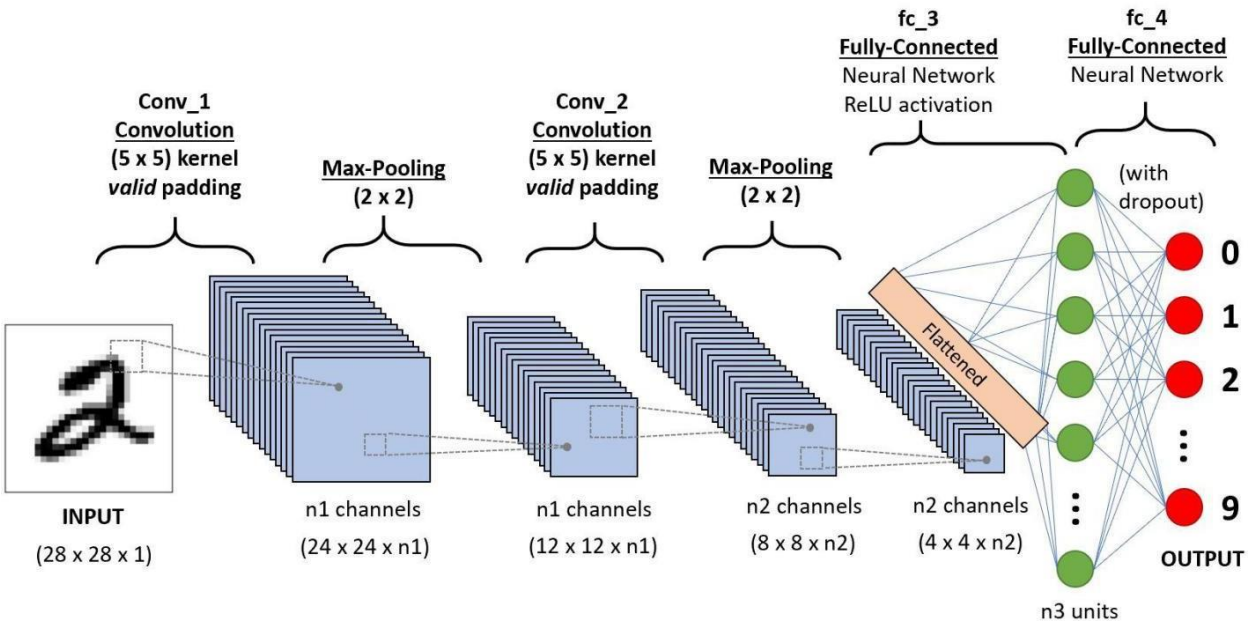


Fig 2: Convolutional Neural Network

A ConvNet is able to **successfully capture the Spatial and Temporal dependencies** in an image through the application of relevant filters. The architecture performs a better fitting to the image dataset due to the reduction in the number of parameters involved and reusability of weights. In other words, the network can be trained to understand the sophistication of the image better.

4.3 Open CV

OpenCV is a cross-platform library using which we can develop real-time **computer vision applications**. It mainly focuses on image processing, video capture and analysis including features like face detection and object detection. Computer Vision can be defined as a discipline that explains how to reconstruct, interrupt, and understand a 3D scene from its 2D images, in terms of the properties of the structure present in the scene. It deals with modeling and replicating human vision using computer software and hardware.

Computer Vision overlaps significantly with the following fields −

Image Processing − It focuses on image manipulation.

Pattern Recognition − It explains various techniques to classify patterns.

Photogrammetry − It is concerned with obtaining accurate measurements from images.

Using OpenCV library we can:-

- Read and write images
- Capture and save videos
- Process images (filter, transform)
- Perform feature detection
- Detect specific objects such as faces, eyes, cars, in the videos or images
- Analyze videos, i.e., estimate the motion in it, subtract the background, and track objects in it.

Colourization problem:

Unlike the RGB color space the CIE Lab color space has color information encoded only in the a (green-red component) and b (blue-yellow component) channels. The L (lightness) channel encodes intensity information only.

The black and white image is the L channel and we had to find the ab values. this becomes quite easy to find using two OpenCV function known as cvtColor and COLOR_BGR2LAB.

The ab space is quantized into 313 bins. Instead of finding the a and b values for every pixel, because of this quantization, we simply need to find a bin number between 0 and 312. (multinomial classification for every gray pixel there are 313 classes to choose)

Architecture:

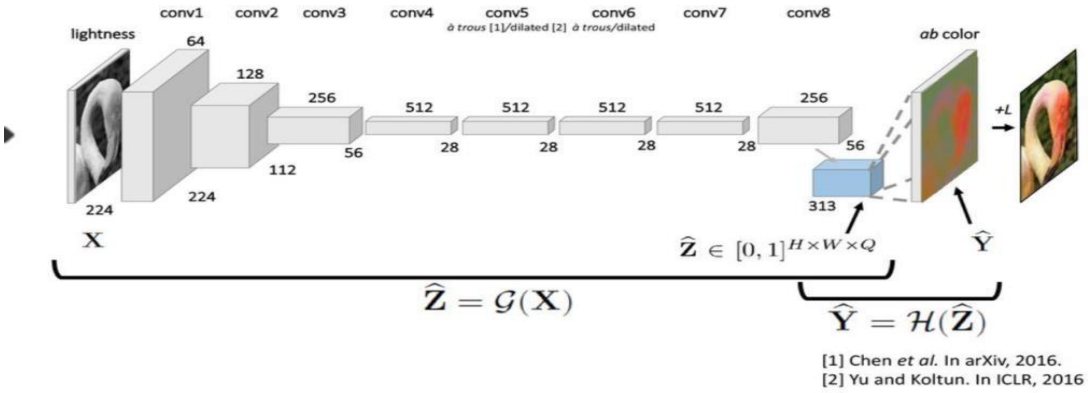


Fig3 : CNN architechure for Image Colorisation

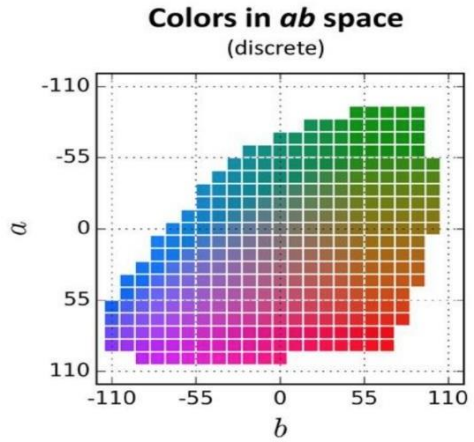


Fig 4: Quantized colors in ab space

The architecture proposed by Zhang et al is a VGG-style network with multiple convolutional blocks. Each block has two or three convolutional layers followed by a Rectified Linear Unit (ReLU) and terminating in a Batch Normalization layer. Unlike the VGG net, there are no pooling or fully connected layers.

4.4 CNN architecture for Colorization.

The input image is rescaled to 224×224. Let us represent this rescaled grayscale input image by

.

When it passes through the neural network shown above, it gets transformed to by the neural network. Mathematically, this transformation by the network can be written as

$$\hat{Z} = G(X)$$

The dimensions of this, where and are the height and width of the output of the last convolution layer. For each of these pixels,contains a vector of values where each value represents the probability of the pixel belonging to that class. Our goal is to find a single pair of **ab** channel values for each probability distribution $\hat{Z}_{h,w}$.

Chapter 5

Implementation

1.1. Data Collection:

The ImageNet challenge dataset comprises 25000 Creative Commons images downloaded from the community photo sharing website Flickr . The images span a vast range of categories, artistic styles, and subject matter.

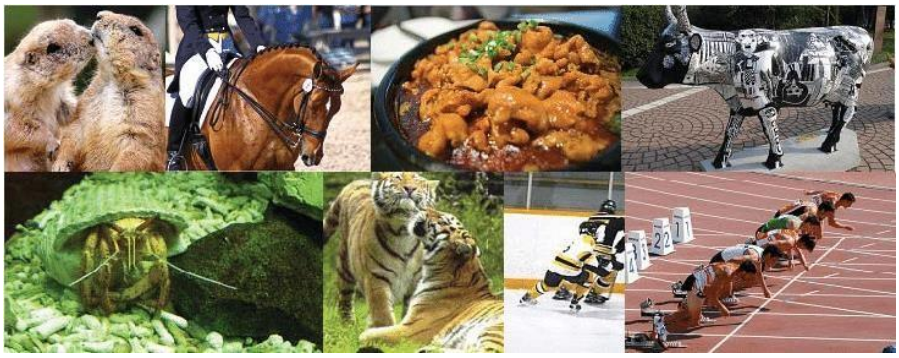


Fig 5: Sample images from ImageNet dataset.

1.2. Data Synthesise:

We preprocess each image in our dataset prior to forwarding it to our network. We scale each image to dimensions of 224 × 224 × 3 and generate a grayscale version of the image of dimensions 224 × 224 × 1. Since the input of our network is the input of the ImageNet-trained VGG16, which expects its input images to be zero-centered and of dimensions 224 × 224 × 3, we duplicate the grayscale image three times to form a (224 × 224 × 3)-sized image and subtract the mean R, G, and B value across all the pictures in the ImageNet dataset. The resulting final image serves as the black-and-white input image for the network.

1.3. Ensemble Training and Model Building:

For regression, we quantify the closeness of the generated image to the actual image as the sum of the `2 norms of the difference of the generated image pixels and actual image pixels in the *U* and *V* channels: Likewise, for classification, we measure the closeness of the generated image to the actual image by the percent of binned pixel values that match between the generated image and actual image for each channel *U* and *V*. We emphasize that classification accuracy alone is not the ideal metric to judge our system on, since the accuracy of color matching against target images does not directly relate with the aesthetic quality of an image.

The degree of color saturation in a given image strongly influences its aesthetic appeal. Ideally, then, the saturation levels present in the training images should be replicated at the system's output, even when the exact hues and tones are not matched perfectly. This metric allows us to quantify the faithfulness of this replication.

1.4. Deep Learning and Model Building

```
colorized = cv2.cvtColor(colorized,cv2.COLOR_LAB2BGR)
colorized = np.clip(colorized,0,1)

colorized = (255 * colorized).astype("uint8")

cv2.imshow("Original",image)
cv2.imshow("Colorized".colorized)
```

Fig 6: Deep Learning Model building

The black and white image is the L channel and we had to find the ab values. this becomes quite easy to find using two OpenCV function known as cvtColor and COLOR_BGR2LAB.For each pixel contains a vector of values where each value represents the probabality of it belonging to the same class. Our goal is to find a single pair of ab channel values for each probability distribution.In this project for the image colourization part, Caffe model has been used. Caffe model is adeep learning framework made with expression, speed and modularity in mind. Caffe model stores the weights of actual layer.

For video colourization:

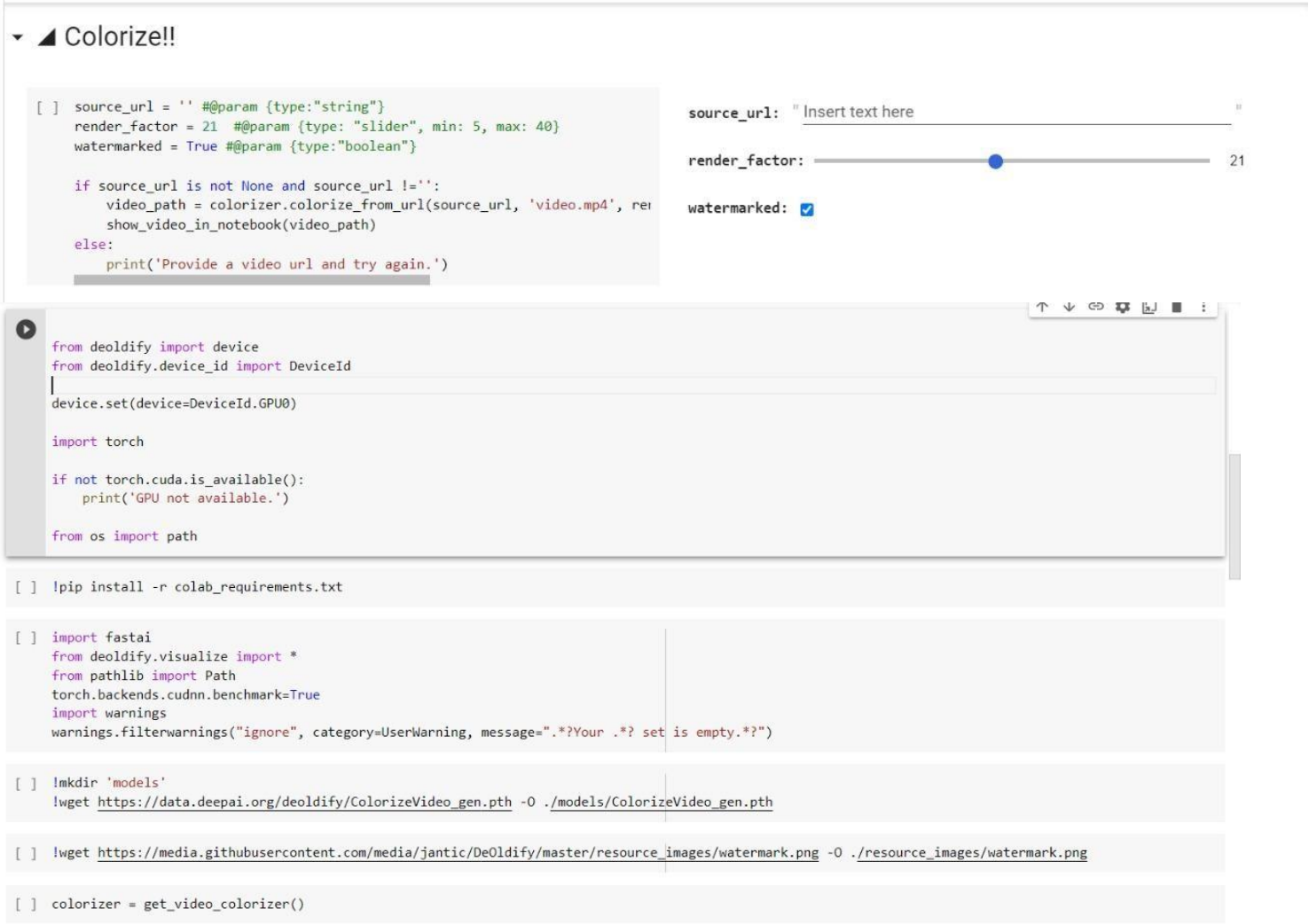
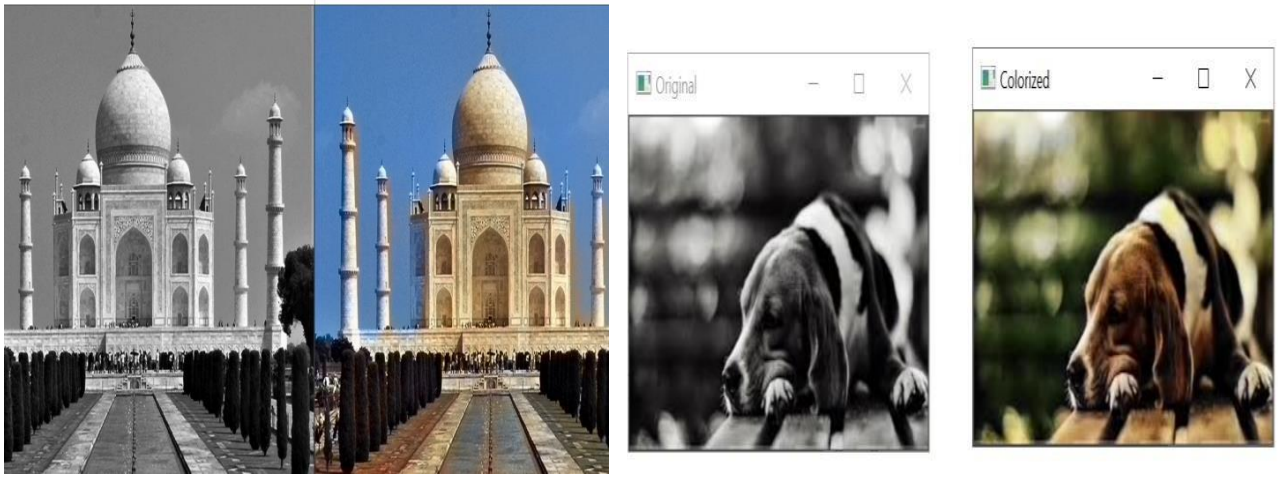


Fig 7: Deoldify is a new effective technique for image to image GAN(Generative adversarial network) training

Chapter 6

Result and Analysis

We had applied the above described model in our input images and videos



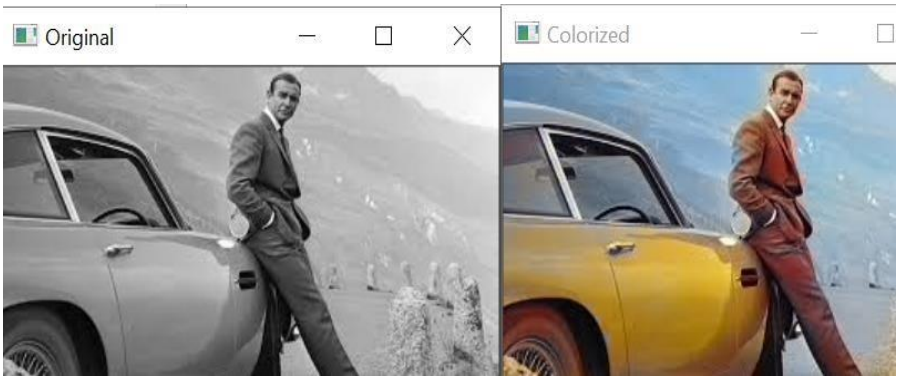


Fig 8. Sample input and output images

Sample test set input and output from ImageNet were more convincing images on nature themes. It is the case because the candidate colors for objects in nature are more well defined than some man-made objects. For example, the sky might be blue, grey or even pink at the a sunset, but it is almost never green.The main challenge our model faces is inconsistency in colors within individual objects.that there exists a noticeable amount of noise in the classification results, with blobs of various colors interspersed throughout the

image. This may result from several factors. It may be the case that the system discretizes the *U* and *V* channels into bins that are too large, which means that image regions that contain color gradients may appear choppier. Also in the case of black and white video colourization we noticed that it is taking too long to display the coloured final video. Mostly shorter videos are giving fast and accurate results.

Chapter 7

Conclusion

The CNN based Image Colorization using OpenCV will provide an easy and efficient way to colorize and transform old greyscale images which will help us a lot to study our past cultures and heritages in depth.. The main features of this model is that it is unique, and has a high output quality.

And as for us as developers, making this project was indeed a very enriching and fruitful experience. It was realised how with a little effort and innovation technology can be put to good use for the society and preservation of our cultural heritage. As a varied number of technologies were used in developing this project, the technical skills and knowledge of each and every member was tried and tested along with their problem solving and social co-operation skills. This gave us an opportunity to learn from each other and also taught how to solve any problem as a team.

We sincerely hope this technology will be able to help people as much as possible and we hope with more research and effort ,this model can be sculpted to help people across a variety of fields and sectors.

7.1. Future Work

Our results indicate that the presented method can be used as a creativity tool to assist human artists in near future.Our work therefore lays a solid foundation for future work. Moving forward, we have identified several avenues for improving our current system. To address the issue of color inconsistency, we can consider incorporating segmentation to enforce uniformity in color within segments. We can also utilize post-processing schemes such as total variation minimization and conditional random fields to achieve a similar end.

Reference

[1] Lasagne. https://github.com/Lasagne, 2015.

[2] R. Dahl. Automatic colorization. http://tinyclouds.org/colorize/, 2016.

[3] X. Glorot and Y. Bengio. Understanding the difficulty of training deep feedforward neural networks. In International conference on artificial intelligence and statistics, pages 249–256, 2010.

[4] B. Hariharan, P. Arbelaez, R. Girshick, and J. Malik. Hyper- ´ columns for object segmentation and fine-grained localization. In Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition, pages 447–456, 2015.

[5] K. He, X. Zhang, S. Ren, and J. Sun. Deep residual learning for image recognition. arXiv preprint arXiv:1512.03385, 2015.

[6] M. J. Huiskes and M. S. Lew. The mir flickr retrieval evaluation. In Proceedings of the 1st ACM international conference on Multimedia information retrieval, pages 39–43. ACM, 2008.

[7] S. Ioffe and C. Szegedy. Batch normalization: Accelerating deep network training by reducing internal covariate shift. arXiv preprint arXiv:1502.03167, 2015.

[8] D. Kingma and J. Ba. Adam: A method for stochastic optimization. arXiv preprint arXiv:1412.6980, 2014.

[9] A. Krizhevsky, I. Sutskever, and G. E. Hinton. Imagenet classification with deep convolutional neural networks. In Advances in neural information processing systems, pages 1097–1105, 2012.

[10] A. Oliva and A. Torralba. Modeling the shape of the scene: A holistic representation of the spatial envelope. International journal of computer vision, 42(3):145–175, 2001.

[11] A. Olmos et al. A biologically inspired algorithm for the recovery of shading and reflectance images. Perception, 33(12):1463–1473, 2004.

[12] O. Russakovsky, J. Deng, H. Su, J. Krause, S. Satheesh, S. Ma, Z. Huang, A. Karpathy, A. Khosla, M. Bernstein, et al. Imagenet large scale visual recognition challenge. International Journal of Computer Vision, 115(3):211–252, 2015.

[13] K. Simonyan and A. Zisserman. Very deep convolutional networks for large-scale image recognition. arXiv preprint arXiv:1409.1556, 2014.

[14] I. Sutskever, J. Martens, G. Dahl, and G. Hinton. On the importance of initialization and momentum in deep learning. In Proceedings of the 30th international conference on machine learning (ICML-13), pages 1139–1147, 2013.

CNN based Image Colorization using OpenCV

Amrit Ghosh 1729009

Abstract: Historians, filmographers, archaeologists etc have long searched for methods for colourising old black and white photographs. Although various colorisation techniques have been invented since, none of them have been able to provide efficient and accurate real time colourisation.

We present a convolutional-neural-network-based system that faithfully colorizes black and white photographic images without direct human assistance. We explore various network architectures, objectives, color spaces, and problem formulations. The final classification-based model we build generates colorized images that are significantly more aesthetically-pleasing than those created by the baseline regression-based model, demonstrating the viability of our methodology and revealing promising avenues for future work.

Individual Contribution and Findings: Before fitting the dataset into the model, it was neccesary that the dataset was properly pre-processed. The task of data pre-proccesing was taken by me. All the images were first converted into a standard format for before fitting into the model.

Individual Contribution to project report preparation: In the project report, I was responsible for,

1. Documentation of the Tools and Technology used Chapter.
2. Explanation of the system environment and hardware used .

Individual Contribution for project presentation and demonstration: I've contributed towards the introduction of our project and explanation of the mission statement.

Prof. Rajdeep Chatterjee
Full Signature of Supervisor

Full signature of the student

CNN based Image Colorization using OpenCV

Arpan Roy Chowdhury 1729016

Abstract: Historians, filmographers, archaeologists etc have long searched for methods for colourising old black and white photographs. Although various colorisation techniques have been invented since, none of them have been able to provide efficient and accurate real time colourisation.

We present a convolutional-neural-network-based system that faithfully colorizes black and white photographic images without direct human assistance. We explore various network architectures, objectives, color spaces, and problem formulations. The final classification-based model we build generates colorized images that are significantly more aesthetically-pleasing than those created by the baseline regression-based model, demonstrating the viability of our methodology and revealing promising avenues for future work.

Individual Contribution and Findings: After fitting and training the model, the responsibility to test the accuracy and efficient was taken by me. The model was tested on different formats and lengths of videos to test the accuracy of the model.

Individual Contribution to project report preparation: In the project report, I was responsible for,

2. Documentation of the Result and Analysis Chapter.

2. Chalking out the strengths and weaknesses of the model.

Individual Contribution for project presentation and demonstration: I've contributed towards the explanation of the video colorisation model and demonstration of its implementation and output .

Prof. Rajdeep Chatterjee
Full Signature of Supervisor

Full signature of the student

CNN based Image Colorization using OpenCV

Avirupa Saha 1729021

Abstract: Historians, filmographers, archaeologists etc have long searched for methods for colourising old black and white photographs. Although various colorisation techniques have been invented since, none of them have been able to provide efficient and accurate real time colourisation.

We present a convolutional-neural-network-based system that faithfully colorizes black and white photographic images without direct human assistance. We explore various network architectures, objectives, color spaces, and problem formulations. The final classification-based model we build generates colorized images that are significantly more aesthetically-pleasing than those created by the baseline regression-based model, demonstrating the viability of our methodology and revealing promising avenues for future work.

Individual Contribution and Findings: After recieving the dataset, I undertook the responsibility to implement the proposed CNN-based deep learning model. The model was fitted and trained on the ImageNet dataset.

Individual Contribution to project report preparation: In the project report, I was responsible for,

1. Documentation of the Implementation Chapter.
2. Step by step explanation of the model building procedure.

Individual Contribution for project presentation and demonstration: I've contributed towards the overview of the deep learning methodology used and explanation of the model implementation.

Prof. Rajdeep Chatterjee
Full Signature of Supervisor

Full signature of the student

CNN based Image Colorization using OpenCV

Krishnendu Kundu 1729030

Abstract: Historians, filmographers, archaeologists etc have long searched for methods for colourising old black and white photographs. Although various colorisation techniques have been invented since, none of them have been able to provide efficient and accurate real time colourisation.

We present a convolutional-neural-network-based system that faithfully colorizes black and white photographic images without direct human assistance. We explore various network architectures, objectives, color spaces, and problem formulations. The final classification-based model we build generates colorized images that are significantly more aesthetically-pleasing than those created by the baseline regression-based model, demonstrating the viability of our methodology and revealing promising avenues for future work.

Individual Contribution and Findings: To build an accurate and efficient model, it was important to have a proper dataset to train the model upon. After going through multiple sources and different datasets, the ImageNet dataset was chosen as it was indeed a very enriched dataset with thousands of images with different resolution, hue, contrast and lighting.

Individual Contribution to project report preparation: In the project report, I was responsible for,

1. Documentation of the Concluding Chapter.
2. Chalking out the future scope of the project.

Individual Contribution for project presentation and demonstration:I've contributed towards the conclusion of our presentation and demonstration of the immense future potential of our project.

Prof. Rajdeep Chatterjee
Full Signature of Supervisor

Full signature of the student

CNN based Image Colorization using OpenCV

Ritwik Das 1729054

Abstract: Historians, filmographers, archaeologists etc have long searched for methods for colourising old black and white photographs. Although various colorisation techniques have been invented since, none of them have been able to provide efficient and accurate real time colourisation.

We present a convolutional-neural-network-based system that faithfully colorizes black and white photographic images without direct human assistance. We explore various network architectures, objectives, color spaces, and problem formulations. The final classification-based model we build generates colorized images that are significantly more aesthetically-pleasing than those created by the baseline regression-based model, demonstrating the viability of our methodology and revealing promising avenues for future work.

Individual Contribution and Findings: After fitting and training the model, the responsibility to test the accuracy and efficient was taken by me. The model was tested on varied categories of with images different resolution, hue, constrast, lighting and image quality.

Individual Contribution to project report preparation: In the project report, I was responsible for,

1. Documentation of the Introductory Chapter.
2. Forming the basic structure of the Project Abstract.

Individual Contribution for project presentation and demonstration: I've contributed towards the overview of the Model Architecture and Result Analysis.

Prof. Rajdeep Chatterjee
Full Signature of Supervisor

Full signature of the student