INDIAN INSTITUTE OF INFORMATION TECHNOLOGY
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IIVP632C COURSE PROJECT

Automatic Road Extraction from Satellite Image

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1 Abstract

This paper presents the project titled "Automatic Road Extraction from Satellite Image" which aims to extract Road networks from Satellite images of the ground. This is more challenging compare to road extraction from the aerial images because satellite images are more noisy and comparatively of the lower resolution than the aerial images. Variety of the network structures with different number of the epochs or iteration times are used to train the model and to determine the model with best network structure so that results can be obtained with more accuracy.

Keywords: *artificial neural network, road extraction, deep convolution neural networks, satellite imaging, binary classification, image augmentation*

2 Introduction

Road network detection is the process of detecting and extracting the road network from high resolution satellite images. It is essential for many applications like map generation and updating. To do this road network detection, resolution of satellite images plays an important role. If experts try to label the road pixels manually, it will take more time and will lead to errors. Hence an automatic method is proposed here.

Satellite images consist of the various parts of the earth and various other planet and stars which are taken through the use of the satellites. Satellite images provides the details about various natural and man-made features of the earth. These help in the various fields of studies like astronomy, agriculture, geology, etc. These are also used in google maps which help in finding and locating the different paths and locations. Road extraction from these images is one of the most important application as it can be of great help for the map, tourists, cabs, etc.

Road which is one of the most important man-made object, is a matter of the great concern for the researchers to be extracted as road extraction can be of great help. Lots of the researches have been done in this field. In the process of the road extraction, the first step can be road detection. This paper introduces the method in which road extraction has been done through the use of the artificial neural networks. This paper uses different type of the artificial neural network structures and test them using different hyperparameters.

3 Problem Statement

Road networks segmentation and extraction are significant part of the map generation (landscape , terrain etc). Rural and urban road segmentation and extraction have varied application from shortest path to destination , traffic regulation, navigation systems , to road network generation of the entire place. Therefore accurately extracting road or network of roads from satellite images becomes an important activity . Satellite images are more noisy and have less resolution in comparison to aerial images . Thus , extracting road from satellite images itself possess a difficult task.

4 Implementation Details

4.1 Learning using Patch based labels

The inputs are a set of satellite images provided and these maps to corresponding binary image which is the expected output for those provided satellite images. These satellite images can either be of the form of RGB or grayscale ,the corresponding mapped image is of the same size of the image. In our training image folder we have two folder the corresponding maps are provided as same image file name but in different folders named ”groundtruth” and ”images”.

We propose modeling the observed map distribution using neural networks. Neural networks are particularly better suited to aerial or satellite image labeling tasks because they offer several distinct advantages. Most importantly, neural networks have been shown to work particularly well on perceptual tasks with large amounts of labeled data, outperforming expert-designed systems in multiple domains.The other advantage is the ease with which the neural networks workings can be parrallelized in the GPU cores this makes it much efficient to be worked with the large datasets and it yields results with more accuracy and precision.
"CNNs" or Convolutional Neural Networks are generalized versions of multi-layers perceptrons which are best networks used in the field of computer vision and image processing, image segmentation.The basic fundamental mathematical operation involved in this is mathematical convolution .So instead of basic matrix multiplication we will perform convolution operation For binary labeling tasks, we use deep neural networks that have one output unit for each pixel of the map patch $\tilde{m}$ with the output of unit i representing the predicted probability that the label i is 1. Since they encode probabilities, these output units use the logistic activation function defined as $\sigma(x) = \frac{1}{1+e^{-x}}$ (i.e a sigmoid function).
More formally, $f_i(s) = \sigma(a_i(s)) = P(m_i = 1|s)$
Here f_i is the value of output in layer 'i' and the a_i is the net input fed to the output. $P(m_i = 1|s)$ indicates the value of corresponding mapped pixel in arbitrary train should be matching in correlation with the following mapped output that we have already trained the data for.

4.2 Proposed Network

4.2.1 Local Feature Encoding

The local feature encoder is a group of convolutional layers designed to extract local features and narrow the feature map size. Commonly a CNN based encoder cascades several convolutional layers with small

kernels into blocks because those blocks have fewer parameters to train but work better in non-linear feature extraction.

4.2.2 Feature Processor

The feature processor is designed to extract context features over the entire feature map. It is built by several blocks of convolutional layers and distributed LSTM layer.

4.2.3 Output Decoder

The output decoder is designed to decode the output tensor of the feature processor to a final row vector. The decoder samples the feature map in horizontal but further narrow the feature map in vertical.

4.3 Network Implementation and post processing

The proposed network is implemented in the Keras platform with TensorFlow backend .We tried running the data based on training models, and the corresponding weights were obtained ,Thus for every input satellite image we get the corresponding CSV output of the image (comma separated value) first value is given as x-y-z where x is the image number y and z are the coordinates based on the patch size as 16, and the second value k is the intensity value. Thus we obtained the desire output image reading that CSV file and making that image using PIL in python. The size of the patch is 16×16 ,So our implementation goes as copying the first value of the pixel i.e a multiple of 16 into a non multiple value which are present in the same grid.

4.4 Masking

The intermediate output generated is a binary image where the white part shows the network of roads while the black part represents the rest.We use this image as a mask on the original image to highlight

the roads while keeping the remaining areas intact. The final output will have the network of roads highlighted in black.

5 Dataset

We have used the **Road_segmentation_dataset** which can be downloaded from:
`https://www.kaggle.com/srikaranand/road-segmentation-dataset`.

6 Base Paper

The base paper which has been used by us for the implementation of this project titled as **Automatic Road Extraction from Satellite Image** is **Volodymyr Mnih and Geoffrey E. Hinton, "Learning to Detect Roads in High-Resolution Aerial Images", Department of Computer Science, University ofToronto, 6 King's College Rd., Toronto, Ontario, M5S 3G4, Canada, 2013**.

The part which we had taken from the base paper is the idea of using neural networks to detect the roads from images. By studying how the base paper has implemented the convolution neural networks and related techniques to detect the roads from high resolution aerial images, we have tried to use it our project. Although the idea of using convolution neural network(CNN) is same, but the CNN model which had been implemented in our project has been modified in order to make it fit for detecting the roads in satellite images as CNN in base paper is only fit for aerial images.

The one of the part which we had modified in our project compared to the method given in base paper is that the base paper has made use of the aerial images while in our project we have used satellite images. Since aerial image which are mainly taken from near to earth surface through drones,etc, hence they are of much higher resolution than the

satellite images which make it much easier to detect patterns like roads in aerial images. While satellite images which are of lower resolution compared to aerial one required better neural network models.

The another modification which we have made from base paper is that we have tried to sharp the input image using appropriate image sharpening filters and sharpening techniques to make the differences clear so that we can yield better and more accurate results. The method used in base paper has not used any such kind of sharpening techniques.

7 Results

We have generated a binary image(Intermediate Output) from the satellite image where the white portion represents the network of roads while the black part depicts the rest. This image is then used as a mask on the original image to obtain the output image(Final Output) which highlights the roads in the original image. The roads are extracted from the network of roads in satellite image with good accuracy .

Figure 1: Input Satellite Image

Figure 2: Intermediate Output

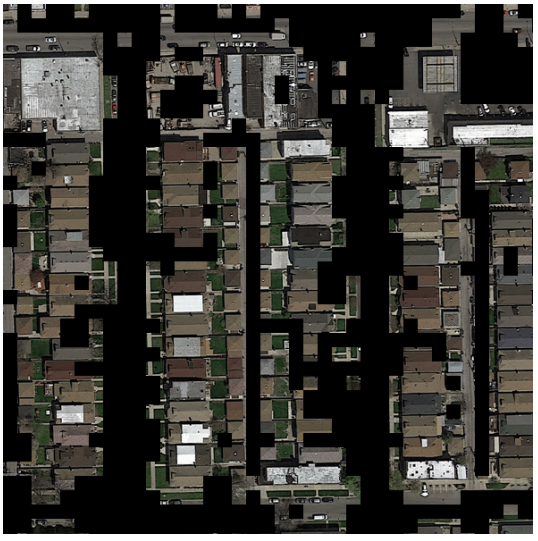

Figure 3: Final Output

8 Activity Time Chart

- Project Title - Start of February
- Literature Review, Problem Statement, Formulation and Report - Mid-February
- Finalizing Methodology - End of February

- Understanding and learning concepts and technologies required - First week of March
- Dataset Collection - First week of March
- Coding and Implementation(75%) -2nd Week of March to 3rd April 2020.
- Complete Coding and Implementation - 12th April 2020
- Testing and Improvement - 15th April 2020
- Submission - 25th April 2020

9 Languages, Tools and Requirements

- Python 2,3
- Keras , Tensorflow , OpenCV and PyTorch Libraries
- Operating System - Linux (Ubuntu) or Windows
- Intel i5 or above processor
- RAM - 8GB minimum

10 Literature Review

10.1 Road detection from Satellite Images, International Journal of Applied Earth Observation and Geoinformation (2007)

Published in 2007, by International Journal of Applied Earth Observation and Geoinformation, authored by M. Mokhtarzade and M.J. Valadan Zoej, this article deals with the possiblity of using Artificial Neural Networks for detecting Roads from High-Resolution Satellite Images on a part of RGB Ikonos and Quick-Bird images from Kish

Island and Bushehr Harbor. It was tested for various network structures with various iteration times and the best network structure and termination condition were selected.
One of the most important advantages of neural networks as compared to conventional statistical methods is that they are distribution-free operators, because the learning and recalling depend on the linear combination of data pattern instead of the statistical parameters of the input data.
In this paper the pixels of the input image were given as input to the Artificial Neural Network. The output is the pixels of output image, each being 0 (if not a pixel of a road) or 1 (pixel of a road). Overall accuracy is actually the percentage of correctly classified pixels to all available pixels in entire image. The networks are again tested across various number of hidden layers. More hidden layers help modulate more complex problems, but in this case the problem is just a low-complexity classification problem, number of hidden layers do not matter beyond a certain range, but only causes more training time.
In [1], a back-propagation neural network was implemented with different hidden layer sizes trained with different iteration times to prevent over-training problem. It was found that there is no need to design more than 10 neurodes in hidden layer as it does not improve results noticeably. In fact, it makes the training and recalling stages more time-consuming.

10.2 Road Extraction from High Resolution Image with Deep Convolution Network

This paper [2] which was named as "Road Extraction from High Resolution Image with Deep Convolution Network" was published in March 2018 by National Engineering Laboratory for Transportation Safety and Emergency Informatics, and authored by Wei Xia, Yu-Ze Zhang, Jian Liu, Lun Luo and Ke Yang. In this paper the authors tried to make a Deep Convolutional Neural Network (DCNN) which would detect Roads in Satellite Images taken by the Satellite **GF-2**. The

GF-2 satellite data is used for experiments, as its images may show optical distortion in small pieces. Experiments in this paper showed an accuracy of more than 80%.
The images of GF-2 satellite are quite prone to Optical Distortion. This paper aims to handle this problem mainly by the following ways. Firstly, inspired by the basic idea of big data, we try to use data of large scale and varied information, in order to gain different conditions; as many as possible. Secondly, we use DCNN methods with very deep layers to learn the abstract features from these conditions. In this experiment, GF-2 data of different locations and seasons in collected and divided into 256x256 sized images, producing thousands of images for training.
According to the experiments, a total correctness of approximately 80% can be obtained through our proposed method.

10.3 Automated Road Extraction from High Resolution Satellite Images

This paper was produced in International Conference on Emerging Trends in Engineering, Science and Technology (ICETEST - 2015) authored by Jose Hormese and Dr. C. Saravanan . In this paper they illustrated a novel approach to road extraction from satellite images using vectorisation approach which mainly applied through 3 steps.

1. the image is segmented to roughly identify the road network regions
2. the decision making and continuity procedure to correctly detect the roads
3. the Vectorization step to identify the line segments or curved segments which represent the roads segmentation .

The vectorization approach is an automatic method in extracting road segments from satellite images. The method adopted is to identify the

road segments which are represented as continuous line segments as the road could be of any arbitrary shape. The start and end points of each line segment is identified and the road segments in the image are correctly extracted.

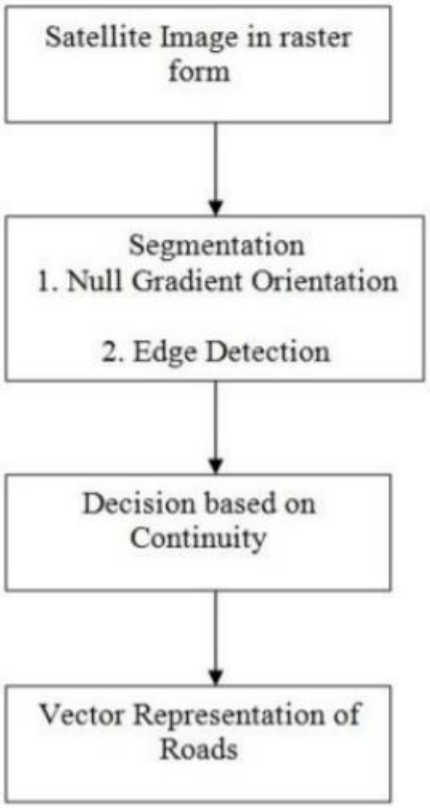

Figure 4 : Automated Road Extraction Flow Diagram

In this paper they cite that this method was more suitable for the rural images as compared to urban areas where man-made objects are less so roads detection are easy . Through segmentation , decision making based on continuity and vectorization procedure the raster satellite images can be converted to vector representation and it is possible to extract roads from satellite images .

11 References

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