Road Detection with Deep Learning in Satellite Images

Zohreh Dorrani
Department of Electrical Engineering, Payame Noor University, Tehran, Iran.
Email: dorrani.z@pnu.ac.ir (Corresponding author)

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ABSTRACT:
Road detection from high-resolution satellite images using deep learning is proposed in this article. The VGG19 architecture, which is one of the deep convolutional neural network architectures, is used in the proposed method. To detect the road, two steps are implemented. To achieve high accuracy, image segmentation is done in the first step. At this stage, based on the semantic division, the objects whose area is small are removed. In the second stage, edge detection of images combines two techniques of segmentation and edge detection to improve road detection. Considering the good accuracy of the VGG19 architecture and the need for few parameters, the obtained results are favorable. To check the performance of the proposed method, the IoU criterion was used. The values obtained for this criterion show an improvement of more than 80%. While this criterion is less than 80% for the compared methods. The obtained results can be used for the purposes of digital mapping, transportation management and many other applications.

KEYWORDS: Convolutional Neural Networks, Deep Learning, Edge Detection, Road Segmentation, Satellite Images, VGG19.

1. INTRODUCTION

Nowadays, due to the expansion of satellites, the analysis and analysis of satellite images [1, 2] is one of the most widely used fields in image processing [3,4]. Due to the accuracy and details of the information required in this field, there are many limitations in the data collection stage, which include the cost of the process and the need to spend a long time [5].

Road detection [6] in aerial images is one of the most critical applications of satellite image analysis. It plays an essential role in transportation applications, because it creates, maintains, and updates the road network database. This information is used in order to perform activities such as traffic management, automatic navigation of vehicles, maintaining security and assessing risks and natural disasters, exchanging and sharing location data in the form of location data infrastructure, and preventing parallel work and repetition placed [7]. The main challenge in road extraction is the complex structure of images, which includes different objects such as roads, houses, trees, etc., with differences in shape and texture. Meanwhile, the ever-increasing increase in deep learning [8] capabilities, which has brought many applications to various sciences and techniques, has caused engineers to pay attention to it and use it in various fields to carry out their projects. Since the introduction of convolutional neural networks, various architectures have been presented that has led to deeper and thus better network and increased accuracy [9]. In this field, VGG architecture has a good structure, and simple and appropriate precision, which has been used in many applications and has had favorable results [10]. Therefore, in this article, this architecture is used to extract roads. In the next section, some research in this field was examined. In the following, the proposed method is analyzed. At the end comes the results and conclusions section.

2. RELATED WORKS

Satellite images contain valuable data that need to be processed and extracted. For this purpose, various techniques have been presented that can extract useful information. The extraction of roads and their segmentation is important information that can be extracted and used for digital mapping. But the presence of factors such as complexity, noise, lack of proper clarity, presence of shadows, obstructions, and environmental factors requires the use of deep learning methods to process these types of images [11]. A method based on deep learning for road detection based on semantic segmentation and edge detection is presented, in which the two techniques of segmentation and edge detection are combined to improve road detection. In this model, a two-part hybrid encoder includes full-resolution feature extraction and high-resolution feature

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encoding. The second part is used to increase the overall receiving field, which provides background information to the network [5].

A deep learning approach using the DenseUNet model is also proposed. This method uses dense connection units and jump connections to solve the problem of decreasing accuracy as the network deepens. On the other hand, the integration of different scales is done in this model, which leads to the strengthening of the network by connections in different layers [12].

SegNet architecture [13] was presented for semantic pixel segmentation. This architecture consists of an encoder network that provides low-resolution encoder feature maps to a decoder network with a pixel classification layer corresponding to the feature maps to generate full input resolution for pixel classification. Therefore, in this model, the input feature map is sampled with a lower resolution. Also, the calculated integration indices are used to perform non-linear sampling to eliminate the need for sampling learning.

For segmentation and separation, fully complex networks (FCNs) [14] can also be used. These networks also use an encoder and a decoder. The first part extracts feature at different levels to segment objects of different sizes, and then a decoder combines the coded features.

3. PROPOSED METHOD

The VGG network has a good and simple structure with a small number of layers and is used in many computer vision fields. This network was introduced with two different architectures VGG16, and VGG19 [15 ,16]. First, the VGG16 network was proposed, and later, with minor changes in the VGG16 network, the VGG19 network was proposed. VGG16 network includes 16 convolutional layers or 16 parametric layers and VGG19 consists of 19 layers. The VGG19 network is an innovative object recognition model and is actually a deep CNN that performs very well in many tasks and datasets other than ImageNet. This network is one of the most widely used image recognition architectures and its architecture is shown in Figure 1.

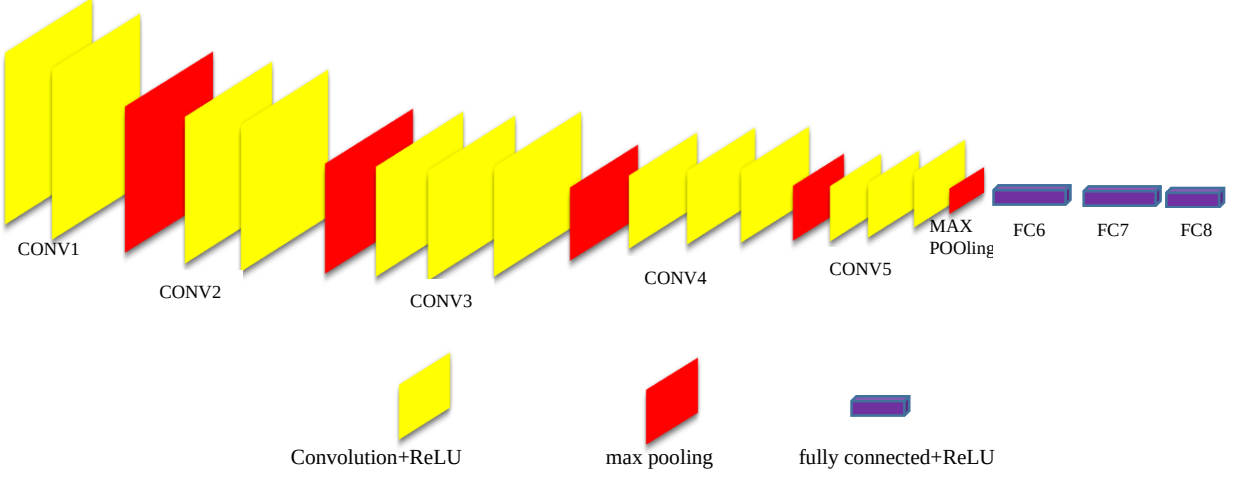

Fig. 1. VGG19.

The unique aspect of VGG19 is that instead of having a large number of meta-parameters, it is a 3x3 filter with a stride of 1 and the max pooling layer is a 2x2 filter with a stride of 2. This architecture includes two convolutional layers with 64 3x3 filters that are placed one behind the other. Then, a 2x2 max pooling layer with a stride of 2 is set. In addition to sampling, this max-pooling layer also has the task of reducing the dimension of features by half. Next, two more convolutional layers with 128 filters of 3x3 and a 2x2 max pooling layer, and 2 jumps are placed. Similarly, three convolutional layers with 256 filters of 3x3and, one 2x2 max pooling layer with 2 hops are included. 3 convolutional layers with 512 filters of 3x3 and a max pooling layer are the continuation of this network, which of course is repeated twice. Finally, the features are converted into a feature vector for fully connected neural layers. Two layers of neurons with dimensions of 4096 are placed one behind the other. Finally, a neural layer with dimensions of 1000, which corresponds to the number of application classes, is considered. The activation function called RELU has been used in all convolution and neuron layers.

Edge detection using VGG19 [17] is used for road detection. Edge detection from raw satellite images is very difficult and does not lead to desirable results. Hence, segmentation is done first and its output is given to edge detection.

Table 1. Size of layer in VGG19.

Layer	size
CONV1	$224 \times 224 \times 64$
CONV2	$112 \times 112 \times 128$
CONV3	$56 \times 56 \times 256$
CONV4	$28 \times 28 \times 512$
CONV5	$14 \times 14 \times 512$
MAX POOling	$7 \times 7 \times 512$
FC6	$1 \times 1 \times 4096$
FC7	$1 \times 1 \times 4096$
FC8	$1 \times 1 \times 1000$

4. RESULT

Reference images [6] have been used to check the proposed method. In this reference, there are 3 satellite images shown in Figure 2. In order to extract roads from these input images, image segmentation has been done first, and using its output, edge detection has been done. For a better comparison, the ground truth is shown in Figure 3b. And in part c of this figure, the results of the method are presented.

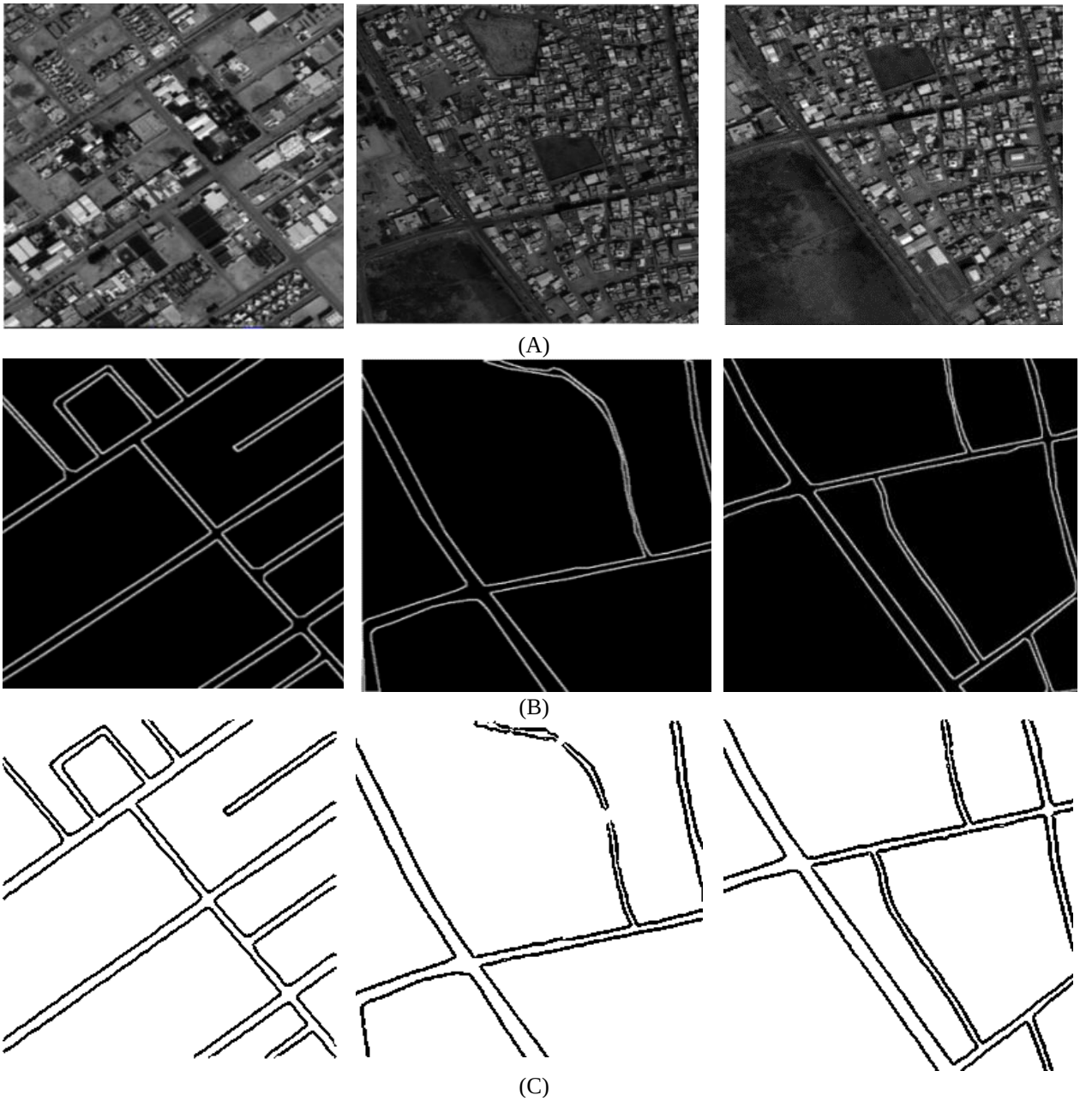

Fig. 2. A: Input Image, B: Ground Truth C: Edge Detection with proposed method.

Comparing the results obtained with ground truth shows that road extraction is done with proper accuracy using deep learning.

The use of evaluation criteria is a suitable method to compare the performance of the proposed method with some existing methods, therefore, the IoU criterion is used, which is obtained by the following relationship [5]:

$$IoU = \frac{1}{c}\sum_{k}^{c}\frac{TP(k)}{TP(k)+FP(k)+FN(k)} \quad (1)$$

C: the number of categories,
TP(k): True Positive,
FP(k): False Positive,
FN(k): False Negative.

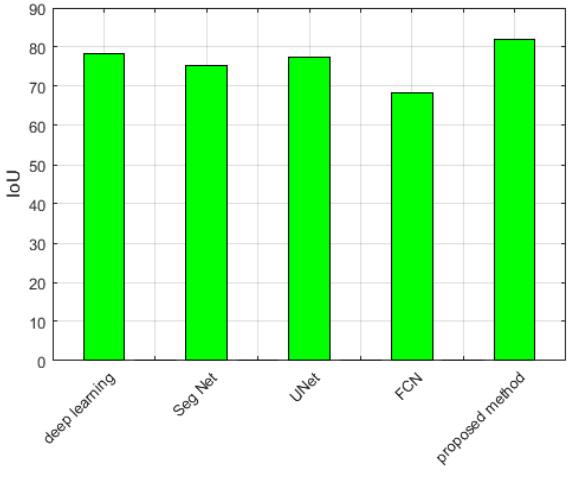

Fig. 3. IoU criterion for proposed method compared to other methods.

The criterion values show that this criterion is above 80% for the proposed method, which is lower than 80% for the compared methods. In the proposed method, an architecture is used that does not require many parameters and therefore can be unique in this aspect.

5. CONCLUSION

Satellite imaging and satellite image processing are used in the mapping. These maps are used in various fields such as agriculture, urban, regional, and forestry planning, and transportation. Today's digital aerial cameras have good storage capabilities. But to do this, they also need a suitable system to store a complete set of images, and the ability to work with very large data and analyze them. In some cases, the ability to prepare a large amount of image data and transfer it to the desired ground reference is required. Computer vision techniques used to process these images can also help to prepare these images. Therefore, in this article, a method based on deep learning was proposed to analyze these images. The VGG19 method was used to extract the roads, which is implemented in two steps. The first stage is segmentation and the next stage is edge detection so that roads can be extracted. The proposed method has led to the improvement of the IoU criterion and has increased its value to over 80%.

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