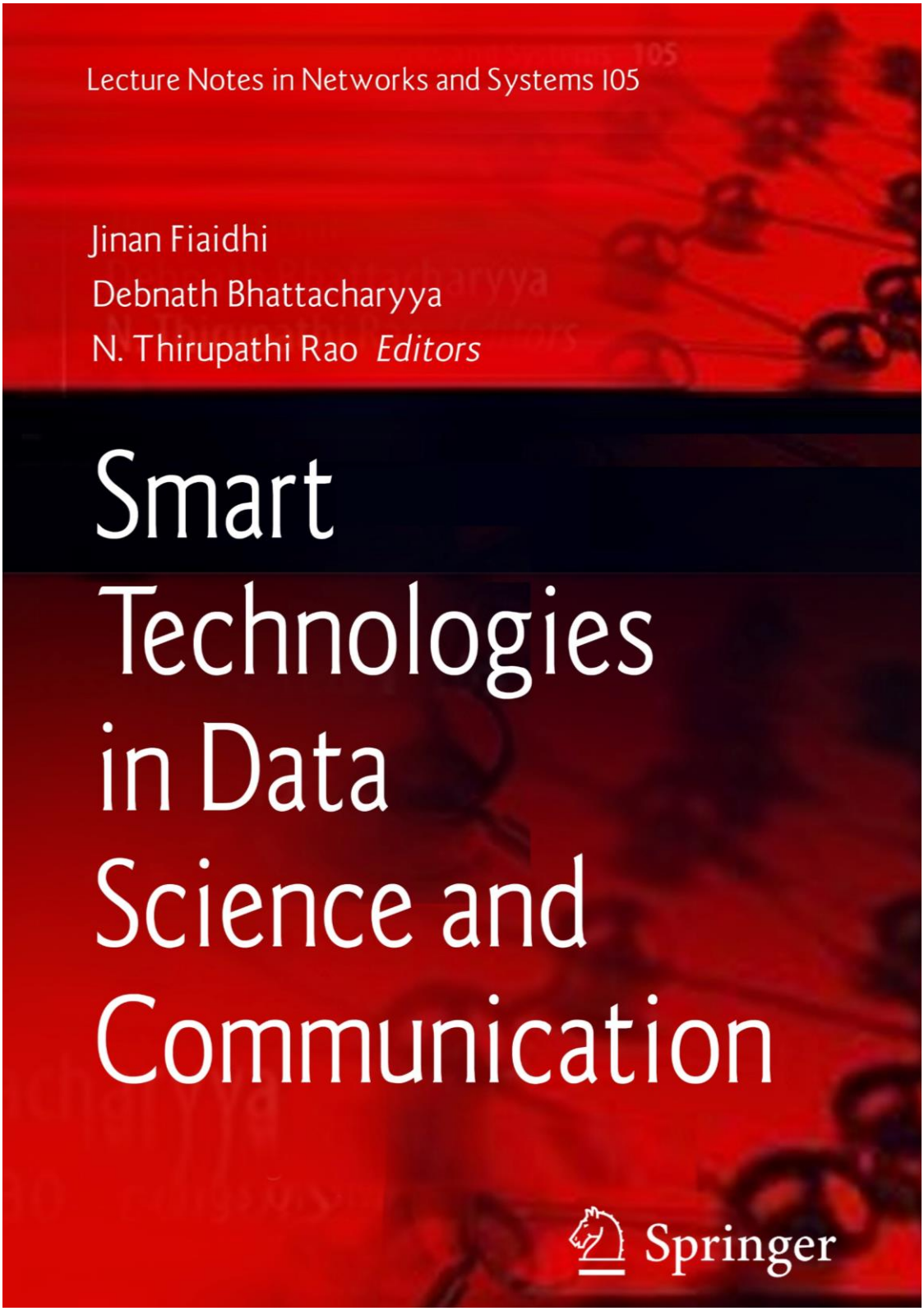
Lecture Notes in Networks and Systems 105
Jinan Fiaidhi
Debnath Bhattacharyya
N. Thirupathi Rao Editors
Smart Technologies in Data Science and Communication
Springer

About the Book:

This book features high-quality, peer-reviewed research papers presented at the International Conference on Smart Technologies in Data Science and Communication (Smart-DSC 2019), held at Vignan's Institute of Information Technology (Autonomous), Visakhapatnam, Andhra Pradesh, India on 13–14 December 2019. It includes innovative and novel contributions in the areas of data analytics, communication and soft computing.

Springer

ISBN: 978-981-15-2406-6

Lecture Notes in Networks and Systems

Volume 105

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ISSN 2367-3370 ISSN 2367-3389 (electronic)
Lecture Notes in Networks and Systems
ISBN 978-981-15-2406-6 ISBN 978-981-15-2407-3 (eBook)
https://doi.org/10.1007/978-981-15-2407-3

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The registered company address is: 152 Beach Road, #21-01/04 Gateway East, Singapore 189721, Singapore

Contents

Roof Edge Detection for Solar Panel Installation

Debapriya Hazra and Yung-Cheol Byun

1 Introduction

Solar panel consists of solar cells which convert light into electricity. Sol or Sun as called by astronomers is the source of light for these solar cells. Solar panels are spread over a large area of the roof where the solar cells conserve renewable energy so that it can be utilized in providing electricity for the home appliances. Installation of solar panels increases access to energy, reduces carbon footprints, and also has low maintenance cost [1]. The amount of energy conserved by the solar panel is directly proportional to the amount of light reaching the panels. Maximum amount of light is emitted by the Sun; therefore, it is important or advisable to align the solar panel with the Sun. So, there is a need to obtain the exact edges of the roof to measure and plan the installation correctly.

To find the boundaries of an object, in our case roof, edge detection is used. Edge detection involves mathematical mechanism which aims to find the points where the image brightness tends to sharpen or change [2]. Connected curves give us the edges of an object in an image which helps in extraction of critical properties or details about the entity. Firstly, noise is removed from an image, then an edge operator is used to detect edges, edges are smoothed using appropriate values of threshold, and then, edge thinning is utilized to remove any factitious points on the edges in an image [2].

Before extracting the edges of the roof tops, it is important to remove any object that is obstructing the boundaries of the roofs. In this paper, we have used Generative Adversarial Network (GAN) for object removal and image completion before

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J. Fiaidhi et al. (eds.), *Smart Technologies in Data Science and Communication*, Lecture Notes in Networks and Systems 105, https://doi.org/10.1007/978-981-15-2407-3_13

detecting the edges of the roof. GAN was invented by Ian Goodfellow and his colleagues in 2014. GAN consists of two deep networks that are the generator and the discriminator. The generative model generates new examples or candidates, whereas the discriminative network evaluates them or classifies them as real or fake. In GAN, the generator and the discriminator are trained together. The generator generates real examples and provides it to the discriminator which updates itself in every next step to classify better between real and fake. There is a feedback system which updates the generator whether it could fool the discriminator. This way, two models compete against each other and play a zero-sum game. When the generator is able to fool the discriminator, no changes are required for the generator, but model parameter has to be updated for the discriminator. Similarly, when discriminator successfully identifies real and fake specimen, the generator has to update its model parameter [3]. This is referred to as the zero-sum game.

In this paper, we have used conditional GAN for object removal from the roof images. Deep convolutional generative adversarial network (DCGAN) has been used for image completion after removing the objects, and then to detect the edges of the roof, we have used Canny edge detection method.

2 Literature Review

In the paper, "A generalized Mumford-Shah model for roof-edge detection," the author has used the Mumford–Shah approach for image segmentation to detect edge of roofs with low contrast [4]. They have compared different variations of the Mumford–Shah model and have concluded that the MS model cannot detect roof edges since it does not include second-order derivative terms. They have modified the parameters in MS model to detect edges of the roof images.

"Edge detection using CNN for Roof Images" is the paper where the author has used transfer learning through Visual Geometry Group (VGG-16) Convolutional Neural Network (CNN) to automatically extract the features. The paper uses Robert edge operator on the automatically extracted features to detect the edges of the roof [5].

In the paper "Automated Edge Detection using Convolutional Neural Network," the author points out that using CNN achieves far better results in detecting edges than any traditional or artificial neural network (ANN) methods [6]. The author claims that CNN generates good results also when it is applied to high-resolution images or live images.

"Adversarial Network for edge detection" is the paper where UNET architecture and conditional generative adversarial network has been used to address edge detection problem. This proposed method claims to achieve a speed of 59 and 26 frames per second for an image resolution of $[256 \times 256 \times 3]$ and $[512 \times 512 \times 3]$, respectively [7]. As the cGAN produces an image that is closed to the real image, the cGAN generator generates edges which are much thinner than the edges obtained from the traditional image processing method.

Edge-enhanced GAN has been used in the paper "Edge-Enhanced GAN for Remote Sensing Image Superresolution" to extract high-frequency edge details in noise-contaminated images [8]. The author claims that the proposed methodology can reconstruct sharp edges and clean image contents that are more realistic and similar to the ground truth [8].

3 Proposed Methodology

In this paper, we have proposed a methodology that uses three steps to obtain the edges of the roof so that the planning for the installation process of the solar panel becomes easier and accurate. The following steps describe our proposed methodology:

1. Removal of the object that is becoming an obstruction in detecting the edges of the roof. To get the clear boundaries of the roof, we use conditional GAN to remove the object from the image.
2. The next step is to restore the background or part of the image from where the object was removed. We used deep convolutional GAN for image restoration.
3. After the object is removed and the image is restored, we detect the boundaries or edges of the roof top. Canny edge detector has been used to detect the edges of the roof.

3.1 Conditional Generative Adversarial Network (cGAN)

cGAN is used to conditionally generate an output. For the generator, the random vector from the latent space is given or conditioned by some extra input in cGAN. The discriminator is also conditioned by giving input image which can be real and fake and an additional input or condition. In short, both the generator and discriminator are conditioned with an additional input in cGAN. We have used cGAN to remove objects like trees, shadow, chimney, and any kind of entity that is guarding the boundaries of the roof. We have developed a user interface, where user can select the pen size and then mark the object to be removed with the pen. Pen size can be changed from 1 to 10. As we can see in Fig. 2, the pen size is 7 and the black part on the left side of the image indicates the object which has been marked by the pen to be removed (Fig. 1).

Fig. 1 Original image

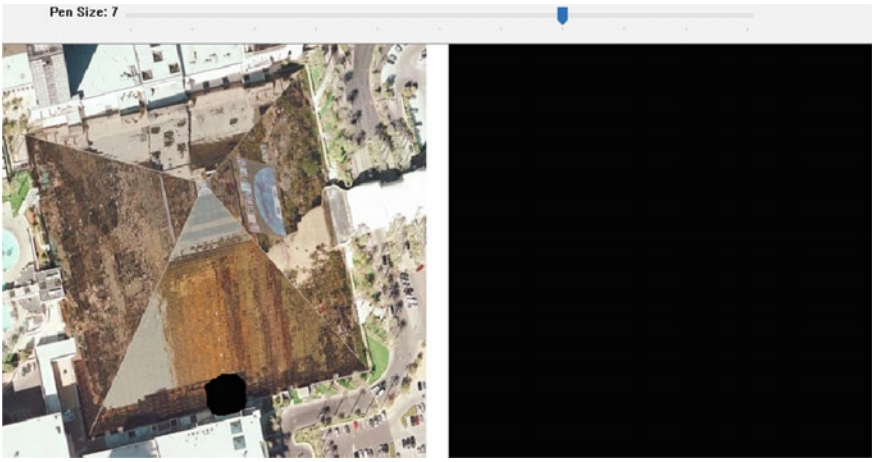

Fig. 2 Marking object with pen that needs to be removed from the image to detect the edges

3.2 Image Restoration Using Deep Convolutional GAN (DCGAN)

DCGAN is one of the network designs for GAN which consists of convolutional layers without max pulling and fully connected layers [9]. DCGAN uses transposed convolution for upsampling and replaces all max pooling with convolutional stride [9]. Except the output layer, batch normalization is used for the generator and the input layer for the discriminator [9]. Figure 3 shows the result of the image completion implemented by DCGAN.

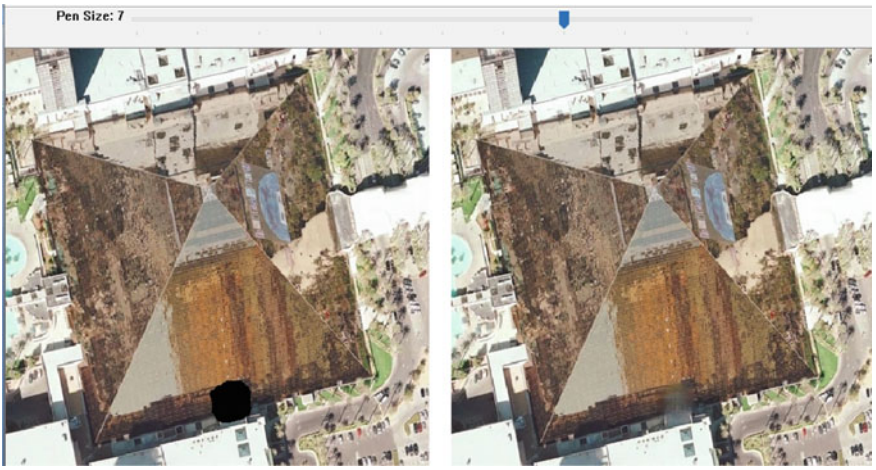

Fig. 3 Image completion using deep convolutional generative adversarial network

3.3 Roof Edge Detection Using Canny Edge Detector

Canny edge detector is a multi-stage detector that applies Gaussian filter first to smooth the image. Then, it finds the intensity gradient and applies non-maximum suppression to remove the fake or extra edges. It applies threshold and detect the edges by hysteresis. After all the preprocessing, removal of object, and image completion, we have used Canny edge detector to detect the accurate edges of the roof for solar panel installation. Figure 4 shows the final result:

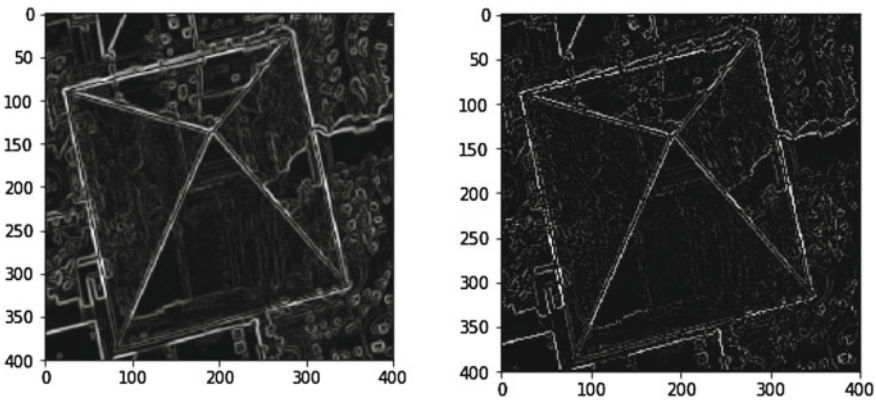

Fig. 4 Roof edge detection using Canny edge detector

4 Conclusion

Our proposed methodology has generated accurate result for roof edge detection which would be helpful to measure and plan for solar panel installation. Usage of cGAN and DCGAN has obtained better results than traditional image processing approaches. We have tested our algorithm with a large image dataset, and the result has been as required and correct 94% of the time.

In future, we would work on automating the whole process of roof edge detection and use machine learning techniques to implement the complete system.

Acknowledgements This research was financially supported by the Ministry of SMEs and Startups (MSS), Korea, under the "Regional Specialized Industry Development Program" supervised by the Korea Institute for Advancement of Technology (KIAT) and "Jeju Industry-University Convergence Foundation" funded by the Ministry of Trade, Industry, and Energy (MOTIE, Korea) [Project Name: Jeju Industry-University convergence Foundation/Project Number: N0002327].

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