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Convolutional Neural Network for Raindrop Detection

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***Abstract*— In the technique of recognizing objects based on camera images, Raindrops that are adsorbed to camera lenses and refracting the incoming light are the main factors of lowering the recognition rate. Existing methods for detecting these droplets mainly define ideal droplet forms and detect areas similar to those defined in the image to determine whether or not to absorb Raindrops in the image. However, since the shape of the droplet varies from lens to lens, it is difficult to determine whether the droplet is absorbed by various cameras by conventional methods. Therefore, this paper presents a Deep learning method of detecting Raindrops of various shapes, which were difficult to detect by conventional signal processing methods.**

I. INTRODUCTION

Raindrops adsorbed by the lens refracts the light that enters the camera lens, causing image disturbance. Image-based recognition algorithms fail to function normally in the distorted image due to deformation where the edge of the image is blurred or bended. Therefore, it is necessary to determine in advance whether Raindrops are adsorbed to prevent misrecognition of image-based recognition algorithms.

Raindrops adsorbed by camera lenses have various sizes and shapes, making it difficult to detect. There is a way to use a stereo camera in traditional methods.[1]. Methods using stereo cameras is to use the characteristics of droplets appearing on both cameras and to detect drops using the refraction of light that appears when they are absorbed by the lens. However, this method requires more than two camera. Another method is to use the Maximum Stable Extremal Regions (MSER)[3]. This method uses inside of a droplet is flat and is mainly based on having a circular shape, and uses MSER to find flat areas and detect areas with circular shapes as Raindrops. This method does not detect various forms of Raindrops, and due to the high complexity of MSER, real-time processing is not possible.

Recently, methods with high accuracy using Deep Learning in the field of image recognition are presented. VGG-16 is the method for detecting Raindrops using Deep Learning.[3]. Unlike other signal processing methods, this method can detect Raindrops in various forms. However, this method has high complexity and is difficult to process in real time.

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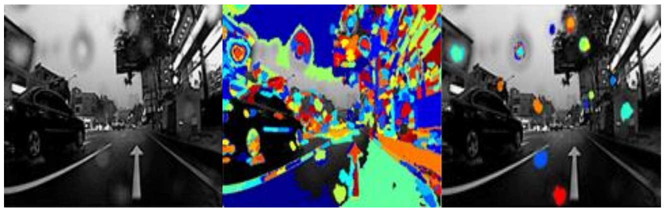

FIGURE. 1. Method for detection of Raindrops using MSER. (a) Original image, (b) Raindrop candidate area detected using MSER, (c) The area of Raindrops detected using a circular form

FIGURE. 2. Various forms of adsorbed Raindrop form. (a) Circular form of Raindrop image, (b) Atypical form of Raindrop image.

VGG-16 is one of the simplest Deep Learning methods that has been developed for image classification in ImageNet data and can be applied to a variety of image classification applications[4]. The existing VGG-16 method was used convolution layer as it is, and only the fully connected layer was changed to detect Raindrops. Therefore, complexity is not much different from VGG-16[3]. This paper developed a simpler network by changing the Convolution Layer of VGG-16 to suit the detection of Raindrops, and this method allows real-time processing enough because the number of parameters in the network is smaller than the original VGG-16.

II. CONVENTIONAL RAINDROP DETECTION METHOD

A. Method for detection of Raindrops using MSER

MSER applies multiple thresholds in the gray image to detect areas with constant brightness in the image[3]. Therefore, the area of Raindrops where the internal brightness is stable is detected by MSER. And in the candidate areas of the Raindrops detected, the candidate areas are removed, not the Raindrops, by using the Raindrops that are usually circular[5]. Figure 1. shows how to detect Raindrops using MSER. However, it is not possible to detect atypical droplets whose shape does not come in a circular form, as shown in Figure 2.

B. Method for detection of Raindrops using VGG-16

An algorithm for detection of Raindrops using the existing VGG-16 only changed the Fully Connected Layer of VGG-16 to determine whether or not to absorb Raindrops in the images[3]. Figure 3. shows the network structure of the existing methods using VGG-16. However, even though Figure 3. is a simple network of structures, it has a parameter

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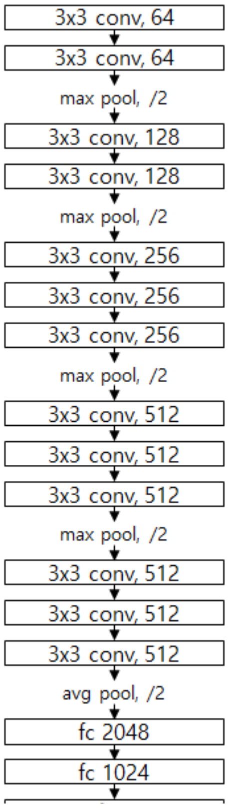


FIGURE. 3. Raindrop detection network using existing VGG-16.

number of 37M when the image size used in this paper is

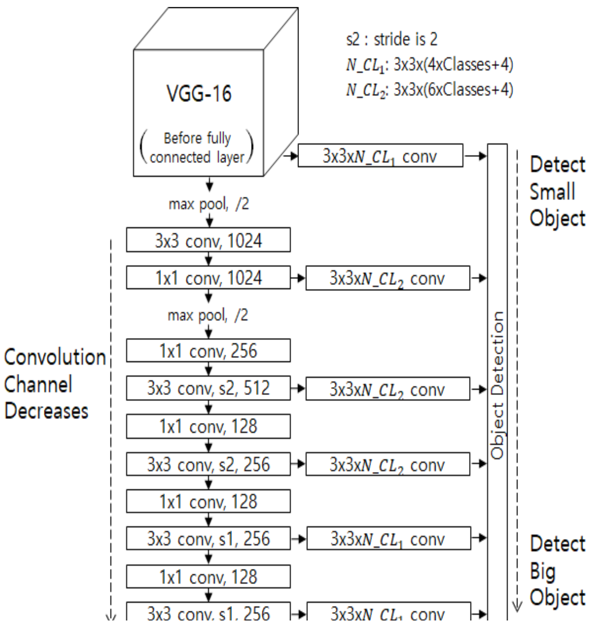


FIGURE. 4. Network Structure of Single Shot Multi-Box Detector (SSD)

160x128. Most parameters occur on the first Fully Connected Layer. The number of parameters occurring on the first Fully Connected Layer is 20M, accounting for approximately 30% of the total number of parameters. Therefore, this paper propose a method of drastically reducing the number of parameters that occur on the Fully-Connected Layer by changing the Convolution Layer.

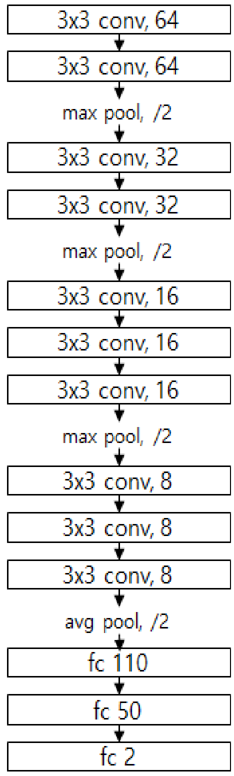
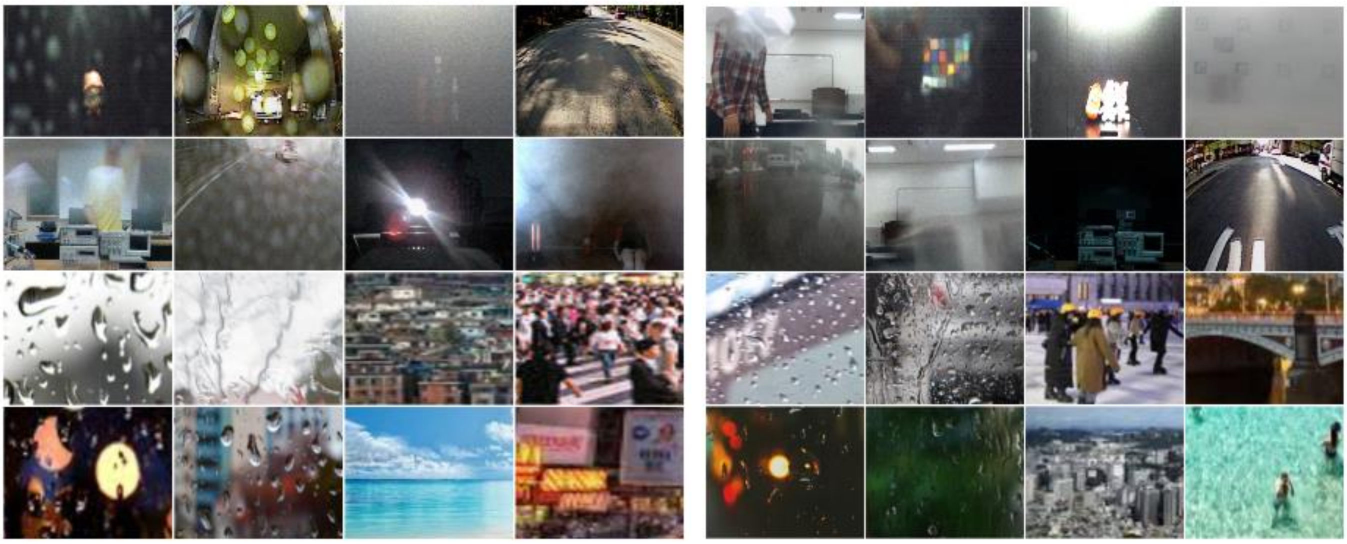


FIGURE. 5. Deformed Water Drop Detection Network of VGG-16 as proposed in this paper

Ⅲ. PROPOSED RAINDROPS DETECTION ALGORITHM

In this paper, the Single Shot Multi-Box Detector (SSD) among the existing Convolution Neural Network (CNN) was referred to in order to detect image disturbance caused by Raindrops in advance[6]. An SSD is a network that detects objects in an image, and it detects large objects while also detecting small objects[6]. Figure 4. shows the network structure of SSD. In this network, larger objects are detected as the layer deepens, and the number of channels on the layer decreases. The image disturbance caused by Raindrops is where large droplets are adsorbed to the lens or small-sized droplets are adsorbed. so In this paper, using the method suggested by SSD, VGG-16 was modified and used to detect Raindrops. Figure 5. shows the structure of the Raindrop detection network proposed in this paper.

The network proposed in this paper has a total number of parameters of 0.15M. This is approximately 250 times less than the 37M parameter number of conventional methods. The proposed network saw a decrease in the number of channels as the layer deepened, which resulted in a decrease in the number of parameters on CNN, with a number of parameters of approximately 0.044M on the first Fully Connected Layer where most of the parameters occurred in the traditional method, significantly reducing the network complexity compared to the traditional method.



(a) (b)

FIGURE. 6 Example Data Base for Network Learning. (a) Training data set, (b) Test data set

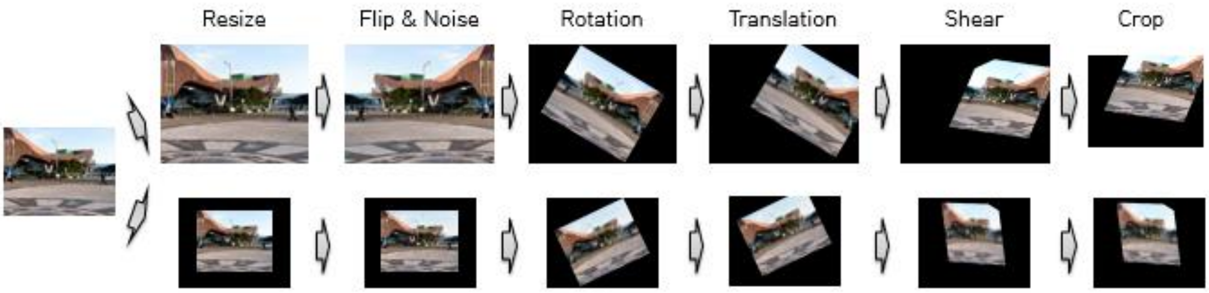


FIGURE 7. Data augmentation example

TABLE 1. Comparison of parameter numbers and detection rates between conventional Raindrops detection methods and proposed methods.
(M: mega)

	MSER	VGG-16	VGG-13	VGG-13 (plain)	Proposed method
Parameter numbers	×	37.78M	93.61M	12.91M	0.15M
Detection rates	0.7730	0.9012	0.9250	0.9360	0.9416

Ⅳ. EXPERIMENT

In this paper, Raindrop image data and normal image data were acquired by camera for network learning and additional data were obtained through searching on the Internet. And with Data Augment algorithm, we've increased the number of image data. Figure 7. shows data augment algorithm. Finally, the data used for learning is 10764 images. Among them, 8261 images were used for training data and the remaining 2503 images were used for test data. The size of the data images is 160×128 . Figure 6. shows the example images acquired.

Table 1. shows the parameter numbers and detection rates of the existing and proposed methods. As shown in Table 1, the signal processing method, MSER, shows a low detection rate in test images consisting of various droplet images. VGG-16 has a higher detection rate than MSER but a higher number of parameters. In addition, in this paper, further tests were conducted on VGG-13, which removed the last three CNNs from VGG-16 and VGG-13 plain, which maintains the number of channels at 64. VGG-13 shows a slight increase not only in the number of parameters that occur on the first Fully Connected Layer but also detection rate also shows a slight increase. This occurs because the image used in this experiment is smaller than the image size used by ImageNet. And VGG-13 plain, which holds the number of channels at 64, shows a decrease in the number of parameters but increases in the detection rate, as the network structure of VGG-16 uses excessive parameters to determine whether Raindrops are judged.

Finally, the method proposed in this paper decreases the number of channels as the layer deepens. As the number of channels decreases, only features remain that determine whether Raindrops are adsorbed or not, and this is ultimately determined by the Fully Connected Layer. Thus, the method proposed in this paper is a network structure suitable for judging disturbance by Raindrops. As shown in Table 1, the proposed method has the highest detection rate with very few parameters compared to other networks.

Ⅴ. CONCLUSION

This paper has developed a simple network by analyzing existing networks to determine only whether Raindrops are adsorbed or not. The developed network is possible method to detect Raindrops in various forms but to process them in real time using CNN's structure because the number of parameters is significantly reduced compared to other networks.

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