Deep Learning based Effective Surveillance System for Low-Illumination Environments

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***Abstract*—Surveillance cameras are installed in various locations and contribute to security maintenance and safety. Thus, the video quality of surveillance cameras is important for safety. However, in situations such as nighttime, low-illumination often causes poor image quality. To solve this problem, we propose a system to help acquire quality images of general surveillance cameras utilized in various places through a combination of image quality improvement networks and object detect networks. This will improve safety in low-illumination areas at night. It is also possible to establish a more effective monitoring system for situations occurring in low-illumination areas.**

Keywords—surveillance; low-illumination; deep learning; object detection; image enhancement;

I. INTRODUCTION

Surveillance cameras are installed in various locations to secure people's safety and prevent emergency situations. However, it is sometimes difficult to obtain clear images, such as surveillance cameras monitoring low-illumination areas. The difficulty of acquiring these images has a bad effect on people's safety. In addition, the difficulty of obtaining images when an accident occurs in the area does not help to identify the cause of the accident. Therefore, improving the low-illumination performance of surveillance cameras is an indispensable issue for keeping the safety of society.

Various methods have been researched using the properties of objects to search vehicle at night. There are vehicle detection methods using the most researched computer vision technology based on vehicle headlight detection and headlight pairing method [1][2]. However, these are generally applicable only if salient features can be found at night, such as vehicles. Therefore, it cannot be applied to objects that do not have bright characteristics, such as person. For this reason, special devices such as infrared camera or thermal camera were used to detect people. But it is practically difficult to install this with all the surveillance cameras. Therefore, inevitably, there is a hole in the surveillance network. Therefore, it is better to use methods to improve the quality of acquired images that can be based on normal surveillance cameras to solve this problem.

There are several studies to improve the quality of camera images[6][7]. From these studies, the change in brightness and contrast of low-light images acquired in an environment such as night can improve the picture quality. Dark video enhancement network (DVENet) [3] shows excellent performance for improving the image performance by changing the brightness of an image to a dark or bright. Using the method of improved image quality of these cameras help to reduce the difficulty of detecting objects in low-illumination as well as allowing them to achieve sufficient performance even with the normal object detector that use color image.

In this paper, the images obtained from the surveillance camera in low-illumination environment at night is quality improved by using DVENet, and object detection system using this quality improved images is proposed. For this purpose, this paper has the following contribution.

- Using image quality improvement technique, object search technique is applied using color images acquired in low-illumination environment.
- Elimination of night low-illumination blind spots from surveillance cameras.
- Establishing the foundation for edge computing systems that can process images acquired from surveillance cameras for immediate use in the event of an accident or accident.

II. RELATED WORKS

A. Deep Learning based Object Detection

Various methods of deep learning algorithms are used to detect objects. A method named Faster-RCNN [4] extracts a feature using the Convolution Neural Network (CNN) after the detection of an object using a specific window. Then the object are defined in the region proposal detected through the final classification process.

These methods inevitably takes a too long time because of using multiple networks. You Only Look Once (YOLO)[5], a method that dramatically shortened time, is a good way to achieve both speed and accuracy in detecting objects. In YOLO, a single network has shown to classify object class, extracting features and creating bounding boxes that enable to detect objects at a speed approximately 10 times faster than the conventional methods.

B. Deep Learning based Object Detection

As a way to improve the performance of low quality images, L. Shen et al.[6] proposed MSR-Net, which uses the CNN architecture to improve the lower image. GLobal illumination Aware and Detail-preserving Network (GLADNet)[7] is to calculate a global illumination estimation for the low-light input, then adjust the illumination

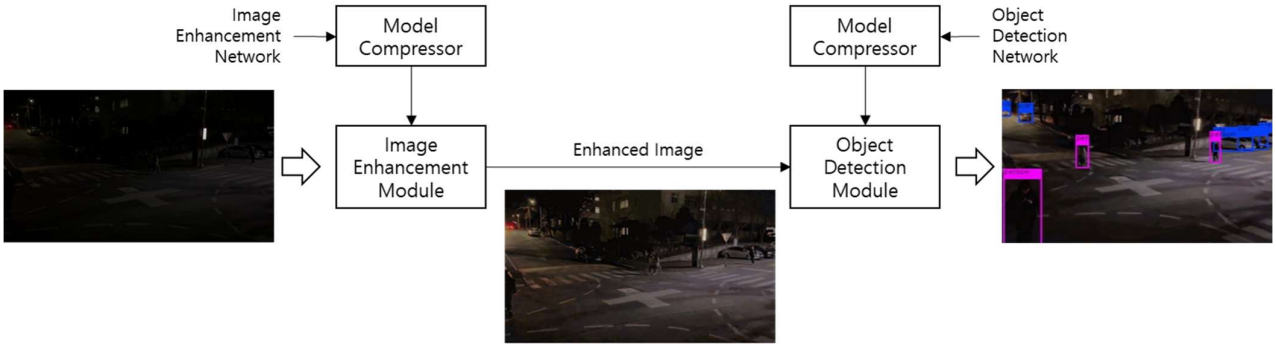

Fig. 1. Proposed System

under the guidance of the estimation and supplement the details using a concatenation with the original input. DVENet[3] shows similar structures to U-net and has a powerful effect on darkening or brightening images.

C. Model Comprssion

Recent deep learning studies are deeper and more complex networks are being studied based on GPUs with very good performance. Learning using the deep learning networks uses millions to billions of parameters, which show excellent performance and provide high accuracy for the tasks you want to apply. However, in some areas, learning or real-time prediction cannot be performed using a deep and complex networks. Most of the reasons are hardware problems with limited resources. Various studies have been done to solve this problem. One of them is the model compression method. This method compresses the deep learning networks so that can perform the necessary tasks with fewer resources. Therefore, it can be applied to areas where work is required with limited resources.

Model compression are divided into methods such as network pruning, low-rank approximation. Quantization, and knowledge distillation[8]. The network pruning method is to remove some of the too many parameters[9]. The low-rank approximation is a method of compressing a network by changing a higher dimensional tensor to a lower dimensional tensor. Quantization is a mapping of large quantities to a finite set of values. The knowledge distillation method is also called the teacher and student network[10]. This is a learning small student networks based on the result of learning using complex, high-performance teacher networks with many existing data.

In this paper, the image enhancement method and object detection method are combined to propose the method of improving night and low-illumination surveillance camera performance. And we also apply model compression techniques for implementing in low-spec computing environments such as edge computing.

III. Proposed System

The proposed system is an effective method at street where light is not lighted well at night. In addition, embedded modules are connected to surveillance cameras so that they can be analyzed directly in the field in order to lay the foundation for edge computing. Once these systems are established, the analyzed images can be viewed directly from the field in the event of an accident.

A. Two Step Process

The proposed system consists of two module. One is the module that improves the quality of the images and the other is detect the objects. In Image Enhancement module, input images are obtained from the surveillance cameras. If it is not low-illumination, such as daytime, then the original image can still be used to navigate objects. However, if low-illumination occurs, passing the image enhancement module adjusts brightness and contrast to improve the image quality.

Improved quality image from image enhancement module are utilized as input images of object detection module. It contains sufficient feature information to detect objects in an RGB image because of the improved quality of the areas that are not detectable due to low-illumination in the original image. Therefore, easy object detection can be performed in the object detection module.

B. Model Compressor

When we work on considering embedded systems with low computing power the aforementioned model gives inadequate performance if we do not incorporate with some other methods like model compression that help to speed up through network compression while keeping the network as accurate as possible. For this purpose, each module is compressed using the model compression method.

At this point, the model compression method applied to the two modules is applied with different compression methods depending on the characteristics of the corresponding network. In object detection module used is a filter-based model compression method. This is one of the network pruning methods. Determine the importance of the filters present in each layer and compress the model by removing filters that are relatively less important. It is also important to set the appropriate rate for the embedded environment used by being able to arbitrarily set the removal rate. And the model compression technique used in the image enhancement module is knowledge distillation. Train student networks using learning result of complex and deep DVENet. In addition, when learning a student network, using local information from where surveillance cameras are installed together as well as information from the teacher network, can gain robust results.

IV. Experiments

NVIDIA Jetson TX2 board and general camera were used for the experiment.

Fig. 2. Original image(Left) and Enhanced image(Right)

A. Image Enhancement

The experimental results in Figure 2 show that the night image quality improvement through image enhancement is very effective. The image on the left is the original image without the camera's post-shot calibration. As the original image becomes darker and darker, the amount of information available on that image decreases. The image on the right was generated through the image enhancement module from the original image. The brightness is significantly improved compared to the original image, indicating that the object detection module has created an image that is very suitable for detection. That means the image enhancement module has excellent performance.

B. Object Detection

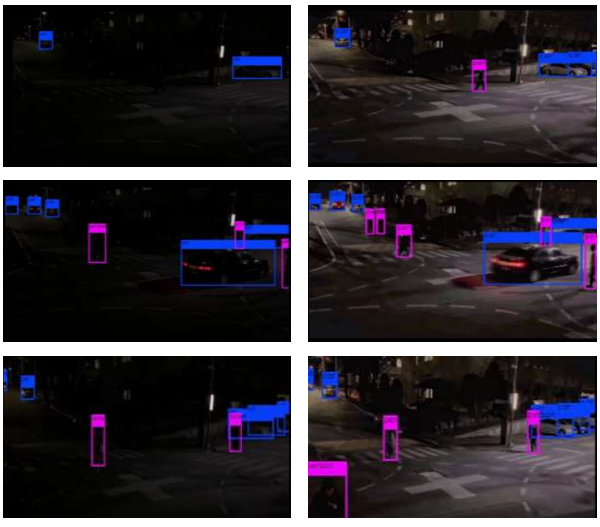

Fig. 3. Object detection in original image(Left) and Object detection in enhanced image(Right)

In Figure 3, the pink box is the result of human detection and the blue box is the result of vehicle detection. In the original image, the detect for objects does not take place properly in the case of loss of appropriate information to detect for objects in black due to low-illumination. However, object detection using enhanced images through image evaluation module showed that image enhancement is effective by detecting for object who were not able to detect due to lack of information in an original image. It can also be expected that surveillance camera images in the low-illumination environment at night will work against the removal of night watch blind spots using the proposed system by showing sufficient effect compared to other existing methods.

V. Conclusion

In this paper, an effective method of securing surveillance images using surveillance cameras for night safety was proposed. The proposed method first improved the image where objects were not detected at night through the image quality improvement method, and then the object was explored through the existing object search method. It was also intended to lay the foundation for edge computing by applying model compression to surveillance cameras monitoring system so that all processes could operate in low computing environments such as embedded systems. From the experimental results, the dark images that could not be identified by the human eye on the actual embedded board could be changed brightly, effectively detecting objects. This is expected to help the surveillance camera system at nighttime. Also effect to reduce blind spot problems due to low-illumination of night surveillance camera monitoring. More effective surveillance camera system establishment is required by combining detail analysis modules for objects detected in future images.

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