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딥러닝 기반 직원 안전용 헬멧과 마스크 분류

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Helmet and Mask Classification for Personnel Safety Using a Deep Learning

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요 약

코로나 시대에서 감염의 위험을 줄이기 위하여 반드시 마스크를 착용하여야 하며, 건축 공사장과 같은 위험한 작업 환경에서 일하는 직원의 안전을 위하여 헬맷을 쓰는 것은 필수불가결하다. 본 논문에서는 헬멧과 마스크의 착용 여부를 분류하는 효과적인 딥러닝 모델 HelmetMask-Net를 제안한다. HelmetMask-Net은 CNN 기반으로 설계되며, 전처리, 컨벌류션 계층, 맥스풀링 계층과 4 가지 출력이 있는 완전결합 계층으로 구성되며, 헬멧, 마스크, 헬멧과 마스크, 헬멧과 마스크을 착용하지 않은 4 가지 경우를 구분한다. 정확도, 최적화, 초월변수의 수를 고려한 실험으로 2 컨볼루션 계층과 AdaGrad 최적화를 가진 구조가 선정되었다. 모의 실험 결과 99%의 정확도를 보여 주었고, 기존의 모델에 비하여 성능이 우수함을 확인하였다. 제안된 분류기는 코비드 19 시대에 직원의 안전을 향상시킬 수 있을 것이다.

ABSTRACT

Wearing a mask is also necessary to limit the risk of infection in today′s era of COVID-19 and wearing a helmet is inevitable for the safety of personnel who works in a dangerous working environment such as construction sites. This paper proposes an effective deep learning model, HelmetMask-Net, to classify both Helmet and Mask. The proposed HelmetMask-Net is based on CNN which consists of data processing, convolution layers, max pooling layers and fully connected layers with four output classifications, and 4 classes for Helmet, Mask, Helmet & Mask, and no Helmet & no Mask are classified. The proposed HelmatMask-Net has been chosen with 2 convolutional layers and AdaGrad optimizer by various simulations for accuracy, optimizer and the number of hyperparameters. Simulation results show the accuracy of 99% and the best performance compared to other models. The results of this paper would enhance the safety of personnel in this era of COVID-19.

키워드

CNN, Classification, Helmet, Mask
CNN, 분류, 헬멧, 마스크

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Ⅰ. Introduction

Personnel safety is critical in complex production environments such as construction sites, mining, and electricity generation plant, etc. For instance, on a construction site, the risk of falling objects from the rooftop can result in a severe head injury or death. The head is the most critical part of the human body that must be protected from such accidents. Wearing a helmet is the most effective mean of protecting the head[1].

Coronavirus disease (COVID-19), which causes severe acute respiratory syndrome coronavirus 2(SARS-Cov-2), has permeated the world after it was first discovered in China in late 2019[2]. Covid-19 is a serious global epidemic[3]. In many places around the world, the use of face mask has been recommended and mandated to the general public to curtail the spread of the virus. Complex production environments are some of the high-risk places where mask usage is important to reduce risk to personnel. Thus, it is pertinent to enforce the use of masks alongside other personnel safety equipment such as the helmet.

Previous studies for personnel safety, particularly on construction sites, have focused on the use of Helmet among other things [4, 5]. Other studies focus on the Mask alone [6-9]. These models are suitable for other public places other than construction sites where Helmet and Mask become essential to protect the personnel from injuries and the spread of COVID-19. In addition, the need for effective deep learning models with fewer trainable parameters to ease computational requirements is pertinent in developing effective models.

Thus, there is a need to consider models that enforce or check for the use of both Helmet and Mask to ensure personnel safety from both injury and COVID-19. This paper proposes HelmetMask-Net for both helmet and mask classification problems. The considered classes for four classification problems include Helmet, Mask, Helmet & Mask, and no Helmet & no Mask. Several HelmetMask-Net network architecture performances are investigated. After using the data preprocessing step, the input image from our dataset is an RGB image of 224x224x3 pixels as resized. We consider 2 to 4 convolutional layers with max pooling and dropout at each convolution layer, a fully-connected layer with 256, and 4 output nodes. The proposed model is evaluated against other models and related works. The main contribution of the research can be summarised :

1. HelmetMask-Net, for classification of multiclass problem: Helmet, Mask, HM(Helmet & Mask), and NHM(no Helmet & no Mask). This is one of the few works to consider both mask and helmet classification problems for construction site applications.
2. Investigation of various HelmetMask-Net architecture for four classification problems.
3. Performance evaluation of the HelmetMask-Net compared to other popular models is presented.

In the following section Ⅱ, the related works are introduced. In section Ⅲ, dataset and methodology are described. Experimental results and performance evaluations are shown in section Ⅳ and Ⅴ respectively. In the final section Ⅵ, conclusion is described.

Ⅱ. Related works

The classification approach has been explored for the Helmet problem. A deep learning method using Single Shot MultiBox Detector (SSD) detection and MobileNet as a classifier has been proposed for helmet detection problems [10]. The model had an accuracy of 85%. Wu and Zhao [5]proposed an automatic Helmet detection with the corresponding colors to enforce the proper use of hardhats. Feature pyramids were extracted using the reverse progressive attention method and SSD was used as a predictor. The best result was obtained with SVM as a classifier. Other related works on helmet problems were found in [11-14].

Mask face detection has also gained interest in this era of COVID-19. For instance, Jauhari, et al. [7]proposed the Viola Jones method for real-time detection of mask face in a pandemic. Chavda, et al. [8]proposed a Multi-Stage CNN architecture to detect improper mask usage. Addagarla, et al. [15]investigated two detection models- FMY3 using Yolov3 and FMNMobile using NASNet Mobile and Resnet_SSD300 algorithm for real-time face mask detection.

On the other hand, classifiers have also been developed to enhance the computer vision model to detect Mask. For instance, Oumina, et al. [6]employ transfer learning (VGG19, Xception, mobileNetv2) to extract features and machine learning (SVM and K-Nearest Neighbors) as classifiers for face mask classification. Similarly, Kayali, et al. [9]investigated deep learning models such as NASNetMobile and ResNet50 for Mask-wearing condition classification; correct, wrong and no mask. Militante, et al. [16]proposed a deep learning approach for facemask classification and physical-distancing detection using the MobileNet model. The proposed model effectively classified persons wearing a cloth mask, N95 Mask, surgical Mask, individuals with no facemask, and detected the individuals maintaining the physical distancing protocol. Meanwhile, Srinivasan, et al. [17]investigated solutions for the detection of a person, social distancing violation, face and classification of face mask classification using object detection, clustering and Convolution Neural Network (CNN) based binary classifier. ResNet, Xception and MobileNet were employed for the classification which gave an accuracy of 91.2%.

Some works have also considered both mask and helmet classification. For instance, Pradana, et al. [18]considered Safety Helmet, Safety Glasses, Safety Masks, and Safety Earmuf for Personal Protective Equipment identification using the CNN model. RGB to grayscale color conversion was applied at the preprocessing stage before the CNN model. However, the model recorded a relatively low accuracy and required preprocessing of the images. CNN model recorded an accuracy of 85.83% for the twelve-classification problem. Our work tries to bridge the gap by integrating both Mask and Helmet classification for personnel safety.

III. Dataset and methodology

3.1 Dataset

The dataset used in this research consists of four classes: Mask, Helmet, HM, and NHM. The mask dataset was obtained from [19]. The dataset of face images Flickr-Faces-HQ3 (FFHQ) has been selected as a base for creating an enhanced dataset composed of correctly and incorrectly masked face images. The NHM dataset consists of only the real face dataset obtained from [20] while the HM dataset where crowdsourced from google images and cropped. The helmet dataset was obtained from the Datafountains dataset [21]. It consists of a safety helmet worn by workers at the construction site. Fig. 1 shows some example images from the dataset and Table 1 presents the dataset composition used in this research.

그림 1. 샘플 이미지
Fig. 1 Sample images

표 1. 데이터세트 구성.
Table 1. Dataset composition

Data Set	Helmet	Mask	HM	NHM
Training Dataset	5160	2867	3569	3471
Validation Dataset	2430	953	2272	1778
Test Dataset	1000	940	1925	1396
Total	**8590**	**4760**	**7766**	**6645**

3.2 Methodology

The proposed method is based on CNN which consists of two steps: data processing and classifier.

3.2.1 Preprocessing

Data processing involves the loading of the image, resizing, normalization and data augmentation techniques like data scaling and flipping. The preprocessed data is then grouped into two groups for training/validation and testing. Fig. 2 shows the block diagram of the proposed method. ① Loading dataset as input, ② Splitting data into two groups, ③ Giving preprocessed training and validation samples to training and classification, ④ Giving preprocessed test samples to the proposed CNN model for testing.

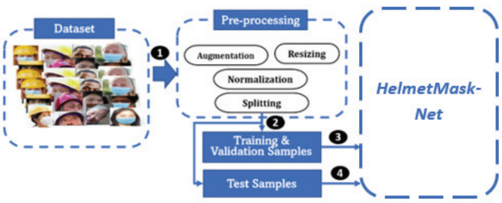


그림 2. 제안된 모델의 블록 다이어그램
Fig. 2 Block diagram of the proposed model

3.2.2 HelmetMask-Net

The structure of CNN used to build the HelmetMask-Net is shown in Fig. 3. We consider 2 to 4 convolutional layers with max pooling and dropout at each convolutional layer, a fully-connected layer and 4 output nodes, which are shown in Fig. 3. We set the four final classification labels as helmet, mask, HM, and NHM.

The number of filters in the first layer is 32 and increases across at a multiple of 2 until it gets a fully connected layer. The HelmetMask-Net design is inspired by [22-23], but we focus on reducing the depth of the model and filters configuration to build a lighter-weight optimal model for Helmet and Mask classification.

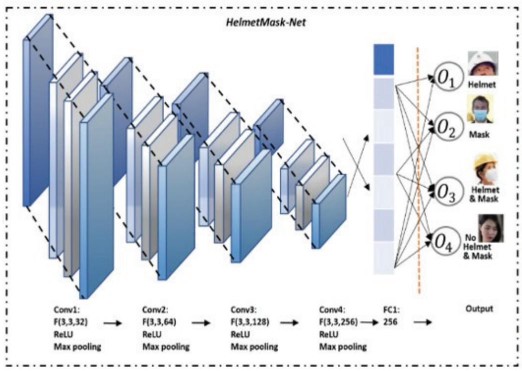


그림 3. HelmetMask-Net 구조
Fig. 3 HelmetMask-Net architecture

Ⅳ. Experimental Results

This section presents the various training, validation, and testing results for the development of the effective model, HelmetMask-Net. The investigations are conducted for four(Helmet, Mask, HM, and NHM) classification problems. The performance of the HelmetMask-Net model against popular models is then evaluated. The model is implemented in Keras using the TensorFlow backend.

4.1 HelmetMask-Net Tuning and architectural investigation

We first determine the optimal hyperparameters for the Helmet-Mask-Net. Table 2 presents the HelmetMask-Net hyperparameter under investigation. In the first phase of the experiment, we focus on determining the optimal dropout and epochs for the model structure that gives the best generalization performance.

표 2. 초월 변수.
Table 2. Hyperparameters

Hyperparameters	Experiment
Filters	Four-layer(32-64-128-256-(FC 256)), Three-layer(64-128-128-(FC 128)), Two-layer(32-64-(FC 64))
Optimizers	RMSprop, Adam, AdaGrad, SGD
Dropout	0.05-0.075
Epoch	10-39
Step per epochs	58

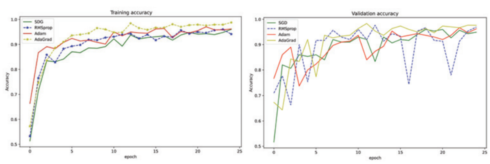
However, before we present the performance of various configurations, a default architecture consists of four layers. Four-layer(32-64-128-256-(FC256)) was employed to determine the optimal dropout and epoch. A dropout is placed between each layer. Then, the softmax function and SGD optimization algorithm are used as an output activation function and optimizer, respectively. The range of the dropout and epochs investigated were 0.05-0.075 and 10-39, respectively, in Table 2. The dropout and epochs of 0.055 and 25 were obtained to be optimal by experiment with the best accuracy of 0.96.

4.2 Four-classification problem

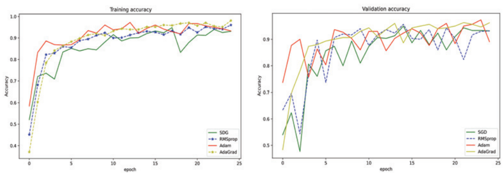
The four-classification problem is considered a more difficult problem where personnel either wear only Mask, only Helmet, Mask and Helmet, or no Helmet and Mask. This situation is the most realistic scenario in the real application. We explore the ability of the HelmetMask-Net to distinguish this situation with high accuracy.

We equally investigate all the architectures for this problem which include the two-layers, three-layers and four layers as described in Table 2. For the training, all the optimizers experienced a progressive improvement throughout the session, reaching an accuracy of above 0.90 in all cases (Fig. 4 (a), (c), (e)). AdaGrad maintains the best performance in all the architectures, while the rest of the optimizers closely compete. On the other hand, the validation performance of the optimizers varied(Fig. 4 (b), (d), (f)). AdaGrad maintains the best progress with steady improvement among some instability of accuracy above 0.90. The rest of the optimizers showed a degree of instability and overfitting in some cases, particularly the RMSprop.

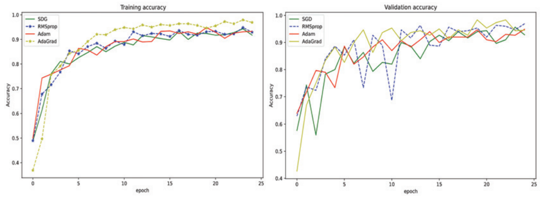
The two-layer architecture demonstrated a better generalization for both training and validation experiments. The optimizers′ performances progress beyond 0.92 accuracies for both the training and validation. Although the validations were rather sporadic, AdaGrad maintained steady progress while RMSprop displays the most unstable progression. Three- and four-layer architectures attained the lower accuracy of 97.725 and 97.05, respectively, compared to two-layer architecture, which recorded 0.99.



(a) two-layer training (b) two-layer validation



(c) three-layer training (d) three-layer validation



(e) four-layer training (f) four-layer validation
그림 4. 컨볼루션 층 수에 대한 훈련과 검증 데이터셋 성능
Fig. 4 training and validation performance as the number of convolutional layer

The two-layer model has best performance testing data with an accuracy of 0.99 in table 3. The three-layer and four-layer model have the accuracies of 0.98 and 0.97 respectively.

표 3. 4 분류 성능 측정
Table 3. Four classification performance metrics

CL	P	R	F1	A
2 CL	0.988	0.985	0.985	0.99
3 CL	0.978	0.978	0.98	0.98
4 CL	0.973	0.97	0.97	0.97

CL: Convolution layer, P: Precision, R: Recall
F1: F1-Score, A: Accuracy

V. Performance evaluation

The HelmetMask-Net shows 0.99, 0.97 and 0.97 TPR for two, three and four layer model in Fig. 5. Two and Three-layer model have the perfect TPR(True positive rate) of 1.0 for Mask. Meanwhile all the models have 0.98 and 0.99 for HM and NHM respectively. The best HelmetMask-Net model is chosen with two-layer(32-64-(FC 64) convolutional network and AdaGrad as illustrated by the TPR plots.

Table 4 shows the performance metrics depending on each class and the convolutional layer.

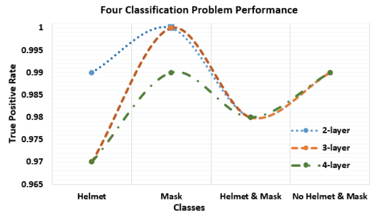


그림 5. TPR을 기반으로 한 분류 성능
Fig. 5 Classification performance based on TPR

표 4. 컨볼루션 계층수에 따른 성능 측정
Table 4. Performance metrics for the number of convolutional layer

# of CL	*Class*	P	R	F1	A
2-CL	Helmet	0.98	0.98	0.98	0.99
	Mask	1	1	1	0.99
	HM	0.98	0.98	0.98	0.99
	NHM	0.99	0.98	0.98	0.99
	Ave	**0.988**	**0.985**	**0.985**	**0.99**
3-CL	Helmet	0.98	0.95	0.97	0.98
	Mask	1	0.99	1	0.98
	HM	0.96	0.98	0.97	0.98
	NHM	0.97	0.99	0.98	0.98
	Ave	**0.978**	**0.978**	**0.98**	**0.98**
4-CL	Helmet	0.99	0.94	0.96	0.97
	Mask	1	0.98	0.99	0.97
	HM	0.93	0.97	0.95	0.97
	NHM	0.97	0.99	0.98	0.97
	Ave	**0.973**	**0.97**	**0.97**	**0.97**

Also, we implement VGG16 and MobileNet to compare with our proposed model. It shows the results of 4 performance evaluation metrics in table 5.

표 5. VGG16 및 MobileNet 성능 메트릭.
Table 5. VGG16 and MobileNet performance metrics

	Class	P	R	F1	A
VGG16	Helmet	0.98	1	0.99	0.99
	Mask	1	1	1	0.99
	HM	1	0.98	0.99	0.99
	NHM	1	1	1	0.99
	Ave	0.995	0.995	0.995	0.99
MobileNet	Helmet	0.99	0.82	0.89	0.91
	Mask	0.88	0.98	0.93	0.91
	HM	0.83	0.91	0.87	0.91
	NHM	0.97	0.93	0.95	0.91
	Ave	0.918	91	91	0.91

And the number of training parameters depends on the layer's output shape size when the model uses the flatten layer to connect a fully connected layer. The proposed HelmetMask-Net with two convolutional layers gets high accuracy of 0.99 with 11.5 million trainable parameters.

The proposed model has a high accuracy of 0.99 same to VGG16, but with less trainable parameters on the same dataset. On the other hand, MobileNet has fewer trainable parameters than our model, but it has a lower accuracy of 0.91 on the same dataset as shown in Table 6.

표 6. 훈련 매개변수에 성능 비교
Table 6. Performance comparison with other works for a trainable parameter

Algorithm	Classifier	Accuracy	Our Dataset	Trainable parameters
Our Framework	elmetMask-Net (four-layer)	0.97	+	7,600,000
Our Framework	elmetMask-Net (three-layer)	0.98	+	10,000,000
Our Framework	elmetMask-Net (two-layer)	0.99	+	11,500,000
VGG16	VGG19-KNN	0.99	+	14,800,000
MobileNet	MobileNet	0.91	+	2,323,000
2021[6]	MobileNetV2	0.97	-	143,700,000
2021[9]	ResNet50	0.92	-	25,600,000

Other related works such as [6], [9], [16], [17], [18], [5], and [10] show lower accuracy of 0.97, 0.92, 0.95, 0.910, 0.860, 0.850 and 0.980 compared to our HelmetMask-Net on a different datasets(Table 7).

"Mask and physical distancing" and HM are considered in [16] and [18] and other related works consider either Mask or Helmet only. The proposed HelmetMask-Net has a reasonable number of hyperparameters and the highest accuracy of 0.99%.

Therefore, HelmetMask-Net is a best solution suitable for effective enforcement of Helmet and Mask in construction sites.

표 7. 정확도 성능 비교
Table 7. Performance Comparison for accuracy

Algorithm	Model	Problem	Our Dataset	Classes	Accuracy
Our Framework (two-layer)	HelmetMask-Ne t	Helmet & Mask	+	4	0.99
2,021[6]	MobileNetV2	Mask	-	2	0.97
2,021[9]	ResNet, MobileNet	Mask	-	3	0.92
2,021[16]	MobileNet	Mask & Physical distansing	-	5	0.95
2,021[17]	MobileNet	Mask	-	2	0.91
2,021[18]	CNN	Helmet & Mask	-	4	0.86
2,021[4]	SSD, SVM	Helmet	-	4	0.85
2,021[10]	CNN, SVM	Helmet	-	4	0.98

VI. Conclusion

COVID-19 has made an urgent matter to ensure personnel safety by enforcing Mask usage as well as other protective gear like Helmet. Unlike most previous studies, which focus on either Helmet or Mask classification, we proposed HelmetMask-Net with 4 labels such as Mask, Helmat, Helmat and Mask and No Helmat and Mask, depending on 2, 3 and 4 convolutional layers. The HelmetMask-Net has been chosen with 2 convolutional layers, AdaGrad optimizer and the small number of hyperparameters.

The proposed HelmetMask-Net would contribute to enhance the safety of personnel in pandemic era like COVID-19.

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