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MILITARY CAMOUFLAGE CLASSIFICATION WITH MASK R-CNN ALGORITHM

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Abstract. Camouflage, which is used as an art of hiding by living things in nature, started to be used in the military field in the 19th century with the widespread use of long-range firearms. When factors such as different nations, environment and climate are considered, we come across camouflages in various colors and patterns. Over time, the camouflage patterns adopted and used by countries or unions have become national identity. This study is on the classification and segmentation of camouflaged soldiers of 5 countries with deep learning. While the similarity of the camouflaged area with the background makes segmentation difficult, it becomes difficult to classify each camouflage pattern due to the cut of the fabric and the different locations of the pattern pieces on each soldier. There are different studies in the literature that are referred to as camouflage or pattern classification. The mentioned studies are in the form of segmentation of camouflaged object or classification of camouflaged objects of different types. Since the segmented and classified objects in this study are camouflaged soldiers, what is expected from the deep learning algorithm is to classify the objects mainly according to the camouflage pattern, not their outlines. In the study, 861 camouflaged soldier images were collected for 5 countries (Türkiye-Azerbaijan, USA, Russia, China, France) and polygonal labeling was made. Türkiye and Azerbaijan are considered a class as they have similar camouflages. For the solution of the problem, military camouflage classification was discussed with the Mask R-CNN algorithm, which is widely used today for object detection, segmentation and classification, and the importance of deep learning algorithms has been proven with such a difficult problem. The training resulted in 0.005219 classification loss and 0.03985 masking loss. The classification and segmentation success rate of the study is 95%.

Keywords. Camouflage, deep learning, Mask R-CNN, classification, segmentation.
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1. Introduction

Until the mid-1800s, armies dressed their soldiers in bright clothes [1]. With the development of more accurate firearms, the first military camouflage was used in 1848 as yellowish dull uniforms by a regiment of the British Indian Army [2]. Towards the end of the 19th century, plain khaki-colored uniforms were adopted by the British army [3]. In addition, in the First World War, patterned uniforms consisting of different colors, which they called 'Fragmentation Camouflage', were used in the German army [3]. While the design of camouflage patterns was in the hands of designers and artists at the beginning of the 20th century, computer technology began to be used in the field of camouflage in the late 1970s [3]. Today, many countries have adopted different camouflage patterns. Even if the camouflages used have different patterns, it is very difficult to derive the mathematical model of these patterns for classification. Although there are image processing approaches for detecting, segmenting or classifying an object, these problems can be solved more accurately and quickly with the evolution of deep learning models.

Different studies have been conducted in the literature on camouflage or pattern classification. Doğan et al. compared different deep learning algorithms such as AlexNet, Vgg16, Vgg19, ResNet50 and GoogleNet on classifying leaf patterns [4]. Gupta et al., with the 58-layer Convolutional Neural Network (CNN) model they customized, made a study that detects various soldiers and equipment with foggy, snowy, night vision consisting of 22 classes [5]. Bayram et al. extracted textural features for camouflage images using Local Binary Patterns (LBP) and classified them with Artificial Neural Networks (ANN), Support Vector Machines (SVM) and K-Nearest Neighborhood Algorithm (KNN) [6]. In this study, Mask R-CNN algorithm [7], which was developed for regional-based object detection and segmentation, was used for segmentation and classification of camouflaged soldier images belonging to 5 different countries. Ömeroğlu et al. used the Mask R-CNN algorithm to detect hangars on high-resolution satellite images with an average accuracy of 85% [8]. Amri et al. used YOLOv5 [9] and Mask R-CNN [10] for stadium detection on multispectral images.

2. Material and Method

2.1. **Material.** For this study, camouflaged soldier images belonging to 5 countries (Türkiye-Azerbaijan, USA, Russia, China, France) were collected and used as a data set. Türkiye and Azerbaijan have similar camouflages due to their joint military efforts. For this reason, it was chosen as a class. The total number of photographs is 558 and contains a total of 861 images of soldiers. The photos are set to 700x700 dimensions and randomly allocated for 80% (448) training and 20% (110) testing.

Images are labeled and ready for training with the LabelMe [11] tool. The number of soldier images used in Table 1 is given separately for each country. Examples of camouflage fabrics belonging to 5 countries are given in Figure 1 and examples of images divided into 5 classes used in Figure 2.

TABLE 1. Distribution of images used in the study.

	Training	**Test**
Türkiye-Azerbaijan	130	28
USA	120	26
Russia	130	34
China	182	35
France	141	35
Total	703	158

FIGURE 1. Examples of camouflage fabrics: Türkiye-Azerbaijan [12], USA [13], Russia [14], China [15], France [16].

FIGURE 2. Examples of camouflaged soldiers: Türkiye-Azerbaijan [17], USA [18], Russia [19], China [20], France [16].

2.2. **Method.** In this study, images were made ready for education by labeling them polygonally with the LabelMe tool. Labeled images were trained with Mask R-CNN algorithm in 20000 iterations and instance segmentation was successfully provided for 5 classes. A fixed learning rate (lr) was not used during the training. The learning rate was reduced in certain steps with the gamma (γ) factor, which is known as the decay or reduction of the learning rate in the deep learning literature, and the training process was continued until the total loss took constant values. Using a fixed and large learning rate will cause the total loss rate to decrease rapidly but will cause the local minimum point to be skipped after a while. Using a fixed and small learning rate will prolong the learning process and may lead to overfitting. Considering the extremely similar characteristics of the classes in the problem, a decreasing learning step approach was preferred. The effect of the gamma multiplier is shown in figure 3. In the study, the learning rate started with the value of 0.004 and was updated by multiplying the value of 0.95 γ so that it decreases by 5% for every 500 steps. After the first 10000 steps of the training, the gamma was set to 0.99 and an update was made every 200 steps.

The Mask R-CNN algorithm used in the study is a region-based convolutional neural network developed based on Faster R-CNN [22]. Instance segmentation is done with Mask R-CNN. This masking process is also the identification of target object pixels in the bounding box predicted by Faster R-CNN.

In Faster R-CNN, first feature mapping is performed with convolutional neural network and then regions containing objects are determined (Region Proposal Network-RPN). The operation in RPN is the basic CNN operation. The region that receives the IoU (Intersection over Union) value, which is the ratio of the highest intersection to the union, from the regions predicted by RPN is sent to the intersection regions called ROI (Region of Interest) in the network. Here, since the bounding box sizes from the RPN are variable, it is converted to a fixed size by clipping (ROI pooling), which the classifier will work more accurately. After the size transformation in the ROI, the class of the predicted region is also determined. The results obtained in Faster R-CNN are sent to the fully connected layer and the class and bounding box information is generated.

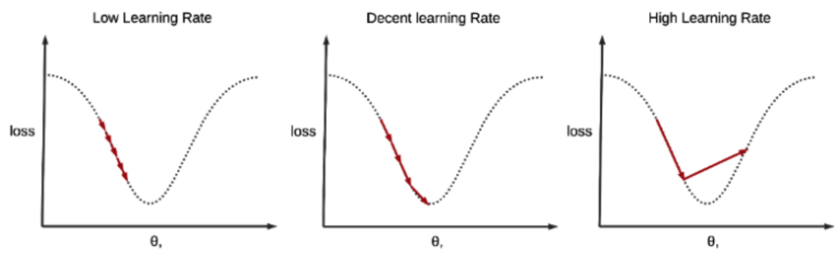

FIGURE 3. Effect of gamma multiplier on learning process: low-constant learning rate, decreasing learning rate, high-constant learning rate [21].

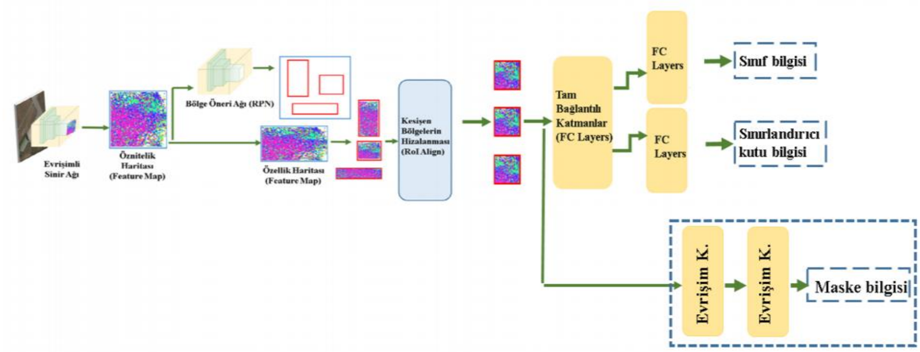

FIGURE 4. General structure of Mask R-CNN [8].

In Mask R-CNN, after ROI, in parallel with the FC layer, mask information is generated by semantic classification. The general structure of Mask R-CNN is given in figure 4. In Mask R-CNN, the loss function (L) is the sum of classification losses (L_{cls}), masking losses (L_{mask}) and frame losses (L_{box}) [23]. The loss function is shown in Equation (1).

$$L = L_{cls} + L_{mask} + L_{box} \quad (1)$$

3. Experimental Studies

The study was carried out with Google Colab on a computer with Intel(R) Xeon(R) CPU @ 2.20GHz processor, Tesla T4 graphics card and 26 GB primary memory, with Detectron2 [24] developed by Facebook Artificial Intelligence Research (FAIR). For training, 558 photographs consisting of 5 classes were collected. This data set contains a total of 861 camouflaged soldiers. In the data set, each class was randomly divided into 80% training and 20% testing.

4. Results

When the model was applied to the test images, it was seen that it predicted with an average of 95% accuracy. The loss rates achieved with 20000 iterations are shown in Table 2. The training metrics formed at the end of the training are given in Figure 5 and the segmentation results obtained with the test images are given in Figure 6.

TABLE 2. Loss *r*ates.

Total Loss	**Loss of Classification**	**Loss of Masking**	**Loss of Frame**
0.061919	0.005219	0.03985	0.01685

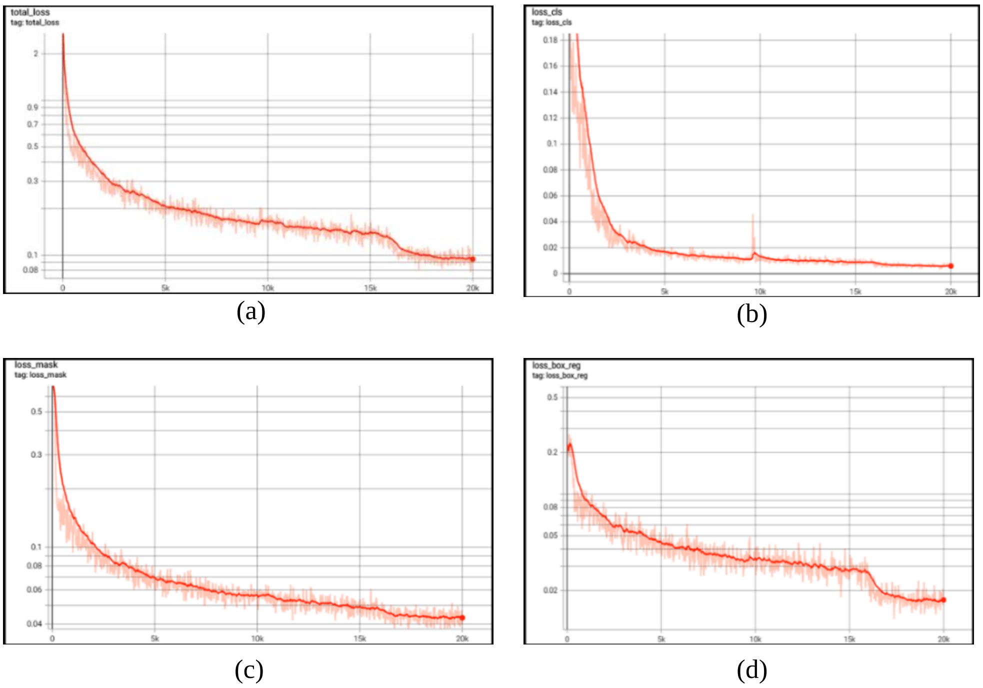

FIGURE 5. Training metrics: (a) *t*otal *l*oss, (b) *l*oss of *c*lassification, (c) *l*oss of *m*asking, (d) *l*oss of *f*rame.

5. CONCLUSIONS

Considering the studies in the literature, even if image processing methods give results for the segmentation of camouflaged objects, different methods are additionally preferred for the selection of some threshold values. In the camouflaged object classifications, since the classified objects are different from each other, the general outlines of the objects rather than the pattern are an effective factor in classification. Considering the mathematical complexity of military camouflage patterns, it is a difficult problem to classify with image processing methods. The fact that the segmented objects in our study were only soldiers enabled the algorithm used to base the patterns for classification. Looking at the classification loss from the training loss rates given in Table 2, it is seen that Mask R-CNN is successful in solving this complex classification problem. On the other hand, the average accuracy estimation is a good value for CNN algorithms.

The results revealed that CNN algorithms are effective not only for classification of objects with different outlines, but also for classification problems with high mathematical complexity. In further studies, different studies can be done by increasing the number of classes.

(Türkiye-Azerbaijan) [25] | (Türkiye-Azerbaijan) [26] | (USA) [27]

(France) [28] | (China) [29] | (Russia) [30]

FIGURE 6. Sample segmentation results with Mask R-CNN.

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