Classification of High-Spatial-Resolution Remote Sensing Scenes Method Using Transfer Learning and Deep Convolutional Neural Network

Wenmei Li, Member, IEEE, Ziteng Wang, Student Member, IEEE, Yu Wang, Student Member, IEEE, Jiaqi Wu, Student Member, IEEE, Yan Jia, and Guan Gui, Senior Member, IEEE

Abstract—The deep convolutional neural network (DeCNN) is considered one of promising techniques for classifying the high-spatial-resolution remote sensing (HSRRS) scenes, due to its powerful feature extraction capabilities. It is well-known that huge high-quality labeled datasets are required for achieving the better classification performances and preventing overfitting, during the training DeCNN model process. However, the lack of high-quality datasets limits the applications of DeCNN. In order to solve this problem, in this article, we propose a HSRRS image scene classification method using transfer learning and the DeCNN (TL-DeCNN) model in a few shot HSRRS scene samples. Specifically, three typical DeCNNs of VGG19, ResNet50, and InceptionV3, trained on the ImageNet2015, the weights of their convolutional layer for that of the TL-DeCNN are transferred, respectively. Then, TL-DeCNN just needs to fine-tune its classification module on the few shot HSRRS samples in a few epochs. Experimental results indicate that our proposed TL-DeCNN method provides absolute dominance results without overfitting, when compared with the VGG19, ResNet50, and InceptionV3, directly trained on the few shot samples.

Index Terms—Deep convolutional neural network (DeCNN), few shot, high-spatial-resolution remote sensing (HSRRS), scene classification, transfer learning.

I. INTRODUCTION

With the development of satellite remote sensing and computer technology, the spatial resolution and texture information of remote sensing image have been improved and corresponding processing approaches have been updated. High-spatial-resolution remote sensing (HSRRS) image with higher spatial resolution and abundant texture details have been performed well in object identification, classification, and information extraction [1]–[3]. In recent years, a lot of HSRRS images have been acquired and significant efforts have been made for land use land cover (LULC) scene classification in the field of pattern recognition [4], [5]. These approaches extract features first from training data and then build a classification model for testing other data. Most of the recognition methods are based on deep learning.

Deep learning has been successfully applied in extraction of abstract and semantic features [6]–[12], and it performs well in target identification, object detection, and classification. The convolutional neural network (CNN) is one of typical deep learning algorithms, and many types of algorithms based on CNN (e.g., ResNet, VGG, Inception) have been developed in computer vision, natural language processing, medical, and remote sensing image processing [13]. These practical applications indicated that the depth of a network is vital for the model, when adding layers to the network, it can extract more complex features. While the model with a deeper layer will obtain better performance and training CNN model, especially the deep CNN (DeCNN) model often requires a lot of labeled data. However, it is hard to obtain a huge amount of labeled data to train the DeCNN model for HSRRS scene classification problem. In addition, it takes a lot of manpower and resources to label the HSRRS data. When the size of labeled data is not large enough, the trained DeCNN model easily show an overfitting problem. Several studies have shown that transfer learning get a good performance in classification and recognition for small scale training data [14].

In this article, we propose a transfer learning and DeCNN (TL-DeCNN) model-based classification method to reduce the overfitting problem and improve the classification accuracy with limited labeled samples. Specifically, three typical DeCNN models, i.e., VGG19, ResNet50, and InceptionV3, are combined with transfer learning, respectively. And these combined algorithms...
are called TL-VGG19, TL-ResNet50, and TL-InceptionV3. To assess the performance of TL-DeCNN for few shot HSRRS scene classification, the retraining and testing accuracy, loss, confusion matrix, overall accuracy (OA), and kappa coefficient (KC) are used. The main contribution of this article includes the following three aspects.

1) The DeCNN-based HSRRS image scene classification method is presented in a few shot samples. We train three CNN models, i.e., VGG19, ResNet50, and InceptionV3, in a few shot samples and evaluate their accuracy. Experiment results show that InceptionV3 is the best mode among the three models.

2) TL-DeCNN-based HSRRS image scene classification is proposed in limited labeled samples case. Our proposed TL-DeCNN model is trained in a limited labeled HSRRS scene samples in a few epochs by considering fine-tune.

3) The DeCNN-based scene classification method is also considered as a benchmark method using large amount of labeled HSRRS images.

The rest of this article is organized as follows. An overview of CNN-based HSRRS image scene classification and transfer learning-based application is presented in Section II. The proposed architectures based on the DeCNN model and TL-DeCNN for HSRRS image scene classification with small and large amounts of labeled data are given in Section III, respectively. In Section IV, the HSRRS image preprocessing, the architecture based on VGG19, ResNet50, and InceptionV3 for scene classification will be described, respectively. Also the evaluation indexes of the classification model will be described. Following, the results of HSRRS scene classification with DeCNN and TL-DeCNN with a few shot samples and quantitative indicators are described in Section V. Meanwhile, the results of the large amount of labeled HSRRS image scene classification based on DeCNN are compared with that of TL-DeCNN with few shot. Finally, some concluding remarks are drawn in Section VI.

II. RELATED WORK

HSRRS image scene classification problem can be extracted subregions into different semantic classes, and it is a fundamental task and significant application for remote sensing, such as urban planning, object detection, and natural resource management. Many recent works have demonstrated that CNN is the most successful and widely applied deep learning method, and has been applied to make HSRRS image scene classification task [16]–[19]. Especially, the DeCNN performs well in semantic features extraction with a lot of convolutional layers and a large amount of training dataset. However, it is difficult to train a DeCNN model with a few samples.

HSRRS image has higher spatial resolution and fewer spectral channels compared with a coarse or medium spatial resolution remote sensing data, and it is more difficult to identify subtle differences among similar land cover types. Meanwhile, the phenomenon “same object represents different spectrum” and “same spectrum belongs to different objects” of HSRRS image leads to the failure in solving lots of classification tasks with high-accuracy demand. Tremendous efforts have been made to develop robust and automatic image classification methods. Machine learning approaches (e.g., support vector machine, random forest, k-nearest neighbor, and multilayer perception) have been used widely in HSRRS image classification, and lots of achievements have been gained [20]–[22].

Recently, deep learning has represented the state of the art in a variety of domains, and CNN as a typical deep learning method, has obtained excellent results in the field of computer vision [23], wireless communications [24], [25] and remote sensing image processing [15], [16]. HSRRS image scene classification based on CNN has achieved excellent results recently. Penatti et al. evaluated the generalization power of CNN features from fully connected layers and obtained a state of the art result with a public HSRRS image data set [26]. Feature fusion strategies to integrate the multilayers features to CNNs for HSRRS image scene classification have been proposed to complete the classification tasks [16], [27]–[30]. Gong et al. proposed a deep structural metric based learning approach for HSRRS image scene classification [31]. Ji et al. proposed a model based on multilevel features and attention model for remote sensing image scene classification [32]. Bi et al. proposed an attention pooling based convolutional network for aerial scene classification [33]. The early works have achieved excellent results in HSRRS image scene classification with a fully training CNN model. However, training a CNN model needs a considerable amount of labeled dataset, which is rather difficult for HSRRS images. Many efforts have been made to add the training samples or improve the robustness of CNN, including data augmentation, detecting adversarial perturbations [34], increasing the depth of CNN and transferring the pretrained CNN model or knowledge into a scene classification task [35].

Transfer learning is an important solution for improving the robustness of CNN-based classification models. Zhang et al. based on the features of adjacent parallel lines searched for regions of interest and confirmed the final targets through transfer learning on the AlexNet [37]. Li et al. proposed a best activation model in the end-to-end process for LULC image classification [4]. Nogueira et al. proposed a method by transferring parameters from a pretrained network and retrained the new network without parameter selection [38]. Zhao et al. combined the pretrained AlexNet with a multilayer perception structure to make classification [39]. Huang et al. constructed a semitransfer DeCNN to make image classification [40].

III. PROPOSED TL-DECNN-BASED METHOD

Deep learning-based HSRRS scene classification problem is still a challenge due to the limited labeled images. In this section, a robust classification method using TL-DeCNN is proposed. The architecture of our proposed TL-DeCNN based HSRRS image scene classification is shown in Fig. 1. We can see that the architecture can be divided into the following three steps.

1) The first step is training classification model based on ImageNet2015 and transferring the knowledge to the target classification task.

2) The second step is fine-tuning with limited labeled HSRRS images.
DeCNN contains more than one layer and a series of convolutional, max pooling, and rectified linear unit (ReLU) functions construct a highway network, which allows the original input information to be passed directly into the next layer. And it is called a highway network, which is applied to make multi-category classification or prediction. Therefore, the equation can be written as

$$\mathcal{T} = f_{\text{CNN}}(\theta; S)$$

where $\mathcal{T}$ is the approximation of $\mathcal{F}$, and the formulas of CCE is given as

$$\text{CCE}(x) = -\sum_{i=1}^{C} y_i \log(f_i(x))$$

where $C$ is the number of categories, $y_i$ is the true label of $i$th category, and $f_i(x)$ is the corresponding output of the model. Hence, features and classifiers will be got through CNN training with ImageNet2015. To extract deeper semantic features, VGG19, ResNet50, and InceptionV3 are applied to train the classification model, respectively. All of the training can be classified into two parts, feature extraction, and classifier. Since only the features or knowledge are useful for the following applications, the introduction of the approaches mainly focuses on the feature extraction.

2) VGG19: One of the most popular DeCNN models is VGG19, which is developed by Simonyan and Zisserman [42]. It is an influential DeCNN model, and it considers the depth of appropriate layers without increasing the total number of parameters. There are 16 convolutional layers and 3 fully connected layers in VGG19 with $3 \times 3$ convolution kernel size and $2 \times 2$ maximum pooling size. And a series of convolutional, max pooling, and rectified linear unit (ReLU) functions construct a convolutional block.

3) ResNet50: ResNet50 is one of the most common DeCNN for object detection and classification with a huge amount of samples, and it well resolves the degradation caused by the increasing number of layers in the network. It has been indicated that ResNet50 performs better in image scene classification than other CNN models in the ImageNet datasets [43]. The main idea of ResNet is to add a direct connection channel in the network, and it is called a highway network, which allows the original input information to be passed directly into the next layer. And its formula is given as

$$x_l = \text{ReLU}(f(x_{l-1}, w_l) + x_{l-1})$$

where $x_{l-1}$ and $x_l$ are the input and output features of the $l$th and $(l+1)$th layers, respectively. $w_l$ is the weights associated with the $l$th layer of ResNet block. Each residual block consists of...
a series of layers, convolutional, batch normalization, pooling, and ReLU. And it can resolve the gradient degradation and overfitting problems very well.

4) InceptionV3: InceptionNet is proposed to increase the depth and width of the network, and finally improve the performance of the neural network. InceptionV3 is one of the most popular InceptionNet for classification [36]. It introduces the idea of factorization into small convolutions and uses branches not only in the inception module but also in the branches, which can promote high-dimensional representations.

5) Transfer Learning-Based Method: Fig. 2 is the schematic diagram of transfer learning, and given a source domain \( D_S \) and learning task \( T_S \), a target domain \( D_T \), and learning task \( T_T \), transfer learning is defined to help improve the learning of the target predictive function \( f_T(\cdot) \) in \( D_T \) with the knowledge in \( D_S \) and \( T_S \), where \( D_S \neq D_T \), or \( T_S \neq T_T \). What is need to be noted is that each domain is a pair \( D_S = (X_S, P(X)_S) \) and \( D_T = (X_T, P(X)_T) \), the condition implies for the source and target tasks, either the term features are different or their marginal distribution are different. Similarly, the tasks have the same requirement. Therefore, it can be inclined to that when the domains are different, either the feature spaces are different or the feature spaces between the domains are the same but the marginal probability distributions are different. And the definition implies that when there is some relationship (overt or covert) between the feature spaces of the two domains, the source and target domains are considered related, and transfer learning can be carried out between the two domains.

There are three topics in transfer learning, the first one is what to transfer, the second is how to transfer, and the third is when to transfer. What to transfer means which part of knowledge can be transferred across domains or tasks. How to transfer means developing algorithms to transfer the knowledge and when to transfer asks in which situations, transfer learning should be done. In this article, we aim to achieve a good performance in the target HSRRS scene classification task by transferring knowledge from the source ImageNet2015 task, and as there are labeled data both in source and task domains, it belongs to the inductive transfer learning setting [44]. Meanwhile, the preliminary trained model based on DeCNN with ImageNet2015 is also geared to deep transfer learning. Compared with the nondeep approach, deep transfer learning automatically extracts more expressive features and meets the requirement of end-to-end in practical applications [44].

C. Fine-Tuning for HSRRS Image Scene Classification Task

Fine-tuning is the process to initialize the HSRRS scene classification task network with the trained knowledge, which is transferred from the ImageNet2015. And the model is trained with the labeled HSRRS images further, the adjustment of parameters is the same with that in scratch training. It requires the layer of the initial network is the same with that of the source network, including the same layer name, types, setting parameters, and so on. The fine-tuning is a vital process for HSRRS scene classification, not only make the network converge as quickly as possible but also make generic features contribute to a specific task. Compared with the learning rate in model training with ImageNet2015 (0.005), the fine-tuning learning rate is smaller (0.001), this setting could improve the accuracy of the HSRRS scene classification.

D. Accuracy Verification

The evaluation metrics include confusion matrix, OA, KC, and precision. The confusion matrix is the most commonly used indicator for evaluating the performances. The OA is an indicator for evaluating the proportion correctly classified. The KC calculated using the confusion matrix is applied to check consistency and evaluate classification precision. It considers not only the OA but also the imbalance of the number of samples in each category. The precision is an indicator measuring the accuracy of each class, and it means the number classified into a certain class, which actually belongs to the true class.

IV. EXPERIMENTS

In this section, to check the performance of the proposed TL-DeCNN, experiments have been conducted on three aspects. The first one is few shot HSRRS image scene classification based on VGG19, ResNet50, and InceptionV3, respectively. The second one is limited labeled HSRRS image scene classification based on TL-DeCNN, which means transferring the knowledge trained by VGG19, ResNet50, and InceptionV3 based on ImageNet2015, to the target limited labeled HSRRS image dataset to make classification, respectively. And the third one is a large amount of labeled HSRRS images for scene classification based on VGG19, ResNet50, and InceptionV3, respectively.

A. Data Description

The HSRRS images collected in urban built-up areas are extracted from the UC merced land use dataset [45] and the remote sensing image classification benchmark dataset [46]. There are ten categories of objects needed to be classified in our experiments, and the sample size of training and testing for few, TL-DeCNN-few and large amount labeled samples are
Fig. 3. Accuracy and loss during training and testing for (a) VGG19, (b) Resnet50, and (c) InceptionV3 with limited labeled HSRRS images.

| Sample Size in Our Experiments |
|--------------------------------|
| **C** | SS ² | FS ³ | TLDCNN-FS ⁴ | LS ⁵ |
|-------|-------|------|-------------|------|
| Airport | 10 | 100 | K¹+10 | 100 | 578 | 100 |
| Avenue | 10 | 100 | K¹+10 | 100 | 444 | 100 |
| Bridge | 10 | 100 | K¹+10 | 100 | 369 | 100 |
| Building | 10 | 100 | K¹+10 | 100 | 914 | 100 |
| Roadside tree | 10 | 100 | K¹+10 | 100 | 321 | 100 |
| Road | 10 | 100 | K¹+10 | 100 | 367 | 100 |
| Marina | 10 | 100 | K¹+10 | 100 | 266 | 100 |
| Parking lot | 10 | 100 | K¹+10 | 100 | 367 | 100 |
| Residents | 10 | 100 | K¹+10 | 100 | 710 | 100 |
| Storeroom | 10 | 100 | K¹+10 | 100 | 1207 | 100 |

¹Category, ²Sample size, ³Few shot learning, ⁴TLDCNN-few shot learning, ⁵Large amount labeled sample.

shown in Table I, respectively. All of the testing sample sizes are the same, and it is 100 samples for each category. The few and TL-DeCNN-few amount of labeled samples for training is randomly selected in the large number of labeled samples. The training samples for TL-DeCNN-few not only contain the few HSRRS image samples but also include the knowledge transferred from the ImageNet2015. Therefore, it combines the prior knowledge with the target to make an identification. It is noticed that effective data augmentation has been made for all of the labeled samples to enlarge the number of training samples, increase their diversity, and enhance the generalization of the trained model [16].

B. HSRRS Image Scene Classification With a Few Shot Samples

In this experiment, VGG19, ResNet50, and InceptionV3 are applied for HSRRS image scene classification in few shot case, respectively.

1) VGG19: There are 16 convolutional layers mainly using $3 \times 3$ convolutional kernels and 3 fully connected layers. The combination of convolutional, BN and ReLu layers constructs a convolutional block. The max-pooling layer is applied in every two or three convolutional blocks. And the convolutional blocks are followed by the dense layers, which are set as 4096, 4096, and 10 in our experiment. Finally, the softmax is applied to make a classification. The accuracy and loss in the training and testing stages are shown in Fig. 3(a). It is easier to see that the accuracy in training is nearly to 100% and that in testing is lower than 40%. Meanwhile, the loss is close to 0 and fluctuating around 8 in training and testing stages, respectively, which means the VGG19 model is overfitting in HSRRS image scene classification with limited labeled samples.

2) ResNet50: As illustrated in Fig. 1, the limited labeled HSRRS images are input into the ResNet50 model. And the accuracy and loss in training and testing phases are shown in Fig. 3(b). It can be seen that the training accuracy is nearly to 100%, and the testing accuracy is about 75% after training and testing process is stabilized. Meanwhile, the training loss is nearly to 0, and the test loss is larger than 2 when the model is stable. Compared with the accuracy and loss of VGG19, ResNet50 obtains a better performance, which reduces the over-fitting phenomenon to some extent. However, the ResNet50 proposed for HSRRS scene classification with few shot samples still demonstrates a certain overfitting problem.

3) InceptionV3: To solve the overfitting problem further, InceptionV3 is applied to the limited labeled HSRRS scene classification task. As described in Section III, the idea of InceptionV3 is the factorization, which promotes high-dimensional representations. The accuracy and loss during training and testing stages are shown in Fig. 3(c). It shows that the accuracy is 100% and 83.0% in training and testing after stabilization, respectively. And the loss is 0 and about 1.8 in the training and testing phases, respectively. Compared with the accuracies and losses of VGG19 and ResNet50, the InceptionV3 is better in solving the overfitting problem. But the testing result is still much worse than that of training, and there is still overfitting for the InceptionV3 model with few shot samples.

C. TL-DeCNN-Based HSRRS Image Scene Classification Method

The TL-DeCNN is proposed to solve the overfitting problem with limited training HSRRS images. Similar with that of few shot experiments, TL-DeCNN experiment is carried out based on limited labeled HSRRS image and knowledge transferred.
The architecture of HSRRS scene classification based on transfer learning and VGG19 (TLVGG19) model can be seen from Fig. 1. The knowledge trained by VGG19 with ImageNet2015 is transferred to the limited labeled HSRRS scene classification task. The accuracy and loss during the task training and testing are shown in Fig. 4(a). When the process is stabilized, the training accuracy is 100%, and the testing accuracy is 90.0%. Meanwhile, the training loss is 0, and the testing loss is nearly to 0.25. Compared with that without transferred knowledge, the HSRRS scene classification task based on TLVGG19 performs better in accuracy and loss. The testing accuracy increases from about 40% to 90%, and the testing loss decreases from about 8 to 0.25. It demonstrates that the proposed approach can greatly reduce the effect of overfitting problems with limited labeled HSRRS images.

2) TLResNet50: In few shot HSRRS image scene classification task, the architecture of transfer learning based on ResNet50 (TLResNet50) is also shown in Fig. 1. Similar to TLVGG19, the architecture transfers the knowledge trained with ImageNet2015 to the target HSRRS scene classification task. The accuracy and loss during task training and testing are shown in Fig. 4(b), the training accuracy is 100% and the testing accuracy is about 96.0% when the processes are stable. The loss is 0 and 0.18 in the training and testing phase after the process stabilized, respectively. Compared with that without transfer knowledge, the testing accuracy increases about 21.2%, and the loss decreases about 91%. This result indicates that the TLResNet50 solve the effect of overfitting problem well with limited labeled HSRRS image.

3) TLInceptionV3: The architecture of transfer learning combined with InceptionV3 (TLLnceptionV3) for limited labeled HSRRS image is also shown in Fig. 1. The accuracies and losses in training and testing processes are shown in Fig. 4(c). After the process is stabilized, the testing accuracy and loss is about 92.4% and 0.26, respectively. Compared with the InceptionV3 without transferred knowledge, the testing accuracy increases by 9.4%, and the testing loss decreases from 1.8 to 0.26, which indicates that the approach we proposed is effective in solving the overfitting problem with limited labeled HSRRS images.

D. HSRRS Image Scene Classification in a Large Number of Labeled Samples

From the abovementioned experiments in Sections IV-B and IV-C, it has been found that the TL-DeCNN architectures, including TLVGG19, TLResNet50, and TLInceptionV3 are efficient and effective in solving the overfitting problem. However, whether the accuracy and loss of TL-DeCNN can compare with that of a large number of labeled samples based on DeCNN. This experiment is carried out with augmented HSRRS images using VGG19, ResNet50, and InceptionV3, respectively.

1) VGG19: As described in Section IV-A, there are more than 1064 samples (the size of the fewest samples is 266, and geometric transformations have been applied for data augmentation) for training in each category in the large amount of labeled data experiment. The accuracies and losses in training and testing are shown in Fig. 5(a), and it can be seen that the testing accuracy is about 90% and the testing loss is about 0.38, which is similar with that of TLVGG19. Therefore, it indicates that compared with the VGG19-based HSRRS scene classification trained with a large number of labeled samples, the TLVGG19 with few shot samples could obtain similar results, and reduces the effect of overfitting problem.

2) ResNet50: The ResNet50 is suitable for scene classification with a large number of labeled samples. The accuracies and losses in training and testing are shown in Fig. 5(b). After about ten epochs, the testing accuracy and loss are stable, and the testing accuracy is close to 98% and the testing loss is nearly to 0. Compared with the testing accuracy and loss in TLResNet50 with few shot samples, ResNet50 architecture with a large number of labeled samples is better for HSRRS scene classification task. It demonstrates that the transfer learning contributes to the classification task, and the performance of TLResNet50 with limited labeled samples is inferior to the approach based on ResNet50 with large amount of labeled samples.

3) InceptionV3: The InceptionV3 is a typical DeCNN for the extraction of deep features. It is good at extracting deep features from a large number of labeled samples. The accuracies and losses of InceptionV3 with a large amount of labeled HSRRS images in training and testing are shown in Fig. 5(c). It can be seen that after about 15 epochs, the testing accuracy and loss are stable, and the former is stable around 99.3%, the latter is stable around 0.1, which is better than that in TLLnceptionV3.
Fig. 5. Accuracy and loss during training and testing for (a) VGG19, (b) Resnet50, and (c) InceptionV3 with large labeled samples.

Fig. 6. Confusion matrix of limited HSRRS image samples based on (a) VGG19, (b) ResNet50, and (c) InceptionV3.

Fig. 7. Confusion matrix of limited HSRRS image samples based on (a) TLVGG19, (b) TLResNet50, and (c) TLInceptionV3.

V. RESULTS AND DISCUSSIONS

First of all, we present the confusion matrix of each DeCNN classifier. Fig. 6 shows the confusion matrix of HSRRS image scene classification with VGG19, ResNet50, and InceptionV3 based on limited labeled samples. The OA of classification is 35.9%, 77.8%, and 87.0% for VGG19, ResNet50, and InceptionV3 architecture, respectively. The KC is 0.287, 0.753, and 0.856 for VGG19, ResNet50, and InceptionV3 architecture, respectively. Fig. 7 shows the confusion matrix of HSRRS image classification with TLVGG19, TLResNet50, and TLInceptionV3 based on limited labeled samples. The OA is 89.0%, 95.7%, and 92.4% and the KC is 0.878, 0.952, and 0.916 for TLVGG19, TLResNet50, and TLInceptionV3 architecture, respectively.
The precision of each category with six different architectures is listed in Table II. The precision for each category is calculated using OA and KC. The OA of VGG19 increases by 53.1%, and the OA of InceptionV3 increases by 5.4%. Meanwhile, for few shot learning, InceptionV3 obtains the best OA and KC when the transferred knowledge is considered. The precision increases to 83%. Most of the precisions are improved, but the precision of the “airport” category decreases from 98% to 89%. It may be caused by the transferred knowledge that is extracted from huge airport information in ImageNet2015. The transferred knowledge contains intricate airport information, which is not similar to the task “airport” in features. In short, the transferred knowledge improves the precisions of most of the categories for DeCNN scene classification tasks.

VI. CONCLUSION

In this article, three TL-DeCNN models, i.e., TLVGG19, TLResNet50, and TLInceptionV3 are proposed for HSRRS scene classification in urban built-up areas. The main contribution of our work is to solve the overfitting and gradient disappearance problems with limited labeled HSRRS images. Three experiments have been carried out: the first one is the DeCNN-based HSRRS scene classification with few shot; the second one is the TL-DeCNN-based scene classification with the same few shot; and the third one is DeCNN-based HSRRS scene classification with a large number of labeled samples. Experimental results show that for few shot HSRRS scene classification, all of the three architectures TLVGG19, TLResNet50, and TLInceptionV3 greatly improve the performance compared with those without transferred knowledge. And the ResNet50...
is more suitable for transfer learning applications compared with VGG19 and InceptionV3, and InceptionV3 could reduce the overfitting and gradient disappearance problems to a certain degree and it performs better with few shot. Meanwhile, DeCNN-based HSRRS scene classification with a large amount of labeled HSRRS images show that their performance are better compared with TL-DeCNN with few shot. It indicates that there is still space for improvement of the classification performance for TL-DeCNN with few shot samples.

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Wenmei Li (Member, IEEE) received the M.S. and Ph.D. degrees from Nanjing University, Nanjing, China, and Chinese Academy of Forestry, Beijing, China, in 2010 and 2013, respectively.

She is currently an Associate Professor with School of Geographic and Biologic Information, Nanjing University of Posts and Telecommunications, Nanjing, China. Since 2018, she has been working for her postdoctoral studies with Nanjing University of Posts and Telecommunications, Nanjing, China. Her research interests include deep learning, optimization, image reconstruct, and their application in land remote sensing.

Ziteng Wang (Student Member, IEEE) received the B.E. degree in electronic information engineering from the North China Institute of Aerospace Engineering, Langfang, China, in 2018. He is currently working toward the master’s degree with the Nanjing University of posts and Telecommunications, Nanjing, China.

His research interests include deep learning, optimization, and their applications in remote sensing image processing.

Yu Wang (Student Member, IEEE) received the B.S. degree in communication engineering, in 2018 from Nanjing University of Posts and Telecommunications, Nanjing, China, where he is currently working toward the Ph.D. degree.

He has authored or coauthored more than 15 papers in peer-reviewed IEEE journal/conferences. His research interests include deep learning, optimization, and its application in wireless communications.

Dr. Wang was the recipient of two best paper awards (i.e., CSPS 2018 and ICEICT 2019).

Jianqi Wu received the B.S. degree in geographic information science, in 2019 from the Nanjing University of Posts and Telecommunications, Nanjing, China, where he is currently working toward the M.A. degree.

His research interests include spatial-temporal fusion, time series, deep learning, and their applications in land remote sensing.

Juan Wang is currently working toward the master’s degree in communication and information engineering with the Nanjing University of Posts and Telecommunications, Nanjing, China.

She has authored or coauthored more than five peer-reviewed IEEE journal/conference papers in deep learning-based physical layer wireless techniques. Her research interest includes machine learning for wireless communications.

Yan Jia received the double M.S. degree in telecommunications engineering and computer application technology from Politecnico di Torino, Turin, Italy, and Henan Polytechnic University, Jiaozuo, China, in 2013, and the Ph.D. degree in electronics engineering from Politecnico di Torino, in 2017.

She is currently with the Nanjing University of Posts and Telecommunications, Nanjing, China. Her research interests include microwave remote sensing, soil moisture retrieval, Global Navigation Satellite System Reflectometry (GNSS-R) applications to land remote sensing, and antenna design.

Guan Gui (Senior Member, IEEE) received the Ph.D. degree from the University of Electronic Science and Technology of China, Chengdu, China, in 2012.

From 2009 to 2014, he joined the Tohoku University as a Research Assistant as well as a Postdoctoral Research Fellow, respectively. From 2014 to 2015, he was an Assistant Professor with the Akita Prefectural University, Akita, Japan. Since 2015, he has been a Professor with Nanjing University of Posts and Telecommunications, Nanjing, China. His recent research interests include artificial intelligence, deep learning, nonorthogonal multiple access, wireless power transfer, and physical layer security.

Dr. Gui has authored or authored more than 200 IEEE Journal/Conference papers and won several best paper awards, e.g., ICC 2017, ICC 2014, and VTC 2014-Spring. He was the recipient of the Member and Global Activities Contributions Award, in 2018, the Top Editor Award of IEEE TRANSACTIONS ON VEHICULAR TECHNOLOGY, in 2019, the Exemplary Reviewer Award of IEEE COMMUNICATIONS LETTERS, in 2017. He was also selected for the Jiangsu Specially-Appointed Professor, in 2016, the Jiangsu High-level Innovation and Entrepreneurial Talent in 2016, the Jiangsu Six Top Talent, in 2018, the Nanjing Youth Award, in 2018. He is serving or served on the editorial boards of several journals, including IEEE TRANSACTIONS ON VEHICULAR TECHNOLOGY, IEEE Transactions on Communications, Physical Communication, Wireless Networks, IEEE ACCESS, Security and Communication Networks, IEEE Communications Express, KSH Transactions on Internet and Information Systems, and Journal on Communications. In addition, he served as a General Co-Chair of Mobimedia 2020, TPC Chair of WiMob 2020, Track Chairs of VTC 2020 spring, ISNCC 2020 and ICC 2020, Award Chair of PIMRC 2019, and TPC member of many IEEE international conferences, including GLOBECOM, ICC, WCNC, PIRMC, VTC, and SPAWC.

Juan Wang is currently working toward the master’s degree in communication and information engineering with the Nanjing University of Posts and Telecommunications, Nanjing, China.

She has authored or coauthored more than five peer-reviewed IEEE journal/conference papers in deep learning-based physical layer wireless techniques. Her research interest includes machine learning for wireless communications.

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