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An end-to-end classification algorithm for single-pass InSAR system based on a new deep learning structure

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In single-pass InSAR system, the water bodies often have relatively low coherence because of their scattering characteristics. The coherence of shadow areas is also very low for receiving no radar echos. Layover areas do not necessarily have low coherence, but their phase measurement might be abnormal because of signals overlying from many targets with the same range. In conventional InSAR processing for generating DEM, phase unwrapping over low coherence areas and layover areas can take a considerate amount of time and memory, and the unwrapped results are generally unreliable and may be with lots of errors. Hence, there is a need to detect water bodies, shadow and layover areas. Once these areas are detected and classified, the phase unwrapping can carried out by avoiding these areas to reduce unwrapped phase errors largely. Then, different strategies can be chosen to deal with these areas. Therefore, DEM accuracy can be improved in a large extent. For this purpose, we present a new algorithm to realize intelligent classification for these areas. It includes mainly two parts: multiple features extraction and fusion (MFEF), and a new deep learning network with multi-path refinement and global information.

Firstly, we present a MFEF method to extract multiple features from SAR images and fuse them with weights. In this stage, we adopt Gabor transform for SAR images with Gabor convolution filter, Gray Level Gradient Co-occurrence Matrix (GLGCM) and multi-scale omnidirectional derivative filter (MSODF) to extract different features. Then, we fuse these features.

In this paper, to realize end-to-end classification, we present a new deep learning structure. It is based on RefineNet network which is one of the most popular semantic segmentation deep learning net structures. The RefineNet adopts a refinement network that explicitly exploits all the information available along down-sampling process to enable high-resolution prediction using residual connections. It achieves much better results in the several public data sets than the majority of existing algorithms. However, we discover that it has the problems of misclassification for the same kind and the not taking full use of global information. Therefore, we introduce the spatial pyramid pooling to utilize more context information, and we adopt the double visual attention mechanism to use the global information fully to resolve the misclassification in the same kind. In addition, we improve the loss function to simplify the network and generate the good generalization capability. Finally, we proposed the new deep learning network structure.

To validate the algorithm, the millimeter wave airborne millimeter single-pass InSAR data are tested. In this experiment, 2600 SAR images with size of 500×500, the corresponding coherence maps and InSAR phases are all utilized. 600 SAR images without being trained are tested. According to the classification results, the accuracy for shadow areas and water bodies is about 89%, the accuracy for layover areas is about 83%. All of these suggest the effectiveness of the proposed algorithm for single-pass InSAR classification. Furthermore, a flooded TerraSAR image is tested too, which indicates the good application of the proposed algorithm.