Classification of Airborne Radar Images Using Multiscale Dense Networks and Comparative Filtering Techniques

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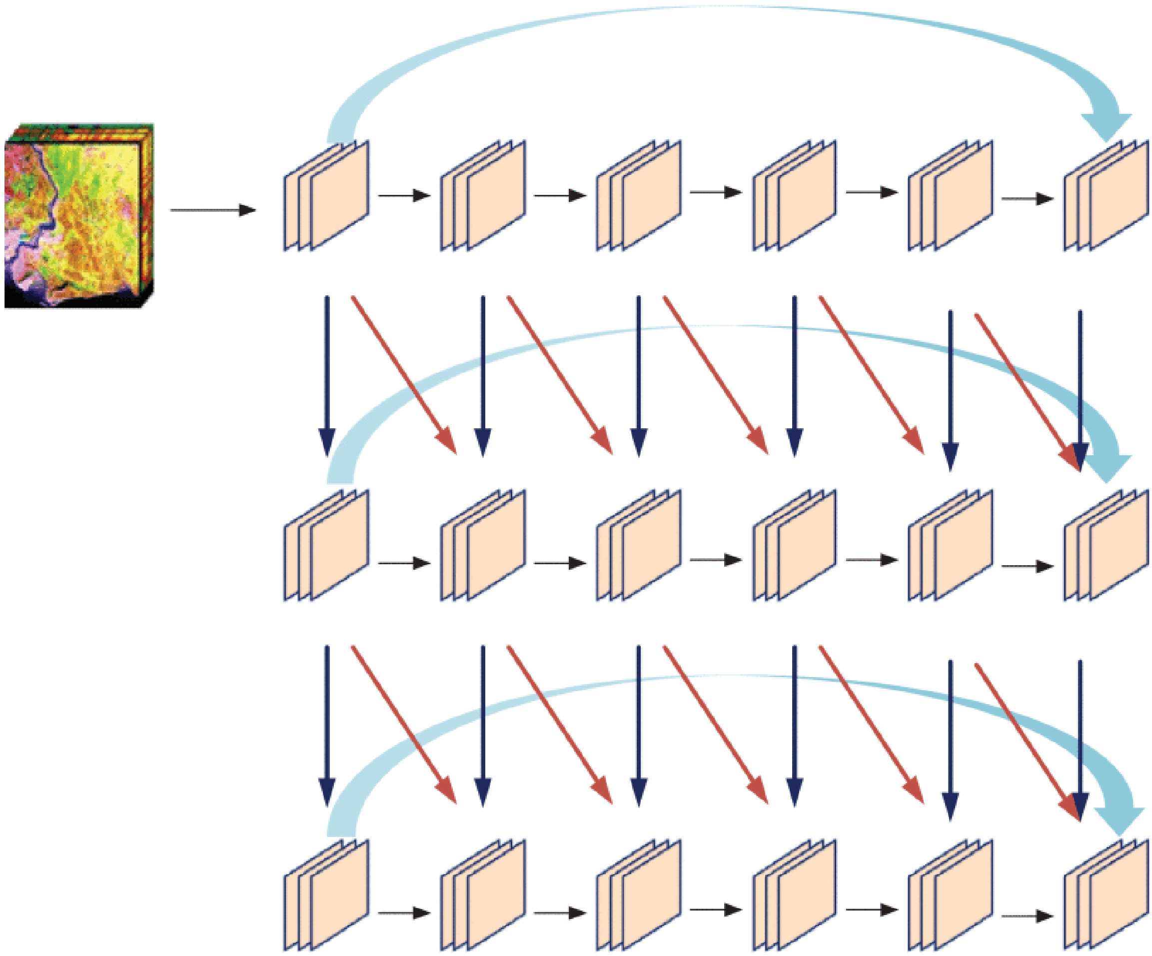
1. Introduction

Airborne radar imaging is a critical tool in remote sensing, capable of capturing detailed surface information regardless of weather conditions. This characteristic makes radar images essential for various applications such as disaster management, environmental monitoring, and urban planning. However, accurate classification of radar images is challenging due to the presence of noise and the variability of textures across different surfaces. To address these issues, this study combines several filtering techniques with a Multiscale Dense Network (MSDNet) to improve classification accuracy, robustness, and computational efficiency.

Previous research has explored the use of individual feature extractors such as Wavelet Transforms, Directional Filter Bank (DFB), and Convolutional Neural Networks (CNNs). While these techniques have shown promise in certain scenarios, this study aims to leverage their complementary strengths by integrating them into a unified MSDNet framework.

The objective of this study is to enhance the classification of airborne radar images by improving feature extraction through a combination of these filtering techniques. The scope of this research covers the evaluation of the combined method on various airborne radar datasets to provide a detailed comparison of each approach's strengths and weaknesses.



Source: IEEE Access, vol. 11, pp. 114146-114154, 2023

Figure 1: Multi-scale dense network (MSDN) architecture.

2. MATERIALS AND METHODS

This study uses multiple airborne radar datasets collected under different environmental conditions, covering both natural and man-made structures such as rivers, roads, and buildings. The classification methods are based on the following three key feature extraction techniques, each of which is introduced in detail below:

2.1 Wavelet Transform

Wavelet Transform is a multiscale analysis technique widely used in image processing and feature extraction. It decomposes the signal in an image into sub-signals at different scales, which helps in extracting edges and texture features. This multiscale analysis is crucial in radar images since they often contain features at various scales, such as large terrain changes and smaller man-made structures.

The advantage of the Wavelet Transform is its ability to provide both time and frequency domain decomposition, allowing for capturing local details in the image. Specifically in airborne radar images, the Wavelet Transform effectively separates noise and texture variations, improving classification accuracy. In this study, Discrete Wavelet Transform (DWT) is employed to decompose the images into multiple scales, extracting local edge information for subsequent classification.

2.2 Directional Filter Bank (DFB)

The Directional Filter Bank (DFB) is a technique designed to enhance directional features in images. Many features in radar images, such as roads, rivers, and building edges, have clear directional characteristics. By applying DFB, these linear features can be enhanced, making it easier for the system to distinguish between man-made and natural structures.

DFB decomposes the image into different directional sub-bands and performs filtering based on the local directional characteristics of the image, extracting horizontal, vertical, and diagonal edge information. In this study, DFB is particularly useful for identifying directional man-made structures like roads and buildings, which are often difficult to distinguish in traditional classification methods. The process involves decomposing radar images into sub-bands in different directions and analyzing them to enhance specific directional features.

2.3 Convolutional Neural Networks (CNNs)

Convolutional Neural Networks (CNNs) are a type of deep learning model specialized in automatically learning hierarchical features from images. CNNs can learn and extract complex features, making them well-suited for handling texture and noise variations in radar images.

In this study, the convolutional layers of CNNs automatically extract local features using convolution kernels, while the pooling layers perform feature downsampling to reduce computational load and enhance classification speed. These features are integrated into the Multiscale Dense Network (MSDNet), allowing the model to process features at multiple scales and orientations simultaneously. Ultimately, by using CNNs, the model can automatically extract high-level abstract features from radar images, thereby improving classification accuracy and adaptability.

3. Results and Discussion

The combined method was evaluated on several airborne radar datasets, and the results show significant improvements in classification accuracy, precision, and recall compared to traditional methods. Specifically, the Wavelet Transform was highly effective at capturing multiscale features, which is crucial for identifying different structures in the images. The DFB technique excelled at enhancing directional features, making it easier to differentiate between artificial and natural structures. The CNNs were able to learn complex features that adapted well to varying image textures and noise levels.

In terms of computational efficiency, the MSDNet framework performed well, demonstrating that the integration of these filtering techniques does not come at the cost of increased processing time. The classification results also show that the combined approach generalizes well across different datasets, providing consistent improvements in performance.

A detailed comparison of the individual filtering techniques revealed that while each method has its strengths, their combination within the MSDNet framework provides a more balanced and effective solution for airborne radar image classification.

4. Conclusion and Recommendation

This study demonstrates the effectiveness of combining Wavelet Transform, Directional Filter Bank, and CNNs within a Multiscale Dense Network for the classification of airborne radar images. The results show that this integrated approach offers superior performance compared to traditional methods, particularly in terms of accuracy and computational efficiency. Future research should explore hybrid methods that further enhance the complementary strengths of these filtering techniques, as well as the application of this approach to other types of remote sensing data.

References

C. Zhang, S. Zhu, D. Xue and S. Sun, "Gabor Filter-Based Multi-Scale Dense Network Hyperspectral Remote Sensing Image Classification Technique," in IEEE Access, vol. 11, pp. 114146-114154, 2023, https://doi.org/10.1109/ACCESS.2023.3323595

G. Priyadharshini and D. R. Judie Dolly, "Comparative Investigations on Tomato Leaf Disease Detection and Classification Using CNN, R-CNN, Fast R-CNN and Faster R-CNN," *2023 9th International Conference on Advanced Computing and Communication Systems (ICACCS)*, Coimbatore, India, 2023, pp. 1540-1545, https://doi.org/10.1109/ACCESS.2023.3323595

Cai-Xia Deng, Zuo-Xian Fu and Xiao-Jian Ma, "The properties of Gabor wavelet transform," *2007 International Conference on Wavelet Analysis and Pattern Recognition*, Beijing, China, 2007, pp. 1504-1507, https://doi.org/10.1109/ICWAPR.2007.4421688