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Remote Sensing with Deep Learning: A Comprehensive Review of Image Classification

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ABSTRACT

Image classification is vital in computer vision due to the growing volume of multimedia data. This paper reviews various object-based classification methods that assist in effective image retrieval. Key techniques discussed include Convolutional Neural Networks (CNN), Recurrent Neural Networks (RNN), Artificial Neural Networks (ANN), Naive Bayes (NB), K Nearest Neighbor (KNN), Multi-Layered Perceptron (MLP), and Kernel Support Vector Machines (SVM). The process involves image acquisition, pre-processing, and segmentation, highlighting the importance of these techniques for information extraction from digital images.

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1. INTRODUCTION

Object classification is straightforward for humans but challenging for machines. The image classification process involves several steps: image pre-processing, object detection, segmentation, feature extraction, and classification. It relies on a database of predefined patterns to categorize images accurately, making it essential in various applications.

1.1 IMAGE CLASSIFICATION TECHNIQUES

- **Image Preprocessing:** Initial corrections, such as radiometric and geometric corrections, are applied to raw data before analysis.

- **Image Classification:** Algorithms discriminate different types in an image using spectral features. Classification can be supervised (using labeled training data) or unsupervised (grouping pixels into clusters without prior labels).
- **Spatial Feature Extraction:** In high-resolution imagery, pixel-based methods may fail, necessitating algorithms that utilize textural, contextual, and geometrical properties.

1.2 IMAGE CLASSIFICATION METHODS

- **Supervised Classification:** Involves training the classifier on labeled pixels, requiring prior knowledge. Common approaches include parallelepiped, minimum distance to mean, and maximum likelihood.
- **Unsupervised Classification:** Groups pixels based on their properties without prior information. The user determines the number of clusters, and the algorithm automatically identifies and labels them.

1.3 DEEP LEARNING TECHNIQUES

- **Fully Connected Neural Networks:** Basic architecture where each neuron in one layer connects to every neuron in the next, using activation functions for output.
- **Convolutional Neural Networks (CNN):** Designed for image classification, consisting of convolutional and pooling layers to process images efficiently.
- **Recurrent Neural Networks (RNN):** Effective for sequences of data, utilizing previous states for current predictions, suitable for applications like natural language processing and image captioning.
- **Artificial Neural Networks (ANN):** Inspired by biological neural networks, consisting of layers of interconnected neurons that learn through a backpropagation algorithm.
- **Naive Bayes Classifier:** A probabilistic model that assigns classes based on the highest estimated probability, performing well with small training sets.
- **K-Nearest Neighbor (KNN):** Classifies based on the majority class of the nearest neighbors, sensitive to dimensionality and outliers.

- **Multi-Layered Perceptron (MLP):** A feed-forward neural network that processes information through layers, capable of nonlinear mappings and requiring careful parameter tuning to avoid overfitting.

- **Kernel Support Vector Machines (SVM):** Maps input features to a higher-dimensional space to find an optimal separating hyperplane, focusing on maximizing the margin between classes.

2. DISCUSSION

Recent advancements in satellite technology have led to an increase in high-resolution remote sensing images, prompting the need for efficient retrieval methods.

- **Hanen Balti et al.[3]** propose a distributed system architecture using a fully connected neural network and the Hadoop framework to manage satellite image data, while employing CNNs for deep semantic feature extraction and object classification.

- **Vahitha Rahman and Vanitha's 2024[1]** study presents a method for multispectral image segmentation using a constrained clustering approach alongside a CGT classifier. The research tackles the complexities of segmenting multispectral images by enhancing accuracy compared to traditional methods. Their findings indicate that this combined approach significantly improves segmentation outcomes, providing useful insights for image analysis in remote sensing applications.

- **Yu-guo Wang and Hua-peng Li[4]** introduce a local spatial sequential (LSS) method within a recurrent neural network (RNN) for hyperspectral image classification. Their approach combines low-level features and enhances classification performance with a nonlocal spatial sequential method (NLSS-RNN).

- **Juan Yang et al.[5]** present a sample purification method using statistical analysis to improve wetlands classification accuracy with artificial neural networks (ANN). Their results indicate that purified training samples significantly enhance classification outcomes.

- **Xiangrong Zhang et al.** [6]utilize a cuckoo search algorithm for attribute weighting in a Naive Bayes classifier, demonstrating improved accuracy and stability compared to other evolutionary algorithms.

- **Ying Li and Bo Cheng** [7]enhance the k-Nearest Neighbor (KNN) algorithm for object-oriented classification of high-resolution remote sensing images, achieving higher accuracy with their improved method compared to traditional KNN approaches.

- **G Rex Sumsion et al.** [8]highlight the effectiveness of multilayer perceptron (MLP) algorithms for tree-species classification using hyperspectral and LiDAR data, employing an ensemble approach to improve classification at the crown level.

- **Hela Elmannai et al.** [9] focus on land characterization from multispectral images, developing a statistical learning classifier using Support Vector Machines (SVM) to address complexities arising from multiple radiance reflections.

3. CONCLUSION

This paper explores various image classification techniques, primarily categorizing them into supervised and unsupervised approaches. The review highlights the different methodologies applied in image segmentation and addresses key research challenges within this domain. Additionally, it examines machine learning systems, particularly the use of multilayer perceptrons, and discusses several widely adopted classification techniques.

The insights provided here offer a solid theoretical foundation for understanding classification methods and selecting the most suitable approaches for specific applications. Recent advancements in hyperspectral sensors represent a significant technological leap for detection and identification purposes. Furthermore, the integration of deep learning in remote sensing serves as a versatile toolkit, paving the way for innovative applications and enhancements in image classification methodologies.

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