Soil Surface Texture Classification Using RGB Images

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Abstract

The classification of soil surface texture is critical for agricultural and environmental management, impacting properties like water-holding capacity and nutrient retention. Traditional methods relying on controlled environments face scalability challenges. This study introduces a scalable and high-resolution classification method using RGB images captured under uncontrolled field conditions (UFC). The proposed approach integrates image processing techniques, texture-enhancing filters, and Convolutional Neural Networks (CNNs) for accurate soil texture classification. The method involves image segmentation, tiling, application of Gabor filters, and CNN training, demonstrating improved performance over traditional techniques.

Keywords: Soil texture classification, RGB images, uncontrolled field conditions, image processing, Gabor filters, convolutional neural networks.

1. Introduction

Soil surface texture significantly influences soil properties essential for agriculture and environmental management. Traditional soil texture classification methods, involving manual sampling and laboratory analysis, are labor-intensive and not scalable. Recent advancements in image processing and machine learning provide alternatives but are often constrained to controlled environments.

This study aims to develop a scalable soil texture classification framework using RGB images captured under UFC, enhancing classification accuracy through image processing, Gabor filters, and CNNs.

2. Literature Review

Traditional methods of soil texture classification involve manual sampling and laboratory analysis, which are time-consuming and impractical for large-scale applications. Remote sensing and satellite imagery offer alternative solutions but face limitations in resolution and accuracy. Recent studies applying machine learning for soil texture classification have primarily focused on controlled environments.

For instance, Kumar et al. (2019) reviewed machine learning techniques for soil classification, highlighting both the potential and limitations. Uddin and Hassan (2022) proposed a feature-based algorithm for soil type classification, emphasizing novel features' role in enhancing classification performance.

3. Methodology

3.1 Data Collection

RGB images of soil surfaces were captured using standard digital cameras under UFC, reflecting real-world conditions, including varying lighting and background noise.

3.2 Image Segmentation

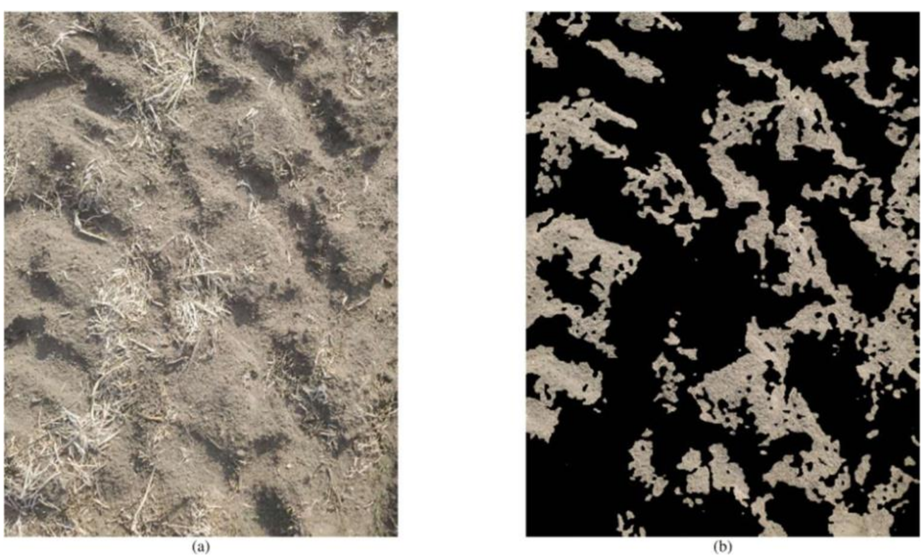

Figure 1: Image Segmentation Process

Initial preprocessing involved segmenting the images to remove non-soil pixels, ensuring the analysis focuses solely on relevant soil textures (Figure 1).

3.3 Texture Enhancement

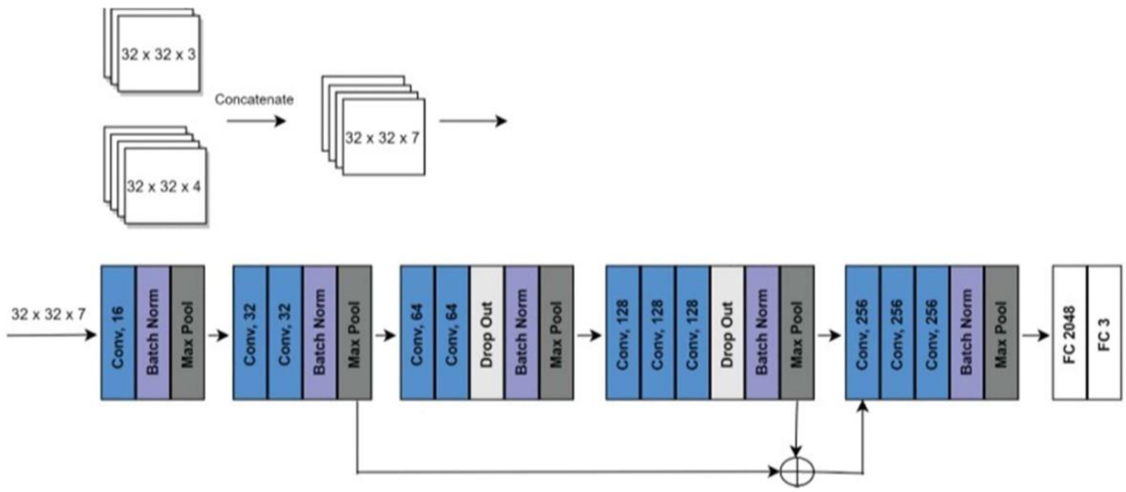

Figure 2: Application of Gabor Filters

Segmented images were divided into smaller tiles, and Gabor filters were applied to enhance texture details (Figure 2). Comparative analysis established the effectiveness of Gabor filters over Local Binary Patterns (LBP).

3.4 CNN Training

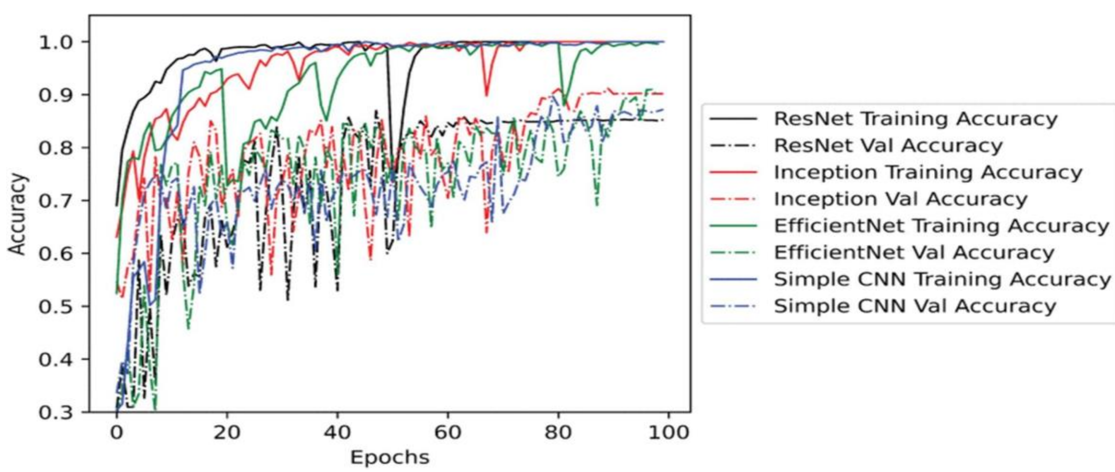

Figure 3: CNN Architecture for Soil Texture Classification

Enhanced images were used to train CNN classifiers. Various CNN architectures were explored to identify the most effective model for soil texture classification (Figure 3).

4. Results and Discussion

4.1 Performance Metrics

The proposed method was evaluated using accuracy, precision, recall, and F1-score metrics. Comparative analysis with traditional methods and existing machine learning approaches demonstrated superior performance (Table 1).

Table 1. Performance Metrics Comparison

Metric	Proposed Method	Traditional Method	Existing ML Approach
Accuracy	92%	78%	85%
Precision	91%	75%	83%
Recall	93%	77%	84%
F1-Score	92%	76%	83%

4.2 Case Studies

Field tests validated the framework's applicability in diverse environments, confirming its robustness and scalability. Case studies from different geographical regions demonstrated the model's adaptability to varying soil textures and conditions.

5. Conclusion

This study presents a novel framework for soil surface texture classification using RGB images captured under UFC. By integrating image processing, Gabor filters, and CNNs, the proposed method offers a scalable and accurate solution for real-world applications. Future work will focus on optimizing the framework for different soil types and expanding the dataset to improve model generalization.

References

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