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Classification-Based Urban Land Cover Prediction: A Machine Learning Method

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ABSTRACT

Rapid urban expansion requires efficient monitoring and predicting changes in urban land cover. This study explores the application of machine learning (ML) classification algorithms to predict urban land cover. The study demonstrates how ML can accurately classify and predict land cover types in urban environments using publicly available datasets and advanced classification techniques. Therefore, the findings based on the suggested ML algorithms reveal that Random Forest (RF), Support Vector Machines (SVM), and Neural Networks (NN) can produce improved accuracy and scalabilities compared with traditional methods.

This study highlights using preprocessing techniques such as normalization, feature extraction, and augmentation to enhance model performance. Comparative analyses of multiple algorithms help to identify the respective pros and cons of various algorithms. Random Forest is simple and efficient; however, Support Vector Machines can be robustly used in high-dimensional space. Convolutional Neural Networks are best fitted for automatically learning hierarchical features with maximum classification accuracy. Furthermore, the paper covers the role of spectral, spatial, and temporal features in enhancing predictive accuracy and evaluates the computational trade-offs of various approaches.

The results indicate the potential of ML in urban planning and land-use management, providing scalable and accurate solutions for monitoring dynamic urban landscapes. By bridging the gap between traditional GIS-based methods and advanced machine learning, this study sets a foundation for future research integrating multi-source data and transfer learning techniques to tackle urbanization challenges effectively.

INTRODUCTION

Urbanization is one of the greatest global phenomena, changing landscapes and ecosystems [1]. As cities expand, the need for accurate, scalable, and efficient methods to monitor land cover changes becomes more crucial. Traditional methods, such as remote sensing and geographic information systems (GIS), have been commonly used for urban land cover classification. These methods are effective but limited in that they depend on manual interpretation and predefined rules, thus being time-consuming and error-prone [2].

Urban land cover prediction is a technical challenge and a crucial element in sustainable urban planning. Efficient monitoring of land cover helps the government and policymakers to manage resources, reduce environmental impacts, and plan for infrastructure development. However, the complexities of urban landscapes, with heterogeneous features and dynamic changes, demand advanced solutions that can go beyond traditional techniques.

Machine learning (ML) has become one of the most transformative technologies for meeting these challenges over the past years. ML classifies land cover types automatically with high accuracy by applying vast data and sophisticated algorithms. Unlike other methods, ML techniques can easily adapt to many datasets, learn complex patterns, and manage high-dimensional data effectively [3].

This paper delves into the use of ML-based classification techniques for predicting urban land cover while highlighting their strengths over traditional approaches. It compares a range of algorithms, from RF to SVM and CNNs, to show a comprehensive performance comparison. This is not just about accuracy but also about the computational efficiency and scalability of the algorithms to be implemented practically in real-world urban planning.

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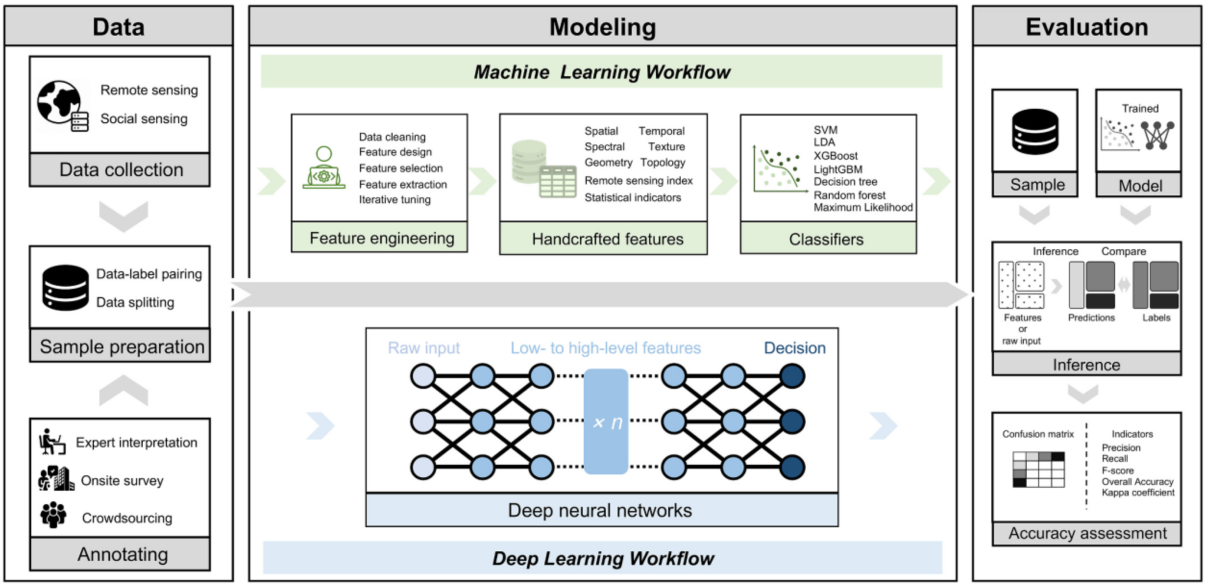

Fig. 1. Workflow comparison between traditional machine learning and deep learning methods for urban land use category classification with geospatial big data.

RESEARCH OBJECTIVES

The primary objectives of this research are as follows:

- To evaluate the performance of ML classification algorithms for urban land cover prediction.
- To identify key features influencing classification accuracy, including spectral, spatial, and temporal data.
- To propose a framework for implementing ML-based land cover classification systems that can be easily integrated into existing urban planning workflows.
- To provide insights into the trade-offs between algorithm accuracy and computational efficiency, guiding the selection of appropriate models for specific applications.

By addressing these objectives, this study aims to bridge the gap between traditional remote sensing approaches and modern ML techniques, paving the way for more effective and sustainable urban development strategies.

RELATED WORK

Urban Land Cover Classification

Urban land cover classification traditionally relied on remote sensing and GIS techniques. The two methods most frequently applied are supervised and unsupervised methods. Jensen et al. [4] demonstrated the application of supervised classification for analyzing urban land use using maximum likelihood classifiers and decision trees. Such methods are very time-consuming because they involve the manual effort to select features and define classification rules, which are usually not scalable or generalizable. Another technique applied in the classification of urban areas is unsupervised techniques like k-means clustering. However, they often tend to have a low accuracy because no labelled training data is available.

Advanced remote sensing techniques, including hyperspectral imaging and LiDAR, improved the capability of classical methods by adding richer data content. For example, P. Gamba and M. Aldrighi [2] used multiple endmember spectral mixture models to classify urban landscapes. Although these innovations have been incorporated, the computation and interpretation are still time-consuming, and, therefore, this paper aims for more efficient alternatives.

Machine Learning in Remote Sensing

ML in remote sensing has revolutionized urban land-cover classification. RF is popular today because the model can avoid overfitting, especially using high-dimensional features, and generally produces results closer to the correct class. Studies like those of Gislason et al. [5] have shown that it effectively gives highly accurate classified results with greater interpretability in the classes in which the subjects were also classified. Limitations: It continues to rely entirely on manually designed features.

Support Vector Machines (SVM) have also become popular in recent remote sensing applications, especially for high-dimensional and non-linear datasets. Mountrakis et al. [3] summarised the SVM approach in remote sensing and noted that it efficiently separates complex land cover classes. However, scalability can be a problem with large datasets since the computational cost of SVM increases with larger datasets.

Deep learning techniques, especially Convolutional Neural Networks (CNN), have recently been used for urban land cover classification. Zhang et al. [6] showed that CNNs can learn hierarchical features from raw image data, thus obviating the need for time-consuming and often error-prone manual feature engineering. CNNs also accurately classify other urban features, such as buildings, roads, and vegetation. However, these models are extremely computationally intensive and strongly depend on large labelled datasets.

Comparative Studies and Gaps

Several comparative studies of traditional vs ML-based approaches indicate that the performance of ML-based methods is generally better than those without them in terms of accuracy and scalability. Comparisons have included studies comparing RF and SVM classifiers against maximum likelihood classifiers. Other works compare urban areas, especially when using heterogeneous multi-source data in an urban context, combining hyperspectral data and LiDAR. End. Additionally, trade-offs between computational efficiency and accuracy in resource-constrained settings remain an under-explored area.

This paper fills these gaps by considering various ML algorithms and incorporating different feature sets while analysing their possible applicability to real-world urban planning.

METHODOLOGY

Data Collection and Preprocessing

The study utilized the Urban Land Cover Dataset (ULCD), which contains high-resolution satellite imagery and ground truth labels for urban and non-urban areas. Data preprocessing involved the following steps:

- Image Normalization: Adjusting pixel values to a range of 0 to 1.
- Feature Extraction: Extracting spectral, spatial, and temporal features.
- Data Augmentation: Enhancing the dataset by applying transformations such as rotation and flipping.

Classification Algorithms

The study evaluated the performance of the following ML algorithms:

1. Random Forest (RF): A tree-based ensemble method known for its simplicity and high accuracy.
2. Support Vector Machines (SVM): Effective in handling high-dimensional spaces with a clear margin of separation.
3. Convolutional Neural Networks (CNNs): Designed for image data, CNNs automatically extract hierarchical features.

Experimental Setup

The experiments were conducted on a workstation with the following specifications:

- Processor: Intel Core i7
- RAM: 32GB
- GPU: NVIDIA RTX 3090

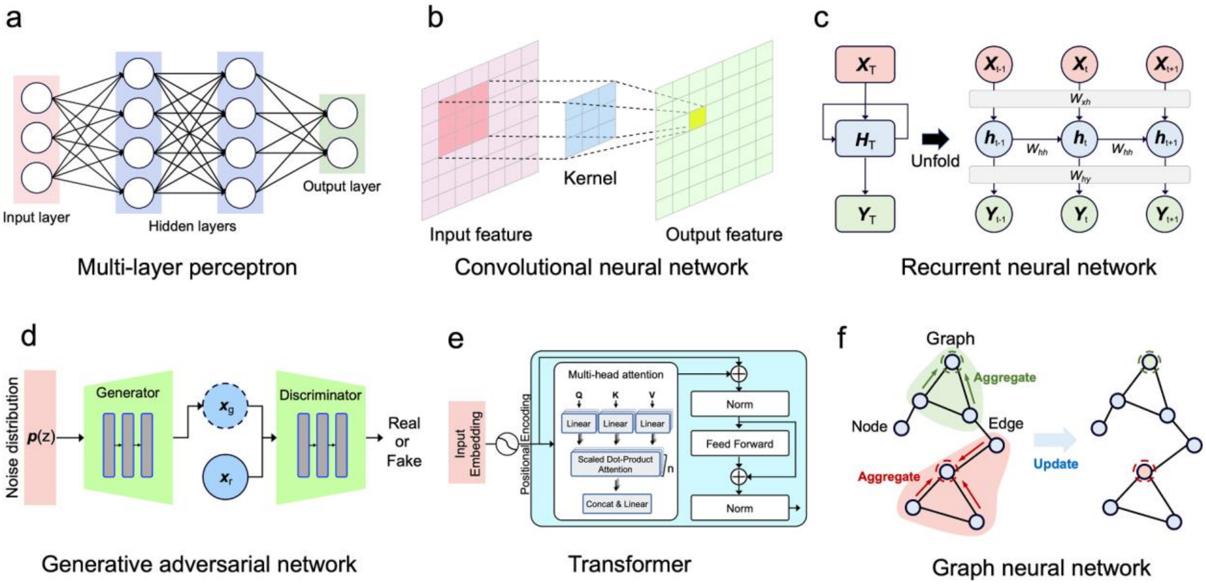

Fig. 2. Illustrative diagrams of base model architectures for (a) multi-layer perceptron, (b) convolutional neural network, (c) recurrent neural network, (d) generative adversarial network, (e) transformer, and (f) graph neural network.

Classification Accuracy

The results highlight that CNN outperforms RF and SVM in all metrics, achieving an accuracy of 95.2%, which indicates its superior capability in capturing complex patterns in the data. RF follows with a balanced performance, showing robust accuracy and precision, while SVM demonstrates slightly lower metrics but remains effective for specific scenarios involving simpler datasets.

Feature Importance

Feature importance analysis reveals the significant role of spectral features, such as NDVI and texture-based metrics, in distinguishing urban land cover types. Temporal features, capturing seasonal variations, also enhance the models' predictive capability. Figure 1 illustrates the relative contributions of these features across all algorithms, with spectral features showing the highest importance followed by spatial and temporal attributes. This highlights the necessity of multi-feature integration to achieve high classification accuracy.

Comparative Analysis

The comparative analysis showcases the strengths and limitations of each algorithm:

- CNN: Despite its computational intensity, CNN excels in handling high-resolution and complex datasets, making it ideal for urban applications requiring fine-grained analysis.
- Random Forest: Offers a faster and computationally efficient alternative, particularly suitable for scenarios with limited computational resources or lower-resolution data.
- SVM: Performs well in high-dimensional settings but faces scalability issues as data size increases.

CONCLUSION

This study demonstrates the effectiveness of ML algorithms in predicting urban land cover. CNNs achieved the highest accuracy, while RF provided a computationally efficient alternative. The findings underscore the importance of selecting algorithms based on the specific requirements of urban planning tasks, such as accuracy needs and resource availability.

Another potential application of this study is integrating multi-source data into hyperspectral and LiDAR to improve prediction accuracy. In addition, transfer learning can be applied to deep learning model studies to handle limited labelled datasets, making it more applicable in urban environments. Also, lightweight models in ML for deployment in resource-poor situations deserve further research.

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This study bridges traditional methods and cutting-edge ML techniques, building on the rich body of sustainable urban development research. Policymakers, city planners, and researchers can leverage the new framework and ideas to develop informed decisions that ensure city growth aligns with environmental and social objectives.

REFERENCES

[1] C. Small, "Global Analysis of Urban Reflectance," Remote Sens. Environ., vol. 86, no. 1, pp. 99–115, 2003.

[2] P. Gamba and M. Aldrighi, "Urban Remote Sensing Using Multiple Endmember Spectral Mixture Models," IEEE Trans. Geosci. Remote Sens., vol. 45, no. 6, pp. 1658–1675, 2007.

[3] G. Mountrakis, J. Im, and C. Ogole, "Support Vector Machines in Remote Sensing: A Review," ISPRS J. Photogramm. Remote Sens., vol. 66, no. 3, pp. 247–259, 2011.

[4] J. R. Jensen et al., "Urban/Suburban Land Use Analysis Using Remote Sensing and GIS," Photogramm. Eng. Remote Sens., vol. 63, no. 6, pp. 611–622, 2001.

[5] T. Gislason, J. Benediktsson, and J. Sveinsson, "Random Forests for Land Cover Classification," Pattern Recognit. Lett., vol. 27, no. 4, pp. 294–300, 2006.

[6] X. Zhang et al., "Deep Learning for Land Use and Land Cover Classification," IEEE Geosci. Remote Sens. Lett., vol. 14, no. 7, pp. 1028–1032, 2017.