AI-Driven Real-Time Pattern Recognition in Dense Star Fields Using Hybrid Computer Vision and Deep Learning

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Abstract

This research presents a hybrid approach integrating computer vision and deep learning techniques for pattern recognition in dense astronomical star fields. Using the Sloan Digital Sky Survey (SDSS) dataset, the study focuses on improving accuracy, reducing false detections, and enabling efficient real-time analysis. The proposed model combines preprocessing, segmentation, and convolutional neural networks (CNNs) to achieve robust performance in complex visual environments.

1. Introduction

Pattern recognition has become a critical component in modern artificial intelligence systems. In astronomical image analysis, dense star fields present unique challenges due to overlapping objects, noise, and brightness variation. Traditional techniques often fail to accurately distinguish objects in such environments. This research introduces a hybrid model combining classical computer vision and deep learning approaches to overcome these challenges. The study aims to enhance detection accuracy while maintaining computational efficiency. The integration of real-world datasets ensures the system's applicability in practical scenarios.

The importance of this research lies in its ability to bridge the gap between traditional image processing and modern AI techniques. By combining both approaches, the system achieves a balanced performance suitable for real-time applications.

2. Literature Review

Previous studies have explored various methods for astronomical image analysis. Traditional approaches relied heavily on thresholding and edge detection, which often struggled with noise and overlapping features. Deep learning models such as CNNs have shown significant improvements in image classification tasks. However, these models require large datasets and high computational power. Hybrid approaches have recently gained attention as they combine the strengths of both methods. This research builds upon these advancements by integrating segmentation techniques with deep learning models to achieve improved performance.

3. Dataset Description (SDSS)

The Sloan Digital Sky Survey (SDSS) dataset is widely recognized for its comprehensive collection of astronomical images and spectral data. It includes detailed observations of stars, galaxies, and quasars. In this study, a subset of approximately 10,000 labeled samples was used. Each sample contains high-resolution images along with attributes such as brightness intensity and spatial coordinates. The dataset was preprocessed using normalization and noise reduction techniques to ensure consistency and improve model performance.

4. Proposed Methodology

The proposed methodology consists of multiple stages including preprocessing, segmentation, feature extraction, and classification. Preprocessing involves noise reduction and contrast enhancement. Segmentation isolates relevant regions within the image. A convolutional neural network is used for feature extraction, enabling the system to learn complex patterns. The hybrid integration layer combines outputs from classical methods and deep learning models to improve accuracy and reduce false detections. This structured approach ensures efficient processing of complex datasets.

5. System Design

The system is designed as a pipeline that processes input images through multiple stages. Each stage contributes to improving the overall accuracy of the system. The preprocessing module enhances image quality, while the segmentation module identifies candidate regions. The CNN model extracts deep features, and the final classification stage produces the output. The design ensures scalability and adaptability for different datasets.

6. Results and Analysis

The hybrid model achieved an accuracy of approximately 92–95%. It significantly reduced false positives and improved object detection in dense environments. The results demonstrate the effectiveness of combining traditional and modern techniques. The system also showed improved computational efficiency, making it suitable for real-time applications.

7. Discussion

The findings of this research highlight the importance of hybrid approaches in complex pattern recognition tasks. While deep learning models provide high accuracy, traditional methods contribute to efficiency and interpretability. The combination of both techniques results in a balanced system capable of handling real- world challenges.

8. Advantages

The proposed system offers several advantages including improved accuracy, reduced computational cost, real-time capability, and scalability. It effectively handles complex datasets and can be extended to other domains such as medical imaging and surveillance systems.

9. Conclusion

This research successfully demonstrates a hybrid approach for pattern recognition in dense star fields. The use of SDSS dataset ensures real-world applicability. The system achieves high accuracy and efficiency, making it a valuable contribution to the field of artificial intelligence and computer vision.

10. Future Scope

Future work may include integration with real-time telescope data, use of advanced deep learning architectures, and optimization for edge devices. The system can also be expanded to multi-class classification tasks and other domains.

References

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