Planetary Recognition and Analysis Model (PRAM): A Unified Deep Learning Framework for Exoplanet Detection

Introduction

The discovery and characterization of exoplanets has revolutionized our understanding of planetary formation and the potential for life beyond Earth. Since the first confirmed exoplanet detection in 1992, over 5,000 exoplanets have been discovered, with thousands more candidates awaiting confirmation. Traditional exoplanet detection methods rely heavily on manual analysis, which is time-intensive. The Planetary Recognition and Analysis Model (PRAM) solves these problems by providing a unified automated detection system.

Methodology

PRAM integrates data from Kepler, TESS, and K2 missions and applies advanced feature engineering to 27 features including orbital period, transit depth, planetary radius, and stellar parameters. It uses an ensemble of XGBoost and Neural Networks, combining their probability outputs to achieve state-of-the-art performance.

A World Away: Hunting for Exoplanets with AI

The search for exoplanets represents one of the most exciting frontiers in modern astronomy. Our team chose this challenge because it addresses critical limitations in traditional exoplanet detection methods. The unprecedented influx of data from space missions such as Kepler, TESS, and K2 requires a powerful, automated approach capable of identifying planetary signals efficiently and accurately.

Abstract

The Planetary Recognition and Analysis Model (PRAM) represents a breakthrough in automated exoplanet detection, combining advanced machine learning techniques with comprehensive astronomical data analysis. This paper presents a unified deep learning framework that integrates data from multiple space missions (Kepler, TESS, K2) to achieve superior accuracy in exoplanet classification. PRAM employs an ensemble approach combining XGBoost gradient boosting with deep neural networks, enhanced by sophisticated feature engineering and class imbalance handling techniques. The model achieves an Area Under the Curve (AUC) score exceeding 0.92, demonstrating exceptional performance in distinguishing confirmed exoplanets from false positives across diverse planetary systems.

Alex AI Team

Hypothesis

We hypothesize that an ensemble of advanced machine learning models can outperform traditional detection methods and improve the reliability of exoplanet classification across diverse datasets

Our Experiment and Project

PRAM integrates Kepler, TESS, and K2 mission data into a single pipeline. The system employs ensemble learning, feature engineering, and data balancing to deliver superior accuracy and confidence scores. In our experiment, PRAM achieved an AUC of 0.9234, accuracy of 0.8756, and average precision of 0.8876 across all mission datasets, outperforming individual models in isolation.

Findings and Current Conclusions

Our results demonstrate that PRAM not only improves classification accuracy but also provides interpretable confidence levels for each prediction. By unifying data from multiple missions, PRAM streamlines the exoplanet detection pipeline and optimizes telescope time for follow-up observations. This unified framework reduces manual effort and increases scientific productivity.

Future Plan

Our future development plan includes multi-class classification of planetary types, integration of spectroscopic data, uncertainty quantification using Bayesian methods, and deployment as a real-time cloud-based API. We also aim to incorporate attention mechanisms for improved interpretability and extend PRAM to include time-series analysis of light curves.

Conclusion

The Planetary Recognition and Analysis Model (PRAM) demonstrates the power of deep learning for exoplanet detection and analysis. Through ensemble methods, robust feature engineering, and cross-mission integration, PRAM sets a new standard for automated exoplanet classification. Our work underscores the potential of AI to accelerate discoveries in astronomy and paves the way for future enhancements in planetary science research.

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Results

The ensemble achieved an AUC of 0.9234, average precision of 0.8876, and accuracy of 0.8756 across missions. Kepler data achieved AUC 0.9456, TESS 0.8967, and K2 0.9123. Top features include transit depth, orbital period, and stellar effective temperature. Predictions are calibrated into confidence levels, from Extremely Likely to Unlikely.

Scientific Applications

PRAM enables efficient prioritization of follow-up observations, seamless integration of multi-mission data, and real-time automated pipeline integration for astronomical data streams.

Limitations and Future Work

Current limitations include dependence on complete feature sets and binary classification only. Future enhancements include multi-class classification, uncertainty quantification, spectroscopic integration, and real-time cloud-based deployment.