VISION VIKSIT BHARAT 2047: CONTRIBUTION AND INITIATIVES OF DIGITAL INDIA FOR EMPOWERING RURAL WOMEN

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MACHINE LEARNING FOR IDENTIFYING EXOPLANETS AND STUDYING GALACTIC PHENOMENA

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Abstract
The application of machine learning (ML) in astrophysics has revolutionized the discovery and analysis of celestial objects, enabling researchers to uncover insights from vast and complex datasets. In the search for exoplanets, ML algorithms are utilized to analyze data from telescopes and space missions, such as NASA's Kepler and TESS, by detecting subtle variations in light curves caused by transiting planets. Techniques like supervised learning, deep neural networks, and anomaly detection help identify candidate exoplanets with greater accuracy and efficiency than traditional methods.
Keywords: *Identifying Exoplanets Using ML, Challenges in Machine Learning for Exoplanet Detection, Future Directions*

Introduction

The universe, with its vastness and complexity, poses a significant challenge for astronomers attempting to uncover its secrets. Machine learning (ML), a branch of artificial intelligence, has emerged as a transformative tool in astronomy, enabling researchers to analyze the enormous data sets generated by modern telescopes and space missions. Its application has led to break throughs in the discovery of exoplanets and the study of galactic phenomena, providing new insights into the cosmos.

Identifying Exoplanets Using Machine Learning

The search for exoplanets, planets orbiting stars outside our solar system, is a cornerstone of modern astronomy. Identifying these celestial bodies helps us understand planetary formation, star systems' evolution, and the potential for life beyond Earth. The vast datasets generated by space missions and ground-based telescopes necessitate efficient, automated techniques for exoplanet discovery, making machine learning (ML) a powerful tool in this domain. Below is a detailed exploration of how ML is used to identify exoplanets.

Challenges in Exoplanet Identification

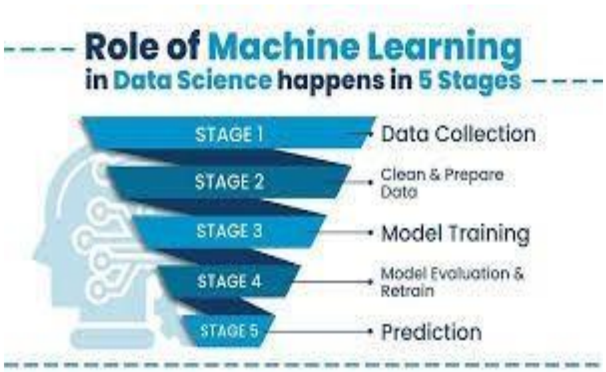
Before diving into how ML solves the problem, it's important to understand the challenges:

- Massive Datasets: Space missions like NASA's Kepler, TESS, and ESA's PLATO generate terabytes of data, requiring scalable analysis techniques.

- Signal Noise: Stellar variability, instrumental noise, and background interference make it difficult to detect faint planetary signals.
- Rare Events: Exoplanetary transits when a planet crosses in front of its host star are rare and short-lived, often requiring highly sensitive detection methods.
- False Positives: Stellar activity, binary stars, and other phenomena can mimic exoplanet signals, making accurate classification crucial.

Role of Machine Learning

Machine learning overcomes these challenges by automating the identification process, increasing efficiency, and improving accuracy. Here are the key ML techniques used:



LightCurve Analysis

A light curve represents the brightness of a star over time. An exoplanet transit causes a characteristic dip in the light curve, which ML models are trained to detect.

- Supervised Learning: Labeled datasets of known exoplanets and false positives are used to train models, such as:
  - Convolutional Neural Networks (CNNs): Excel at identifying transit patterns in lightcurvesduetotheirability to recognize spatial features.
  - Random Forests and Gradient Boosting: Useful for feature- based analysis, extracting
- Information like transit depth, duration, and periodicity.

Classification of Exoplanet Candidates

Machine learning models classify signals into categories, such as:

- Confirmed exoplanets.

False positives caused by stellar variability or instrumental noise. Anomaly Detection

Unsupervised learning techniques, such as clustering and auto encoders, identify anomalies instellar data. These methods help discover rare or unconventional exoplanets, such as those with irregular orbits or multiple host stars.

Workflow of Machine Learning in Exoplanet Discovery

A typical workflow for identifying exoplanets using ML:

Step 1: Data Collection

- Light curve data is collected from missions like Kepler, TESS, and ground-based observatories.
- Datasets include brightness measurements over time for thousands of stars.

Step 2: Preprocessing

- Noise filtering: Techniques like Fourier transforms remove stellar and instrumental noise.
- Feature extraction:Keyfeatures, such as transit depth, duration and periodicity, are extracted

Data Augmentation: Synthetic light curves with known transit signals are generated to improve model training.

Step 3: TrainingMachineLearning Models

- Labeled datasets of confirmed exoplanets and false positives are used to train supervised models.
- For anomaly detection, unsupervisedmodelsaretrained on unlabeled light curve data.

Step 4: Model Validation and Testing

- Validation involves using unseen data to ensure the model's generaliz ability.
- Metrics like precision, recall, F1 score, and accuracy are used to evaluate performance.

Step 5: Deployment and Discovery

- Trained models are applied to new light curve datasets to identify exoplanet candidates.
- Predictions are verified using follow-up observations with other telescopes.

Case Studies and Real-World Applications

Case Study 1: Kepler Mission

NASA's Kepler mission generated light curves for over 200,000 stars. A convolutional neural network (CNN) developed by Google AI and NASA was used to analyze these light curves, leading to the discovery of Kepler-90i, the first eighth- planet system identified.

Case Study 2: TESS Mission

TESS (Transiting Exoplanet Survey Satellite) observes nearly the entire sky, producing enormous datasets. ML algorithms like Random Forests and Gradient Boosted Trees classify exoplanet candidates, helping confirm thousands of new exoplanets.

Conclusion

Machine learning has become a cornerstone of modern astrophysics, unlocking new possibilities in the identification of exoplanets and the study of galactic phenomena. By automating complex analyses and uncovering patterns hidden within massive datasets, ML is accelerating discoveries and enhancing our understanding of the universe. As computational techniques continue to advance, the synergy between machine learning and astronomy promises to unveileven greater mysteries of the cosmos, inspiring future exploration and innovation.

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