COSMOS

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**Literature Survey**

1. *Space Debris Tracking with the Poisson Labeled Multi- Bernoulli Filter*

Cament et al. (2021) propose a Bayesian filter-based ap- proach to space object (SO) tracking using simulated optical telescope observations. Their method incorporates the Prob- abilistic Admissible Region (PAR), which limits the search space for newborn objects by enforcing constraints on or- bital semi-major axis and eccentricity. The authors utilize the Poisson Labeled Multi-Bernoulli (PLMB) filter for multi- target tracking, combining the PAR approach with a Partially Uniform Birth (PUB) intensity model to better estimate ini- tial orbits. They test the method using simulated trajectories derived from real Two-Line Element (TLE) data and obser- vations from twelve Falcon telescope network observatories. Performance evaluation is conducted through the Optimal Sub-Pattern Assignment (OSPA) and CLEAR MOT metrics, which confirm the effectiveness of the model even under sparse observations. The study highlights the advantages of labeled Random Finite Set (RFS) approaches, particularly the computational efficiency of the PLMB filter compared to other multi-target tracking algorithms such as Probability Hypothesis Density (PHD) and Generalized Labeled Multi- Bernoulli (GLMB) filters. By optimizing the initialization of new SO tracks and refining measurement updates, this work provides a robust framework for improving space situational awareness.

1. *Stereo Vision-Based Object Detection for Autonomous Nav- igation in Space Environments*

Duba et al. (2024) present a stereo vision-based intelligent system for detecting space objects, aimed at enhancing au- tonomous navigation in space. The authors address the limi- tations of current stereo cameras, such as Intel RealSense and OAK-D Lite, which have limited depth perception capabilities that make them unsuitable for space applications. Their pro- posed system employs two vertically aligned omnidirectional stereo cameras, spaced 10 cm apart, and integrates a Single Shot Multibox Detector (SSD) deep learning model to identify objects. The distance to detected objects is determined using the triangulation method, allowing for depth perception up to 1.1 km. This approach is particularly beneficial for space debris removal operations, as it enables real-time localization and mapping of objects in space. The authors argue that their method is well-suited for scenarios where objects are within

close range of a spacecraft, making it a valuable tool for path planning and collision avoidance. By leveraging stereo vision and deep learning, this study contributes to the development of intelligent space navigation systems capable of autonomous object detection and avoidance.

1. *A Deep Learning Approach for Satellite and Debris Detec- tion: YOLO in Action*

Ahamed et al. (2023) explore the application of deep learning for detecting satellites and space debris using You Only Look Once (YOLO) object detection algorithms. Their study evaluates the performance of YOLOv4, YOLOv5, and YOLOv8 on a dataset containing satellite and debris images. The research highlights the advantages of deep learning over traditional manual classification methods, emphasizing the efficiency of convolutional neural networks (CNNs) in auto- matically extracting relevant features from images. Evaluation metrics such as Precision, Recall, Mean Average Precision (mAP), Box Loss, and Class Loss indicate that YOLOv5 and YOLOv8 outperform YOLOv4, particularly in detecting small objects. The study underscores the importance of au- tomated detection techniques for space situational awareness, as manual analysis of satellite imagery is time-consuming and impractical given the increasing number of Resident Space Objects (RSOs). By demonstrating the high accuracy and real- time processing capabilities of YOLO models, this research provides a scalable solution for satellite and debris monitoring.

1. A Survey on Image Processing-Based Techniques for Space Debris Detection

Jahirabadkar et al. (2022) provide a comprehensive review of image processing techniques for space debris detection, categorizing methods into ground-based tracking, satellite- based observation, simulation-based detection, and fusion- based techniques. Ground-based approaches, including radar and telescopic imaging, are widely used but suffer from limitations such as atmospheric interference and coverage constraints. Satellite-based methods leverage onboard sensors to capture high-resolution visible and thermal images, im- proving detection accuracy in non-sunlit areas. The authors emphasize the potential of deep learning and machine learning techniques in enhancing space debris identification, particu- larly through the fusion of visible and thermal imaging. This hybrid approach overcomes the shortcomings of single-sensor detection methods by combining complementary information. The survey concludes that while deep learning-based fusion

techniques hold promise for improving detection rates, further research is needed to optimize computational efficiency and minimize false positives.

1. *Detecting Space Debris Using Deep Learning Algorithms: A Survey*

Jharbade and Dixit (2022) analyze the application of deep convolutional neural networks (DCNNs) for space debris detection, focusing on image-based methods. They discuss the challenges of detecting high-speed debris in orbit and the limitations of traditional observation techniques such as radar and monocular photography. The study categorizes space debris based on size, speed, and detectability, highlighting the difficulties associated with tracking small, fast-moving objects. The authors explore various deep learning architec- tures, including AlexNet, VGGNet, GoogleNet, and ResNet, demonstrating their ability to outperform traditional classifi- cation methods in image recognition tasks. They advocate for the use of deep learning in real-time space debris detection, arguing that CNN-based approaches can significantly enhance the accuracy and efficiency of tracking systems. The survey concludes that integrating deep learning with space-based observation platforms will be critical for future space debris monitoring initiatives.

1. *Deep Learning-Based Space Debris Detection Applied to Radar Processing*

This study investigates the role of deep learning in radar- based space debris detection. Traditional radar processing methods struggle with high false alarm rates and difficulty distinguishing debris from background noise. By incorporating deep learning models into radar signal analysis, the authors demonstrate improved classification accuracy and reduced false positives. The paper discusses various neural network architectures optimized for radar data processing, including recurrent neural networks (RNNs) and convolutional neural networks (CNNs). The study highlights the advantages of deep learning in extracting meaningful features from radar echoes, enabling more precise debris identification. The authors con- clude that deep learning-based radar processing represents a promising approach for enhancing space situational awareness, particularly in detecting smaller debris fragments that tradi- tional methods might overlook.

1. *Space Debris Detection Over Intersatellite Communication Signals*

Anttonen et al. (2021) propose a novel approach to space debris detection using intersatellite communication signals as a hidden radar capability. Their Space-Borne Radar and Com- munications (SBRC) system leverages 5G satellite constella- tions to passively detect debris without requiring dedicated radar infrastructure. The method exploits existing communica- tion signals to estimate debris motion and range, reducing the need for additional power and spectrum allocation. Through sophisticated simulations, the authors demonstrate that the SBRC approach can effectively track high-velocity debris in

low Earth orbit (LEO), even at long distances. The study underscores the potential of integrating radar functionality into satellite communication systems, offering a cost-effective and scalable solution for space debris monitoring.

1. *Enhanced YOLOv8-Based Method for Space Debris Detec- tion Using Cross-Scale Feature Fusion*

Guo et al. (2025) introduce an improved approach to space debris detection by enhancing the YOLOv8 object detection framework. The authors incorporate a lightweight cross-scale feature fusion module into the network’s architecture to bol- ster its capability in fusing features across different scales. Additionally, they implement a content-aware reassembly of features module to enhance the quality of feature reconstruc- tion. These modifications aim to improve both the accuracy and speed of detecting space debris, especially in complex celestial backgrounds. Experimental results, utilizing datasets from large-field-of-view optical telescopes, demonstrate that the enhanced model achieves superior detection performance while maintaining computational efficiency.

1. *Event Detection from Novel Data Sources: Leveraging Satellite Imagery Alongside GPS Traces*

Ekin Ugurel et al. propose a novel data fusion methodology integrating satellite imagery with privacy-enhanced mobile data to augment the event inference task. This method en- ables real-time or historical analysis of small-scale disasters, search and rescue operations, and active conflict detection. By leveraging mobile data for human mobility approximation and satellite imagery for environmental changes, this framework enhances rapid response capabilities in emergency situations. The study highlights challenges such as data privacy concerns, resolution limitations in satellite imagery, and the need for real-time processing pipelines to facilitate actionable insights. Future directions include refining deep learning models for better feature extraction and optimizing data fusion techniques to improve robustness.

1. *CSIP-Net: Convolutional Satellite Image Prediction Net- work for Meteorological Satellite Infrared Observation Imag- ing*

Jiang et al. introduce CSIP-Net, a deep learning model designed to predict geosynchronous satellite observation sequences. By leveraging convolutional neural networks (CNNs), the model effectively predicts meteorological satellite images, significantly improving short-term weather forecast- ing, particularly precipitation prediction. The study compares CSIP-Net with existing deep learning models, demonstrating its superior ability to capture spatial and temporal dependen- cies in satellite images. The results indicate that CSIP-Net reduces forecasting errors, making it a promising tool for operational meteorology. However, challenges such as limited training data and the need for domain adaptation techniques are highlighted as areas for further exploration.

1. *Advances in Solar Forecasting: Computer Vision with Deep Learning*

Paletta et al. explore the integration of computer vision and deep learning in solar forecasting. The study highlights the limitations of traditional numerical weather prediction models and showcases how multisensor Earth observations, combined with machine learning, enhance forecasting accuracy. The research emphasizes the use of satellite imagery and ground- level sky cameras for cloud movement analysis, providing a more robust framework for predicting solar energy variability. The study demonstrates that deep learning-based cloud clas- sification and motion estimation significantly improve short- term solar power generation forecasts, making them valuable for optimizing renewable energy grid integration. Further advancements in transfer learning and multi-sensor fusion are proposed to refine prediction accuracy.

1. *Fusion of Satellite Images and Weather Data With Trans- former Networks for Downy Mildew Disease Detection*

Maillet et al. present a multimodal deep learning approach that combines satellite images with weather data to detect downy mildew disease in crops. The study introduces a novel transformer-based fusion architecture that integrates visual and environmental data, significantly improving disease prediction accuracy. The model is tested on agricultural datasets, demon- strating its ability to predict disease outbreaks before visible symptoms appear. The research contributes to precision agri- culture by minimizing pesticide use and optimizing localized crop treatment. Challenges such as data imbalance, model interpretability, and computational complexity are discussed, along with potential solutions including active learning and transfer learning techniques.

1. *Precipitation Nowcasting with Satellite Imagery*

Ivashkin et al. propose a deep learning framework for precipitation nowcasting using satellite imagery. The model utilizes convolutional and recurrent neural networks to analyze cloud movement and predict short-term precipitation patterns. The study demonstrates the model’s effectiveness in improving real-time weather forecasting accuracy compared to traditional numerical models. A key innovation is the integration of attention mechanisms to enhance feature selection in cloud dynamics. The study also discusses the challenges of acquiring high-resolution satellite data, computational efficiency, and potential biases in training data that may affect generalization.

1. *Vision Transformers for Robust Analysis of Satellite Im- agery*

Gamarra et al. investigate the application of Vision Trans- formers (ViTs) for land use classification using satellite im- agery. Their experiments on the WILDS Out-of-Distribution (OOD) benchmark indicate that ViTs offer potential for OOD detection but require architectural modifications for improved generalization. The study suggests that integrating additional metadata and refining learning strategies could enhance ViT performance in satellite image analysis. It also examines the

challenges of transformer-based models, such as high compu- tational demands and the need for extensive labeled datasets. The authors propose self-supervised learning and augmenta- tion strategies to mitigate these challenges and improve model adaptability.

1. *STC-ViT: Spatio-Temporal Continuous Vision Transformer for Weather Forecasting*

Saleem et al. introduce STC-ViT, a transformer-based model for weather forecasting that integrates continuous-time Neural ODE layers with multi-head attention. This approach improves the modeling of spatiotemporal weather patterns, addressing limitations in conventional transformer models. The study highlights the advantages of physics-informed loss functions for enforcing atmospheric constraints, leading to more accurate and computationally efficient weather predictions. The model is benchmarked against operational Numerical Weather Pre- diction (NWP) models and other deep learning approaches, showcasing superior performance in both short-term and long- term forecasting. Future improvements include refining loss functions and incorporating additional geospatial data sources.

1. *Manipulation Detection in Satellite Images Using Vision Transformer*

Horva´th et al. propose an unsupervised manipulation de- tection technique for satellite images using Vision Trans- formers. Their model detects spliced areas within images, outperforming existing unsupervised detection methods. The study presents a novel dataset containing manipulated satellite images and demonstrates the efficacy of transformer-based approaches in satellite image forensics. The research high- lights the challenges of detecting sophisticated forgeries, such as GAN-based manipulations, and explores techniques for improving robustness against adversarial attacks. The study concludes that hybrid transformer-CNN models may offer improved detection accuracy and generalization for future forensic applications.