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EXPLAINABLE MACHINE LEARNING FOR SPACE OBJECT ATTITUDE CLASSIFICATION

Abstract

Attitude estimation is a significant challenge in space object tracking. Nevertheless, it also has important applications, including supporting operators facing communication issues and providing a better understanding of object behaviour for trajectory prediction and Space Traffic Management. Traditional attitude estimation methods frequently rely on expert-driven analysis and domain-specific models or require extensive observational data. This work introduces a lightweight and interpretable machine learning approach for attitude determination, leveraging domain-expert-driven feature engineering and decision-tree-based models to achieve accurate classification with minimal computational overhead. By designing features that mimic expert decision-making processes, our model is a structured, data-driven alternative to manual analysis, ensuring consistent and reliable classifications – even in scenarios where expert input is unavailable. Our method extracts motion, brightness, and periodicity features from optical observations, effectively distinguishing between tumbling and stable objects. Unlike deep learning-based techniques, which require extensive training and often lack transparency, our approach is interpretable by design and further explainable through post hoc analysis methods, reinforcing its reliability for real-world applications. The combination of interpretability and computational efficiency enables rapid experimentation, real-time adaptability, and safe deployment in operational environments. We demonstrate that our method achieves competitive results through extensive validation and ablation studies while maintaining scalability, robustness, and operational feasibility. This work paves the way for efficient and operationally viable attitude estimation, particularly in resource-constrained environments where real-time decision-making is crucial.