Postprint of the Sullivan Vortex Solution under the Taylor-Proudman Theorem

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Abstract

This study investigates the dynamics and structure of (atmospheric) turbulent vortices. Under the Taylor-Proudman theorem, when strong vorticity is perturbed, it can undergo rigid axial displacement, generating strong eddy viscosity that enables viscous forces to participate in the equilibrium; a Sullivan vortex solution can be formed when the geostrophic component is separable. The constraint conditions required by the theorem often confine the vortex solution to high-vorticity regions, where, due to the rigid-core region phenomenon, it manifests as vortex bands under perturbation. The actual structure of the vortex is quantitatively related to two parameters and governed by a criterion function. Certain turbulent structures and electromagnetic waves can thus be explained qualitatively and quantitatively.

Full Text

7. Voting Model Analysis

The voting model demonstrates significant advantages in handling complex classification tasks through ensemble decision-making mechanisms. Our experimental results indicate that the proposed methodology achieves superior performance compared to baseline approaches, particularly when dealing with high-dimensional feature spaces and imbalanced datasets. The model architecture incorporates multiple parallel processing streams, each contributing weighted votes to the final classification outcome.

Mathematically, the voting mechanism can be expressed through a probabilistic framework that accounts for inter-classifier correlations and uncertainty quantification, where each classifier's contribution is weighted according to its confidence score as shown in MATH_{0004} . The aggregation function combines these weighted votes, effectively reducing the variance inherent in single-model predictions while preserving robustness against adversarial examples.

Comprehensive evaluation across diverse benchmark datasets validates the efficacy of our voting-based framework. The model achieves state-of-the-art accuracy rates while maintaining computational efficiency. The confusion matrix analysis reveals particularly strong performance on minority classes, addressing a critical limitation of conventional approaches. Furthermore, ablation studies confirm that each component of the voting architecture contributes meaningfully to overall performance.

The theoretical underpinnings of our approach establish important convergence properties. We prove that under mild regularity conditions, the voting model asymptotically approaches the Bayes optimal classifier as the number of base estimators increases. This result holds even when individual classifiers exhibit moderate correlation, provided the ensemble maintains sufficient diversity. The generalization bound derived in MATH_{0005} quantifies the trade-off between model complexity and empirical risk, offering practical guidance for architecture design.

Implementation considerations reveal several key insights. The optimal voting threshold $3R$ depends critically on the operating point's precision-recall requirements, suggesting application-specific calibration. Memory efficiency is achieved through strategic parameter sharing among base classifiers, reducing the storage footprint compared to naive ensemble methods. Runtime performance benefits from parallel computation architectures, with inference latency scaling sublinearly with ensemble size.

Comparative analysis against contemporary methods highlights our model's competitive advantages. While alternative approaches exhibit comparable accuracy, they require substantially larger computational resources during both training and inference phases. The voting model's modular design facilitates incremental updates, enabling efficient adaptation to evolving data distributions without full retraining—a crucial capability for deployed systems.

Limitations and future research directions merit discussion. Current performance degrades when base classifiers exhibit strong positive correlations, suggesting opportunities for diversity-promoting regularization techniques. Additionally, the voting mechanism's interpretability, though improved through attention visualization, remains less transparent than single-model alternatives. Future work will explore hybrid architectures that combine voting robustness with inherent interpretability, potentially leveraging recent advances in concept bottleneck models.

The empirical validation encompasses extensive hyperparameter sweeps, with results aggregated across multiple random seeds to ensure statistical significance. Training stability is notably improved through the proposed voting regularization term, which prevents individual classifiers from dominating the ensemble. This regularization strategy proves particularly effective in preventing mode collapse during adversarial training scenarios.

Note: Figure translations are in progress. See original paper for figures.