Novelty Assessment Report

Paper: Slicing Wasserstein over Wasserstein via Functional Optimal Transport

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Abstract

Wasserstein distances define a metric between probability measures on arbitrary metric spaces, including meta-measures (measures over measures). The resulting Wasserstein over Wasserstein (WoW) distance is a powerful, but computationally costly tool for comparing datasets or distributions over images and shapes. Existing sliced WoW accelerations rely on parametric meta-measures or the existence of high-order moments, leading to numerical instability. As an alternative, we propose to leverage the isometry between the 1d Wasserstein space and the quantile functions in the function space $L_2([0,1])$. For this purpose, we introduce a general sliced Wasserstein framework for arbitrary Banach spaces. Due to the 1d Wasserstein isometry, this framework defines a sliced distance between 1d meta-measures via infinite-dimensional L_2-projections, parametrized by Gaussian processes. Combining this 1d construction with classical integration over the Euclidean unit sphere yields the double-sliced Wasserstein (DSW) metric for general meta-measures. We show that DSW minimization is equivalent to WoW minimization for discretized meta-measures, while avoiding unstable higher-order moments and computational savings. Numerical experiments on datasets, shapes, and images validate DSW as a scalable substitute for the WoW distance.

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Core Task Landscape

This paper addresses: **Comparing Distributions over Non-Euclidean Objects using Optimal Transport**

A total of **50 papers** were analyzed and organized into a taxonomy with **18 categories**.

Taxonomy Overview

The research landscape has been organized into the following main categories:

- **Computational Methods and Algorithmic Frameworks**
- **Non-Euclidean Geometries and Manifold Structures**
- **Reproducing Kernel Hilbert Spaces and Feature Embeddings**
- **Theoretical Foundations and Mathematical Analysis**
- **Regression, Inference, and Statistical Modeling**
- **Applications and Domain-Specific Methods**
- **Specialized Formulations and Extensions**

Complete Taxonomy Tree

- Comparing Distributions over Non-Euclidean Objects using Optimal Transport Survey Taxonomy
- Computational Methods and Algorithmic Frameworks
  - Sliced and Projection-Based Approaches ★ (5 papers)
  - [0] Slicing Wasserstein over Wasserstein via Functional Optimal Transport (Anon et al., 2026) View paper
  - [1] An introduction to sliced optimal transport (Nguyen, 2025) View paper
  - [8] Non‑Euclidean Sliced Optimal Transport Sampling (Courty, 2024) View paper
  - [22] A Novel Sliced Fused Gromov-Wasserstein Distance (Beinert, 2025) View paper
  - [47] Non-Euclidean Sliced Optimal Transport Sampling Software (Courty, 2024) View paper
  - Entropic Regularization and Sinkhorn Methods (3 papers)
  - [15] Efficient Numerical Strategies for Entropy-Regularized Semi-Discrete Optimal Transport (Khamlich, 2025) View paper
  - [16] Hilbert sinkhorn divergence for optimal transport (Qian Li, 2021) View paper
  - [25] Quantum entropic regularization of matrix-valued optimal transport (G. Peyré, 2019) View paper
  - Neural and Learning-Based Optimal Transport (3 papers)
  - [10] Deep shells: Unsupervised shape correspondence with optimal transport (Eisenberger, 2020) View paper
  - [19] Universal Neural Optimal Transport (Geuter, 2022) View paper
  - [27] Neural Optimal Transport with Lagrangian Costs (Pooladian, 2024) View paper
- Non-Euclidean Geometries and Manifold Structures
  - Hyperbolic and Curved Spaces (4 papers)
  - [6] Bridging the space gap: Unifying geometry knowledge graph embedding with optimal transport (Yuhan Liu, 2024) View paper
  - [33] Existence and uniqueness of optimal transport maps in locally compact $CAT(0)$ spaces (Bürdülima, 2023) View paper
  - [35] Hyperbolic Optimal Transport (Ng, 2025) View paper
  - [42] Unsupervised hierarchy matching with optimal transport over hyperbolic spaces (Alvarez-Melis, 2020) View paper
  - Spherical, Circular, and Compact Manifolds (4 papers)
  - [9] LCOT: Linear circular optimal transport (Martín, 2023) View paper
  - [11] Logarithmic-Sobolev inequalities on non-compact Euclidean submanifolds: sharpness and rigidity (Balogh, 2024) View paper
  - [12] Transportation onto log-Lipschitz perturbations (Max Fathi, 2024) View paper
  - [29] Nonparametric measure-transportation-based methods for directional data (M. Hallin, 2024) View paper

- General Riemannian and Metric Spaces (5 papers)
  - [21] Generalized dimension reduction using semi-relaxed Gromov-Wasserstein distance (Ranthony A. Clark, 2025) View paper
  - [28] Optimal Transport on Null Hypersurfaces and the Null Energy Condition (Fabio Cavalletti, 2024) View paper
  - [34] Backward martingale transport and Fitzpatrick functions in pseudo-Euclidean spaces (Dmitry Kramkov, 2024) View paper
  - [39] Domain Adaptation as Optimal Transport on Grassmann Manifolds (Tianhang Long, 2022) View paper
  - [46] Measure estimation on manifolds: an optimal transport approach (Vincent Divol, 2022) View paper
  - Gromov-Wasserstein and Metric-Metric Alignment (2 papers)
  - [20] Joint Metric Space Embedding by Unbalanced OT with Gromov-Wasserstein Marginal Penalization (Beier, 2025) View paper
  - [24] Synchronizing probability measures on rotations via optimal transport (Birdal, 2020) View paper
- Reproducing Kernel Hilbert Spaces and Feature Embeddings (3 papers)
  - [2] Gaussian Process regression over discrete probability measures: on the non-stationarity relation between Euclidean and Wasserstein Squared Exponential Kernels (Antonio Candelieri, 2025) View paper
  - [4] Metric Learning for 3D Point Clouds Using Optimal Transport (Siddharth Katageri, 2024) View paper
  - [14] Optimal transport in reproducing kernel hilbert spaces: Theory and applications (Zhen Zhang, 2019) View paper
- Theoretical Foundations and Mathematical Analysis
  - Convergence and Statistical Properties (2 papers)
  - [26] Empirical optimal transport on countable metric spaces: Distributional limits and statistical applications (Tameling, 2019) View paper
  - [43] Empirical optimal transport between different measures adapts to lower complexity (Shayan Hundrieser, 2024) View paper
  - Geometric and Differential Structure (3 papers)
  - [7] Geometric thermodynamics for the Fokker–Planck equation: stochastic thermodynamic links between information geometry and optimal transport (Sosuke Ito, 2024) View paper
  - [13] HOTA: Hamiltonian framework for Optimal Transport Advection (Buzun, 2025) View paper
  - [23] Natural gradient via optimal transport (Wuchen Li, 2018) View paper
  - Martingale and Stochastic Constraints (2 papers)
  - [44] Procrustes metrics on covariance operators and optimal transportation of Gaussian processes (Masarotto, 2019) View paper
  - [45] Backward martingale transport maps and equilibrium with insider (Kramkov, 2023) View paper
- Regression, Inference, and Statistical Modeling
  - Distribution-on-Distribution Regression (2 papers)
  - [17] Neural local wasserstein regression (Inga Girshfeld, 2025) View paper
  - [38] Geodesic Optimal Transport Regression (Zhu, 2023) View paper
  - Conditional and Bayesian Inference (2 papers)
  - [48] Conditional Optimal Transport on Function Spaces (Bamdad Hosseini, 2025) View paper
  - [50] Functional time series forecasting of distributions: A Koopman-Wasserstein approach (Ziyue Wang, 2025) View paper
- Applications and Domain-Specific Methods
  - Graph and Network Learning (1 papers)
  - [3] Enhancing Unsupervised Graph Few-shot Learning via Set Functions and Optimal Transport (Yonghao Liu, 2025) View paper
  - Domain Adaptation and Transfer Learning (2 papers)
  - [31] Curriculum reinforcement learning using optimal transport via gradual domain adaptation (Huang, 2022) View paper
  - [49] Modeling User Preferences as Distributions for Optimal Transport-based Cross-domain Recommendation under Non-overlapping Settings (Suzumura, 2025) View paper
  - Generative Modeling and Sampling (1 papers)
  - [30] Advances in optimal transport for biology; from manifold learning to generative modeling (Huguet, 2025) View paper
  - Scientific and Specialized Applications (3 papers)
  - [18] On the design and evaluation of generative models in high energy density physics (A. Shukla, 2025) View paper
  - [37] Quantifying functionally equivalent species and ecological network dissimilarity with optimal transport distances (Kai M. Hung, 2025) View paper
  - [40] Geometric Optimal Transport for Cross-Modal Medical Manifold Alignment: A Differential Approach to Multimodal Diagnosis (Yuan Shen, 2025) View paper
- Specialized Formulations and Extensions (4 papers)
  - [5] Multivariate quantiles and regularized optimal transport (Thurin, 2024) View paper
  - [32] Infinite-dimensional optimization for zero-sum games via variational transport (Lewis Liu, 2021) View paper
  - [36] Transport Inequalities on Euclidean Spaces for Non-Euclidean Metrics (S. Bobkov, 2020) View paper
  - [41] Optimal Transport Methods for Statistical Analysis of Shape Distributions and Images (Wilson, 2024) View paper

Narrative

Core task: comparing distributions over non-Euclidean objects using optimal transport. The field has evolved into a rich taxonomy spanning seven major branches that address distinct but interconnected challenges. Computational Methods and Algorithmic Frameworks focus on efficient solvers and projection-based techniques such as sliced approaches, which reduce high-dimensional transport problems to tractable one-dimensional projections. Non-Euclidean Geometries and Manifold Structures tackle transport on curved spaces—ranging from hyperbolic geometries to Riemannian manifolds—where classical Euclidean assumptions break down. Reproducing Kernel Hilbert Spaces and Feature Embeddings leverage kernel methods to handle complex data types, while Theoretical Foundations and Mathematical Analysis provide rigorous convergence guarantees and geometric insights. Regression, Inference, and Statistical Modeling apply transport-based distances to prediction and uncertainty quantification, Applications and Domain-Specific Methods demonstrate utility in biology, recommendation systems, and medical imaging, and Specialized Formulations and Extensions explore variants like unbalanced or Gromov-Wasserstein distances that relax standard constraints.

Within the computational branch, sliced and projection-based methods have emerged as a particularly active line of work, balancing scalability with approximation quality. Sliced Optimal Transport Introduction[1] and Non-Euclidean Sampling Software[47] illustrate how projections can be extended beyond Euclidean settings, while Sliced Fused Gromov-Wasserstein[22] combines slicing with structure-aware matching. The original paper, Slicing Wasserstein Functional[0], sits squarely in this projection-based cluster, contributing new theoretical or algorithmic insights into how slicing strategies generalize to non-Euclidean domains. Compared to Non-Euclidean Sliced Sampling[8], which emphasizes sampling procedures on manifolds, Slicing Wasserstein Functional[0] appears to focus more directly on the functional analytic properties of sliced transport. Meanwhile, works like Gaussian Process Wasserstein Kernels[2] and RKHS Optimal Transport[14] pursue complementary kernel-based embeddings, highlighting an ongoing trade-off between projection simplicity and the expressiveness of feature-space methods.

Related Works in Same Category

The following **4 sibling papers** share the same taxonomy leaf node with the original paper:

1. An introduction to sliced optimal transport

Authors: Nguyen, Khai, Khai Nguyen | **Year/Venue**: 2025 | **URL**: View paper

Abstract

Sliced Optimal Transport (SOT) is a rapidly developing branch of optimal transport (OT) that exploits the tractability of one-dimensional OT problems. By combining tools from OT, integral geometry, and computational statistics, SOT enables fast and scalable computation of distances, barycenters, and kernels for probability measures, while retaining rich geometric structure. This paper provides a comprehensive review of SOT, covering its mathematical foundations, methodological advances, computat...

Relationship Analysis

Both papers belong to the Sliced and Projection-Based Approaches category, utilizing one-dimensional projections to reduce computational complexity in optimal transport. The original paper introduces a novel double-sliced Wasserstein (DSW) metric specifically for comparing meta-measures (distributions over distributions) by combining classical slicing with functional optimal transport via quantile function embeddings in L2 space, while the candidate paper is a comprehensive survey that provides foundational theory and broad coverage of sliced optimal transport methods across various domains. The key difference is that the original paper presents a specific technical contribution (DSW for meta-measures with Gaussian process projections), whereas the candidate is an introductory survey covering the entire field of sliced optimal transport including foundations, advances, extensions, and applications.

2. Non‑Euclidean Sliced Optimal Transport Sampling

Authors: Courty, Nicolas, Baptiste Genest, Coeurjolly, David, et al. (7 authors total) | **Year/Venue**: 2024 • Computer graphics forum (Print) | **URL**: View paper

Abstract

In machine learning and computer graphics, a fundamental task is the approximation of a probability density function through a well‑dispersed collection of samples. Providing a formal metric for measuring the distance between probability measures on general spaces, Optimal Transport (OT) emerges as a pivotal theoretical framework within this context. However, the associated computational burden is prohibitive in most real‑world scenarios. Leveraging the simple structure of OT in 1D, Sliced O...

Relationship Analysis

Both papers belong to the Sliced and Projection-Based Approaches category, leveraging one-dimensional projections to reduce computational complexity of optimal transport. They share the common goal of efficiently computing optimal transport distances through slicing techniques, with the original paper focusing on slicing Wasserstein over Wasserstein distances via functional optimal transport using quantile functions in L2 space, while the candidate paper extends sliced optimal transport sampling to non-Euclidean domains (spherical, hyperbolic, and projective spaces) for blue noise sampling applications. The key difference is that the original paper addresses meta-measures (distributions over distributions) through double-slicing and Gaussian process projections, whereas the candidate paper focuses on sampling probability measures on Riemannian manifolds using geodesic-based slicing.

3. A Novel Sliced Fused Gromov-Wasserstein Distance

Authors: Beinert, Robert, Moritz Piening, Robert Beinert | **Year/Venue**: 2025 • arXiv.org | **URL**: View paper

Abstract

The Gromov--Wasserstein (GW) distance and its fused extension (FGW) are powerful tools for comparing heterogeneous data. Their computation is, however, challenging since both distances are based on non-convex, quadratic optimal transport (OT) problems. Leveraging 1D OT, a sliced version of GW has been proposed to lower the computational burden. Unfortunately, this sliced version is restricted to Euclidean geometry and loses invariance to isometries, strongly limiting its application in practice....

Relationship Analysis

Both papers belong to the Sliced and Projection-Based Approaches category, using one-dimensional projections to reduce computational complexity of optimal transport. They overlap in addressing computational challenges of Wasserstein distances through slicing techniques, but differ fundamentally in their target spaces and methods: the original paper introduces a double-sliced approach for meta-measures (distributions over distributions) using functional optimal transport and Gaussian process projections in L2 space, while the candidate paper focuses on slicing the Gromov-Wasserstein distance for comparing metric measure spaces with different underlying geometries through hierarchical optimal transport and quadrature-based 1D projections.

4. Non-Euclidean Sliced Optimal Transport Sampling Software

Authors: Courty, Nicolas, Coeurjolly, David | **Year/Venue**: 2024 | **URL**: View paper

Abstract

Source code of the article:Genest, Baptiste, Nicolas Courty, and David Coeurjolly. "Non-Euclidean Sliced Optimal Transport Sampling", Computer Graphics Forum (Proceedings of Eurographics), April, 2024

Relationship Analysis

Both papers belong to the Sliced and Projection-Based Approaches category, utilizing one-dimensional projections to reduce computational complexity in optimal transport. The candidate paper focuses on software implementation for non-Euclidean sliced optimal transport sampling, providing computational tools for the domain. In contrast, the original paper develops theoretical foundations for slicing Wasserstein distances over Wasserstein spaces (meta-measures) via functional optimal transport, introducing the double-sliced Wasserstein (DSW) metric with applications to comparing distributions of images, shapes, and datasets.

Contributions Analysis

This paper presents **3 main contributions**, each analyzed against relevant prior work:

Contribution 1: General sliced Wasserstein framework for arbitrary Banach spaces

Description: The authors develop a generalized sliced Wasserstein distance framework that extends beyond Euclidean spaces to arbitrary separable Banach spaces. This framework uses a reference measure on the dual space to define projections and establishes metric properties under suitable conditions.

This contribution was assessed against **10 related papers** from the literature. Papers with potential prior art are analyzed in detail with textual evidence; others receive brief assessments.

1. A Novel Sliced Fused Gromov-Wasserstein Distance

URL: View paper

Brief Assessment

Sliced Fused Gromov-Wasserstein[22] focuses on slicing techniques for Gromov-Wasserstein distances in metric spaces with isometric invariance, not on developing a general sliced Wasserstein framework for arbitrary separable Banach spaces with dual space projections.

2. Non-Euclidean Sliced Optimal Transport Sampling

URL: View paper

Brief Assessment

Non-Euclidean Sliced Sampling[8] focuses on sliced optimal transport for specific constant curvature manifolds (spherical, hyperbolic, projective spaces) rather than developing a general framework for arbitrary separable Banach spaces with reference measures on dual spaces.

3. Central limit theorem for the Sliced 1-Wasserstein distance and the max-Sliced 1-Wasserstein distance

URL: View paper

Brief Assessment

Sliced Wasserstein CLT[54] focuses on central limit theorems and statistical properties of sliced 1-Wasserstein distances in Banach spaces, not on developing a general framework with reference measures on dual spaces for arbitrary separable Banach spaces.

4. Wasserstein-Aligned Hyperbolic Multi-View Clustering

URL: View paper

Brief Assessment

Hyperbolic Multi-View Clustering[58] focuses on applying sliced Wasserstein distance specifically to hyperbolic spaces (Lorentz manifold) for multi-view clustering tasks, not on developing a general framework for arbitrary Banach spaces. The candidate's scope is narrower and application-specific.

5. Sliced-Wasserstein Distances and Flows on Cartan-Hadamard Manifolds

URL: View paper

Brief Assessment

Cartan-Hadamard Sliced Flows[52] focuses on sliced-Wasserstein distances specifically on Cartan-Hadamard manifolds (Riemannian manifolds with non-positive curvature), not on arbitrary separable Banach spaces. The geometric structures and technical approaches differ fundamentally.

6. Sliced and radon wasserstein barycenters of measures

URL: View paper

Brief Assessment

Sliced Radon Barycenters[55] focuses on computing barycenters of measures using 1-d Wasserstein distances along radial projections, not on developing a general sliced Wasserstein framework for arbitrary separable Banach spaces with reference measures on dual spaces.

7. Spherical tree-sliced Wasserstein distance

URL: View paper

Brief Assessment

Spherical Tree-Sliced[51] focuses specifically on spherical geometries and hypersphere manifolds, not on general Banach spaces. The candidate develops spherical trees and spherical radon transforms for measures on spheres, which is a different technical direction from the original paper's framework for arbitrary separable Banach spaces.

8. Wasserstein of Wasserstein loss for learning generative models

URL: View paper

Brief Assessment

Wasserstein of Wasserstein[57] focuses on using Wasserstein distance as a ground metric for images in generative modeling, not on developing a general sliced Wasserstein framework for arbitrary Banach spaces.

9. Tree-Sliced Entropy Partial Transport

URL: View paper

Brief Assessment

Tree-Sliced Entropy[53] focuses on tree metric spaces and partial transport for unbalanced measures, not on general Banach space extensions of sliced Wasserstein distances.

10. Sliced optimal transport on the sphere

URL: View paper

Brief Assessment

Spherical Sliced Transport[56] focuses specifically on sliced optimal transport on the sphere (S^2) using vertical slice and semicircle transforms, not on general Banach spaces. The candidate's framework is domain-specific to spherical geometry rather than arbitrary separable Banach spaces.

Contribution 2: Double-sliced Wasserstein (DSW) metric for meta-measures

Description: The authors introduce the DSW metric, which combines classical spherical slicing with infinite-dimensional L2-projections parametrized by Gaussian processes. This provides a computationally efficient alternative to the Wasserstein over Wasserstein distance for comparing distributions over distributions.

This contribution was assessed against **10 related papers** from the literature. Papers with potential prior art are analyzed in detail with textual evidence; others receive brief assessments.

1. Large-scale optimal transport and mapping estimation

URL: View paper

Brief Assessment

Large-scale Mapping Estimation[65] focuses on computing optimal transport plans and Monge maps between distributions using dual stochastic approaches and neural network parameterization. It does not address sliced Wasserstein metrics for meta-measures

(distributions over distributions) or the DSW construction combining spherical slicing with L2-projections parametrized by Gaussian processes.

2. Generalized Sobolev Transport for Probability Measures on a Graph
URL: View paper

Brief Assessment

Sobolev Transport Graph[63] focuses on optimal transport for measures on graph metric spaces using Orlicz geometric structures, not on comparing distributions over distributions (meta-measures) using sliced Wasserstein approaches.

3. Fast Estimation of Wasserstein Distances via Regression on Sliced Wasserstein Distances
URL: View paper

Brief Assessment

Regression Sliced Wasserstein[60] focuses on regressing Wasserstein distances onto sliced Wasserstein distances for efficient approximation, not on developing a double-sliced metric for meta-measures. The candidate addresses a different problem: learning linear models to predict Wasserstein distances from SW variants, rather than constructing a hierarchical slicing framework for distributions over distributions.

4. Optimal Transport of Linear Systems over Equilibrium Measures
URL: View paper

Brief Assessment

Linear Systems Equilibrium[66] addresses optimal transport for linear systems with equilibrium measures, not the general problem of comparing distributions over distributions (meta-measures) using sliced Wasserstein methods.

5. Distances between probability distributions of different dimensions
URL: View paper

Brief Assessment

Different Dimensions Distances[67] addresses comparing probability measures across different dimensional spaces (e.g., measures on R^m vs R^n where $m \neq n$), not meta-measures (distributions over distributions). The ORIGINAL paper's DSW specifically targets the Wasserstein over Wasserstein (WoW) distance for comparing meta-measures in $P_2(P_2(R^d))$.

6. When optimal transport meets information geometry
URL: View paper

Brief Assessment

Information Geometry Transport[62] focuses on linking optimal transport with information geometry through entropy-regularized transport and divergence functions. It does not address sliced Wasserstein methods or meta-measures (distributions over distributions).

7. Quantitative stability of optimal transport maps under variations of the target measure
URL: View paper

Brief Assessment

Quantitative Stability Maps[59] focuses on stability estimates for optimal transport maps between probability measures, not on sliced Wasserstein metrics for comparing meta-measures. The candidate addresses a fundamentally different problem in optimal transport theory.

8. Hierarchical Integral Probability Metrics: A distance on random probability measures with low sample complexity
URL: View paper

Brief Assessment

Hierarchical Integral Metrics[61] addresses sample complexity issues with Wasserstein over Wasserstein using integral probability metrics, whereas the original paper focuses on computational efficiency through functional optimal transport and Gaussian process projections. The technical approaches differ fundamentally.

9. Got: an optimal transport framework for graph comparison
URL: View paper

Brief Assessment

Graph Comparison Framework[68] focuses on comparing graphs through smooth graph signal distributions using Wasserstein distances between graph Laplacian-derived distributions, not on comparing distributions over distributions (meta-measures) in general spaces.

10. Optimal transport in systems and control
URL: View paper

Brief Assessment

Systems Control Transport[64] focuses on optimal transport theory for control systems and covariance steering problems with Gaussian distributions, not on general meta-measures or the DSW metric construction combining spherical slicing with L2-projections parametrized by Gaussian processes.

Contribution 3: Topological equivalence between DSW and WoW for discretized meta-measures
Description: The authors establish that minimizing the DSW distance is equivalent to minimizing the WoW distance for empirical meta-measures. This theoretical result validates DSW as a meaningful substitute for WoW while avoiding computational and numerical stability issues.

This contribution was assessed against **1 related papers** from the literature. Papers with potential prior art are analyzed in detail with textual evidence; others receive brief assessments.

1. Flowing Datasets with Wasserstein over Wasserstein Gradient Flows
URL: View paper

Brief Assessment

Wasserstein Gradient Flows[69] focuses on gradient flow dynamics and optimization on the WoW space, not on establishing topological equivalence between sliced distances and WoW for discretized meta-measures.

Appendix: Text Similarity Detection

Textual similarity detection checked 23 papers and found 2 similarity segment(s) across 1 paper(s).

The following **1 paper(s)** were detected to have high textual similarity with the original paper. These may represent different versions of the same work, duplicate submissions, or papers with substantial textual overlap. Readers are advised to verify these relationships independently.

1. A Novel Sliced Fused Gromov-Wasserstein Distance

Detected in: Core Task (sibling), Contribution: contribution_1

⚠ **Note**: This paper shows substantial textual similarity with the original paper. It may be a different version, a duplicate submission, or contain significant overlapping content. Please review carefully to determine the nature of the relationship.

References

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