Novelty Assessment Report

Paper: TrajFlow: Nation-wide Pseudo GPS Trajectory Generation with Flow Matching Models
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Abstract

The importance of mobile phone GPS trajectory data is widely recognized across many fields, yet the use of real data is often hindered by privacy concerns, limited accessibility, and high acquisition costs. As a result, generating pseudo–GPS trajectory data has become an active area of research. Recent diffusion-based approaches have achieved strong fidelity but remain limited in spatial scale (small urban areas), transportation-mode diversity, and efficiency (requiring numerous sampling steps). To address these challenges, we introduce TrajFlow, the first flow-matching–based generative model for GPS trajectory generation. TrajFlow leverages the flow-matching paradigm to improve robustness across multiple geospatial scales and incorporates a trajectory harmonization & reconstruction strategy to jointly address scalability, diversity, and efficiency. Using a nationwide mobile phone GPS dataset with millions of trajectories across Japan, we show that TrajFlow consistently outperforms diffusion-based and deep generative baselines at urban, metropolitan, and nationwide levels. As the first nationwide, multi-scale GPS trajectory generation model, TrajFlow demonstrates strong potential to support inter-region urban planning, traffic management, and disaster response, thereby advancing the resilience and intelligence of future mobility systems.

Core Task Landscape

This paper addresses: **Pseudo GPS Trajectory Generation**

A total of **29 papers** were analyzed and organized into a taxonomy with **19 categories**.

Taxonomy Overview

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

- **Privacy-Preserving Trajectory Synthesis**
- **Deep Learning-Based Trajectory Generation**
- **Domain-Specific Trajectory Synthesis**
- **Rule-Based and Map-Driven Trajectory Generation**
- **Trajectory Analysis and Auxiliary Methods**
- **Autonomous Navigation and Control Applications**
- **Route Optimization and Planning**

Complete Taxonomy Tree

- Pseudo GPS Trajectory Generation Survey Taxonomy
- Privacy-Preserving Trajectory Synthesis
  - Differential Privacy-Based Trajectory Synthesis (3 papers)
  - [2] Synthesizing realistic trajectory data with differential privacy (Xinyue Sun, 2023) View paper
  - [7] Puts: Privacy-preserving and utility-enhancing framework for trajectory synthesization (Xinyue Sun, 2023) View paper
  - [9] DPT: differentially private trajectory synthesis using hierarchical reference systems (Xi He, 2015) View paper
  - Functional Data Analysis for Privacy-Preserving Synthesis (1 papers)
  - [16] Generating Synthetic Functional Data for Privacy-Preserving GPS Trajectories (Arianna Burzacchi, 2024) View paper
- Deep Learning-Based Trajectory Generation
  - Flow Matching and Diffusion Models ★ (2 papers)
  - [0] TrajFlow: Nation-wide Pseudo GPS Trajectory Generation with Flow Matching Models (Anon et al., 2026) View paper
  - [11] Geo-lucid Conditional Diffusion Models for High Physical Fidelity Trajectory Generation (M Yang, 2025) View paper
  - Individual-Based Mobility Generation (3 papers)
  - [1] GeoAvatar: A big mobile phone positioning data-driven method for individualized pseudo personal mobility data generation (Peiran Li, 2025) View paper
  - [10] Learning to Generate Pseudo Personal Mobility (Li Peiran, 2023) View paper
  - [28] Big Mobile Phone GPS Data Driven Pseudo Personal Mobility Generator (æ□□æ²□ç□¶, n.d.) View paper
  - High-Fidelity Synthetic Dataset Creation (1 papers)
  - [5] Synmob: Creating high-fidelity synthetic gps trajectory dataset for urban mobility analysis (Y Zhu, 2023) View paper
- Domain-Specific Trajectory Synthesis
  - Cellular Network Association Trace Synthesis (1 papers)
  - [6] SynthCAT: Synthesizing Cellular Association Traces with Fusion of Model-Based and Data-Driven Approaches (Feng Lyu, 2024) View paper
  - Maritime and Aerospace Synthetic GPS Data (4 papers)
  - [18] "Synthetic GPS Dataset for AI-Based Spoofing Detection on Maritime Autonomous Surface Ships" (Agrebi, 2025) View paper
  - [19] Simulation of GPS-based Launch Vehicle Trajectory Estimation using UNSW Kea GPS Receiver (S Biswas, 2016) View paper

    - [20] Synthetic GPS Data Generation and AI Detection-Response for Spoofing on Maritime Autonomous Surface Ships (I Agrebi, 2025) View paper
    - [25] Generation of GNSS Observables for LEO Satellites Using High-Fidelity Models (S Husain, 2017) View paper
    - Bicycle Route Synthetization (1 papers)
    - [13] Synthetization of bicycle route data from aggregate GPS-based cycling data and its utility for bicycle route choice analysis (Stefan Huber, 2021) View paper
- Rule-Based and Map-Driven Trajectory Generation
    - Road Network-Based Synthetic Trajectory Generation (1 papers)
    - [21] Scalable generation of synthetic GPS traces with real-life data characteristics (Konrad BÃ¶sche, 2012) View paper
    - GPS Art and Geometric Route Planning (2 papers)
    - [14] Automatic route planning for GPS art generation (A. Waschk, 2018) View paper
    - [27] GPS Drawing on Street Networks: Extracting Routes from Polygonal Coverings (N Baloian, n.d.) View paper
    - High-Precision Map Construction from GPS Data (1 papers)
    - [3] Construction and application of artificial intelligence crowdsourcing map based on multi-track GPS data (Yong Wang, 2024) View paper
- Trajectory Analysis and Auxiliary Methods
    - Stop and Move Classification (1 papers)
    - [22] A probabilistic stop and move classifier for noisy GPS trajectories (Luke Bermingham, 2018) View paper
    - GPS Route Management and Similarity Search (1 papers)
    - [24] Efficient management and search of GPS routes (Mariescu-Istodor, 2017) View paper
    - Delivery Time and Urban Freight Modeling (1 papers)
    - [4] Development of a Delivery Time-Period Selection Model for Urban Freight Using GPS Data (Ryota Kodera, 2025) View paper
- Autonomous Navigation and Control Applications
    - Indoor and Pseudo-GPS for Autonomous Robots (2 papers)
    - [8] Proposal for generation of a pseudo GPS signal used in indoor mode for navigation testing of small autonomous flying robot (Aicha Aissa Bokhtache, 2023) View paper
    - [26] Distributed control of distributed parameter systems using mobile actuator and sensor networks (Wang, 2005) View paper
    - UAV Autonomous Navigation with GPS Setpoints (1 papers)
    - [17] Autonomous Navigation Based on Proportional Controller with GPS Setpoint for UAV in External Environments (Darwin Merizalde, 2020) View paper
    - Cooperative Vehicle Coordination and Deception (1 papers)
    - [29] A coordination strategy for cooperative radar network deception by autonomous vehicle teams (Waun, 2004) View paper
- Route Optimization and Planning
    - Competition and Search-Rescue Route Optimization (2 papers)
    - [15] A Model for Optimal Route Planning in Rogaining Competitions (KesÃ¤lÃ¤, 2025) View paper
    - [23] Route Optimization in Service of a Search and Rescue Artificial Social Intelligence (Y Wang, 2023) View paper
    - Population Synthesis Methods (1 papers)
    - [12] GPS: Genesis Population Synthesis (Chakrabarty, 2024) View paper

Narrative

Core task: Pseudo GPS trajectory generation. The field encompasses a diverse set of approaches for creating synthetic movement data that mimics real-world GPS traces. At the highest level, the taxonomy reveals several major branches: Privacy-Preserving Trajectory Synthesis focuses on protecting user identity while maintaining statistical utility; Deep Learning-Based Trajectory Generation leverages neural architectures such as GANs, VAEs, and more recently flow matching and diffusion models to learn complex mobility patterns; Domain-Specific Trajectory Synthesis tailors generation methods to particular contexts like delivery logistics or bicycle routing; Rule-Based and Map-Driven Trajectory Generation relies on explicit constraints and road network structure; Trajectory Analysis and Auxiliary Methods provide supporting techniques for segmentation and feature extraction; while Autonomous Navigation and Control Applications and Route Optimization and Planning address real-time path planning and control problems. Representative works span from early rule-based systems like DPT[9] to modern deep generative models such as Synmob[5] and SynthCAT[6], illustrating the field's evolution toward data-driven, scalable synthesis.

Within the deep learning branch, a particularly active line of work explores flow matching and diffusion models, which offer stable training dynamics and high-fidelity sample generation. TrajFlow[0] sits squarely in this emerging cluster, employing flow-based generative modeling to produce realistic trajectories. Its closest neighbor, Geo-lucid Diffusion[11], similarly adopts diffusion techniques but may emphasize different conditioning strategies or geographic priors. Both contrast with earlier GAN-based approaches like Synmob[5], which can suffer from mode collapse, and with privacy-centric methods such as DPT[9] that prioritize differential privacy guarantees over generative flexibility. Meanwhile, domain-specific efforts like Delivery Time Selection[4] and Bicycle Route Synthesis[13] demonstrate how task constraints shape generation, highlighting an ongoing tension between general-purpose generative models and specialized, application-driven synthesis. TrajFlow[0] thus represents a shift toward leveraging modern probabilistic frameworks to balance realism, diversity, and computational efficiency in trajectory generation.

Related Works in Same Category

The following **1 sibling papers** share the same taxonomy leaf node with the original paper:

1. Geo-lucid Conditional Diffusion Models for High Physical Fidelity Trajectory Generation

Authors: M Yang, A Sharma, M Farhadloo | **Year/Venue**: 2025 | **URL**: View paper

Abstract

â¦ Synmob: Creating high-fidelity synthetic gps trajectory dataset for urban mobility analysis. Advances in Neural Information Processing Systems 36 (2023), 22961â 22977. â¦

Relationship Analysis

Both papers belong to the Flow Matching and Diffusion Models category, employing generative models for high-fidelity GPS trajectory synthesis. They overlap in addressing trajectory generation using advanced generative frameworks, but the original paper (TrajFlow) focuses on flow matching models for nationwide, multi-scale trajectory generation with emphasis on transportation-mode diversity and efficiency, while the candidate paper (Geo-lucid) appears to focus on conditional diffusion models with emphasis on physical fidelity in synthetic GPS trajectory datasets for urban mobility analysis. The key difference lies in the generative paradigm (flow matching vs. diffusion) and scale of application (nationwide multi-scale vs. urban-focused).

Contributions Analysis

Overall novelty summary. TrajFlow introduces the first flow-matching-based generative model for GPS trajectory synthesis, positioning itself within the 'Flow Matching and Diffusion Models' leaf of the taxonomy. This leaf contains only two papers, indicating a relatively sparse but emerging research direction. The paper's core contribution—applying flow matching to trajectory generation—represents a methodological shift from diffusion-based approaches (its sole sibling, Geo-lucid Diffusion) toward more efficient probabilistic frameworks. The taxonomy reveals this is a nascent area within the broader 'Deep Learning-Based Trajectory Generation' branch, which itself competes with privacy-preserving, rule-based, and domain-specific synthesis methods.

The taxonomy structure shows TrajFlow sits adjacent to several related directions. The 'Individual-Based Mobility Generation' leaf (three papers) focuses on personalized trajectory modeling, while 'High-Fidelity Synthetic Dataset Creation' (one paper) emphasizes benchmark dataset construction. These neighboring leaves share the goal of realistic synthesis but differ in conditioning strategies and scale. The 'Privacy-Preserving Trajectory Synthesis' branch (four papers across two leaves) represents an orthogonal concern—formal privacy guarantees—that TrajFlow does not explicitly address. The taxonomy's scope notes clarify that flow matching methods belong specifically to generative modeling, excluding rule-based approaches in the 'Road Network-Based Synthetic Trajectory Generation' leaf.

Among 26 candidates examined, no papers clearly refute TrajFlow's three main contributions. The first contribution (flow-matching framework) examined 10 candidates with zero refutations, suggesting novelty in applying this specific generative paradigm to GPS trajectories. The second contribution (unified harmonization and OD-conditioned normalization) examined 6 candidates, again with no refutations, indicating the integration strategy may be distinctive. The third contribution (nationwide multi-scale modeling) examined 10 candidates without refutation, though the limited search scope means prior work at similar geographic scales could exist beyond the top-26 semantic matches. The statistics reflect a focused literature search rather than exhaustive coverage.

Based on the limited search scope of 26 candidates, TrajFlow appears to occupy a relatively novel position within an emerging subfield. The sparse 'Flow Matching and Diffusion Models' leaf and absence of refutable prior work suggest methodological distinctiveness, though the analysis cannot rule out relevant work outside the top-K semantic neighborhood. The nationwide scale claim warrants particular caution, as geographic coverage may not be well-captured by semantic search alone.

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

Contribution 1: First flow-matching-based generative framework for GPS trajectory modeling

Description: The authors introduce TrajFlow, the first application of flow matching models to GPS trajectory generation. They demonstrate that this paradigm provides improved robustness and stability when generating trajectories across multiple spatial scales compared to diffusion-based approaches.

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.

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1. Flow-based spatio-temporal structured prediction of motion dynamics

URL: View paper

Brief Assessment

Spatio-temporal Structured Prediction[45] applies flow-based models to general spatio-temporal structured prediction tasks (trajectory prediction, motion prediction, time series forecasting, segmentation), not specifically to GPS trajectory generation or modeling at multiple geospatial scales.

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2. Beyond Imitation: Constraint-Aware Trajectory Generation with Flow Matching For End-to-End Autonomous Driving

URL: View paper

Brief Assessment

Constraint-Aware Trajectory[49] applies flow matching to autonomous driving trajectory generation for vehicles, not GPS trajectory modeling for human mobility. The candidate focuses on end-to-end vehicle planning with safety constraints, while the original addresses nationwide human mobility generation across multiple spatial scales.

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3. Motion Manifold Flow Primitives for Language-Guided Trajectory Generation

URL: View paper

Brief Assessment

Language-Guided Trajectory[50] applies flow matching to robot motion primitives for task-conditioned trajectory generation, not GPS trajectory modeling. The domains are fundamentally different: GPS trajectories involve geospatial mobility data, while the candidate focuses on robot manipulation and navigation tasks.

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4. Principled Pathways Towards Autonomy and Emergence in Agents

URL: View paper

Brief Assessment

Principled Pathways Autonomy[52] applies flow matching to drone swarm trajectory generation for 3D formations, not GPS trajectory modeling for human mobility. The application domains and technical objectives are fundamentally different.

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5. Preference Trajectory Modeling via Flow Matching for Sequential Recommendation

URL: View paper

Brief Assessment

Preference Trajectory Modeling[53] applies flow matching to sequential recommendation (modeling user preference trajectories over items), not GPS trajectory generation. The domains are fundamentally different—one models spatial mobility patterns, the other models item interaction sequences.

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6. TrajLearn: Trajectory Prediction Learning using Deep Generative Models

URL: View paper

Brief Assessment

TrajLearn[46] focuses on trajectory prediction (estimating future paths from current/historical data) using generative modeling of mobility flows with hexagonal spatial representation, not flow matching models for GPS trajectory generation as in the original paper.

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7. UniConFlow: A Unified Constrained Generalization Framework for Certified Motion Planning with Flow Matching Models

URL: View paper

Brief Assessment

UniConFlow[51] applies flow matching to robot motion planning and trajectory generation for robotic systems, not GPS trajectory modeling. The candidate focuses on certified motion planning with kinodynamic constraints for mobile navigation and manipulation tasks, which is a fundamentally different application domain from GPS trajectory generation.

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8. Large language model-driven probabilistic trajectory prediction in the Internet of Things using spatio-temporal encoding and normalizing flows

URL: View paper

Brief Assessment

LLM Trajectory Prediction[44] focuses on probabilistic trajectory prediction using normalizing flows in IoT contexts, not flow-matching-based generative modeling for GPS trajectory generation as proposed in the original paper.

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9. Motion Manifold Flow Primitives for Task-Conditioned Trajectory Generation Under Complex Task-Motion Dependencies

URL: View paper

Brief Assessment

Motion Manifold Primitives[48] applies flow matching to robot motion primitives and language-guided trajectory generation in robotics, not GPS trajectory modeling. The domains and applications are fundamentally different.

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10. FlowDrive: moderated flow matching with data balancing for trajectory planning

URL: View paper

Brief Assessment

FlowDrive[47] applies flow matching to autonomous vehicle trajectory planning in driving scenarios, not GPS trajectory generation from mobile phone data. The candidate focuses on real-time motion planning for self-driving cars, while the original addresses pseudo-GPS trajectory synthesis for urban mobility analysis.

Contribution 2: Unified framework integrating trajectory harmonization, OD-conditioned normalization, and flow-based training

Description: The authors propose a methodological design that combines trajectory harmonization using the RDP algorithm, origin-destination conditioned normalization, and flow matching training. This unified approach simultaneously tackles the challenges of multi-scale generation, transportation-mode diversity, and computational efficiency.

This contribution was assessed against **6 related papers** from the literature. Papers with potential prior art are analyzed in detail with textual evidence; others receive brief assessments.

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1. Eco-Driving Modeling Environment

URL: View paper

Brief Assessment

Eco-Driving Modeling[43] focuses on eco-driving simulation using driver simulators and fuel consumption modeling, not on trajectory generation or flow-matching frameworks for mobility data.

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2. : Diffusion network with multi-attribute aggregation for trajectory generation

URL: View paper

Brief Assessment

Multi-attribute Aggregation Diffusion[39] focuses on multi-scale aggregation modules for trajectory generation but does not address the specific combination of RDP-based harmonization, flow matching training, and OD-conditioned normalization that forms the core of the original paper's unified framework.

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3. Geo-lucid Conditional Diffusion Models for High Physical Fidelity Trajectory Generation

URL: View paper

Brief Assessment

Geo-lucid Diffusion[11] appears to focus on conditional diffusion models for trajectory generation with physical fidelity constraints, which differs from TrajFlow's flow-matching paradigm combined with RDP harmonization and OD-conditioned normalization. The candidate's limited context does not provide sufficient detail to assess overlap with this specific unified framework design.

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4. TourismMinds: A Geo-augmented LLM Framework for Semantic-aware Trajectory Analytics and Generation

URL: View paper

Brief Assessment

TourismMinds[40] focuses on tourism trajectory analytics with semantic understanding and LLM-based generation, not on multi-scale mobility generation with flow matching models. The candidate's harmonization approach serves different purposes in a tourism context.

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5. Cross-Attention Diffusion Model for Semantic-Aware Short-Term Urban OD Flow Prediction

URL: View paper

Brief Assessment

Urban OD Flow[42] focuses on short-term urban origin-destination flow prediction using cross-attention diffusion models, not trajectory generation with flow matching and RDP harmonization.

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6. Estimating Origin-Destination Matrices in Helsinki's Public Transport through Multi-Source Data Fusion

URL: View paper

Brief Assessment

Helsinki OD Matrices[41] focuses on estimating origin-destination matrices for public transport using iterative proportional fitting (IPF) to fuse smartphone trajectory data with automated passenger counts. This is fundamentally different from the original paper's trajectory generation framework using flow matching and RDP harmonization.

Contribution 3: First nationwide multi-scale GPS trajectory generation model

Description: The authors present TrajFlow as the first model capable of generating GPS trajectories at nationwide scale while maintaining performance across urban, metropolitan, and nationwide spatial levels. They validate this using a nationwide mobile phone GPS dataset with millions of trajectories across Japan.

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. Pseudo-pflow: Development of nationwide synthetic open dataset for people movement based on limited travel survey and open statistical data

URL: View paper

Brief Assessment

Pseudo-pflow[36] focuses on generating synthetic people movement data from travel surveys and statistical data, not GPS trajectory generation using flow matching or diffusion models. The methodologies and data sources are fundamentally different.

2. Leveraging the Spatial Hierarchy: Coarse-to-fine Trajectory Generation via Cascaded Hybrid Diffusion

URL: View paper

Brief Assessment

Coarse-to-fine Trajectory[33] focuses on hierarchical spatial decomposition (road segment-level to GPS-level) within cities, not nationwide multi-scale generation across urban/metropolitan/nationwide levels as claimed by the original paper.

3. AI-empowered trajectory anomaly detection for intelligent transportation systems: A hierarchical federated learning approach

URL: View paper

Brief Assessment

Hierarchical Federated Learning[38] focuses on trajectory anomaly detection in intelligent transportation systems using federated learning and blockchain, not on GPS trajectory generation across spatial scales.

4. DPT: differentially private trajectory synthesis using hierarchical reference systems

URL: View paper

Brief Assessment

DPT[9] focuses on differentially private trajectory synthesis using hierarchical reference systems for privacy protection, not on nationwide multi-scale generation capability. The paper addresses privacy-preserving trajectory synthesis rather than demonstrating generation performance across multiple spatial scales (urban, metropolitan, nationwide) as claimed in the original work.

5. Nationwide synthetic human mobility dataset construction from limited travel surveys and open data

URL: View paper

Brief Assessment

Nationwide Synthetic Mobility[37] focuses on activity-based synthetic mobility generation using agent models and statistical data, not GPS trajectory generation using deep generative models across spatial scales.

6. Deep activity model: A generative approach for human mobility pattern synthesis

URL: View paper

Brief Assessment

Deep Activity Model[34] focuses on generating activity chains (sequences of activity types, start/end times) from household travel survey data, not GPS trajectories. The candidate explicitly states it models 'activity chains' and uses HTS data, whereas the original paper generates continuous GPS coordinate sequences at multiple spatial scales using flow matching on mobile phone GPS data.

7. The scales of human mobility

URL: View paper

Brief Assessment

Scales Human Mobility[31] focuses on analyzing and modeling the hierarchical spatial structure of existing human mobility data to understand characteristic scales, not on generating synthetic GPS trajectories. The paper infers spatial containers from real trajectories rather than generating new trajectories at nationwide scale.

8. A hierarchical indoor and outdoor model for semantic trajectories

URL: View paper

Brief Assessment

Hierarchical Semantic Trajectories[30] focuses on spatial data modeling and graph-based representations for trajectory analysis, not on generative models for synthesizing GPS trajectories at multiple scales.

9. HRNet: Differentially Private Hierarchical and Multi-Resolution Network for Human Mobility Data Synthesization

URL: View paper

Brief Assessment

HRNet[32] focuses on differentially private human mobility data synthesis using hierarchical networks for location encoding, not on nationwide multi-scale GPS trajectory generation across urban/metropolitan/nationwide levels using flow matching.

10. A Hierarchical Hybrid Learning Framework for Multi-Agent Trajectory Prediction

URL: View paper

Brief Assessment

Hierarchical Hybrid Learning[35] focuses on multi-agent trajectory prediction for autonomous vehicles in traffic scenes, not GPS trajectory generation across spatial scales. The technical domains are fundamentally different.

Appendix: Text Similarity Detection

No high-similarity text segments were detected across any compared papers.

References

- [0] TrajFlow: Nation-wide Pseudo GPS Trajectory Generation with Flow Matching Models View paper
- [1] GeoAvatar: A big mobile phone positioning data-driven method for individualized pseudo personal mobility data generation View paper

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