GAMS: Geospatial Knowledge Enhanced Agentic Framework for Urban Human Mobility Behavior Simulation

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Abstract

Recently, researchers have explored leveraging the commonsense knowledge and reasoning capabilities of large language models to accelerate human mobility simulation. However, these methods suffer from several critical shortcomings, including inadequate modeling of urban spaces, poor integration with individual mobility patterns, and weak alignment with collective mobility distributions. To address these limitations, we propose **G**eospatial Knowledge Enhanced **A**gentic framework for **M**obility **S**imulation (**GAMS**), an agentic framework that leverages the language based geospatial foundation model to simulate human mobility in urban space. **GAMS** comprises three core modules: MobExtractor, which extracts template-based mobility profiles and synthesizes new ones during simulation; GeoGenerator, which generate trajectory points considering collective mobility knowledge and urban geospatial knowledge; and TrajEnhancer, which captures individual mobility regularities from real-world trajectories and refine to generate style-aligned synthetic trajectories. Experiments on three real-world datasets show that **GAMS** achieves superior performance over various state-of-the-art methods, demonstrating strong performance across diverse urban environments. Our code and dataset are available at https://github.com/tsinghua-fib-lab/GAMS.

1 Introduction

Human mobility simulation is a critical real-world task with widespread applications across many domains (Pappalardo et al., 2023), such as supporting the implementation of the 15-minute city concept in urban development by modeling residents' daily activities (Zheng et al., 2023), optimizing transportation strategies through travel behavior simulation, and validating intervention policies in epidemic prevention and control. Given its significant value, the research community has studied this problem extensively for many years, resulting in a range of effective solutions. Early efforts, such as mechanism-based models like TimeGeo (Jiang et al., 2016), have gradually been supplemented—and surpassed—by recent deep learning approaches, such as MoveSim (Feng et al., 2020), ActSTD (Yuan et al., 2022), and DSTPP (Yuan et al., 2023) and on. Despite remarkable progress, key challenges remain—particularly concerning the spatial transferability of methods, as well as the controllability and interpretability of the generated mobility behaviors.

To address these challenges, recent research has explored integrating LLMs into mobility simulation, leveraging their role-playing (Gao et al., 2024; Wang et al., 2024b; Gao et al., 2023; Piao et al., 2025), commonsense knowledge (OpenAI, 2022; Touvron et al., 2023; Ding et al., 2024) and reasoning capabilities (Wei et al., 2022; Xu et al., 2025) to achieve promising results. The most crucial and challenging aspect of applying LLMs to mobility simulation lies in effectively incorporating spatial information. Existing work (Gurnee and Tegmark, 2024; Shao et al., 2024) has shown that simply utilizing general-purpose LLMs is insufficient for accurately understanding urban space. As a result, studies such as CoPB (Shao et al., 2024) and LLMob (Wang et al., 2024a) have proposed specific mechanisms within their frameworks to mitigate this limitation and harness the strengths of LLMs for sequential modeling and reasoning. However, these approaches typically combine spatial knowledge and LLMs in a relatively independent manner, fusing information in an ad hoc fashion. Moreover, spatial knowledge is often simplified to facilitate model comprehension, and the integration process remains largely unidirectional, lacking feedback-driven optimization or iterative reasoning updates.

Recently, geospatial LLMs such as

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CityGPT (Feng et al., 2025b) and LAMP (Balsebre et al., 2024) have emerged, directly enhancing general LLMs with urban spatial knowledge through post-training and achieving impressive results on geospatial tasks such as urban spatial knowledge question answering. In these works, they convert the urban spatial knowledge into the language format and train the general model to enhance the urban spatial knowledge. This progress offers a new perspective on incorporating spatial knowledge into LLMs and enables deeper collaboration between spatial knowledge and spatial reasoning in downstream task.

In this paper, we introduce **GAMS**, an agentic framework that achieves more controllable, accurate, and generalizable human mobility simulation. The framework operates through three synergistic core components. First, **MobExtractor** analyzes raw trajectory data to extract and summarize high-level mobility profiles for enabling the controllable generation of mobility. Next, **GeoGenerator** leverages a geospatially-aware LLM with specific mechanisms to translate these abstract patterns into realistic location sequences with collective distribution constrains. Finally, **TrajEnhancer** ensures the output's fidelity, it employs direct preference optimization to perform **trajectory style alignment**, conforming the generated paths to real-world data patterns and enforcing spatio-temporal consistency. A multi-dimensional feedback mechanism unifies this three-stage pipeline, enabling **GAMS** to iteratively refine the generation process. This continuous improvement loop enhances both the realism and adaptability of the simulated human mobility. Besides, built upon an enhanced geospatial-knowledge enhanced LLM, **GAMS** natively integrates urban spatial knowledge into the reasoning and generation process of LLMs.

In summary, our contributions are:

- To our knowledge, **GAMS** is the first to integrate an geospatial foundation model with rich geospatial knowledge and multi-dimensional feedback for controllable and generalized mobility simulation.
- For controllable generation, we design a dual-phase architecture based MobExtractor, which condenses mobility patterns into compact linguistic representations, then synthesizes new user-specific patterns through profile-aware feature fusion.
- To generate mobility patterns that align with collective urban mobility regularities, we build a geospatial foundation model with fine-grained urban geographic knowledge fine-tuning and tailored mechanism design.
- We introduce multi-dimensional feedback in the framework to progressively align the generated trajectories with real-world trajectories, ensuring that the simulated mobility better conforms to individual mobility regularity and style.
- Experimental results on three real-world datasets demonstrate that the proposed **GAMS** framework significantly outperforms existing methods in human mobility simulation, achieving more than a 17% improvement in a composite metric capturing various mobility regularities.

2 Related Work

Mobility Simulation. Mobility simulation includes synthesizing data based on statistical laws, generating simulated data in virtual space, and generating mobility data in real urban spaces. On the basis of macroscopic statistical laws (Brockmann et al., 2006; Roth et al., 2011; Liang et al., 2012), researchers proposed a series of mobility simulation models to depict individual behavior mechanism (Pappalardo and Simini, 2018; Wang et al., 2019; Pappalardo and Simini, 2018; Jiang et al., 2016). While these mechanism models are concise but fail to capture complex human mobility patterns and model the impact of urban structure. With the rapid development of deep learning, different model structures were designed to model the complex dynamics of mobility behaviors (Feng et al., 2020; Long et al., 2023; Liu et al., 2024). However, these deep learning methods face challenges of data sparsity, poor transferability and low explainability.

LLM for Geospatial Tasks. Since LLMs are geospatially knowledgeable (OpenAI, 2022; Bhandari et al., 2023; Touvron et al., 2023), researchers pay attention to leverage LLM in geography and urban science field by solving domain-specific tasks like geospatial understanding tasks (Brown et al., 2020; Mai et al., 2023; Roberts et al., 2023; Feng et al., 2025b) and geospatial prediction tasks (Wang et al., 2023; Beneduce et al., 2025; Feng et al., 2025a; Gong et al., 2024). LLMs can achieve good results in global-scale or national-scale tasks with simple prompt engineering (Manvi et al., 2024b,a)

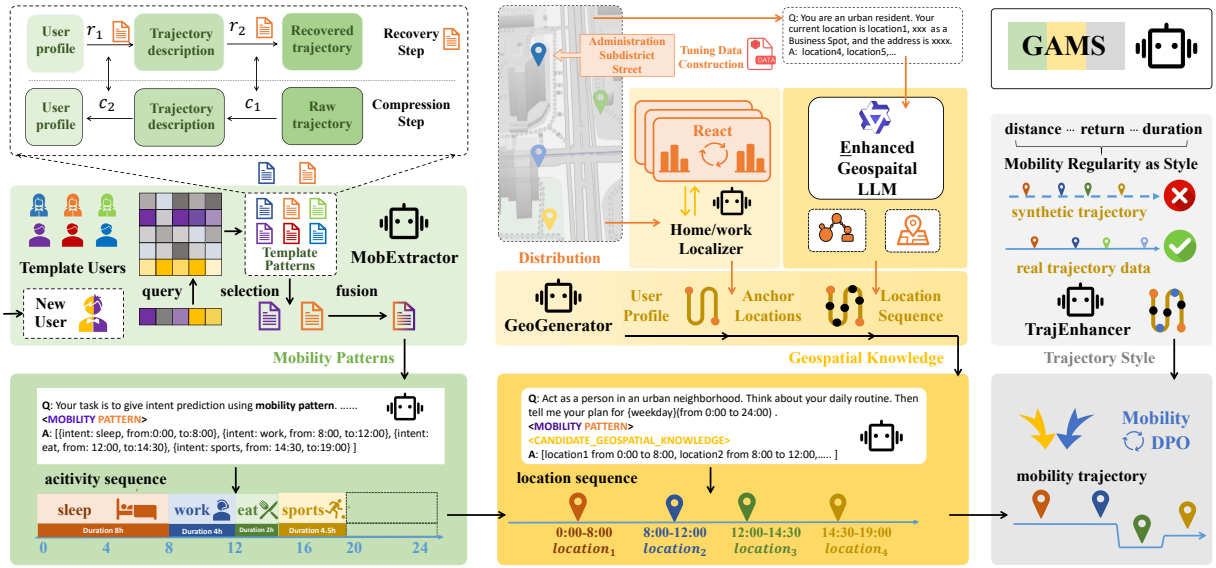


Figure 1: The framework of **GAMS**, with components arranged from left to right: MobExtractor, GeoGenerator, and TrajEnhancer.

or a trained linear layer (Gurnee and Tegmark, 2024). However, when breaks down to city scale, well-designed agentic frameworks and fine-tuning methods are required to enable LLMs to acquire urban structural knowledge (Feng et al., 2025b; Balsebre et al., 2024) and enhance task-specific performance via geospatial knowledge alignment. However, they are primarily designed for question-answering tasks and performs poorly on complex, structured tasks like trajectory generation, without an agentic framework that orchestrates multiple specialized modules to leverage their knowledge effectively for simulation.

LLM for Mobility Simulation. With the successful application of LLM in geospatial tasks, researchers are exploring the potential of applying LLMs to human mobility simulation (Wang et al., 2024a; Shao et al., 2024; Wang et al., 2024a; Li et al., 2024; Jiang et al., 2024; Yan et al., 2024). They extract individual knowledge from the user profile and historical trajectories, then synthesize simulated data (Wang et al., 2024a), map simulated data to real urban spaces using mechanistic models (Shao et al., 2024; Li et al., 2024), or generate real-world trajectories based on the given urban spatial information (Wang et al., 2024a). They perform well in few-shot scenarios and exhibit good transferability. However, they insufficiently model real urban structures, and fail to capture collective mobility patterns.

We define urban human mobility simulation as the task of generating daily trajectories $T = \{v_1, v_2, ..., v_n\}$ for a target agent over a 24-hour period. Each visit $v_i = \langle t_i, c_i, p_i \rangle$ comprises a timestamp t_i, geographic coordinates c_i, and a specific POI category p_i. Given a user profile P_u (e.g., occupation, age), the objective is to synthesize a sequence that preserves both individual habits and collective urban mobility distributions.

3 Methodology

GAMS is an agentic framework for generating trajectories in real urban spaces by incorporating urban-knowledgeable LLM with multi-dimensional feedback. As shown in Figure 1, our methodology is a three-stage pipeline that progressively generates realistic human mobility behaviors. Details of each components are introduced below.

3.1 MobExtractor: Semantic Mobility Pattern Extraction for Controllable Simulation

As shown in the left part of Figure 1, to derive semantically consistent activity sequences from user profiles, we design MobExtractor with a "compress-then-recover" architecture.

Instead of relying on empirical experience to infer activity sequences from user profiles, we adopt a semantic compression-reconstruction framework. Specifically, we first employ a compression stage to automatically distill raw trajectories into semantic trajectory descriptions and learn 'compression insights'. Subsequently, we implement a reconstruction stage to get 'reconstruction insights' that apply compression insights in reverse to the genera-

tion process. For new users without historical data, our approach first retrieves the top-K semantically similar template users via profile embedding. We then perform cross-user insight fusion to synthesize generalized prompts, which guide the LLM to generate high-fidelity daily trajectory descriptions and personalized movement sequences.

Mobility pattern recovery. As shown in Figure 1, in the mobility patterns reconstruction phase, the model learns high-level correlations between user profiles P_u, semantic trajectory descriptions S_u and raw trajectories T_u through a dual-phase compression-reconstruction process. The model automatically distill observed patterns and correlations into interpretable natural language rules, including $\mathbf{c}_1$, $\mathbf{c}_2$ in compression stage and $\mathbf{r}_1$, $\mathbf{r}_2$ in reconstruction stage.

- **Compression.** In compression stage, the model maps a raw trajectory T_u and its associated profile P_u to a compact semantic trajectory description S_u: c_2 (Trajectory-to-Description) captures behavioral habits and motivations, and c_1 (Description-to-Profile) identifies key profile determinants and influencing features from the trajectory descriptions. This step can be described by Eq. (1).

$$S_u = \text{LLM}_{\text{compress}}(T_u, P_u; c_1, c_2) \quad (1)$$

- **Reconstruction.** During reconstruction, the model acquires *reconstruction insights* that map user profiles back to raw trajectories: r_1 (Profile-to-Description) maps the static user profile P_u back to a semantic trajectory description by referencing c_1, while r_2 (Description-to-Trajectory) restores the raw trajectory T_{syn} from the fused descriptions and candidate POIs based on c_2.

Mobility pattern generation. As shown in Figure 1, in the generation phase, the model generates mobility patterns or trajectory descriptions for users with only profile information. To enhance the model's generalization capability, we retrieve the top K most similar template users P' for each new user P_{new} and then fuse compression insights of P'.We compare two retrieving methods, the detailed definitions of which are provided in the Appendix A.1.

After acquiring similar users, we sequentially perform the following steps: (1) $\mathbf{c}_2$ Insight Fusion: Use LLM to integrate key profile factors and high-order mobility characteristics in $\mathbf{c}_2$ of the similar template users. (2) Trajectory Description Generation: Using the fused $\mathbf{c}_2$ insight, generate trajectory descriptions by referencing $\mathbf{r}_1$ and $\mathbf{r}_2$ in compression stage. (3) $\mathbf{c}_1$ Insight Fusion: Use LLM to integrate both the unique movement patterns and universal movement patterns in $\mathbf{c}_1$ of the similar template users. (4) Mobility Pattern Generation: Use fused $\mathbf{c}_1$ insight and trajectory descriptions to generate mobility patterns for new users.

The whole generation process can be described by Eq. (2).

$$S_{\text{new}} = \text{LLM}_{\text{gen}}(P_{\text{new}}, \text{Fuse}(c_1', c_2'); r_1, r_2) \quad (2)$$

The resulting semantic description S_{new} is subsequently grounded into a POI-level trajectory by GeoGenerator.

3.2 GeoGenerator: Integrating Geospatial and Collective Mobility Knowledge

As previously discussed, existing methods struggle to effectively leverage urban structural knowledge. To address this challenge, following the recent practice from community (Balsebre et al., 2024; Feng et al., 2025b), we train a urban-knowledgeable LLM as the foundation for integrating geospatial knowledge.

As shown in the middle of Figure 1, GeoGenerator features two key components: the Anchor Location Extractor and the Urban Structure Mapper. First, the Anchor Location Extractor generates critical anchor points based on user profiles, collective mobility distributions, and urban geographic knowledge. These anchor points are then transformed into intent-composed trajectories by integrating mobility patterns extracted in 3.1. Subsequently, the Urban Structure Mapper, built upon an enhanced geospatial LLM, maps these intent-driven trajectories into realistic urban locations, aligning them with the underlying city structure. Detailed prompts of Geogenerator can refer to Appendix A.8.

3.2.1 Anchor Location Extractor

The locations of homes and workplaces serve as the most important anchor points in human mobility trajectories, significantly shaped by individual user profiles and regional characteristics. To effectively identify these critical anchor locations, we propose a two-step extraction method.

Macro-to-micro cascaded generation. We implement a hierarchical reasoning-execution-reflection framework to progressively refine spatial

distributions. We transfer coordinates of all homes and workplaces into a coarse-to-fine address representation: *administrative area* → *subdistrict* → *street* → *POI*. In the reasoning stage, the model integrates regional descriptive summaries with user profiles to constrain spatial search. The execution stage then selects the optimal region based on these contextual priors. Finally, the model generates precise location of home/workplace at the POI scale, ensuring fine-grained spatial accuracy.

Reflection with collective distribution. To ensure collective fidelity, we incorporate urban-scale distribution as feedback. After each execution cycle, the system computes the generated spatial distribution and performs a reflection analysis against ground-truth distribution. The model then dynamically adjusts individual assignments in subsequent iterations to minimize distributional divergence, effectively aligning synthesized results with real-world urban constraints.

3.2.2 Urban Structure Mapper

To generate the remaining location points in a mobility trajectory beyond the two anchor locations (home and workplace) from the previous stage, we introduce an Urban Structure Mapper (referred to as UrbanMapper). Given the anchor points and activity sequences, this module flexibly integrates urban spatial structure information to synthesize the remaining trajectory points.

Enhancing Geospatial LLM To mitigate geographic hallucinations and improve spatial precision when generating specific location in real urban space, we augmented the knowledge embedded in LLM through fine-tuning with fine-grained urban spatial data. At a finer granularity, we posit that urban space is composed of three fundamental elements: points (POIs), lines (streets), and polygons (AOIs)(Dempsey et al., 2010). Among these, points (POIs) constitute the most basic building blocks, which also serve as the foundational components of trajectories. Therefore, we construct our training data based on POI-level granularity. To simulate human cognitive and exploratory processes in urban spaces, we generate navigation paths between population-weighted randomly sampled origin-destination (OD) POIs, recording all traversed POIs along the pathways, and subsequently identifying specified-category POIs within defined radius around each recorded waypoint. The radius is determined by the average jump distance between consecutive trajectory points and is correlated with the user's mobility pattern, while the category is related to user's intention at each time point. We construct a fine-tuning dataset comprising 39,000 question-answer pairs, encompassing all POIs of specified categories within certain radius around every sampled POI.

We activate the LLM's internalized geospatial awareness by substituting abstract coordinates with semantically rich address representations. We specifically investigate two formats: (1) **Hierarchical addresses** (e.g., *District* → *Subdistrict* → *Street* → *POI*) to provide structural constraints and reduce recall hallucinations. (2) **Human-intuitive spatial relations** (e.g., *100m from the intersection of Road B and C*) to prompt the model to associate nearby geographic entities and their attributes.This linguistic grounding enables the model to infer realistic activity ranges and generate locations with high semantic and spatial fidelity.

3.3 TrajEnhancer: Enhancing Mobility Trajectory with Mobility Style Alignment

After processing by MobExtractor and GeoGenerator, we obtain a preliminary location sequence that integrates user activity patterns and urban structural knowledge. However, such sequences may still lack fine-grained spatiotemporal coherence and individualized movement styles observed in real-world mobility. To bridge this gap, we introduce TrajEnhancer, which refines the generated trajectories through implicit alignment with real human mobility patterns using the Direct Preference Optimization (DPO) framework. This module ensures that synthetic trajectories not only follow high-level intents but also exhibit realistic temporal dynamics and spatial regularities.

As shown in the right part of Figure 1, TrajEnhancer performs integrated reasoning by synthesizing urban geospatial knowledge (generated in Section 3.2) and mobility patterns (extracted in Section 3.1). It first constructs daily activity plans for target users based on their profiles and historical patterns, consisting of semantic intentions (e.g., "dining out", "commuting") and temporal constraints (e.g., duration). Then, it generates realistic movement trajectories by jointly reasoning over user profiles, activity plans, anchor points, and contextual urban knowledge—ensuring spatial plausibility and temporal consistency.

To further enhance the spatiotemporal continuity and personalization of the generated trajectories, we employ an iterated DPO training pipeline.

The training data is constructed from pairs of model-generated trajectories (from current version **GAMS**) and corresponding real user trajectories. We adapt DPO to the mobility generation setting by treating real human trajectories as preferred responses and synthetic ones as dispreferred. The loss implicitly learns a reward function that captures spatiotemporal regularities and individual behavioral patterns, guiding the model to generate more realistic and personalized trajectories without explicit reward modeling. The formula is described by Eq. (3).

$$\mathcal{L}(\theta) = -\mathbb{E}_{(u,\tau_w,\tau_l)\sim\mathcal{D}} \left[\log\sigma\left(\beta \log \frac{\pi_\theta(\tau_w \mid u, \mathcal{K}_{\text{geo}}, \mathcal{P}_{\text{mob}})}{\pi_{\text{ref}}(\tau_w \mid u, \mathcal{K}_{\text{geo}}, \mathcal{P}_{\text{mob}})} - \beta \log \frac{\pi_\theta(\tau_l \mid u, \mathcal{K}_{\text{geo}}, \mathcal{P}_{\text{mob}})}{\pi_{\text{ref}}(\tau_l \mid u, \mathcal{K}_{\text{geo}}, \mathcal{P}_{\text{mob}})} \right) \right], \tag{3}$$

where u denotes the user profile, τ_w and τ_l are the preferred (e.g., real) and less preferred (e.g., synthetic) trajectories, respectively, $\mathcal{D}$ is the mixed trajectory dataset, π_θ is the trainable policy model, π_{ref} is the fixed reference policy, $\mathcal{K}_{\text{geo}}$ and $\mathcal{P}_{\text{mob}}$ represent urban geospatial knowledge and extracted mobility patterns, respectively, and β is the temperature coefficient controlling the regularization strength.

Based on the above formula, we implement a closed-loop workflow: training $\rightarrow$ deployment $\rightarrow$ testing $\rightarrow$ data collection $\rightarrow$ retraining, executed over multiple cycles. Through this progressive, multi-phase refinement, we continuously enrich the model's urban geographic understanding and strengthen its ability to capture individual mobility characteristics. Ultimately, this process enhances framework's spatiotemporal reasoning capabilities, enabling more realistic and personalized human mobility simulation.

4 Experiments

4.1 Experimental Setup

Datasets. We conduct the main experiments on two real-world mobility datasets, Tencent and ChinaMobile, both collected in Beijing. For additional cross-city evaluation, we use the Shanghai-ISP dataset collected in Shanghai. Table 2 reports the statistics of the two primary datasets, while the Shanghai-ISP results are provided in Table 10. To test **GAMS** 's performance on public datasets, we employ open street map's road network data and AOI data along with global POI data from Foursquare to jointly represent urban spaces. This does not compromise the overall experimental results. This confirms the transferability of **GAMS** across different datasets, and can achieve reasonably good performance even on smaller, lower-quality datasets.

Metrics. Following previous work (Feng et al., 2020; Shao et al., 2024), we evaluate the quality of generated mobility data from three dimensions, including statistical evaluation, aggregation evaluation and semantics evaluation. We also use Toponym Valid Ratio (TVR) to measure geographic knowledge hallucination, and Composite Mean Reciprocal Rank (CMRR) to measure overall performance across all metrics. Detailed metrics are described in appendix.

Methods. We evaluated our model in comparison with several state-of-the-art approaches, categorized into the following three groups: mechanistic models (TimeGeo (Jiang et al., 2016)), deep learning based methods (MoveSim (Feng et al., 2020), ActSTD (Yuan et al., 2022), DSTPP (Yuan et al., 2023)), LLM based methods (CoPB (Shao et al., 2024), LLMob (Wang et al., 2024a)).

4.2 Main Results

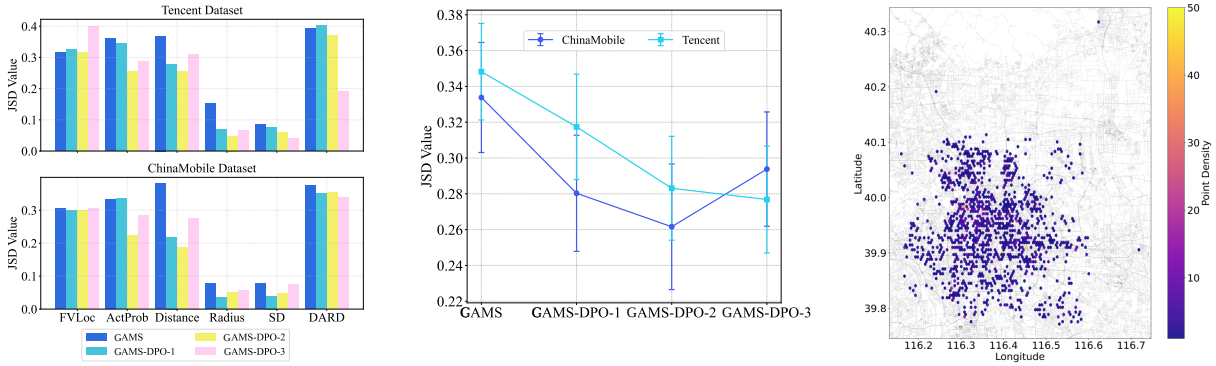
We want to validate the model's ability to generate geospatially accurate trajectories in real-world urban space without external geographic knowledge and with only limited user profile information. To ensure fair comparison, for LLM-based models, we employ llama3.1-8b as LLM core, while removing all specific location names (except anchor points) and manually extracted user-specific trajectory features from prompts; for deep-learning-based methods, we reduce the training-to-test ratio to 3:7 (which may slightly inflate their results because it is not feasible to completely remove the dependency on geographic knowledge from their frameworks).

4.3 Ablation Studies

Impact of collective knowledge and individual knowledge. As we introduce in section 3.1 and section 3.2, we integrate individual knowledge through extracting mobility patterns in MobExtractor, while incorporating collective knowledge via introducing feedback in reflection stage of Anchor Location Extractor. By analysing experimental results in Table 8 and generation results in Figure 3, we find that

Table 1: Performance comparison of mobility simulation methods across datasets. Best and second-best results are highlighted in **bold** and underline, respectively.

Dataset	Model	Generation Metrics								CMRR↑
		FVLoc↓	ActProb↓	Distance↓	Radius↓	SI↓	SD↓	DARD↓	STVD↓	
Tencent	TimeGeo	0.3671	0.5915	0.3053	0.3267	0.2312	0.3414	0.6972	0.6899	0.1798
	ActSTD	0.3518	0.6972	0.2815	0.1007	0.6880	0.0907	0.6946	0.6371	0.2574
	DSTPP	0.3115	0.5236	**0.1599**	0.1589	0.6880	0.0308	0.6863	0.6742	0.4458
	MoveSim	0.3650	**0.2647**	0.3876	0.3192	0.2309	0.1716	0.4946	**0.5271**	0.4354
	CoPB	**0.2744**	0.3907	0.1997	0.2394	0.4131	0.1915	0.4089	0.5660	0.4146
	LLMob	0.5044	0.3723	0.5266	0.1723	**0.1618**	0.0752	0.4400	0.6639	0.3420
	GAMS	0.3213	0.2769	0.2596	**0.0517**	0.3362	**0.0457**	**0.3832**	0.6540	**0.5208**
ChinaMobile	TimeGeo	0.3825	0.6793	0.4009	0.5466	0.5139	0.3065	0.5762	0.6907	0.1940
	ActSTD	0.4025	0.6900	0.4577	0.3400	0.5749	**0.0452**	0.6891	0.6947	0.2673
	DSTPP	0.3895	0.6794	0.3991	0.2553	0.5320	0.0989	0.6774	0.6613	0.2229
	MoveSim	0.3776	0.2413	0.5117	0.3810	0.3720	0.1063	0.5264	**0.5775**	0.3479
	CoPB	**0.2724**	0.2097	0.2690	0.1948	0.4794	0.2282	0.4997	0.5817	0.4479
	LLMob	0.5130	0.4198	0.5387	0.1690	**0.1207**	0.0839	0.3976	0.6585	0.4003
	GAMS	0.2994	**0.1244**	**0.1867**	**0.0507**	0.2524	0.0473	**0.3544**	0.6776	**0.7125**



(a) Detailed results for various metrics. (b) Aggregated performance. (c) Trajectory visualization

Figure 2: Results of individual mobility regularity alignment results for TrajEnhancer across various metrics and DPO iterations.

Table 2: Basic information of the trajectory datasets

Datasets	**Tencent**	**ChinaMobile**
Duration	2019.10.1 – 2019.12.31	2017.7.1 – 2017.8.31
City	Beijing	Beijing
#Users	100,000	1,246
#Trajectory Points	297,363,263	4,163,651

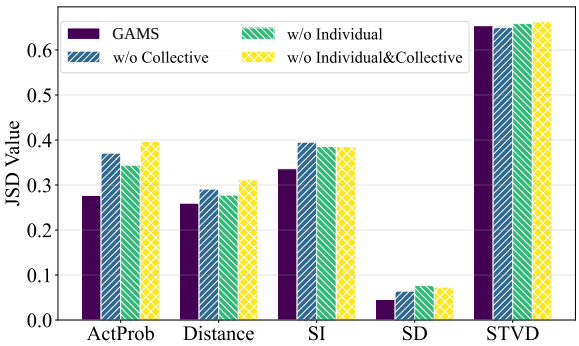


Figure 3: Ablation study on model designs (generation phase), where lower values indicate better performance.

the original implementation significantly outperforms both the individual-knowledge-ablated (w/o Individual) and collective-knowledge-ablated variants (w/o Collective), confirming that by integrating individual and collective knowledge, the model can more accurately understand the relationship between mobility patterns, specific user profiles and real-world urban spatial patterns, consequently generating trajectories that better align with user profile and actual urban mobility distributions.

Impact of Trajectory Style Alignment. We evaluate overall performance of trajectory enhancement module in Table 8. As visually confirmed in Figure 2b, there is an overall reduction in JSDs across successive DPO iterations, indicating that TrajEnhancer progressively enhances the spatiotemporal continuity of generated trajectories to approximate real-world mobility patterns. Variations of each metric are visualized in Figure 2a.

Robustness Analysis and Semantic Alignment

Table 3: Performance comparison of different LLMs within the **GAMS** framework. Best and second-best results are highlighted in **bold** and underline, respectively.

Dataset	Base Model	Generation Metrics									CMRR↑
		FVLoc↓	ActProb↓	Distance↓	Radius↓	SI↓	SD↓	DARD↓	STVD↓	TVR↑	
Tencent	LLaMA3.1-8B	0.4315	0.4649	0.3109	0.0920	0.2751	0.0883	0.3810	0.6672	0.9570	0.1630
	LLaMA3-70B	0.4342	0.3102	0.2985	0.0529	0.2053	0.0460	**0.2896**	0.6573	0.9560	0.4260
	Qwen2-72B	0.4119	0.3421	0.4384	0.1028	0.2128	0.1072	0.3203	0.6601	0.8420	0.1829
	Qwen3-235B	0.4089	0.2738	0.3582	0.1015	0.2899	0.1725	0.3569	0.6416	0.8247	0.2639
	GPT-4o-mini	0.4119	**0.2499**	0.3753	0.1143	0.1874	0.1218	0.3046	0.6624	0.8672	0.3402
	Gemma3-27B	0.3994	0.3903	0.4160	0.0695	**0.1717**	0.0506	0.3265	0.6570	0.8252	0.3583
	Mistral-7Bv3	0.4089	0.3547	0.3064	0.0811	0.3101	0.0980	0.3574	0.6677	0.8854	0.2036
	CityGPT	0.4342	0.3849	0.3108	0.1062	0.3076	0.0574	0.3166	**0.6356**	0.9196	0.2961
	GAMS-LLM	**0.3213**	0.2769	**0.2596**	**0.0517**	0.3362	**0.0457**	0.3832	0.6540	**1.0000**	**0.6111**
ChinaMobile	LLaMA3.1-8B	0.3992	0.4434	0.4045	0.0640	0.2521	0.0731	0.3987	0.6788	0.9684	0.2088
	LLaMA3-70B	0.4059	0.4120	0.3452	0.0638	0.2031	0.0517	0.3372	0.6792	0.9650	0.3125
	Qwen2-72B	0.4027	0.4414	0.3770	0.0618	0.2164	0.0479	0.3525	0.6780	0.8535	0.2958
	Qwen3-235B	0.3992	0.5140	0.4254	0.0937	0.2976	0.0949	0.3791	0.6586	0.8228	0.2118
	GPT-4o-mini	0.4027	0.4493	0.4894	0.0714	0.2802	0.0630	0.3689	0.6644	0.7836	0.1736
	Gemma3-27B	0.3994	0.3903	0.4160	0.0695	**0.1717**	0.0506	**0.3265**	**0.6570**	0.8252	0.5470
	Mistral-7Bv3	0.4059	0.4344	0.3806	0.0913	0.2035	0.0822	0.3608	0.6821	0.9007	0.1859
	CityGPT	0.3992	0.4816	0.3153	0.0879	0.2448	0.0832	0.3646	0.6686	0.8725	0.2512
	GAMS-LLM	**0.2994**	**0.1244**	**0.1867**	**0.0507**	0.2524	**0.0473**	0.3544	0.6776	**1.0000**	**0.6991**

of DPO. To further discern whether TrajEnhancer aligns semantic intent rather than merely fitting statistical distributions, we conducted robustness evaluations under two types of behavior drift: *Temporal Drift* (shifting timestamps by ± 2 hours) and *Pattern Drift* (randomly modifying 20% of activity categories). As shown in Table 11 in Appendix, **GAMS**-DPO maintained a significantly lower degradation, indicating that the iterated DPO pipeline effectively captures the underlying spatiotemporal regularities, allowing the model to remain robust against schedule and lifestyle variations.

Geospatial Generalization and Stability. We further evaluate GAMS against TimeGeo, ActSTD, and CoPB on the Shanghai-ISP dataset. As shown in Table 10, GAMS achieves the best performance on five of the eight metrics, including FVLoc, SI, SD, DARD, and STVD. TimeGeo, CoPB, and ActSTD perform best on ActProb, Distance, and Radius, respectively. These results show that GAMS maintains balanced performance across spatial, temporal, and semantic dimensions in a new urban environment, providing evidence of its cross-city generalization ability.

Performance comparison between the enhanced geospaital LLM. We test the performance of multiple open-source and closed-source LLMs in experimental scenarios. The results in Table 3 demonstrate that CityGPT, a representative geospatial knowledge enhanced LLM, can provide more authentic and fine-grained urban geospatial knowledge compared to other larger-parameter models. Additionally, GAMS-LLM which used as the geospatial foundation model in our framework, achieves the highest CMRR, indicating its superior ability to capture the connections between user profiles, mobility patterns and geospatial knowledge.

5 Conclusion

In this paper, we propose **GAMS**, an agentic framework for generating realistic human mobility behavior trajectories. **GAMS** utilizes geospatial foundation model's inherent geospatial knowledge while incorporating advanced commonsense reasoning techniques to capture underlying movement patterns. Extensive experiments on real-world trajectory datasets demonstrate the framework's capability to directly generate realistic trajectories from new user profiles.

Limitations

First, despite the use of a geospatial foundation model for knowledge enhancement, the inherent hallucination tendency of LLMs may introduce spurious geographic facts; we mitigate this by combining exact matching with semantic similarity to handle long-tail cases.

Second, our evaluation relies on established real-world mobility datasets from prior literature, which inevitably constrain the scale and geographic diversity of simulated users.

Third, the integration of a large language model as a geospatial reasoning component incurs substantial computational overhead, as training requires approximately tens of hours on 4 A100 GPUs, limiting accessibility.

Ethical Considerations

This work uses human mobility data obtained from prior studies and handled in accordance with the applicable data-use terms. We use de-identified and aggregated information and do not release raw trajectories or personally identifying information. The generated trajectories should not be used for individual-level tracking, surveillance, or decisions affecting individuals.

We used a large language model solely for proofreading and language polishing. All technical content, experimental design, analysis, and final revisions were produced and verified by the authors.

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A Appendices

A.1 Comparison of embedding-based vs. language-based in MobExtractor

- **Language-based**: Use LLM to select the top K most similar users based on semantic user profile characteristics, then directly output the ID and similarity score of each selected user.
- **Embedding-based**: Find similar users based on similarity scores of user profile embeddings(Yu et al., 2024). First, we construct a template user profile embedding matrix $\mathbf{E}_{\text{template}} \in \mathbb{R}^{m \times d}$, using the profiles of m template users. Then we encode user profile of new user into an embedding $\mathbf{e}_{1\times d}$, computing cosine similarities sim_ibetween $\mathbf{e}_{1\times d}$ and $\mathbf{E}_{\text{template}}$. Finally, we retrieve the top K users $\mathcal{T}$ with highest similarity scores.

A comparison of the overall experimental results between the language-based and embedding-based methods is presented in Table 4. The results show that embedding-based method performed comparably to the language-based approach, demonstrating that embeddings effectively capture critical user profile details. Moreover, the embedding-based method is more cost-efficient and easier to generalize for large-scale experiments. Therefore, we employ the embedding-based method as our primary approach in the experiments.

A.2 Comparison of different methodologies in Urban Structure Mapper.

By comparing results of geoknowledge enhanced LLM, **GAMS** with map tools (**GAMS** -Map) and **GAMS** with social networks (**GAMS** -Social) in Figure 4, we find that enhanced CityGPT based **GAMS** outperforms other methods with visibly lower JSDs. This suggests that implicitly incorporating geographic knowledge in trajectory generation tasks is reasonable, and enhanced CityGPT offers greater advantages over traditional GIS tools and social relationships.

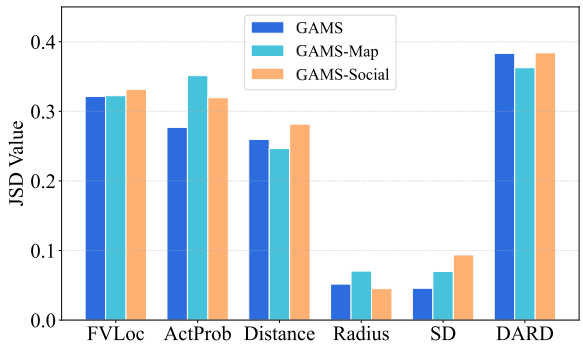


Figure 4: Methodological comparisons in GeoGenerator, where lower values indicate better performance. Here, '**GAMS**-Map' refers to the CityGPT with map tools, and '**GAMS**-Social' refers to the CityGPT with social graph integration.

A.3 Detailed Metrics

- **Individual evaluation.** We calculate Jensen–Shannon Divergence (JSDs) on the following metrics of per user: Distance, Radius, Step Interval (SI), Step Distance (SD) and Spatial-temporal Visits Distribution (STVD).
- **Collective evaluation.** We evaluate the quality of all generated data from a collective perspective, calculating JSDs on following metric of all users: Frequently visited locations (FVLoc), which is defined as the overall distributions of top 40 most frequently visited locations across all users.
- **Semantics evaluation.** To evaluate the plausibility of generated mobility data, we map venue categories to user intents and compute JSDs on following category-related metrics at both individual and collective levels: Daily Activity Routine Distribution (DARD) and Activity Probability (ActProb).
- **Hallucination evaluation.** We define Toponym Valid Ratio (TVR), which is the ratio of valid generated toponyms to total generated toponyms, to assess the degree of hallucination in the model's candidate geospatial knowledge generation. A higher TVR signifies lower hallucination frequency and better generation quality.
- **Comprehensive evaluation.** To holistically as-

Table 4: Performance comparison of embedding-based vs. language-based similarity methods in MobExtractor for trajectory generation. Best results for each metric are highlighted in **bold**.

Dataset	Similarity Method	Generation Metrics							
		FVLoc↓	Prob↓	Distance↓	Radius↓	SI↓	SD↓	DARD↓	STVD↓
Tencent	Embedding-based	0.3148	0.3611	**0.3687**	**0.1533**	**0.4566**	0.0845	**0.3931**	**0.6533**
	Language-based	**0.3027**	**0.3474**	0.3950	0.1674	0.4679	**0.0650**	0.3936	0.6583
ChinaMobile	Embedding-based	0.3118	**0.3872**	**0.2942**	**0.0691**	0.5054	0.0619	**0.3935**	**0.6400**
	Language-based	**0.2992**	0.4792	0.3701	0.0794	**0.4766**	**0.0616**	0.4156	0.6546

sess model performance, we propose the Composite Mean Reciprocal Rank (CMRR) metric, computed through a two-stage process: (1) calculating the reciprocal rank of each metric relative to all comparable models, then (2) computing the arithmetic mean of these reciprocal ranks across all metrics. A higher CMRR indicates more consistently superior performance across all evaluation dimensions.

A.4 Results on Mobility Recovery

To verify MobExtractor's efficacy in high-level mobility patterns extraction, we examine if template users can reconstruct their mobility patterns using extracted profile-specific semantic mobility pattern descriptions. We employ GeoGenerator to map mobility patterns to real trajectories in urban spaces. We compare the experimental results of our method with other trajectory generation methods. It should be noted that **GAMS** relies solely on user profiles as external input, whereas comparative methods explicitly incorporate additional external information such as geographical data. The results of evaluating performance are detailed in Table 5. The results demonstrate that **GAMS** achieves superior performance on 7 of 16 metrics in both data sets, with particularly outstanding advantages in metrics evaluating individual mobility capability (Radius) and behavioral habits (DARD). **GAMS** also exhibits commendable performance in terms of spatial continuity within trajectories (Distance and SD). This superior performance of **GAMS** can be attributed to its comprehensive consideration of the alignment between urban geographical knowledge and user mobility patterns.

A.5 Downstream Application: Epidemiological Simulation

To evaluate the practical realism and utility of the trajectories generated by our framework, we deploy them in a representative downstream task: simulation of infectious disease transmission. Specifically, we feed the synthetic mobility data produced by **GAMS** and a baseline method (ActSTD) into an epidemic propagation model that tracks the daily counts of Susceptible (S), Infectious (I), and Recovered (R) individuals. From multiple simulation runs, we compute the mean absolute percentage error (MAPE) across days to quantify fidelity relative to real-world epidemic dynamics. As shown in Table 6, **GAMS** explicitly accounts for both individual behavioral patterns and collective social influences, generating a denser and more realistic contact network. This enables the simulated epidemic curve to closely align with observed transmission patterns in real populations. In contrast, ActSTD largely neglects collective interaction effects, resulting in an extremely sparse contact network with isolated, linear transmission chains that are prone to premature termination. Consequently, its simulation outcomes exhibit excessive smoothness: daily population states (S, I, R) change very slowly and show high variance across runs, failing to capture the stochastic yet structured nature of real outbreaks. These results demonstrate that the trajectories generated by **GAMS** not only achieve higher statistical realism but also possess functional validity in complex, real-world decision-support scenarios such as public health modeling.

A.6 Data preprocessing

Trajectory data preprocessing Among the 100,000 users in the Tencent dataset, 44,313 users have both complete user profiles and accurate coordinates for their home and workplace. We conduct Collective Knowledge Extractor experiment using this subset of data. For each mobility dataset, we select the top 150 users with the highest average daily trajectory points for Geographic Knowledge Extraction, among which we randomly assign 100 users for trajectory recovery and the remaining 50 users for trajectory generation. We utilize the top 1,500 users with relatively higher average daily trajectory points for Individual Knowledge Extractor.

Table 5: Performance comparison of trajectory recovery methods across datasets.

Dataset	Model	Recovery Metrics								CMRR↑
		FVLoc↓	ActProb↓	Distance↓	Radius↓	SI↓	SD↓	DARD↓	STVD↓	
Tencent	TimeGeo	0.3555	0.6673	0.1506	0.2749	0.2010	0.3362	0.6895	0.6921	0.1890
	ActSTD	0.2007	0.6737	**0.0841**	0.0581	0.6880	0.0606	0.6910	0.6746	0.3494
	DSTPP	0.1975	0.3582	0.1346	0.2611	0.3960	0.0775	0.4824	0.4233	0.2792
	MoveSim	0.1966	0.1647	0.3176	0.3189	0.2009	0.1315	0.4456	**0.4141**	0.4045
	CoPB	0.1981	0.3592	0.1322	0.2270	0.3858	0.1885	0.3930	0.5474	0.3000
	LLMob	**0.1213**	**0.0891**	0.1822	0.1330	**0.1618**	0.0630	0.3961	0.5923	**0.5563**
	GAMS	0.3421	0.2444	0.2087	**0.0340**	0.2945	**0.0443**	**0.2681**	0.6284	0.5146
ChinaMobile	TimeGeo	0.3766	0.6862	0.3779	0.2908	0.4517	0.3057	0.6874	0.6845	0.1619
	ActSTD	0.2985	0.6862	0.4336	0.2816	0.5321	**0.0324**	0.6905	0.6907	0.2631
	DSTPP	0.2136	0.3722	0.1570	0.2705	0.2941	0.1537	0.5692	**0.4350**	0.3708
	MoveSim	0.1776	**0.1496**	0.3300	0.2619	0.4514	0.0950	0.4346	0.4617	0.4104
	CoPB	0.2677	0.2287	0.1415	0.1948	0.4735	0.1945	0.4790	0.5474	0.2917
	LLMob	**0.1560**	0.1590	0.1654	0.0763	**0.1207**	0.0718	0.3795	0.6560	0.5417
	GAMS	0.3055	0.3664	**0.1339**	**0.0717**	0.3464	0.0484	**0.3248**	0.6601	**0.5563**

Table 6: Mean absolute percentage error (%) for the susceptible (S), infectious (I), and recovered (R) compartments. Lower values indicate better performance.

Method	S (%)	I (%)	R (%)
GAMS	13.23	40.17	30.32
ActSTD	51.71	53.65	52.76

We aligned the private dataset with public datasets by replacing the private dataset's urban elements (including AOIs, POIs and roads) with relevant elements in OSM and Foursquare. Notably, while the aligned mobility dataset becomes sparser, this does not compromise the overall experimental results. This confirms the transferability of GAMS accross different datasets, and can achieve reasonably good performance even on smaller, lower-quality datasets.

DPO training data construction We construct the training dataset using the corpus output by GAMS. We employ Qwen2.5-72B, a large language model primarily trained on Chinese corpora, to extract mobility patterns while leveraging CityGPT for urban geographical knowledge. Our experimental setup involves 300 training users and 1200 test users, with all textual outputs from GAMS being collected for analysis. Using Qwen2.5-72B, we evaluate the quality of mobility pattern extraction from this corpus by assigning quality scores on a 0-10 scale, where we select textual outputs scoring below 5 as negative samples while using the corresponding individuals' real trajectories as positive samples for our training data construction.

A.7 Ablation studies

The hierarchical address representation is designed to activate geographic knowledge in CityGPT by associating location names with their attributes across defined regional hierarchies, resulting in generating more accurate locations with reduced hallucinations. In comparison, the human-centric address representation directly prompt the model to recall neighborhood geographic information from the training corpus. Results in Table 9 demonstrate that the second one performs better, likely because training corpus of CityGPT has been pre-aligned with OSM data.

A.8 Examples

Here, we present the detailed prompt for the *Geo-generator* module.

```
###### Explore Geographical Knowledge

You are an urban resident planning your next
    point of interest (POI) to visit based on
    current <INTENT> and <LOCATION>.

<INTENT>

You are going to eat, so the next POI should
    belong to:
{POI_categories}.

<LOCATION>

Your current location is {POI_name}, and the
    next POI should be within 3 km of your
    current location.
Please list five POIs you are most likely to
    visit next.

###### Utilize Geographical Knowledge

Act as a person in an urban neighborhood. Think
    about your daily routine and generate a plan
     for a weekday (from 0:00 to 24:00),
    explaining it. Follow these principles:
```

Table 7: Performance comparison of different LLMs in trajectory recovery within the GAMS framework.

Dataset	Base Model	Recovery								
		FVLoc↓	ActProb↓	Distance↓	Radius↓	SI↓	SD↓	DARD↓	STVD↓	TVR↑
Tencent	LLaMA3.1-8B	0.3468	0.2776	0.1913	0.0362	0.3070	0.0794	0.3300	0.6774	0.9697
	LLaMA3-70B	0.4468	0.3180	**0.1770**	0.0529	0.1697	**0.0383**	0.2684	0.6310	0.9541
	Qwen2-72B	0.4421	0.3567	0.2177	0.0785	0.1682	0.0881	0.2848	**0.6091**	0.8224
	Qwen3-235B	0.4468	0.3152	0.1646	0.0687	0.2819	0.0895	0.3255	0.6178	0.9040
	GPT-4o-mini	0.4468	0.3682	0.2737	0.1022	0.1650	0.1038	**0.2628**	0.6170	0.7844
	Gemma3-27B	0.4468	0.3134	0.3243	0.0887	**0.1637**	0.0964	0.2789	0.5967	0.8477
	Mistral7Bv3	0.4468	0.2799	0.2273	0.0639	0.2030	0.0865	0.2886	0.6265	0.9035
	GAMS	**0.3421**	**0.2444**	0.2087	**0.0340**	0.2945	0.0443	0.2681	0.6284	**1.0000**
ChinaMobile	LLaMA3.1-8B	0.3176	0.3964	0.2930	0.0987	0.2400	0.0612	0.3760	0.6769	0.9815
	LLaMA3-70B	0.4118	0.3826	0.2746	0.0753	0.1953	0.0501	0.3333	0.6615	0.9690
	Qwen2-72B	0.4118	0.4025	0.3616	0.1050	0.2190	0.0864	0.3373	0.6535	0.8306
	Qwen3-235B	0.4118	0.4242	0.2852	0.0770	0.3615	0.0564	0.4550	0.6595	0.9310
	GPT-4o-mini	0.4118	0.4666	0.3737	0.1285	0.2175	0.0803	0.3276	**0.6468**	0.8561
	Gemma3-27B	0.4118	0.4752	0.3390	0.0871	**0.1684**	0.0883	0.3346	0.6480	0.8436
	Mistral7Bv3	0.4118	0.5327	0.2345	0.0876	0.2598	0.0665	0.3582	0.6488	0.9164
	GAMS	**0.3055**	**0.3664**	**0.1339**	**0.0717**	0.3464	**0.0484**	**0.3248**	0.6601	**1.0000**

Table 8: Performance comparison of different methodology variants in UrbanMapper.

Dataset	Variant	Recovery Metrics							
		FVLoc↓	ActProb↓	Distance↓	Radius↓	SI↓	SD↓	DARD↓	STVD↓
Tencent	GAMS	**0.3421**	0.2444	0.2087	0.0340	**0.2945**	0.0443	**0.2681**	0.6284
	GAMS w/o C	0.3761	0.2721	0.2285	0.0688	0.3431	0.0614	0.2814	0.6365
	GAMS w/o I	0.3421	0.3721	0.1995	0.0267	0.2985	0.0229	0.3221	**0.6219**
	GAMS w/o I&C	0.3421	0.3887	**0.1563**	0.0660	0.3342	0.0377	0.3166	0.6448
	GAMS-M	0.3680	0.2458	0.1838	0.0266	0.3215	0.0334	0.3066	0.6250
	GAMS-M w/o C	0.3421	0.3108	0.1828	0.0790	0.2963	0.0390	0.3271	0.6478
	GAMS-M w/o I	0.3468	0.3248	0.1735	0.0469	0.2722	**0.0330**	0.3150	0.6265
	GAMS-M w/o I&C	0.3568	0.3794	0.1746	0.0305	0.3147	0.0467	0.2937	0.6283
	GAMS-S	0.3421	**0.2136**	0.1699	**0.0195**	0.3790	0.0378	0.3161	0.6301
	GAMS-S w/o C	0.3421	0.3240	0.2058	0.0412	0.3001	0.0435	0.3178	0.6269
	GAMS-S w/o I	0.3421	0.3504	0.1655	0.0596	0.2655	0.0513	0.3115	0.6259
	GAMS-S w/o I&C	0.3468	0.3518	0.1783	0.0790	0.3202	0.0543	0.3151	0.6356
ChinaMobile	GAMS	**0.3055**	**0.3664**	**0.1339**	0.0717	0.3464	0.0484	**0.3248**	0.6601
	GAMS w/o C	0.3055	0.3784	0.2162	0.0975	0.3330	0.0592	0.3393	0.6753
	GAMS w/o I	0.3118	0.3771	0.1956	0.0676	0.3207	0.0451	0.3693	**0.6437**
	GAMS w/o I&C	0.3118	0.3742	0.2117	0.0654	0.3500	0.0490	0.3792	0.6501
	GAMS-M	0.3055	0.3780	0.1468	**0.0340**	0.3106	0.0633	0.3526	0.6550
	GAMS-M w/o C	0.3118	0.3971	0.1934	0.0704	0.3482	0.0532	0.3592	0.6594
	GAMS-M w/o I	0.3055	0.4141	0.2122	0.0454	0.3198	**0.0396**	0.3574	0.6526
	GAMS-M w/o I&C	0.3118	0.4100	0.1846	0.0874	0.3643	0.0796	0.3336	0.6546
	GAMS-S	0.3055	0.3687	0.1669	0.0601	**0.2896**	0.0578	0.3409	0.6622
	GAMS-S w/o C	0.3055	0.3869	0.1795	0.0775	0.2973	0.0567	0.3427	0.6643
	GAMS-S w/o I	0.3118	0.4006	0.1713	0.0377	0.3081	0.0643	0.3717	0.6572
	GAMS-S w/o I&C	0.3055	0.3926	0.2303	0.0871	0.3371	0.0708	0.3766	0.6524

Table 9: Performance comparison of human vs. hierarchical address types in recovery and generation tasks. Best results for each metric are highlighted in **bold**.

Dataset	Task	Address Type	Performance Metrics								
			Loc↓	Prob↓	Dist↓	Rad↓	SI↓	DailyLoc↓	SD↓	DARD↓	STVD↓
Tencent	Recovery	Human	**0.3421**	**0.3383**	**0.2728**	**0.1212**	**0.4479**	0.1803	**0.0578**	**0.3849**	**0.6391**
		Hierarchical	0.3420	0.3117	0.2852	0.1004	0.4639	**0.1397**	0.0779	0.4099	0.6336
	Generation	Human	**0.3148**	**0.3611**	**0.3687**	0.1533	**0.4566**	**0.1687**	**0.0845**	**0.3931**	**0.6533**
		Hierarchical	0.3089	0.3840	0.4577	**0.1283**	0.4690	0.1975	0.1114	0.4092	0.6512
ChinaMobile	Recovery	Human	0.3118	**0.3872**	0.2942	**0.0691**	**0.3054**	0.1217	0.0619	**0.3935**	**0.6400**
		Hierarchical	0.3118	0.4648	**0.2828**	0.0986	0.4945	**0.0379**	**0.0587**	0.4143	0.6425
	Generation	Human	0.3059	**0.3317**	0.3807	0.0778	**0.4624**	**0.0980**	**0.0767**	**0.3757**	0.6591
		Hierarchical	**0.2992**	0.3586	**0.3251**	**0.0767**	0.4789	0.1497	0.0909	0.3888	**0.6614**

```
1. **Retain key features**:
   Consider important features in <TRAJECTORY_
     DESCRIPTION> and retain them in your plan.
     Refer to <IMPORTANT_FEATURES>.

2. **Supplement sparse data**:
   Use general knowledge (e.g., shortest-path
     algorithms) to enrich sparse information in
     <TRAJECTORY_DESCRIPTION>. Refer to <GENERAL_
     INFORMATION>.

3. **Incorporate high-level patterns**:
   Reflect movement patterns, travel habits, and
      user motivations. Refer to <HIGH_LEVEL_
     FEATURES>.

4. **Select POIs**:
   Choose one POI per time period from <
     CANDIDATE_POIS>.

<TRAJECTORY_DESCRIPTION>

{trajectory_description}

<IMPORTANT_FEATURES>

{important_features_of_trajectory}

<GENERAL_INFORMATION>

{general_information_of_trajectory}

<HIGH_LEVEL_FEATURES>

{high_level_features_of_trajectory}

<CANDIDATE_POIS>

{candidate_pois}
```

A.9 Visualization of Generated Trajectory Data

To demonstrate that **GAMS** effectively captures the relationships between user profiles, mobility patterns, and trajectories in real urban spaces, we visualized the anchor points and single-day trajectory point distributions for different user profiles generated by the model in Figure 6.

A.10 Generated mobility patterns of different user profiles

We compared the distributions of anchor points and trajectory points generated by the model for three types of user profiles in Figure 6. The first row in the left panel represents to the user profiles of 20-year-old, moderately-income male with a bachelor's degree working as an IT engineer(Profile 0). Generated work locations (Figure 5b)of this group show a higher degree of clustering in city centers compared to their residential locations(Figure 5a), and the overall trajectory point distribution is relatively dispersed(Figure 5c), suggesting that they tend to reside in suburban areas to reduce living costs, while working in IT-related companies concentrated in urban centers. The second row corresponds to young females in Finance/Accounting/Auditing/Tax/Cashier with a bachelor's degree and a moderate income(Profile 1). Generated workplaces and residences of Profile 1 cluster around major corporate hubs, suggesting that they often work in larger companies and rent apartments nearby their workplaces. The third row represents middle-aged males in Network Sales/Operations/Services with a bachelor's degree and a moderate income(Profile 2).Compared to the previous two user types, the trajectories generated for Profile 2 appear more scattered and irregular, demonstrating less regular mobility patterns, as they may travel more frequently for business.

A.11 Computational Efficiency

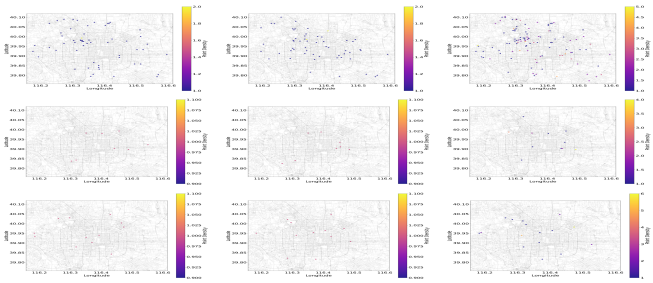
Fine-tuning GAMS-LLM, based on Llama 3.1-8B, on 39K POI-level training pairs takes approximately 2.5 hours on two A100 GPUs. The subsequent DPO stage takes approximately 2 hours for three iterations.

Generating a complete daily trajectory containing approximately 10 POI visits takes about 70 seconds per user on a single A100 GPU. This end-to-end latency includes user retrieval in MobExtractor, geospatial reasoning in GeoGenerator, and trajectory refinement in TrajEnhancer. Although GAMS is slower than the deep-learning baseline MoveSim, which requires less than 0.1 seconds per user, its iterative LLM-based reasoning provides improved transferability and interpretability.

The embedding-based retrieval in MobExtractor and the independence of trajectory generation across users allow the framework to process users in parallel.

A.12 Baselines

- **TimeGeo**(Jiang et al., 2016): It uses statistical methods to model temporal patterns while leveraging the r-EPR mechanism to model spatial patterns of user mobility data.
- **ActSTD**(Yuan et al., 2022): It adopts a GAIL framework, combining continuous spatio-temporal dynamics modeling with generative adversarial training to generate mobility data.
- **DSTPP**(Yuan et al., 2023): It employs a diffusion model to learn the joint spatio-temporal



(a) Home (b) Workplace (c) Trajectory

Figure 6: Comparison of Mobility patterns in real urban spaces of different user profiles.

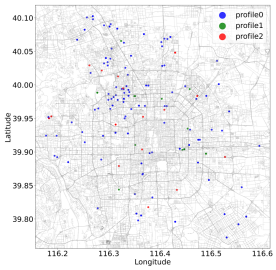


Figure 5: Comparison of daily movement patterns

Table 10: Performance comparison of different models on the Shanghai-ISP dataset. Best results for each metric are highlighted in **bold**.

Model	Performance Metrics							
	FVLoc↓	ActProb↓	Distance↓	Radius↓	SI↓	SD↓	DARD↓	STVD↓
ActSTD	0.3287	0.5125	0.2894	**0.0456**	0.4013	**0.0365**	0.4827	0.5934
TimeGeo	0.3045	**0.1622**	0.1776	0.0822	0.3941	0.0460	0.5394	0.6575
CoPB	0.3208	0.2379	**0.1512**	0.0576	0.3923	0.0394	0.6843	0.6739
GAMS	**0.2945**	0.3567	0.2123	0.0482	**0.3856**	0.0389	**0.3832**	**0.5612**

Table 11: Performance comparison under different drift conditions. Best results for each metric are highlighted in **bold**. Degradation percentages are shown in parentheses.

Method	Performance Metrics			
	Clean↓	Temporal Drift↓	Pattern Drift↓	Avg. Degradation↓
GAMS -SFT (Ablation)	0.4100	0.5330 (+30.0%)	0.5945 (+45.0%)	+37.5%
GAMS -DPO (Ours)	**0.3832**	**0.4522** (+18.0%)	**0.5058** (+32.0%)	**+25.0%**

distribution, incorporating a co-attention module for modeling spatio-temporal point processes.

- **MoveSim**(Feng et al., 2020): It adopts a generative-adversarial framework in which the generator utilizes a self-attention-based sequence modeling network to capture temporal transitions and the discriminator distinguishes synthetic trajectories by incorporating key mobility patterns.
- **CoPB**(Shao et al., 2024): It leverages LLM to infer mobility-related habits and motivations from user profiles, then apply mechanistic models to map these patterns to real urban spaces.
- **LLMob**(Wang et al., 2024a): It derives mobility patterns from predefined trajectory features using LLM, then selects positive/negative training samples from historical mobility data for adversarial learning.