Urban Pulse: Transformer-based Analytics of Spatio-temporal Urban Stratification (2016-2025)

Shilin Ou

February 6, 2026

1 Title & Abstract

Title: Urban Pulse: Transformer-based Analytics of Spatio-temporal Urban Stratification (2016-2025)
Abstract: Cities are often perceived as static mosaics of neighborhoods, yet they function more like evolving organisms with metabolic rates of change. This project challenges the traditional "snapshot" approach to urban visualization by constructing a longitudinal "Digital Twin" that spans a crucial decade of socio-economic shifts (2016-2025) across ten major cities. By integrating Uber's H3 spatial indexing with a custom *Deep Urban Transformer* architecture, we aim to capture the invisible "velocity" of urban stratification. Our research treats every hexagonal grid cell as a living entity, using Variational Autoencoders (VAE) to extract its "evolutionary DNA" and map its trajectory within a high-dimensional latent space. This project will visualize how globalized consumption patterns—driven by the "viral" expansion of anchor brands—are actively reshaping local community identities.

2 Project Description

Goals & Vision
Our project is driven by a critical question: In an era of rapid urban renewal, are our cities becoming more diverse or merely more homogenized? While traditional maps can show us where poverty or wealth resides *today*, they fail to illustrate the *momentum* of these forces. A neighborhood that appears stable might actually be in the midst of a violent "gentrification shock," while another might be trapped in a "poverty attractor" with no escape velocity. We frame the city not as a collection of buildings, but as a manifold of evolving socio-economic functions. By tracing the historical pathways of over 20,000 urban hex-cells, we aim to provide urban planners and community advocates with a predictive lens that reveals the trajectory of neighborhood change before it becomes irreversible.
Community Value & Ethics
This digital twin serves as a computational critique of modern planning by aligning urban data analytics with UN Sustainable Development Goal 11: Sustainable Cities and Communities [1]. Our Transformer-based model aims to identify and visualize the erosion of this unique memory by standardized global chain brands, addressing SDG Target 11.4, which calls for strengthened efforts to protect and safeguard the world's cultural and natural heritage. By rendering these invisible socio-economic shifts visible, we empower communities to advocate for inclusive policies that preserve local character and prevent displacement.

3 Data Strategy

Spatio-temporal Infrastructure
To enable a fair comparison across different cities and timelines, we have engineered a standardized data pipeline. We utilize Uber's H3 Hexagonal Hierarchical Spatial Index at Resolution 8 (edge length approx. 460m). This ensures that a "neighborhood" unit in London is topologically identical to one in New

York or Chicago.

Processing & Alignment

By querying the OpenStreetMap Overpass API with annual timestamps, we harvest a decade-long sequence of Points of Interest (POI) data. We focus on seven key functional dimensions, including retail, dining, healthcare, and education.

4 Visualization Design

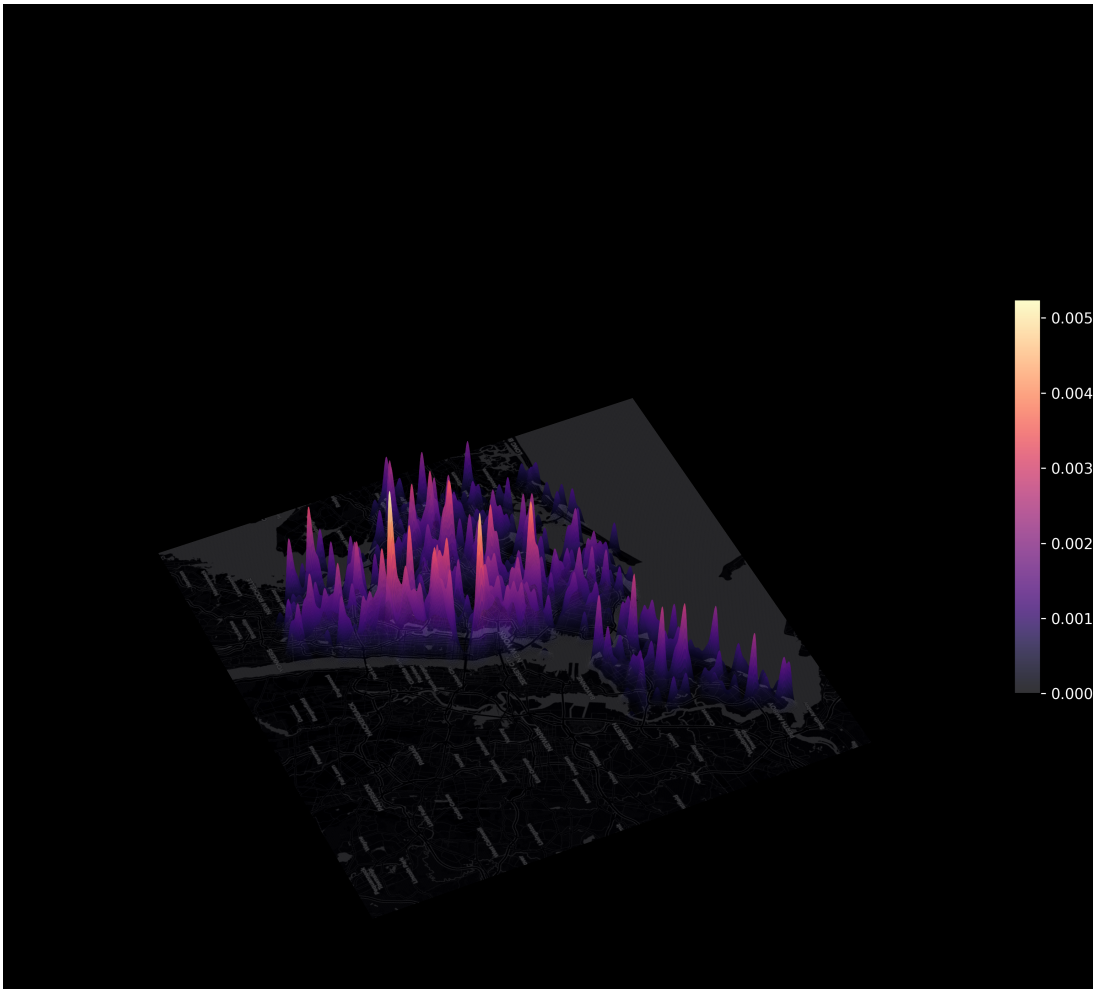

Figure 1: **The Urban Pulse 3D Dashboard (New York Case Study).** This visualization, generated from our Deep Urban Transformer, maps the latent "Gentrification Pressure" onto the H3 grid topology. Taller bars indicate higher structural instability and potential for displacement.

Our visualization strategy moves beyond static heatmaps to interactive, narrative-driven 3D experiences. We propose two primary visualization modules: the Manifold Trajectory Map and the Urban Pulse 3D Dashboard.

The Manifold Trajectory Map will abstract the city into a field of moving particles. Each particle represents a neighborhood, and its movement corresponds to its socio-economic evolution within the latent space. Users will see "streams" of neighborhoods migrating from one functional cluster to another, visually revealing the "homogenization" hypothesis where diverse trajectories converge into standardized archetypes.

The Urban Pulse 3D Dashboard (See Figure 1) visualizes the "Gentrification Pressure Index" as the height of hexagonal columns. As users slide through the timeline from 2016 to 2026, they witness the

”pulse” of the city—watching high-value zones expand like a biological organism consuming adjacent areas. This dynamic metaphor makes the abstract concept of displacement viscerally apparent.

5 Community Engagement

Connection to Urban Futures (Jiading & Fengxian)
During our visit to the *Jiading Urban Planning Exhibition Hall* and the *Fengxian Waving Cube*, we observed how official narratives often present a static, idealized ”future city.” By visualizing the ”Manifold Drifting,” we provide a rigorous reality check to the civic imagination, ensuring that future planning is grounded in the lived realities of urban evolution rather than just architectural renderings.

6 Work Plan & Collaboration

Data Architecture (Weeks4): This role involves managing the persistent API harvesting tasks and finalizing the H3 spatial aggregations. The output will be a rigorously curated dataset, documented to ensure transparency and reproducibility.
Algorithmic Modeling (Weeks5): This phase focuses on the *DeepUrbanTransformer*. We will tune hyper-parameters to ensure the model captures meaningful latent representations and perform the ”Manifold Drifting” calculations to identify ”Attractor” states.
Visualization & Narrative (Weeks6): The final phase bridges the gap between code and community, translating Python-generated 3D plots into a cohesive visual narrative for the final report and poster.

Project Collaboration Links

- **Canva Poster:** https://www.canva.cn/design/DAHAKBa4yCA/lOUWQLeCQOj92ht5MHLryA/edit?utm_content=DAHAKBa4yCA&utm_campaign=designshare&utm_medium=link2&utm_source=sharebutton
- **GitHub Organization/Repository:** https://github.com/Owen-1234/301Final
- **Hugging Face Dataset:** https://huggingface.co/datasets/Shilin-1234/Infor301

References

[1] Z. Xu and V. Coors, “Combining system dynamics model, gis and 3d visualization in sustainability assessment of urban residential development,” *Building and Environment*, vol. 47, pp. 272–287, 2012.