A Fluctuation-Aware Agent for Modeling Emerging Urban Intents

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Urban Mobility · Mobility Uncertainty · Probabilistic Intent Modeling

BACKGROUND

- City mobility is not purely habitual since people switch between routine and dynamic intent daily.
- Next-POI systems are built to predict the expected next location, systematically missing moments of genuine exploration.
- Study sites: Tokyo (2,293 users) and New York City (1,083 users), Foursquare check-in data, 2014.

RESEARCH GAP

- Existing models treat behavioral uncertainty as noise and optimize it away.
- No prior work uses prediction uncertainty as a signal for detecting intent change, or links it to physical urban structure.

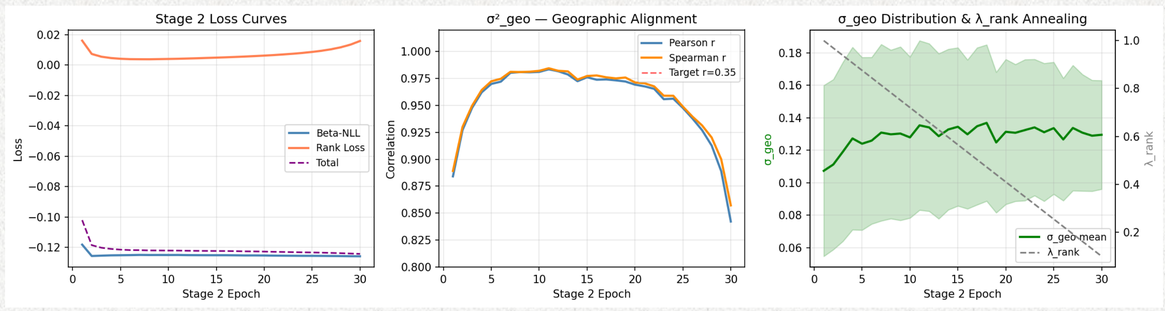
AIM

- Model mobility uncertainty as a real-time indicator of emerging urban intent.
- Test whether this uncertainty signal reflects actual urban spatial structure.
- Evaluate robustness gains for sparse or irregular mobility sequences.

METHODS

Gaussian Intent Encoder

User intent is modeled as a Gaussian distribution. The dynamic variance σ^2 serves as an intent stability indicator: low σ^2 reflects routine adherence; high σ^2 signals emerging exploration. Training uses β-NLL loss with time-decay weights for irregular check-in gaps.

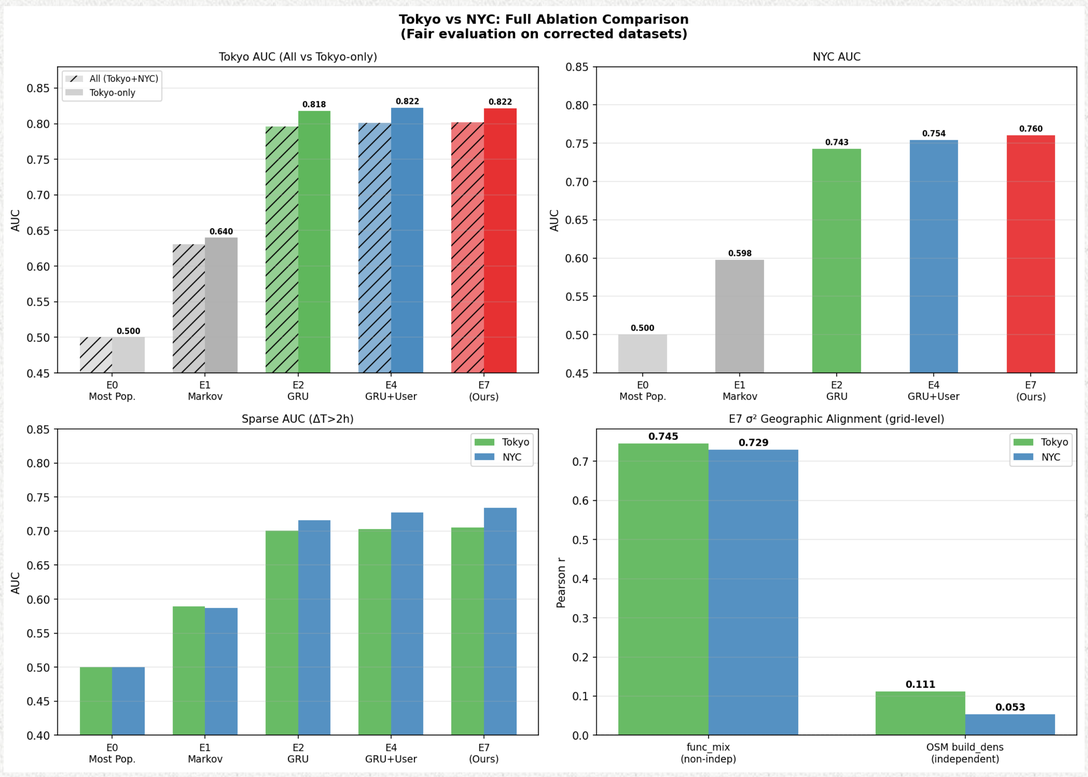


Detect-and-Switch Framework

Two-stage training: Stage 1 trains the GRU encoder to convergence (Val AUC = 0.797). Stage 2 freezes the encoder and trains the variance head independently with pairwise ranking supervision. Encoder gradient = 0 throughout Stage 2 uncertainty modeling adds no cost to prediction performance.

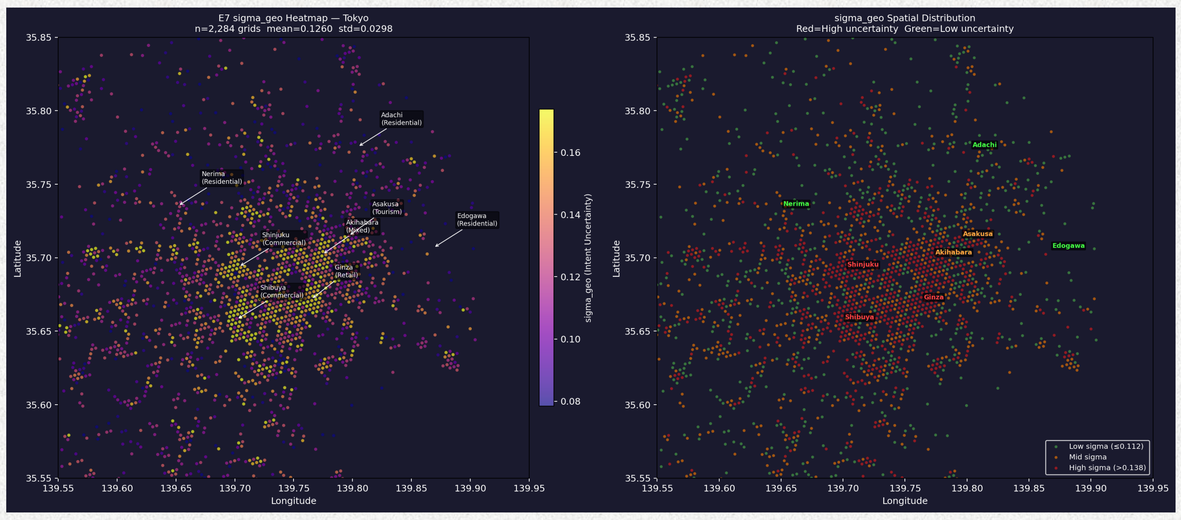
FINDINGS

Prediction Performance



Uncertainty as a Spatial Signal

- σ^2 validated against OpenStreetMap building data (unseen during training).
- Tokyo: $\rho = 0.135$, $p < 10^{-7}$ · NYC: $r = 0.053$, $p < 10^{-100}$
- High-σ^2 zones spatially align with functionally mixed, commercially active areas where serendipitous exploration actually occurs.



CONCLUSIONS

- σ^2 is a reliable, real-time signal for emerging urban intent across both cities.
- The Detect-and-Switch framework disentangles routine from exploration without sacrificing prediction accuracy.
- Modeling intent fluctuation shifts urban AI from optimizing efficiency toward supporting city vitality.

FUTURE APPLICATIONS

- Map σ^2 hotspots to inform urban design and identify serendipity-rich zones.
- Incorporate real-time contextual inputs: events, weather, time-of-day.
- Extend to continuous intent trajectories beyond binary routine/switch labels.

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