
Graph Enhanced Attention Network for Explainable POI Recommendation

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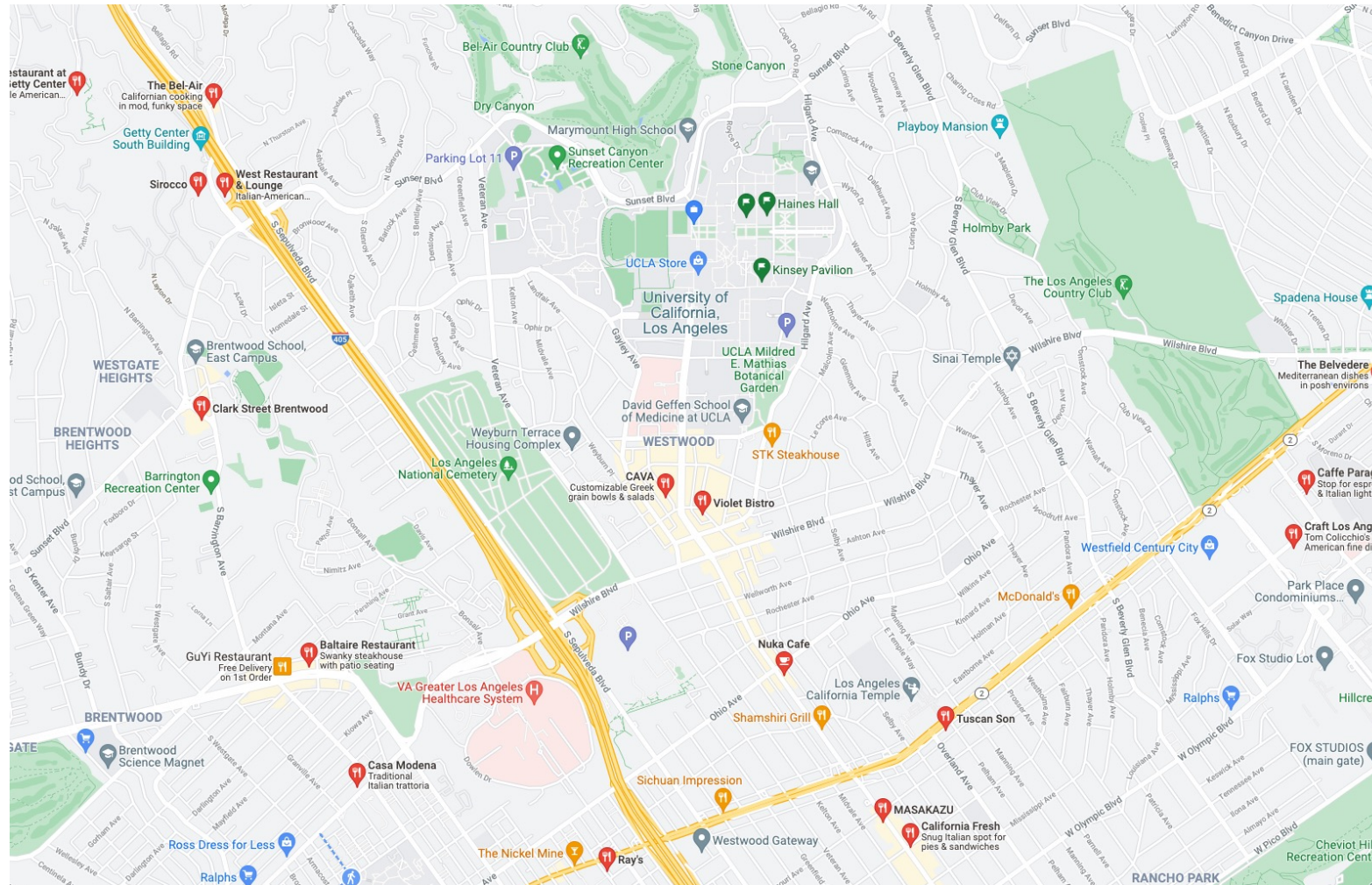
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Point-of-interest (POI)



Point-of-interest (POI)

Ad · belmontpark.com/san-diego/attractions ▾
Join Our Fall Event Series

Belmont Park
4.5 ★★★★★ (12,796)
Amusement park · 3146 Mission Blvd
Beachside amusement park with retro vibe
Open until 10:00 PM

Balboa Park
4.8 ★★★★★ (59,149)
Tourist attraction
Multi-attraction park covers 1,200 acres
Open 24 hours
"Definitely a must visit whether you're a local or just visiting."

Old Town San Diego State Historic Park
4.6 ★★★★★ (21,441) · \$\$
Tourist attraction · 4002 Wallace St
Open-air living-history museum
Open until 5:00 PM
"Also the sherrif museum and any other place you can visit."

Cabrillo National Monument
4.8 ★★★★★ (9,016)
Tourist attraction · 1800 Cabrillo Memorial Dr
Historic lighthouse with expansive views
Open until 5:00 PM
"After the museum we visited the lighthouse."

Maritime Museum of San Diego
4.7 ★★★★★ (3,064)
Tourist attraction · 1492 N Harbor Dr
Destination for restored antique ships
Open until 5:00 PM
"Must visit if you love ships"

Sunset Cliffs Natural Park
4.8 ★★★★★ (5,273)
Tourist attraction · Ladera St
Rocky cliffs overlooking the ocean
Open 24 hours

Point-of-interest (POI)

POI: POINT OF INTEREST

1. POI: locations that customers of online business directories or review forums are interested in.
2. LBSN: location-based social network
3. E.g.: Yelp, Foursquare, etc.

Point-of-interest (POI)

DRAWBACKS OF EXISTING POI ALGORITHMS

1. Attributes of individual have been largely ignored.

The image shows a screenshot of a user profile on a review platform. The profile is for 'John P.' and is highlighted with a yellow border. The 'About John P.' section is highlighted with a yellow box and has an arrow pointing to it from the text 'User profile'. The profile includes a 'Rating Distribution' bar chart, 'Review Votes' (Useful 18, Funny 7, Cool 5), and a '1 Compliment'. The 'Location' is Playa del Rey, Los Angeles, CA, and the user has been on the platform since November 2012. The 'My Last Meal On Earth' is 'gargantuan sirloin cooked mid-rare/medium'. The profile also shows a review for 'American Beauty' with a 4.5 rating and a detailed text review.

Rating Distribution

Stars	Count
5 stars	10
4 stars	10
3 stars	3
2 stars	3
1 star	1

Review Votes

- Useful 18
- Funny 7
- Cool 5

1 Compliment

Location
Playa del Rey, Los Angeles, CA

Yelping Since
November 2012

Find Me In
westside LA

My Hometown
SLO

When I'm Not Yelping...
I'm working on product & service development for clients

Why You Should Read My Reviews
honest, concise, sometimes mildly amusing

My Last Meal On Earth
gargantuan sirloin cooked mid-rare/medium

Point-of-interest (POI)

DRAWBACKS OF EXISTING POI ALGORITHMS

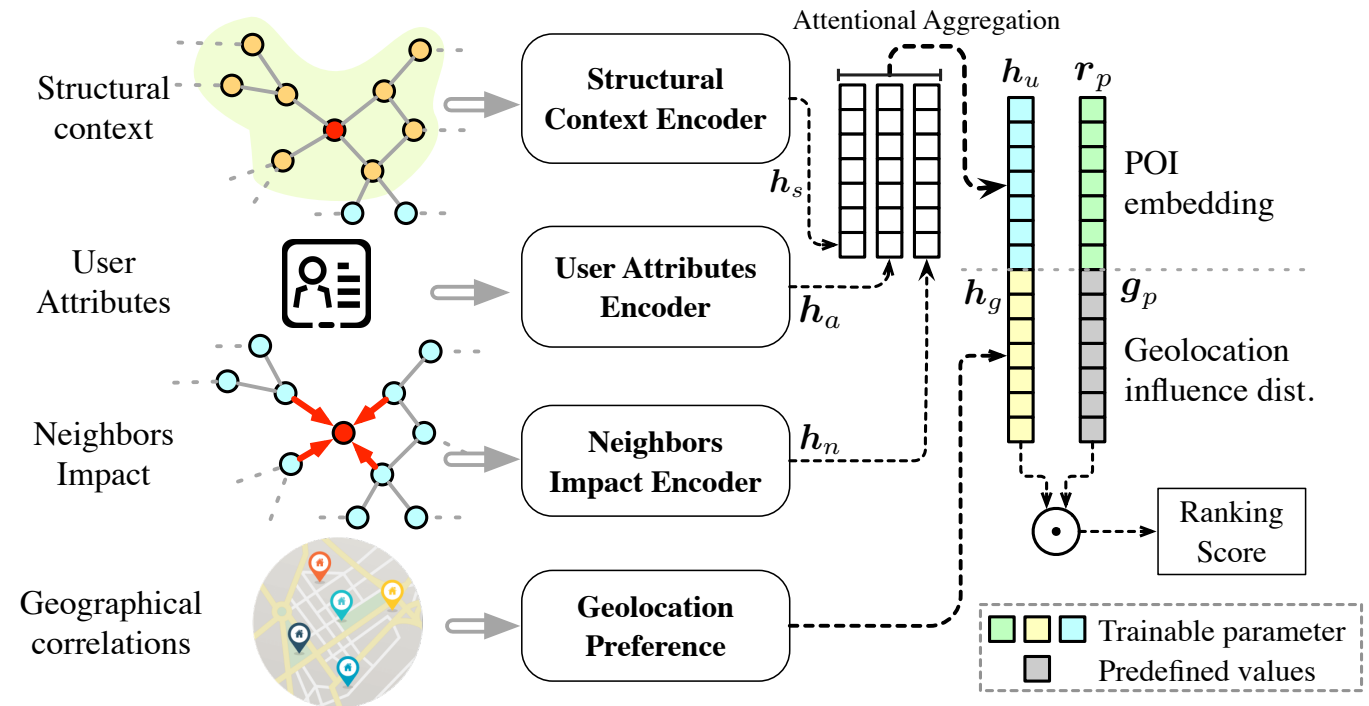
1. Attributes of individual have been largely ignored.
2. Existing models preserve the information of users or POIs by latent presentation without explicitly highlighting salient factors or signals.

GEAPR

GRAPH ENHANCED ATTENTION NETWORK FOR EXPLAINABLE POI RECOMMENDATION

Four factors:

1. Structural Context
2. Neighbor Impact
3. User Attributes
4. Geolocation Influence



Structural Context

- **Motivation:** Check-in can be motivated by neighboring users with high structural proximity in the social network since they have a similar social context.
- The structural context tries to model the commonality of the close neighbors of a certain user.
- **How to:**
 - Random Walk with Restarts (RWR) (M_a is adjacency matrix, $p^{(0)}$ is the col of M_a)

$$\mathbf{p}^{(r)} = \gamma \mathbf{p}^{(0)} + (1 - \gamma) \mathbf{p}^{(r-1)} [\mathbf{D}^{-1} \mathbf{M}_a],$$

$$\mathbf{D}_{ii} = \sum_{j=1}^{n_u} \mathbf{M}_{a,ij}.$$

$$\mathbf{h}'_s = \sum_{r=1}^R \mathbf{p}^{(r)}$$

$$\mathbf{h}_s = \text{ReLU}(\mathbf{W}_2^T (\text{ReLU}(\mathbf{W}_1^T \mathbf{h}'_s + \mathbf{b}_1)) + \mathbf{b}_2),$$

Neighborhood Impact Factor

- **Motivation:** one may naturally check in the POIs suggested by friends
- **How to:**
 - GAT: graph attention network
 - Aggregate information from direct neighbors and compute the attention to pinpoint significant neighbors

$$\mathbf{h}_n = \sigma \left(\sum_{j \in \mathcal{N}_G(u)} \alpha_{uj} \mathbf{W}_n \mathbf{v}_j \right)$$

Non-linear function

The friends of u

Learable parameter

Neighborhood Impact Factor

- Motivation: one may naturally check in the POIs suggested by friends
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$$\mathbf{h}_n = \sigma \left(\sum_{j \in \mathcal{N}_G(u)} \alpha_{uj} \mathbf{W}_n \mathbf{v}_j \right)$$

$$\alpha_{uj} = \frac{\exp \left(\text{LeakyReLU} \left(\mathbf{a}^T [\mathbf{W} \mathbf{v}_u \parallel \mathbf{W} \mathbf{v}_j] \right) \right)}{\sum_{i \in \mathcal{N}_G(u)} \exp \left(\text{LeakyReLU} \left(\mathbf{a}^T [\mathbf{W} \mathbf{v}_u \parallel \mathbf{W} \mathbf{v}_i] \right) \right)}$$

Attribute Interactive Factor

- **Motivation:** The combinatorial possibilities of feature interactions create diverse influences on the users' preference towards POIs, which has been thoroughly studied in feature-based recommender systems.
- **How to:** We combine feature-based FM method with attention mechanism to analyze feature interaction while maintaining the interpretability.

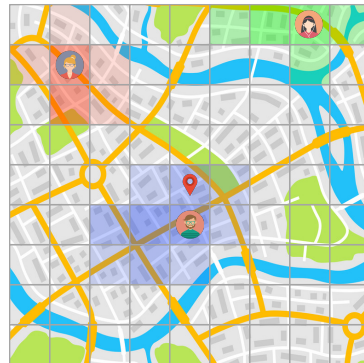
$$\mathbf{h}_a = \mathbf{w}_0 + \sum_{i=1}^m \beta_i \mathbf{f}_i + \sum_{i=1}^m \sum_{j=i+1}^m \lambda_{ij} \mathbf{f}_i \odot \mathbf{f}_j,$$

First- and
second- order
attention weights

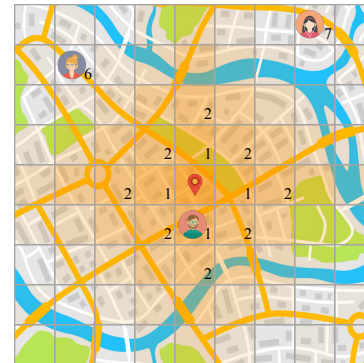
Feature
representation

POI Geographical Influence

- Two aspects:
 - Learnable user geolocational interest
 - Predefined POI area influence
- Geo-preference: $\mathbf{h}_g \in \mathbb{R}^{(n_{\text{long}} \cdot n_{\text{lat}})}$
- POI influence:
$$g_{p,t} = K \left(\frac{d_{\text{man}}(p, t)}{\sigma_g} \right)$$



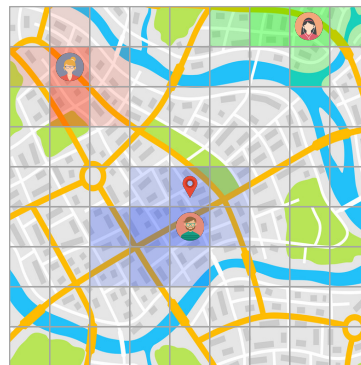
User geo-preference



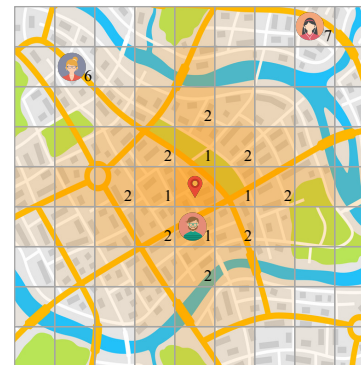
POI influence area

POI Geographical Influence

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- POI influence:
$$g_{p,t} = K \left(\frac{d_{\text{man}}(p, t)}{\sigma_g} \right)$$



User geo-preference



POI influence area

GEAPR can be **painlessly transplanted** to geolocation-irrelevant recommendation scenarios by simply detaching the geolocation module.

Objective and Optimization


- Attention-based aggregation:

$$\mathbf{h}_u = \pi_s \cdot \text{ReLU}(\mathbf{h}_s) + \pi_n \cdot \text{ReLU}(\mathbf{h}_n) + \pi_a \cdot \text{ReLU}(\mathbf{h}_a)$$

$$\pi_{x \in \{s, n, a\}} = \frac{\exp(\mathbf{w}^T \text{ReLU}(\mathbf{h}_x))}{\sum_{x' \in \{s, n, a\}} \exp(\mathbf{w}^T \text{ReLU}(\mathbf{h}_{x'}))}$$

$$s_{u,p} = [\mathbf{h}_u || \mathbf{h}_g] \cdot [\mathbf{r}_p || \mathbf{g}_p] = \mathbf{h}_u^T \mathbf{r}_p + \mathbf{h}_g^T \mathbf{g}_p.$$

POI personalization
representation



Objective and Optimization

- Attention-based aggregation:

$$\mathbf{h}_u = \pi_s \cdot \text{ReLU}(\mathbf{h}_s) + \pi_n \cdot \text{ReLU}(\mathbf{h}_n) + \pi_a \cdot \text{ReLU}(\mathbf{h}_a)$$

$$\pi_{x \in \{s, n, a\}} = \frac{\exp(\mathbf{w}^T \text{ReLU}(\mathbf{h}_x))}{\sum_{x' \in \{s, n, a\}} \exp(\mathbf{w}^T \text{ReLU}(\mathbf{h}_{x'}))}$$

$$s_{u,p} = [\mathbf{h}_u || \mathbf{h}_g] \cdot [\mathbf{r}_p || \mathbf{g}_p] = \mathbf{h}_u^T \mathbf{r}_p + \mathbf{h}_g^T \mathbf{g}_p.$$

- L2 Regularization and Loss Function (Point-wise and Pair-wise)

$$L = L_{\text{rank}}(\mathcal{D}, \mathcal{D}') + cL_{\text{reg}}$$

$$L_{\text{rank-po}} = - \sum_{\mathcal{D}, \mathcal{D}'} (y \log(\sigma(s_{u,p})) + (1 - y) \log(1 - \sigma(s_{u,p}))).$$

$$L_{\text{rank-pa}} = \sum_{\mathcal{D}, \mathcal{D}'} -\Delta_{u,p,p'} + \log(1 + \exp(\Delta_{u,p,p'})). \quad \Delta_{u,p,p'} = s_{u,p} - s_{u,p'}.$$

Experiments

DATASET

- Yelp Challenge Round 13
- Subsets of Toronto and Phoenix

Table 2: Statistics of the datasets for evaluation.³

Dataset	#.User	#.POI	#.Reviews	#.U-Cxn	%.Reviews	%.U-Cxn
Toronto	9582	9102	234388	104402	2.687×10^{-3}	1.139×10^{-3}
Phoenix	11289	9633	249029	163900	2.290×10^{-3}	1.286×10^{-3}

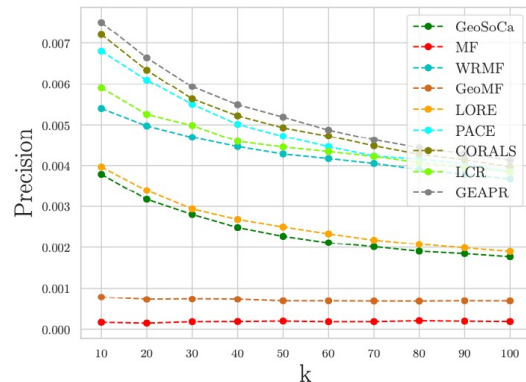
Experiments

METRIC AND BASELINE MODELS

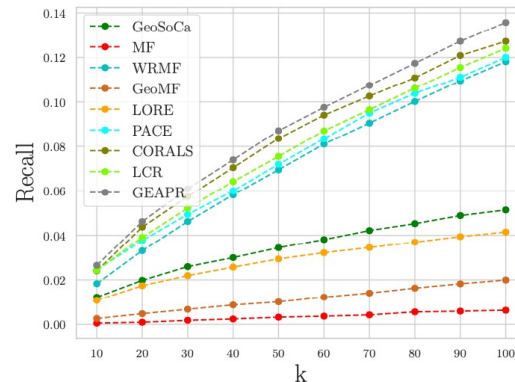
- Mean Average Precision@k
- Precision@k and Recall@k
- Eight baseline models
 - Matrix factorization based
 - Deep learning based

Experiments

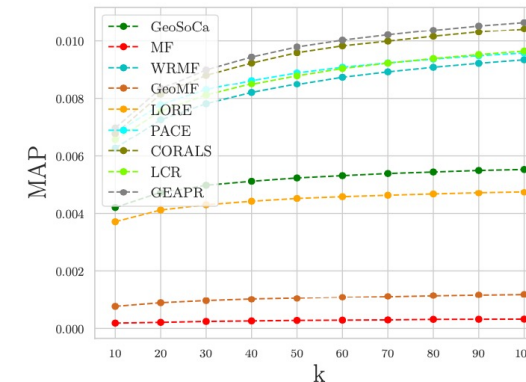
RESULTS



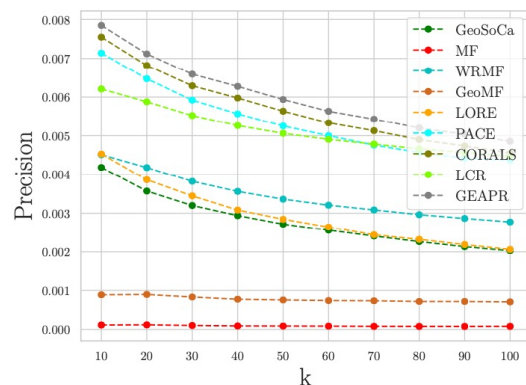
(a) Prec@k for Toronto



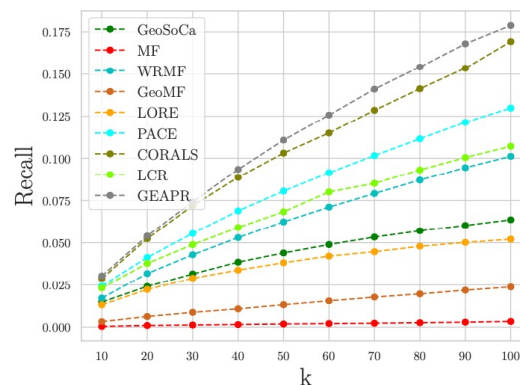
(b) Recall@k for Toronto



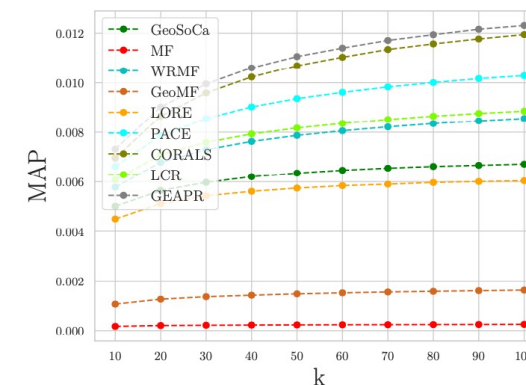
(c) MAP@k for Toronto



(d) Prec@k for Phoenix



(e) Recall@k for Phoenix

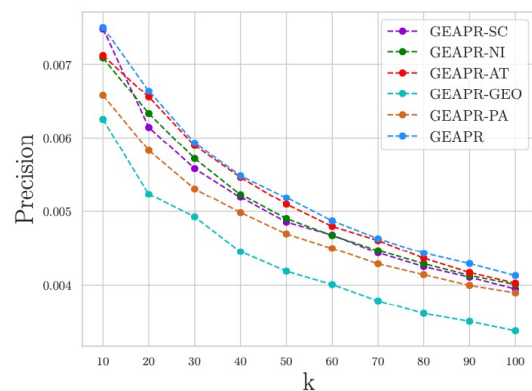


(f) MAP@k for Phoenix

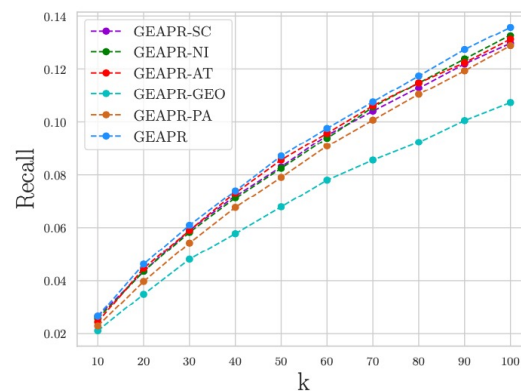
Figure 3: Performance evaluation of GEAPR compared with baseline models.

Experiments

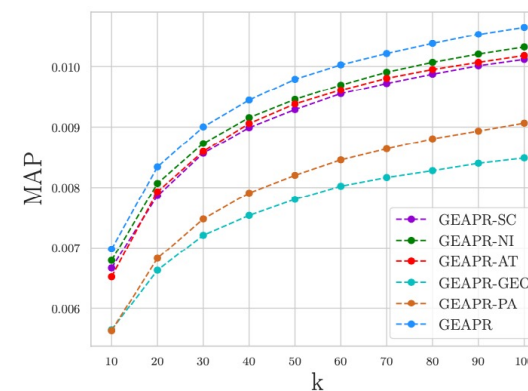
ABLATION STUDY



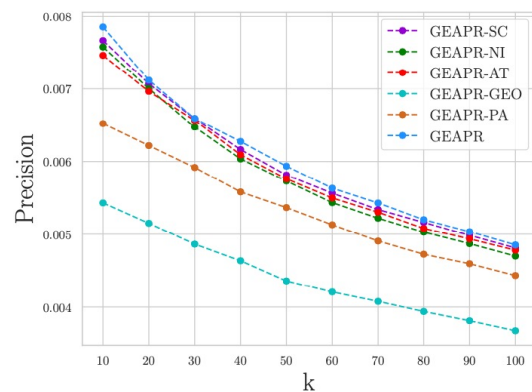
(a) Prec@k for Toronto



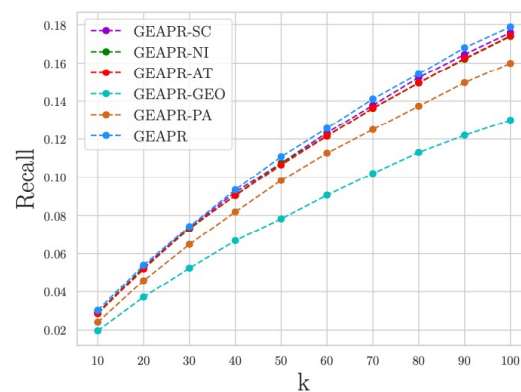
(b) Recall@k for Toronto



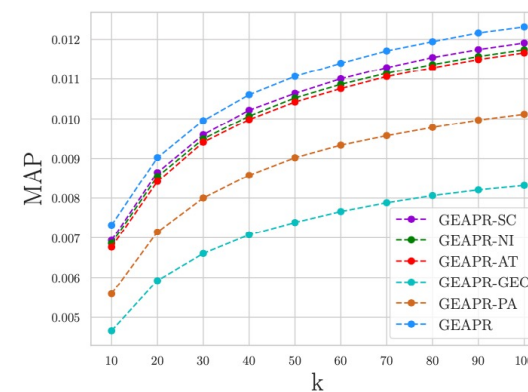
(c) MAP@k for Toronto



(d) Prec@k for Phoenix



(e) Recall@k for Phoenix



(f) MAP@k for Phoenix

Figure 4: Ablation study of GEAPR compared with its variants.

Conclusion

- We proposed GEAPR: a graph-enhanced POI recommendation algorithm that incorporates
 - User friendship network information
 - User attributes
 - Geolocation features.
- GEAPR decomposes the motivation of user check-ins into four different aspects.
- GEAPR employs the attention mechanism to generate interpretations that reveal the salient motivating factors, influential neighbors, informative attribute interactions, and heated geographical areas, etc.

Other materials

- Code: <https://github.com/zyli93/GEAPR>
- Reproducibility details: Please refer to the paper
- Paper ID: **afp1813**
- See you in the poster session!

Thanks for listening!

- We would like to thank the reviewers for the feedback.
- See you in the poster session.



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