Supplementary Material of IJCAI-18 submission - Paper ID : 327

APPENDIX

Due to the page limit, the experimental results on Foursquare-LA dataset, detailed algorithm with updating rules and the dataset statistics are not included in the current submission of Paper 327. And we list them in this supplementary material.

Detailed Algorithm

The detailed algorithm with the parameter updating rules is shown in **Algorithm** 1.

Algorithm 1 Our Proposed Methodology

Input: check-in data D
repeat
  E-Step:
  $\langle z_{u,i,j}\rangle \leftarrow \frac{\sigma_1^2 w(\chi_{u,i,j}-\hat{\chi}_{u,i,j}-\rho d_{i,j}^{-1})+\hat{z}_{u,i,j}^{-1}\sigma_2^2}{w^2\sigma_1^2+\sigma_2^2}$
  $\langle z_{u,i,j}^2\rangle \leftarrow \frac{\sigma_1^2\cdot\sigma_2^2}{\sigma_2^2+w^2\cdot\sigma_1^2}+\langle z_{u,i,j}\rangle^2$
  M-Step:
  $\sigma_1^2 \leftarrow \frac{1}{N_{u,d}}\sum_{u,d}(\langle z_{u,i,j}^2\rangle - 2\langle z_{u,i,j}\rangle\cdot\hat{z}_{u,i,j}^{-1}+\hat{z}_{u,i,j}^{-2})$
  $\sigma_2^2 \leftarrow \frac{1}{N_{u,d}}\sum_{u,d}(w^2\cdot\langle z_{u,i,j}^2\rangle + (\hat{\chi}_{u,i,j}+\rho d_{i,j}^{-1})^2 + \chi_{u,i,j}^2 + 2w\cdot\langle z_{u,i,j}\rangle\cdot(\hat{\chi}_{u,i,j}+\rho d_{i,j}^{-1}) - 2w\cdot\chi_{u,i,j}\cdot\langle z_{u,i,j}\rangle) - 2\chi_{u,i,j}\cdot(\hat{\chi}_{u,i,j}+\rho d_{i,j}^{-1})$
  $\rho \leftarrow \frac{\sum_d d_{i,j}^{-1}\cdot(\chi_{u,i,j}-w\langle z_{u,i,j}\rangle)-\sum_d d_{i,j}^{-1}\cdot\hat{\chi}_{u,i,j}}{\sum_d d_{i,j}^{-2}}$
  $w \leftarrow \frac{\sum_{u,d}\langle z_{u,i,j}\rangle\cdot(\chi_{u,i,j}-\hat{\chi}_{u,i,j}-\rho d_{i,j}^{-1})}{\sum_{u,d}\langle z_{u,i,j}^2\rangle}$
  $\gamma_1 \leftarrow \hat{\chi}_{u,i,j}+\rho\cdot d_{i,j}^{-1}+w\langle z_{u,i,j}\rangle-\chi_{u,i,j}$
  $\boldsymbol{v}_u^{U,J} \leftarrow \boldsymbol{v}_u^{U,J}+\alpha(2\boldsymbol{v}_j^{J,U}\cdot\gamma_1)$
  $\boldsymbol{v}_j^{J,U} \leftarrow \boldsymbol{v}_j^{J,U}+\alpha(2\boldsymbol{v}_u^{U,J}\cdot\gamma_1)$
  $\boldsymbol{v}_j^{J,I} \leftarrow \boldsymbol{v}_j^{J,I}+\alpha(2\boldsymbol{v}_i^{I,J}\cdot\gamma_1)$
  $\boldsymbol{v}_i^{I,J} \leftarrow \boldsymbol{v}_i^{I,J}+\alpha(2\boldsymbol{v}_j^{J,I}\cdot\gamma_1)$
  $\boldsymbol{e}_u^{U,J} \leftarrow \boldsymbol{e}_u^{U,J}+\alpha(2\boldsymbol{e}_j^{J,U}\cdot(\hat{z}_{u,i,j}-\langle z_{u,i,j}\rangle^{-1}))$
  $\boldsymbol{e}_j^{J,U} \leftarrow \boldsymbol{e}_j^{J,U}+\alpha(2\boldsymbol{e}_u^{U,J}\cdot(\hat{z}_{u,i,j}-\langle z_{u,i,j}\rangle^{-1}))$
  $\boldsymbol{e}_j^{J,I} \leftarrow \boldsymbol{e}_j^{J,I}+\alpha(2\boldsymbol{e}_i^{I,J}\cdot(\hat{z}_{u,i,j}-\langle z_{u,i,j}\rangle^{-1}))$
  $\boldsymbol{e}_i^{I,J} \leftarrow \boldsymbol{e}_i^{I,J}+\alpha(2\boldsymbol{e}_j^{J,I}\cdot(\hat{z}_{u,i,j}-\langle z_{u,i,j}\rangle^{-1}))$
until convergence
Return: $\boldsymbol{\Theta}$

Experiments

Datasets

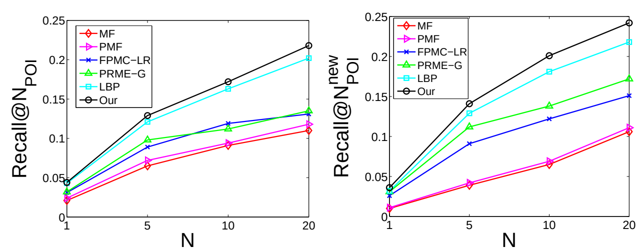
Besides the two datasets Foursquare(NYC) and Gowalla which are provided by [Bao *et al.*, 2012] and [Cheng *et al.*, 2012] respectively, We also evaluate the models on Foursquare(LA) which is provided by [Bao *et al.*, 2012]. The statistics of the three datasets are listed in Table 1. Each dataset is split into two non-overlapping subsets to evaluate the model performance (for each user, the earliest 80% of check-ins as training set, and the remaining 20% check-ins as test set).

Table 1: Dataset Statistics

	#User	#POI	#Check-in
Foursquare-LA	2470	81361	123782
Foursquare-NYC	3401	106974	178143
Gowalla	1488	92679	226116

Performance Comparison on Next POI Recommendation (Foursquare-LA)

Fig.2(a) and Fig.2(b) show the experimental results for the "exact" next POI recommendation and the "exact" next new POI recommendation on Foursquare-LA dataset. The observations are consistent with that of the other two datasets described in the current submission (See Sec.4.3).



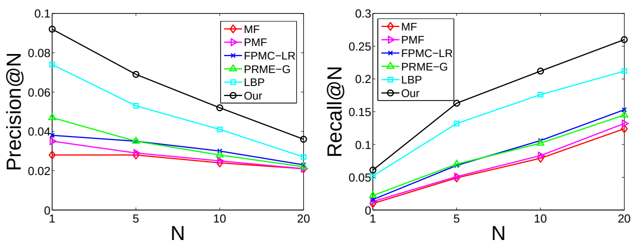
(a) LA-Next POI (b) LA-Next New POI

Figure 1: Performance Comparison on Next POI Recommendation

Performance Comparison on γ-hour Next POI Recommendation (Foursquare-LA, $\gamma = 6$)

To make a fair comparison with the existing works, we further evaluate the performance of next POI recommendation by considering consecutive next check-ins within γ hours as the next location set (γ is set to 6 following [Cheng *et al.*, 2013] and [Feng *et al.*, 2015]).

Fig.2 depicts the comparison results on Foursquare-LA dataset when considering the next POI as a set of locations. Again, similar observations to that in paper for the other two datasets can be obtained. It's obvious to see that our proposed model also consistently outperforms other baselines.



(a) LA-Precision (b) LA-Recall

Figure 2: Performance Comparison on γ-hour Next POI Recommendation($\gamma = 6$)

Performance Comparison on Transition Interval(Foursquare-LA)

Fig.3 shows the performance comparison on transition interval predictions. The results show that the proposed model always achieves the highest precision over baselines, which proves that our model is capable of providing effective POI recommendations to users as well as predicting how soon it will happen. We also compute MAPE between the predicted transition intervals and the ground truth of the test set (See Table 2). Lower values indicate more accurate predictions. It is evident that the proposed model outperforms the baselines by a significant margin. Fig.4 shows the performance comparison by relaxing the threshold T, and our method outperforms all the baselines again. Again, the observations are consistent with that in our submission.

Table 2 tabulates the MAPE between the predicted transition intervals and the ground truth of the test set. Our proposed model achieves more accurate predictions than other baselines on Foursquare-LA dataset.

Table 2: MAPE for our model and baselines on Foursquare-LA

	MF	PMF	FPMC	Our
Foursquare-LA	13.79	11.45	5.68	1.75
Foursquare-NYC	14.87	12.64	6.72	1.84
Gowalla	16.95	14.12	7.89	2.15

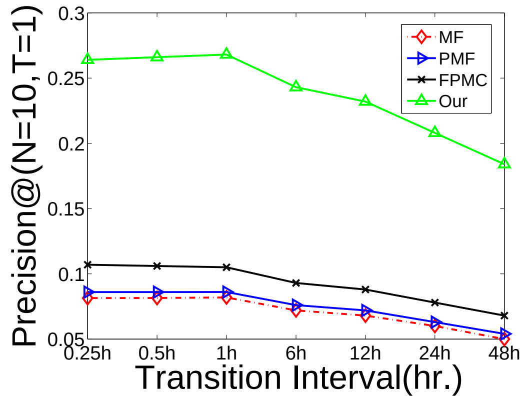


Figure 3: Performance Comparison for Transition Interval Prediction (Foursquare-LA)

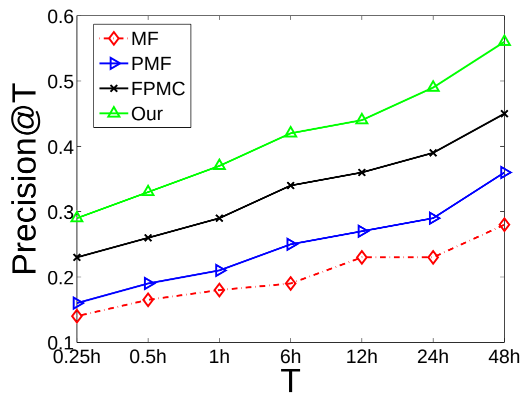


Figure 4: Transition interval prediction v.s. T (Foursquare-LA)

Detailed Performance Comparison on Specific Time Period for Next POI Recommendation

In this section, we report the detailed performance comparison under different settings of time period from different future time. For example, setting with $TP = [0.5, 1]$ denotes that we consider next check-ins after 0.5 to 1 hour from now as the next location set. In contrast to MF and PFM, FPMC-LR, PRME-G and LBP are more competitive baselines. To present a more clear comparison, we only report the performance comparison on recall for the three datasets. The detailed performance comparison are tabulated in Table 3- Table 8.

Please note that, in general, with the setting of time interval increasing, the number of check-in within the time interval increases which lead the upper bound of recall@N to decrease. Again, our proposed method consistently outperforms the competitive baselines by a large margin for all three datasets.

Table 3: Performance Comparison for Next POI Recommendation, $TP = [0.5, 1]$

Metrics	Foursquare-LA				Foursquare-NYC				Gowalla			
	F-LR	P-G	LBP	Our	F-LR	P-G	LBP	Our	F-LR	P-G	LBP	Our
top1	0.030	0.027	0.045	**0.059**	0.042	0.043	0.062	**0.075**	0.011	0.011	0.013	**0.019**
Improve	96.7%	119%	31.1%		78.6%	74.4%	21.0%		72.7%	72.7%	46.2%	
top5	0.099	0.098	0.197	**0.255**	0.143	0.152	0.187	**0.233**	0.146	0.164	0.179	**0.269**
Improve	158%	160%	29.4%		62.9%	53.3%	24.6%		84.2%	64.0%	50.3%	
top10	0.142	0.145	0.265	**0.327**	0.181	0.178	0.235	**0.304**	0.223	0.237	0.276	**0.429**
Improve	130%	126%	23.4%		68.0%	70.8%	29.4%		92.4%	81.0%	55.4%	
top20	0.201	0.226	0.316	**0.399**	0.205	0.209	0.306	**0.383**	0.304	0.318	0.368	**0.554**
Improve	98.5%	76.5%	26.3%		86.8%	83.3%	25.2%		82.2%	74.2%	50.5%	

Table 4: Performance Comparison for Next POI Recommendation, $TP = [1, 2]$

Metrics	Foursquare-LA				Foursquare-NYC				Gowalla			
	F-LR	P-G	LBP	Our	F-LR	P-G	LBP	Our	F-LR	P-G	LBP	Our
top1	0.021	0.022	0.042	**0.051**	0.027	0.026	0.037	**0.045**	0.009	0.010	0.012	**0.017**
Improve	143%	132%	21.4%		66.7%	73.1%	21.6%		88.9%	70.0%	41.7%	
top5	0.085	0.091	0.158	**0.198**	0.126	0.130	0.168	**0.207**	0.083	0.092	0.104	**0.157**
Improve	133%	118%	25.3%		64.3%	59.2%	23.2%		89.2%	70.7%	51.0%	
top10	0.133	0.141	0.246	**0.312**	0.167	0.171	0.243	**0.299**	0.161	0.159	0.203	**0.301**
Improve	135%	121%	26.8%		79.0%	74.9%	23.0%		87.0%	89.3%	48.3%	
top20	0.202	0.216	0.298	**0.383**	0.219	0.225	0.301	**0.387**	0.231	0.228	0.301	**0.433**
Improve	89.6%	77.3%	28.5%		76.7%	72.0%	28.6%		87.4%	89.9%	43.9%	

Table 5: Performance Comparison for Next POI Recommendation, $TP = [2, 3]$

Metrics	Foursquare-LA				Foursquare-NYC				Gowalla			
	F-LR	P-G	LBP	Our	F-LR	P-G	LBP	Our	F-LR	P-G	LBP	Our
top1	0.024	0.022	0.026	**0.034**	0.031	0.032	0.039	**0.047**	0.011	0.012	0.013	**0.018**
Improve	41.7%	54.5%	30.8%		51.6%	46.9%	20.5%		63.6%	50.0%	38.5%	
top5	0.132	0.126	0.173	**0.216**	0.138	0.141	0.179	**0.222**	0.069	0.072	0.082	**0.112**
Improve	63.6%	71.4%	24.9%		60.9%	57.4%	24.0%		62.3%	55.6%	36.6%	
top10	0.187	0.171	0.213	**0.275**	0.189	0.194	0.231	**0.293**	0.132	0.143	0.163	**0.218**
Improve	47.1%	60.8%	29.1%		55.0%	51.0%	26.8%		65.2%	52.4%	33.7%	
top20	0.234	0.216	0.265	**0.339**	0.221	0.226	0.291	**0.368**	0.193	0.192	0.243	**0.326**
Improve	44.9%	56.9%	27.9%		66.5%	62.8%	26.5%		68.9%	69.8%	34.2%	

Table 6: Performance Comparison for Next POI Recommendation, $TP = [3, 6]$

Metrics	Foursquare-LA				Foursquare-NYC				Gowalla			
	F-LR	P-G	LBP	Our	F-LR	P-G	LBP	Our	F-LR	P-G	LBP	Our
top1	0.023	0.025	0.031	**0.038**	0.015	0.014	0.018	**0.022**	0.011	0.012	0.015	**0.018**
Improve	65.2%	52.0%	22.6%		46.7%	57.1%	22.2%		63.6%	50.0%	20.0%	
top5	0.081	0.078	0.101	**0.122**	0.071	0.072	0.085	**0.105**	0.062	0.068	0.081	**0.105**
Improve	50.6%	56.4%	20.8%		47.9%	45.8%	23.5%		69.4%	54.4%	29.6%	
top10	0.122	0.119	0.142	**0.173**	0.115	0.112	0.131	**0.166**	0.116	0.124	0.148	**0.191**
Improve	41.8%	45.4%	21.8%		44.3%	48.2%	26.7%		64.7%	54.0%	29.1%	
top20	0.168	0.171	0.200	**0.241**	0.143	0.141	0.173	**0.212**	0.169	0.176	0.224	**0.285**
Improve	43.5%	40.9%	20.5%		48.3%	50.4%	22.5%		68.6%	61.9%	27.2%	

Table 7: Performance Comparison for Next POI Recommendation, $TP = [6, 12]$

Metrics	Foursquare-LA				Foursquare-NYC				Gowalla			
	F-LR	P-G	LBP	Our	F-LR	P-G	LBP	Our	F-LR	P-G	LBP	Our
top1	0.021	0.025	0.027	**0.033**	0.018	0.017	0.021	**0.026**	0.010	0.011	0.013	**0.016**
Improve	57.1%	32.0%	22.2%		44.4%	52.9%	23.8%		60.0%	45.5%	23.1%	
top5	0.086	0.078	0.113	**0.142**	0.073	0.072	0.087	**0.106**	0.054	0.061	0.069	**0.088**
Improve	65.1%	82.1%	25.7%		45.2%	47.2%	21.8%		63.0%	44.3%	27.5%	
top10	0.125	0.119	0.176	**0.217**	0.99	0.101	0.124	**0.151**	0.106	0.105	0.134	**0.170**
Improve	73.6%	82.4%	23.3%		52.5%	49.5%	21.8%		60.4%	61.9%	26.9%	
top20	0.165	0.171	0.221	**0.276**	0.145	0.151	0.178	**0.219**	0.164	0.162	0.216	**0.267**
Improve	67.3%	61.4%	24.9%		51.0%	45.0%	23.0%		62.8%	64.8%	23.6%	

Table 8: Performance Comparison for Next POI Recommendation, $TP = [12, 24]$

Metrics	Foursquare-LA				Foursquare-NYC				Gowalla			
	F-LR	P-G	LBP	Our	F-LR	P-G	LBP	Our	F-LR	P-G	LBP	Our
top1	0.019	0.018	0.024	**0.031**	0.017	0.018	0.021	**0.026**	0.013	0.014	0.017	**0.021**
Improve	63.2%	72.2%	29.2%		52.9%	44.4%	23.8%		61.5%	50.0%	23.5%	
top5	0.072	0.073	0.098	**0.129**	0.068	0.067	0.079	**0.100**	0.068	0.073	0.089	**0.115**
Improve	79.2%	76.7%	31.6%		47.1%	49.3%	26.6%		69.1%	57.5%	29.2%	
top10	0.107	0.099	0.146	**0.184**	0.104	0.109	0.131	**0.162**	0.113	0.118	0.151	**0.188**
Improve	72.0%	85.9%	26.0%		55.8%	48.6%	23.7%		66.4%	59.3%	24.5%	
top20	0.151	0.144	0.201	**0.244**	0.147	0.143	0.186	**0.226**	0.168	0.172	0.224	**0.278**
Improve	61.6%	69.4%	21.4%		53.7%	58.0%	21.5%		65.5%	61.6%	24.1%	