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Social Influence Attentive Neural Network for Friend-Enhanced Recommendation

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Overview

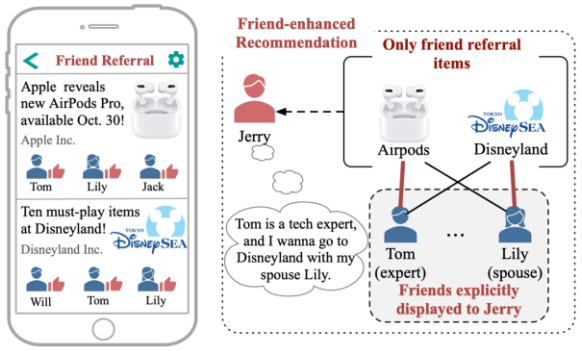

Fig. 1. A typical illustration of the friend-enhanced recommendation. The left shows the scenario that *Jerry* is recommended two articles, with friends (e.g., *Tom*) who have interacted with (shared, liked, etc.) them explicitly shown underneath. The right shows the formalization of the FER problem, where only friend referral items will be recommended and friends who interacted with the item are explicitly displayed to user.

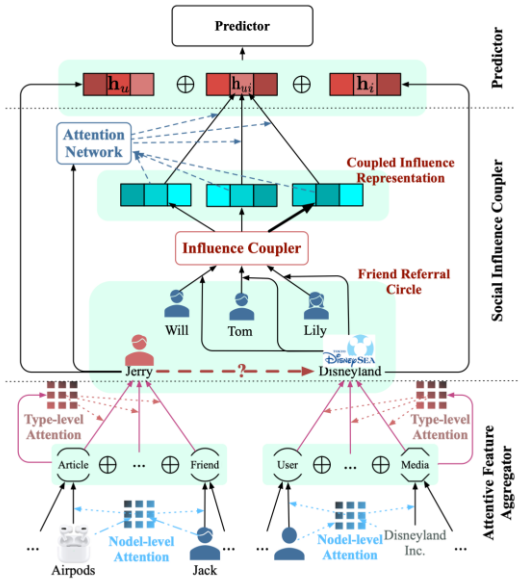

Fig. 2. The overall architecture of SIAN. The attentive feature aggregator hierarchically aggregates heterogeneous neighbour features with node- and type-level attention, and outputs the representations of users and items (i.e., $\mathbf{h}_u$ and $\mathbf{h}_i$). The social influence coupler couples the influence of each influential friends and the item, to encode the explicit social influence into the representation (i.e., $\mathbf{h}_{ui}$).

Friend-Enhanced Recommendation

Social Influence Attentive Neural Network

Table 2. Results on three datasets. The best method is bolded, and the second best is underlined. * indicate the significance level of 0.01.

Dataset	Model	AUC		F1		Accuracy	
		d=32	d=64	d=32	d=64	d=32	d=64
Yelp	MLP	0.6704	0.6876	0.6001	0.6209	0.6589	0.6795
	DeepWalk	0.7693	0.7964	0.6024	0.6393	0.7001	0.7264
	node2vec	0.7903	0.8026	0.6287	0.6531	0.7102	0.7342
	metapath2vec	0.8194	0.8346	0.6309	0.6539	0.7076	0.7399
	DeepWalk+fea	0.7899	0.8067	0.6096	0.6391	0.7493	0.7629
	node2vec+fea	0.8011	0.8116	0.6634	0.6871	0.7215	0.7442
	metapath2vec+fea	0.8301	0.8427	0.6621	0.6804	0.7611	0.7856
	GCN	0.8022	0.8251	0.6779	0.6922	0.7602	0.7882
	GAT	0.8076	0.8456	0.6735	0.6945	0.7783	0.7934
	HAN	0.8218	0.8476	0.7003	0.7312	0.7893	0.8102
	TrustMF	0.8183	0.8301	0.6823	0.7093	0.7931	0.8027
	DiffNet	0.8793	0.8929	0.8724	0.8923	0.8698	0.8905
	SIAN	**0.9486***	**0.9571***	**0.8976***	**0.9128***	**0.9096***	**0.9295***
Douban	MLP	0.7689	0.7945	0.7567	0.7732	0.7641	0.7894
	DeepWalk	0.8084	0.8301	0.7995	0.8054	0.8295	0.8464
	node2vec	0.8545	0.8623	0.8304	0.8416	0.8578	0.8594
	metapath2vec	0.8709	0.8901	0.8593	0.8648	0.8609	0.8783
	DeepWalk+fea	0.8535	0.8795	0.8347	0.8578	0.8548	0.8693
	node2vec+fea	0.8994	0.9045	0.8732	0.8958	0.8896	0.8935
	metapath2vec+fea	0.9248	0.9309	0.8998	0.9134	0.8975	0.9104
	GCN	0.9032	0.9098	0.8934	0.9123	0.9032	0.9112
	GAT	0.9214	0.9385	0.8987	0.9103	0.8998	0.9145
	HAN	0.9321	0.9523	0.9096	0.9221	0.9098	0.9205
	TrustMF	0.9034	0.9342	0.8798	0.9054	0.9002	0.9145
	DiffNet	0.9509	0.9634	0.9005	0.9259	0.9024	0.9301
	SIAN	**0.9742***	**0.9873***	**0.9139***	**0.9429***	**0.9171***	**0.9457***
FWD	MLP	0.5094	0.5182	0.1883	0.1932	0.2205	0.2302
	DeepWalk	0.5587	0.5636	0.2673	0.2781	0.1997	0.2056
	node2vec	0.5632	0.5712	0.2674	0.2715	0.2699	0.2767
	metapath2vec	0.5744	0.5834	0.2651	0.2724	0.4152	0.4244
	DeepWalk+fea	0.5301	0.5433	0.2689	0.2799	0.2377	0.2495
	node2vec+fea	0.5672	0.5715	0.2691	0.2744	0.3547	0.3603
	metapath2vec+fea	0.5685	0.5871	0.2511	0.2635	0.4698	0.4935
	GCN	0.5875	0.5986	0.2607	0.2789	0.4782	0.4853
	GAT	0.5944	0.6006	0.2867	0.2912	0.4812	0.4936
	HAN	0.5913	0.6025	0.2932	0.3011	0.4807	0.4937
	TrustMF	0.6001	0.6023	0.3013	0.3154	0.5298	0.5404
	DiffNet	0.6418	0.6594	0.3228	0.3379	0.6493	0.6576
	SIAN	**0.6845***	**0.6928***	**0.3517***	**0.3651***	**0.6933***	**0.7018***

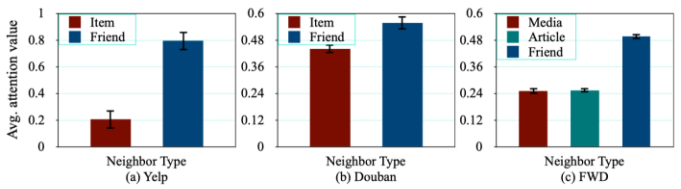

Fig. 3. Attentive aggregator analysis of *User*.

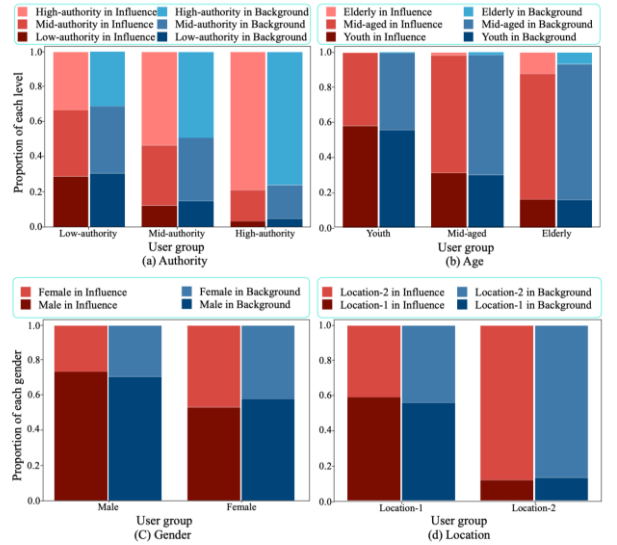

Fig. 4. Social influence analysis w.r.t user attributes. For each attribute and user group (e.g., the authority and the low-authority group in (a)), the left is the influence distribution while the right is the background distribution. In each bar, the height of each different-colored segment means the proportion of an attribute value in the influence or background distribution. Best read in color.

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Outline

- Motivation
- SIAN
- Experiments
- Conclusions

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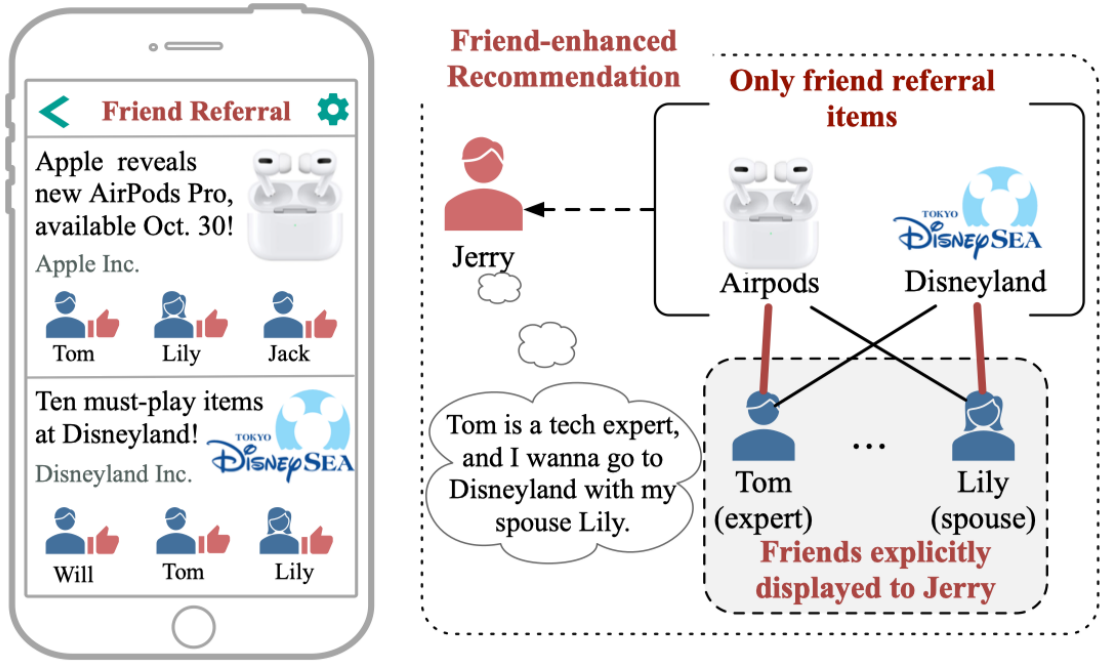
Motivation

- People are more willing to actively express their opinions and share information with friends on social platforms
- Friends become essential information sources and high-quality information filters.
- …

Images from the Internet.

Friend-enhanced Rec.



Friend-enhanced Recommendation

- Only recommends items that friends have interacted with
- All friends who have interacted with the item are explicitly displayed to the user attached to the recommended item

Friend Referral Circle (FRC)

- friend set having interacted with the item

FRC has even changed the recommendation paradigm compared to classical social recommendation

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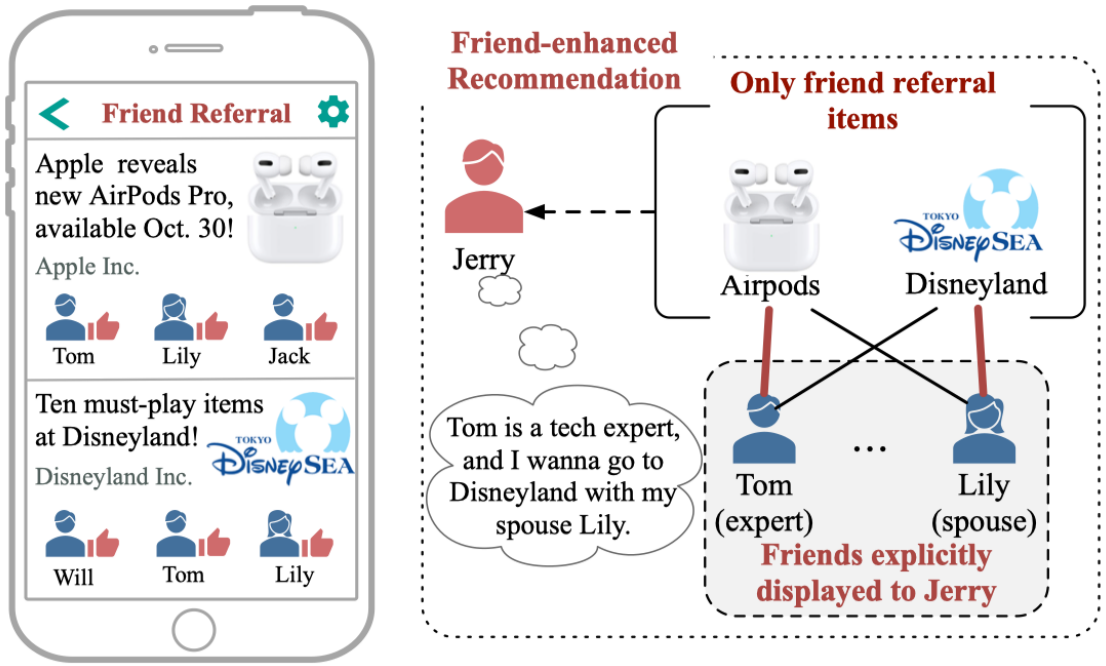
Friend-enhanced Rec.



The reasons for a user clicking an article may come from

- interests in item contents (item)
- the recommendation of an expert (item-friend combination)
- the concerns on his friends themselves (friend).

Challenges

C1: How to extract key information from multifaceted heterogeneous factors?

- *FER involves multiple heterogeneous factors such as item contents, friend referrals and their interactions*

C2: How to exploit explicit friend referral information?

- *The explicit friend referrals greatly emphasize the importance of social information in recommendation*

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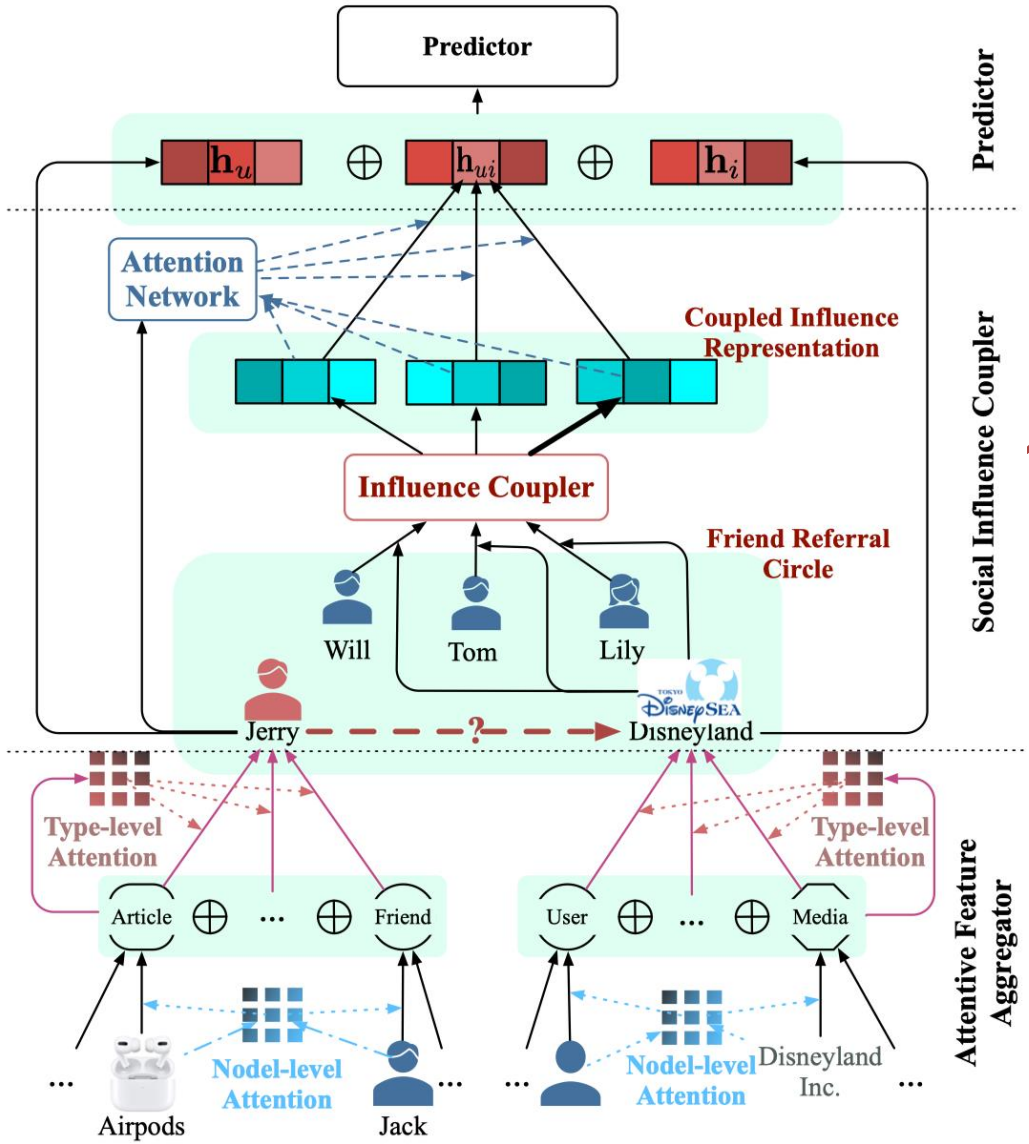
Overall Framework of SIAN

Social Influence Attentive Neural network (SIAN)



C2:
Social influence coupler to couple influence diffusing through the explicit friend referral circles

C1:
Attentive feature aggregator with both node- and type-level aggregations

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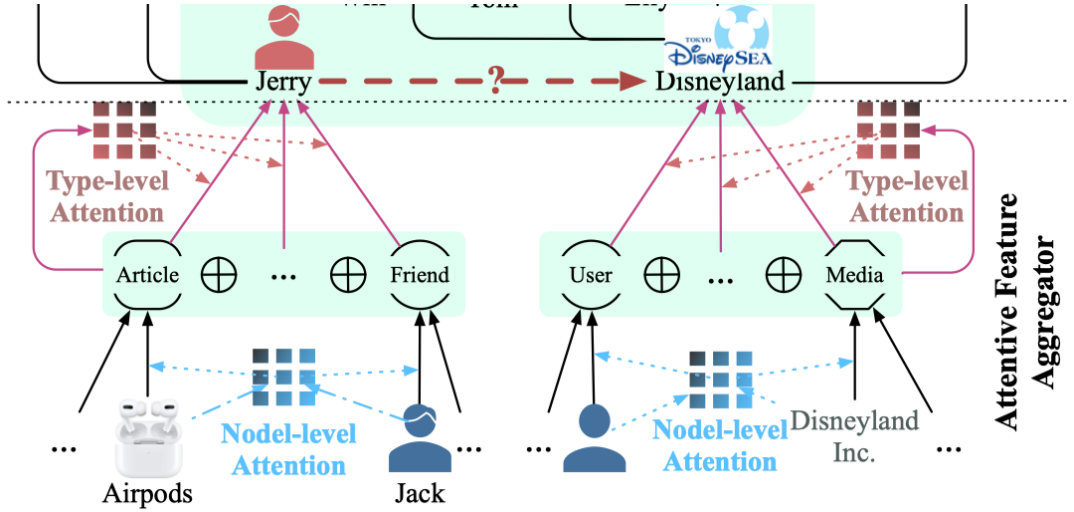
Attentive Feature Aggregator



Node-level Attentive Aggregation

$$\mathbf{p}_u^t = \mathrm{ReLU}(\mathbf{W}_p(\sum\nolimits_{k\in\mathcal{N}_u^t} \alpha_{ku}\mathbf{x}_k) + \mathbf{b}_p)$$

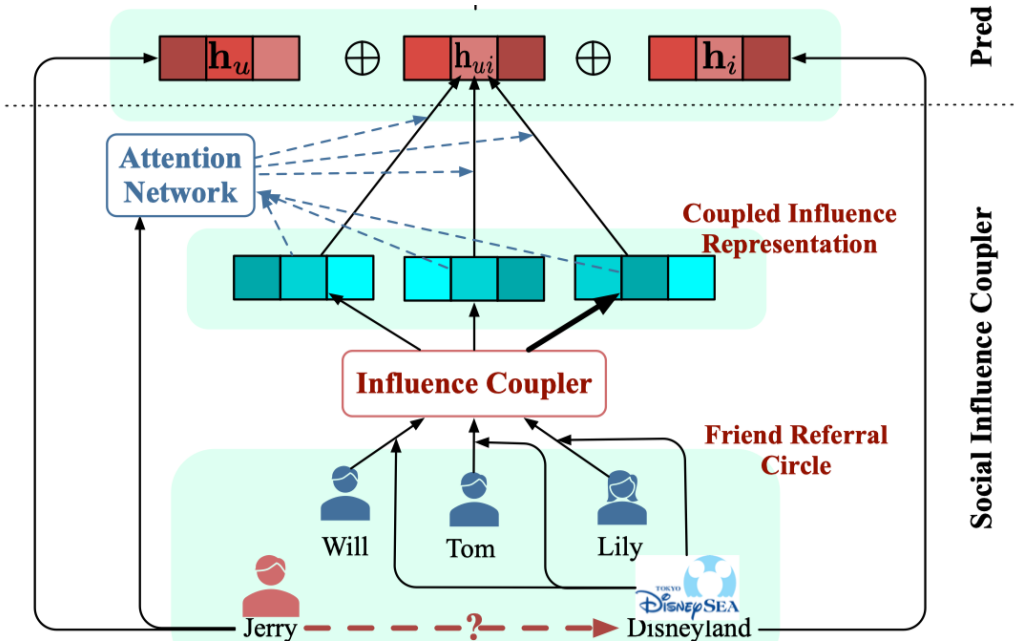
$$\alpha_{ku} = \frac{\exp(f([\mathbf{x}_k \oplus \mathbf{x}_u]))}{\sum_{k'\in\mathcal{N}_u^t}\exp(f([\mathbf{x}_{k'} \oplus \mathbf{x}_u]))}$$

Type-level Attentive Aggregation

$$\mathbf{h}_u = \mathrm{ReLU}(\mathbf{W}_h \sum\nolimits_{t\in\mathcal{T}} \beta_{tu}\mathbf{p}_u^t + \mathbf{b}_h)$$

$$\beta_{tu} = \frac{\exp(\mathbf{a}_t^\top[\mathbf{p}_u^{t_1} \oplus \mathbf{p}_u^{t_2} \oplus \cdots \oplus \mathbf{p}_u^{t_{|\mathcal{T}|}}])}{\sum_{t'\in\mathcal{T}}\exp(\mathbf{a}_{t'}^\top[\mathbf{p}_u^{t_1} \oplus \mathbf{p}_u^{t_2} \oplus \cdots \oplus \mathbf{p}_u^{t_{|\mathcal{T}|}}])}$$

Social Influence Coupler



- **Coupled Influence Representation**

$$\mathbf{c}_{\langle v,i \rangle} = \sigma(\mathbf{W}_c \phi(\mathbf{h}_v, \mathbf{h}_i) + \mathbf{b}_c)$$

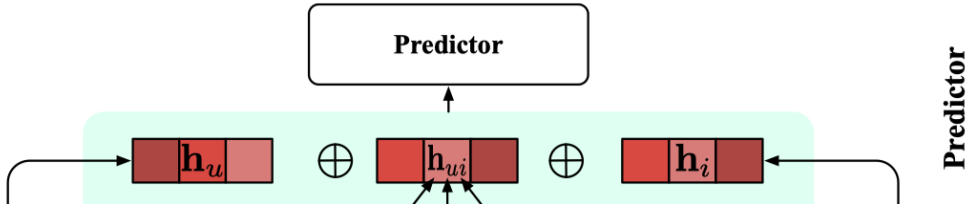
- **Attentive Influence Degree**

$$d'_{u \leftarrow \langle v,i \rangle} = \sigma(\mathbf{W}_2(\sigma(\mathbf{W}_1 \phi(\mathbf{c}_{v,i}, \mathbf{h}_u) + \mathbf{b}_1)) + b_2)$$

$$d_{u \leftarrow \langle v,i \rangle} = \frac{\exp(d'_{u \leftarrow \langle v,i \rangle})}{\sum_{v' \in \mathcal{C}_u(i)} \exp(d'_{u \leftarrow \langle v',i \rangle})}$$

$$\mathbf{h}_{ui} = \sum_{v \in \mathcal{C}_u(i)} d_{u \leftarrow \langle v,i \rangle} \mathbf{c}_{\langle v,i \rangle}$$

Behavior Prediction



$$\mathbf{h}_o = \sigma(\mathbf{W}_{o_2}(\sigma(\mathbf{W}_{o_1}([\mathbf{h}_u \oplus \mathbf{h}_{ui} \oplus \mathbf{h}_i]) + \mathbf{b}_{o_1}) + \mathbf{b}_{o_2})$$

$$\hat{y}_{ui} = \text{sigmoid}(\mathbf{w}_y^\top \mathbf{h}_o + b_y)$$

$$- \sum_{\langle u,i \rangle \in \mathcal{E}_R} (y_{ui} \log \hat{y}_{ui} + (1 - y_{ui}) \log (1 - \hat{y}_{ui})) + \lambda ||\Theta||_2^2$$

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Experiments

3 datasets

Datasets	Nodes	#Nodes	Relations	#Relations
Yelp	User (U) Item (I)	8,163 7,900	User-User User-Item	92,248 36,571
Douban	User (U) Book (B)	12,748 13,342	User-User User-Book	169,150 224,175
FWD	User (U) Article (A) Media (M)	72,371 22,218 218,887	User-User User-Article User-Media Article-Media	8,639,884 2,465,675 1,368,868 22,218

4 types of baselines

- feature/structure-based methods (MLP, DeepWalk, node2vec and metapath2vec)
- fusion of feature/structure ({DeepWalk, node2vec, metapath2vec}+fea)
- graph neural network methods (GCN, GAT and HAN)
- social recommendation methods (TrustMF and DiffNet).

Experimental Results

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	GAT	0.5944	0.6006	0.2867	0.2912	0.4812	0.4936
	HAN	0.5913	0.6025	0.2932	0.3011	0.4807	0.4937
	TrustMF	0.6001	0.6023	0.3013	0.3154	0.5298	0.5404
	DiffNet	0.6418	0.6594	0.3228	0.3379	0.6493	0.6576
	SIAN	**0.6845***	**0.6928***	**0.3517***	**0.3651***	**0.6933***	**0.7018***

- SIAN outperforms all baselines in all metrics on three datasets
- Type-level attentive aggregation is not limited by the predefined meta-paths used in previous methods
- Friend referral factor may take the dominating position in FER

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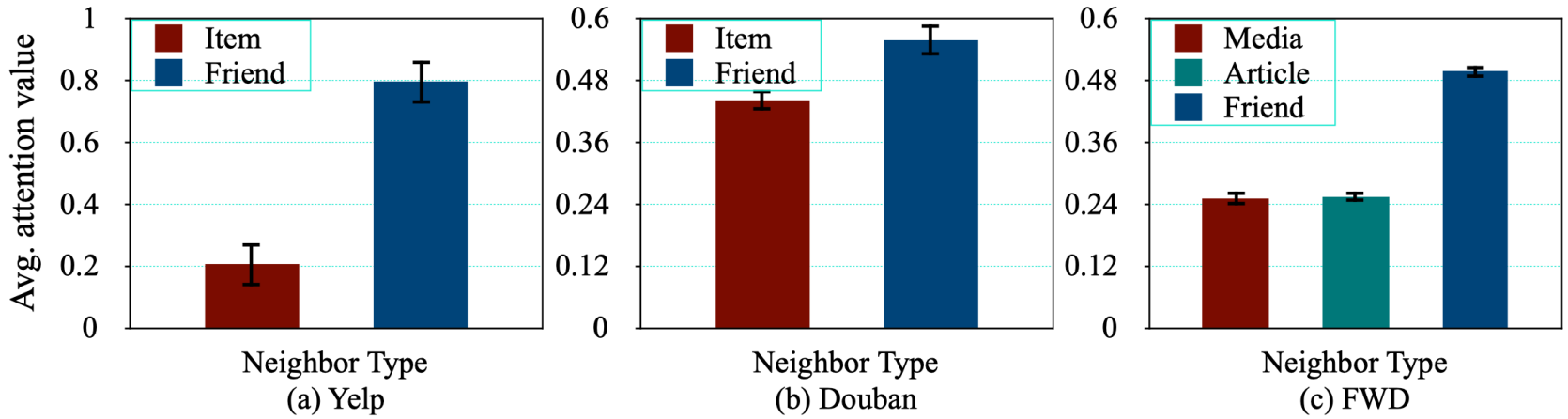
Impacts of Multifaceted Info.



- The average attention value of the Friend type is significantly larger than 0 that other types.
- It is perhaps astonishing that the model pays more attention to users' social relationships.
- This also justifies the proposed social influence coupler in SIAN, which plays an important role in extracting preferences from FRCs.

Analysis on Social Influence

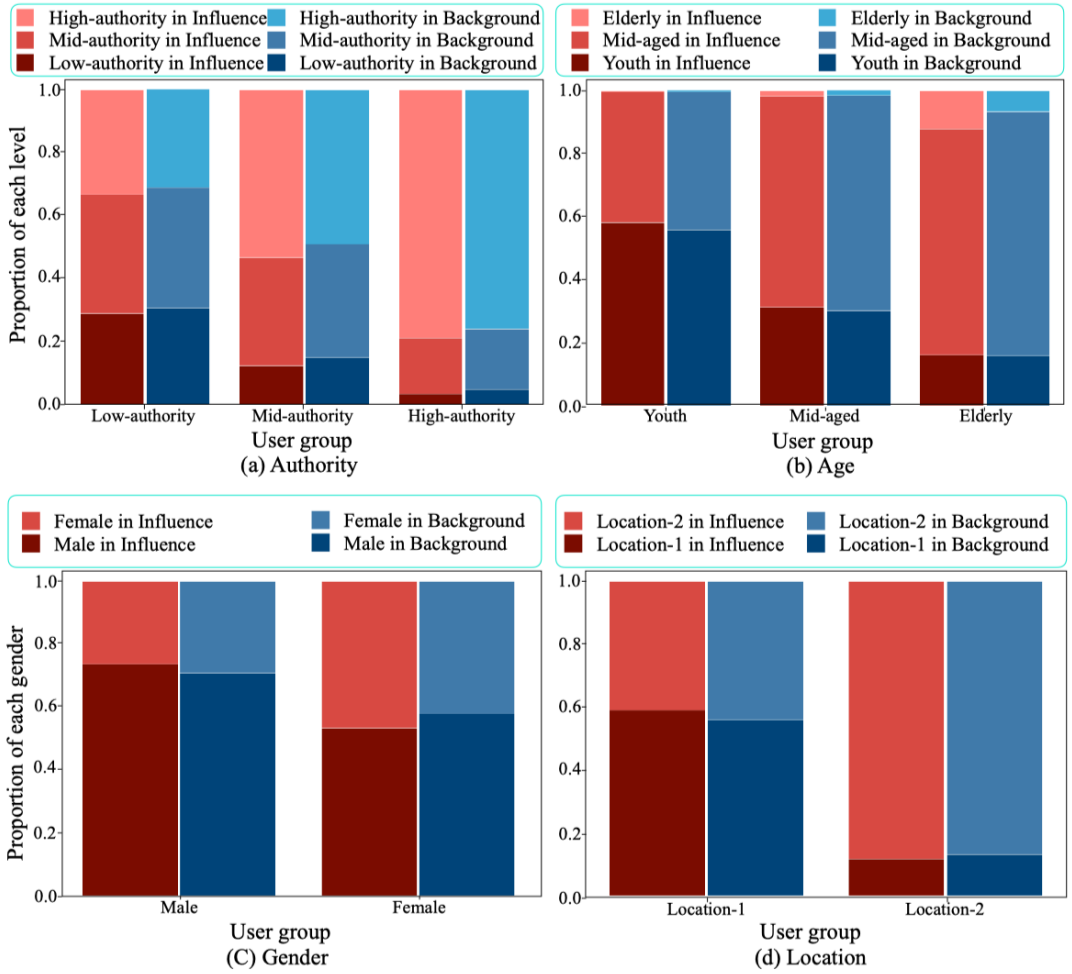


Fig. 4. Social influence analysis w.r.t user attributes. For each attribute and user group (e.g., the authority and the low-authority group in (a)), the left is the influence distribution while the right is the background distribution. In each bar, the height of each different-colored segment means the proportion of an attribute value in the influence or background distribution. Best read in color.

- User behaviors are more influenced by their friends who are more authoritative, regardless of what authority the user him/herself has
- Users are easy to be influenced by their friends which are similar to themselves (similar age/location/gender).

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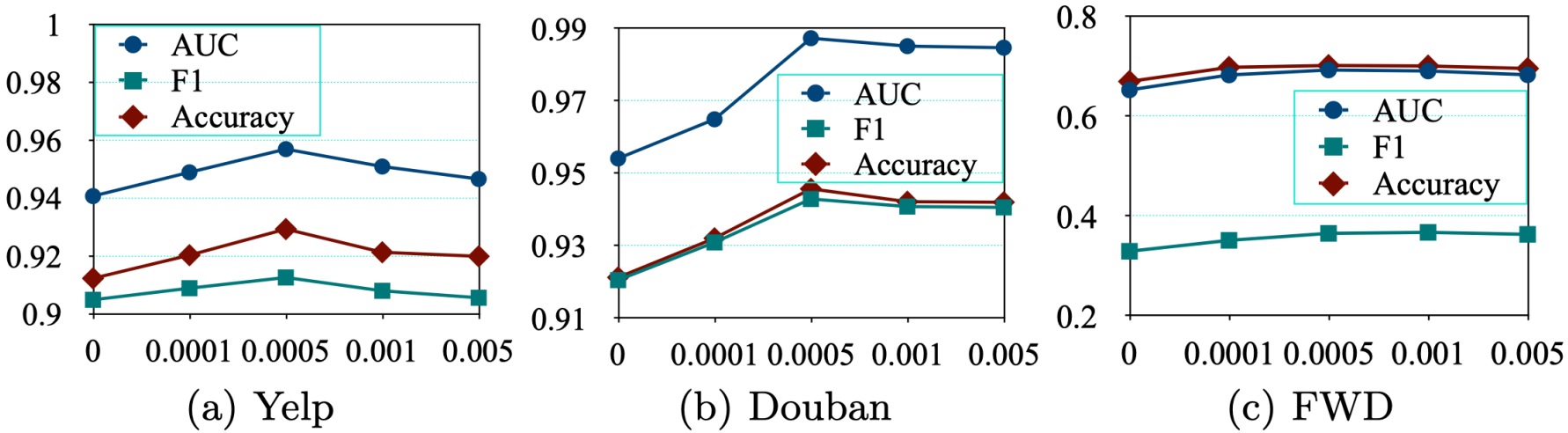
Parameters Analysis



- the optimal performance is obtained near $\lambda = 0.0005$,
- λ cannot be set too small or too large to prevent overfitting and underfitting.

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Conclusions

- A novel friend-enhanced recommendation problem and a social influence attentive neural network (SIAN).
- SIAN learns user and item representations with a two-level attentive aggregator and distills preferences from the unique friend referral circles with a social influence coupler.
- Experimental results demonstrate that SIAN significantly outperforms state-of-the-art baselines, and reveal interesting sociological patterns.

Thank you !

Q&A

More materials in
http://shichuan.org
http://www.yfang.site
https://yuanfulu.github.io

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