KGTrust: Evaluating Trustworthiness of SIoT via Knowledge Enhanced Graph Neural Networks

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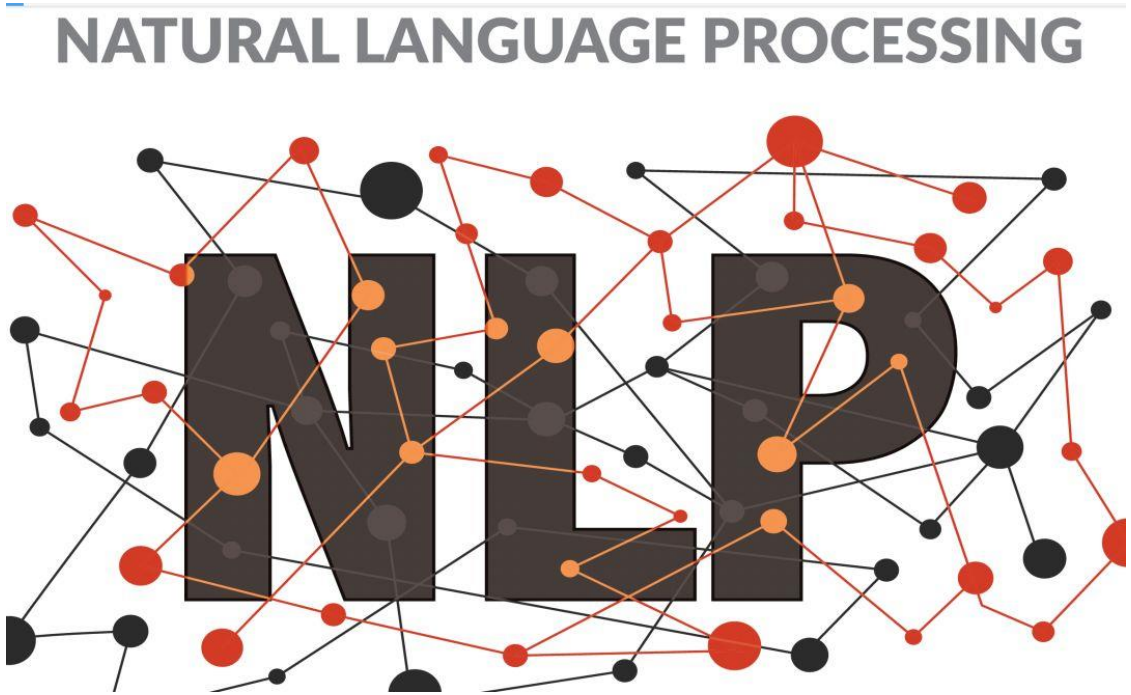
Reported by Junhao Cao



1.Introduction

2.Method

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Introduction

Graph neural networks for trust evaluation typically adopt a straightforward way such as one-hot or node2vec to comprehend node characteristics, which ignores the valuable semantic knowledge attached to nodes.

The structure of SIoT is usually complex, the properties of SIoT trust (including asymmetric, propagative, and composable nature) hard to preserve during information propagation.

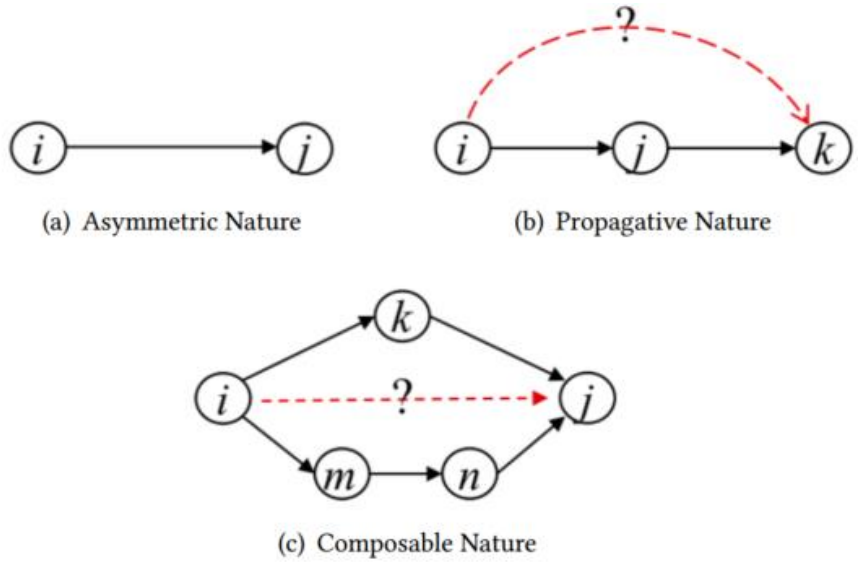


Figure 1: The illustration of properties of SIoT trust.

Asymmetric Nature

$$t_{ij} \neq t_{ji}. \quad (1)$$

Propagative Nature

$$t_{ij} \wedge t_{jk} \Rightarrow t_{ik}. \quad (2)$$

Method

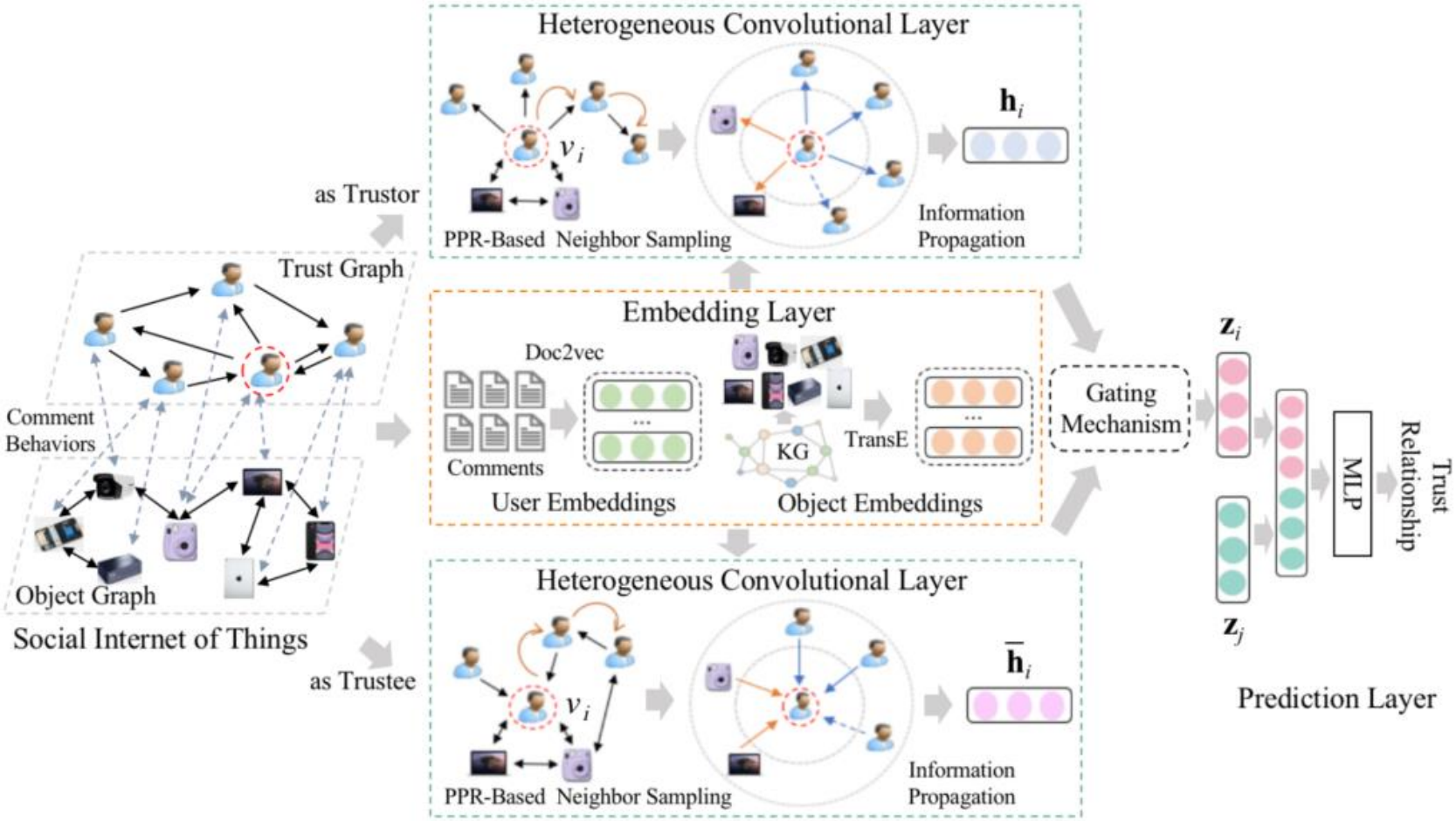
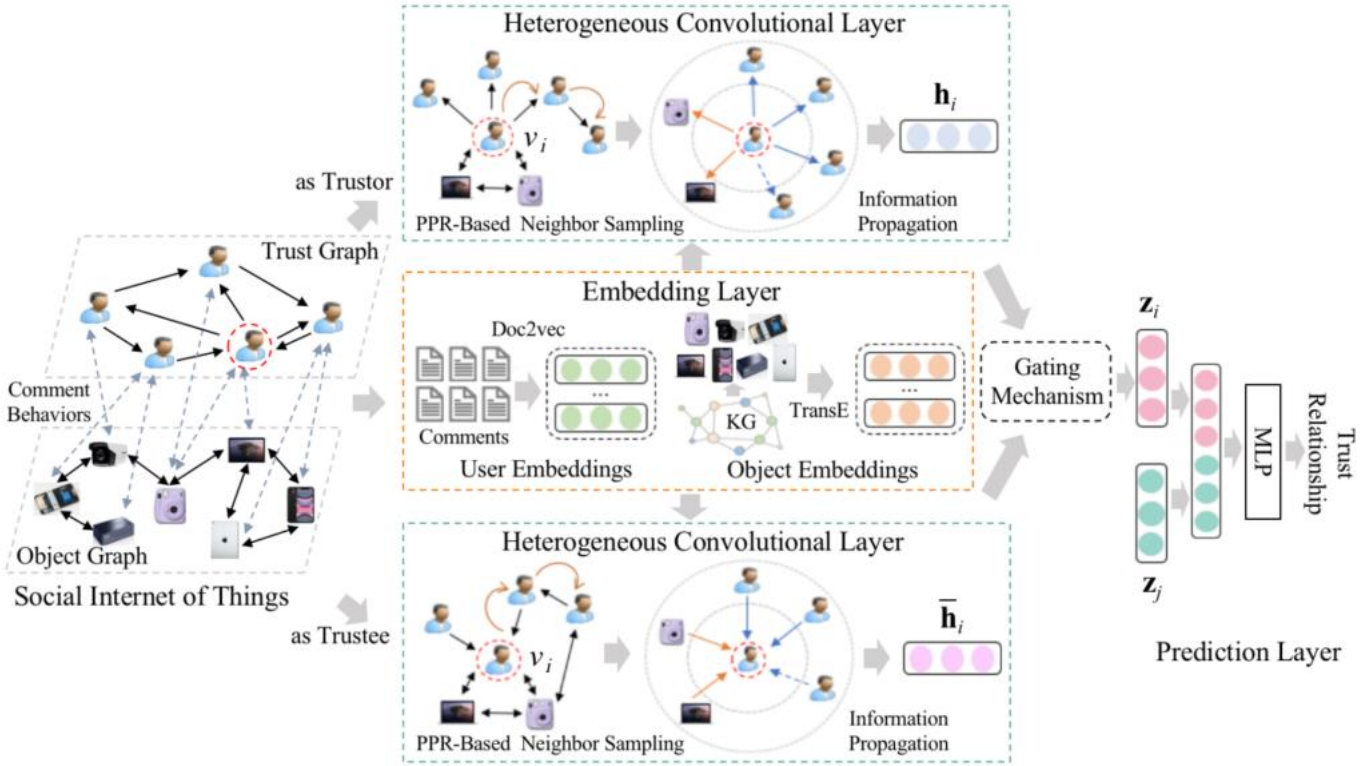


Figure 2: The architecture of KGTrust, which is constituted of three key components: 1) Embedding Layer: a comprehensive user and object modeling by integrating user comments and external knowledge triples; 2) Heterogeneous Convolutional Layer: a knowledge enhanced graph neural network to further mine and learn node latent embeddings; as well as 3) Prediction Layer: measuring the trust relationships between user pairs.

Method



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$$G = (V, E, \mathcal{A}, \mathcal{R}, \psi, \varphi),$$

$$\psi : V \rightarrow \mathcal{A}$$

$$\varphi : E \rightarrow \mathcal{R}$$

$$\mathcal{A} \in \{\text{user, object}\}$$

$$\mathcal{R} \in \{\langle \text{user, user} \rangle, \langle \text{user, object} \rangle, \langle \text{object, user} \rangle, \langle \text{object, object} \rangle\}$$

$$\begin{aligned} \mathbf{m}_i^{(l)} &= \mathrm{AGG}^{(l)}(\{\mathbf{h}_j^{(l-1)} : v_j \in \mathcal{N}(v_i)\}), \\ \mathbf{h}_i^{(l)} &= \mathrm{UPD}^{(l)}(\mathbf{h}_i^{(l-1)}, \mathbf{m}_i^{(l)}), \end{aligned} \tag{3}$$

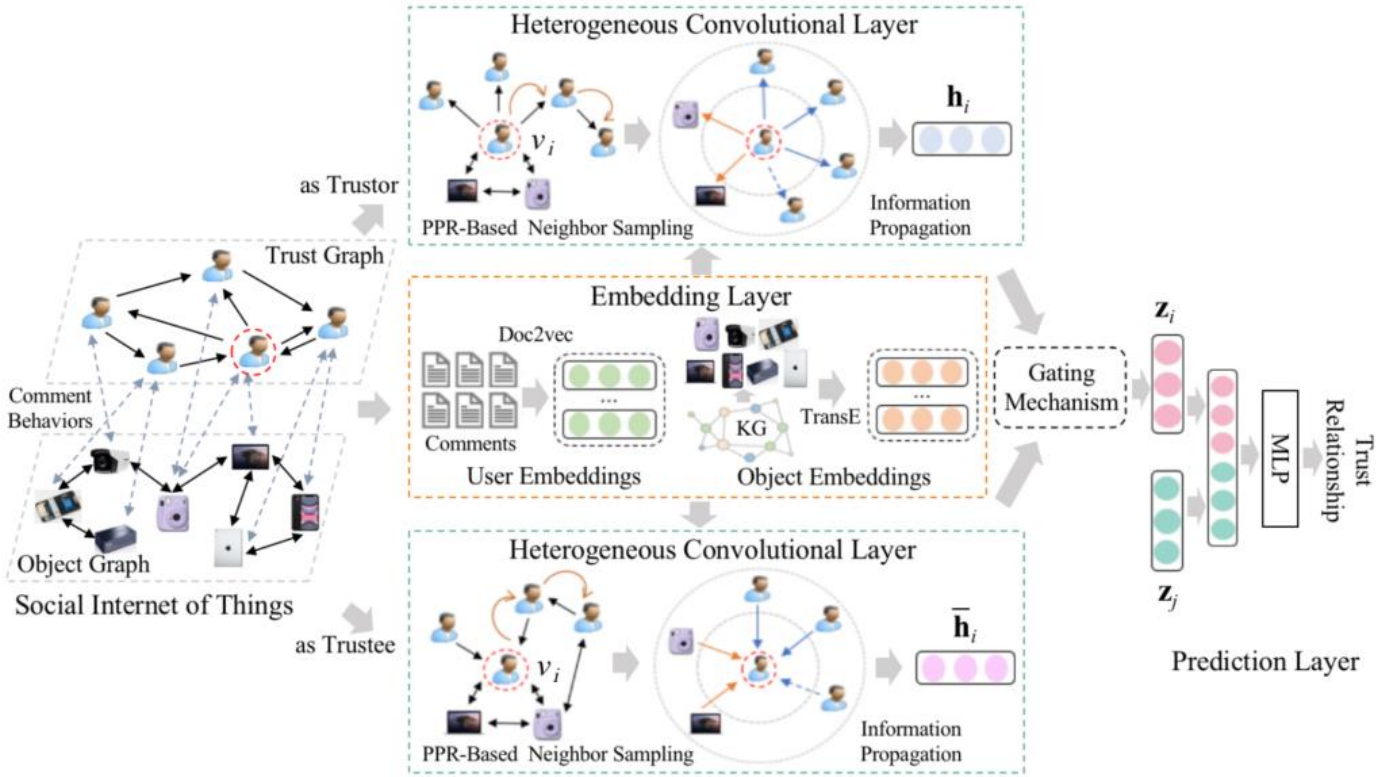
Embedding Layer

$$\mathbf{h}_i = \mathrm{Doc2vec}(d_i). \tag{4}$$

$$f(h, r, t) = -||\mathbf{h} + \mathbf{r} - \mathbf{t}||_2^2, \tag{5}$$

$$\mathbf{h}_i' = \mathbf{W}_{\psi_i} \cdot \mathbf{h}_i, \tag{6}$$

Method



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PPR-Based Neighbor Sampling

$$\mathbf{P} = (1-\lambda)\hat{\mathbf{A}}\mathbf{P} + \lambda\mathbf{I}, \tag{7}$$

$$\hat{\mathbf{A}} = \tilde{\mathbf{D}}^{-\frac{1}{2}}\tilde{\mathbf{A}}\tilde{\mathbf{D}}^{-\frac{1}{2}}$$

$$N_i = \underset{V' \subset V_U, |V'|=k}{\arg\max} \sum_{v_j \in V'} p_{ij}, \tag{8}$$

Information Propagation

$$\mathbf{h}_\psi = \sum\nolimits_{v_j} \hat{a}_{ij}\mathbf{h}'_j. \tag{9}$$

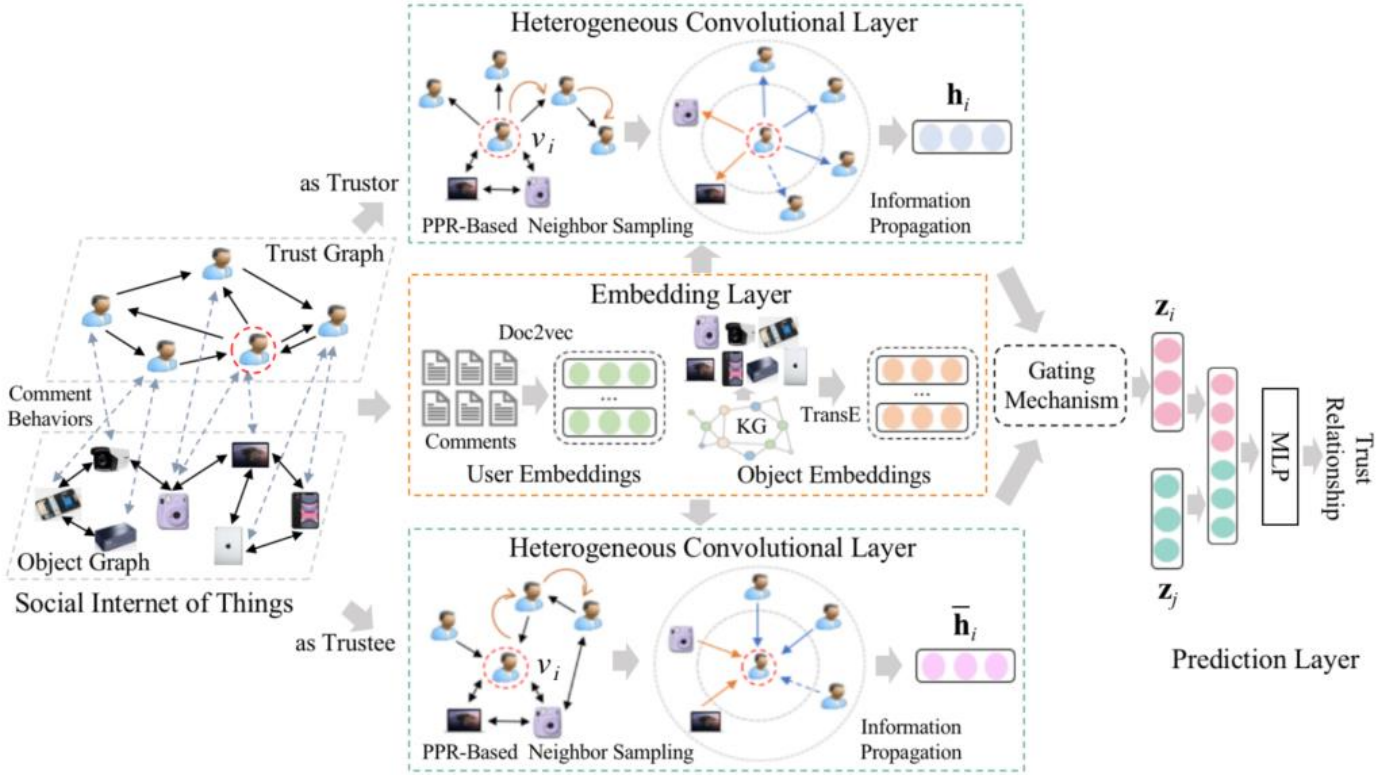
$$\alpha_\psi = \mathrm{softmax}_\psi(\sigma(\eta_\psi^T[\mathbf{h}'_i, \mathbf{h}_\psi])), \tag{10}$$

$$\beta_{ij} = \mathrm{softmax}_{v_j}(\sigma(\gamma^T \cdot \alpha_{\psi'}[\mathbf{h}'_i, \mathbf{h}'_j])), \tag{11}$$

$$\mathbf{H}^{(l)} = \sigma(\sum\nolimits_{\psi \in \mathcal{A}} \mathbf{B}_\psi \cdot \mathbf{H}_\psi^{(l-1)} \cdot \mathbf{W}_\psi^{(l-1)}), \tag{12}$$

$\mathbf{B}_\psi = (\beta_{ij})_{n\times n}$ rep resents the attention matrix.

Method



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Information Fusion

$$\mathbf{z}_i = \mathbf{g}_e \odot \mathbf{h}_i + (1 - \mathbf{g}_e) \odot \bar{\mathbf{h}}_i, \tag{13}$$

$$\mathbf{g}_e = \text{sigmoid}(\tilde{\mathbf{g}}_e), \tag{14}$$

$$\tilde{y}_{ij} = \text{softmax}(\text{MLP}(\mathbf{z}_i \,\|\, \mathbf{z}_j)), \tag{15}$$

$$\mathcal{L} = -\sum_{v_i v_j} y_{ij} \ln \tilde{y}_{ij}, \tag{16}$$

Experiment

Table 1: Statistics of the datasets.

	FilmTrust	Ciao	Epinions
#Users	1508	4409	8174
#Objects	2071	12,082	11,379
#Comment Behaviors	-	136,105	306,133
#Trust Relationships	1853	88,649	224,589
Trust Network Density	0.0008	0.0046	0.0034

"-" denotes no such information provided by the dataset.

Experiment

Table 2: Performance comparions on three SIoT datasets in terms of Accuracy (%) and F1-Score (%). (bold: best)

Datasets	Metrics	GAT	SGC	SLF	STNE	SNEA	DeepTrust	AtNE-Trust	Guardian	KGTrust
FilmTrust	Accuracy	68.29	75.61	65.55	72.87	63.91	53.05	63.11	77.74	**79.82**
	F1-Score	71.74	77.14	65.65	73.27	66.67	64.63	65.13	79.78	**80.92**
Ciao	Accuracy	64.28	69.93	72.17	71.33	68.97	50.17	68.23	72.17	**72.56**
	F1-Score	71.36	70.34	73.39	71.38	70.83	66.52	71.50	73.50	**74.30**
Epinions	Accuracy	72.05	78.62	80.83	79.51	74.63	58.38	74.35	80.82	**81.39**
	F1-Score	75.57	78.76	80.95	78.57	74.92	64.80	74.88	81.11	**81.84**

Experiment

Table 3: Performance comparions with different training ratios on three SIoT datasets. (bold: best)

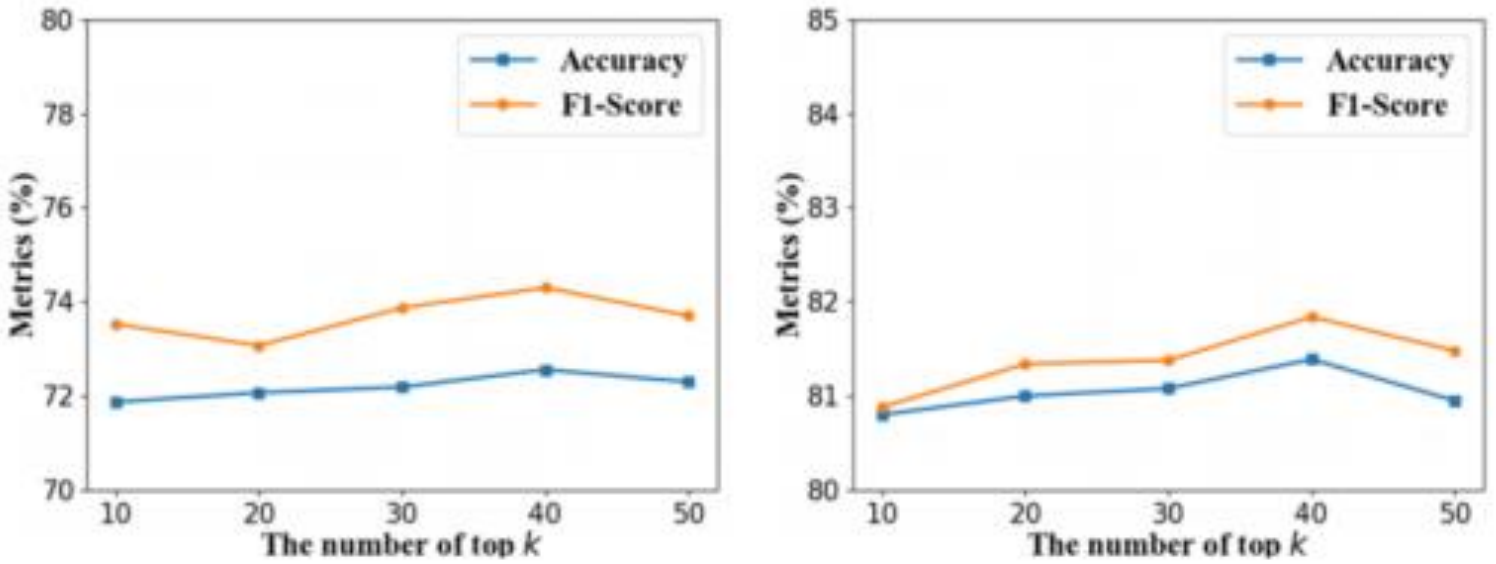
Datasets	Metrics	Training	GAT	SGC	SLF	STNE	SNEA	DeepTrust	AtNE-Trust	Guardian	KGTrust
FilmTrust	Accuracy (%)	50%	60.36	71.26	54.96	69.42	60.14	49.51	60.17	74.14	**74.94**
		60%	62.79	72.21	55.51	69.98	61.01	50.08	60.72	74.81	**76.11**
		70%	64.39	73.16	61.22	72.14	62.90	50.20	62.14	75.51	**78.16**
		80%	67.28	74.01	63.61	72.78	63.30	51.68	63.00	76.45	**79.66**
		90%	68.29	75.61	65.55	72.87	63.91	53.05	63.11	77.74	**79.82**
	F1-Score (%)	50%	62.35	71.52	56.48	69.44	62.45	60.11	60.27	75.52	**75.98**
		60%	63.51	72.40	57.37	70.17	62.68	60.38	61.69	76.52	**76.73**
		70%	66.80	73.83	62.23	72.17	64.83	62.20	63.42	78.56	**78.94**
		80%	68.34	74.40	65.00	72.33	65.12	63.41	63.88	79.08	**80.47**
		90%	71.74	77.14	65.65	73.27	66.67	64.63	65.13	79.78	**80.92**
Ciao	Accuracy (%)	50%	59.76	67.40	71.32	70.69	66.88	49.80	62.24	71.27	**71.72**
		60%	61.03	68.29	71.66	70.87	67.82	50.01	62.66	71.62	**72.11**
		70%	62.17	68.39	71.89	70.92	68.15	50.03	63.52	71.90	**72.34**
		80%	63.01	68.81	72.08	71.05	68.53	50.07	66.58	71.94	**72.36**
		90%	64.28	69.93	72.17	71.33	68.97	50.17	68.23	72.17	**72.56**
	F1-Score (%)	50%	66.47	67.53	71.87	70.83	67.68	61.30	62.76	71.84	**72.85**
		60%	68.08	68.58	72.68	70.85	68.87	61.38	63.03	72.28	**73.11**
		70%	70.61	68.78	72.88	71.07	69.45	61.77	65.37	72.67	**73.23**
		80%	70.85	69.76	73.00	71.32	70.15	63.63	69.92	73.32	**74.06**
		90%	71.36	70.34	73.39	71.38	70.83	66.52	71.50	73.50	**74.30**
Epinions	Accuracy (%)	50%	61.70	77.22	79.99	79.04	73.84	55.53	71.90	80.15	**80.59**
		60%	61.92	77.57	80.05	79.13	74.12	56.25	73.01	80.22	**80.65**
		70%	64.76	77.82	80.44	79.32	74.36	56.71	73.40	80.31	**80.96**
		80%	70.79	78.17	80.60	79.45	74.59	58.23	73.59	80.55	**81.14**
		90%	72.05	78.62	80.83	79.51	74.63	58.38	74.35	80.82	**81.39**
	F1-Score (%)	50%	65.60	77.63	80.08	78.18	73.28	61.27	72.87	80.41	**81.05**
		60%	66.64	77.92	80.15	78.22	73.73	63.93	73.74	80.51	**81.11**
		70%	72.67	78.05	80.46	78.46	74.19	64.10	73.80	80.58	**81.46**
		80%	72.84	78.56	80.63	78.50	74.61	64.36	74.29	80.86	**81.70**
		90%	75.57	78.76	80.95	78.57	74.92	64.80	74.88	81.11	**81.84**

Experiment

Table 4: Comparisons of our KGTrust and its five variants on three SIOT datasets in terms of Accuracy (%) and F1-Score (%). For FilmTrust, we do not introduce structured triples as no object descriptions provided, while such information is provided by Ciao and Epinions.

Datasets	FilmTrust		Ciao		Epinions	
	Accuracy	F1-Score	Accuracy	F1-Score	Accuracy	F1-Score
KGTrust	**79.82**	**80.92**	**72.56**	**74.30**	**81.39**	**81.84**
- w/o Triples	-	-	71.10	72.48	80.51	80.86
- w/o PPR	78.29	78.74	72.12	72.88	80.71	81.19
- w/o Trustee	78.13	79.18	59.07	64.60	70.73	72.10
- w/o Trustor	77.22	78.37	60.58	65.67	70.62	72.01
KGTrust (Con)	76.76	77.51	59.28	64.74	70.75	73.10

Experiment



(a) Ciao (b) Epinions

Figure 3: The performance with different numbers of top k for PPR-based neighbor sampling.

Experiment

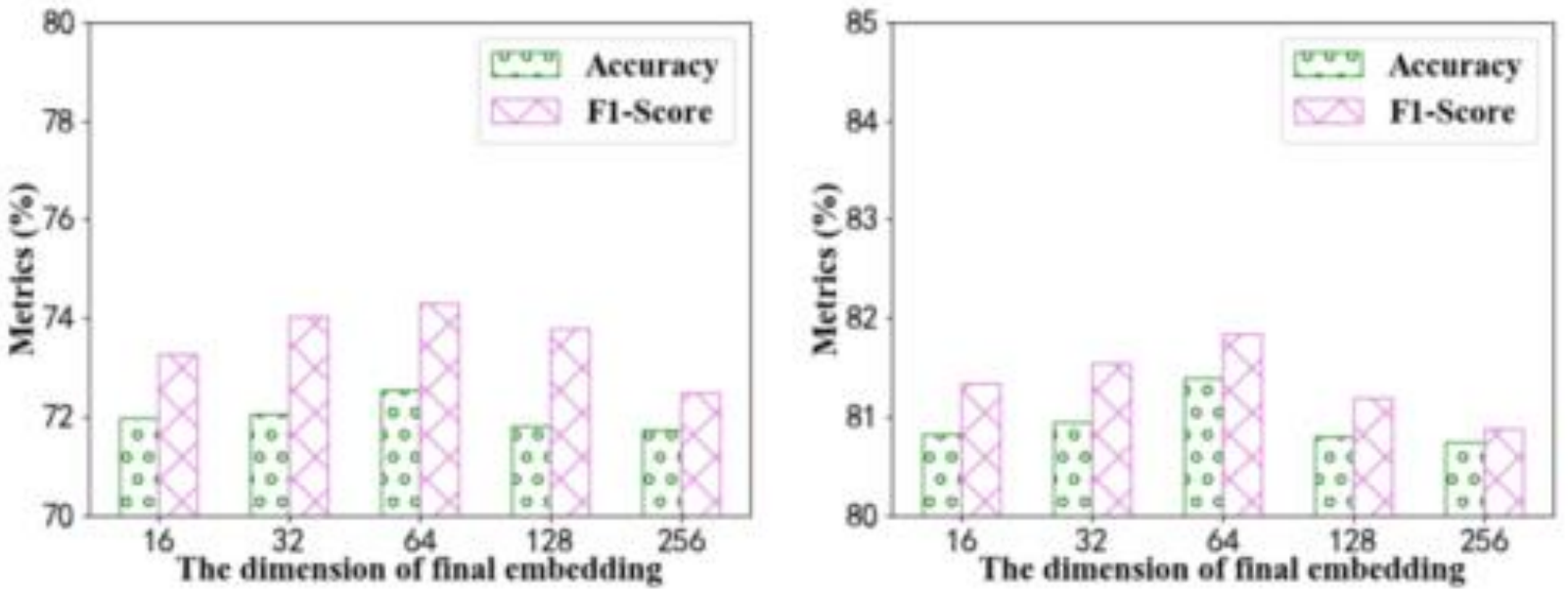


Figure 4: The performance with different dimensions of final embedding.

Thank you!