MATRI: A Multi-Aspect and Transitive Trust Inference Model

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Joint work with

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Roadmap

- Background and Motivations
- Modeling Multi-Aspect
- Incorporating Trust Bias
- Incorporating Trust Transitivity
- Empirical Evaluations
- Conclusions

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Trust

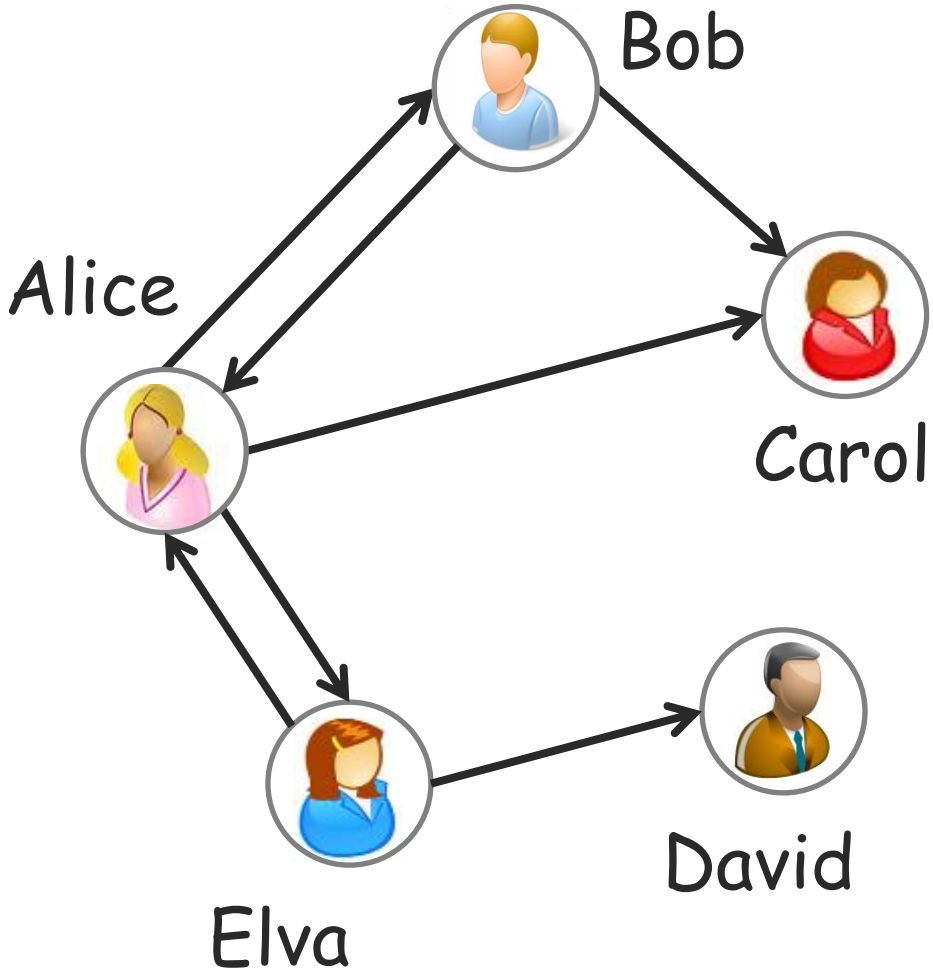
Epinions

Unbiased Reviews by Real People

ebay™ Browse by category

"Trust is the subjective probability by which an individual (trustor), expects that another individual (trustee) will perform well on a given action."

Trust Inference



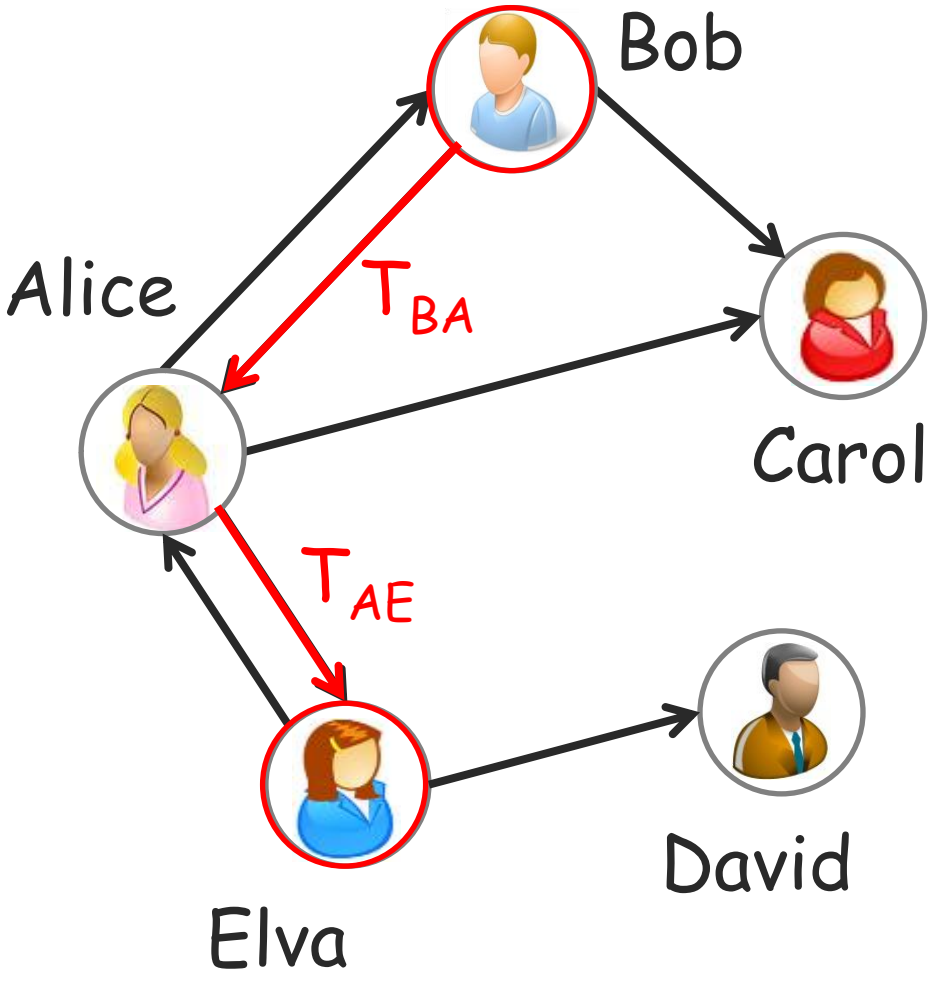
: Trust

How to infer the unknown trust relationships?

E.g., to what extent should Bob trust Elva?

Trust Properties:
Transitivity, Multi-Aspect, Trust Bias

P1: Trust Transitivity

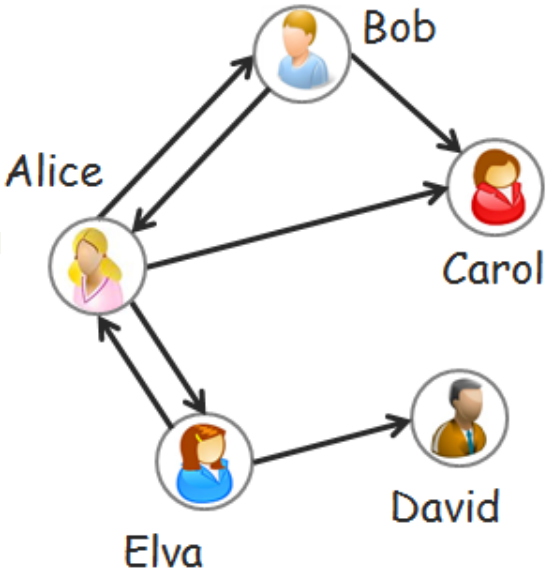


Bob -> Elva (T_{BE})?

Trust transitivity (or trust propagation):

$T_{BE} = T_{BA} * T_{AE}$

P2: Multi-Aspect



Trustor Preferences

Delivering time	Product price	
1	1	Alice
1	0	Bob
1	0	Carol
0	1	David
0	1	Elva

trustors

factors

Trustee Capabilities

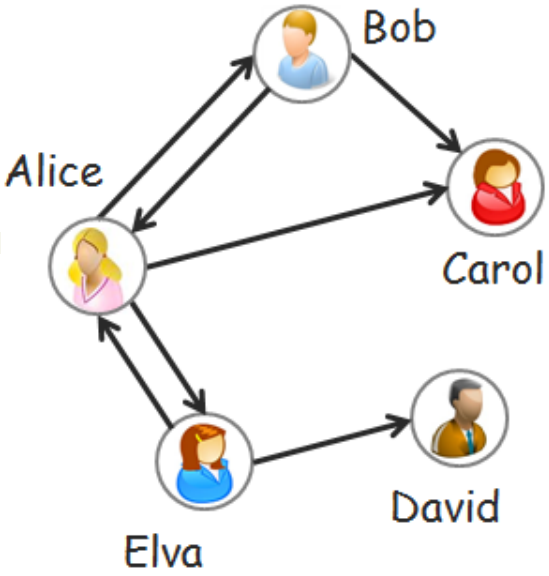
Delivering time	Product price	
0.5	0.5	Alice
1	0	Bob
1	0	Carol
0	1	David
0	1	Elva

trustees

factors

Bob -> Elva (T_{BE})?

P3: Trust Bias



Overall avg. rating: 0.5

	Alice	Bob	Carol	David	Elva
Trustor bias:	0.2	0.4	-0.3	-0.1	0.1
Trustee bias:	-0.1	0.2	0.1	0.2	-0.2

Bob -> Elva (T_{BE})? $T_{BE} = 0.4 - 0.2 + 0.5 = 0.7$

This Paper

- Q1: how to characterize multi-aspect trust directly from trust ratings?
- Q2: how to incorporate trust bias?
- Q3: how to incorporate trust transitivity?

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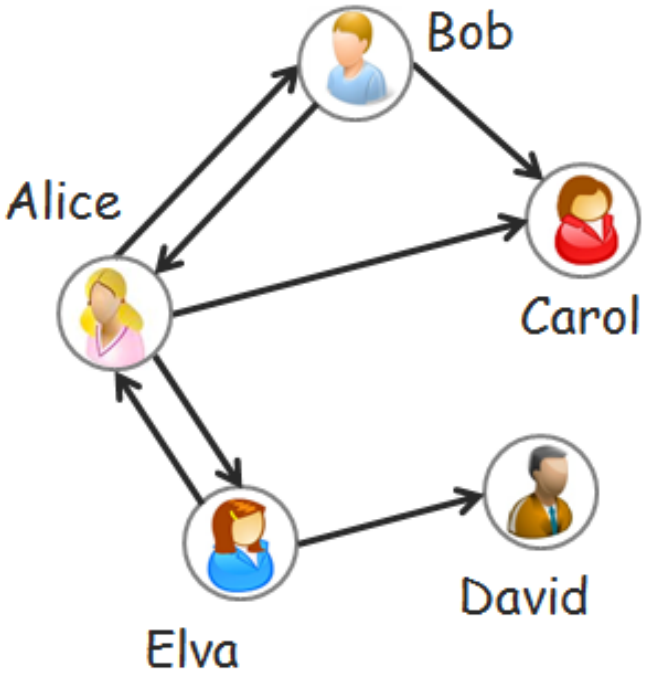
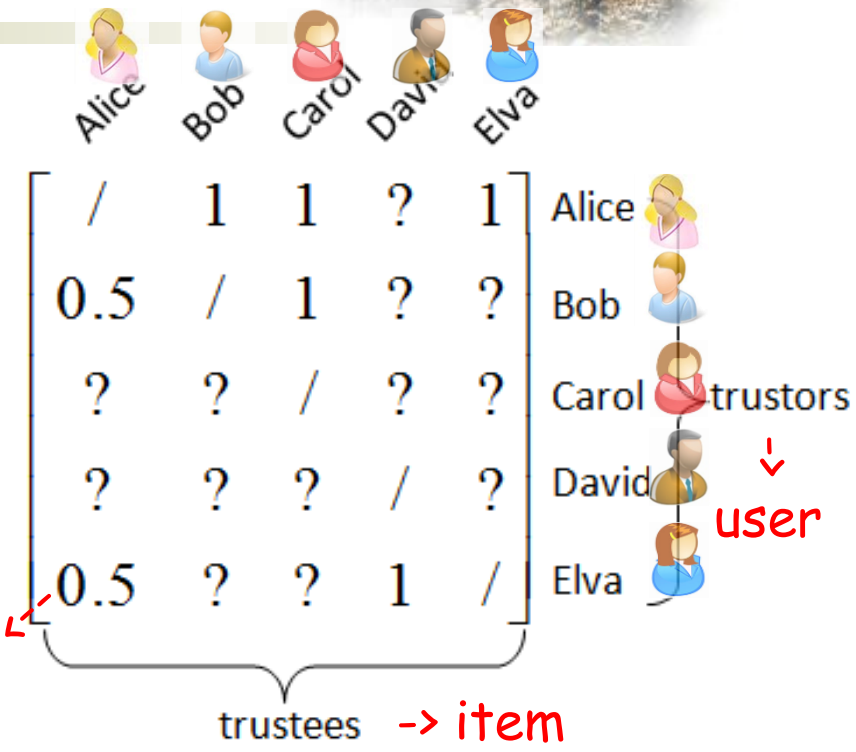
Modeling Multi-Aspect





$$\min_{\mathbf{F},\mathbf{G}} \sum_{(i,j)\in\mathcal{K}} (\mathbf{T}(i,j) - \mathbf{F}(i,:)\mathbf{G}(j,:)')^2 + \lambda||\mathbf{F}||_{fro}^2 + \lambda||\mathbf{G}||_{fro}^2$$

Modeling Multi-Aspect

$$\min_{\mathbf{F},\mathbf{G}} \sum_{(i,j)\in\mathcal{K}} (\mathbf{T}(i,j) - \mathbf{F}(i,:)\mathbf{G}(j,:)')^2 + \lambda||\mathbf{F}||_{fro}^2 + \lambda||\mathbf{G}||_{fro}^2$$

$\mathbf{T}$ =

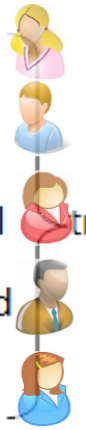
	Alice	Bob	Carol	David	Elva
Alice	/	1	1	?	1
Bob	0.5	/	1	?	?
Carol	?	?	/	?	?
David	?	?	?	/	?
Elva	0.5	?	?	1	/

trustors; trustees

$\mathbf{F}$ =

	Delivering time	Product price
Alice	1	1
Bob	1	0
Carol	1	0
David	0	1
Elva	0	1

trustors; factors



$\mathbf{G}$ =

	Delivering time	Product price
Alice	0.5	0.5
Bob	1	0
Carol	1	0
David	0	1
Elva	0	1

trustees; factors

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Incorporating Trust Bias

- Three types of trust bias:
  - Global bias (μ), trustor bias (x), trustee bias (y)

$$\min_{\mathbf{F},\mathbf{G}} \sum_{(i,j)\in\mathcal{K}} (\mathbf{T}(i,j) - \mathbf{F}(i,:)\mathbf{G}(j,:)')^2 + \lambda\|\mathbf{F}\|_{fro}^2 + \lambda\|\mathbf{G}\|_{fro}^2$$

Subject to:

$$\mathbf{F}(:,1) = \mu\mathbf{1},\ \mathbf{G}(:,1) = \alpha_1\mathbf{1}/\sqrt{n} \quad \text{(global bias)}$$

$$\mathbf{F}(:,2) = \mathbf{x},\ \mathbf{G}(:,2) = \alpha_2\mathbf{1}/\sqrt{n} \quad \text{(trustor bias)}$$

$$\mathbf{F}(:,3) = \alpha_3\mathbf{1}/\sqrt{n},\ \mathbf{G}(:,3) = \mathbf{y} \quad \text{(trustee bias)}$$

$$\min_{\mathbf{F}_0,\mathbf{G}_0,\boldsymbol{\alpha}} \sum_{(i,j)\in\mathcal{K}} (\mathbf{T}(i,j) - (\boldsymbol{\alpha}'[\mu, \mathbf{x}(i), \mathbf{y}(j)]' + \mathbf{F}_0(i,:)\mathbf{G}_0(j,:)'))^2$$

$$+\lambda\|\mathbf{F}_0\|_{fro}^2 + \lambda\|\mathbf{G}_0\|_{fro}^2 + \lambda\|\boldsymbol{\alpha}\|^2$$

Computing Bias

Global Bias:

Trustor Bias:

Trustee Bias:

$$\begin{cases} \mu = \sum_{(i,j)\in\mathcal{K}} \mathbf{T}(i,j)/|\mathcal{K}| \\ \mathbf{x}(i) = \sum_{j,(i,j)\in\mathcal{K}} \mathbf{T}(i,j)/|row_i| - \mu \\ \mathbf{y}(j) = \sum_{i,(i,j)\in\mathcal{K}} \mathbf{T}(i,j)/|col_j| - \mu \end{cases}$$

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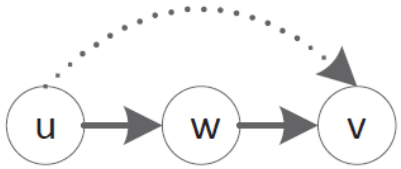
Incorporating Trust Transitivity

- Four types of trust propagation

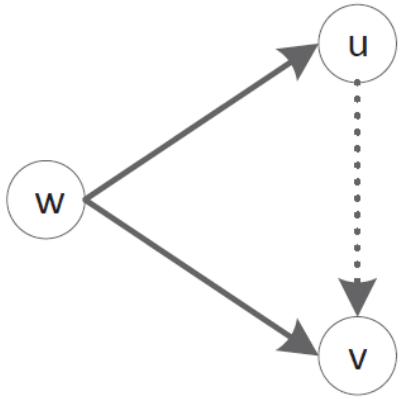


(a) Direct propagation

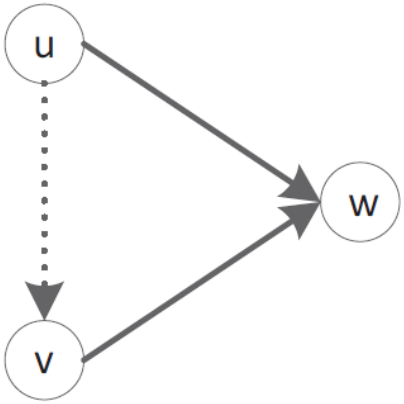
(b) Transpose trust

: known trust

: inferred trust



(c) Co-citation



(d) Trust coupling

(a) T * T
(b) T'
(c) T' * T
(d) T * T'

(i,j) → Z_{ij}

Computing Propagation

Propagation: (z_{ij})

$$
\begin{cases}
\mathbf{T}^t(i,j) = \mathbf{L}(i,:)(\mathbf{R}'\mathbf{L})^{t-1}\mathbf{R}(j,:)' \\
(\mathbf{T}')^t(i,j) = \mathbf{R}(i,:)(\mathbf{L}'\mathbf{R})^{t-1}\mathbf{L}(j,:)' \\
(\mathbf{T}'\mathbf{T})^t(i,j) = \mathbf{R}(i,:)((\mathbf{L}'\mathbf{L})(\mathbf{R}'\mathbf{R}))^{t-1}(\mathbf{L}'\mathbf{L})\mathbf{R}(j,:)' \\
(\mathbf{T}\mathbf{T}')^t(i,j) = \mathbf{L}(i,:)((\mathbf{R}'\mathbf{R})(\mathbf{L}'\mathbf{L}))^{t-1}(\mathbf{R}'\mathbf{R})\mathbf{L}(j,:)'
\end{cases}
$$

Our Final Model: MaTrI

Trust bias

Trust transitivity

$$\min_{\mathbf{F}_0,\mathbf{G}_0,\alpha,\beta} \sum_{(i,j)\in\mathcal{K}} (\mathbf{T}(i,j) - (\alpha'[\mu, \mathbf{x}(i), \mathbf{y}(j)]' + \beta'\mathbf{z}_{ij} + \mathbf{F}_0(i,:)\mathbf{G}_0(j,:)'))^2 + \lambda||\mathbf{F}_0||_{fro}^2 + \lambda||\mathbf{G}_0||_{fro}^2 + \lambda||\alpha||^2 + \lambda||\beta||^2$$

Multi-Aspect

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Experiments

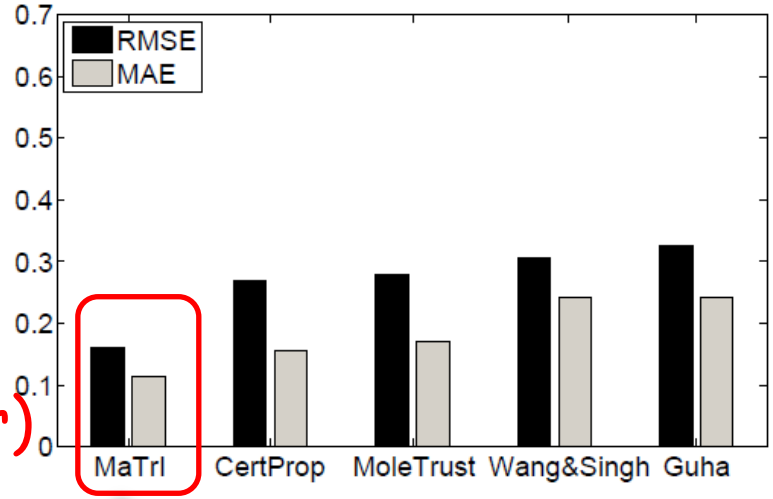
- Datasets
  - Advogato (http://www.trustlet.org/wiki/Advogato_dataset)
  - PGP (Pretty Good Privacy)

- Effectiveness: how accurate is the proposed MATRI for trust inference?
- Efficiency: how fast is the proposed MATRI?

Effectiveness Results

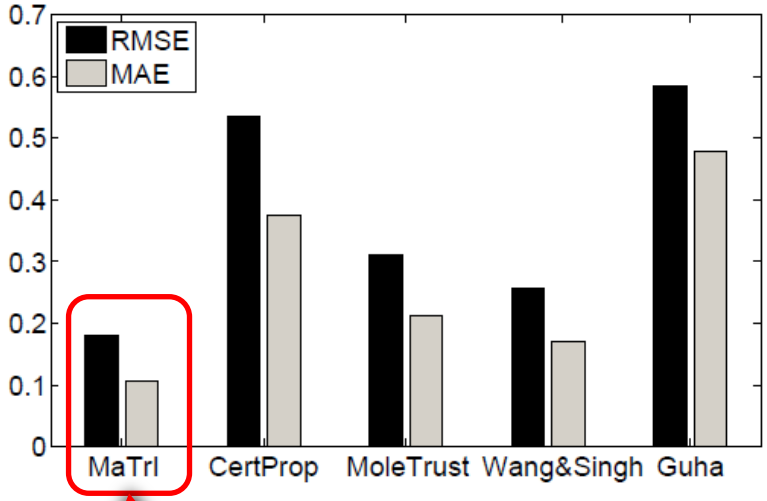
Comparisons with trust propagation models.

(better)



(a) *advogato* data set

Our method



(b) *PGP* data set

Our method

Effectiveness Results

Comparisons with related methods. Smaller is better.

RMSE/MAE	advogato	PGP
SVD	0.629 / 0.579	0.447 / 0.306
HCD	0.269 / 0.219	0.314 / 0.216
KBV	0.179 / 0.125	0.217 / 0.133
MATRI	0.159 / 0.113	0.181 / 0.105

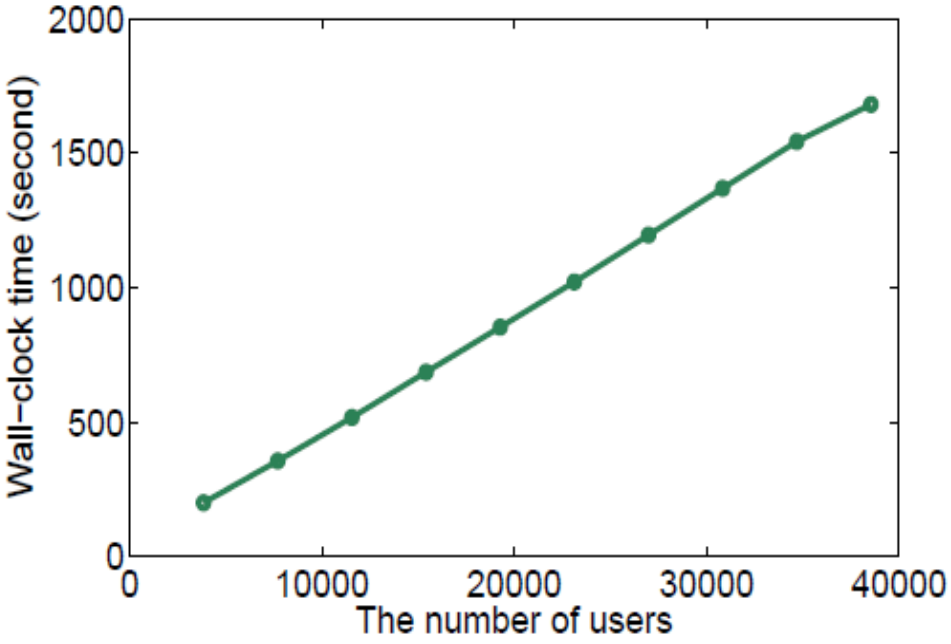
Our method

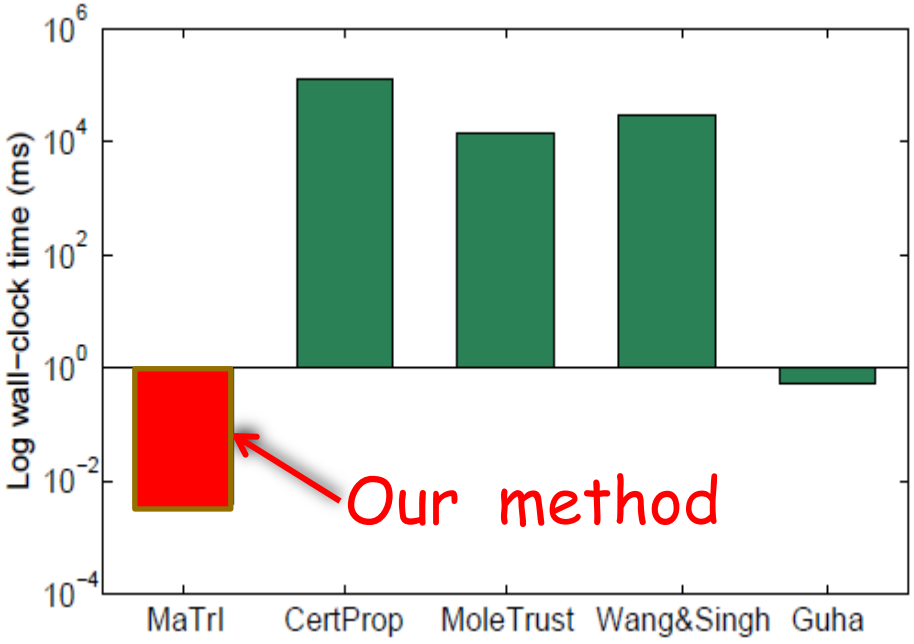
HCD: C. Hsieh et al., Low rank modeling of signed networks. *KDD 2012.*
KBV: Y. Koren et al., Matrix factorization techniques for recommender systems. *Computer 2009*

Efficiency Results

Pre-computational time: $O(m+n)$

Online response time: $O(1)$





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Conclusions

An Integral Trust-Inference Model

- Q1: how to characterize multi-aspect?
  - A1: analogy to recommendation problem
- Q2: how to incorporate trust bias?
  - A2: treat bias as specified factors
- Q3: how to incorporate trust transitivity?
  - A3: propagation through factorization

Empirical Evaluations

- Effectiveness: **>10%** improvement
- Efficiency:
  - **linear** in pre-computation
  - **constant** online response

Thanks !

Q&A