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[illegible], Member, IEEE, [illegible], Senior Member, IEEE

Abstract— [illegible]

Index Terms— [illegible]

◆

1 INTRODUCTION

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2 “FOLLOWING” LINK CASCADE MODEL

neighbor-ing lin

$v \in V$

$\in E$

e A B

$n,$

$t(e_{uv}) = \perp$

A

$C.$

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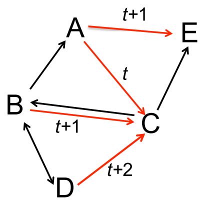
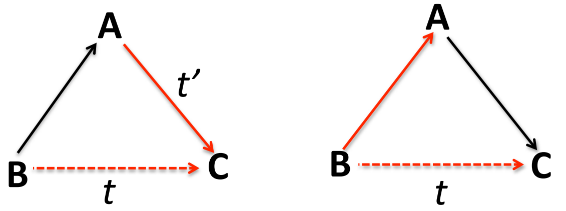
Organization.



E . 2.



(a) Follower diffusion

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(. ., $\delta = 7$), ff .
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e', ff -
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f e) B
A f C,
B A f C
A f C.
B C f
f C f C. ,

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. , f
ff .
. f ff . e_{AC}
f t, f B f e_{BC}
e_{AC} $t+1$ e_{AC} ff e_{BC} f $t+1$.
, e_{BC} ff e_{DC} f $t+2$.
, f A f e_{AE} e_{AC}
$t+1$ e_{AC} ff e_{AE} f $t+1$.
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ff -
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f , ,
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f f
f f
. , f-
f , . ., f-
f .
ff

Follower diffusion. f f A f C f
t', f f B f C
t $t' \le t \le t'+\delta$, B A' f f -
$t'-1$, f
f f e_{AC} f f e_{BC}.
f f f C f ,
follower diffusion.

. f f ff
(A,B,C) e_{BA}
$t'-1$. , f f -
ff , . ., $t'-1$, B f -
f A, C f f B, .
, f ff

Followee diffusion. f f B f A f
t', f f B f C
t $t' \le t \le t'+\delta$, C A' f f -
($t'-1$),
f f f e_{BA} f f e_{BC}.
f f f B f ,
followee diffusion. .
f f ff .

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3 DATA AND OBSERVATIONS

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3.1 Data Collection

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3.2 Observations

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f $0 \leq t - t' \leq \delta$ (δ
f).
, $C_\triangle$ -
$\triangle$, $C^+_\triangle$
B f C $[t', t'+\delta]$. $|C_\triangle|$ f
$\triangle$. $r_\triangle$
f B f C , -

$$r_\triangle = \frac{|C^+_\triangle|}{|C_\triangle|}. \tag{1}$$

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f f

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- ff ff ff

Pattern significance.
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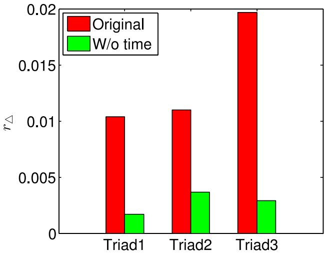

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A f C f , C

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f C f .

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Diffusion decay. ff f ff

, f δ $1, 2, 3, 5, 7$ 10 .

f δ, $r_\triangle$ f ff -

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δ , $r_\triangle$,

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f , $r_\triangle$ f ff

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f B A f $C,$ A'

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(.), B A f C

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A' f C' . , f f B f -

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Other observations. f f ff ,

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0-). , -

e_{BA}, - -

e_{AB}, e_{AB} e_{BA}.

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A B ff

f B f C -

A B (+).

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ff f f .

f f ff ,

ff ff -

f A C.

f (- , - ,

- , -) f f

ff . f ,

- f A C

ff f f B f C

- f C A (+ − 0).

f B f A f , B -

A' f C A'

f C' , A' C

B C.

Summary. , f f

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ff ff ,

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(+) - -
f A C ff -
f A f C B f C (+ $-$ 0).

4 MODEL LEARNING

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Likelihood function. ,
f
f .
$\theta = \{h_{e'e}, g_{e'e}\}$ -
f . , f

(e', e). ff $h_{e'e}$
$g_{e'e}$ f (e', e) f

(f e , ( ) . ( )- . ( ) . ( ) 0.0 0 / . 0 f (00 .)-00 . 0.

$y_{e'e}$ f e'
e $[t_{e'}, t_e]$, f $t_{e'}$
t_e, e' e f . , $y_{e'e}$
e' e f t_e

$$\begin{aligned} y_{e'e} &= 1 - h_\triangle g_\triangle \sum_{t=t_{e'}}^{t_e} (1-g_\triangle)^{t-t_{e'}} \\ &= h_\triangle (1-g_\triangle)^{t_e - t_{e'}+1} + (1-h_\triangle). \end{aligned} \tag{6}$$

, f ff
f . $e \in \mathcal{E}$
f
δ . f -
e' $y_{ee'}$ f $e' \in R_e$, R_e
f f e f $t_e + \delta$. -
$y_{ee'}$. ( ), $t_{e'}$
t_e t_e $t_e + \delta$.
- f

$$\log \mathcal{L} = \sum_{e\in\mathcal{E}} \left\{ \log \sum_{\vec{\alpha}_{S_e}} \prod_{e' \,\in\, S_e} x_{e'e}^{\alpha_{e'}} y_{e'e}^{1-\alpha_{e'}} + \sum_{e'\in R_e} \log y_{ee'} \right\}.$$

EM algorithm.
.
$q(e|\vec{\alpha}_{S_e}) = \frac{p(e|\vec{\alpha}_{S_e})}{p(e|S_e)}$
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f
- f

$$\begin{aligned} \log \mathcal{L} &= \sum_{e\in\mathcal{E}} \left\{ \log \sum_{\vec{\alpha}_{S_e}} \hat{q}(e|\vec{\alpha}_{S_e}) \frac{p(e|\vec{\alpha}_{S_e})}{\hat{q}(e|\vec{\alpha}_{S_e})} + \sum_{e'\in R_e} \log y_{ee'} \right\} \\ &\geq \sum_{e\in\mathcal{E}} \left\{ \sum_{\vec{\alpha}_{S_e}} \hat{q}(e|\vec{\alpha}_{S_e}) \log \frac{p(e|\vec{\alpha}_{S_e})}{\hat{q}(e|\vec{\alpha}_{S_e})} + \sum_{e'\in R_e} \log y_{ee'} \right\}, \end{aligned}$$

ˆ f -
. $\hat{q}(e|\vec{\alpha}_{S_e}) \log \hat{q}(e|\vec{\alpha}_{S_e})$
f ,
.
$Q(\theta, \hat{\theta})$

$$Q(\theta, \hat{\theta}) = \sum_{e\in\mathcal{E}} \left\{ \sum_{\vec{\alpha}_S} \right.$$

$$h_{\triangle} = \frac{\sum_{(e',e)\in C^{+}_{\triangle}} \hat{D}_{e'e} + \sum_{(e',e)\in C^{-}_{\triangle}} \hat{B}_{e'e}}{|C_{\triangle}|}, \quad (12)$$

$$g_{\triangle} = \frac{\sum_{(e',e)\in C^{+}_{\triangle}} \hat{A}_{e'e}}{\sum_{(e',e)\in C^{-}_{\triangle}} \hat{B}_{ee'}(\delta+1) + \sum_{(e',e)\in C^{+}_{\triangle}} \hat{D}_{e'e}(t_e - t_{e'}+1)}. \quad (13)$$

. ( ) ( ), $C^{+}_{\triangle}$ $C^{-}_{\triangle}$. $A_{e'e}$, $B_{e'e}$ $D_{e'e}$ f , $A_{e'e}$ $B_{e'e}$. ( ) ( ), $D_{e'e}$ f

$$D_{e'e} = B_{e'e} + A_{e'e} - A_{e'e}B_{e'e}. \quad (14)$$

.

Algorithm 1. .

```
: $G = (V, E, t)$
: $\theta = \{h_{\triangle}, g_{\triangle}\}$
    $h_{\triangle}$ $g_{\triangle}$ (0, )
    E-  $e \in \mathcal{E}$
        $e' \in S_e$
            $x_{e'e}$ . ( )
            $y_{e'e}$ . ( )
        $e' \in S_e$
            $A_{e'e}$ . ( )
            $B_{e'e}$ . ( )
0           $D_{e'e}$ . ( )
        $e' \in R_e$
            $B_{ee'}$ . ( )
    -  $\triangle = 1$ 24
        $h_{\triangle}$ . ( )
        $g_{\triangle}$ . ( )
    Convergence
```

5 APPLICATIONS

, ff - , f f .

.

f f .

Follower maximization. v, f f k f S f v f f .

. i f f v. $u \notin S$, f f - f $(S \cup \{u\})$ (-), (S) f f S. ff (f. f), ff f f S v f ff . , f e' e . ( ). f S, f f

S (S) R . , f v .0. - , ff f f ff f f .

Followee maximization. f f - . ff f f f - - , f - f f f f f f - ff . , f f . , v, k f v f f v . f ff f .

Algorithm 2. / .

```
: $G = (V, E)$, $v$, $k$
: f /f $S$
    $S = \emptyset$ $R$ 0,000
    $i = 1$ to $k$
        $u \in V \backslash S$
            $s_u = 0$
            $r = 1$ to $R$
                $s_u += |FCM(S \cup \{u\})|$
            $s_u = s_u / R$
        $S = S \cup \{argmax_{u \in V \backslash S} s_u\}$
```

6 EXPERIMENTS

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6.1 Experimental Setup

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Evaluation metrics. -

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f -f f

. $\{h_\triangle\}$ $\{g_\triangle\}$

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$p(e|S_e)$ f

S_e . (0) .

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f f $p(e|S_e) > \tau$. , , -

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$p(e|S_e)$ f

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Comparison methods.

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Basic. f f

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f).

SVM. f f -

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f .

LRC. f f -

f f .

f

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Collaborative filtering (CF): -

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f u, u

. f u

w, u f

w. -

, f u f v -

f f

$$CF\_score(u,v) = \sum_w I(w,v) sim(w,u),$$

$sim(w,u)$ w u,

. ., f -

$I(w,v)$ f w f v 0 -

. $\{v\}$ u

$CF\_score(u,v)$.

SimRank. f -

u f v

f f -

0 . $\{v\}$ f

u .

Katz. f

u f v -

f u v. f -

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Random-random model (RR). -

- .

, f u

f v, u w

f , w v -

f . e_{uv} -

(u,w,v) .

, f u f v

$$RR\_score(u,v) = \frac{1}{|F(u)|} \sum_w I(u,w) I(w,v) \frac{1}{|F(w)|},$$

$|F(u)|$ f f

u, $I(u,w)$ f u f w 0 -

. $\{v\}$ u

$RR\_score(u,v)$.

Preferential attachment with communities (PAC).

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f u

f v, β,

u f f -

u $1-\beta$, u f

. α, v f

f (. ., f -

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$1-\alpha$, v f f

. ,

f u f v

$$PAC\_score(u,v) = \beta\left(\alpha \frac{|N(v)|}{\sum_{v \in C(u)} |N(v)|} + (1-\alpha)\frac{1}{|C(u)|}\right) + (1-\beta)\left(\alpha \frac{|N(v)|}{\sum_{v \in V} |N(v)|} + (1-\alpha)\frac{1}{|V|}\right),$$

$|N(v)|$ f f f v. $C(u)$

f

f u,

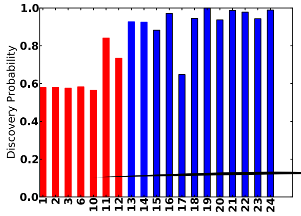
0 . V f f

f u, f f

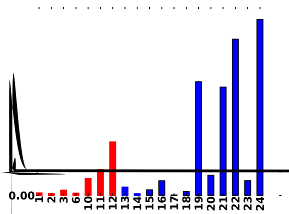
u. f-

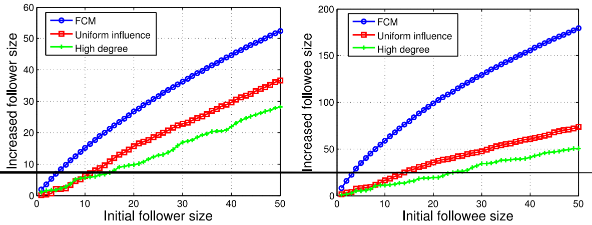
f fα β f 0 0. .

-



(a) Discovery Probabilities





(a) Follower maximization (b) Followee maximization

E . 11. [illegible]

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Per-triad analysis.

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Model parameter analysis. ,

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Delay analysis. δ

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Convergence analysis. f -

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6.3 Application Improvement

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7 RELATED WORK

Diffusion model and influence maximization.
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