A Novel Social Influence Model based on Multiple States and Negative Social Influences

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KID Lab

- **K**nowledge and **I**nformation **D**iscovery Lab
- http://kid.ee.ncku.edu.tw

Research Areas

- Data Mining and Database
  - Time Series Mining
  - Social Network Analysis
  - Information Management
- Multimedia Information Retrieval
- Ubiquitous Computing
  - Mobile Computing
  - Cloud Computing
- Bioinformatics

Social Network Research

- Social Influence
- Community Detection
- Topic Detection and Tracking
- Social Recommendation
- Team Formation

Social Network

- Social networking websites allow users to establish their own personal communities or social networks based on relationships of friends.

http://www.facebook.com/

http://twitter.com/

Information Spread

- Social network plays a fundamental role as a medium for the spread of information among members.
  - daily life, photos
  - opinion, ideas,

Viral Marketing

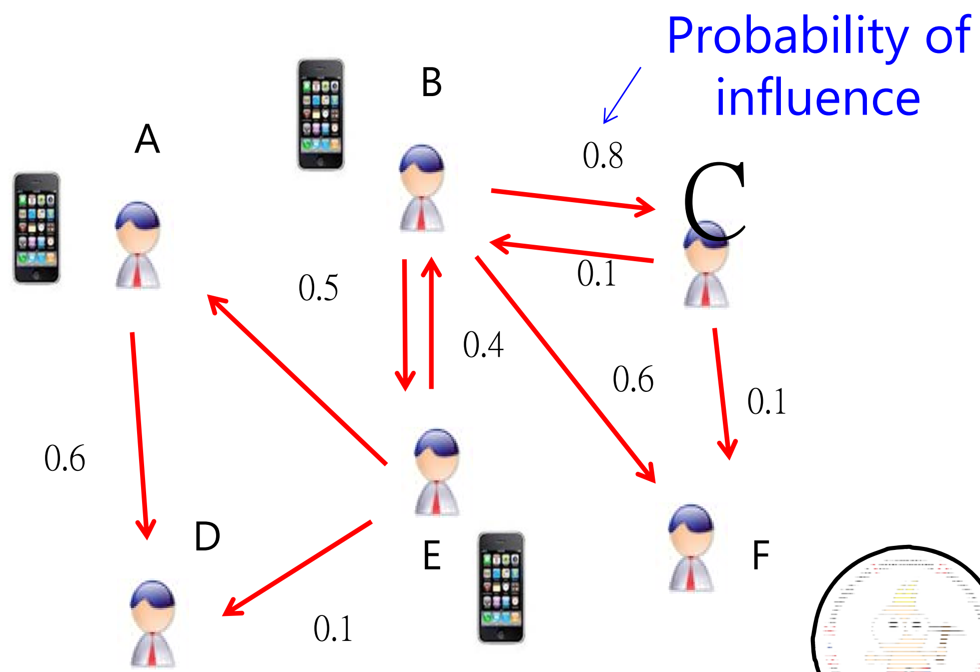
- Direct marketing takes the "word-of-mouth" effects to significantly increase profits.
- Minimize marketing cost and more generally maximize profit.
- Find a small number of influential users to adopt a new product, and subsequently trigger a large cascade of further adoptions.

Social Influence

- The social influence represents the influential power between people
  - Emotions or belief could be affected and changed by others.
- A social influence model could learn the influence diffusion process in the social network.

Influential Model

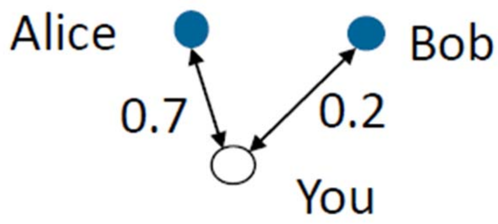
- The three most basic and popular models
  1. Linear Threshold Model
  2. Independent Cascade Model
  3. Heat Diffusion Model



Linear Threshold Model

- A node *v* is influenced by each neighbor *w* according to a weight $b_{v,w}$ such that

$$\sum_{w \text{ neighbor of } v} b_{v,w} \leq 1$$

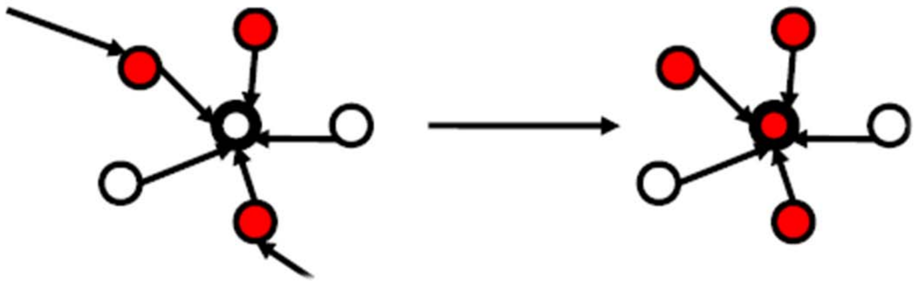


- Each node *v* has a loading threshold $\theta_{\boldsymbol{v}}$
  - Can be chosen uniformly at random
  - Can be proportional to the initial load

Linear Threshold Model

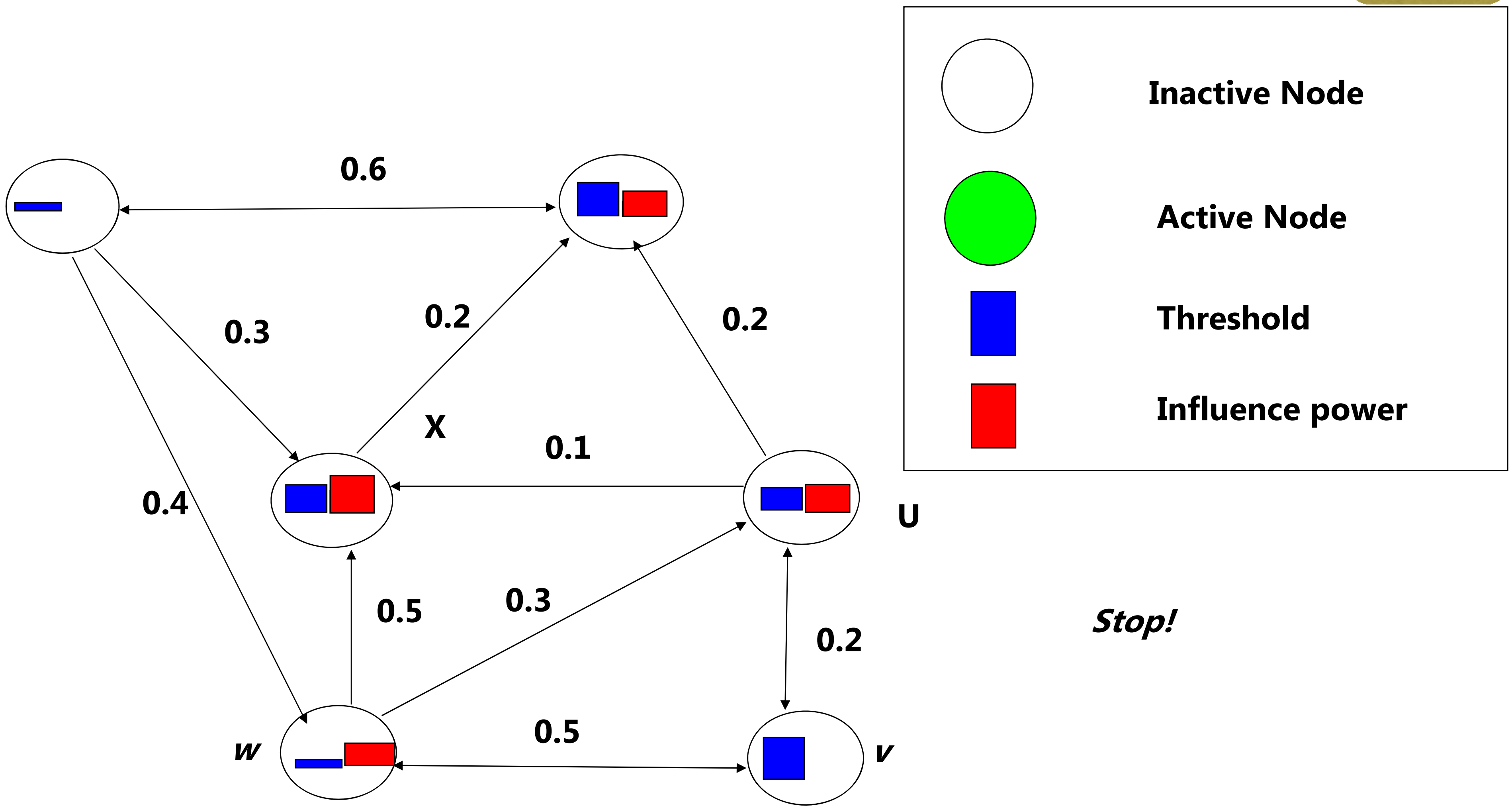
- A node *v* becomes active/overheat if

$$\sum_{w \text{ neighbor of } v} b_{v,w} \geq \theta_v$$



- Continue until no more activations are possible

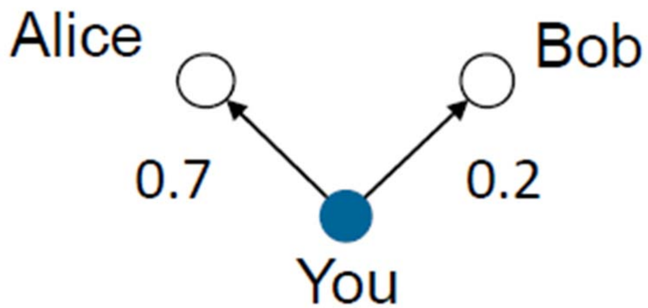
Linear Threshold Model



Stop!

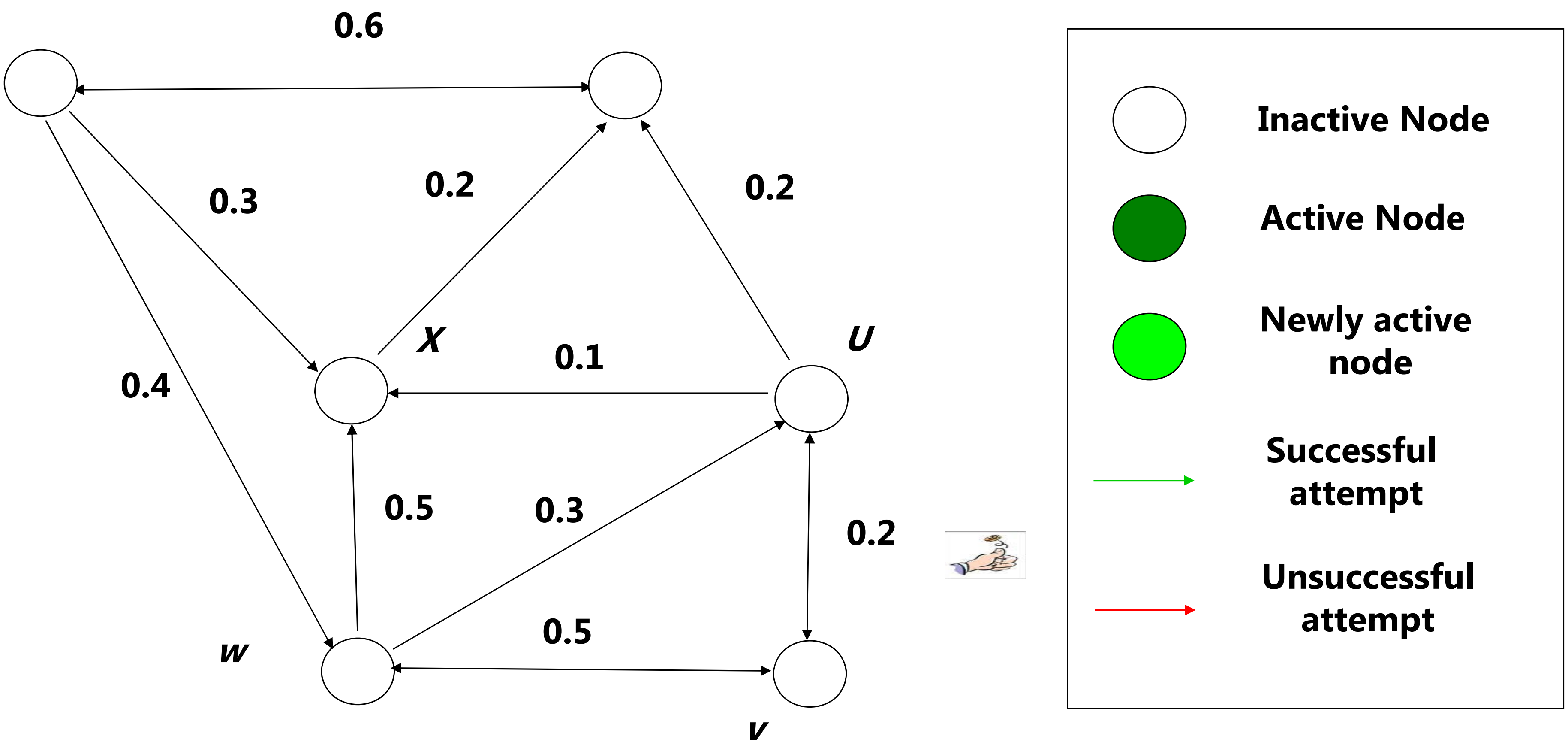
Independent Cascade Model

- When a node v becomes active, it has a single chance of activating each currently inactive neighbor w.
- The activation attempt succeeds with probability pv,w



- Run until no more activations are possible

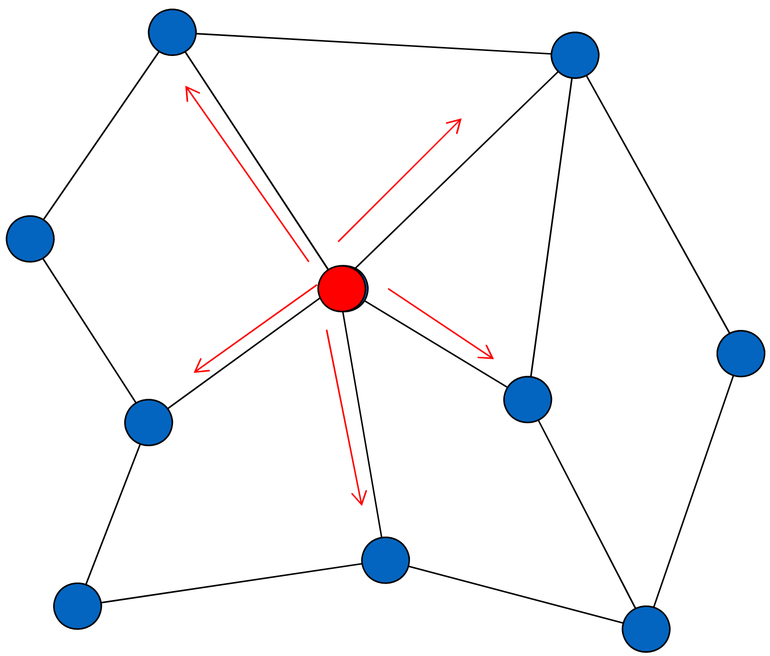
Independent Cascade Model



Stop!

Heat Diffusion Model

- The influence will spread as similar as heat and lead to heat balance.
- There are no active and inactive states in this model but the model take time decay into account.



Heat Diffusion Model

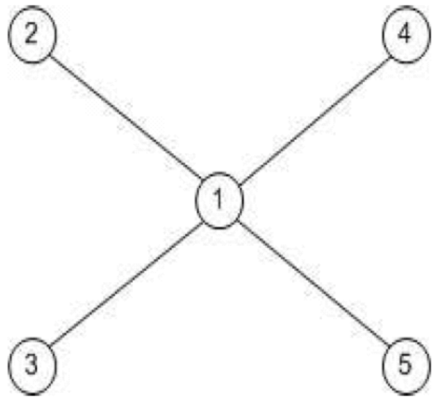
$$H_{ij} = \begin{cases} 1, & (v_i, v_j) \in E \text{ or } (v_j, v_i) \in E \\ -d(v_i), & i = j, \\ 0, & \text{otherwise.} \end{cases}$$

$$\mathbf{f}(t) = e^{\alpha t \mathbf{H}} \mathbf{f}(0)$$

α	Thermal conductivity
$\mathrm{d}(v_i)$	Degree of node i
$f_i(t)$	Heat value of node i at time t
$f(0)$	Vector of the initial heat distribution
$f(t)$	Vector of the heat distribution at time t

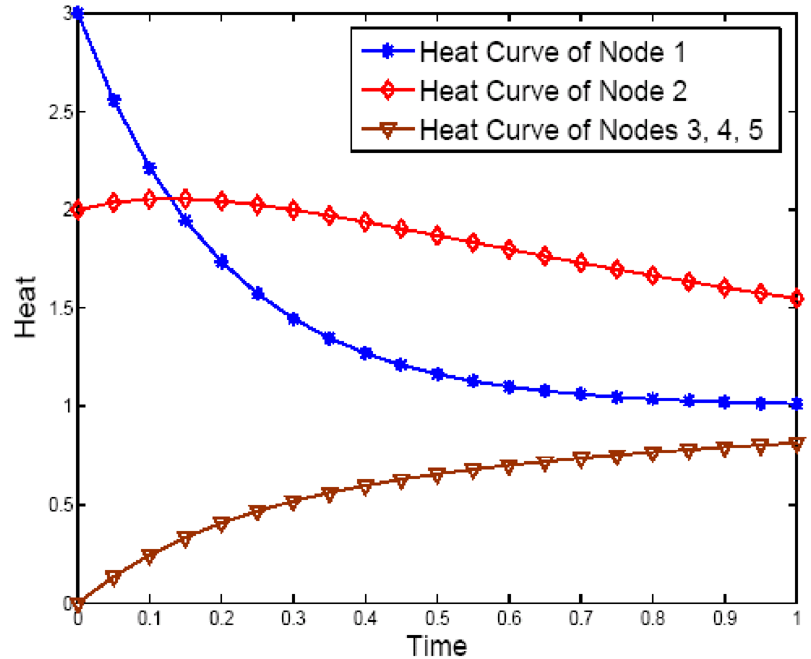
Heat Diffusion Model

At time 0, suppose node 1 is given 3 units of heat, and node 2 is given 2 units of heat.



$$\mathbf{f}(0) = [3, 2, 0, 0, 0]^{\mathbf{T}}$$

$$\mathbf{H} = \begin{pmatrix} -4 & 1 & 1 & 1 & 1 \\ 1 & -1 & 0 & 0 & 0 \\ 1 & 0 & -1 & 0 & 0 \\ 1 & 0 & 0 & -1 & 0 \\ 1 & 0 & 0 & 0 & -1 \end{pmatrix}$$



Curve of heat change with time

$$\mathbf{f}(t) = e^{\alpha t \mathbf{H}} \mathbf{f}(0)$$

Diffusion Models	Influence mode		Topic	Item popularity	User	External influence	Influence time	Negative influence
	Threshold	Probability						
LT	●							
IC		●						
HD							●	
TIC (ICDM, 2012)		●	●					
TLT (ICDM, 2012)	●		●					
AIR (ICDM, 2012)	●		●		●			
MDM (ISWSM, 2012)		●	●	●	●			
External Influence in Networks (KDD, 2012)		●		●		●	●	
MFAD (PAKDD, 2015)		●	Flexible Feature					
IC-N (SDM, 2011)		●						●
MOO (ASONAM, 2015)	●						●	●

Topic-aware IC Model (TIC)

- All the information can be classified in several topics$[1, K]$
- The probability $p_{v,u}^{z}$ indicates the influential power on topic $\mathrm{z} \in [1, K]$ between user v and u on an edge (v, u)
- γ_i^z indicates the topic distribution for each item i
- The strength of influence of **v** on **u** for item i becomes

$$p_{v,u}^{i} = \sum_{z=1}^{K} \gamma_i^z p_{v,u}^{z}$$

Topic-aware LT Model (TLT)

- Each node u chooses a threshold θ uniformly at random from [0 , 1]
- At time t, a node u, which is not yet active, on item i, is submitted to an influence weight

$$W_i^t(u) = \sum_{z=1}^{K} \sum_{v \in \mathcal{F}_i(u,t)} \gamma_i^z p_{v,u}^z$$

- If $W_i^t(u) \geq \theta_u$, u becomes active at time t+1

Topic-aware Social Influence Propagation Models (AIR)

- Authoritativeness of a user in a topic
- Interest of a user for a topic
- Relevance of an item for a topic

Diffusion Models	Influence mode		Topic	Item popularity	User	External influence	Influence time	Negative influence
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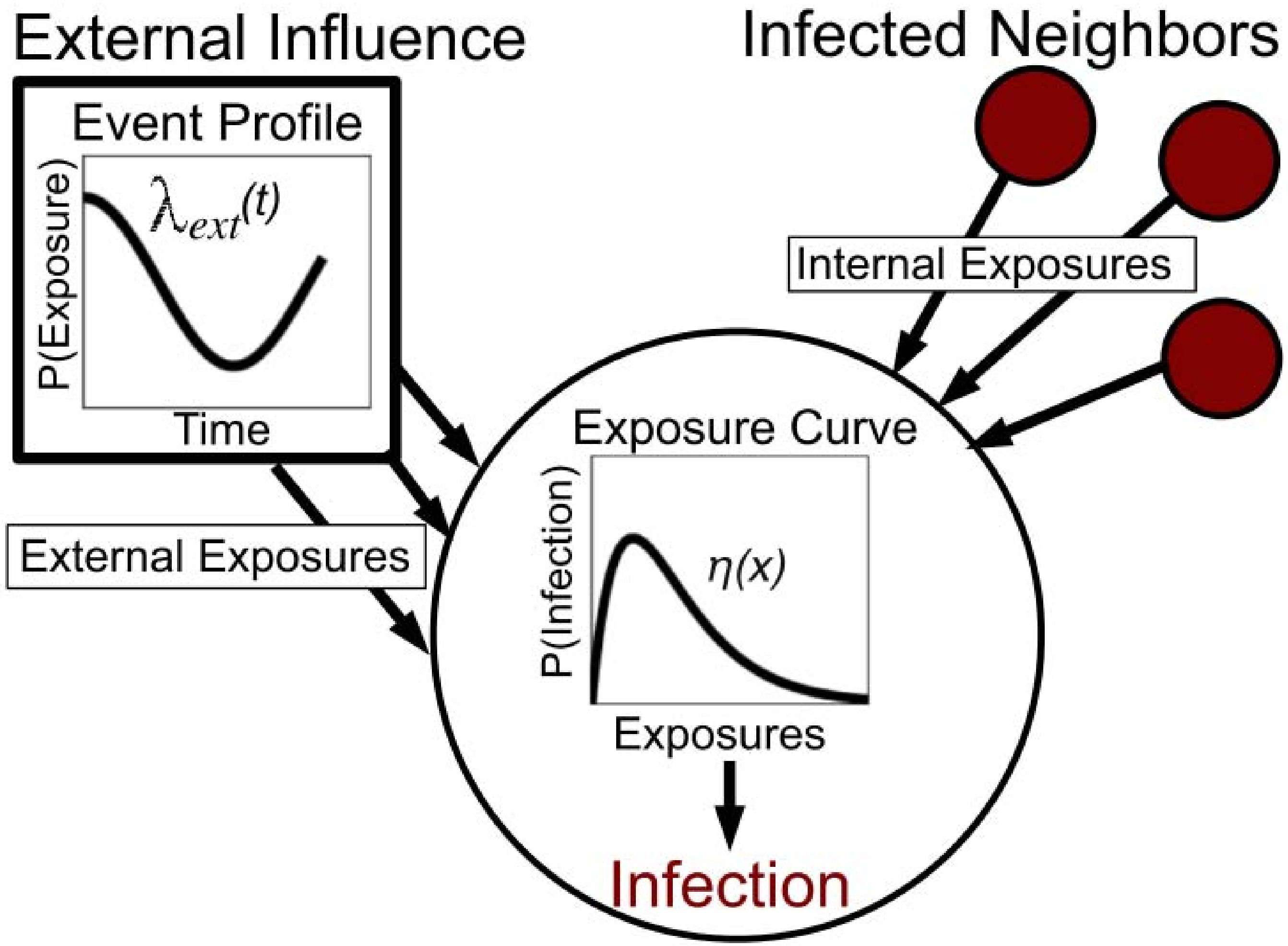
MOO (ASONAM, 2015)	●						●	●

Virality and Susceptibility in Information Diffusions (MDM)
(ISWSM, 2012)

- Item virality
  - Two widely used item virality definitions are popularity and viral coefficient
- User virality
  - The conventional approach to measure user virality is Fanout, i.e., the average number of friends the user diffuses items to
- User susceptibility
  - The fraction of items the user adopts once they are introduced to the user

Information Diffusion and External Influence in Networks (KDD,2012)



Multiple Factors-Aware Diffusion in Social Networks (MFAD) (PAKDD, 2015)

A node u activated in timestamp t_{i-2} tries to influence its inactivated out-neighbor v with probability $p_{u,v}$ in timestamp t_{i-1}. (*influence transmission*)

The influence is transmitted successfully.

v receives the influence and the activation of v is then predicted by $f_v(x)$. (*adoption decision*)

v *is activated.*

v tries to influence its inactivated out-neighbor z with probability $p_{v,z}$ in timestamp t_i. (*influence transmission*)

Multiple Factors-Aware Diffusion in Social Networks (MFAD) (PAKDD, 2015)

- MFAD aims to design a diffusion model in which factors considered are flexible to extend and change.

- Two-stage Learning:

  1. Learning classifier of nodes

     - To predict the adoption behavior of a node

  2. Learning the transmission probability

Influence Maximization in Social Networks When Negative Opinions May Emerge and Propagate (IC-N)(SDM, 2011)

- Independent Cascade Model with Negative Opinions
  - Three node states: neutral, positive, and negative
  - A parameter q called quality factor, which indicates the probability that a node stays positive

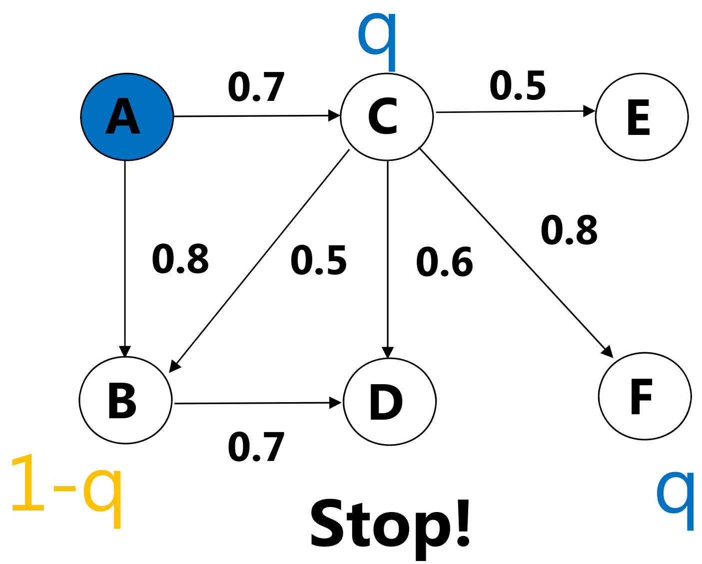
Influence Maximization in Social Networks When Negative Opinions May Emerge and Propagate (IC-N)(SDM, 2011)

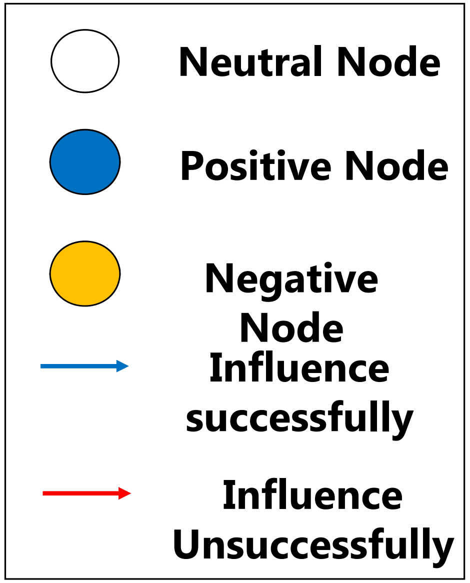
- If v is activated by a positive node u, v becomes positive with probability q and become negative with probability (1 - q).

- A negatively activated node in the previous step also tries to negatively activate its non-active neighbors, and if successful the neighbors become negative

- If several nodes try to activate the same node in one step, the order of activation trials is random

Independent Cascade Model with Negative Opinions (IC-N)





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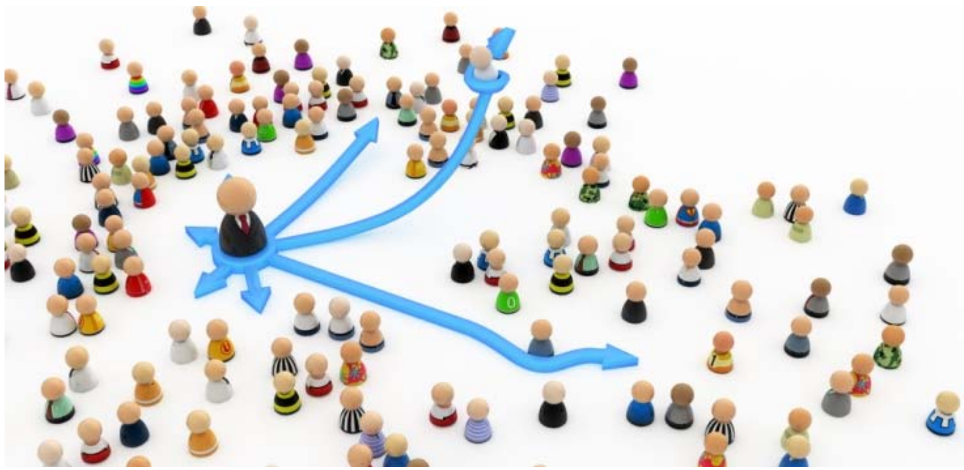
MFAD (PAKDD, 2015)		●	Flexible Feature					
IC-N (SDM, 2011)		●						●
MOO (ASONAM, 2015)	●						●	●

Motivations

- Social influence models all categorize nodes into active and inactive states.
  - *Active state: Node has been influenced, and owns influential power to affect others.*
  - *Inactive state: Node receives not enough influence to be an active node, and has no influential power.*



Motivations

- Previous models have following limitations.
  - Related models only consider the possibility of positive influence.
  - If nodes have been influenced successfully and become active, these nodes could not return to the inactive state.
  - Most of models do not take time effect into account.

- We proceed a Multi-state Open Opinion model (MOO model).
  - Multiple states of opinions with state threshold table.
  - An influence diffusion process including time decay.

Multi-state Open Opinion Model based on Positive and Negative Social Influences

Y.-C. Chen, H.-S. Ma and J.-W. Huang

The 2015 IEEE/ACM Advances in Social Networks Analysis and Mining (ASONAM 2015)

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MOO Model

- Multi-State Open Opinion Model based on Positive and Negative Social Influences (MOO model)
  - Multiple states
  - Positive / negative influence
- Influence Propagation
  - Time decay

Opinion States

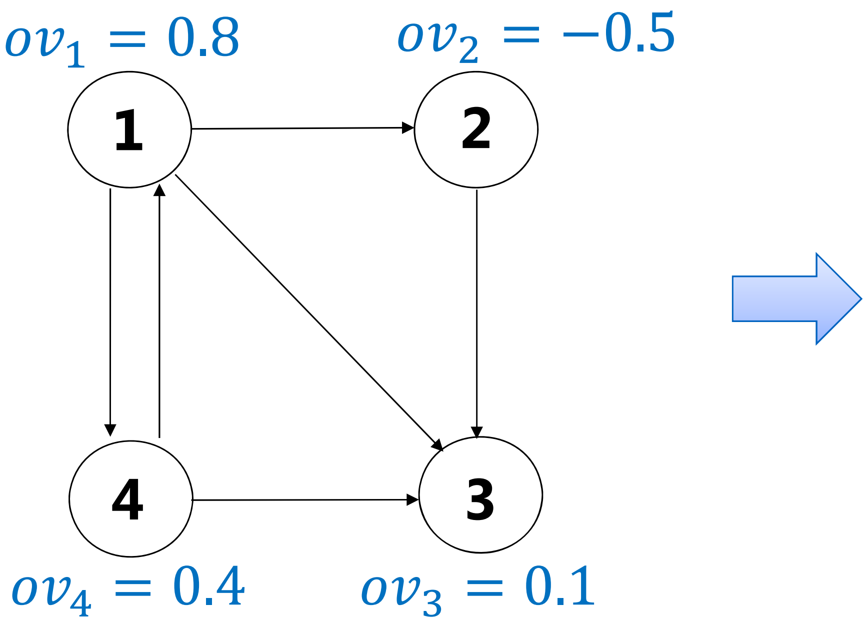
- Definition 1: Opinion State (OS)
  - ① Positive and Active (**PA**)
    - ◆ Node with positive opinion can influence others.
  - ② Positive and Inactive (**PI**)
    - ◆ Node with positive opinion do not influence others.

Opinion States

- Definition 1: Opinion State (OS)
  - ③ Neutral (**N**)
    - ◆ Node without enough opinion do not influence others.
  - ④ Negative and Inactive (**NI**)
    - ◆ Node with negative opinion do not influence others.
  - ⑤ Negative and Active (**NA**)
    - ◆ Node with negative opinion can influence others.

Opinion Values

- Definition 2: Opinion Value (OV)
  - The opinion could be quantified as value. Every user has his/her opinion value ov_i, where ov_i is the opinion value of user i. We collect all of the opinion values as vector $\overrightarrow{ov} = [ov_1\ ov_2 \ldots ov_n]$.



$\overrightarrow{ov} = [0.8\ \ -0.5\ \ \ 0.1\ \ \ 0.4]$

State Threshold Table

- Definition 3: State Threshold Table (STT)
  - The opinion value mapping to opinion states by personal state threshold table. We define an unique $STT_i = [\theta_{PA}\ \theta_{PI}\ \theta_{NI}\ \theta_{NA}]$ on each user.

PA
θ_{PA}
PI
θ_{PI}
N
θ_{NI}
NI
θ_{NA}
NA

$$OS_k = \begin{cases} PA, & OV_k \geq \theta_{PA} \\ PI, & \theta_{PA} > OV_k \geq \theta_{PI} \\ N, & \theta_{PI} > OV_k > \theta_{NI} \\ NI, & \theta_{NI} \geq OV_k > \theta_{NA} \\ NA, & \theta_{NA} \geq OV_k \end{cases}$$

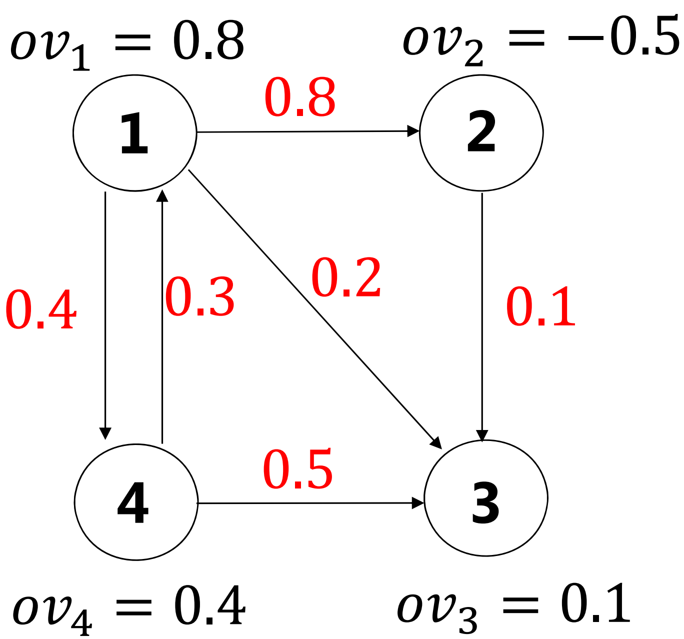
Opinion States

- The relation of above definitions are shown as follows.

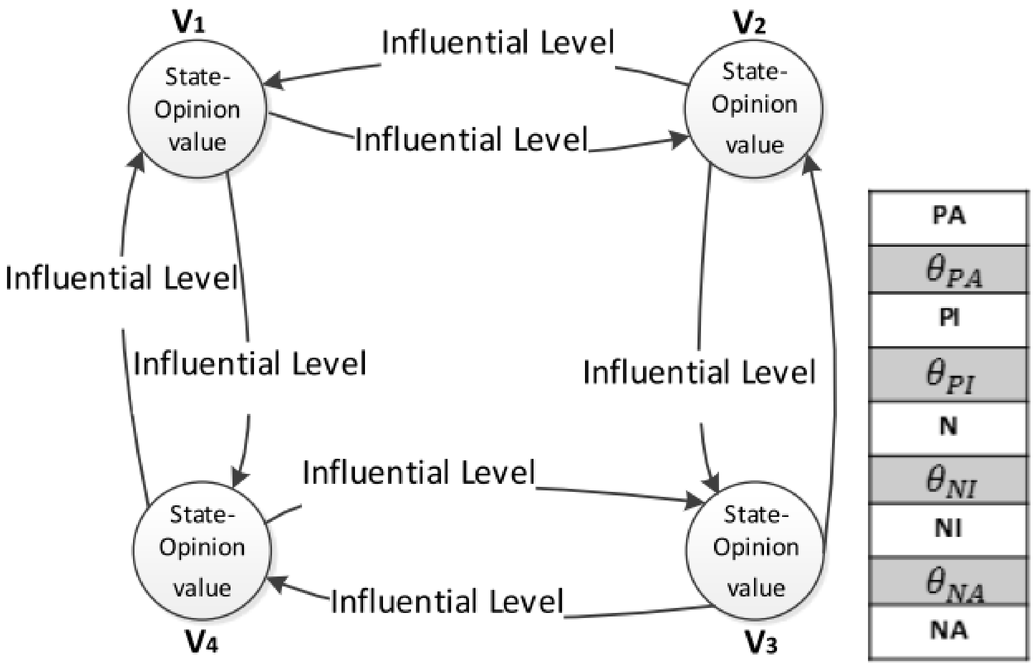
$$\text{Opinion} \xrightarrow{Quantify} \text{Opinion Value} \xrightarrow[STT]{Mapping} \text{Opinion State}$$

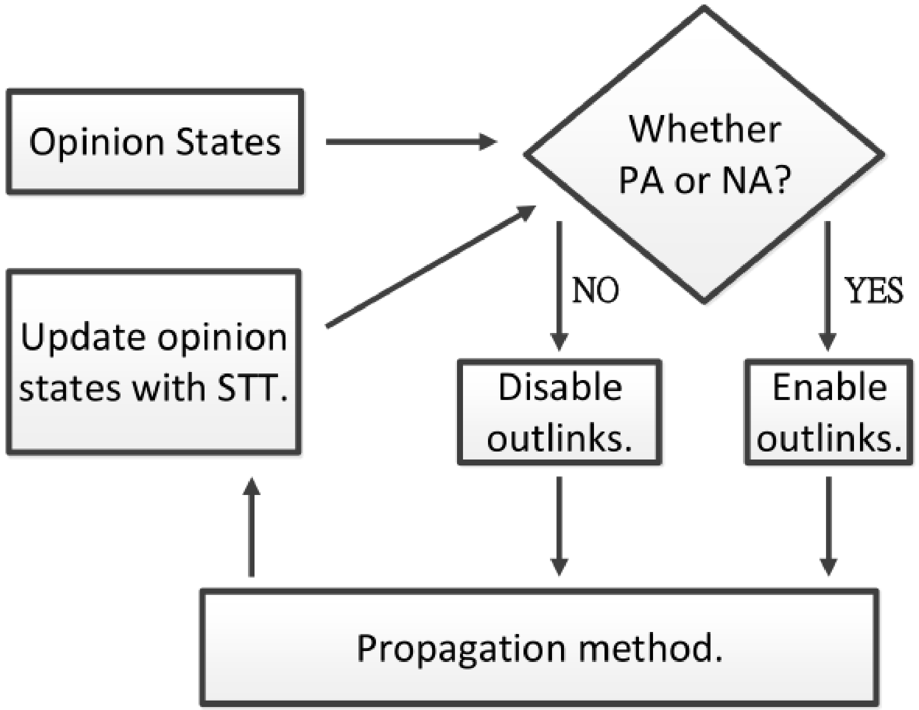
Influential Level

- Definition 4: Influential Level
  - The strength of influential power between users.
  - A directed edge with weight w_{ij} represents the influential level.



Model Overview



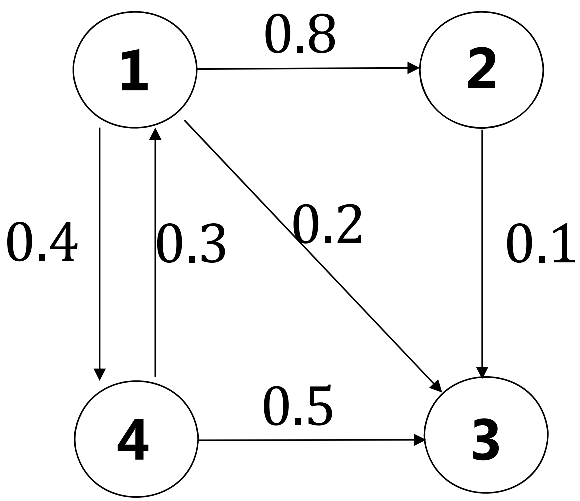


Diffusion Matrix

- The Diffusion Matrix (DM) shows the relation of propagation. We indicate the influence will be divided or shared by number of friends in DM. Each entry in DM is denoted:

$$dm_{ji} = \begin{cases} \frac{1}{od_i} w_{ij}, (v_i, v_j) \epsilon E \\ 0, otherwise \end{cases}$$

where od_i *is the outdegree of* i.



$$DM = \begin{bmatrix} 0 & 0 & 0 & \frac{1}{2} * 0.3 \\ \frac{1}{3} * 0.8 & 0 & 0 & 0 \\ \frac{1}{3} * 0.2 & \frac{1}{1} * 0.1 & 0 & \frac{1}{2} * 0.5 \\ \frac{1}{3} * 0.4 & 0 & 0 & 0 \end{bmatrix}$$

Influence Propagation

- MOO model includes the information decay.
  - $$OV_t = e^{-(t-t_0)\alpha} DM_{t-1}\hat{OV}_{t-1} + \hat{OV}_{t-1}$$

    Influence from neighbors — Original OV

$$OV_t \xrightarrow{Normalized} \hat{OV}_t$$

- If a node receives only positive/negative influences from its neighbors of the same state, there is little effect on its opinion value [*].

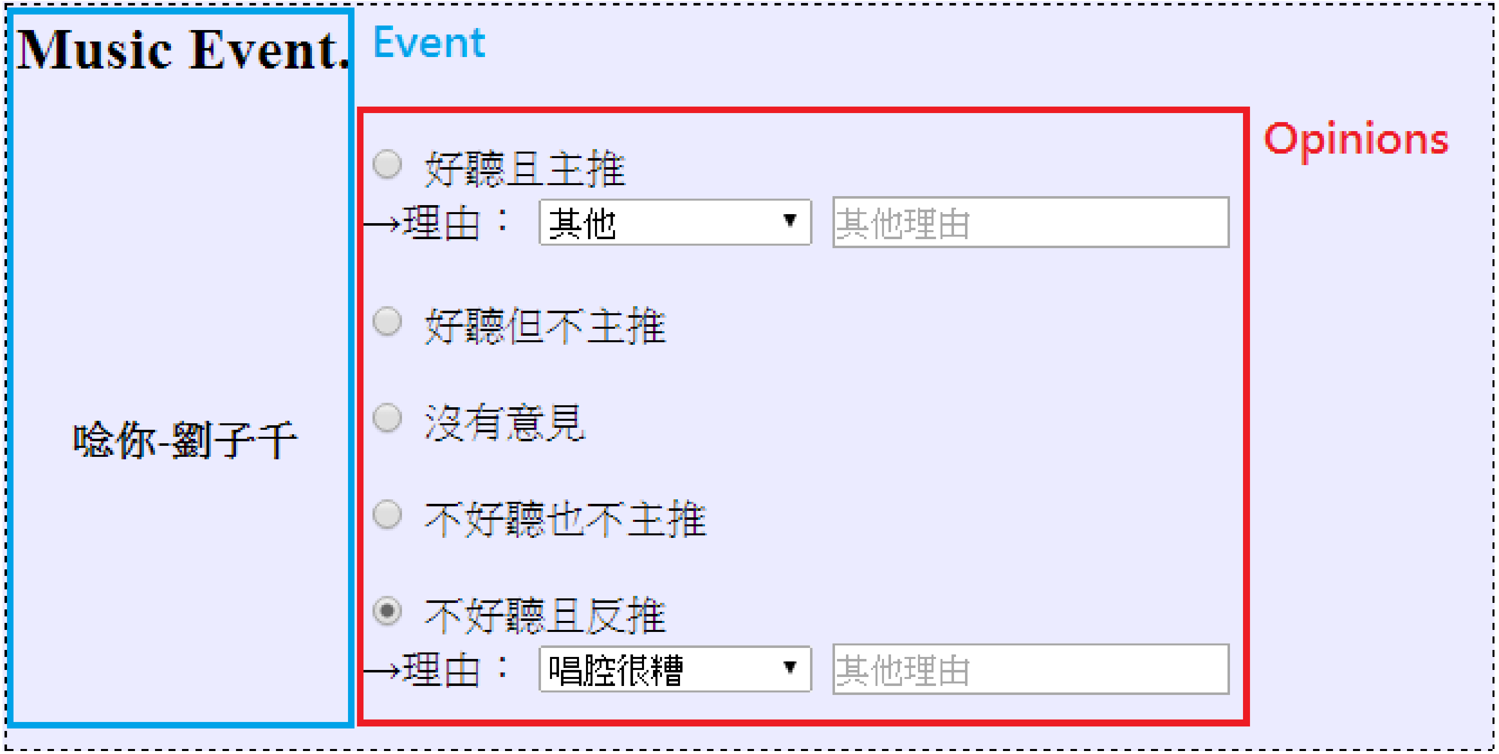
[*] D. Crandall, D. Cosley, D. Huttenlocher, J. Kleinberg, and S. Suri. Feedback effects between similarity and social influence in online communities. In ACM SIGKDD International Conference on Knowledge Discovery and Data Mining, pages 160 – 168, 2008.

Experiment

- Experiment Design
- Compared Methodology
- Performance Evaluation

Experiment Design

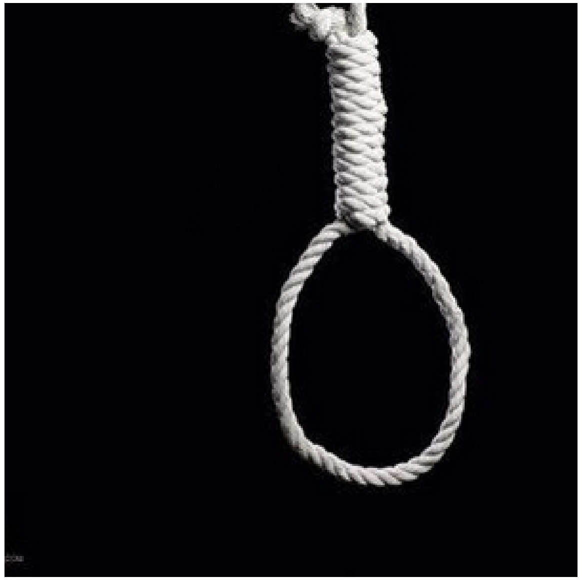
- We built a social influence website that connects with Facebook to measure the influence of users.



Experiment Design

- According to the result of survey, we assign the corresponding opinion values and opinion states to each user.

廢除死刑



好友評論：

User: 1 ：反推

→ 不處死，可能再次危害社會

User: 2 ：反推

→ 不處死，可能再次危害社會

User: 3 ：反推

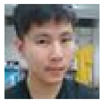
→ 犯罪預防與威嚇作用

User: 7 ：反推

→ 不處死，可能再次危害社會

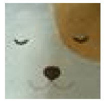
User: 8 ：反推

→ 不處死，可能再次危害社會



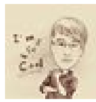
User: 9 ：反推

→



User: 13 ：反推

→ 犯罪預防與威嚇作用



User: 14 ：反推

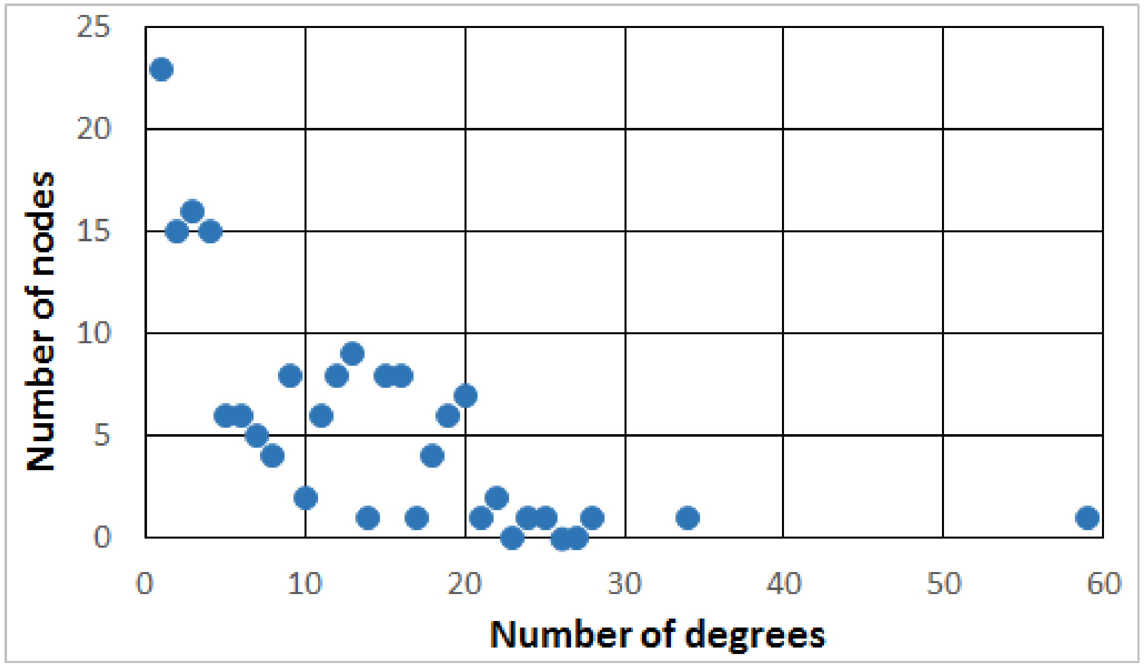
→ 平息，滿足被害人或親屬不平

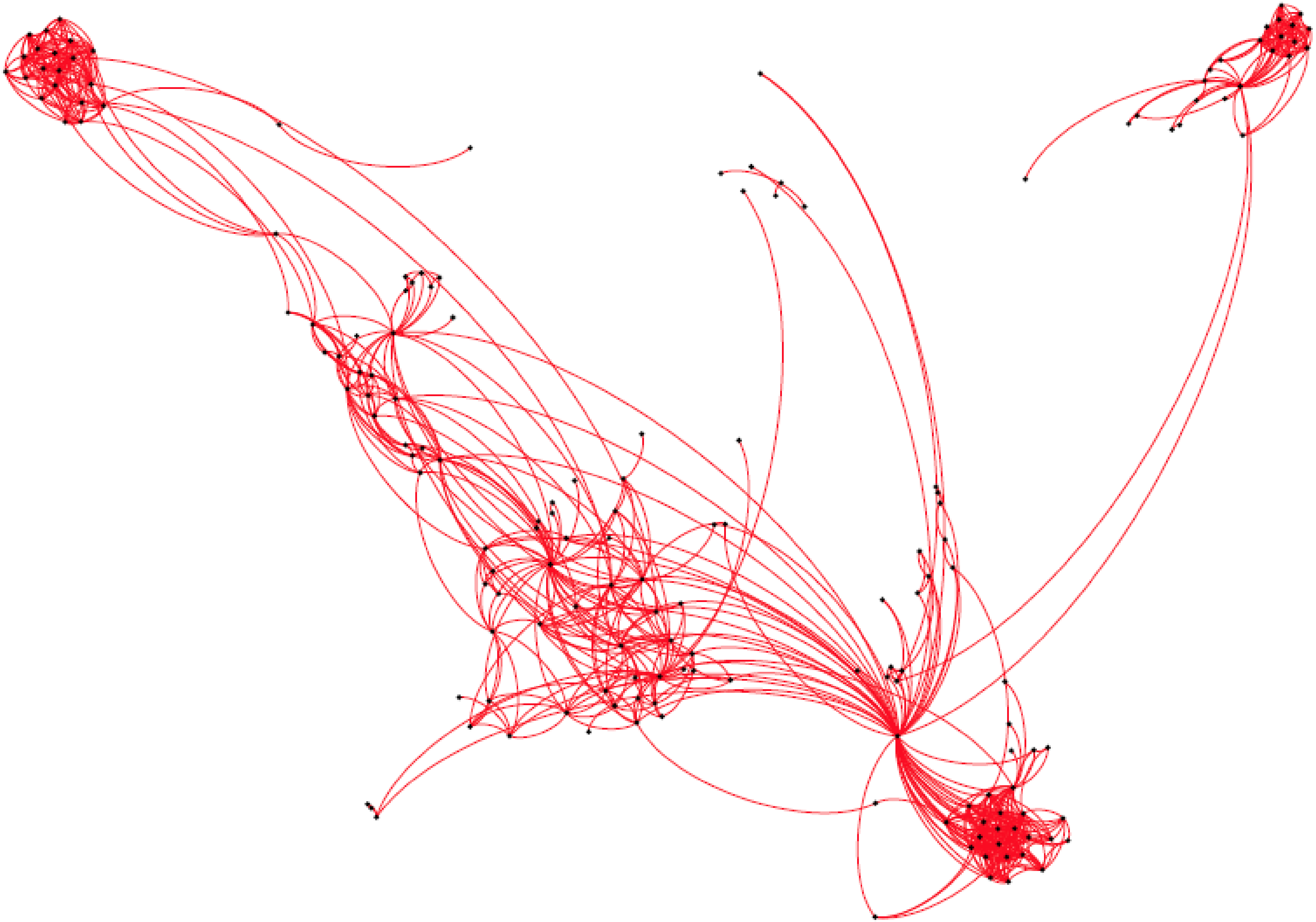
User: 15 ：反推

→ 犯罪預防與威嚇作用

Experiment Design

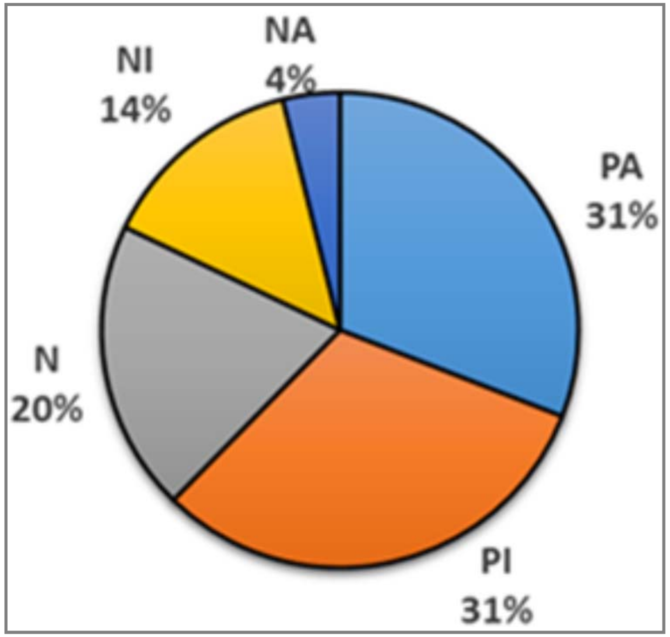
- 232 users.
- 1532 edges.
- 183 users having at least one edge
- 8.93 average degrees.



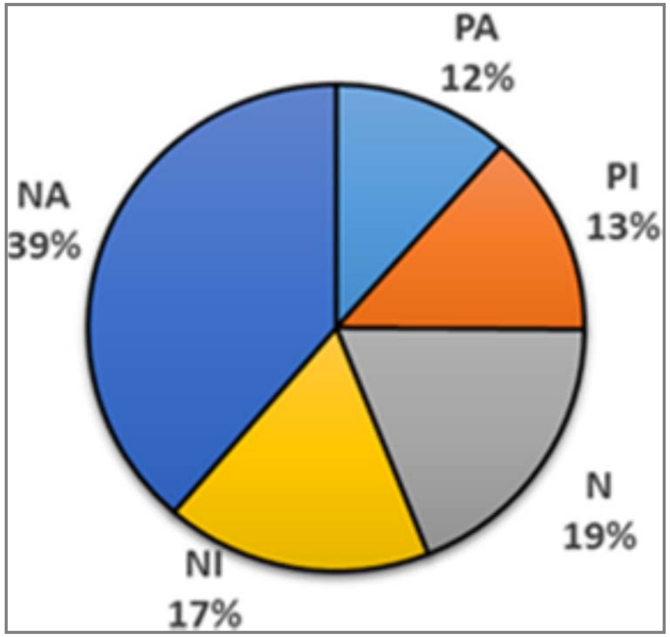


Experiment Design

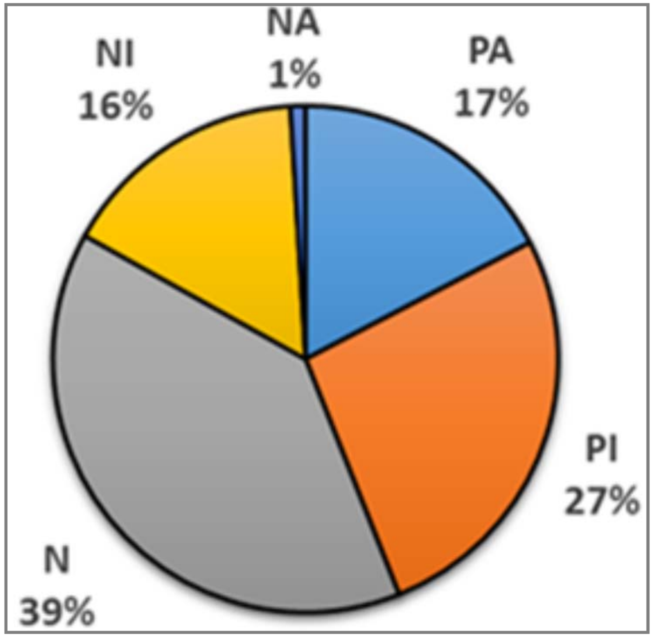
- 8 events (4 positive, 3 negative, and 1 neutral)



- Positive events



- Negative events



- Neutral events

Compared Methodology

- Experiments on two states
  - MOO model and related models compared predictive opinion states with users' final opinion states in the website.
    - PA → Active.
    - PI, N, NI and NA →Inactive.

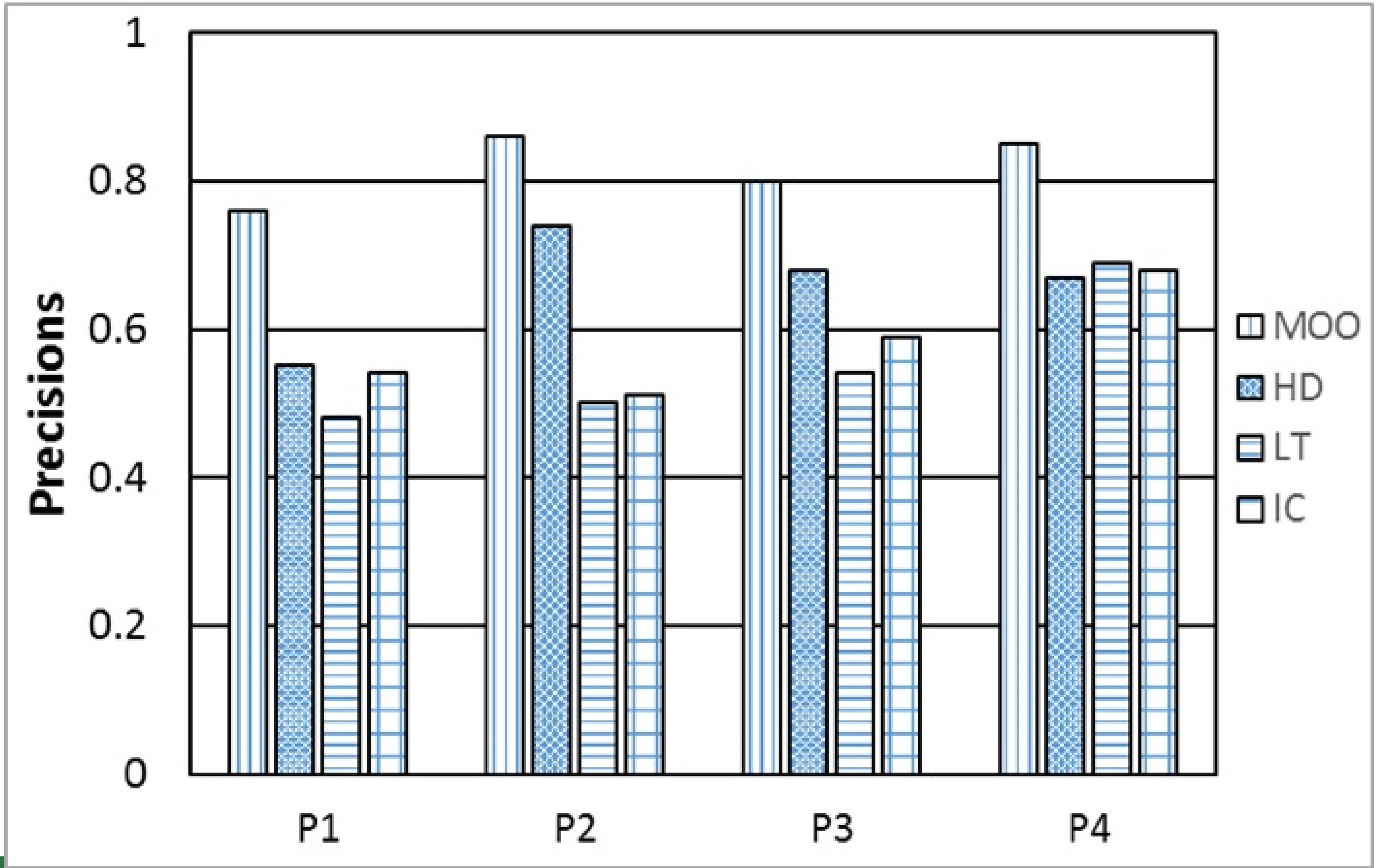
Compared Methodology

- Experiments on five states
  - MOO model compared predictive five states with users' final states.

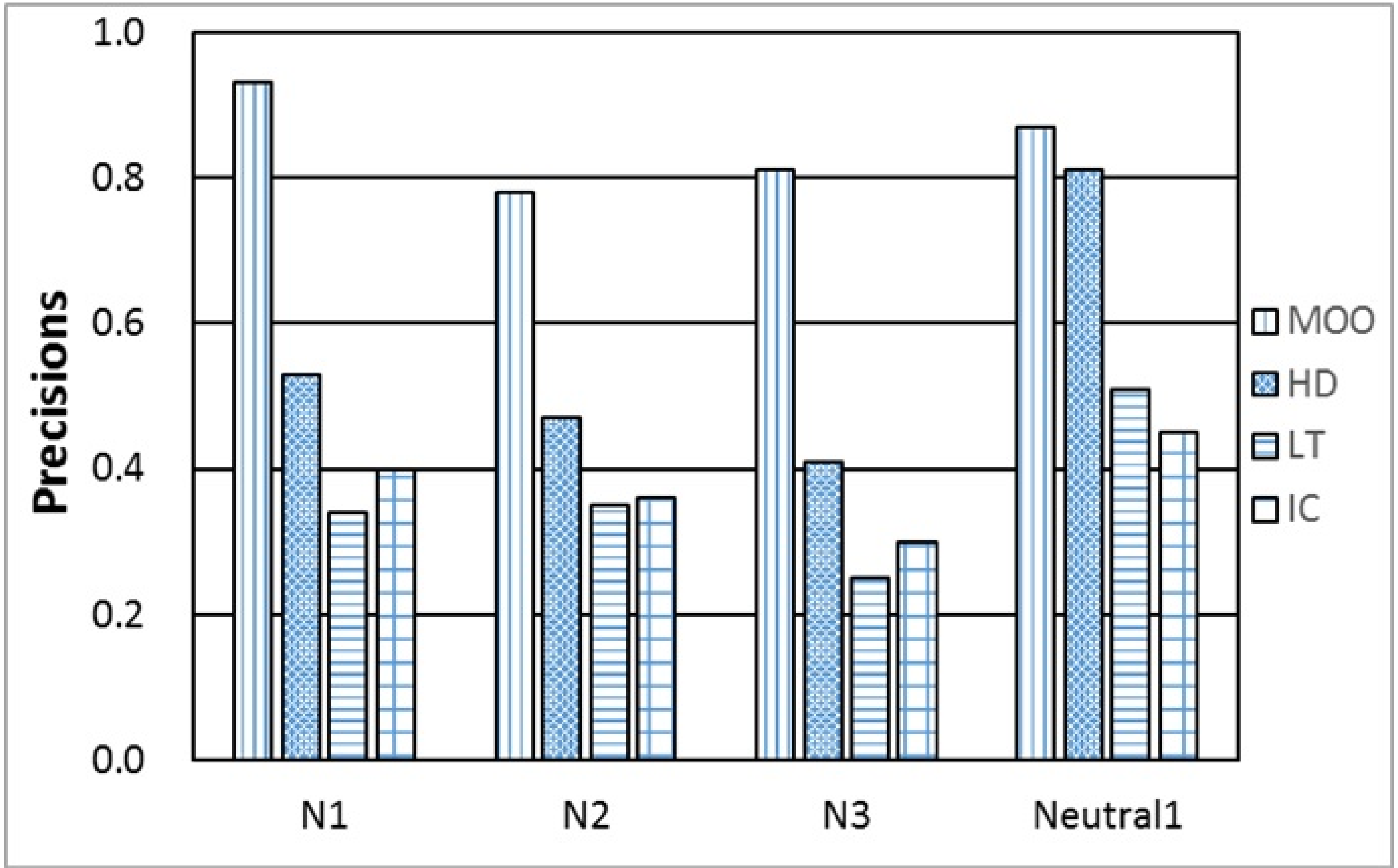
$$Precision = \frac{n_c}{n}$$

    - *n: Number of nodes.*
    - *n_c: Number of nodes which are predicted correctly.*

Two States in Positive Events



Two States in Negative and Neutral Events



Precision of Five States

MOO model	n	n_c	Precision
PA	87	75	86.2%
PI	45	21	46.7%
N	8	2	25.0%
NI	7	5	71.4%
NA	3	2	66.7%

- Positive events

MOO model	n	n_c	Precision
PA	18	12	66.7%
PI	22	4	18.2%
N	19	13	68.4%
NI	29	20	69.0%
NA	60	52	86.7%

- Negative events

MOO model	n	n_c	Precision
PA	26	21	80.8%
PI	39	22	56.4%
N	61	29	47.5%
NI	23	10	43.5%
NA	1	1	100.0%

- Neutral events

Conclusions

- We have proposed a Multi-State Open Opinion Model (MOO model) based on positive and negative social influences
- MOO model has multiple states and considers positive and negative influence at the same time.
- The experimental results show that MOO model outperforms previous models in precisions of prediction.

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- http://kid.ee.ncku.edu.tw