Two Step Graph-based Semi-supervised Learning for Online Auction Fraud Detection

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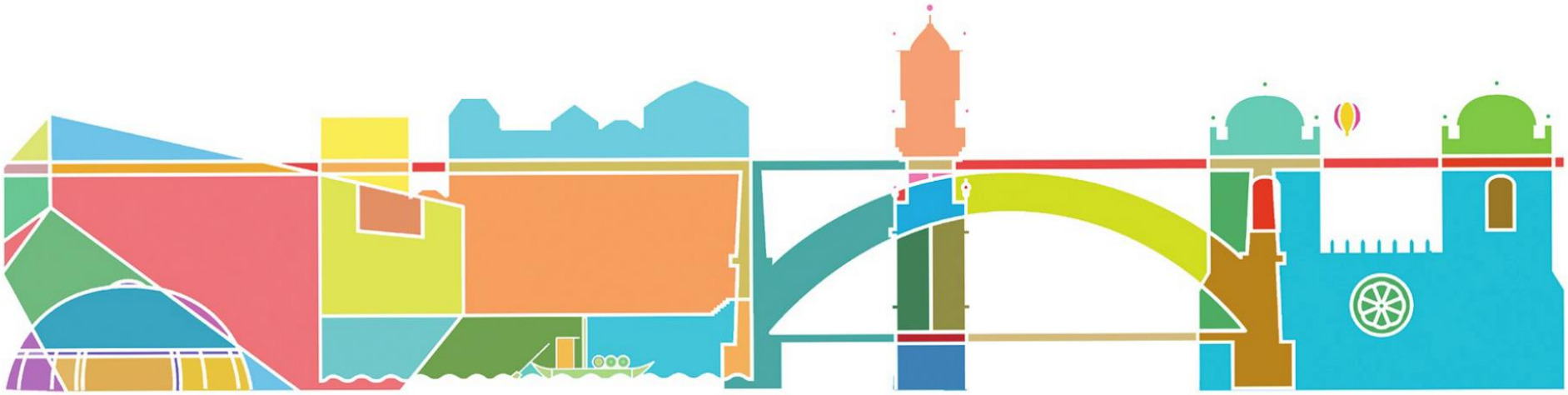
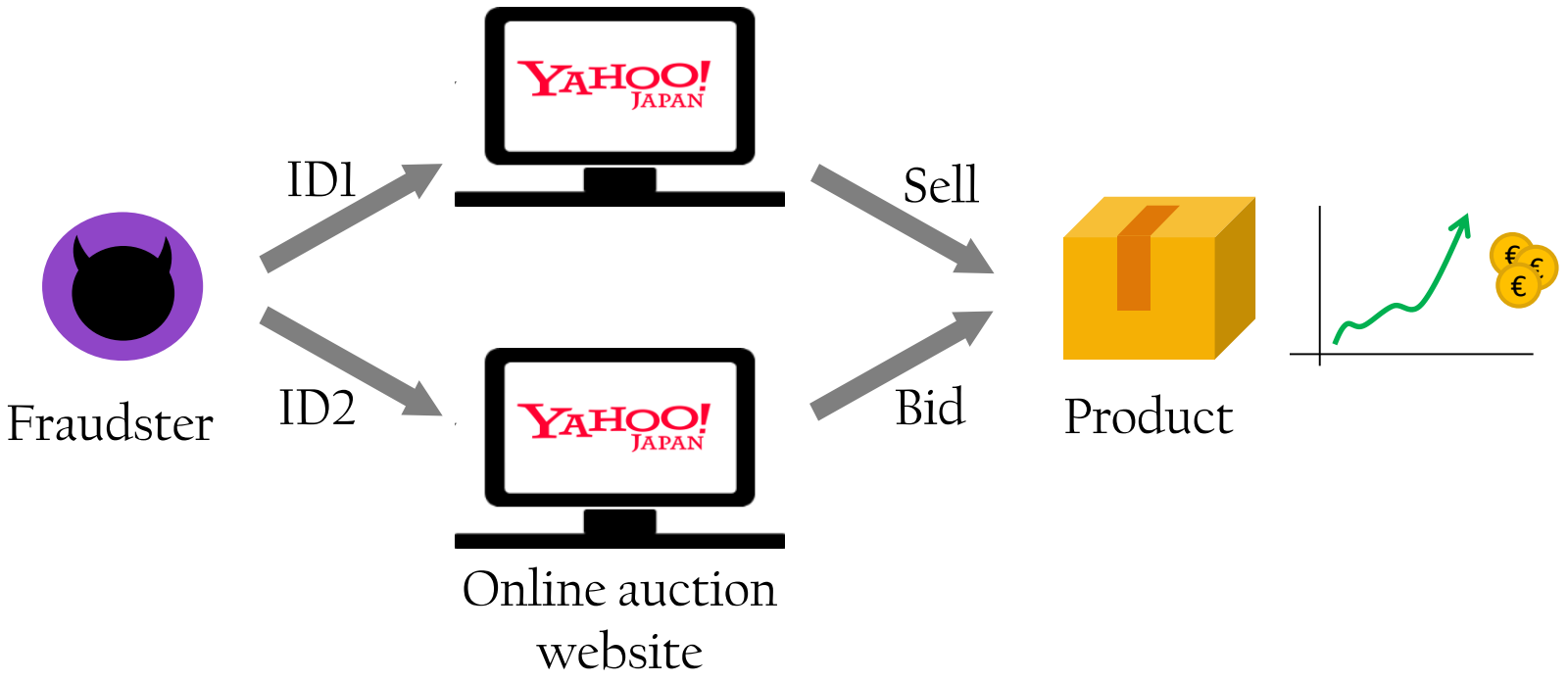


Definition of Fraudster

Competitive Shilling

auction users who bid on their product, as other user IDs, in order to drive up the final price.



Key Ideas

Fraudsters

- frequently participate in auctions hosted by fraudulent sellers working in a same group

Innocents

- rarely interact with fraudsters
- frequently interact with famous sellers

  or

  uniformly interact with various sellers

Key Ideas

Fraudsters

Innocents

- frequently participate in auctions hosted by fraudulent sellers working in a same group

Homophily

- rarely interact with fraudsters
- frequently interact with famous sellers

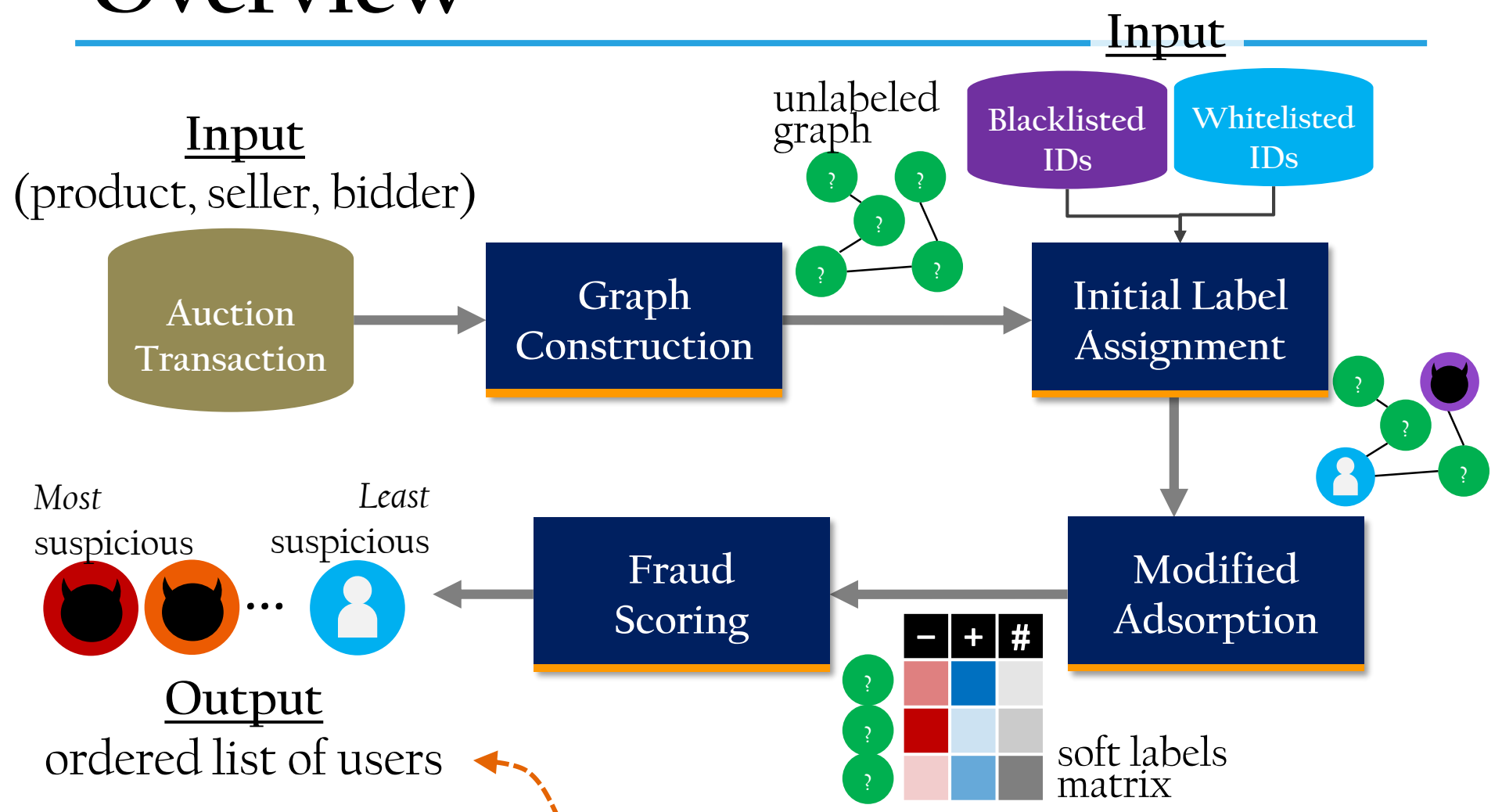
or

Uniformly interact with various sellers

Contributions

1. Novel application of Modified Adsoprtion (MAD) [Talukdar & Crammer, ECMLPKDD'09]
   - Have been previously used in NLP
   - **H**omophily: smoothness constraint
   - **U**niformity of **innocents**: dummy label
2. Incorporate weighted degree centrality
   - Fraudsters tend to form very strong ties.
   - Help us to yield better results

Overview

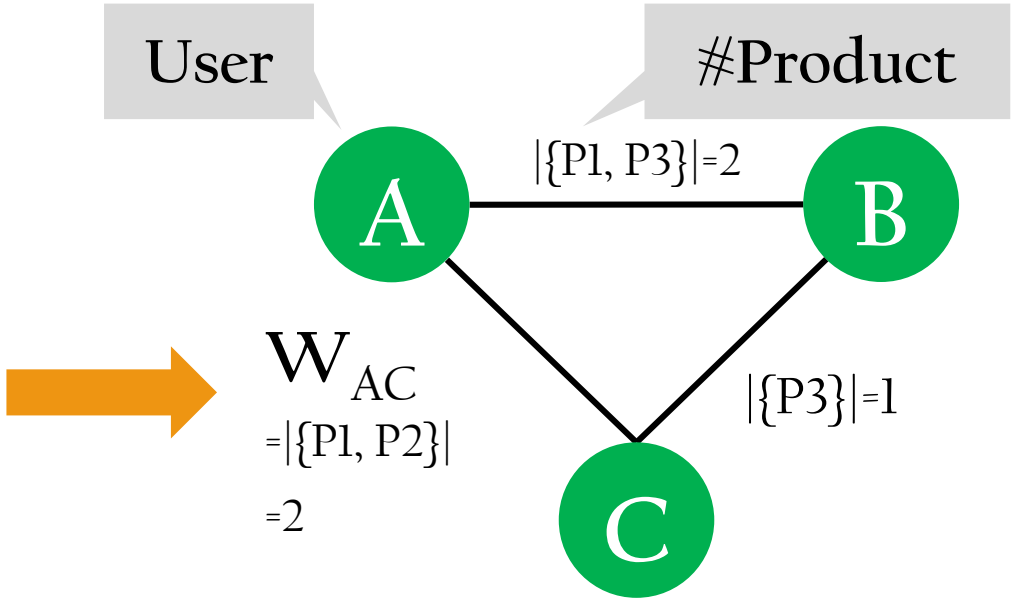


Objective: Fraudsters working in the same collusion with the blacklisted users are ranked at the top.

Graph Construction

Product	Seller	Bidder
P1	A	B
P1	A	C
P2	A	C
P3	B	A
P3	B	C
P3	B	C
P3	B	C

Online auction transaction

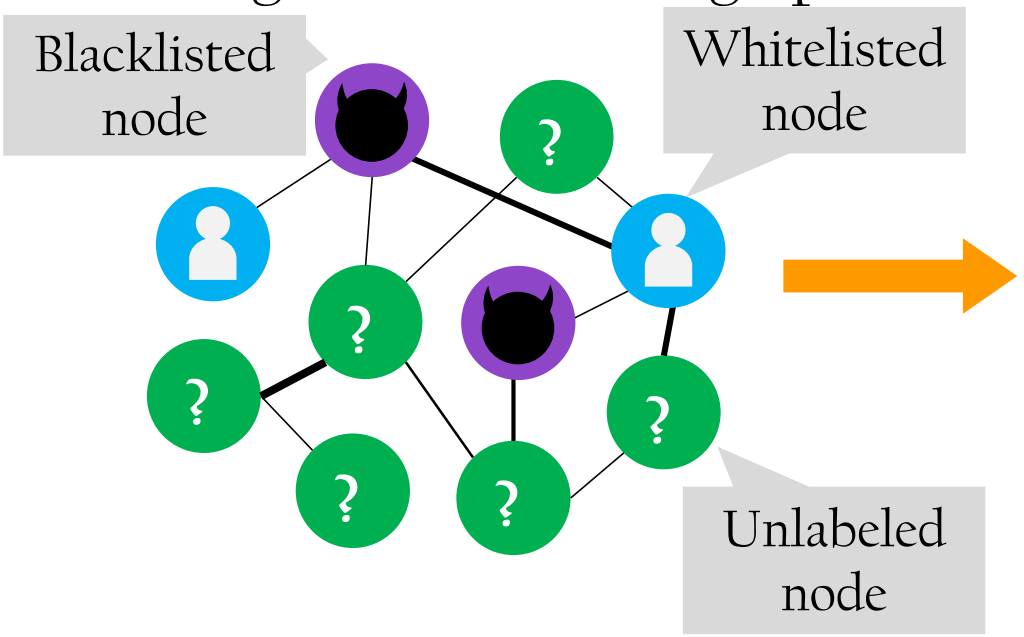


Weighted undirected graph

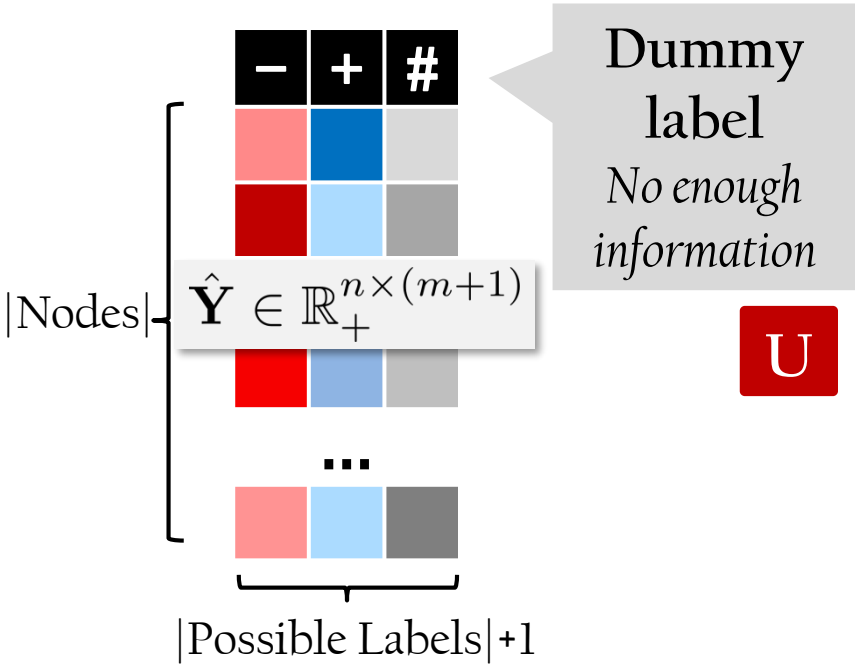
Graph-based SSL

Modified Adsorption (MAD) [Talukdar & Crammer,'09] is used.

Input: partially labeled weighted undirected graph



Output: soft label matrix



Node: instance that want to classify
Edge: similarity between instances

Assign a score indicating likelihood of being each label (soft labels)

Dummy Label

- Exceptional case of all other labels

Entropy
Amount of uncertainty

$$\text{dummy}_v \sim -\sum_{u \in N(v)} \frac{\mathbf{W}_{uv}}{k_w(v)} \log \frac{\mathbf{W}_{uv}}{k_w(v)}$$

Neighbors of vertex v

Weighted degree of vertex v

$$k_w(v) = \sum_{u \in N(v)} \mathbf{W}_{uv}$$

U

The score of dummy is high when the vertex uniformly interacts with its neighbors.

Modified Absorption (MAD)

Tradeoff between fitting and smoothness constraints

- Fitting: retain initial labels of seed nodes
- Smoothness: assign same labels to adjacent nodes

H

Solving the convex optimization problem

$$\min_{\hat{\mathbf{Y}}} \sum_{l \in \mathcal{L}} \left[\mu_1 (\mathbf{Y}_l - \hat{\mathbf{Y}}_l)^\top \mathbf{S} (\mathbf{Y}_l - \hat{\mathbf{Y}}_l) + \mu_2 \hat{\mathbf{Y}}_l^\top \mathbf{L} \hat{\mathbf{Y}}_l + \mu_3 \left\| \hat{\mathbf{Y}}_l - \mathbf{R}_l \right\|^2 \right]$$

Fitting Smoothness Regularization

where $\hat{\mathbf{Y}}$ is a matrix storing scores of labels (soft label matrix)

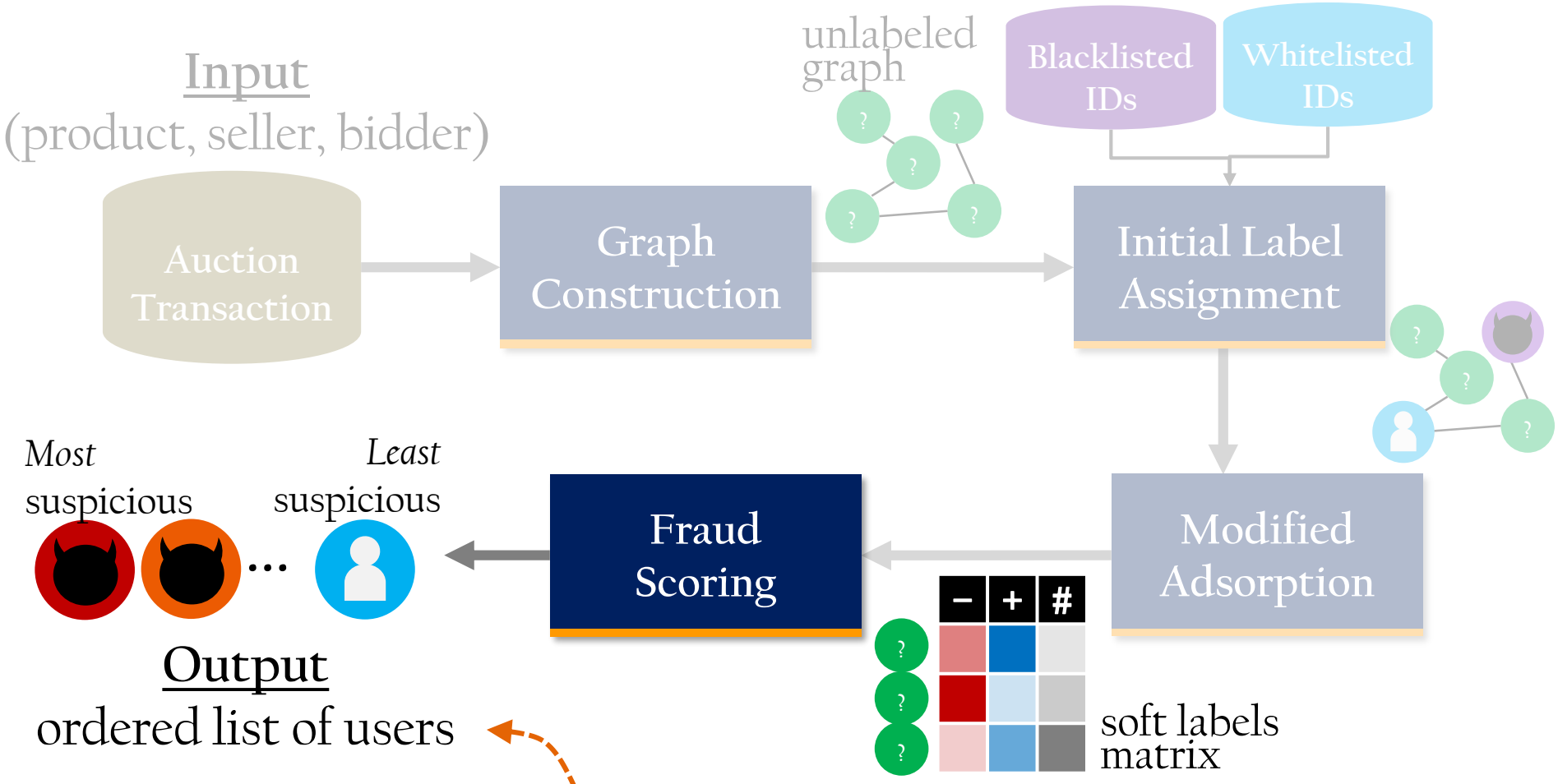
$\mathbf{Y}$ stores seed information

$\mathbf{S}$ indicates positions of seed vertices

$\mathbf{L}$ is the Laplacian matrix

$\mathbf{R}$ encodes scores of the dummy label and L^2 regularization.

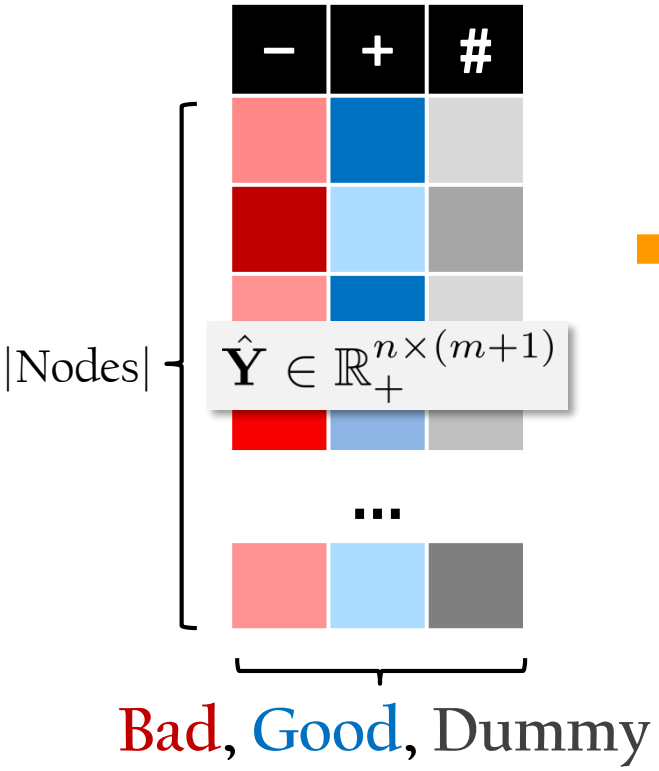
Overview (2)



Objective: Fraudsters working in the same collusion with the blacklisted users are ranked at the top.

Fraud Scoring

Input: soft label matrix



Output: fraud score of nodes

$$\varphi(v, \hat{\mathbf{Y}}) = \frac{\hat{\mathbf{Y}}_{v1}}{\sum_{l=1}^{m+1} \hat{\mathbf{Y}}_{vl}}$$

MAD

The ratio of Bad's score to total scores

Contributions

1. Novel application of Modified Adsoprtion (MAD) [Talukdar & Crammer, ECMLPKDD'09]
   - **H**omophily: smoothness constraint
   - **U**niform interaction of innocents: dummy label
2. Incorporate weighted degree centrality (WDC)
   - Fraudsters form very strong ties.

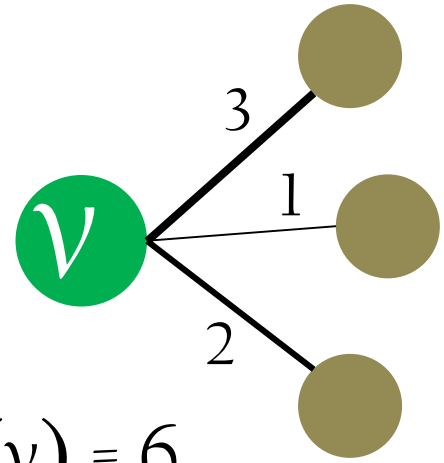
Weighted Degree Centrality (WDC)

Weighted degree centrality of vertex *v* is the total weights of edges originating from *v*

$$k_w(v) = \sum_{u \in N(v)} \mathbf{W}_{uv}$$

Neighbors of *v*

Weight of an edge (*u*,*v*)

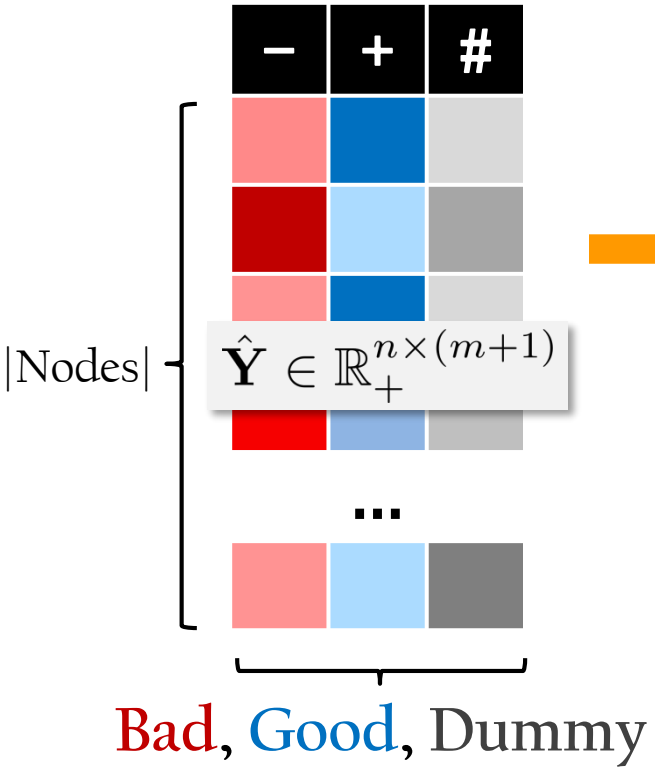


$k_w(v) = 6$

Fraudsters tend to have higher *weighted degree centralities because of stronger ties.*

Fraud Scoring + WDC

Input: soft label matrix



Output: fraud score of nodes

$$\rho(v, \hat{\mathbf{Y}}) = \varphi(v, \hat{\mathbf{Y}}) + \frac{\gamma}{|N(v)|} \sum_{u \in N(v)} \mathbf{W}_{uv}\, \varphi(u, \hat{\mathbf{Y}})$$

2-STEP

Neighbors of vertex *v*

Weight of an edge (*u*,*v*)

$$\varphi(v, \hat{\mathbf{Y}}) = \frac{\hat{\mathbf{Y}}_{v1}}{\sum_{l=1}^{m+1} \hat{\mathbf{Y}}_{vl}}$$

MAD

Experiments

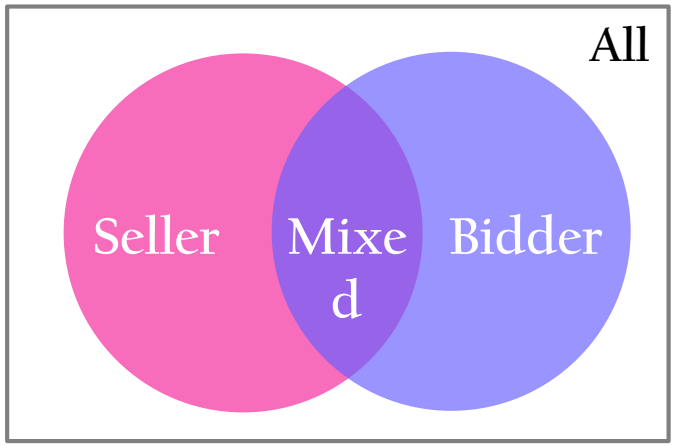
- Questions
  1. Does the dummy label help?
  2. Comparison with unsupervised methods
  3. Comparison with a state-of-the-art Sybil defense method
- Evaluation metric

  Used normalized discounted cumulative gain (NDCG) to compare results with the blacklisted users

  Higher NDCG is better.

Dataset

- Real-world dataset from YAHUOKU[1]
  - The largest online auction site in Japan
  - Operated by Yahoo! Japan
- Auction transaction
  - ≈ 16 million transactions
  - ≈ 2 million users
  - ≈ 550 blacklisted users
  - ≈ 10,000 whitelisted users



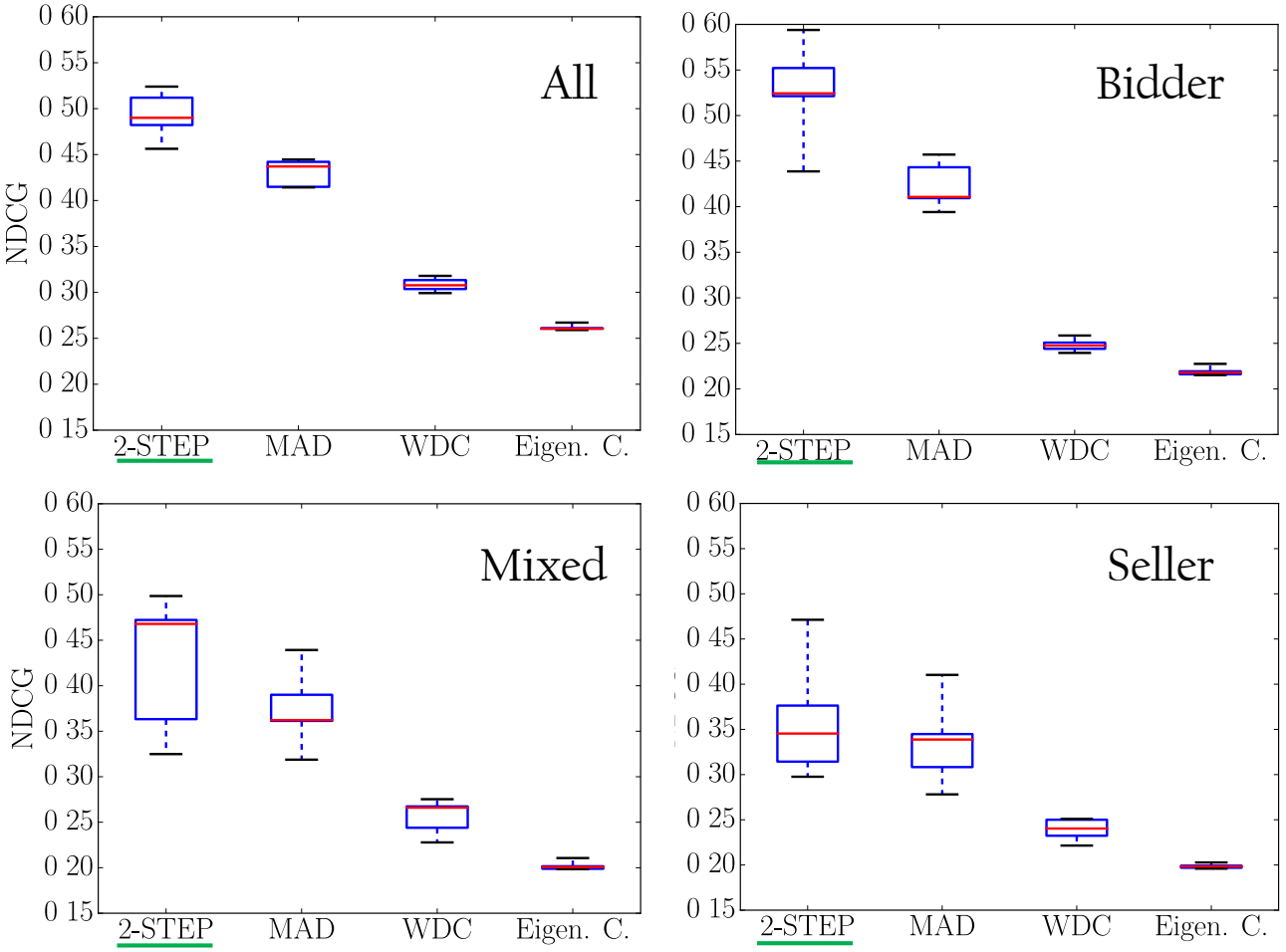
[1] auctions.yahoo.co.jp/

With VS Without Dummy Label

Node type	with dummy		w/o dummy	
	‹NDCG›	SD	‹NDCG›	SD
All	0.431	0.015	0.406	0.019
Bidder	0.423	0.026	0.397	0.035
Seller	0.336	0.049	0.284	0.029
Mixed	0.374	0.044	0.319	0.024

- Dummy label has a true advantage.
- Support the key idea that innocents tend to interact with neighbors uniformly

Proposed VS Unsupervised



Compare with
1) Weighted degree centrality (WDC)
2) Eigenvector centrality (Eigen. C.)

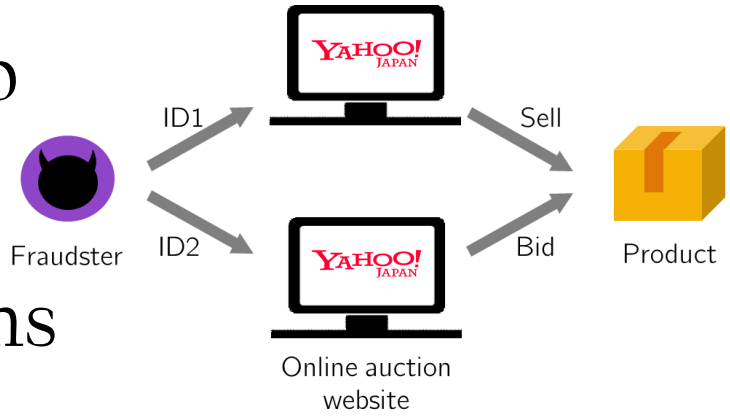
2-STEP method outperforms MAD.

Unsupervised methods yield poor results.

Fraudulent sellers are more difficult.

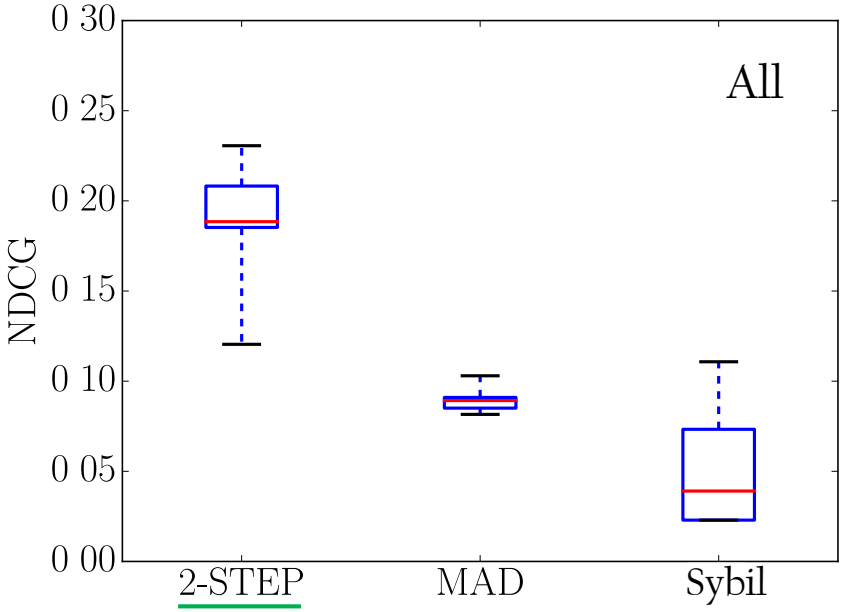
Sybil Defense Method

- Sybil: malicious attackers who
  - create multiple identities
  - influence working of systems

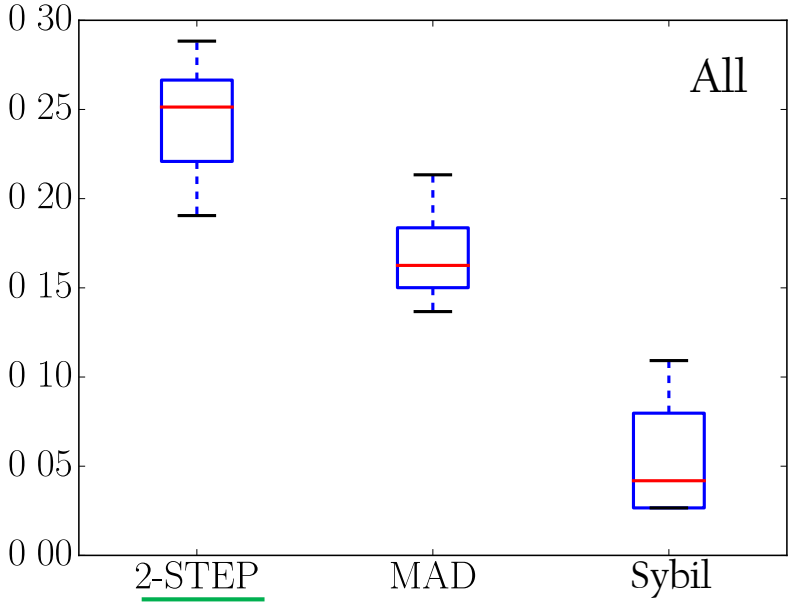


- Shill bidders are one type of Sybil
- We compared our method with a state-of-the-art Sybil defense method [Viswanath et al., SIGCOMM'10]
  - On basis of community detection

Proposed VS Sybil



Calculated from top 100



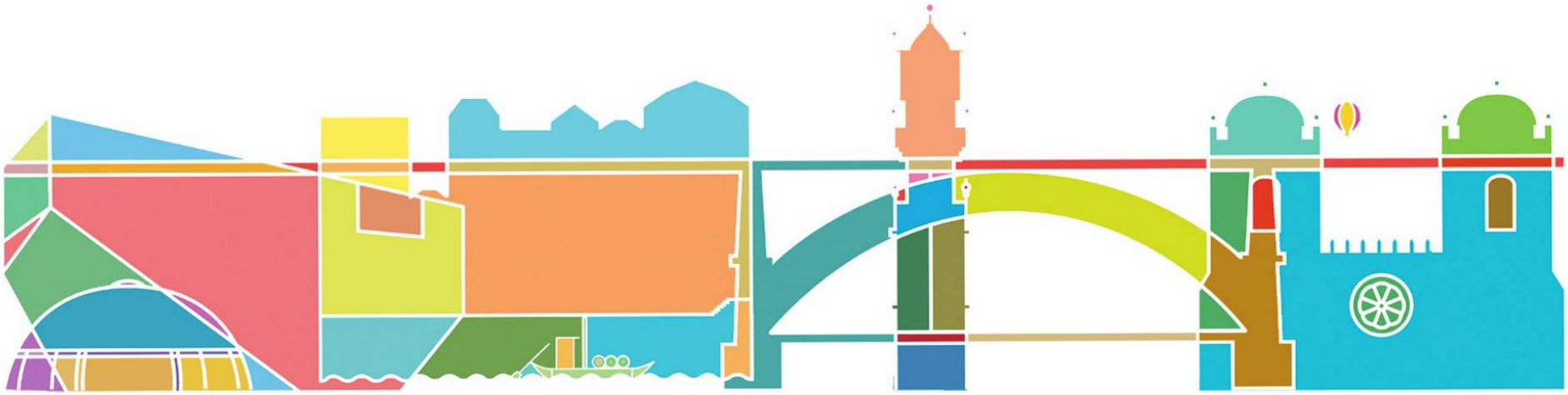
Calculated from top 500

- Our method outperforms the state-of-the-art Sybil defense method.
- Fraudsters and innocents may not form well-established communities.

Conclusion

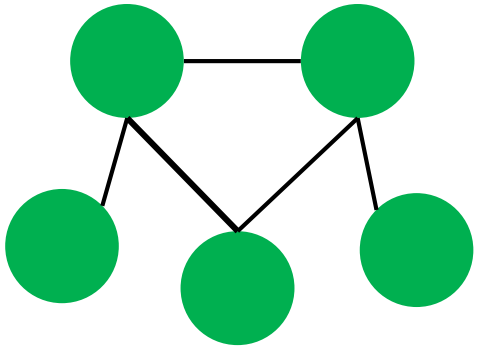
- Proposed an online auction fraud detection approach
- Motivated by two main ideas
  - **U**niformity of innocents
  - **H**omophily
    - Fraudsters tend to have higher WDCs.
- Incorporated WDC to the method
- Our extended method yields better results.

Thank you

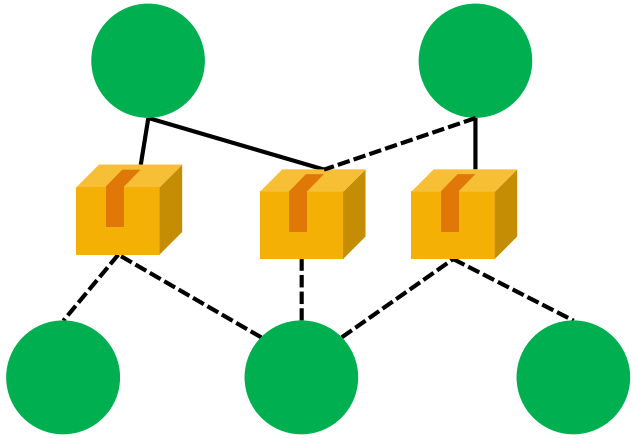


Future Works

- Study limitation of the method
- Incorporate other heuristics
  - Bidding strategy
  - Value of products
- Extend the method to heterogeneous network



Homogeneous network



Heterogeneous network

Scalability

- The optimization process of MAD can be parallelized in MapReduce framework.
  - Map: sends its current label to neighbors
  - Reduce: update its label information
- Hadoop-based implementation is available.
  - Junto Label Propagation Toolkit: https://github.com/parthatalukdar/junto/