Actionable Objective Optimization for Suspicious Behavior Detection on Large Bipartite Graphs

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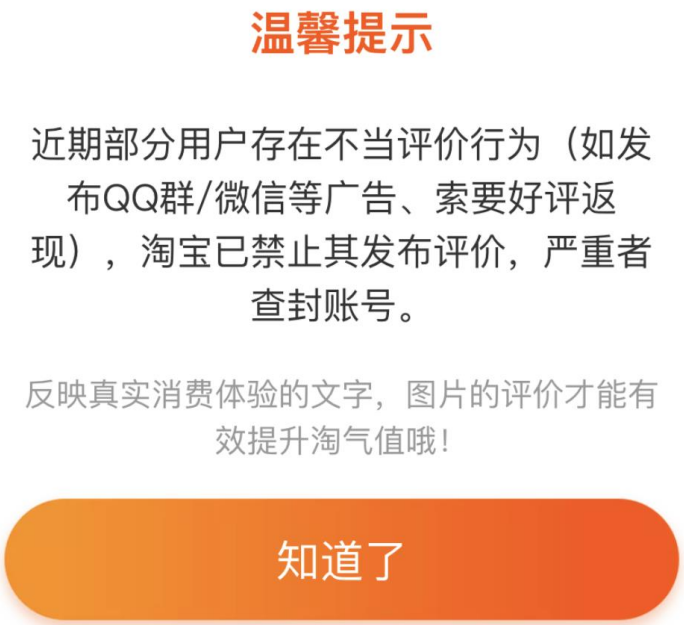
Suspicious Behavior on Bipartite Graph

- Bot followers in social networks.
- Bully buyers in e-commercial platforms.



Notice:
Recently, there are some customers making improper evaluations and comments like posting ads or asking for cashbacks. Taobao.com has banned them from posting any comments.

Suspicious Behavior on Bipartite Graph

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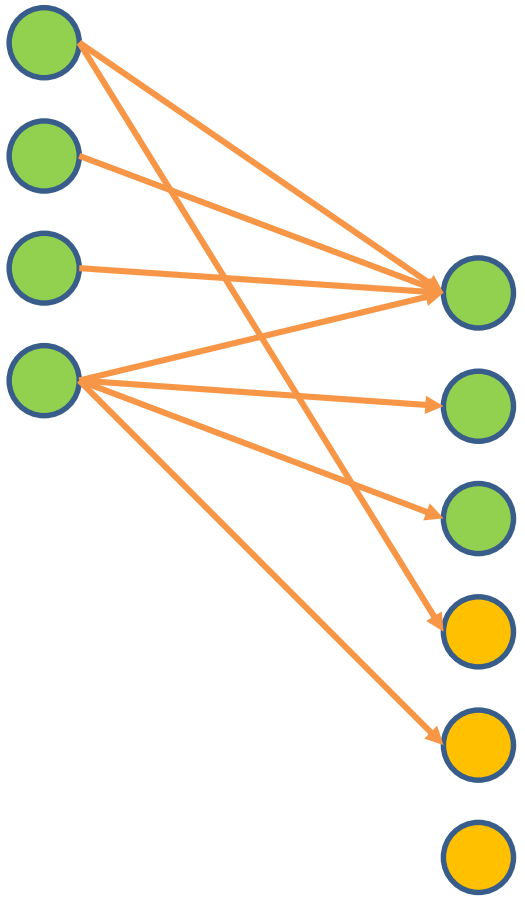
- Bot followers in social networks.
- Bully buyers in e-commercial platforms.

- Behavior: source users $\longrightarrow$ target users.
- Source users: followers, buyers.
- Target users: followees, sellers.

Key Observation/Assumption

- Fraudsters' avoiding effort forms dense blocks.



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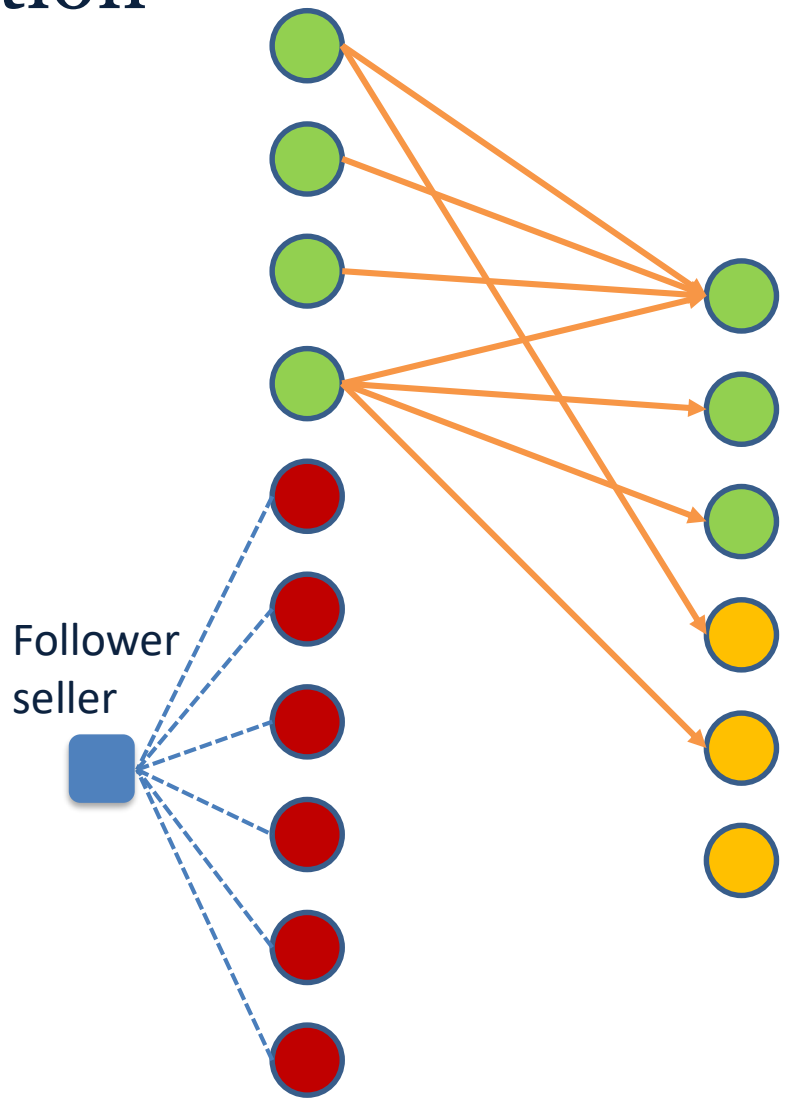

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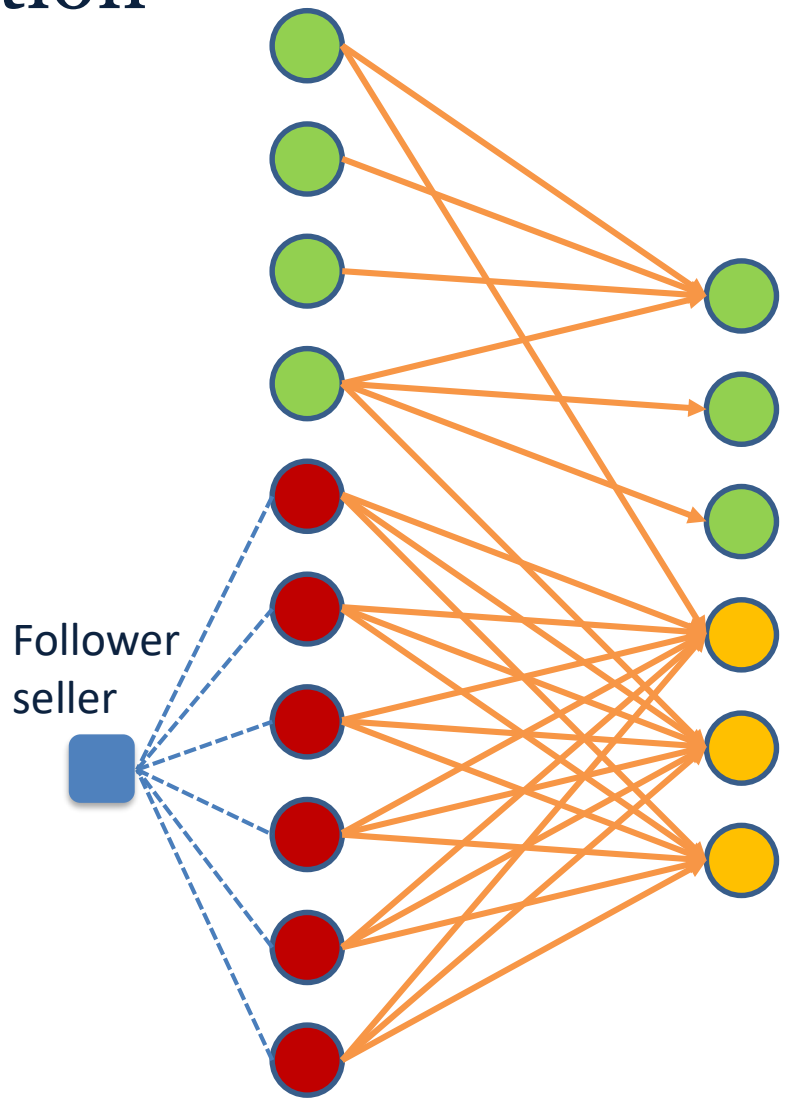
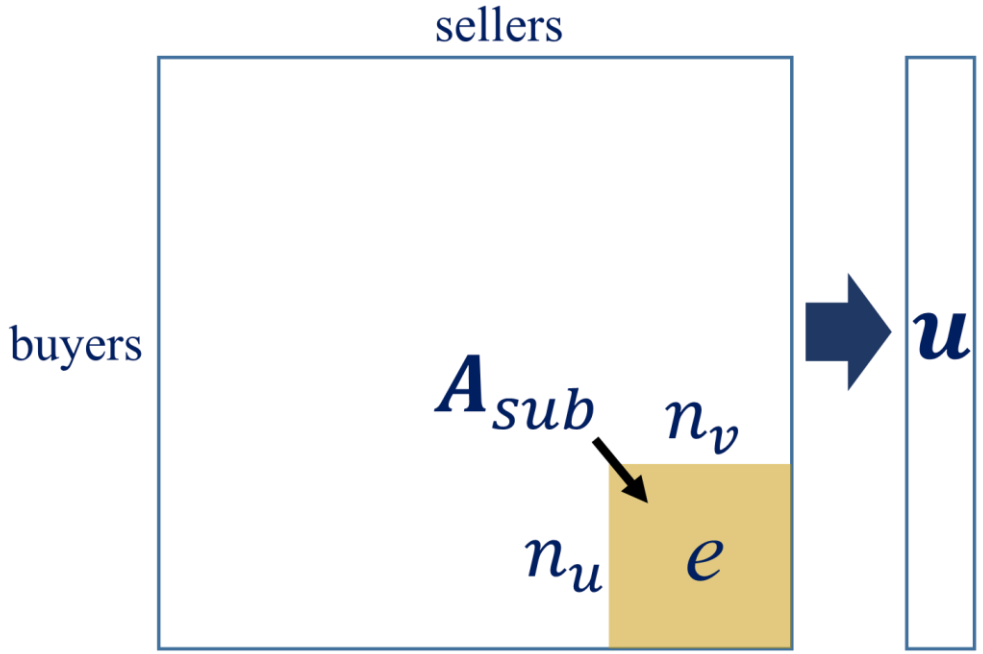


Existing Methods

- Find a dense subgraph.
- Find the suspiciousness vector $\boldsymbol{u}$.

$$\max_{u} J(\boldsymbol{A}_{sub}(\boldsymbol{u})) \quad (1)$$

$$J(A_{sub}) = \frac{e}{n_u \times n_v} \quad (2)$$



Does it work?

- Yes but **NOT Actionable**!

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- Yes but **NOT Actionable**!
- Serious consequence of false positive.
  - An important email is thrown into spam.
  - A normal Twitter/Taobao account is banned.
- Double check the reported suspicious users?

Large size of data.

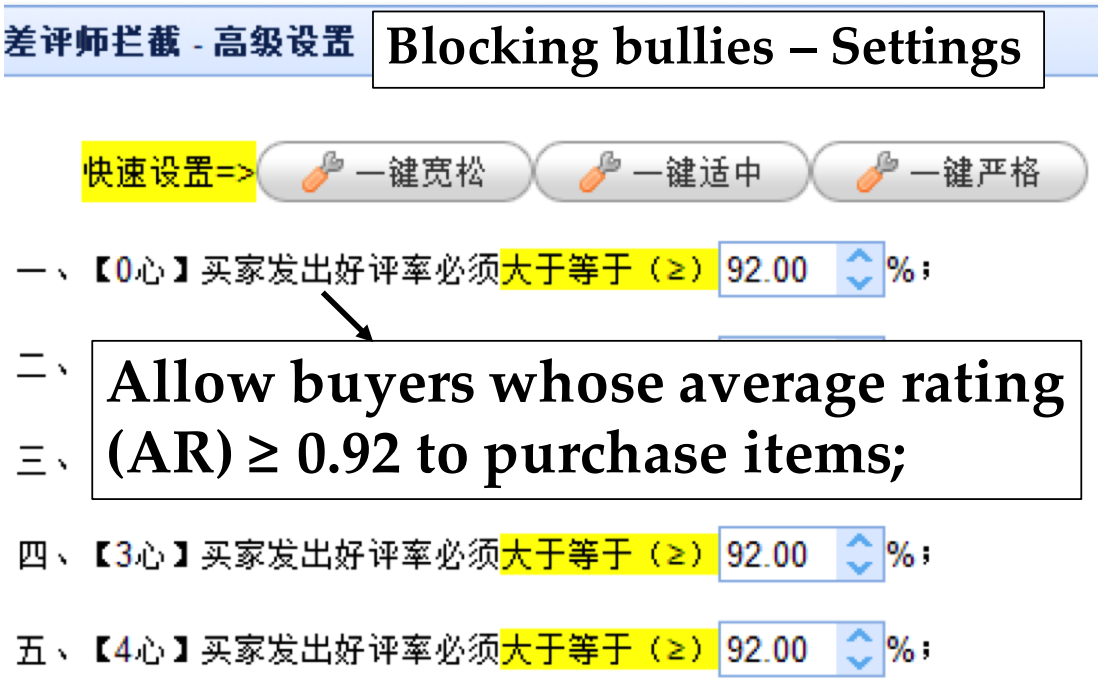
- Heavy human labor.

What is actionable?

- Blocklist function

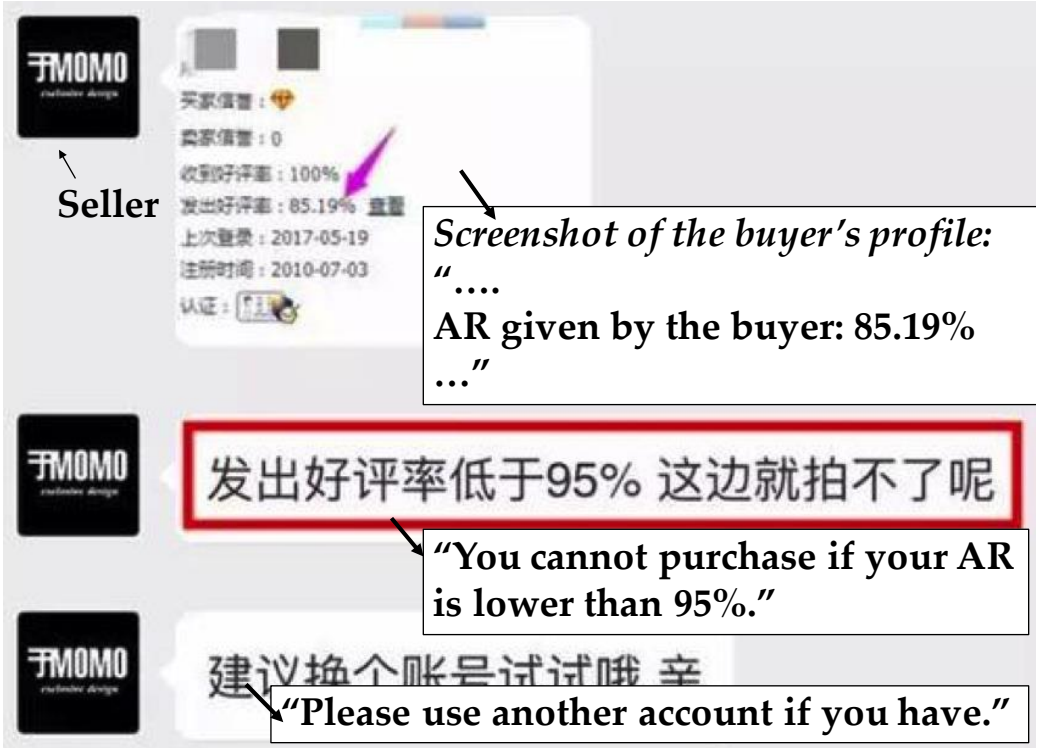
What is actionable?

- Blocklist function
- Blocking plug-ins.

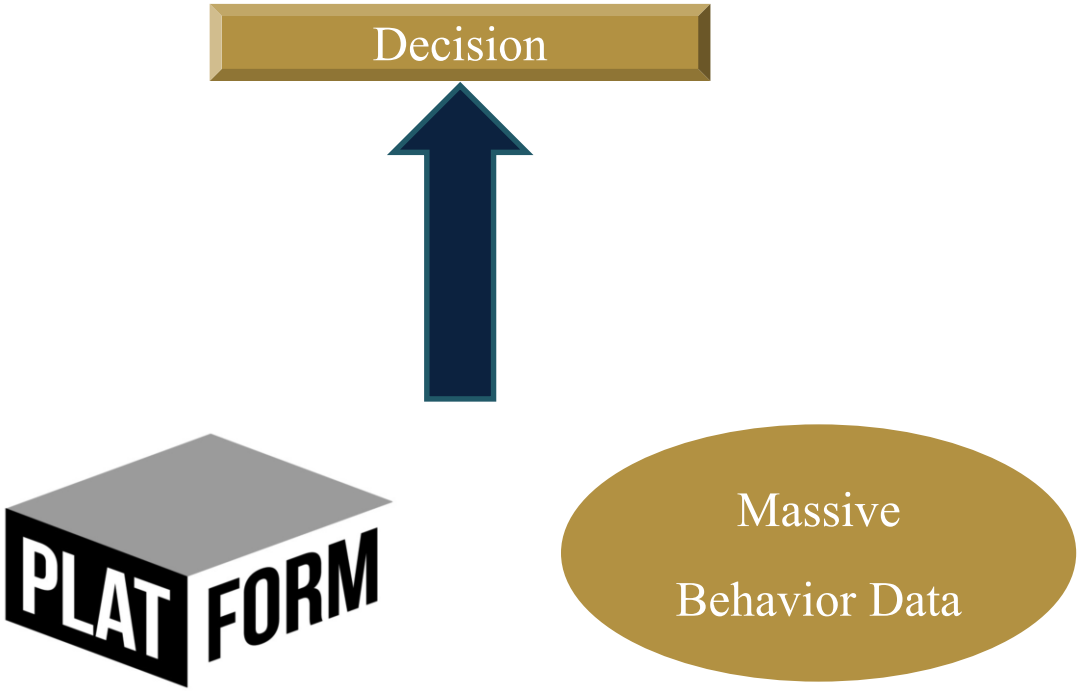


What is actionable?

- Blocklist function
- Blocking plug-ins.



Observation



Observation

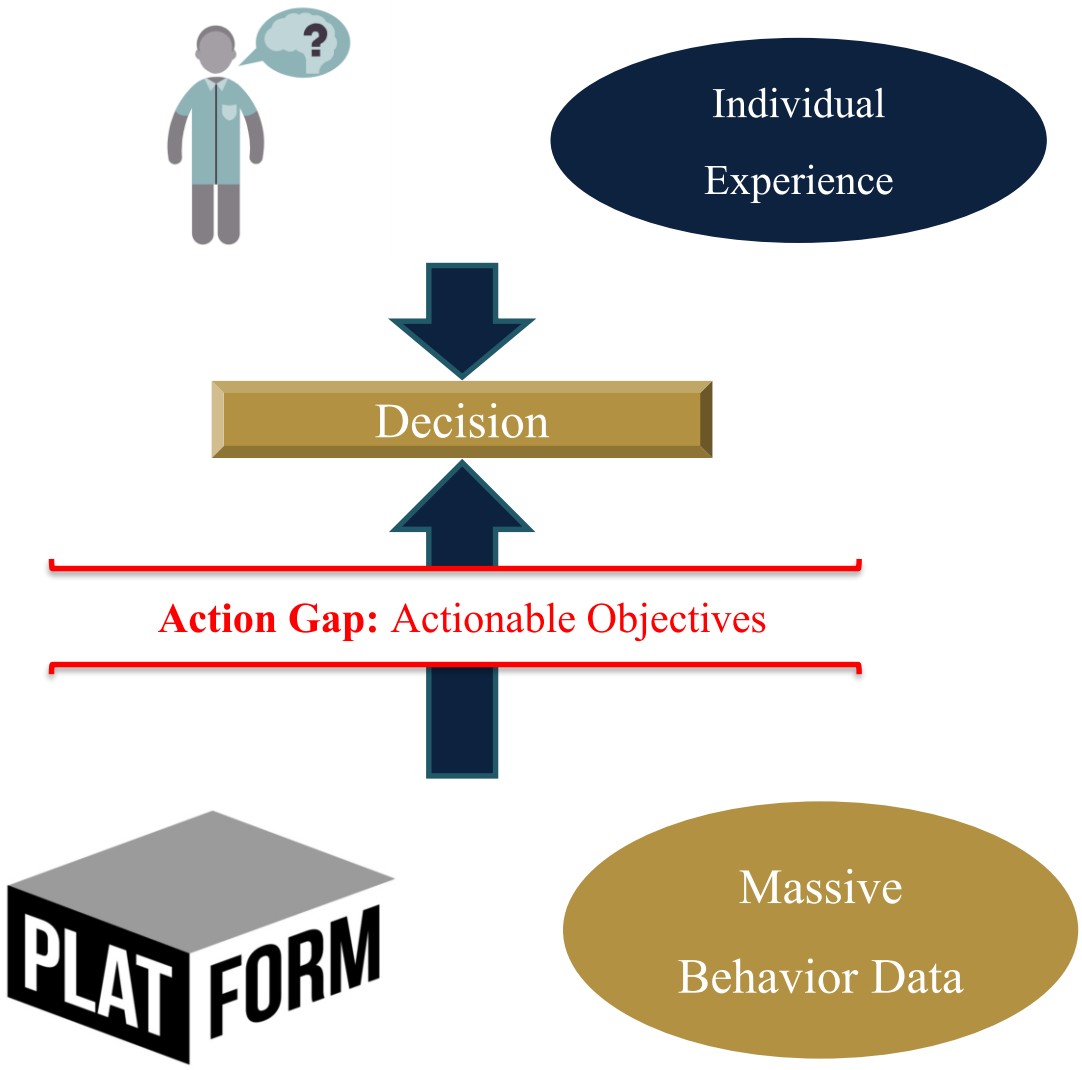
Individual Experience

Decision

PLAT FORM

Massive Behavior Data

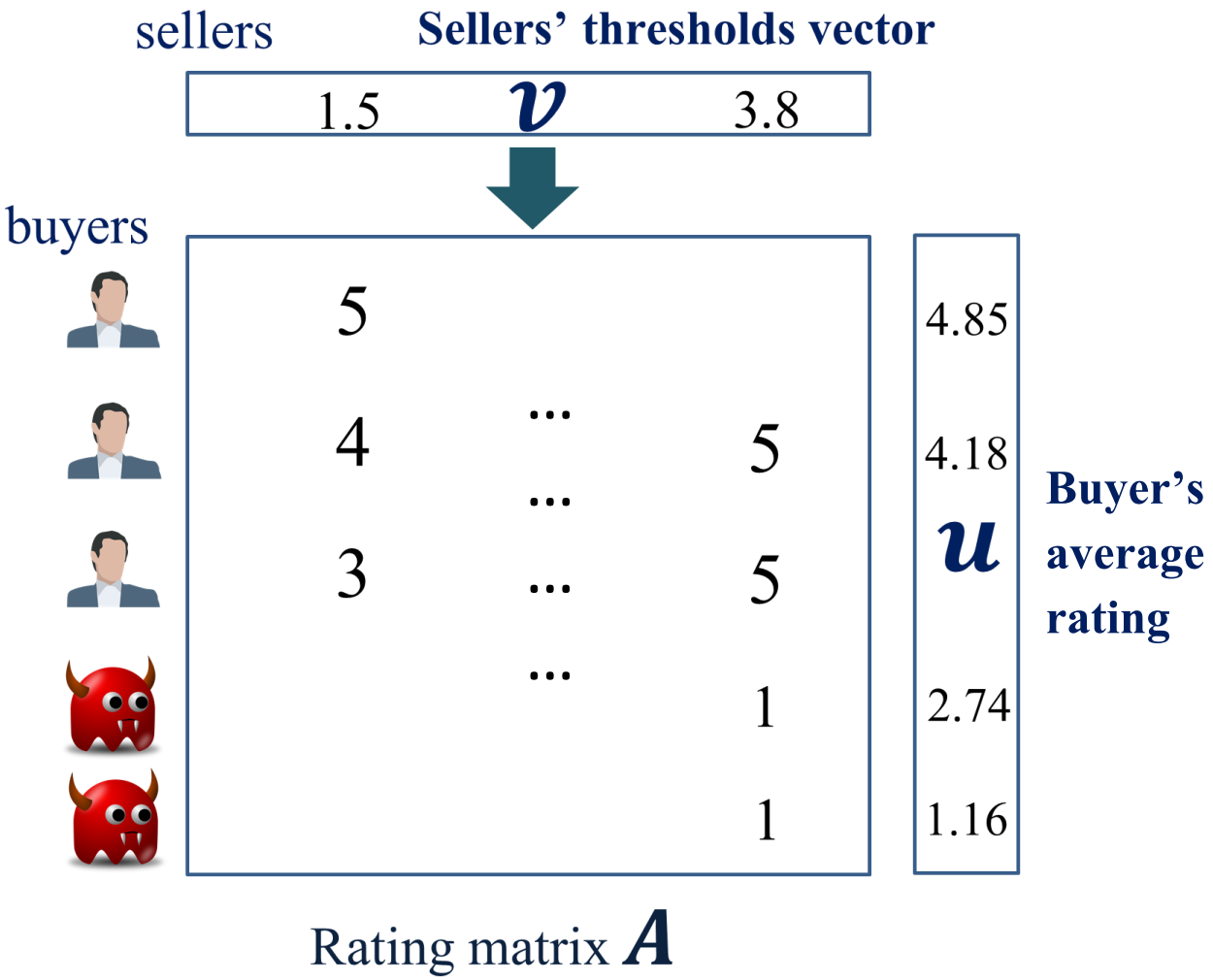
The Gap


?
Individual
Experience
Decision
Action Gap: Actionable Objectives
PLAT FORM
Massive
Behavior Data

Our Idea


sellers
buyers
5
4
3
1
1
4.85
4.18
u
2.74
1.16
Buyer's average rating
Rating matrix A

Our Idea


sellers
Sellers' thresholds vector
1.5
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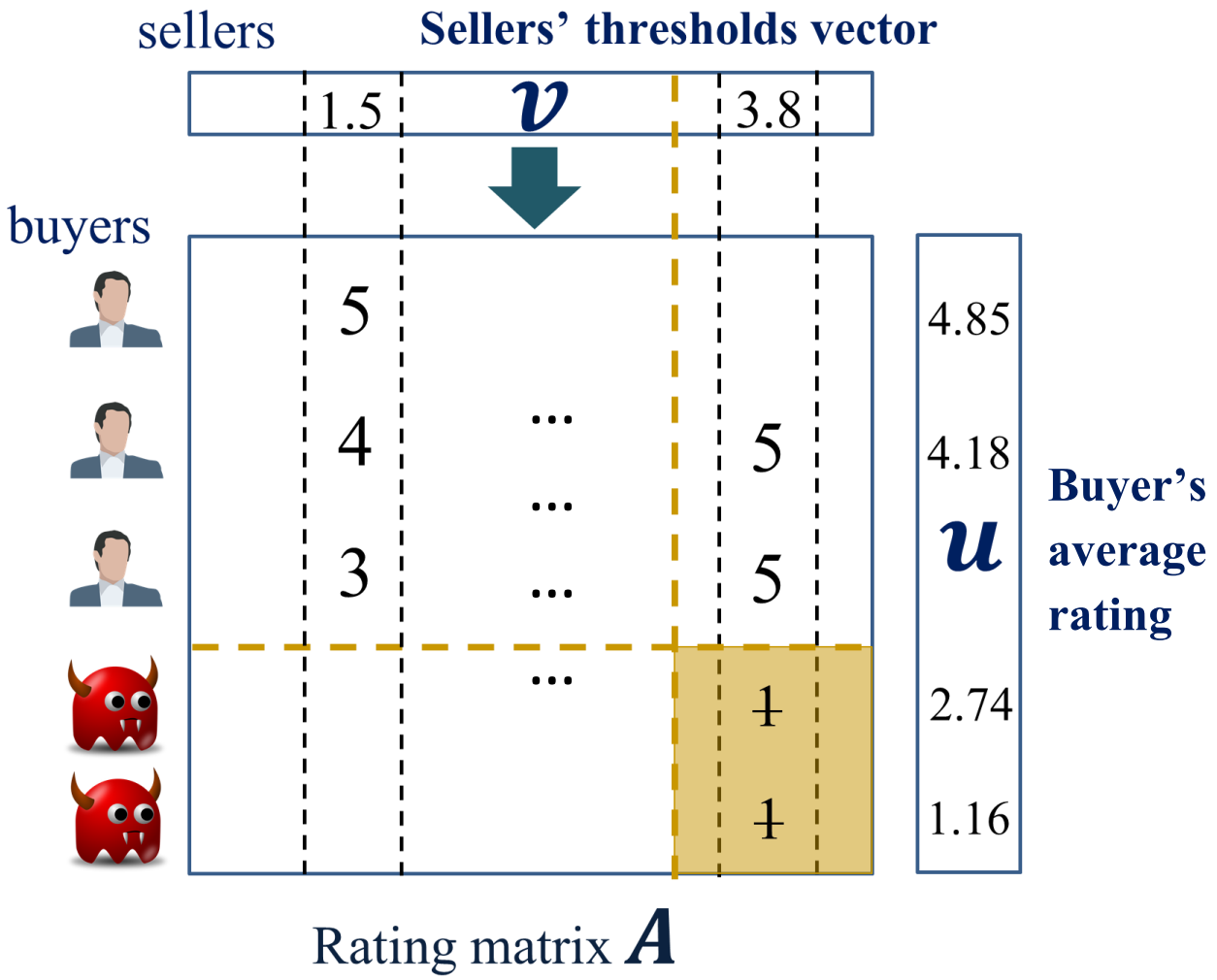
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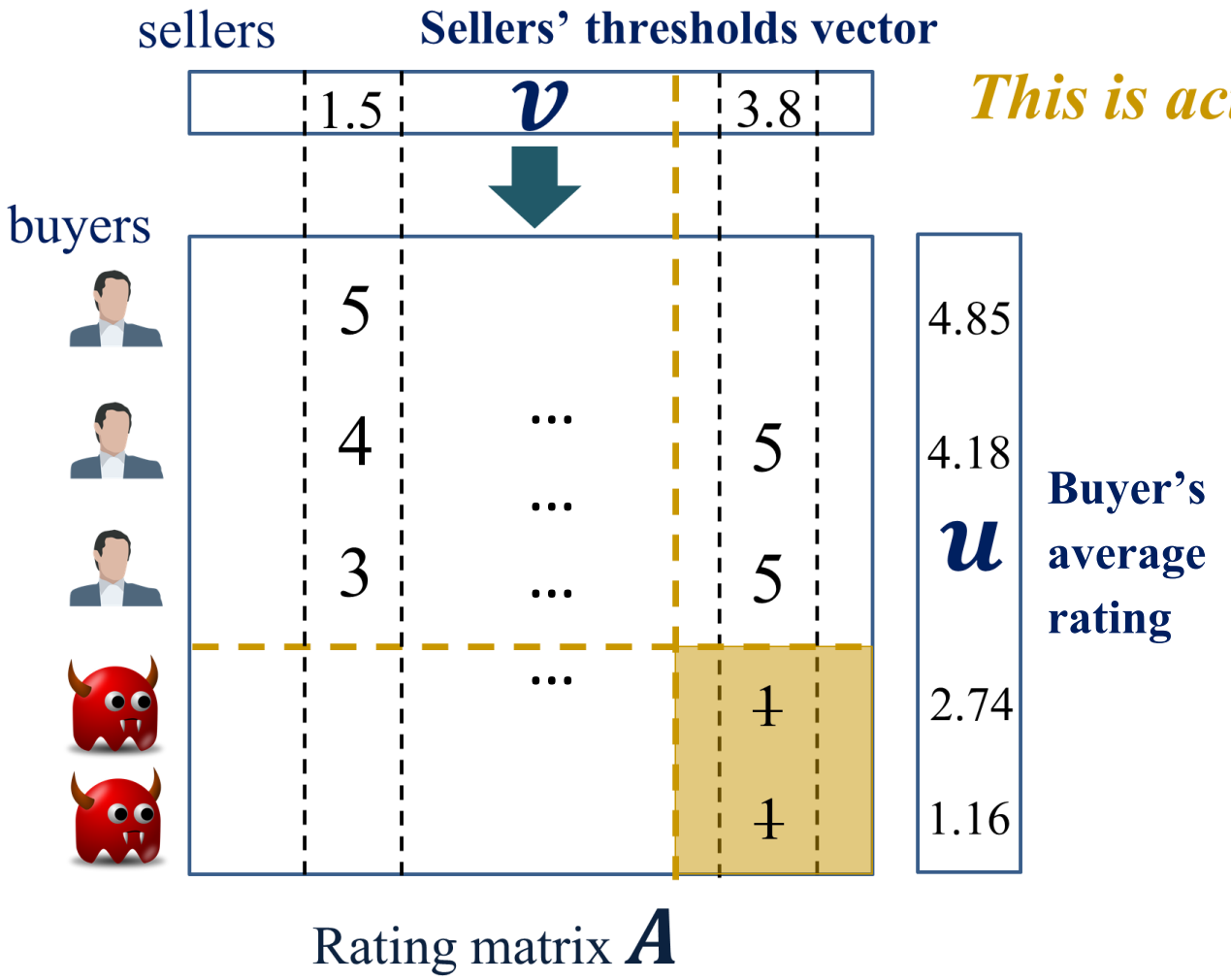
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This is actionable!
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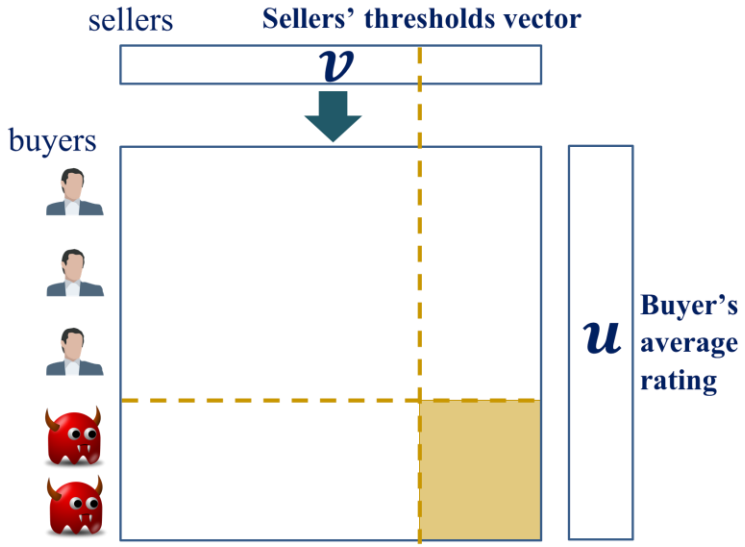
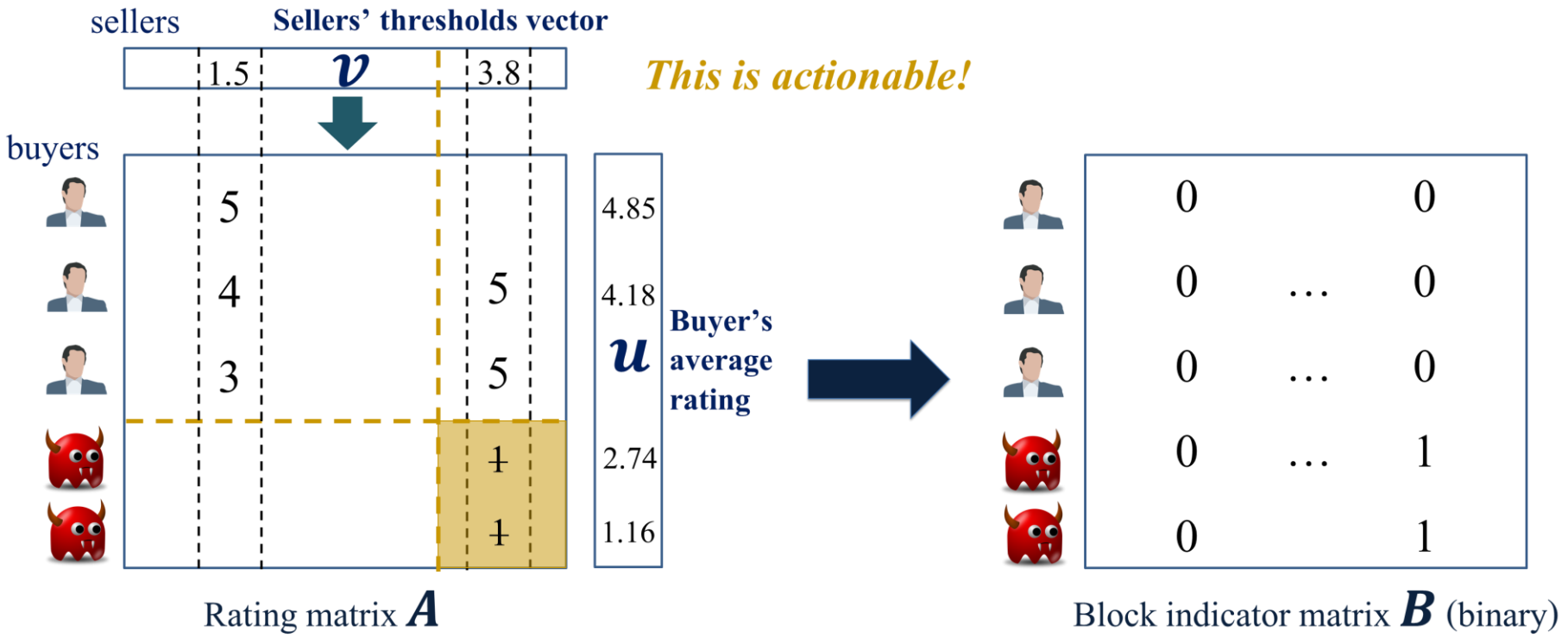
Our Idea

- Use **platform's big data**.
- Learn the best **threshold for everyone**.
- Actionable Objective Optimization (AOO): find the threshold vector $\boldsymbol{v}$.



AOO



$$B_{ij} = \begin{cases} 1, & if\ I_{ij} = 1\ and\ u_i < v_j; \\ 0, & otherwise. \end{cases} \quad (3)$$

AOO

- Calculate the indicator vectors.

$$c^{(u)} = \mathbf{B} \cdot \mathbf{1}_m \tag{4}$$

$$c^{(v)} = \mathbf{B} \cdot \mathbf{1}_n \tag{5}$$

$$s_i^{(u)} = \begin{cases} 1, & if\ c_i^{(u)} \geq \beta^{(u)}; \\ 0, & otherwise. \end{cases} \tag{6}$$

$$s_j^{(v)} = \begin{cases} 1, & if\ c_j^{(v)} \geq \beta^{(v)}; \\ 0, & otherwise. \end{cases} \tag{7}$$

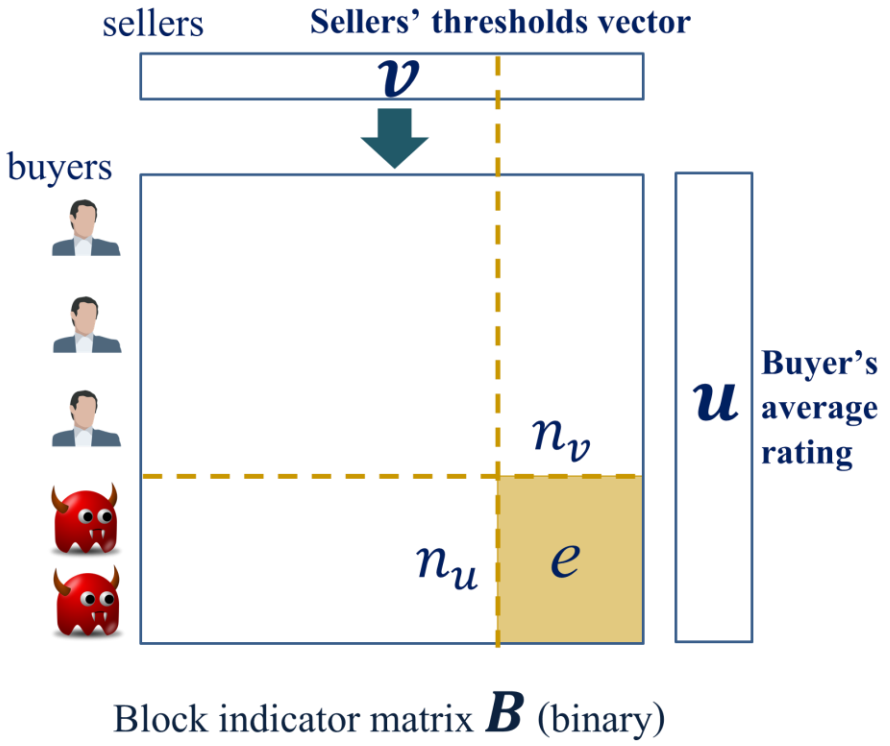
AOO

- Find the size and sum of the block.

$$n_u = \mathbf{1}_n^T \cdot s^{(u)} \quad (8)$$

$$n_v = \mathbf{1}_m^T \cdot s^{(v)} \quad (9)$$

$$e = s^{(u)^T} \cdot \mathbf{B} \cdot s^{(v)} \quad (10)$$



AOO

- Objective function that we want to maximize.

$$J_d(\boldsymbol{v}) = \frac{e}{n_u \times n_v} \tag{11}$$

$$= \frac{s^{(u)^T} \cdot \mathbf{B} \cdot s^{(v)}}{(\mathbf{1}_n^T \cdot s^{(u)})(\mathbf{1}_m^T \cdot s^{(v)})} \tag{12}$$

AOO

- Find the partial derivatives with respect to $\boldsymbol{v}$.

$$\frac{\partial J_d}{\partial v_k} = \frac{1}{n_u n_v}\frac{\partial e}{\partial v_k} - \frac{e}{n_u^2 n_v}\frac{\partial n_u}{\partial v_k} - \frac{e}{n_u n_v^2}\frac{\partial n_v}{\partial v_k} \tag{13}$$

$$\frac{\partial n_u}{\partial v_k} = \sum_{i=1}^{n}\sum_{j=1}^{m}\frac{\partial n_u}{\partial B_{ij}}\frac{\partial B_{ij}}{\partial v_k} \tag{14}$$

$$= \alpha^2 \sum_{i=1}^{n} s_i^{(u)}\left(1 - s_i^{(u)}\right) B_{ik}(1 - g(v_k - u_i)) \tag{15}$$

AOO

$$\frac{\partial n_v}{\partial v_k} = \sum_{i=1}^{n}\sum_{j=1}^{m}\frac{\partial n_v}{\partial B_{ij}}\frac{\partial B_{ij}}{\partial v_k} \tag{16}$$

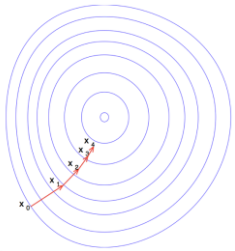
$$= \alpha^2 s_k^{(v)}(1 - s_k^{(v)})\sum_{i=1}^{n} B_{ik}(1 - g(v_k - u_i)) \tag{17}$$

$$\frac{\partial e}{\partial v_k} = \sum_{i=1}^{n}\sum_{j=1}^{m}\frac{\partial e}{\partial B_{ij}}\frac{\partial B_{ij}}{\partial v_k} \tag{18}$$

$$= \alpha^2 \sum_{i=1}^{n} s_i^{(u)}\left(1 - s_i^{(u)}\right)\sum_{q=1}^{m} B_{iq}s_q^{(v)} + n\alpha s_k^{(v)}\left(1 - s_k^{(v)}\right)\sum_{p=1}^{n} B_{pk}s_p^{(u)} + s_k^{(v)}\sum_{i=1}^{n} s_i^{(u)} \tag{19}$$

AOO

$J_d(\boldsymbol{v})$ and $\frac{\partial J_d}{\partial \boldsymbol{v}}$



Sellers' thresholds vector

$\boldsymbol{v}$

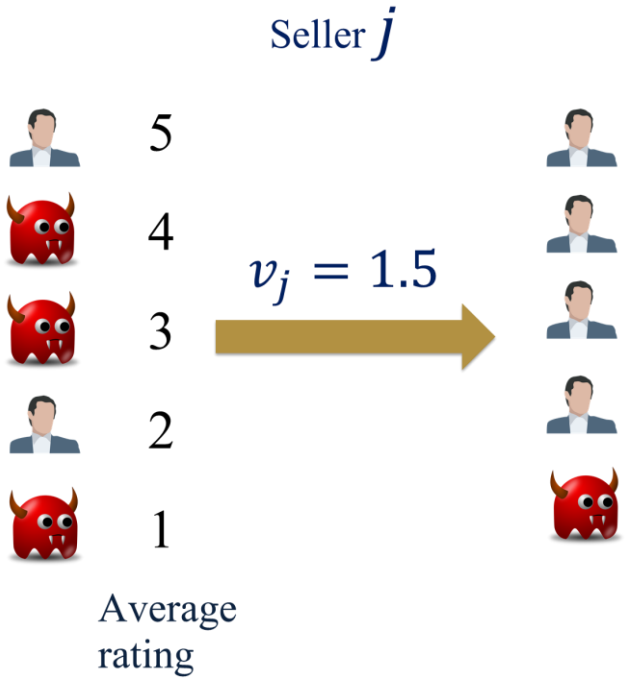
Each seller

Experiments

- On both synthetic datasets and real-world datasets.
- Baselines:
  - SpokEn (Prakash, et al., 2010)
  - CatchSync (Jiang, et al., 2014)
  - Fraudar (Hooi, et al., 2016)
  - Actionable version of each of them.

Actionable Version Baselines

Actionable Version Baselines



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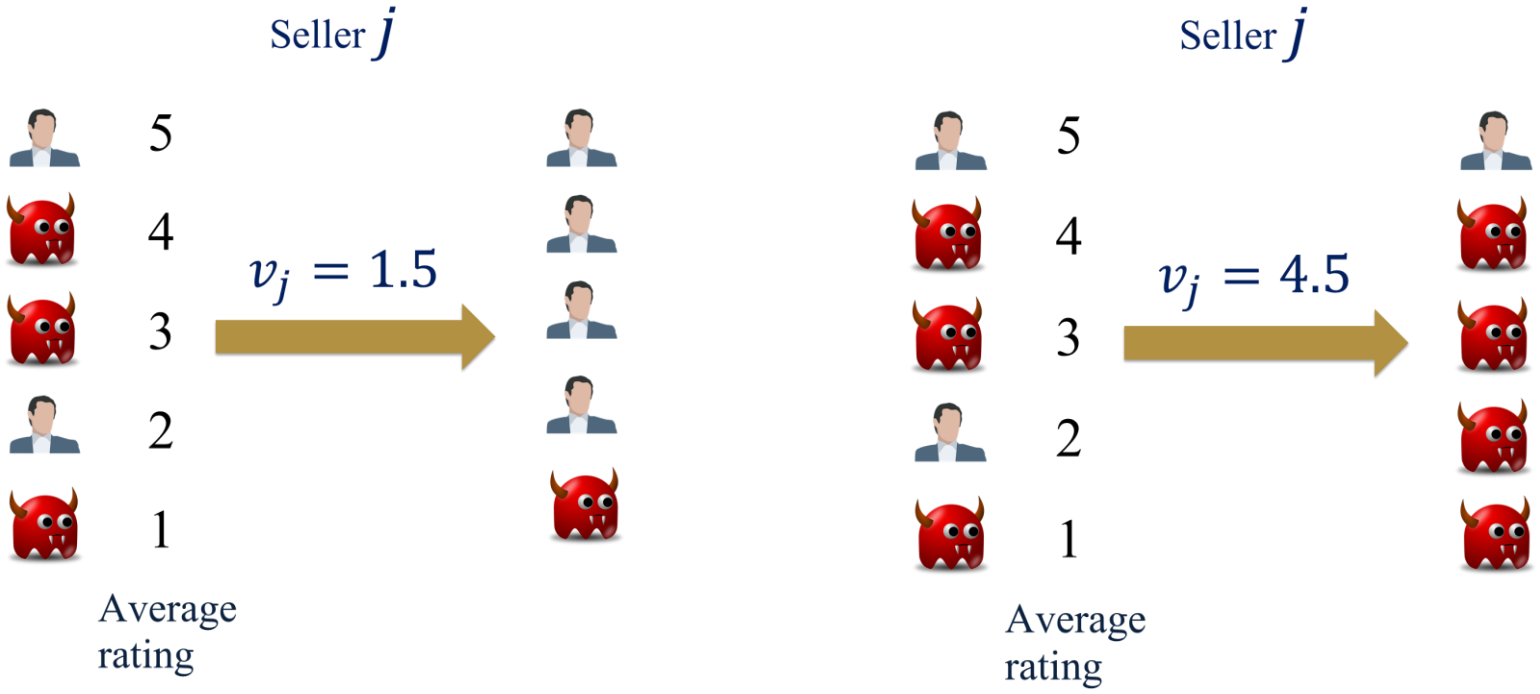
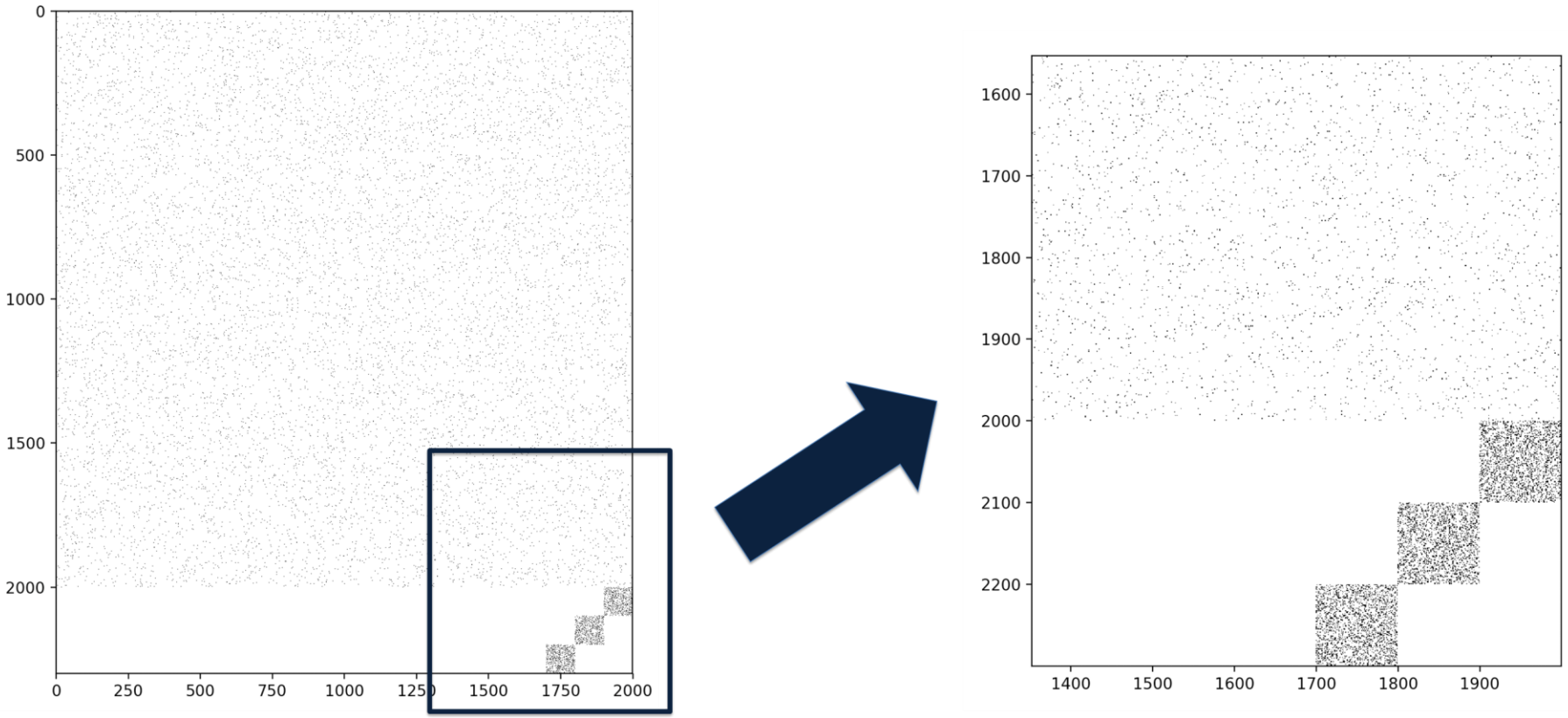
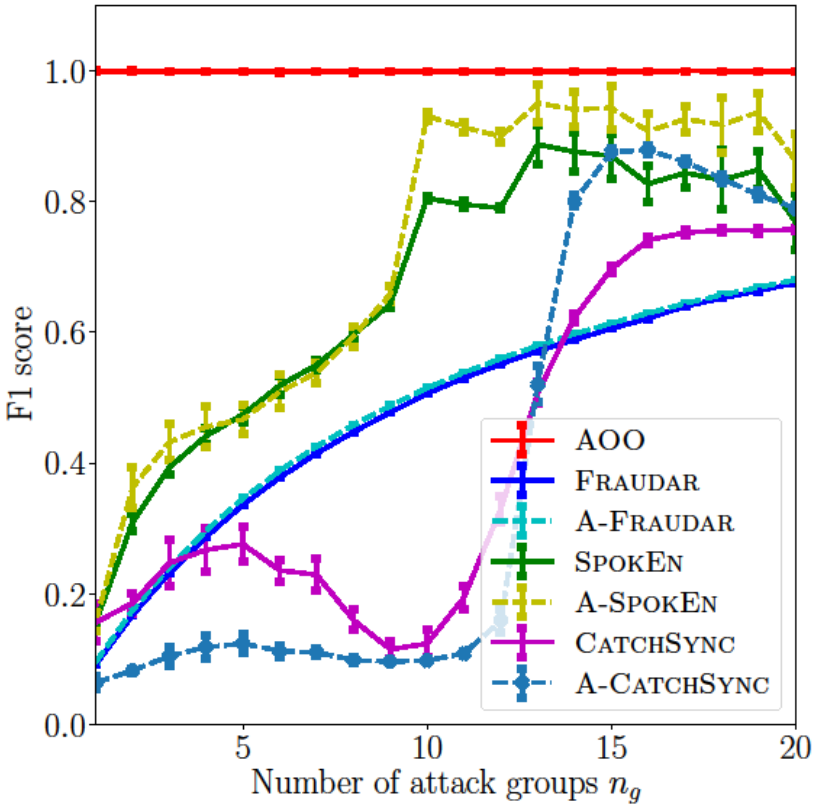


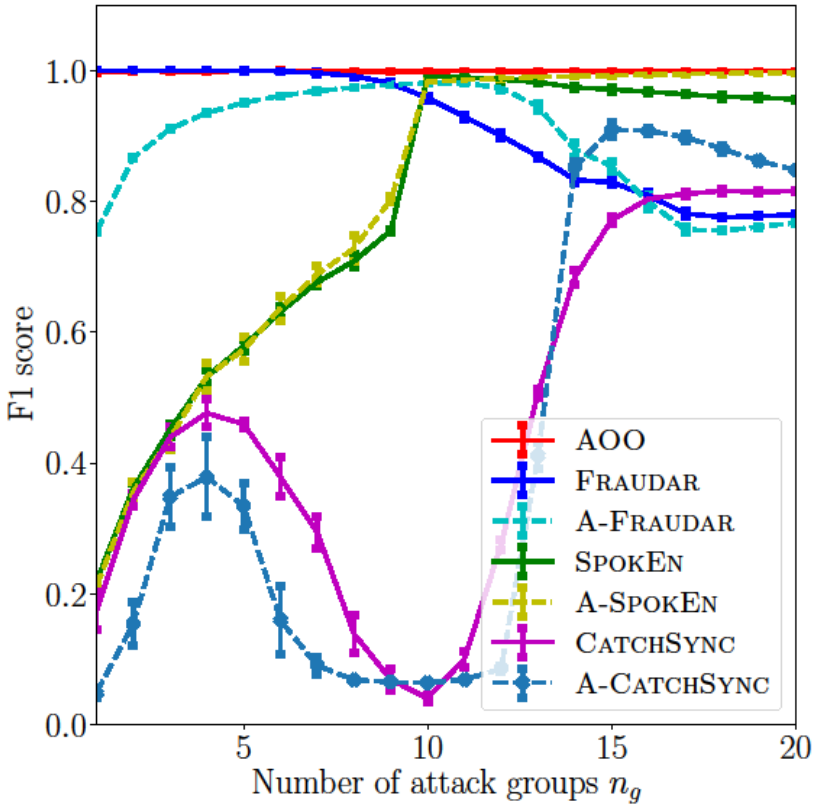
Synthetic Data



Experiment Results



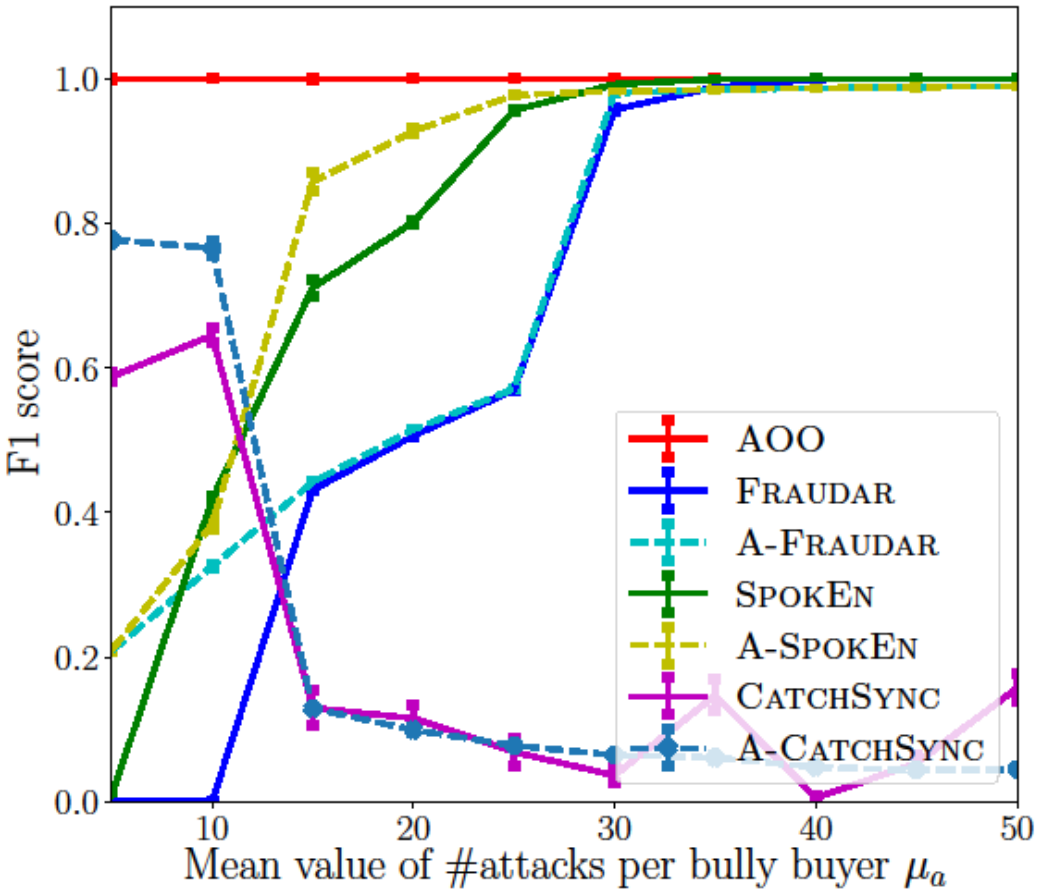
Sparse blocks



Dense blocks

Experiment Results

- Changing the attack density.
- Number of blocks = 3.



Real-word Dataset

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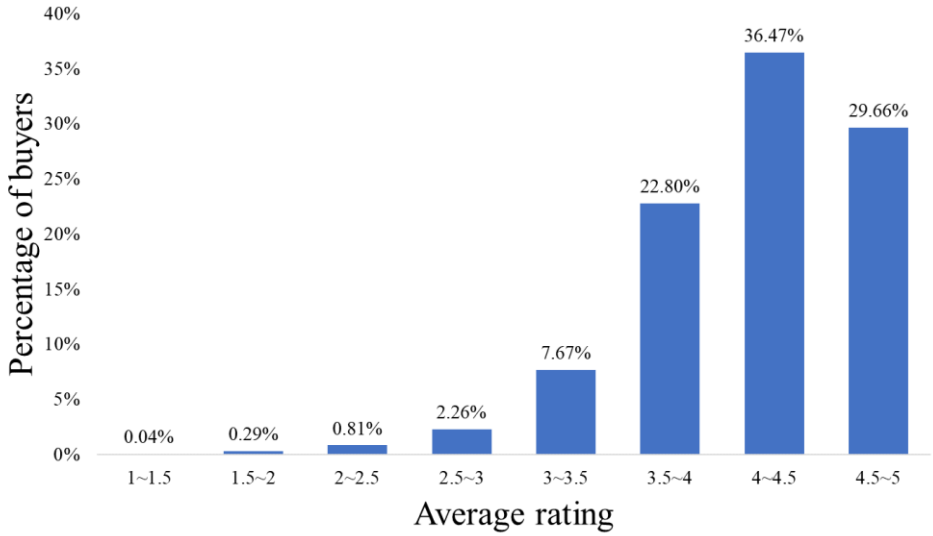
- Amazon reviews in 2015.
- 4,552 users (buyers).
- 6,347 products (sellers).

- 231,600 ratings with reviews.

Observations on Real-word Dataset



Buyers' average rating distribution

Word cloud of all reviews

Observation on the Results

Word cloud of all reviews blocked by AOO

Word cloud of all bad reviews not blocked by AOO

Conclusions

- Revisited the problem of suspicious behavior detection from the perspective of individuals.
- Proposed a novel Actionable Objective Optimization (AOO) method that finds actionable solution of preventing fraud behaviors to happen.
- Experimental results showed that AOO is effective and efficient.

Thank you!

- Any questions?

Synthetic Experiment Results

- Quadratic time complexity.
- $O(mn_r t)$.
  - m: number of users.
  - n_r: number of ratings.
  - t: number of iterations.