On the Fairness of Time-Critical Influence Maximization in Social Networks

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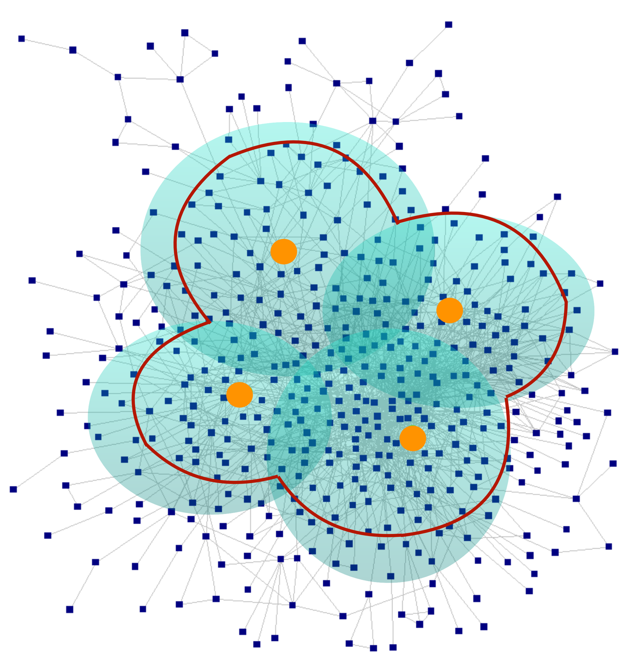
1. What is Influence maximization?

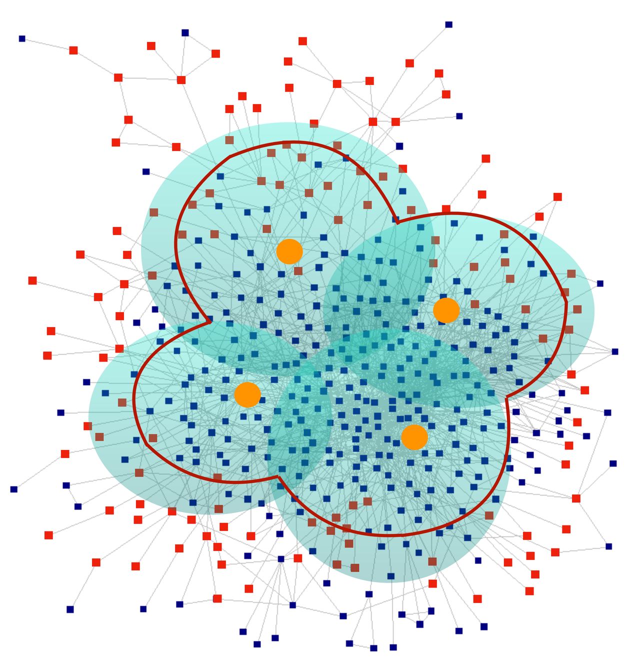
- Several **impactful** applications:
  - Social recommendations, viral marketing, information dissemination, etc
- Time-critical influence maximization (TCIM)
  - Select seed nodes that maximize influence before a **time deadline**
  - Examples include job advertisement, health related information dissemination etc



Seeds
Influenced

2. TCIM is unfair

- Traditional influence maximization:
  - Considers nodes to be **homogenous**
  - Ignores **sensitive feature** groups (men, women, *etc*)
  - Could result in disproportionate influence propagation
- Time deadline can **exacerbate** disparity



Women
Men
Seeds
Influenced

3. How can we measure fairness?

- **Our Notion**: **Parity** of average influence
- **Our Measure**:

$$\max_{i,j \in \{1,2,\ldots,k\}} \left| \frac{f_\tau(S; V_i, G)}{|V_i|} - \frac{f_\tau(S; V_j, G)}{|V_j|} \right|$$

where,

$$f_\tau(S; V, G) = \mathbb{E}\Big[\sum_{v \in V, t_v \geq 0} \mathbf{1}(t_v \leq \tau)\Big],$$

S is the seed set
V is the node set
G is the graph
t_v is the time node v was influenced
τ is the time deadline
k is the number of groups

4. TCIM-Budget problem

$$\max_{S \subseteq V} \sum_{i}^{k} f_\tau(S; V_i, G)$$

subject to $|S| \leq B$

- Problem is **NP-Hard**
- **Approximate solution**: Objective function is monotone submodular
- Guarantee: Total amount of influence

5. Fair TCIM-Budget problem

$$\max_{S \subseteq V} \sum_{i}^{k} f_\tau(S; V_i, G)$$

subject to $|S| \leq B$

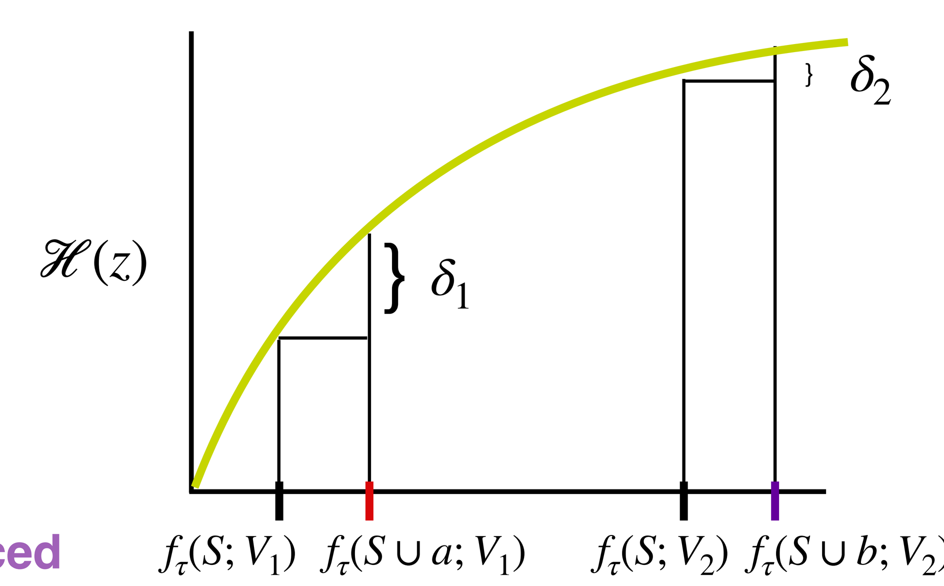
and $\max_{i,j} \left| \frac{f_\tau(S; V_i, G)}{|V_i|} - \frac{f_\tau(S; V_j, G)}{|V_j|} \right| \leq c$

No approximate solution: Problem is **not** monotone submodular

$\mathscr{H}(z) := \log(z)$

$\mathscr{H}(z) := \sqrt{(z)}$

Surrogate: $\max_{S \subseteq V} \sum_{i=1}^{k} \mathscr{H}(f_\tau(S; V_i, G))$ subject to $|S| \leq B$



- Objectives
  - Higher value for higher influence
  - Increases more when **underrepresented groups are influenced**
- Guarantee: Total amount of influence

6. TCIM-Cover problem

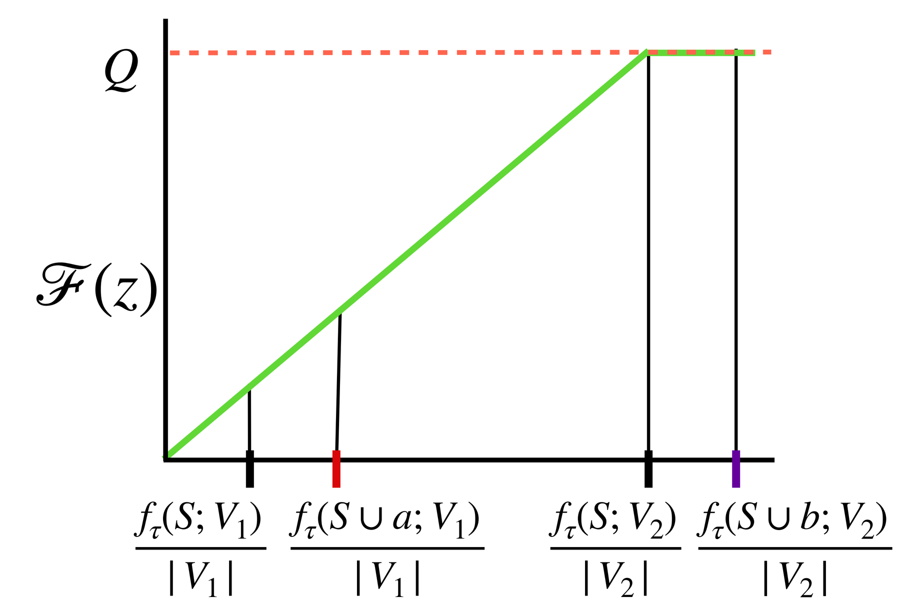
$$\min_{S \subseteq V} |S| \quad \text{subject to} \quad \frac{f_\tau(S; V, G)}{|V|} \geq Q$$

- Problem is **NP-Hard**
- **Approximate solution**: Objective function is monotone submodular
- Guarantee: Size of the seed set

7. Fair TCIM-Cover problem

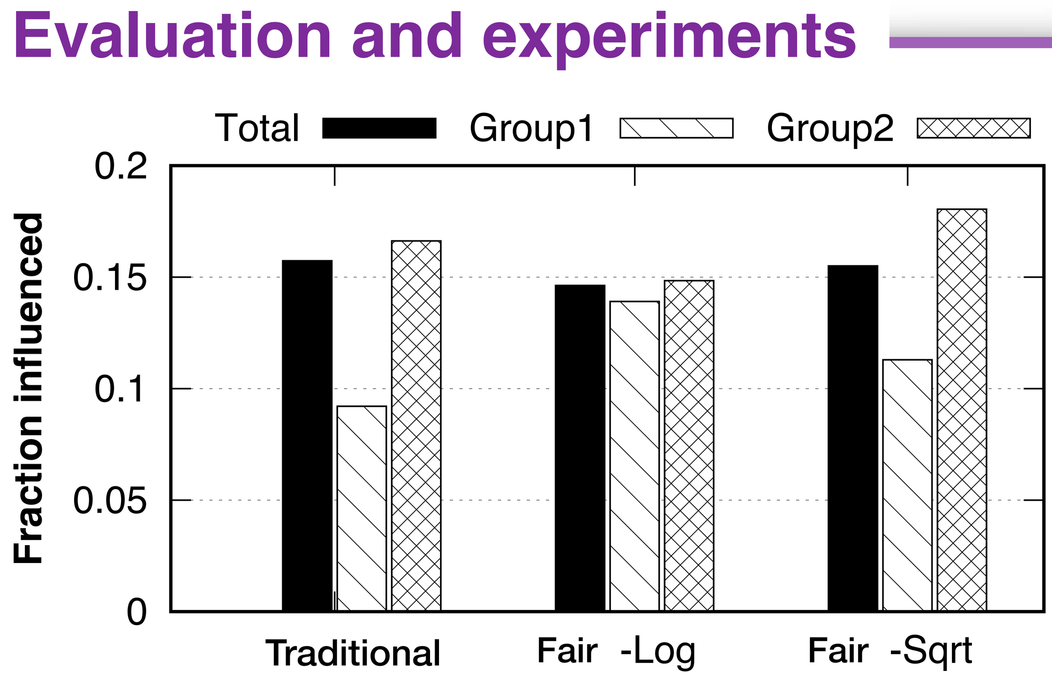
Fair formulation: $\min_{S \subseteq V} |S|$ subject to $\frac{f_\tau(S; V_i, G)}{|V_i|} \geq Q \quad \forall i$

$$\mathscr{F} = \min \left\{ \frac{f_\tau(S; V_i, G)}{|V_i|}, Q \right\}$$



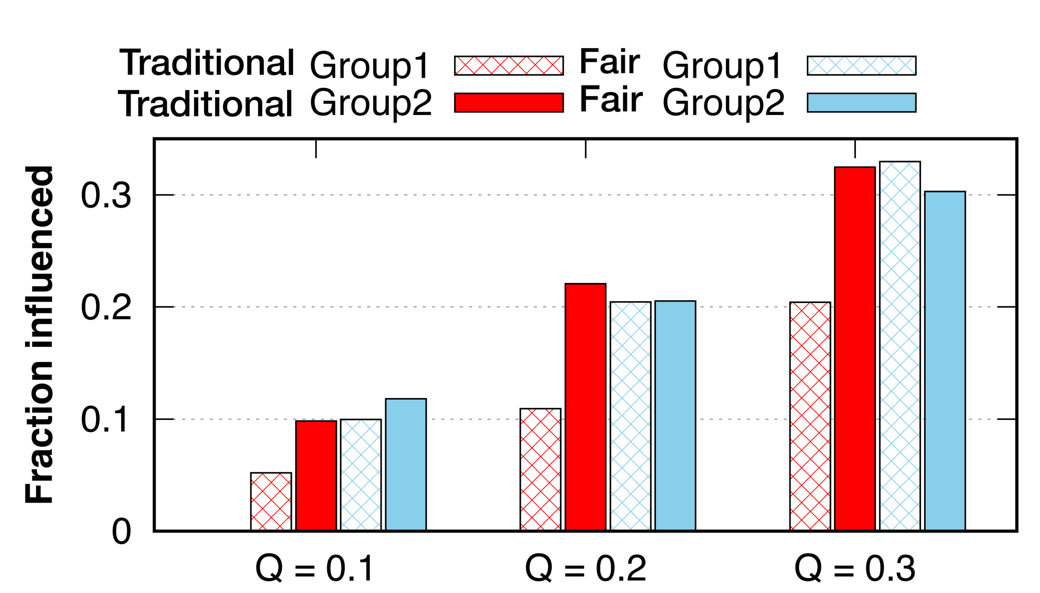
- Objectives
  - **All groups** should be influenced by at least the required quota
  - The disparity between the groups is bounded by $1 - Q$
  - Stop increasing constraint objective when the required quota is met for each group
- Guarantee: Size of the seed set

8. Evaluation and experiments



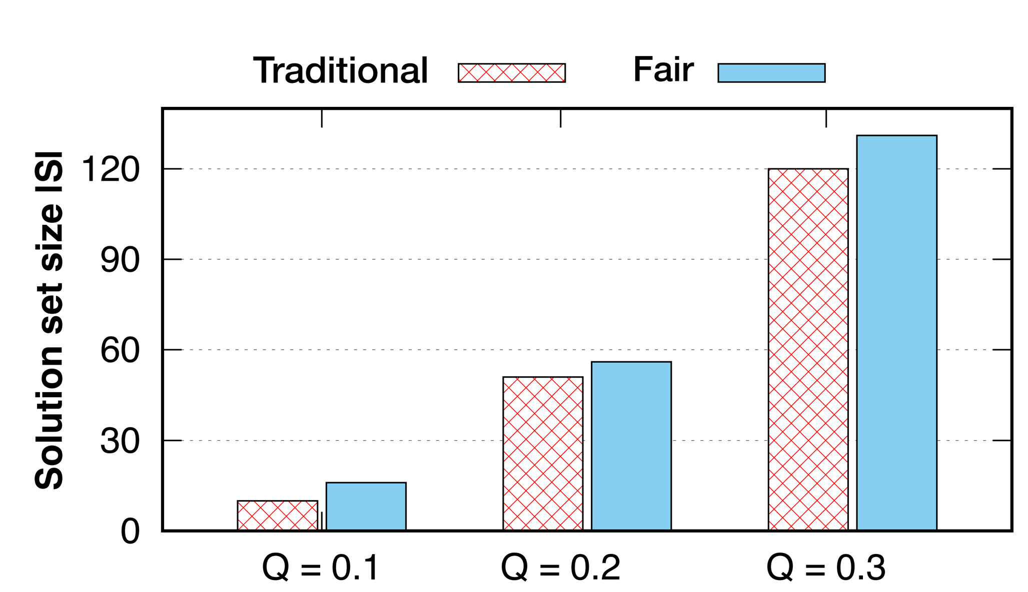
TCIM-Budget vs Fair TCIM-Budget

- **More proportional influence** between different groups at a **small cost of total influence**
- Reduction in disparity depends on the **curvature** of the surrogate function



TCIM-Cover vs Fair TCIM-Cover: Disparity

- Our method covers **all the groups** and results in **low disparity**



TCIM-Cover vs Fair TCIM-Cover: Cost

- Fairness comes at the cost of **slightly larger solution set sizes**

Dataset: Rice Facebook, Group 1: 97 nodes, Group 2: 344 nodes

Paper: https://tinyurl.com/fair-influence-maximization