Strategic Disclosure of Opinions on a Social Network

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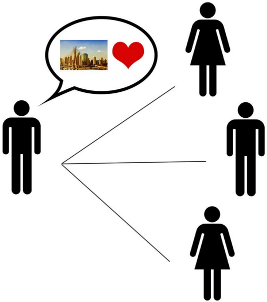
Introductory Example



"São Paulo is the best city in the world!"

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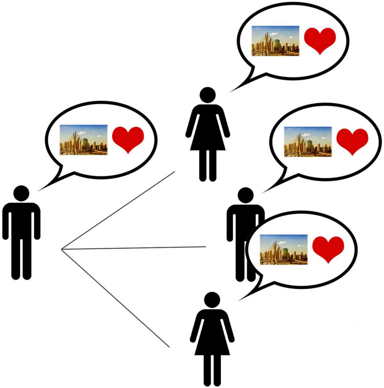

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Talk Overview

1. Opinion Diffusion Process
2. Games of Influence
3. Computational Complexity
4. Conclusion and Future Work

Formal Framework

Opinions, influence powers, states

- N is a set of n agents
- I is a set of m issues

- $B_i : I \longrightarrow \{0, 1\}$ is the opinion of agent i

  $B_i(p) = 1$ iff i believes that p
- $V_i : I \longrightarrow \{0, 1\}$ is the influence power (visibility) of agent i

  $V_i(p) = 1$ iff i influences others about her opinion on p

- A state consists of all opinions and visibilities of all the agents

Formal Framework

Influence network, update via aggregation

- An influence network is a directed irreflexive graph $E \subseteq N \times N$

  $(i, j) \in E$ iff agent i influences agent j

$$\begin{tikzcd}[row sep=small] & 2 \\ 1 \arrow[ur] \arrow[r] \arrow[dr] & 3 \\ & 4 \end{tikzcd}$$

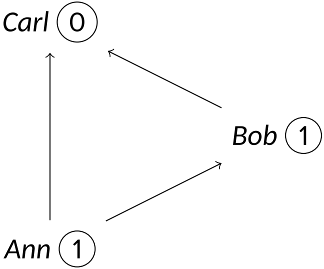
The opinion update is a two-step process:

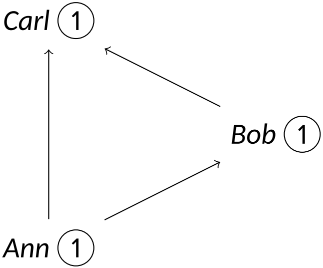
1. Agents decide how to use their influence power on issues
2. Agents update opinions via an aggregation procedure

Unanimous Aggregation

We focus on the unanimous aggregation procedure

> Agent *i* updates her opinion on *p* iff all *i*'s influencers using their influence are unanimous (else, she keeps her current opinion)





Games of Influence

An influence game is a tuple $IG = \langle N, I, E, \{F_i\}_{i \in N}, S_0, \{\gamma_i\}_{i \in N} \rangle$

- S_0 is the initial state
- γ_i is the individual goal of agent i

Goals are expressed in Linear Temporal Logic, with atoms:

- op(i,p) "*i* believes that *p*"
- vis(i,p) "*i* uses her influence power on *p*"

$$\begin{aligned} \mathrm{Influence}(i, C, J) \quad := \quad & \Diamond\Box \bigwedge_{p \in J} \Big((\mathrm{op}(i,p) \rightarrow \bigcirc \mathrm{pcon}(C,p)) \\ & \wedge (\neg \mathrm{op}(i,p) \rightarrow \bigcirc \mathrm{ncon}(C,p)) \Big). \end{aligned}$$

Strategies and Solution Concepts

Agents have actions reveal(J) and hide(J') — use your influence power on the issues in J and not on the issues in J'

We consider two types of strategies

- Memory-less: associate action to state
- Perfect-recall: associate action to finite sequence of states

Solution concepts (for this talk)

Weakly dominant strategy: agent doesn't gain with different strategy

Nash equilibrium: no agent gains by changing (alone) her strategy

Game Theoretic Results

Memory-less strategies

Always using your influence power is not necessarily a dominant strategy for the Influence goal.

$$
\begin{array}{lcccc}
 & A \longrightarrow & B \longrightarrow & C \longrightarrow & D \\
S_0: & 0 & 1 & 0 & 1 \\
S_1: & 0 & 0 & 1 & 0 \\
S_2: & 0 & 0 & 0 & 1
\end{array}
$$

- $\gamma_B = \text{Influence}(B, \{D\}, \{p\})$
- B: always use influence power over p
- C: use influence power over p *unless* A, B and C agree on p

$\Rightarrow$ What if B does *not* use her influence power over p in S_0?

Computational Complexity Results

Memory-less strategies

M-Nash: Given IG and strategy profile, is it a NE of IG?

Theorem

M-Nash is in P-SPACE for memory-less strategies.

- Encoding of unanimity rule and strategies as LTL formulas
- Validity checking for LTL is in P-SPACE

Computational Complexity Results

Perfect-recall strategies

E-Nash: Given IG, is there a NE of IG?

U-Nash: Given IG, is there a unique NE of IG?

Theorem

Both problems are in 3-EXPTIME for perfect-recall strategies.

- Translation into Graded Strategy Logic formulas
- Model checking of these formulas over a corresponding CGS

B. Aminof, V. Malvone, A. Murano, and S. Rubin. Graded Strategy Logic: Reasoning about Uniqueness of Nash Equilibria (AAMAS-2016).

Conclusion and Future Work

- Extended POD model with minimal strategic element
- Complex setting (both game-theoretically & computationally)
- Interesting connection with iterated boolean games

≫ Allow agents more actions (e.g., lying)

≫ Study different aggregation procedures