Echo chambers and opinion diversity in the Voter Model: towards regulation strategies for social networks

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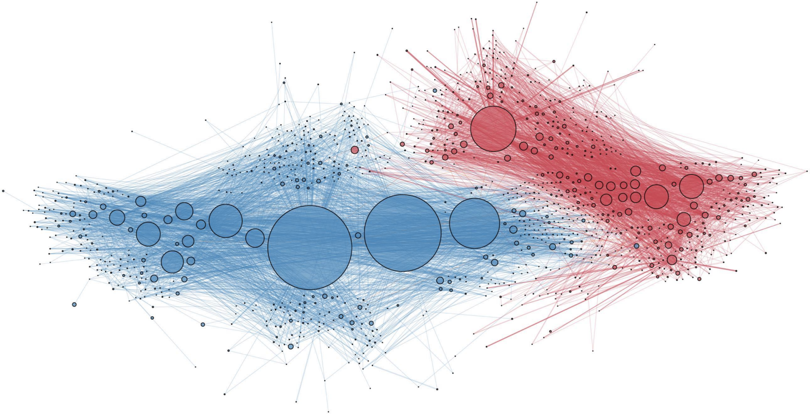
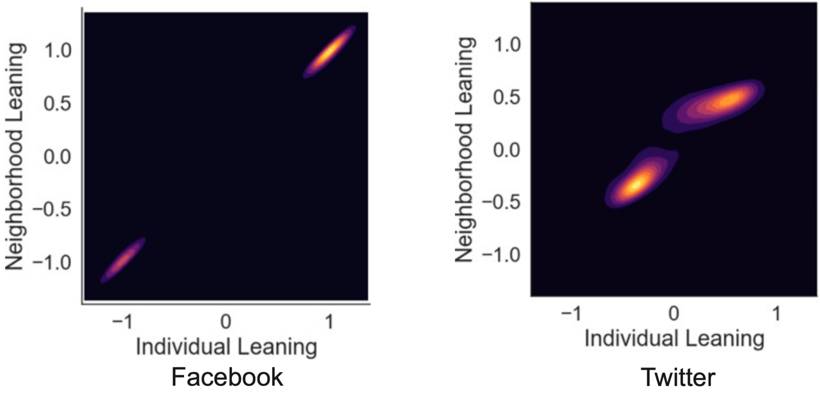
Context

Echo chambers: Australian conspiracies



Weber et al. (2020). #ArsonEmergency and Australia's "Black Summer": Polarisation and Misinformation on Social Media. MISDOOM 2020.

Echo chambers: American societal issues



Cinelli et al. (2021). The Echo Chamber Effect on Social Media. PNAS.

Consequences

- polarisation
- fake news
- conspiracy theories
- radicalisation
- ...

Metrics of interest

Accessible opinion diversity: variance of opinions agents are exposed to.

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Echo chamber effect: proportion of congruent opinions agents are exposed to.

VM: how to compute disagreement?

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Steering the echo chamber effect

The Voter Model

- Agent set $\mathcal{N} = \{1, \ldots, N\}$
- Directed, weighted network: $j \xrightarrow{w_{ij}} i$
- Opinion set $\mathcal{S} = \{1, \ldots, S\}$
- Exogenous influences $z_i^{(s)}$ for $i \in \mathcal{N}, s \in \mathcal{S}$

Exogenous: inner bias, recommender system, political campaign, ...

Dynamics and convergence

When the clock of i rings:

- with probability w_{ij}, copy j's opinion
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If each node i can be reached by a node j with $z_j^{(s)} > 0$ then there is a unique state of equilibrium. **We assume so.**

Distribution of opinions at equilibrium

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From Masuda (2015):

$$x_i^{(s)} = \sum_{j \in \mathcal{N}} w_{ij} x_j^{(s)} + z_i^{(s)}, \tag{1}$$

where $x_i^{(s)} \triangleq P(\sigma_i = s)$.

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Interpretation (Yildiz et al., 2013)

- Artificial node n_s with opinion s and edges $n_s \xrightarrow{z_i^{(s)}} i$.
- $x_i^{(s)}$ is the probability that a (backward) random walk initiated at i reaches n_s before any other $n_{s'}$.

Discord probabilities

How to compute $\rho_{ij} \triangleq P(\sigma_i \neq \sigma_j)$?

Special case: independent opinions

Opinions of i and j are independent if either:

- σ_i or σ_j is constant, or
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Independent case

$$\rho_{ij} = \sum_{s \in \mathcal{S}} x_i^{(s)}(1 - x_j^{(s)}). \tag{2}$$

General case

Not as simple...

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Equilibrium values

$$\rho_{ij} = \frac{1}{2}\left[\sum_{k\in\mathcal{N}} w_{ik}\rho_{jk} + \sum_{k\in\mathcal{N}} w_{jk}\rho_{ik} + \sum_{s\in\mathcal{S}} z_i^{(s)}(1-x_j^{(s)}) + \sum_{s\in\mathcal{S}} z_j^{(s)}(1-x_i^{(s)})\right]. \tag{3}$$

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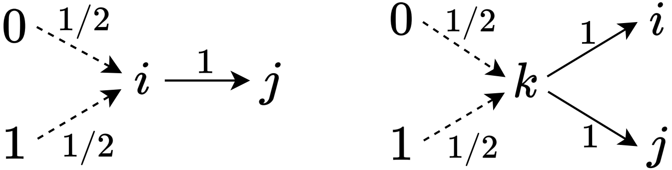
- Linear system $\simeq N^2$.
- Unique solution, thanks to the earlier assumption.

Importance of dependencies

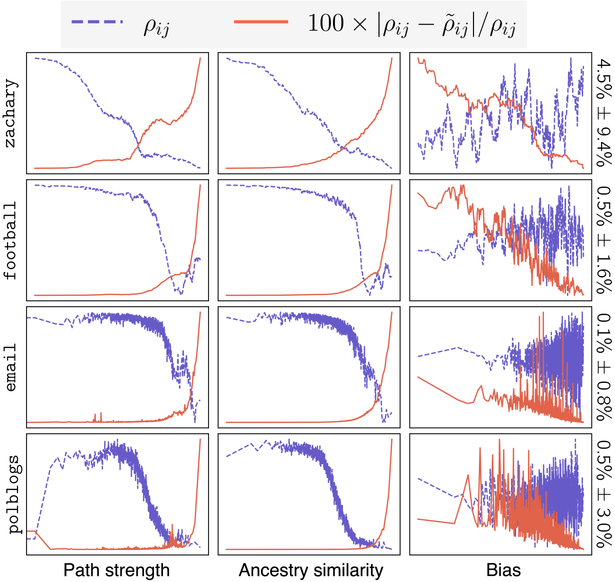


(a) Path $i \to j$.   (b) Common ancestor k.

Eq. 3 (general case) $\implies \rho_{ij} = 1/4$,

Eq. 2 (independent case) $\implies \rho_{ij} = 1/2$.

Stronger dependency... higher difference!



Generalised active links density

Average discord: a simple mean is not enough...

- heterogenous edge weights
- long-range influences

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GALD

$$\langle \rho \rangle = \frac{\sum_{i<j} (w_{ij}^{\infty} + w_{ji}^{\infty}) \rho_{ij}}{\sum_{i<j} (w_{ij}^{\infty} + w_{ji}^{\infty})}. \tag{4}$$

where w_{ij}^{∞} is the (i, j)-th component of the matrix exponential

$$e^{W} = \sum_{k=1}^{\infty} \frac{1}{k!} W^{k}. \tag{5}$$

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Metrics of interest in the Voter Model

Echo chamber effect

Proportion of congruent opinion agent i sees:

$$\Gamma_i = \frac{\sum_{j \in \mathcal{N}} w_{ij}(1 - \rho_{ij})}{\sum_{j \in \mathcal{N}} w_{ij}}. \tag{6}$$

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Accessible opinion diversity

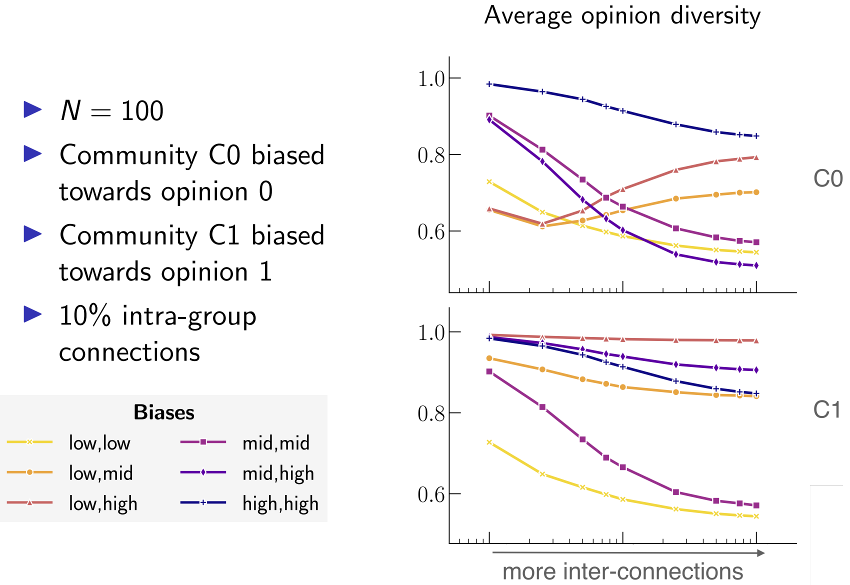
Variance of opinions agent i sees:

$$\Phi_i = \frac{S}{S-1} \sum_{s \in \mathcal{S}} y_i^{(s)}(1 - y_i^{(s)}). \tag{7}$$

where $y_i = \sum_{j \in \mathcal{N}} w_{ij} x_j / \sum_{j \in \mathcal{N}} w_{ij}$.

Connections with different minds does not mean more diverse opinions...

- $N = 100$
- Community C0 biased towards opinion 0
- Community C1 biased towards opinion 1
- 10% intra-group connections



...but there is more hope for the echo chamber effect!

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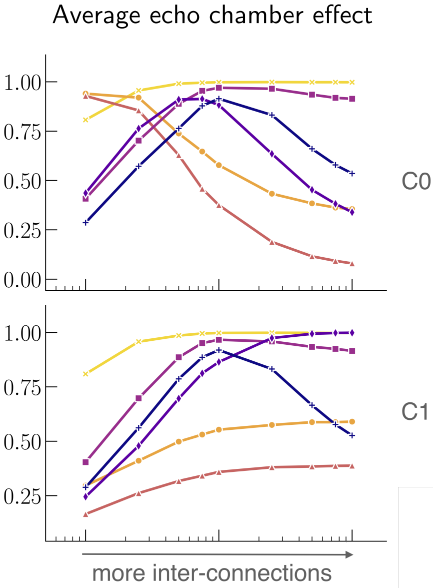

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Find opinion recommendation rates to maximise the average Opinion Diversity.

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Macroscopical perspective

Homogeneous networks with global information (subreddit, FB pages, ...)

Setting

- Complete network.
- Two possible opinions $\{0, 1\}$.
- Bias $z^{(0)} > 0, z^{(1)} = 0$ for everyone. $\Rightarrow$ **Pure echo chamber**

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Objective

Find the optimal recommendation rate $z^{(1)}$ that maximises the average Accessible Opinion Diversity:

$$\langle \Phi \rangle = \frac{4z^{(0)}z^{(1)}}{[z^{(0)} + z^{(1)}]^2}. \tag{8}$$

We must be careful...

Don't flood users with recommendations!

We require $z^{(1)} \leq B$ for a chosen B.

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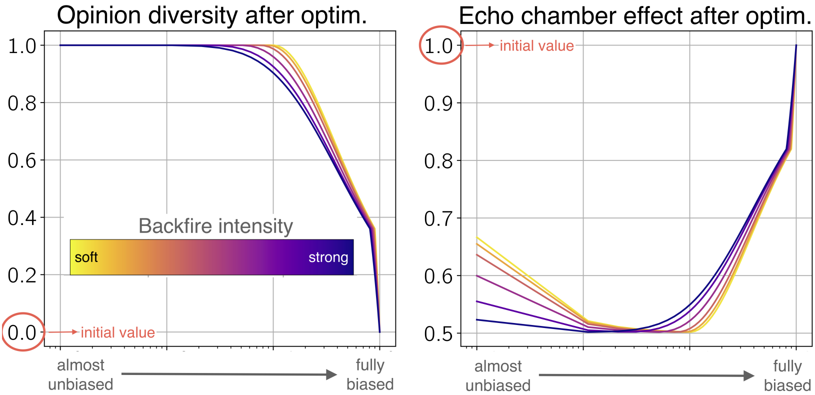
Backfire effect: too much incongruent opinions can reinforce prior beliefs!

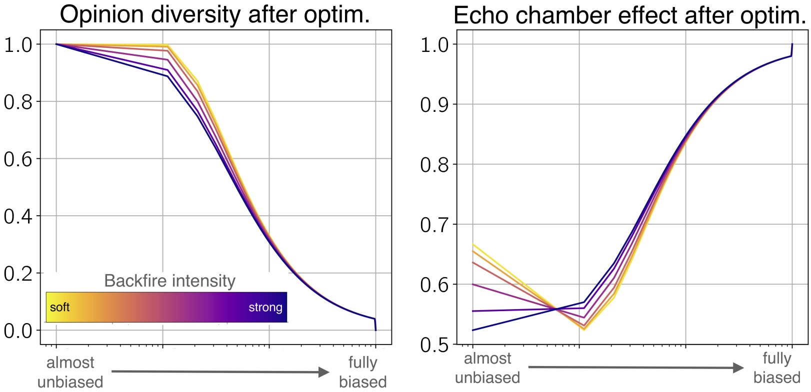
Recommendation rate $z^{(1)} \implies z^{(0)}$ incremented by $\alpha z^{(1)}$, with $0 < \alpha < 1$.

The macroscopical perspective can increase opinion diversity and reduce the echo chamber effect



$B = 10^{-1}$.

Also works with lower budgets



$B = 10^{-2}$.

What is happening exactly?

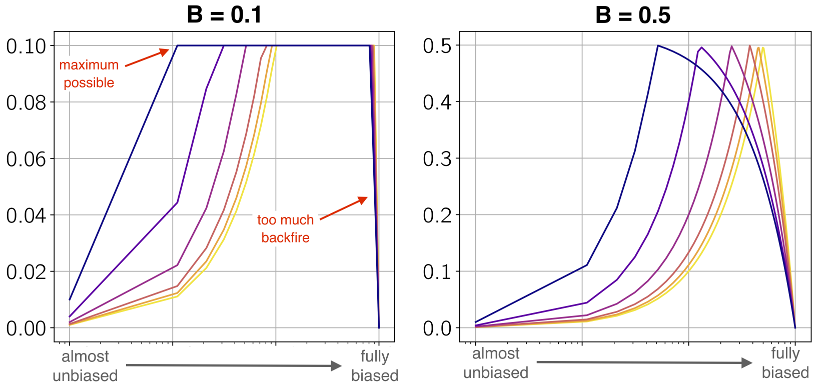


Figure: Optimal recommendation rate z_1 for $B = 0.1, 0.5$.

Thank you!

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