Modelling Multi-dimensional Opinions and Polarization Formation

The Opinioneers
Michael Andres, Florian Dorner, Gian Luca Gehwolf, Fabian Hafner, David Metzger
Complex Social Systems
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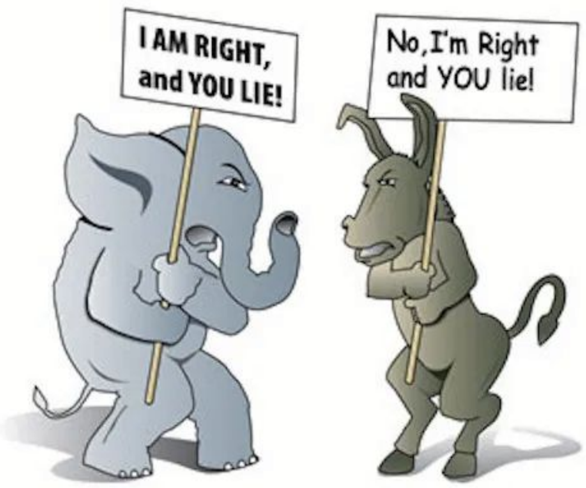
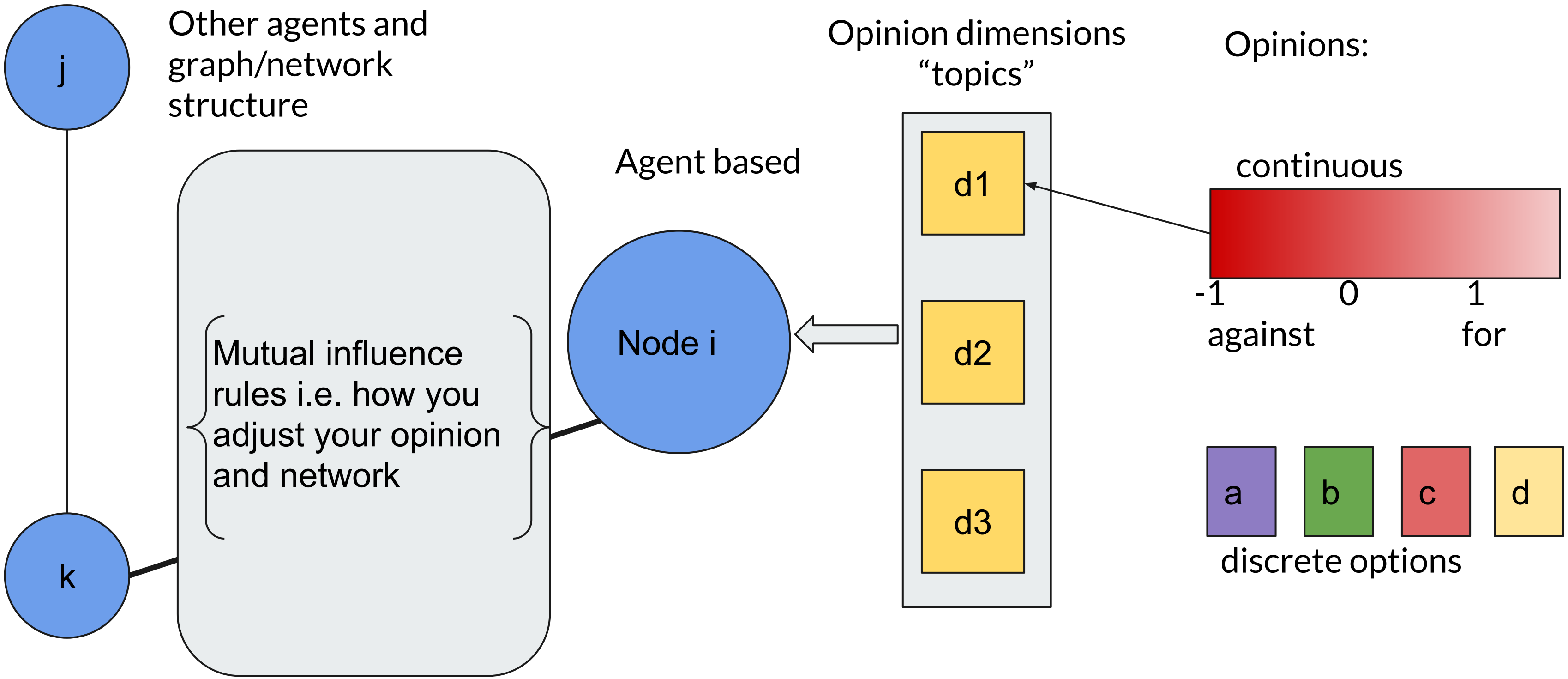
Motivation

1. Political polarization is a threat to political stability
2. How can opinion polarization be simulated?
    - Weighted Balance Theory Model by Schweighofer et al. (2020)
3. How can opinion polarization dynamics be influenced by...
    - Network structures
      → Coevolution of networks and opinions model developed by Holme and Newman (2006)
    - Bots



Source: http://thecontextofthings.com/2014/01/12

How do opinion formation models work?

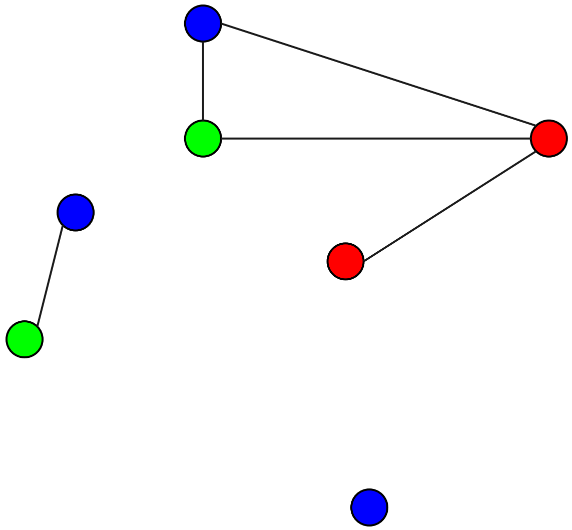


Model 1: coevolution of opinions and networks

Holme et al. 2006

Discrete, 1D opinions
Randomly initialized network

Example: 30 students need to choose where to go for lunch

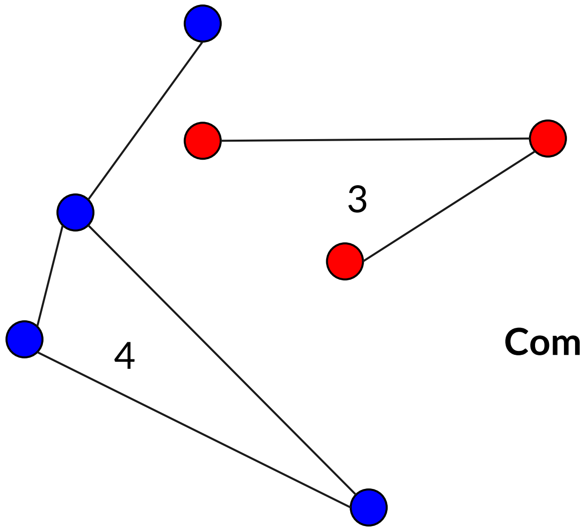


Model 1: coevolution of opinions and networks

Holme et al. 2006

Discrete, 1D opinions
Randomly initialized network

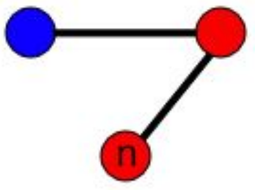
Convergence when communities have consensus



Community Size

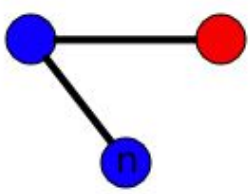
Coevolution Model - influence rules

with probability Φ



connect to like-minded

with probability 1-Φ

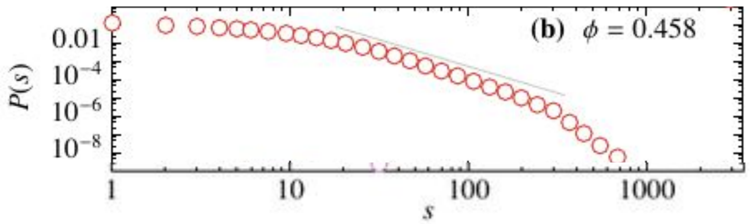


adjust my opinion

Comparison of Results

Holme 2006

Histograms of community sizes (avg)



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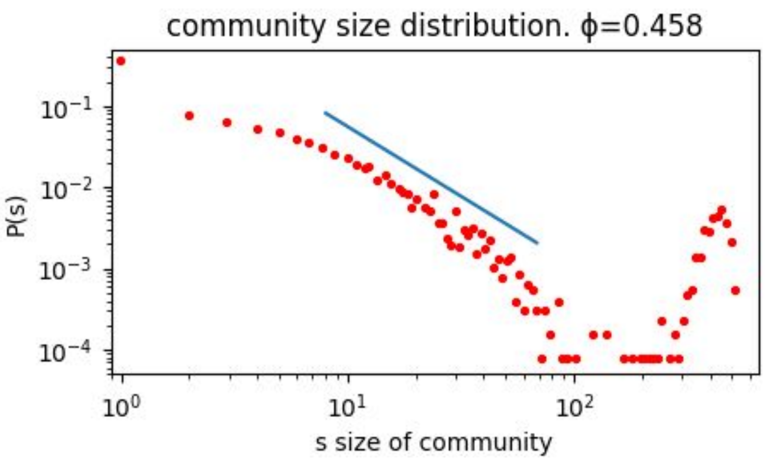


Model 2: Weighted Balance Theory

Schweighofer et al. 2020

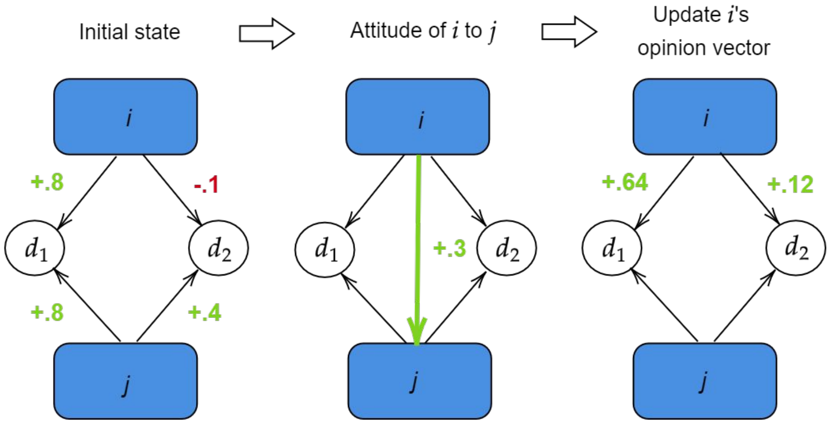
- Multidimensional, continuous opinions [-1,+1], no network. Political topics.

- How opinions **change** depends on **overall opinion similarness**

→ **Hyperpolarization:** extreme and clustered opinions
  → Two-party system

Model 2: Weighted Balance Theory

- Interpersonal **attitude Aij** as measure of closeness
    - within [-1,+1] based on signed geometric mean and sigmoid evaluative extremeness
    - Equilibrium / fixed points
    $\mathbf{o}(i)_{eq} \simeq \pm\mathbf{o}(j)$

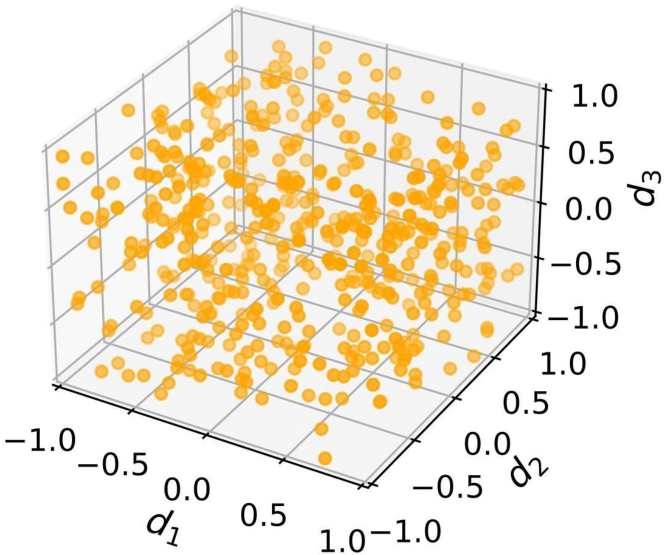


$$A_{ij} := f\left(\frac{1}{D}\sum_{d=1}^{D} \mathrm{SGM}(o_d(i), o_d(j))\right) \qquad f(x) = \mathrm{sign}(x)|x|^{1-e}$$

$$\mathbf{o}(i) \leftarrow \mathbf{o}(i) + \alpha\left[\mathbf{b}^{ij} - \mathbf{o}(i)\right] + \xi(0, z) \qquad \mathbf{b}^{ij} := \begin{pmatrix} b_1^{ij} \\ \vdots \\ b_D^{ij} \end{pmatrix} := \begin{pmatrix} \mathrm{SGM}(o_1(j), A_{ij}) \\ \vdots \\ \mathrm{SGM}(o_D(j), A_{ij}) \end{pmatrix}$$

Model 2: Weighted Balance Theory

Hyperpolarisation

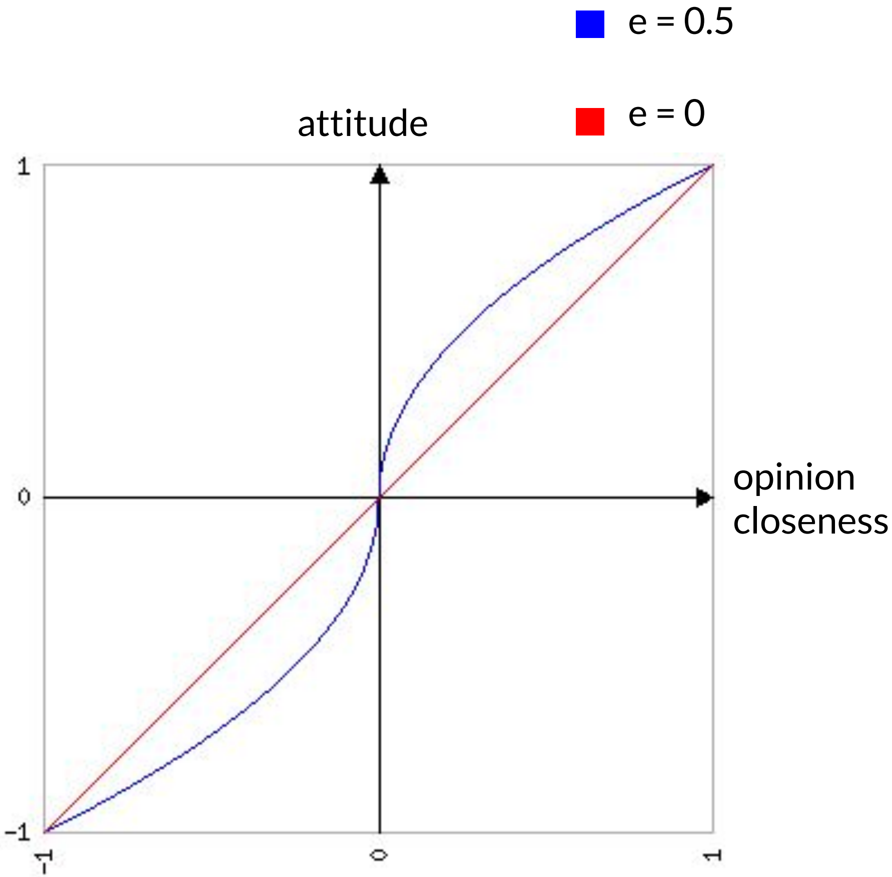


Evaluative extremeness

$$f(x) = \text{sign}(x)|x|^{1-e}$$

slightly agree on average ⟶ like person a lot

slightly disagree on average ⟶ dislike a lot



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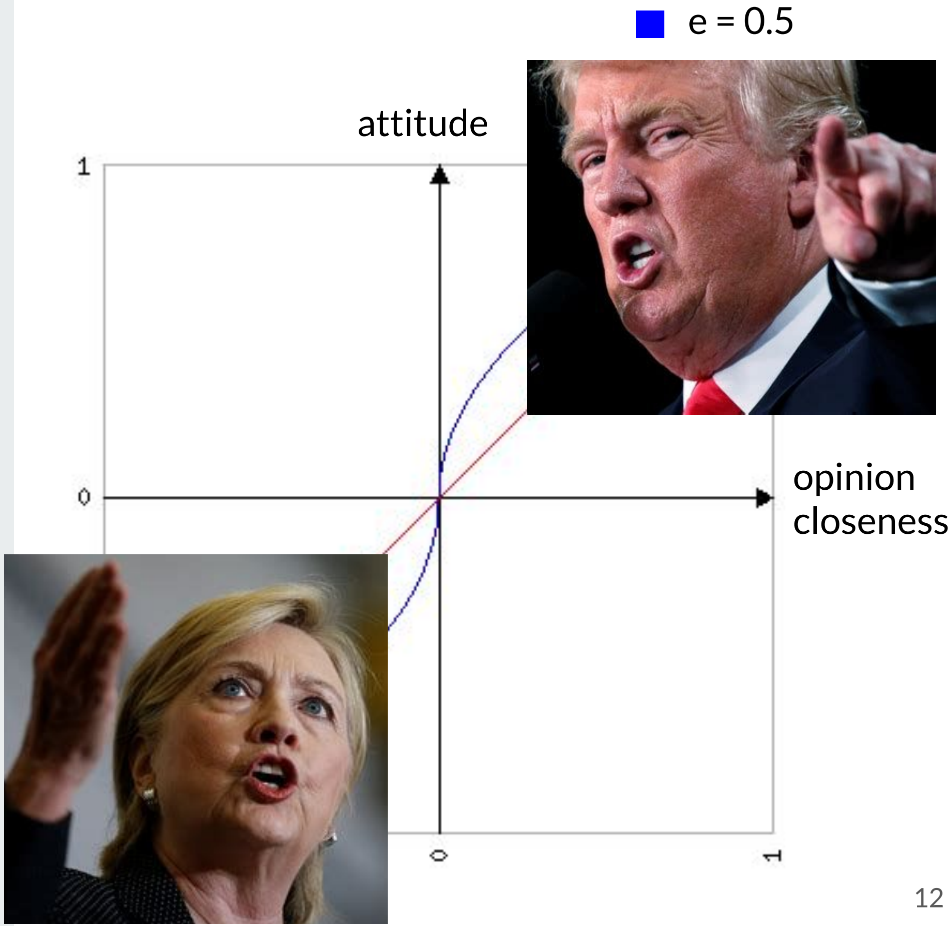


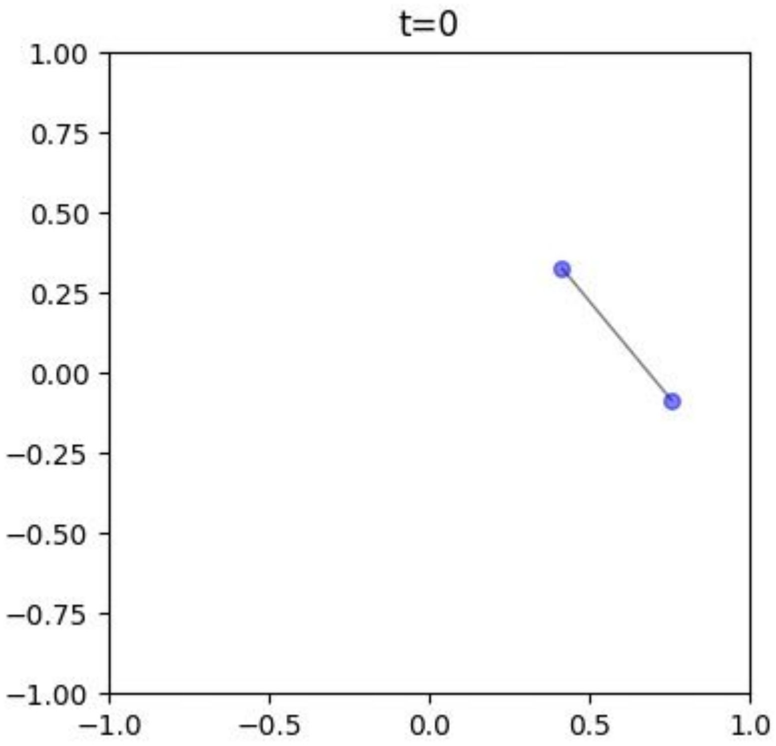
Images: Carlo Allegri / Reuters, Chris Keane / Reuters

Evaluative extremeness

$$f(x) = \mathrm{sign}(x)|x|^{1-e}$$

e > 0 creates drift to corners

→ not entirely unrealistic, but still surprising



Model 3: Generalized WBT Model

- WBT Model implemented into network structure
- With probability Φ:

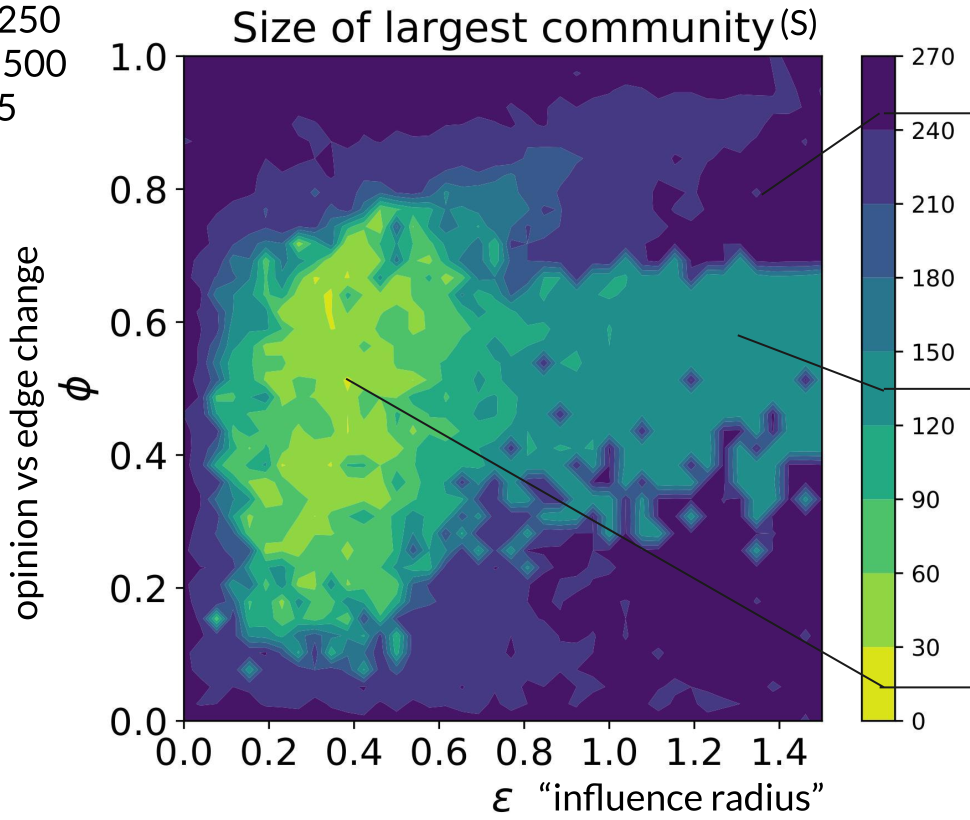
$$\text{connect}(\mathbf{o}(i), \mathbf{o}(j)) = \begin{cases} 1 & \text{if } |\mathbf{o}(i) - \mathbf{o}(j)| < \varepsilon(N, D, z) \\ 0 & \text{else} \end{cases}$$

- With probability 1-Φ:

$$\text{update}(\mathbf{o}(i), \mathbf{o}(j)) = \mathbf{o}(i) + \alpha \left[\mathbf{b}^{ij} - \mathbf{o}(i)\right] + \xi(0, z)$$

→ **New behavior**: clusters, phase transitions

N=250
M=500
D=5



singular cluster
→ complete **alignment**

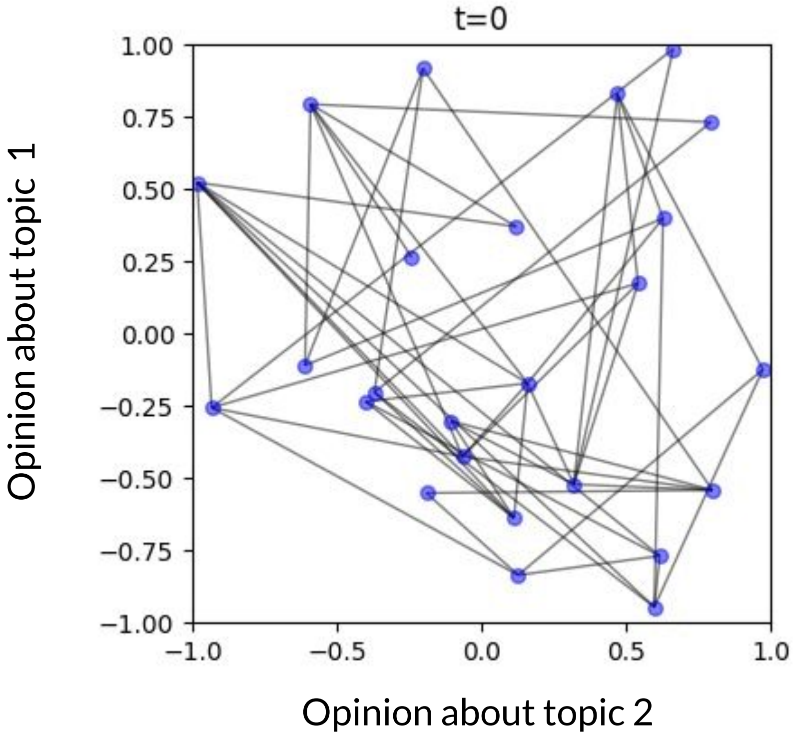
possible
hyperpolarization

opinion **fragmentation**

Observation: convergence into ~S/N similarly sized clusters

Graph evolution

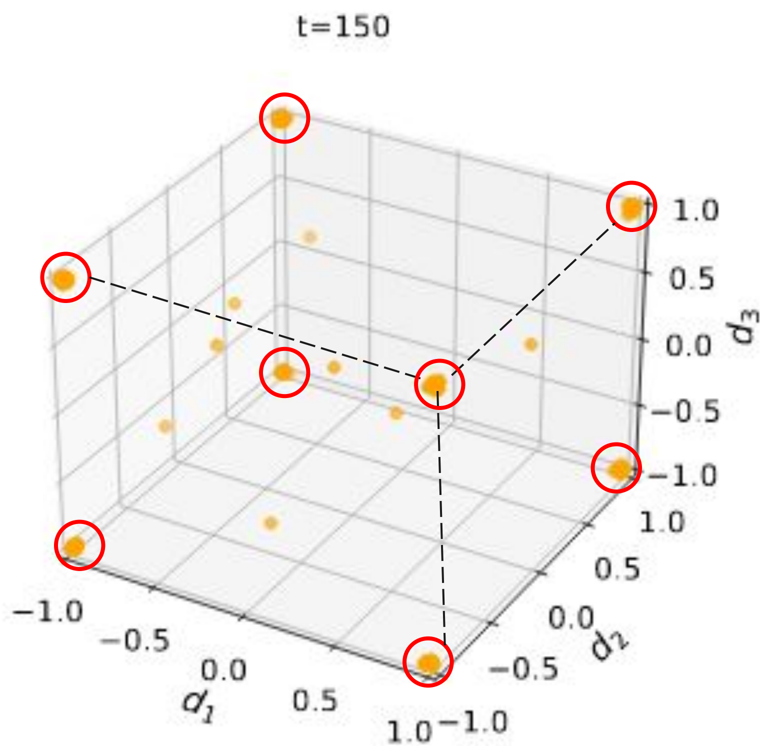
from random to polarized



$\varphi = 0.52, \varepsilon = 0.4$

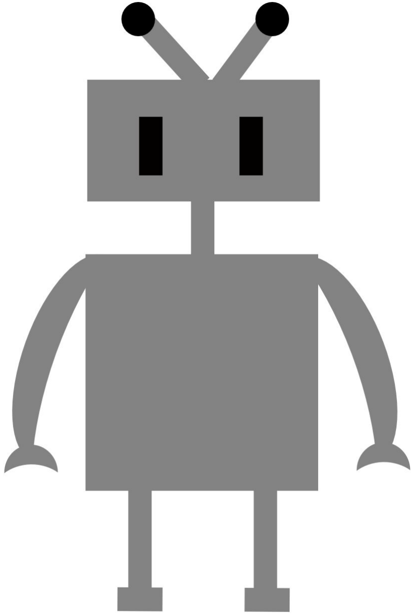
In some cases no hyperpolarization, just polarization & fragmentation

Clusters in the corners + some disconnected nodes



φ= 0.45,ε= 0.3

Bots

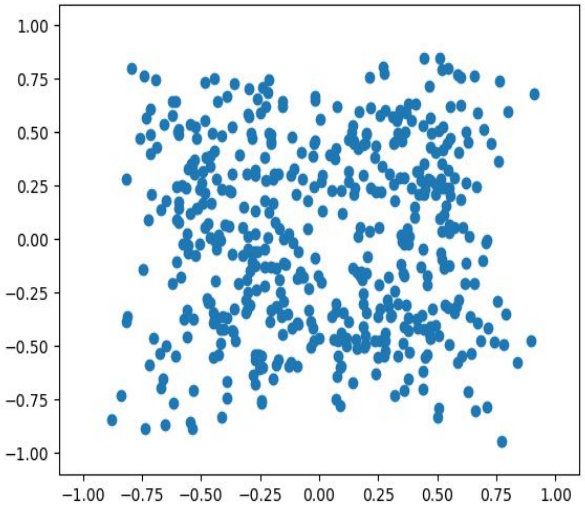


- Like normal nodes but don't change their opinion

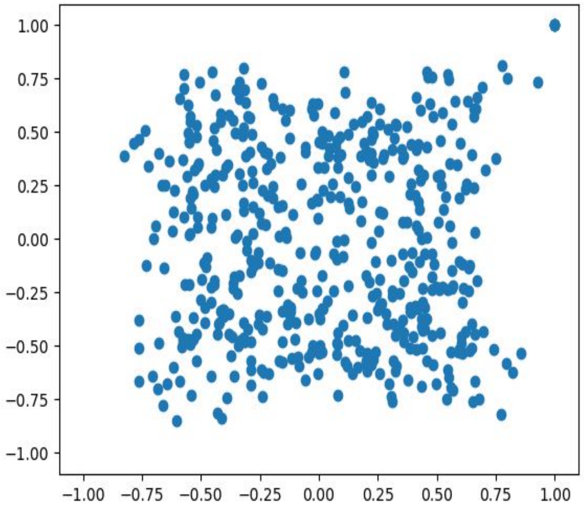
- This presentation:
    - Bots all have same extreme opinion in all dimensions

Bots (e=0, fully connected network)

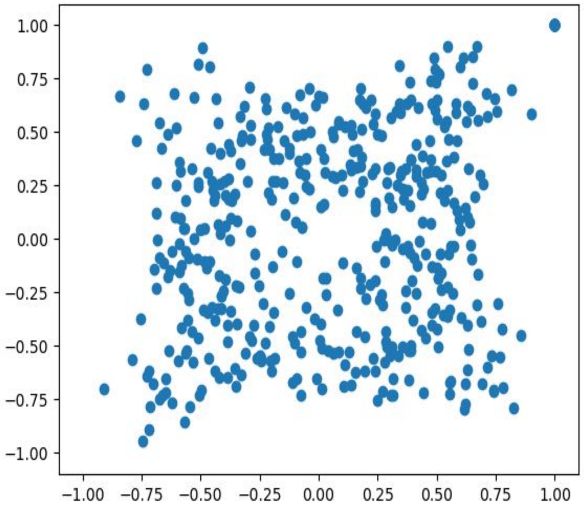
0/500 nodes are bots



5/500 nodes are bots

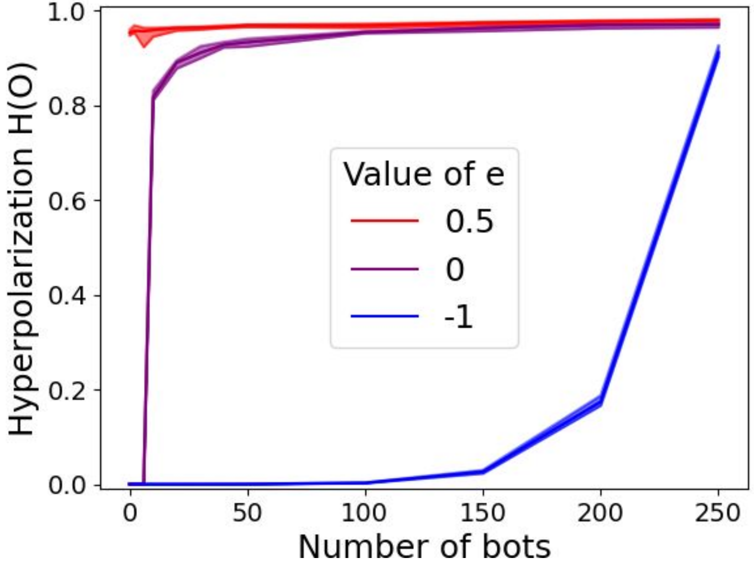


50/500 nodes are bots

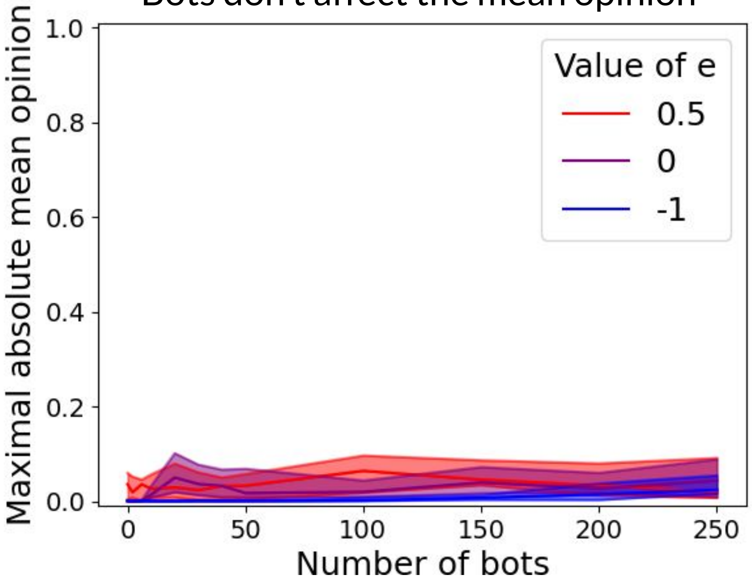


Bots (e=0, fully connected network)

Bots affect polarization

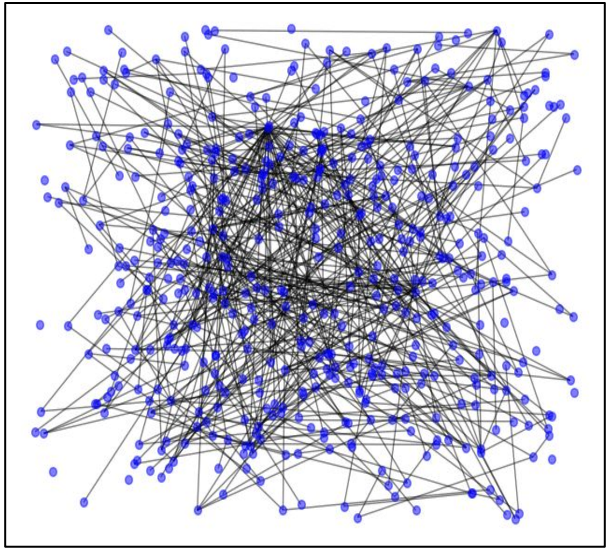


Bots don’t affect the mean opinion

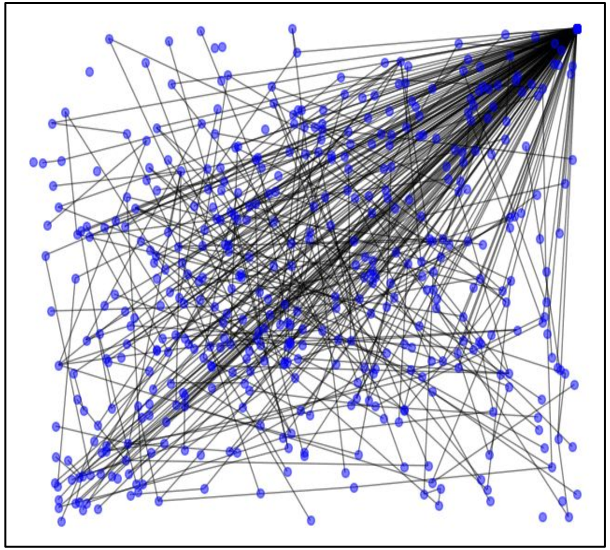


Bots in dynamic BA graph (e=0,ϕ=0.5,ε=1)

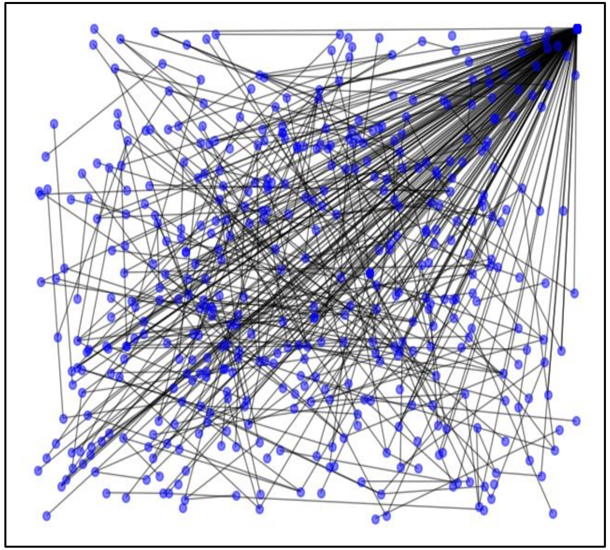
No bots



50 bots

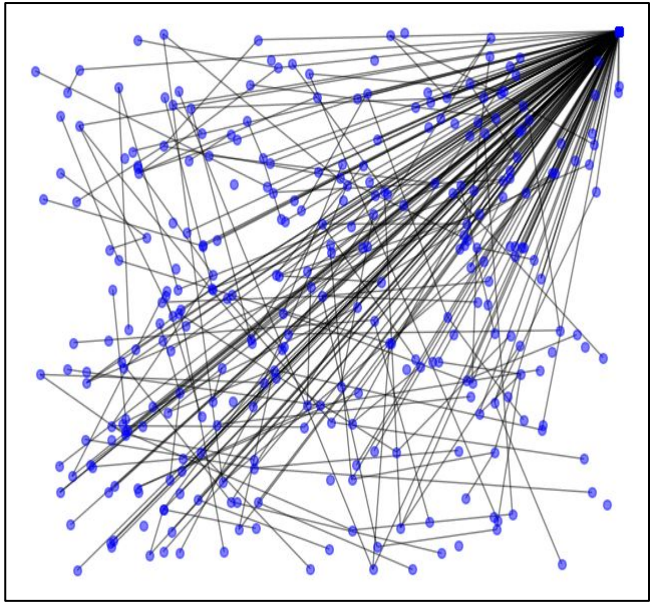


50 bots, bots can connect to all

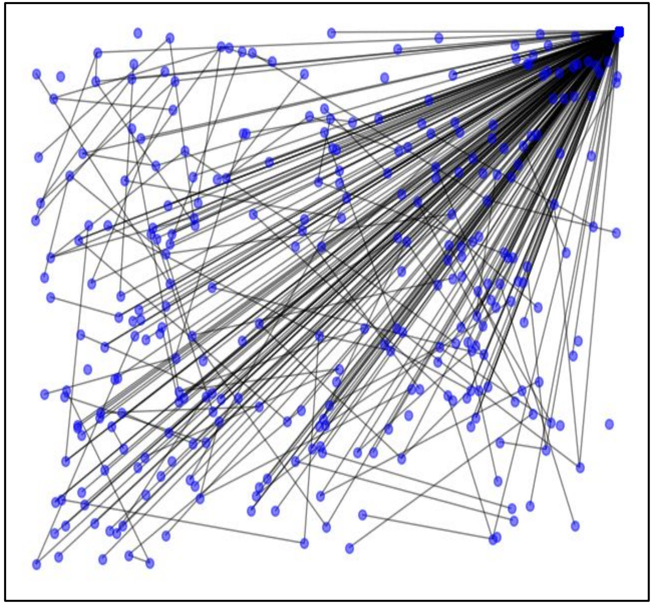


Bots in dynamic BA graph (e=0,ϕ=0.5,ε=1)

200 bots

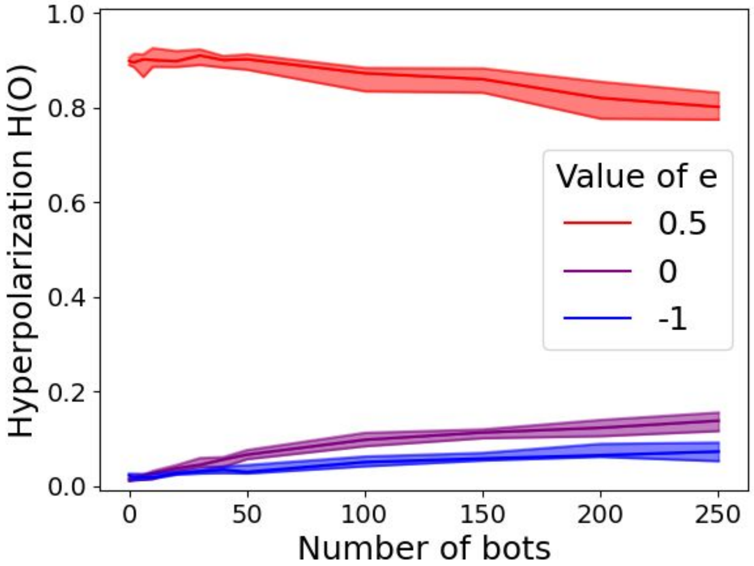


200 bots, bots can connect to all

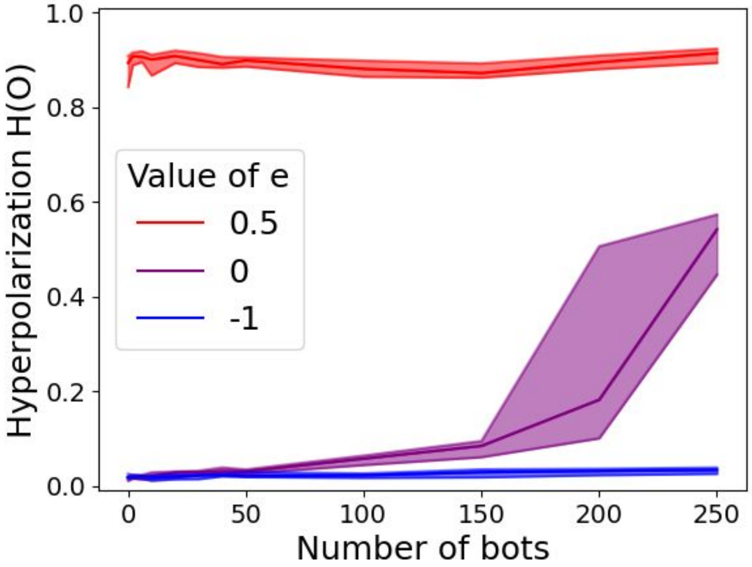


Bots in dynamic BA graph (e=0,ϕ=0.5,ε=1)

Bots connect like all other nodes



Bots can connect to all



Conclusion

Reproduction of Models

Extensions

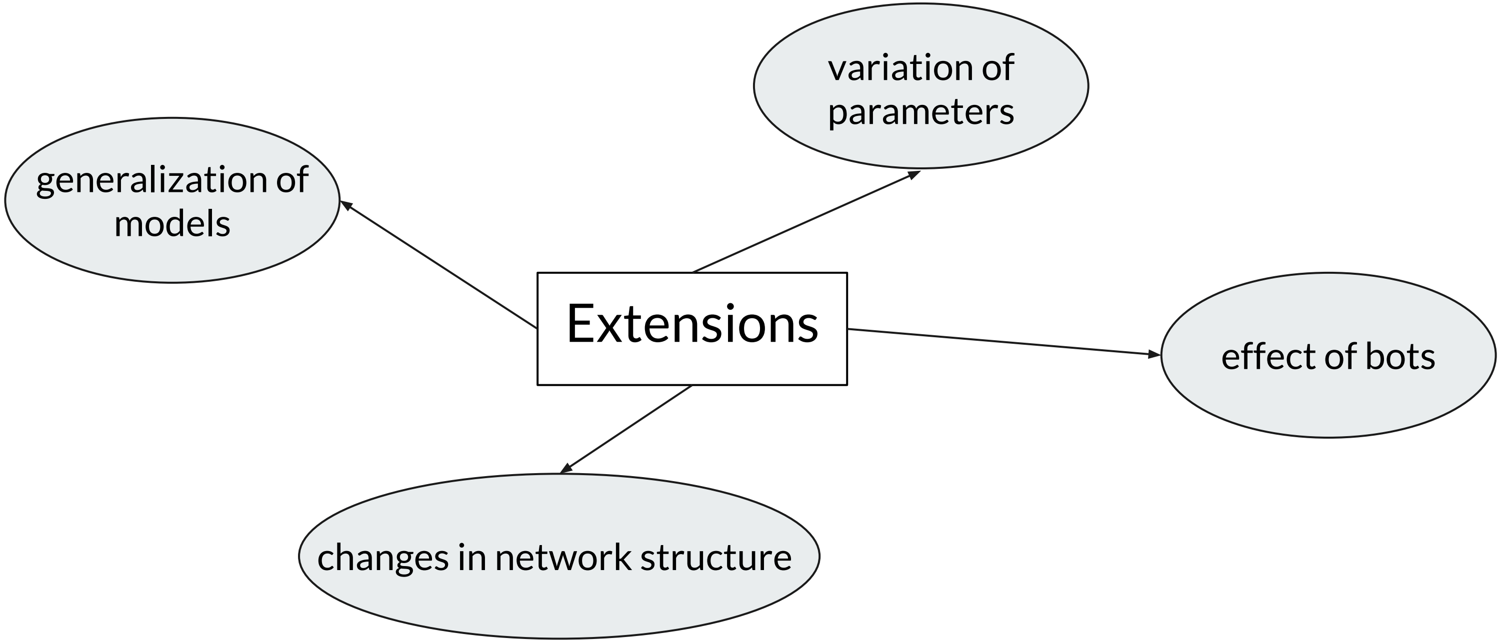
Critique

Conclusion

Reproduction of Models

- very similar findings for reproduced experiments and parameters
- only minor deviations due to smaller networks
- indicates other results also likely valid for larger networks

Conclusion



variation of parameters
generalization of models
Extensions
effect of bots
changes in network structure

Conclusion

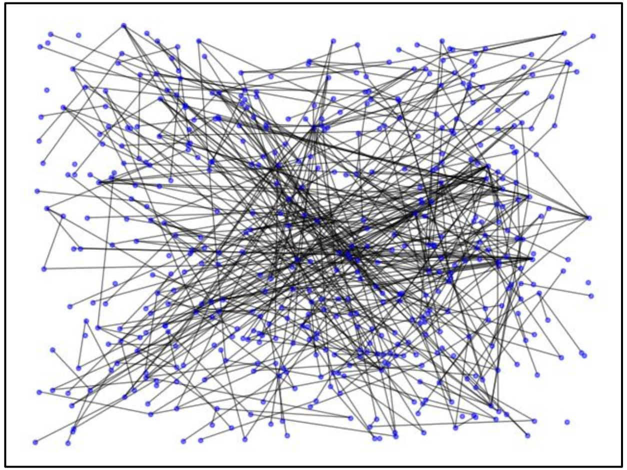
(Hyper)polarization only allows (one) extreme opinion on every topic within one group

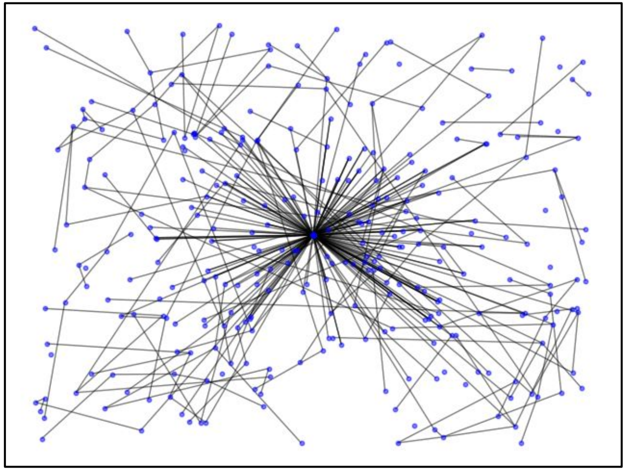
Critical assumption on evaluative extremeness & attitude as function of opinions only

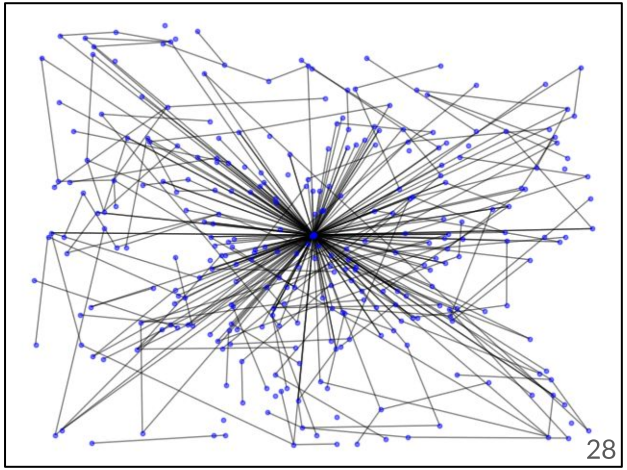
Critique

In general: different models can have very different outcomes

Thank you for your attention

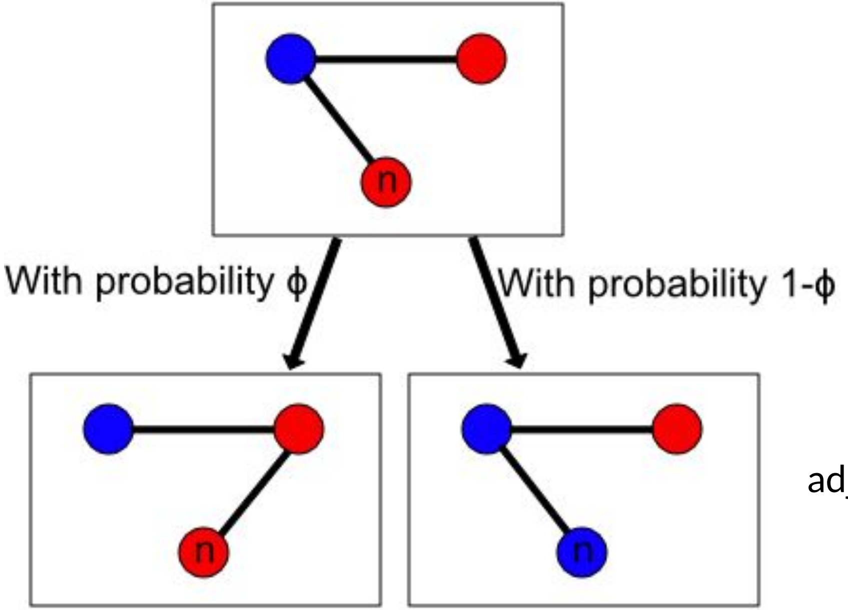






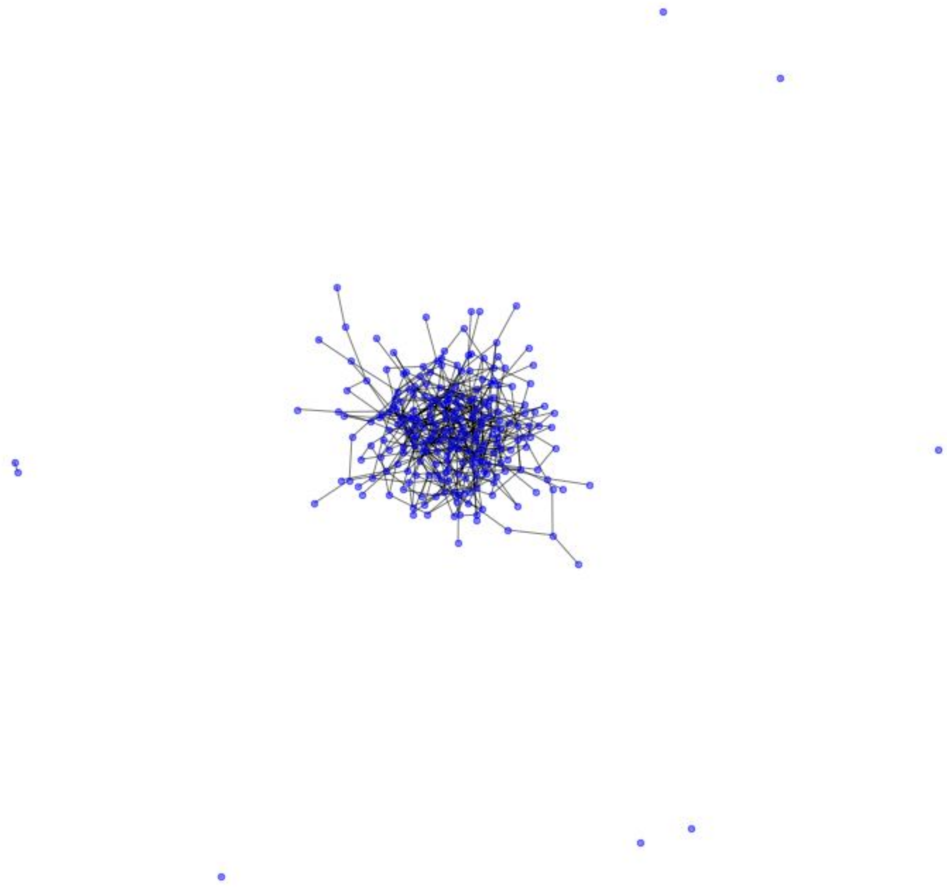
Questions?

Coevolution Model



connect to like-minded

adjust my opinion



Implementation

1. Implement our own coevolution model
   → compare it to the coevolution model of Holme and Newman (2006)

2. Implement our own WBT model
   → compare to WBT model of Schweighofer et al. (2020)

3. Combine these two models to a generalized model

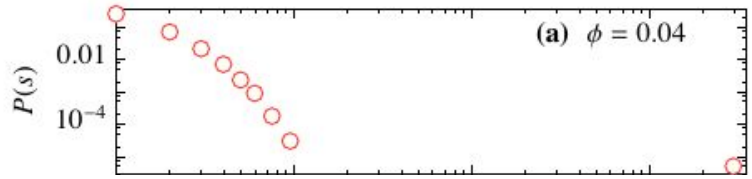
Model 2: Weighted Balance Theory

- simultaneous emergence of opinion extremeness and issue constraint (**Hyperpolarization**)

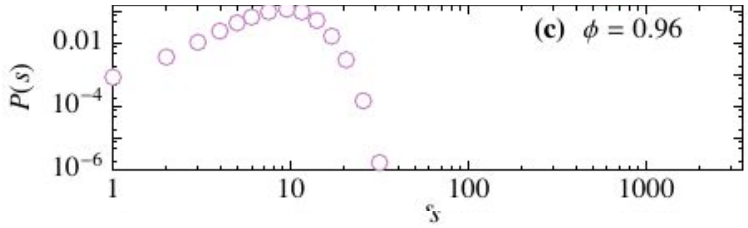
  → Two-party system, where all opinions are diametrically opposed

Comparison of Results

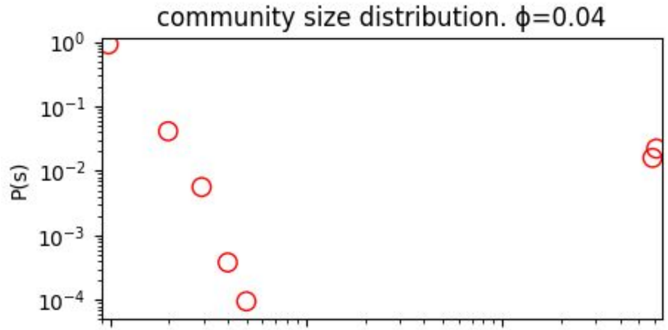
Holme 2006

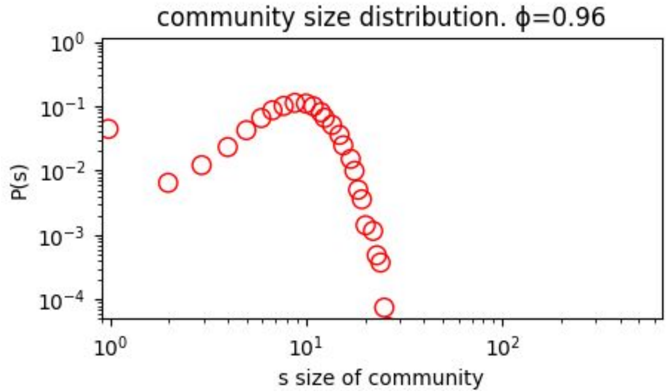


Histograms of community sizes (avg)



Reproduced by us.
N=320





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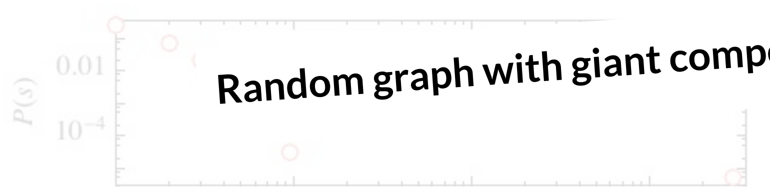
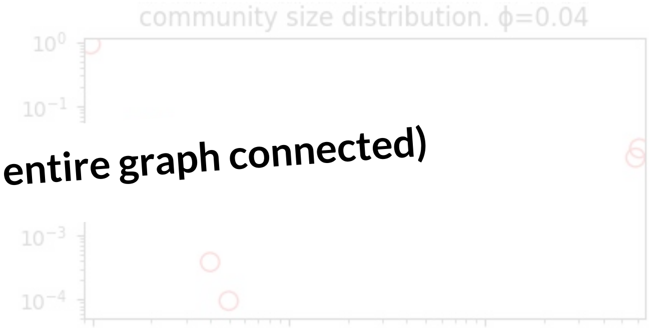
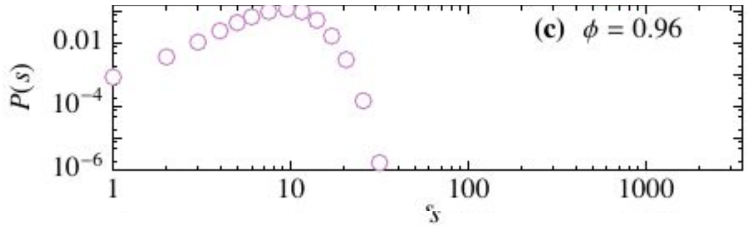
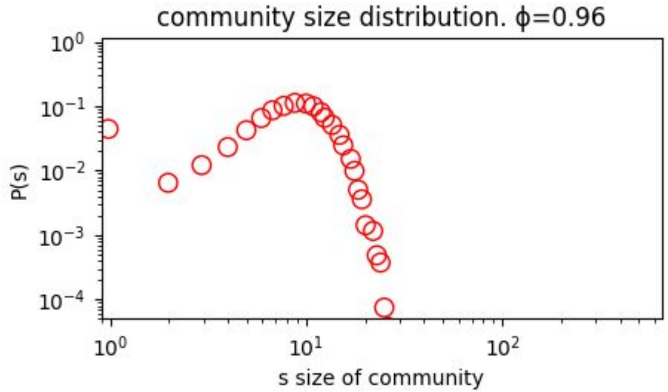
Holme 2006





Random graph with giant component (almost entire graph connected)





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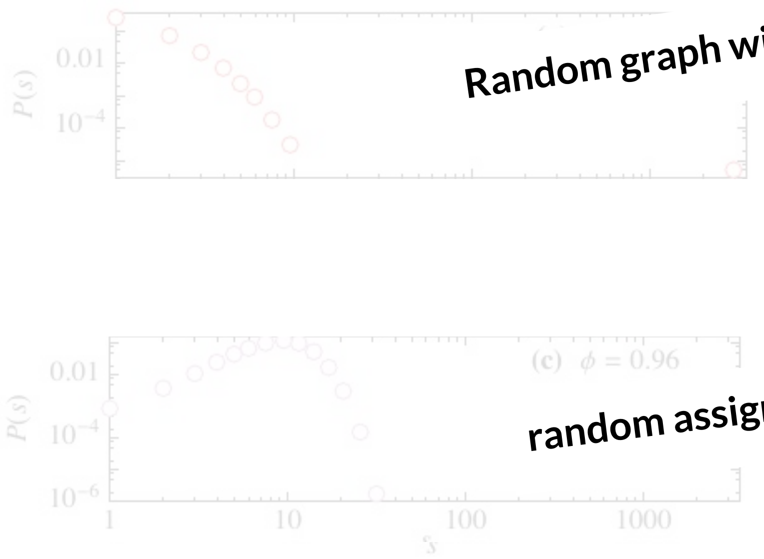
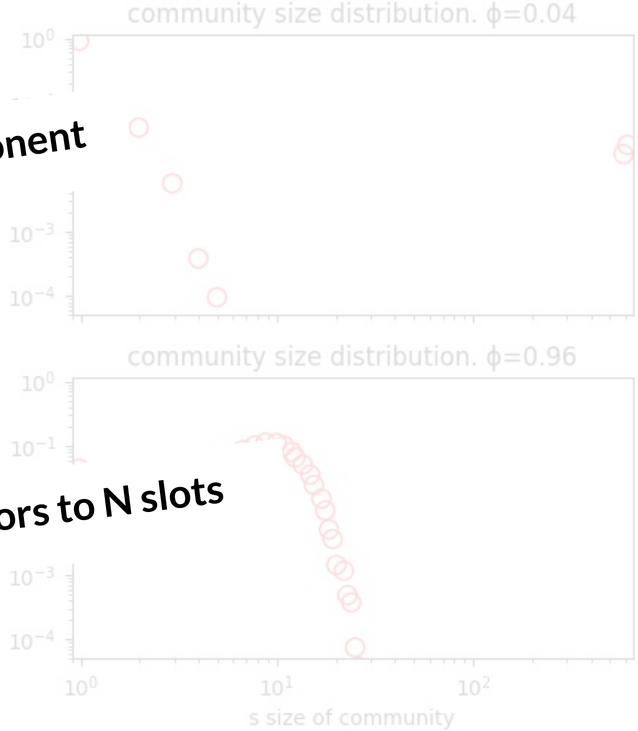




Random graph with giant component

random assignment on K colors to N slots

Model 2: Weighted Balance Theory

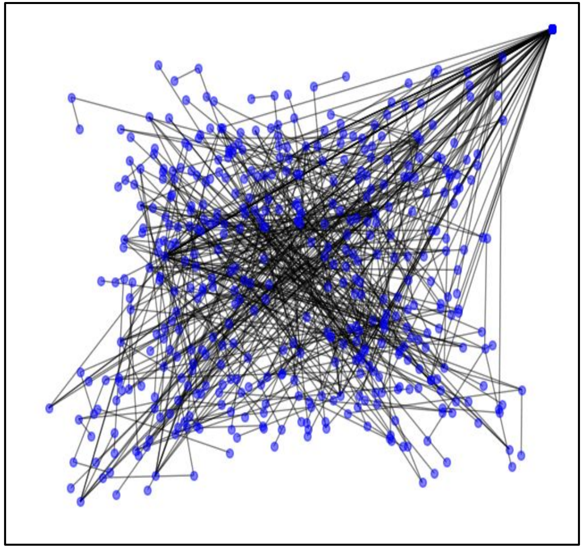
- simultaneous emergence of opinion extremeness and issue constraint (**Hyperpolarization**)

  → Two-party system
- Multi-dimensional opinion vectors with values within [-1,+1]
- Interpersonal attitudes within [-1,+1] weighted with sigmoid-function and parameter e

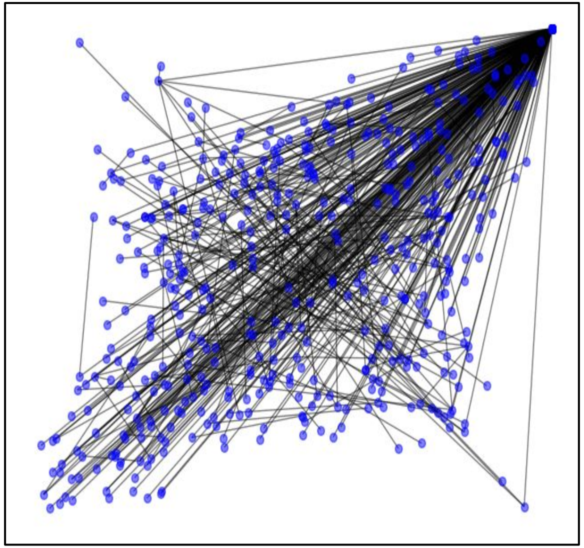
  → **evaluative extremeness** (Backfire-Effect, convergence of like-minded agents)

Bots in static Barabási–Albert graph (e=0)

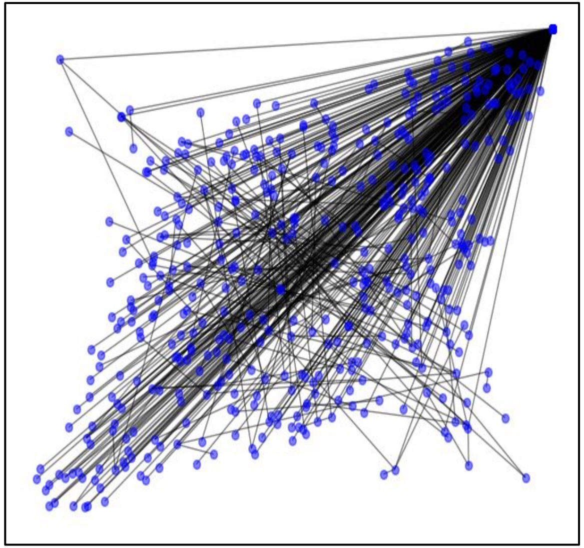
50 bots in least connected nodes



50 bots in random nodes

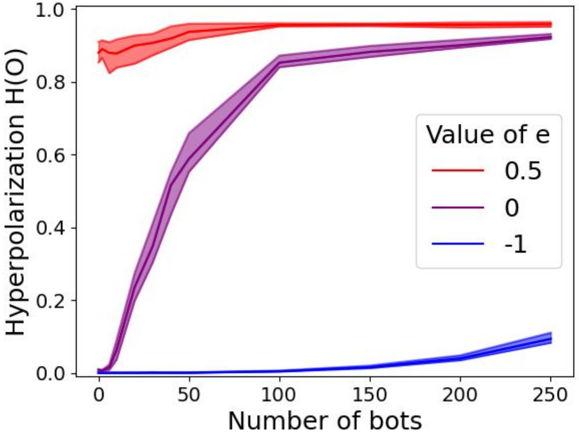


50 bots in most connected nodes

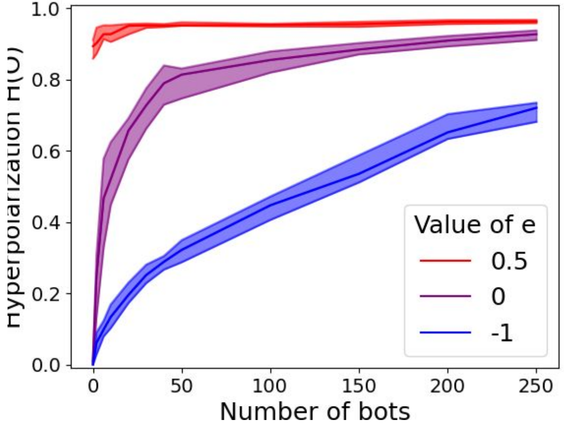


Bots in static Barabási–Albert graph (e=0)

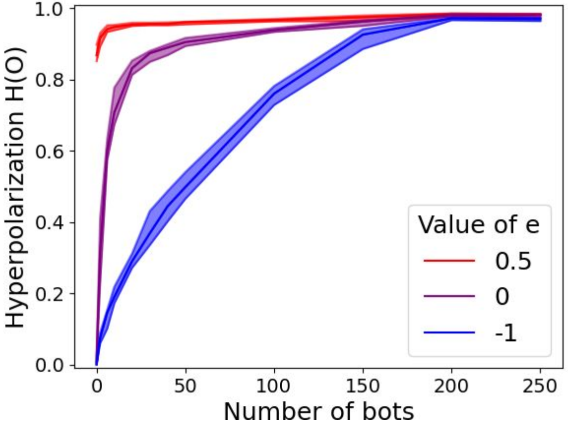
bots in least connected nodes

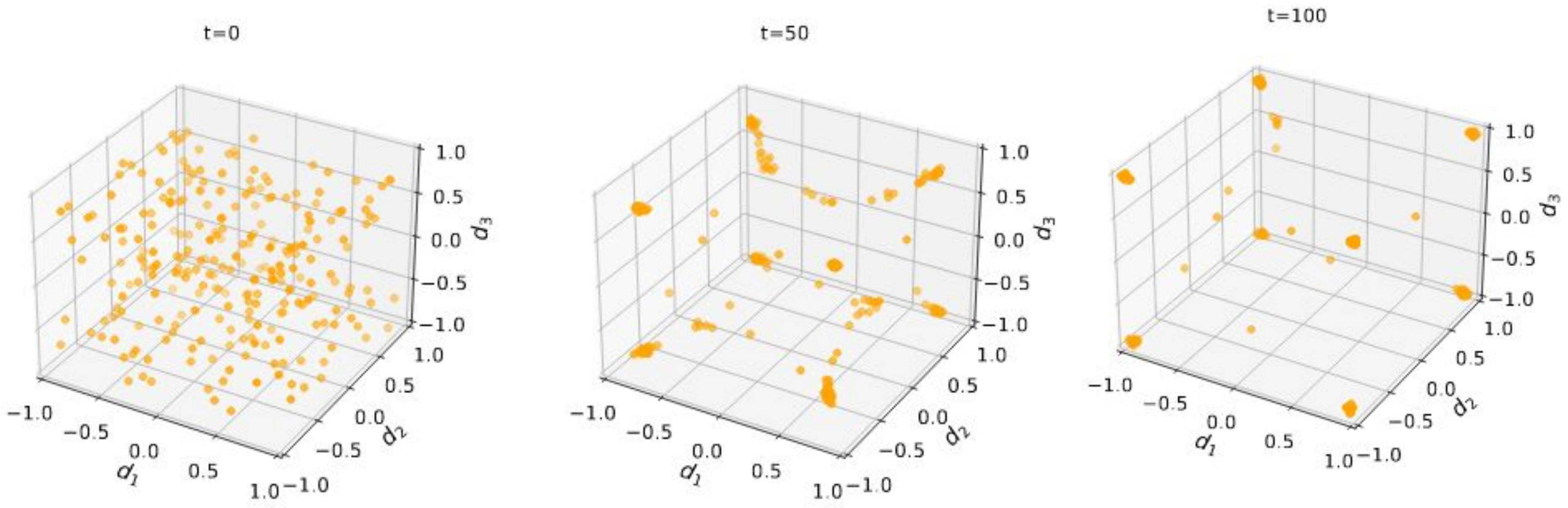


bots in random nodes



bots in most connected nodes





General Model,N= 250,D= 3,e= 0.3,α= 0.3,φ= 0.45,ε(N,D,z) = 0.3.