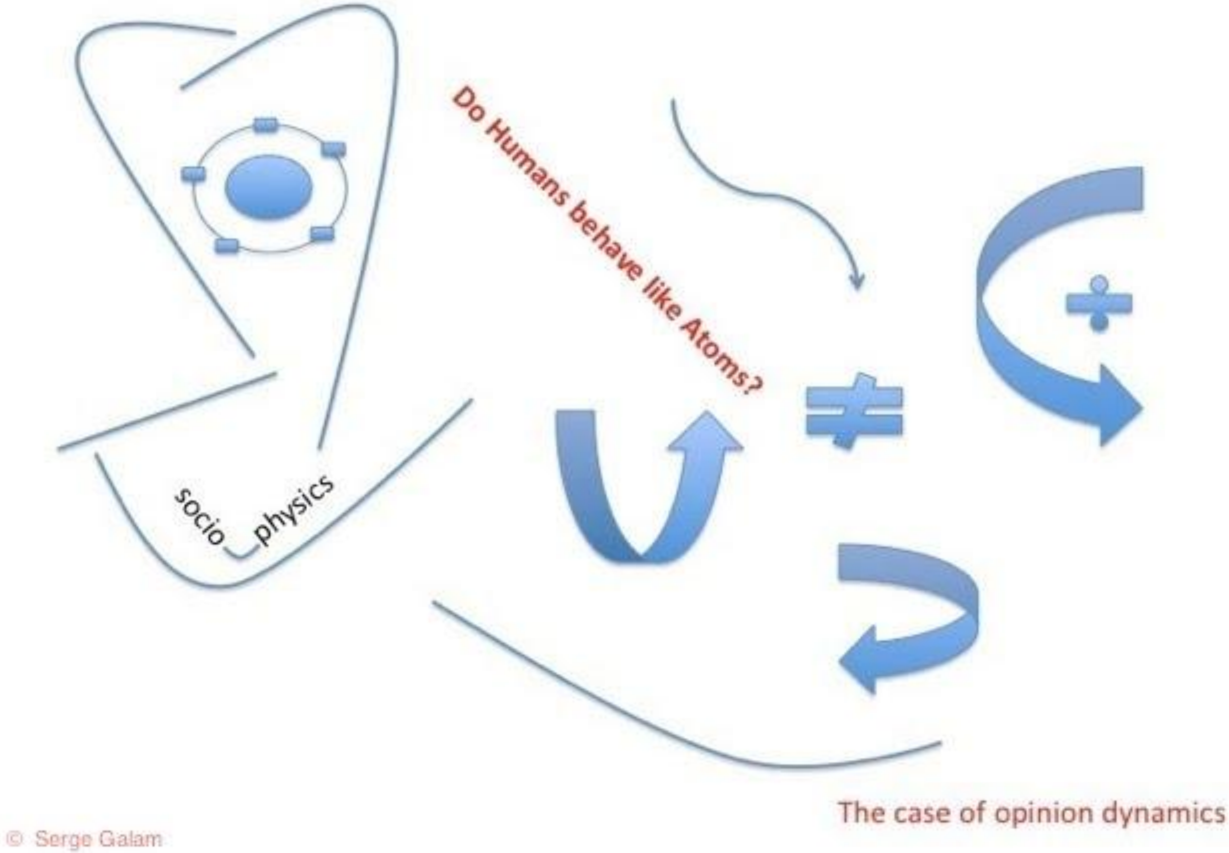
Sociophysics



European Territorial Cooperation Programme
Greece-Bulgaria 2007-2013
INVESTING IN OUR FUTURE

Blagoevgrad 2013

European Territorial Cooperation Progamme
Greece - Bulgaria 2007 - 2013
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What is sociophysics?

- As a field it is not yet well established.
- It does, however, influence heavily the field of Econophysics.
- It also gathers the interest of great sociologists who can think “out of the box”.

What is sociophysics?

- Sociophysics is the study of social questions posed by physicists and sociologists and dealt with physics methods.
- The idea of a physical modeling of social phenomena is in some sense older than the idea of statistical modeling of physical phenomena.

What is sociophysics?

- The discovery of quantitative laws in the collective properties of a large number of people (birth and death rates or crime statistics), helped in the development of statistics, and it led many scientists and philosophers to call for some quantitative understanding of how such precise regularities arise out of the apparently erratic behavior of single individuals.

What is sociophysics?

- This point of view was well known to Maxwell and Boltzmann and probably played a role when they abandoned the idea of describing the trajectory of single particles and introduced a statistical description for gases, laying the foundations of modern statistical physics.

What is sociophysics?

Sociophysics was born this way:

Sociology → Statistics →

Statistical Physics → Sociophysics

What is sociophysics?

- Very few books have so far been written on the subject:

1. Econophysics and Sociophysics (B.K. Chakrabarti, A. Chakraborti, A. Chaterjee) → 2006
2. Sociophysics: A Physicist's Modeling of Psycho-political Phenomena (S. Galam) → 2012
3. Econophysics: Background and Applications in Economics, Finance, and Sociophysics (G. Savoiu) → 2012
4. Modeling the Interplay Between Human Behavior and the Spread of Infectious Diseases (P. Manfredi, A. D'Onofrio) → 2013

Is it a new concept?

- Adolphe Quetelet (a statistician and astronomer originally) back in the 1830s started using statistics to express social science phenomena.
- He introduced mean values, and normal distributions to a science Comte (one of the founders of sociology) had termed social physics (and led Comte to rename it to sociology)

Is it a new concept?

- Most research in sociology was done at the macro level.
- Only recently (late 90’s), with computational sciences already developed, did sociologists started to use network theory to study society at the micro level.

What subjects does it deal with?

- Opinion dynamics and opinion formation are some of the most widespread topics of sociophysics.
- Study of group formation and community detection is also very important.
- Crowd dynamics and self organization of social systems.

Schelling's checkerboard model

Schelling said:

One day I was flying home from Chicago, and I did not have anything to read. I wondered what to do (…) So, I drew a line on a sheet of paper, put down (…) X's and O's, and said now suppose I thought that these were black and whites, and both had ideas about neighbors. I started moving them around (…)

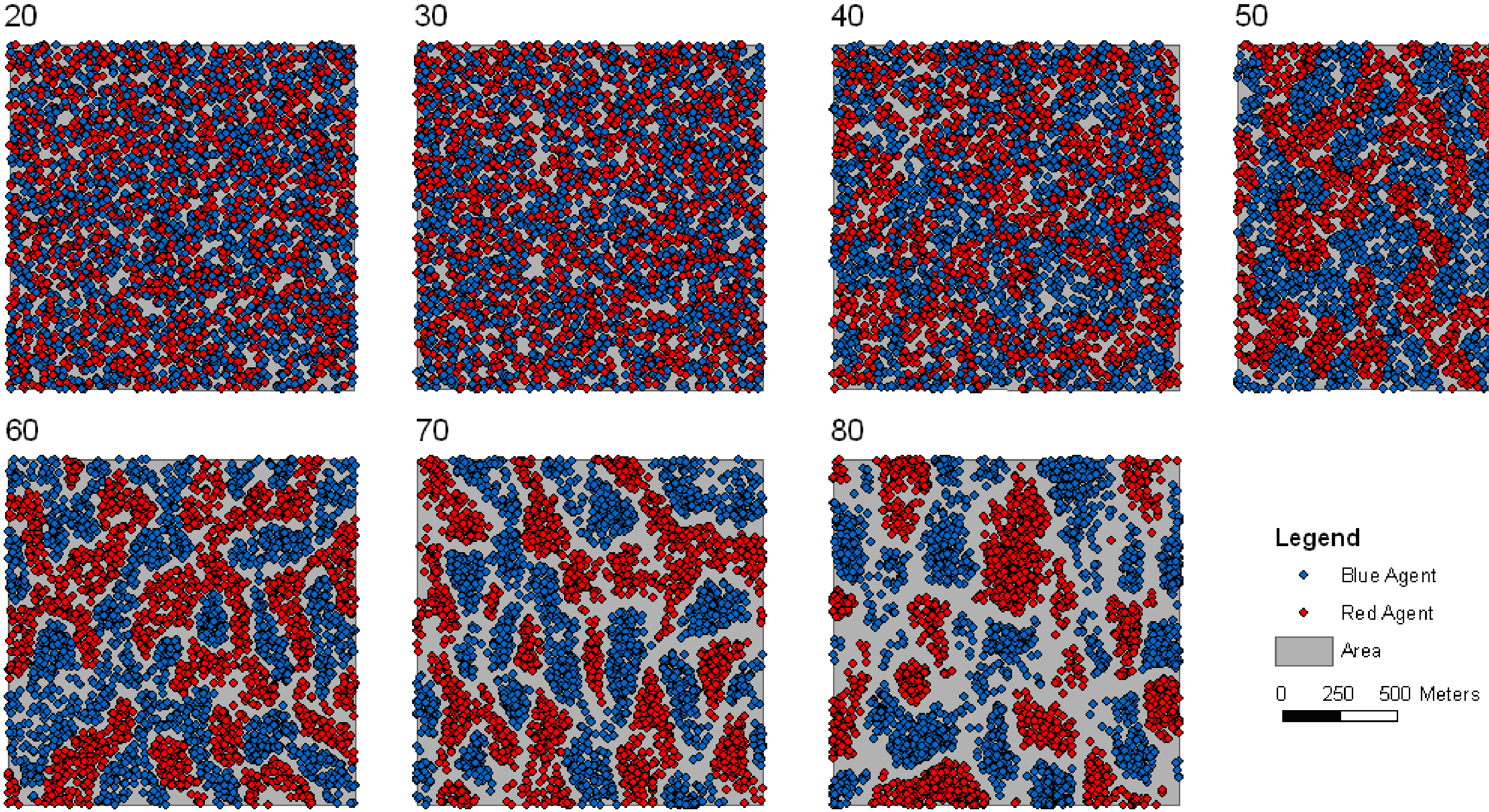
Schelling's checkerboard model

I had to erase marks to move them, and was extremely clumsy, but by the time my plane landed in Boston I decided this was going to prove interesting.

- Segragation is evident in social systems.
- Lets run a simple program

Schelling's checkerboard model

Example from physics



Schelling’s checkerboard model

- Even mild preferences → total segregation
- Simple agent’s rules can create complex global patterns or emergent behavior
- A milestone in the study of emergent global phenomena based on local social interactions
- Lead to “Agent based modeling”

Serge Galam

- In 1982 Serge Galam termed the social physics field as Sociophysics and used mean-behaviour to describe a strike in the real world.
- There are examples where a situation is more important than the individual’s habits and they dictate his behaviour.
- He bridged the micro level (individual) with the macro level (group - society).

Sociophysics

- In social phenomena, the basic constituents are not particles but humans, and every individual interacts with a limited number of peers, usually negligible compared to the total number of people in the system.
- In spite of that, human societies are characterized by stunning global regularities.

Sociophysics

- There are transitions from disorder to order, like the spontaneous formation of a common language and culture or the emergence of consensus about a specific issue.
- There are examples of scaling and universality.

Sociophysics

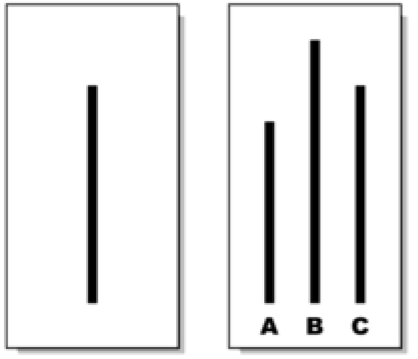
- These macroscopic phenomena naturally call for a statistical physics approach to social behavior, i.e., the attempt to understand regularities at large scale as collective effects of the interaction among single individuals, considered as relatively simple entities.

Social Conformity

- Conformity means the obedience to authority, peer pressure, social validation
- Conformity is the main mechanism of collective actions
- Generally we say "*when in doubt, imitate*", or "*when in Rome, act Roman"*
- People hate/fear standing out in a croud.

Asch conformity experiment

- A group of people were given two cards:



- They were then instructed to find which line in the second card is the one shown in the first

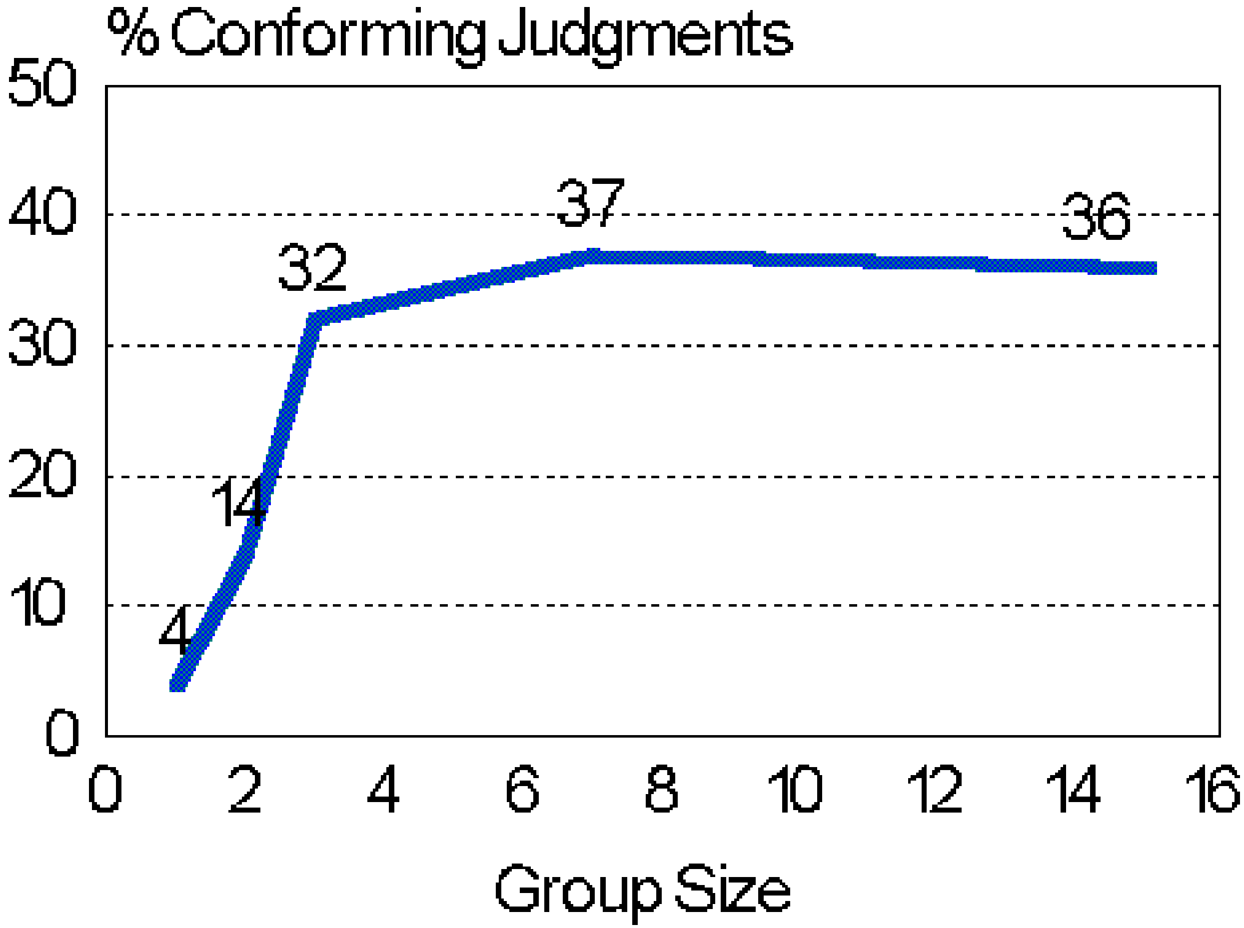
Asch conformity experiment

- The room had 5 people that gave the wrong answer ON PURPOSE (confederates) and one that did not know the answer and had to choose (the real participant).
- About 75% of the real participant answers were also wrong.

Asch conformity experiment

- *In some cases, when the majority says something, we do not question it and it can lead us to a mistake.*
- *Even if you know something is wrong (or suspect it might be) you may not say it!*

Asch conformity experiment



Opinion dynamics models

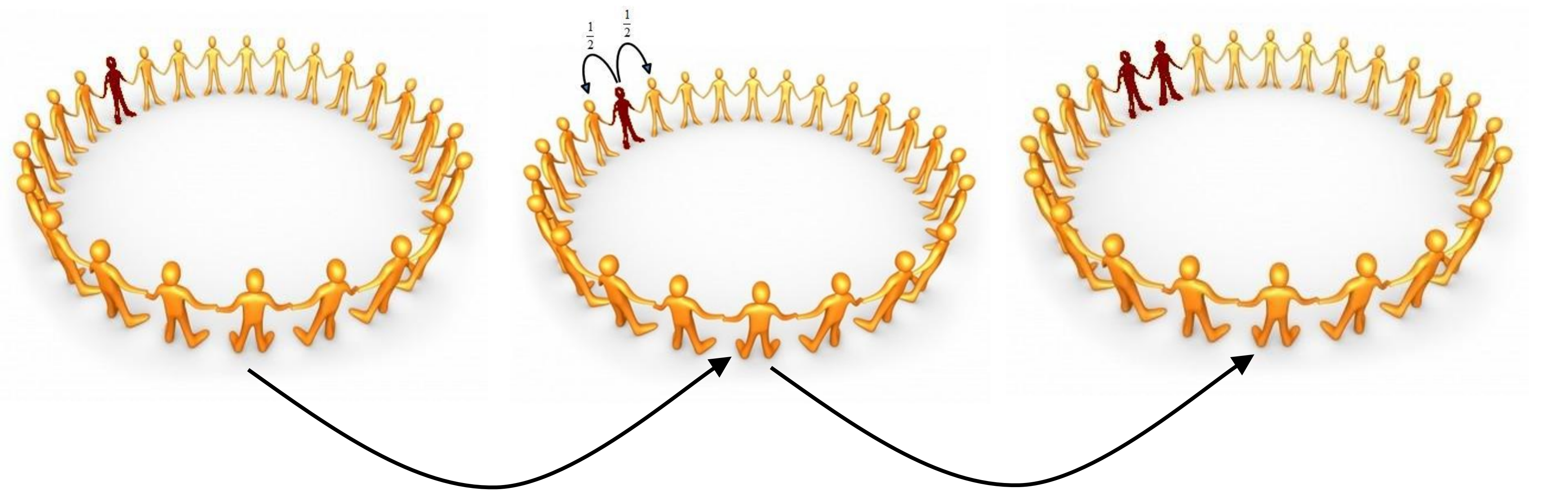
- Voter Model
- Majority Rule Model
- Sznajd Model
- Bounded confidence Models
- Other Models

Voter model

Voter Model not models voting!

Voter model

- Get influenced by one of your neighbors



Voter model

- One is given a lattice or graph whose vertices are called cells or sites.
- Each site x has a set of neighbor sites (including the site itself) which are said to be near x and which may influence the state of the site x which is either **On** or **Off** (**1** or **-1**).

Voter model

- Uniformly, a site x is chosen at random and its state is updated according to the following rule:
- One counts the number of **On** sites near the chosen site.
- The site then turns (or stays) **On** with probability *f*, which is a predetermined function whose parameters we modify.

Voter model

- One then repeats this process by picking another site, updating, and so on.
- This generates a sequence of configurations that is reminiscent of diffusion.
- The function *f* is usually chosen to be increasing so that a site is more and more likely to be **On** if more and more of it's neighboring sites are **On**.

Voter model

- *f* is chosen so that the system is symmetric under color change, meaning that if we invert the state of each cell, apply the update process, and invert the system again, we should get the same result (probabilistically) as if we simply updated the system.

Voter model

- We choose a lattice on the plane (Z * Z).
- In simulations it is only possible to consider a finite number of sites, so one chooses the integer lattice "wrapped around" every *m* steps in the x direction and every *n* steps in the y direction.
- *f* is such that a site will not turn **On** or **Off**, unless it has a neighbor of similar preference.

Voter model

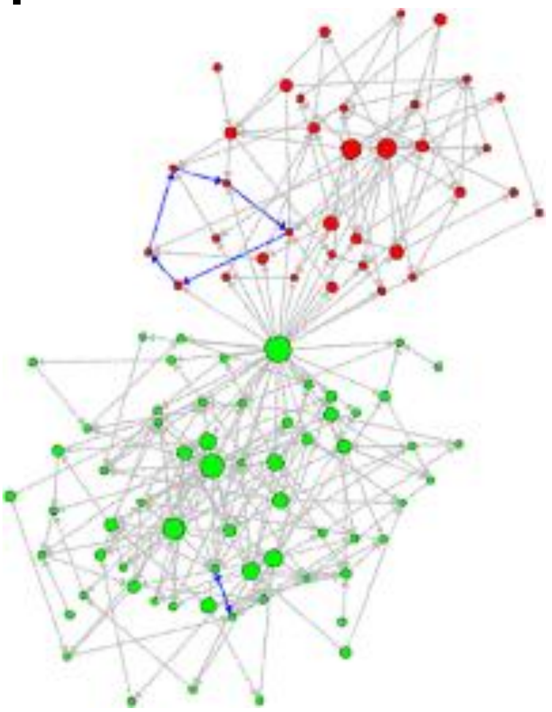
- Example

Voter model

- It is now heavily used in networks
- When considering disordered topologies, different ways of defining the voter dynamics, which are perfectly equivalent on regular lattices, give rise to nonequivalent generalizations of the voter model.

Voter model

- When the degree distribution is heterogeneous, the order in which a site and the neighbor to be copied are selected does matter, because high-degree nodes are more easily chosen as neighbors than low-degree ones.

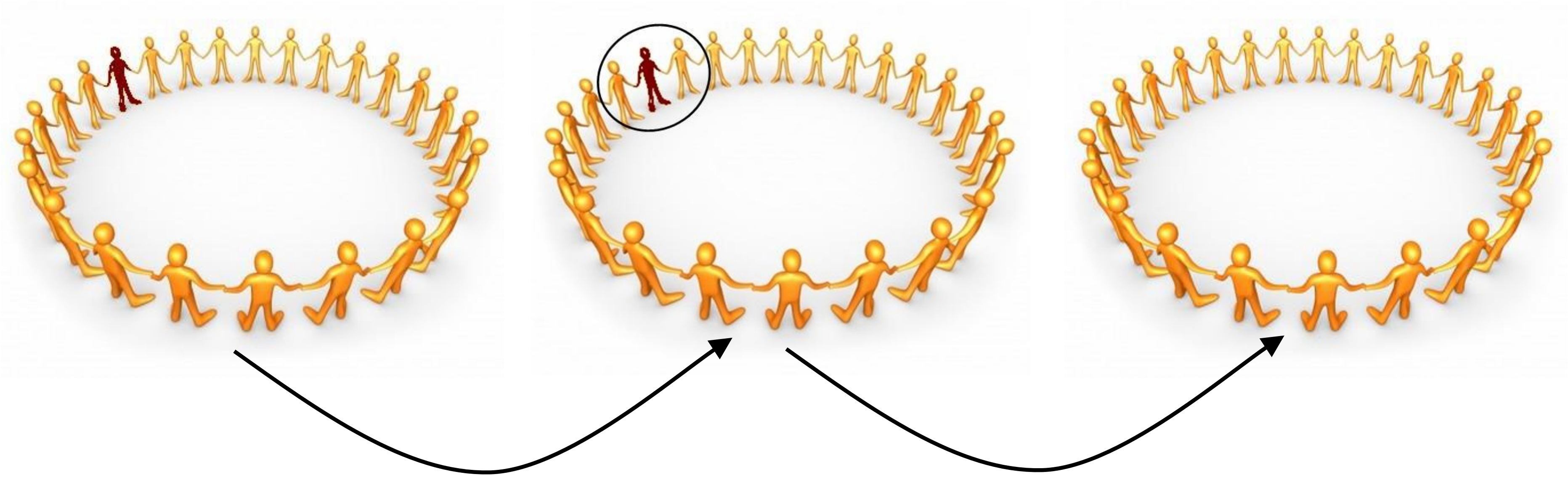


Voter model

Make an example on the board on why on networks it is quite different than on lattices.

Majority Rule model

- Do what most people around you do!



Majority Rule model

- In a population of N agents, endowed with binary opinions, a fraction p_+ of agents has opinion **+1** while a fraction $p_-=1-p_+$ has opinion **−1**.
- For simplicity, suppose that all agents can communicate with each other, so that the social network of contacts is a complete graph.

Majority Rule model

- At each iteration, a group of *r* agents is selected at random discussion group: as a consequence of the interaction, all agents take the majority opinion inside the group.
- This is the basic principle of the majority rule (MR) model, which was proposed to describe public debates (by S. Galam).

Majority Rule model

- The group size *r* is not fixed, but is selected at each step from a given distribution.
- If *r* is odd, there is always a majority in favor of either opinion.
- If *r* is even, instead, there is the possibility of a tie, i.e., that either opinion is supported by exactly *r*/2 agents.

Majority Rule model variants

- There are some variants in this model that are interesting and in some cases realistic:

1. Agents can move in space (Galam)
2. Agents interact with a variable number of neighbors (Tessone)
3. An extension to three opinions (Gekle)

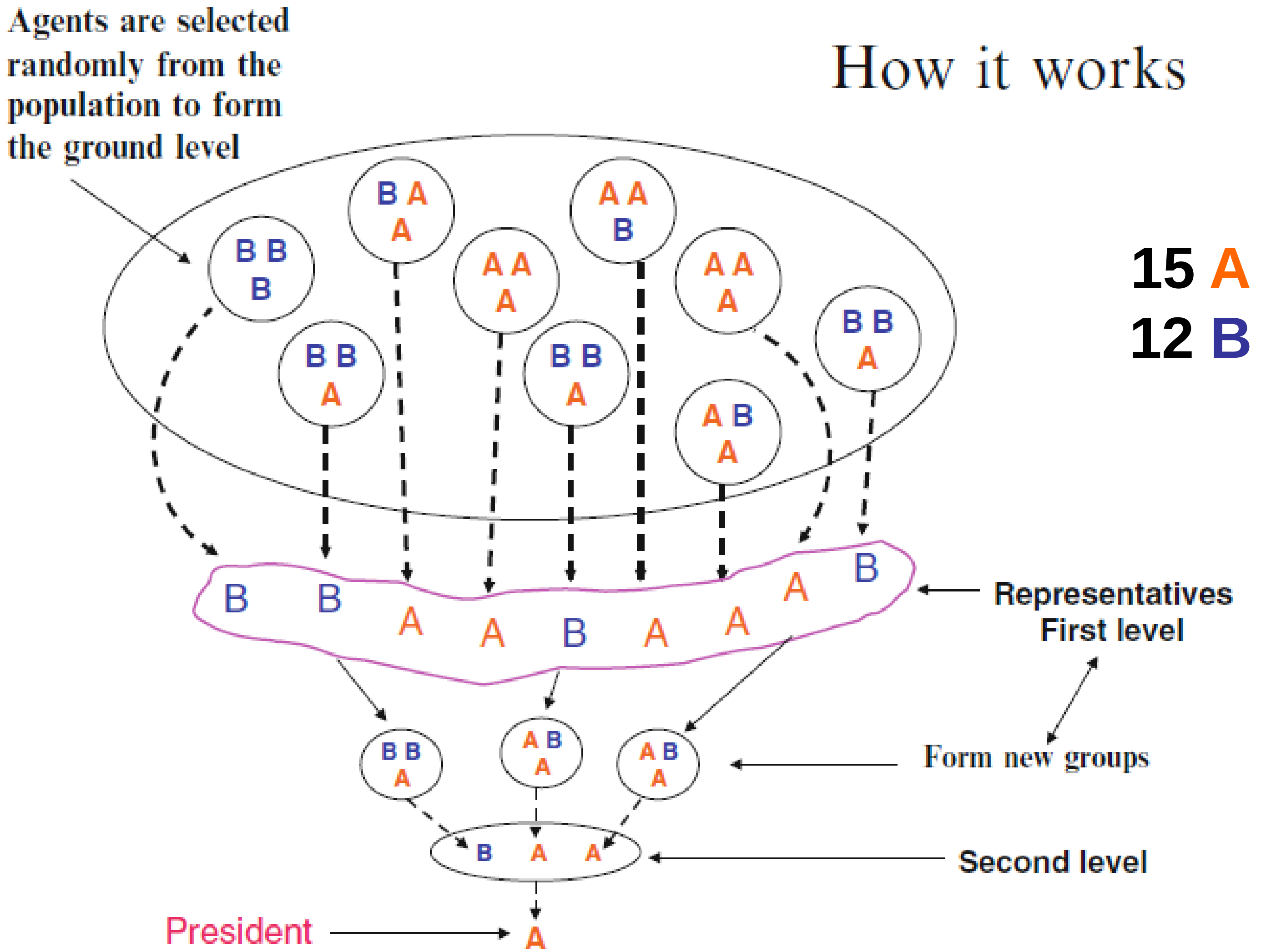
Majority Rule model variants

4. A probability to favor a particular opinion exists, which can vary among different individuals and/or social groups (Galam)
5. “Contrarians” exist (agents that take the majority opinion initially, but right after switch to the opposite opinion (Galam).

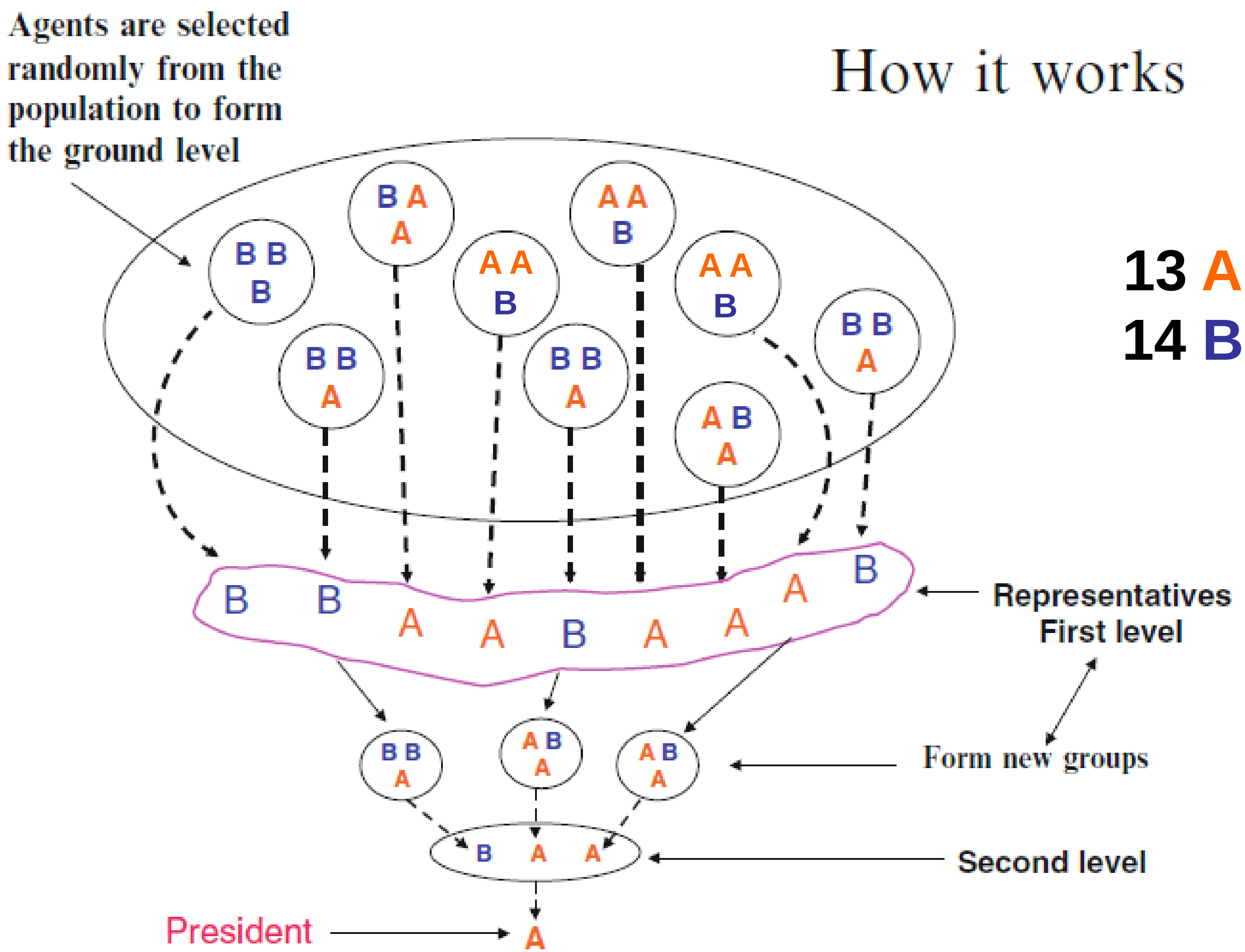
Majority Rule model variants

6. Presence of one-sided contrarians and unsettled agents (Borghesi and Galam)
7. Presence of inflexible agents that always stay by their side (Galam)
8. The majority-minority (MM) model, where one accounts for the possibility that minorities take over (Mobilia and Redner).

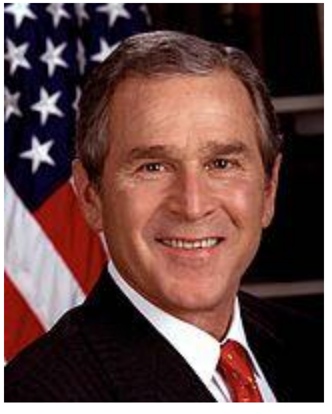
Majority Rule model example



Majority Rule model example



Is a majority model realistic?

- Majorities do not ALWAYS elect the president in some systems.
- i.e.  Vs  in the 2000 USA presidential elections.

Is a majority model realistic?

- Al Gore had 543,000 more votes!
- To be exact George Bush had 50,456,002 and Al Gore had 50,999,897.
- Because of the complexities of the political system rules, George Bush had more electoral votes (271 vs 266).
- So, George Bush won.

Is a majority model realistic?

1st party
Bersani
345 (C)
123 (S)
10,047,507
29.5%

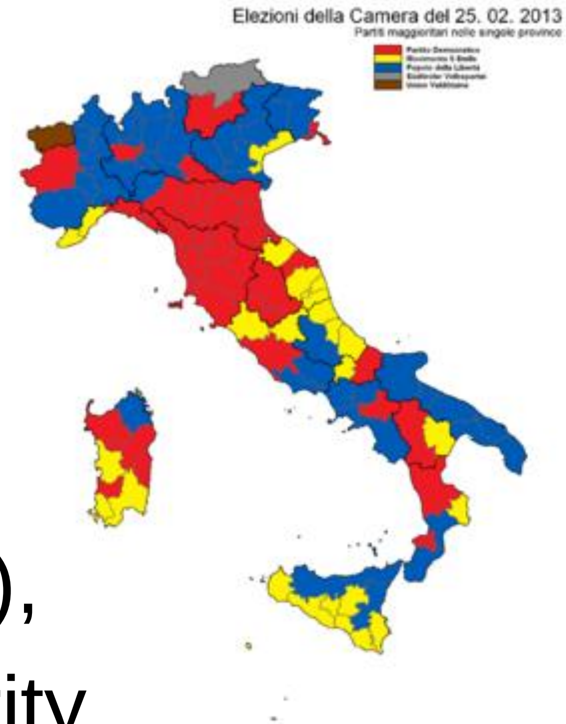
2nd party
Berlusconi
125 (C)
117 (S)
9,923,100
29.1%

3rd party
Grillo
109 (C)
54 (S)
8,688,545
25.5%

4th party
Monti
47 (C)
19 (S)
3,591,560
10.5%

Is a majority model realistic?

So Bersani won the elections but was unable to create a government because he had very few votes on the Senate (123/319), even though he had the majority in the Chamber of Deputies (345/630).



Sznajd model

- We would not pay attention to a single guy staring at a blank wall
- However, if a group of people stares at that wall, we may be tempted to do the same.
- Convincing somebody is easier for two or more people than for a single individual.

Sznajd model

- In its original version, agents occupy the sites of a linear chain, and have binary opinions, denoted by Ising spin variables.
- A pair of neighboring agents i and $i+1$ determines the opinions of their two nearest neighbors $i-1$ and $i+2$, according to the following rules:

Sznajd model

a) If $s_i = s_{i+1}$, then $s_{i-1} = s_i = s_{i+1} = s_{i+2}$
b) If $s_i \neq s_{i+1}$, then $s_{i-1} = s_{i+1}$ and $s_{i+2} = s_i$

- So, if the agents of the pair share the same opinion, they successfully impose their opinion on their neighbors.
- If, instead, the two agents disagree, each agent imposes its opinion on the other agent’s neighbor.

Bounded confidence models

1. Continuous opinions

- So far, opinion was a discrete variable, which represents a reasonable description in several instances.
- However, there are cases in which the position of an individual can vary smoothly from one extreme of the range of possible choices to the other.

Bounded confidence models

- As an example, one could think of the political orientation of an individual, which is not restricted to the choices of extreme right or left but includes all options in between.
- These may be indicated by the geometric position of the seat of a deputy in the Parliament

Bounded confidence models

2. Deffuant model

- Consider a population of N agents, represented by the nodes of a graph, where agents may discuss with each other if the corresponding nodes are connected. Each agent i is initially given an opinion x_i, randomly chosen in the interval [0,1].

Bounded confidence models

- The dynamics is based on random binary encounters, i.e., at each time step, a randomly selected agent discusses with one of its neighbors on the social graph, also chosen at random.
- If the difference of the opinions of two agents exceeds a threshold nothing happens, otherwise they both converge.

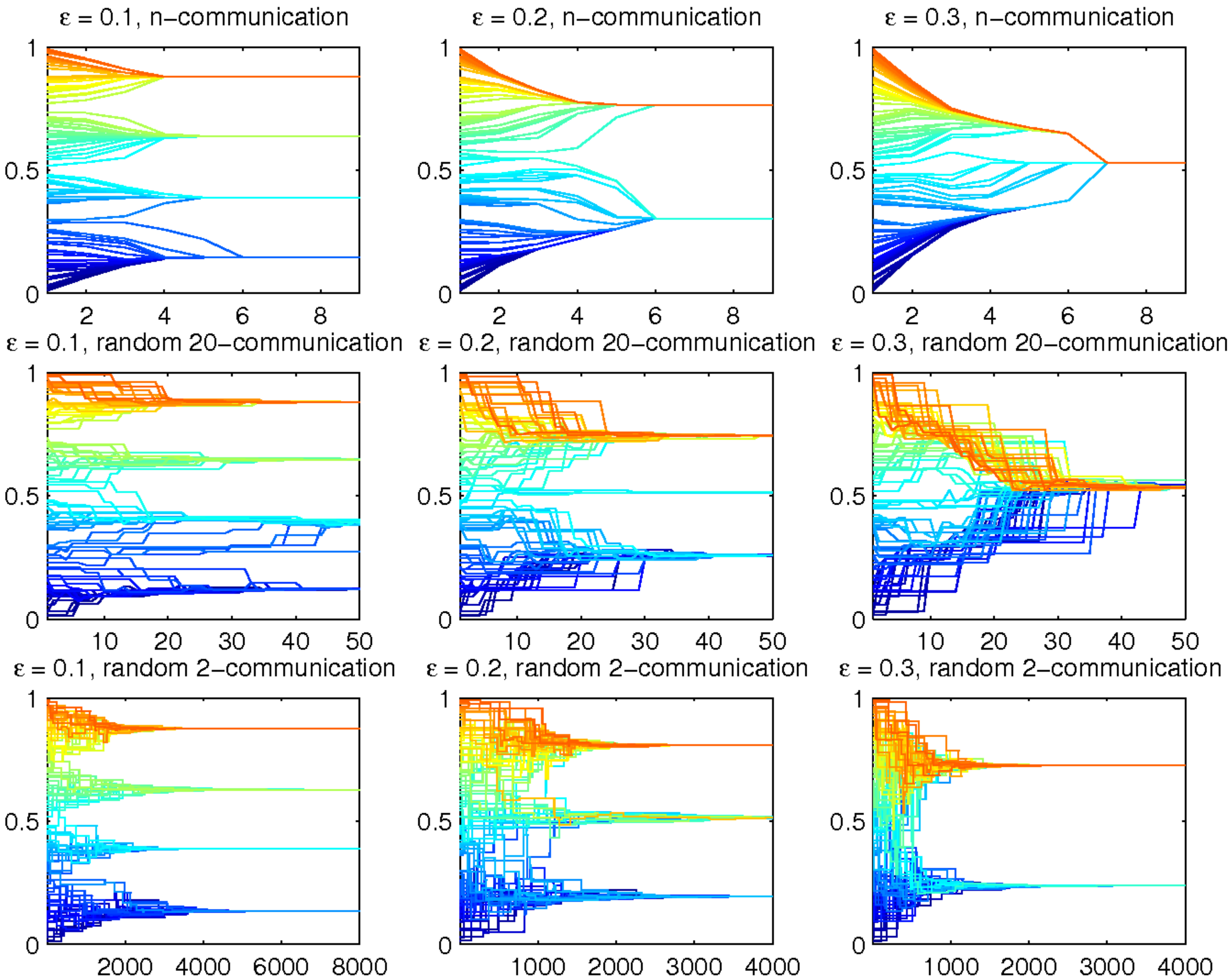
Bounded confidence models

3. Hegselmann-Krause (HK) model

- The HK model is similar to Deffuant.
- Opinions take real values in an interval, say [0,1], and an agent *i*, with opinion x_i, interacts with neighboring agents whose opinions lie in the range $x_i-\varepsilon$, $x_i+\varepsilon$, where ε is the uncertainty.

Bounded confidence models

- The difference is given by the update rule: agent *i* does not interact with one of its compatible neighbors, like in Deffuant, but with all its compatible neighbors at once.


ε = 0.1, n−communication
ε = 0.2, n−communication
ε = 0.3, n−communication
ε = 0.1, random 20−communication
ε = 0.2, random 20−communication
ε = 0.3, random 20−communication
ε = 0.1, random 2−communication
ε = 0.2, random 2−communication
ε = 0.3, random 2−communication

Bounded confidence models

- Deffuant's prescription is suitable to describe the opinion dynamics of large populations, where people meet in small groups, like pairs.
- In contrast, the HK rule is intended to describe formal meetings, where there is an effective interaction involving many people at the same time.

Other Models

1. Ising based model by Jiang:

- An agent surrounded by a majority of neighbors with equal opinion will flip its opinion with the usual Metropolis probability, $\exp^{(-\Delta E/T)}$, where ΔE is the increase of the Ising energy due to the flip, and T is the social temperature.

Other Models

- When the majority of neighbors disagrees with the agent's opinion, the latter flips with a probability q, which accounts for the possibility that agents keep their opinion in spite of social pressure "inflexible agents".
- For q=1, one recovers the usual Ising dynamics.

Other Models

2. Binary opinion model by Bartolozzi:

- Binary opinions, evolve according to heat bath dynamics.
- An opinion field acts on a spin.

Other Models

- When the stochastic noise exceeds a threshold, the time evolution of the average opinion of the system is characterized by large intermittent fluctuations.
- A comparison with the time series of the Dow-Jones index at New York’s Stock Exchange reveals striking similarities.

Other Models

3. Kuperman and Zanette model :

- Opinions are affected by 3 processes:

i. social imitation, occurring via majority rule

ii. fashion, expressed by an external modulation acting on all agents

iii. individual uncertainty, expressed by random noise.

Other Models

- Stochastic resonance was observed.
- A suitable amount of noise leads to a strong amplification of the system's response to the external modulation.
- The phenomenon occurs as well if one varies the size of the system for a fixed amount of noise.

Other Models

- Several more models exist:
- Kuramoto variant opinion models.
- Kinetic models of opinion dynamics.
- Combination of binary and continuous opinion approaches models.
- Models focusing on specific types of opinions (fashion, personal taste, elections etc).

Crowd behavior

Crowd behavior

- Collective motion is very common in nature.
- Flocks of birds, schools of fish, and swarms of insects are among the most spectacular manifestations

Crowd behavior

- Collective motion is very common in nature.
- Flocks of birds, schools of fish, and swarms of insects are among the most spectacular manifestations
- Humans display similar behavior in many instances: pedestrian motion, panic, vehicular traffic, etc.

Flocking

- Initially, the directions of the velocity vectors are randomly assigned, so that there is no organized flow of particles in the system.
- After some relaxation time, the system reaches a steady state.

Flocking

- At each time step, a particle *i* assumes the average direction of motion of the particles lying within a local neighborhood S_i, with a random perturbation,
- Noise is a realistic ingredient of the model, relaxing the strict prescription of alignment to the average direction of motion of the neighboring peers.

Pedestrian behavior

- Pedestrian behavior has been studied empirically since the 1950s.
- The first physical modeling was proposed by Henderson in 1971,who conjectured that pedestrian flows are similar to gases or fluids and measurements of pedestrian flows were compared with Navier-Stokes equations.

Pedestrian behavior

- Realistic macroscopic models should account for effects like maneuvers to avoid collisions, for which energy and momentum are not conserved.
- They should also consider the “granular” structure of pedestrian flows, as each pedestrian occupies a volume that cannot be penetrated by others.

Applause dynamics

- Applause represents another remarkable example of social self-organization.
- At the end of a good performance, the audience, after an initial uncoordinated phase, often produces a synchronized clapping, where everybody claps at the same time and with the same frequency.

Applause dynamics

- Synchronization occurs in many biological and sociological processes:

i. flashing of Southeast Asian fireflies

ii. chirping of crickets

iii. oscillating chemical reactions

iv. menstrual cycles of women living together for long times.

Mexican wave

- An example of coherent collective motion, i.e., the Mexican wave, also called La Ola.
- La Ola is the wave created by spectators in football stadia when they rapidly leap from the seats with their arms up and successively sit down while a neighboring section of people starts the same sequence.

Applause dynamics

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