Agent-based models:

Theory and applications

General approach
Three models

By Yérali Gandica

1) From simple local rules → To Global emergent phenomena

2) Understand all the resulting states and its relation with the ingredients

3) To search for signs of universality

Models for social dynamics

Main models for population dynamics:

- Voter model: social and physics
- Majority rule model
- Bounded confidence models

Main model for population dynamics:

- Schelling model for segregation

Main model for cultural dynamics:

- Axelrod model

Echo Chambers: A model for opinion dynamics

http://www.complexity-explorables.org/explorables/loyale-with-cheese/

I. Axelrod Model
(model for the dissemination of culture)

Who is Axelrod and what was the motivation for his model?

Robert Axelrod is an American political scientist. He is Professor of Political Science and Public Policy at the University of Michigan where he has been since 1974. He is best known for his interdisciplinary work on the evolution of cooperation. His current research interests include complexity theory (especially agent-based modeling), international security, and cyber security.

Robert Axelrod

I. Axelrod Model

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Who is Axelrod and what was the motivation for his model?

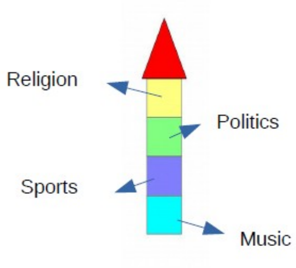
The Dissemination of Culture: A Model with Local Convergence and Global Polarization

Robert Axelrod

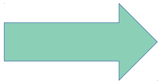
The Journal of Conflict Resolution, Volume 41, Issue 2 (Apr., 1997), 203-226.

If people tend to become more alike in their beliefs, attitudes, and behavior when they interact, why do not all such differences eventually disappear?

I. Axelrod Model
(model for Cultural Dynamics)



Each agent is a vector



Agents placed in a square lattice of L x L sites

The state of the ith agent is defined by a set of F cultural features (F-dimensional vector)

All the features are randomly assigned with an uniform distribution of the integers in the interval [1,q]

Iterate:

(1) Choose randomly two nearest neighbor agents i and j,

(2) calculate the number of shared features (cultural overlap) between the agents ℓ_{ij}. If $0 < \ell_{ij} < F$:

then (3) with probability ℓ_{ij}/F set $C_{ik} = C_{jk}$, pick up randomly a feature k such that $C_{ik} = C_{jk}$.

Output: The biggest cluster size, in terms of q.

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Nonequilibrium Phase Transition in a Model for Social Influence

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[2]*Istituto Nazionale per la Fisica della Materia (INFM), Trieste-SISSA Unit, Via Beirut 2-4, I-34014 Trieste, Italy*
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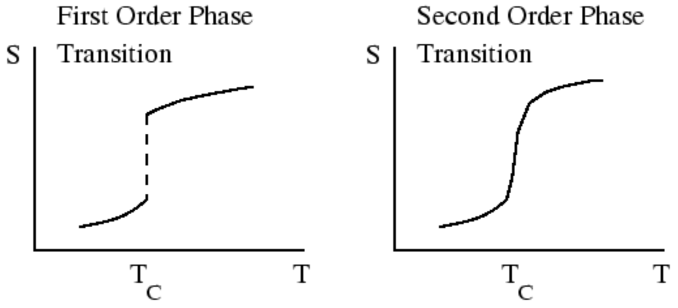
(Received 6 March 2000)

Absorbing state over grids:

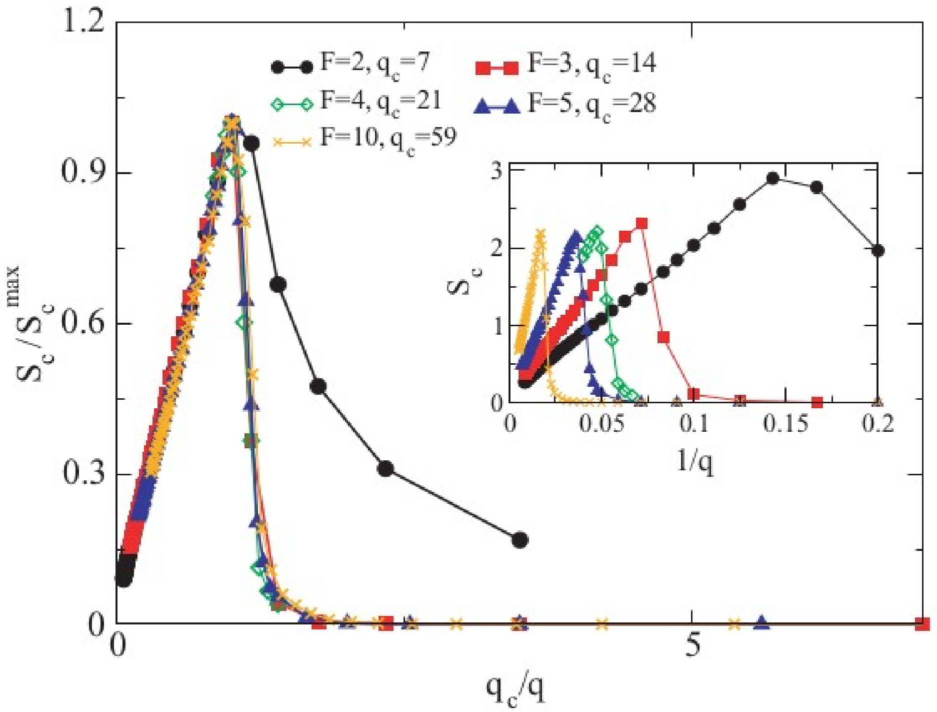
Continuous order-disorder transition in F=2, and abrupt one in F>2



PHYSICAL REVIEW E **84**, 046109 (2011)

Cluster-size entropy in the Axelrod model of social influence: Small-world networks and mass media

Y. Gandica,[1] A. Charmell,[2] J. Villegas-Febres,[2] and I. Bonalde[1]

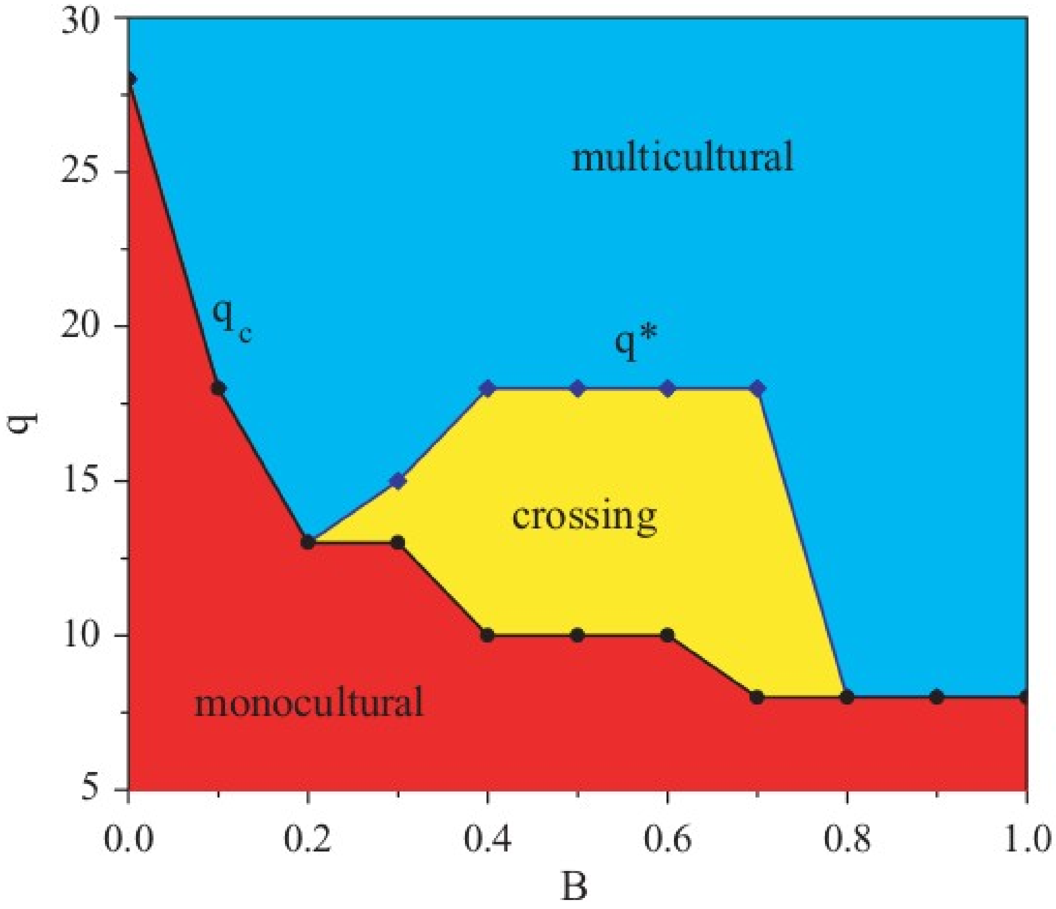


$$S_c(P) = -\sum_s W_s(P) \ln W_s(P)$$

Cluster-size entropy

Normalized cluster-size entropy Sc /Sc max against the normalized probability of occupation qc /q for a network of disorder p = 0 and size 40 × 40 for different values of F . The data suggest that the Axelrod model for F = 2 is in a different universality class from that for F > 2.

If we apply an external field, the system enters in a “crossing phase,” (a large cultural cluster whose state is not aligned with the external field)

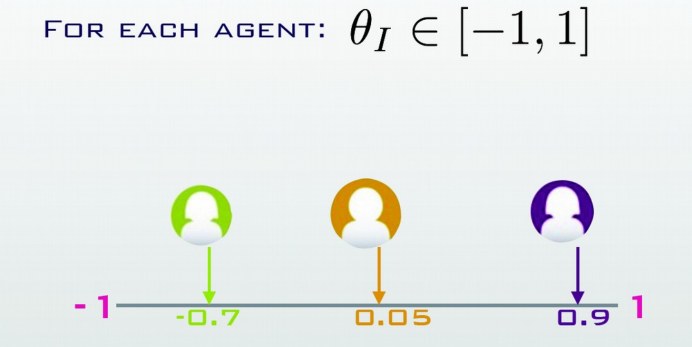


q − B phase diagram of the Axelrod model obtained for F = 5 in a
40 × 40 regular network. Each point represents an average of 50–100 realizations

II. Bounded confidence Model

(model for Opinion Dynamics)

Agents



Continuous opinions

<u>Compromise strategy</u>: after a constructive debate, the positions of the interacting agents get closer to each other

II. Bounded confidence Model

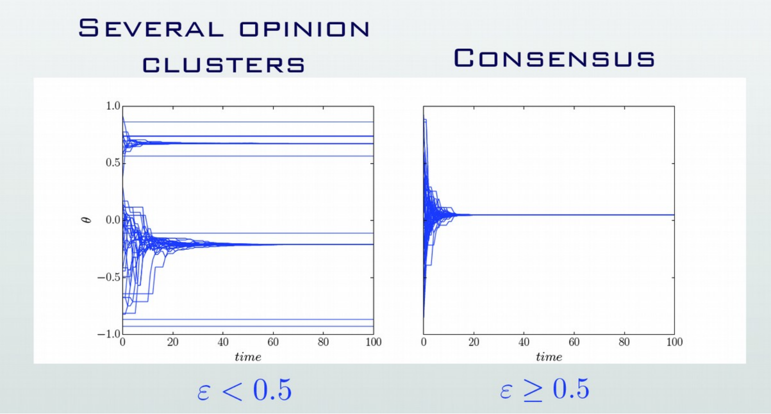
(model for Opinion Dynamics)

tolerance threshold

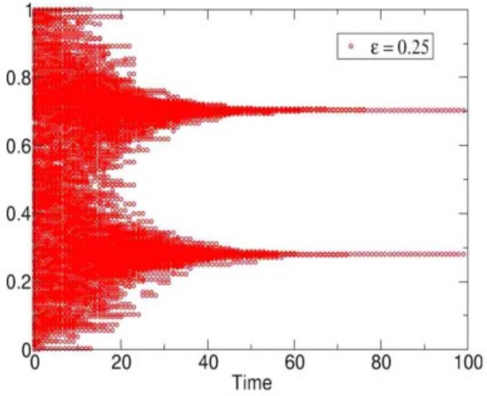
Dynamic rule

CONFIRMATION BIAS	$if \quad \lvert\theta_I - \theta_J\rvert < \varepsilon$
COGNITIVE DISSONANCE	$\langle\theta\rangle_{IJ} = (\theta_i + \theta_J)/2$ $\theta_I = \theta_J = \langle\theta\rangle_{IJ}$

In practice, there is a real discussion only if the opinions of the people involved are sufficiently close to each other



The final configuration can be approximated by the expression 1 / 2ϵ.



At stationarity, agents belonging to different opinion clusters cannot interact with each other → the opinion of each cluster must differ by at least ϵ from the opinions of its neighboring clusters. In this way, within an interval of length 2ϵ centered at a cluster, there cannot be other clusters.

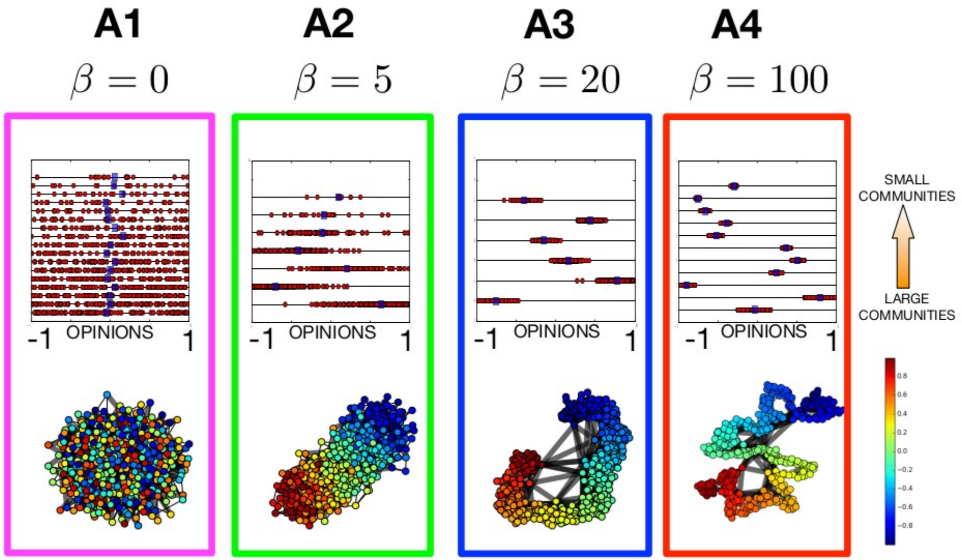
On complete graphs, regular lattices, random graphs, and scale-free networks, for $\epsilon > \epsilon_{C=1/2}$, all agents share the same opinion 1 / 2 → **complete consensus.**

This may be a general property of the Deffuant model, independent of the underlying social graph

The Role of Homophily in the Emergence of Opinion Controversies

Floriana Gargiulo[1] and Yerali Gandica[2]

[1] GEMASS, CNRS, Université de Paris-Sorbonne, 20 rue Berbier-du-Mets, Paris 75013, France
[2] CeReFiM and Namur Center for Complex Systems - NaXys, University of Namur, 8 Rempart de la Vierge, 5000 Namur, Belgium



Each line represent a community (ordered from the larger on the bottom to the smaller on the top); the red points represent the agents opinions inside each community, the blue square is the average opinion of the community. Increasing β the opinion range inside the communities is smaller

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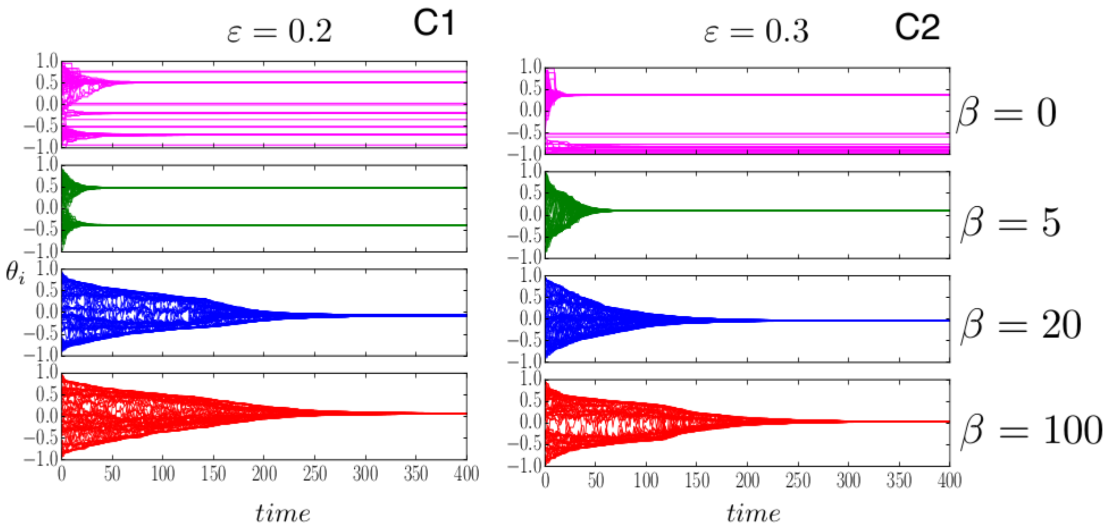

II. Schelling model

(model for segregation)

Thomas Crombie Schelling (April 14, 1921 – December 13, 2016) was an American economist and professor of foreign policy, national security, nuclear strategy, and arms control at the School of Public Policy at University of Maryland, College Park. He was also co-faculty at the New England Complex Systems Institute. He was awarded the 2005 Nobel Memorial Prize in Economic Sciences (shared with Robert Aumann) for "having enhanced our understanding of conflict and cooperation through game-theory analysis”.

Thomas Schelling

<u>Motivation for the model:</u>

He wanted to understand why professors’ offices in his university were completely segregated by group of friends. He showed that even a small preference to have the same number of wanted neighbour can lead to total global segregation

II. Schelling model

(model for segregation)

Tolerance parameter T

Stay if at least T of the neighbors are “kin”

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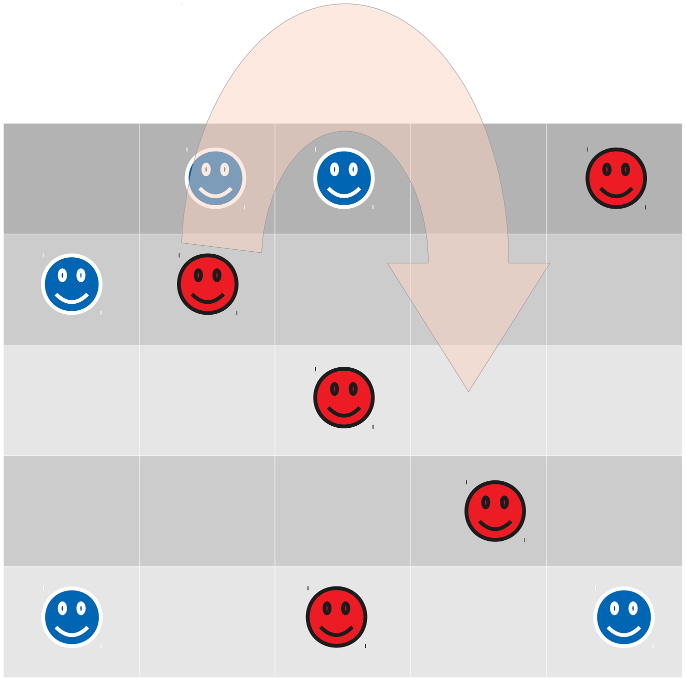
(model for segregation)



Tolerance parameter T

Stay if at least T of the neighbors are “kin”

If T=0.5 the agent will move

II. Schelling model

(model for segregation)

Tolerance parameter T

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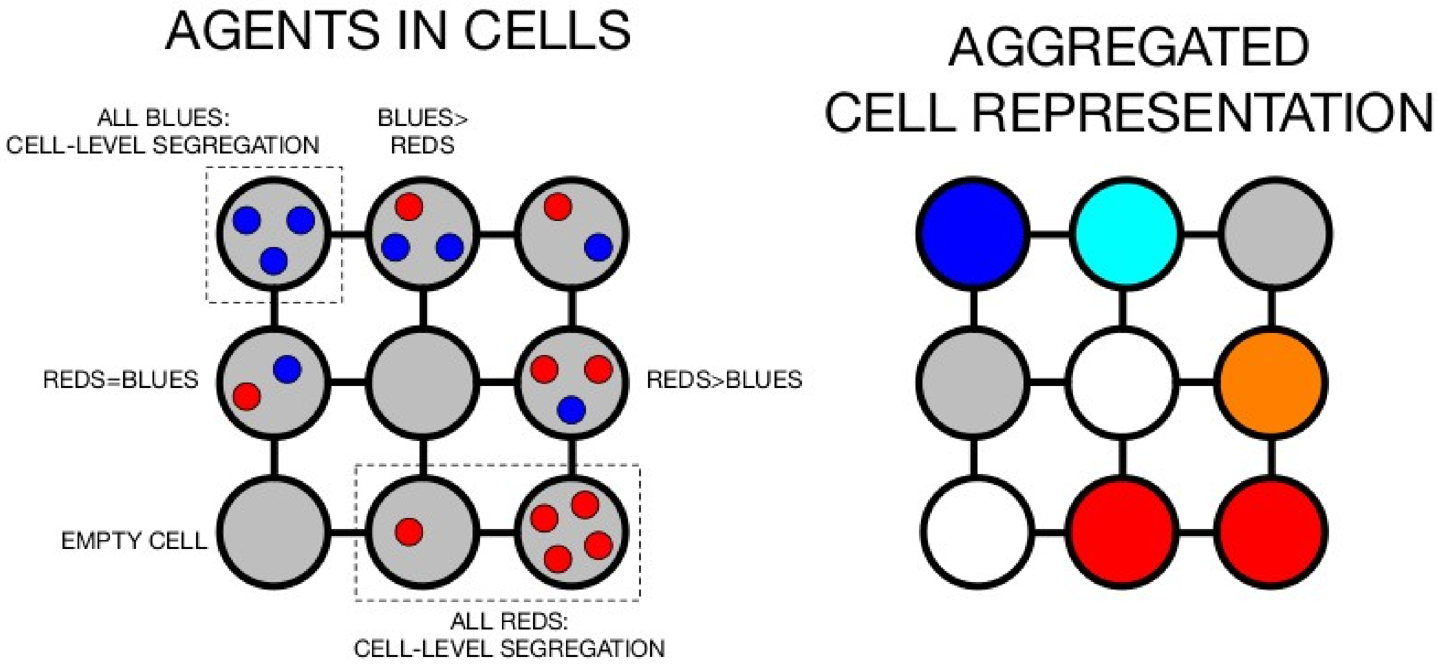
Whether checking out or not the destination before moving is part of the model’s version

The model can be simulated in a metapopulation framework



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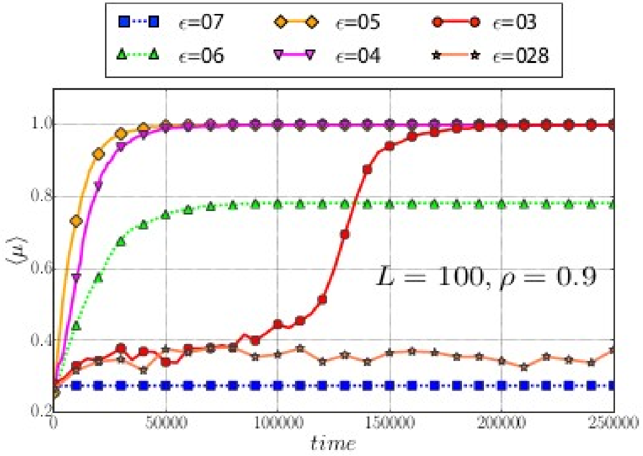
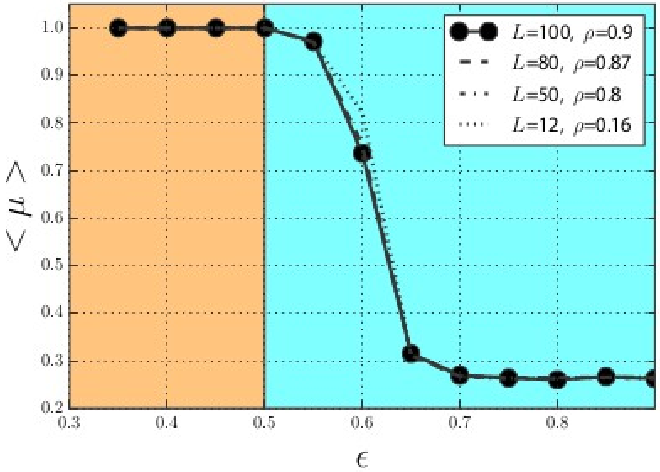
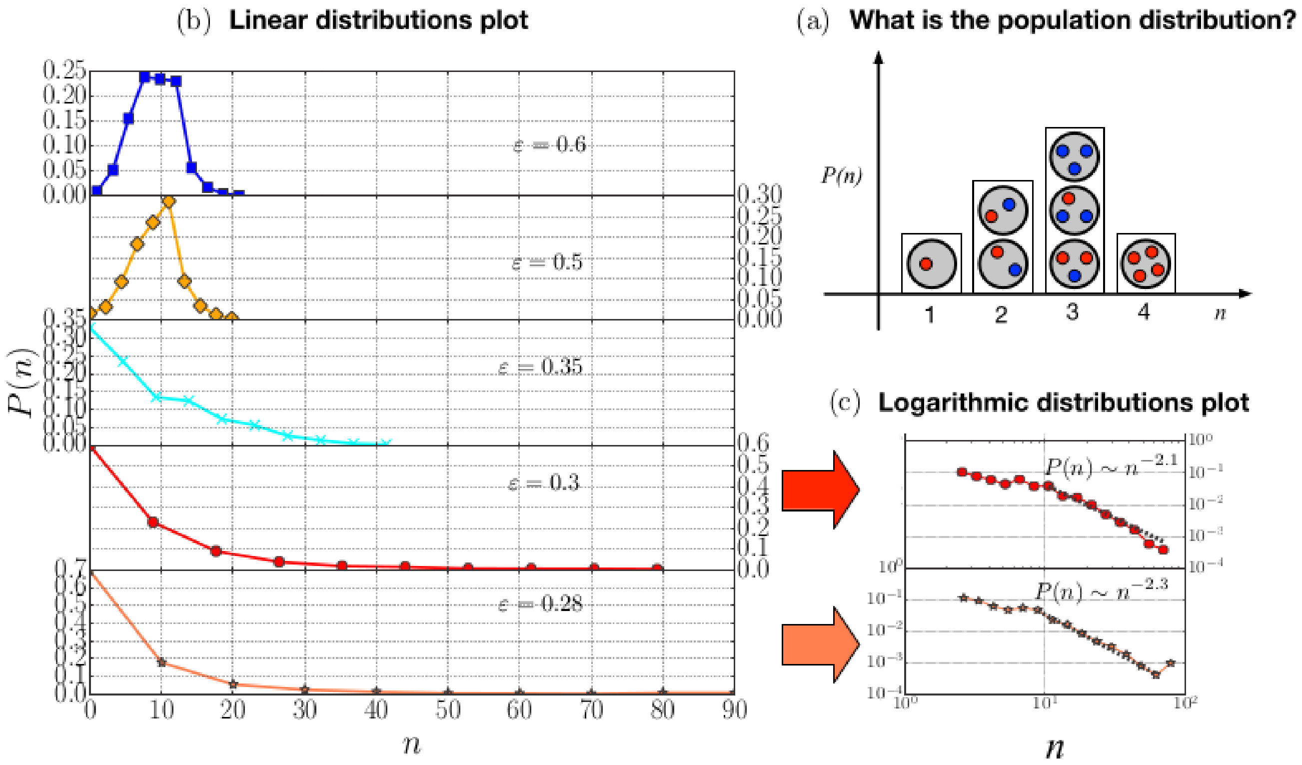
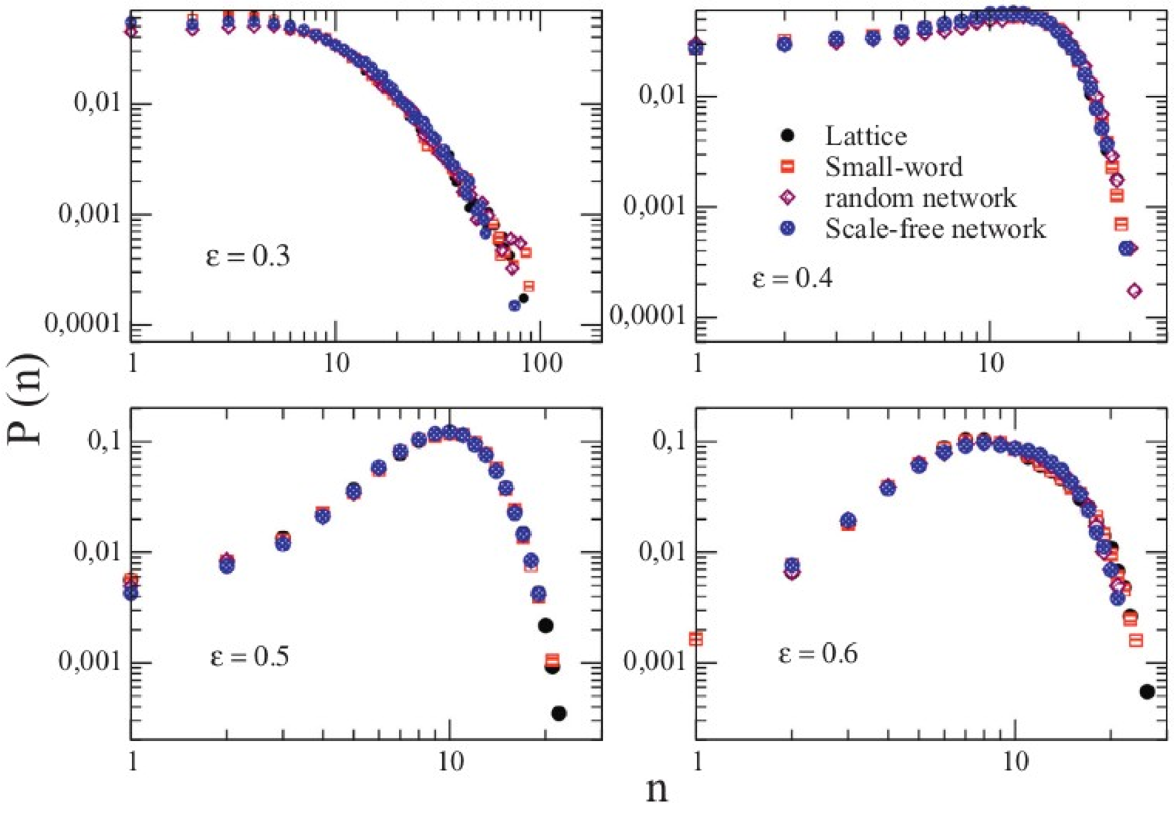




$$\langle \mu \rangle = \frac{1}{\sum_{i|(n_i^B+n_i^A)>0} 1} \sum_{i|(n_i^B+n_i^A)>0} \frac{|n_i^B - n_i^A|}{n_i^B + n_i^A}.$$


(b) Linear distributions plot
$\varepsilon = 0.6$
$\varepsilon = 0.5$
$\varepsilon = 0.35$
$\varepsilon = 0.3$
$\varepsilon = 0.28$
$P(n)$
n
(a) What is the population distribution?
P(n)
1
2
3
4
n
(c) Logarithmic distributions plot
$P(n) \sim n^{-2.1}$
$P(n) \sim n^{-2.3}$
n

What about other topologies?



Distribution of the nodes population