

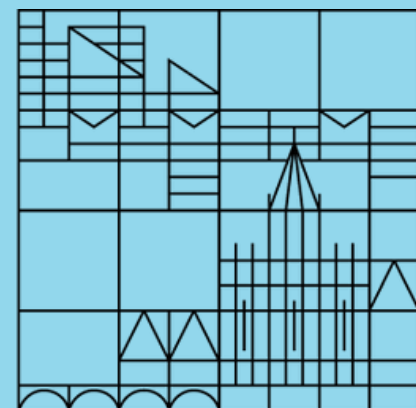
UNIVERSITÄT KONSTANZ



Modelling Culture and Language

Computational Modelling of
Social Systems

Universität
Konstanz



Giordano De Marzo
Max Pellert

Seminars Dates

April 9, 2024–The Basics of Agent-Based Modeling

April 16, 2024–Modelling segregation: Schelling's model

April 23, 2024–Modelling Culture and Language

April 30, 2024–Diversity, Minorities and Granovetter's Model

May 7, 2024–Opinion dynamics

May 14, 2024–Power Laws and Black Swans

May 15, 2024–Network Theory

May 21, 2024–Resilience in social networks

June 4, 2024 –Spreading in networks

Students Seminars Dates

June 19, 2024

- Stroligo Alisea, Ruhe Adrian, Saleth Peer

June 25, 2024

- Hennig Dajana, Amann Jakob, Fröhlich Nicolas

June 26, 2024

- King Julia, Aytac Robin, Keßler Raphaela, Helten Marius

July 2, 2024

- Gießing Lennart, Wagner Theresa, Jones Katrina, Solar Elena

July 3, 2024

- Froitzheim Lea, Tiedemann Leonard, Strauch Liane, Wiederspohn Jens

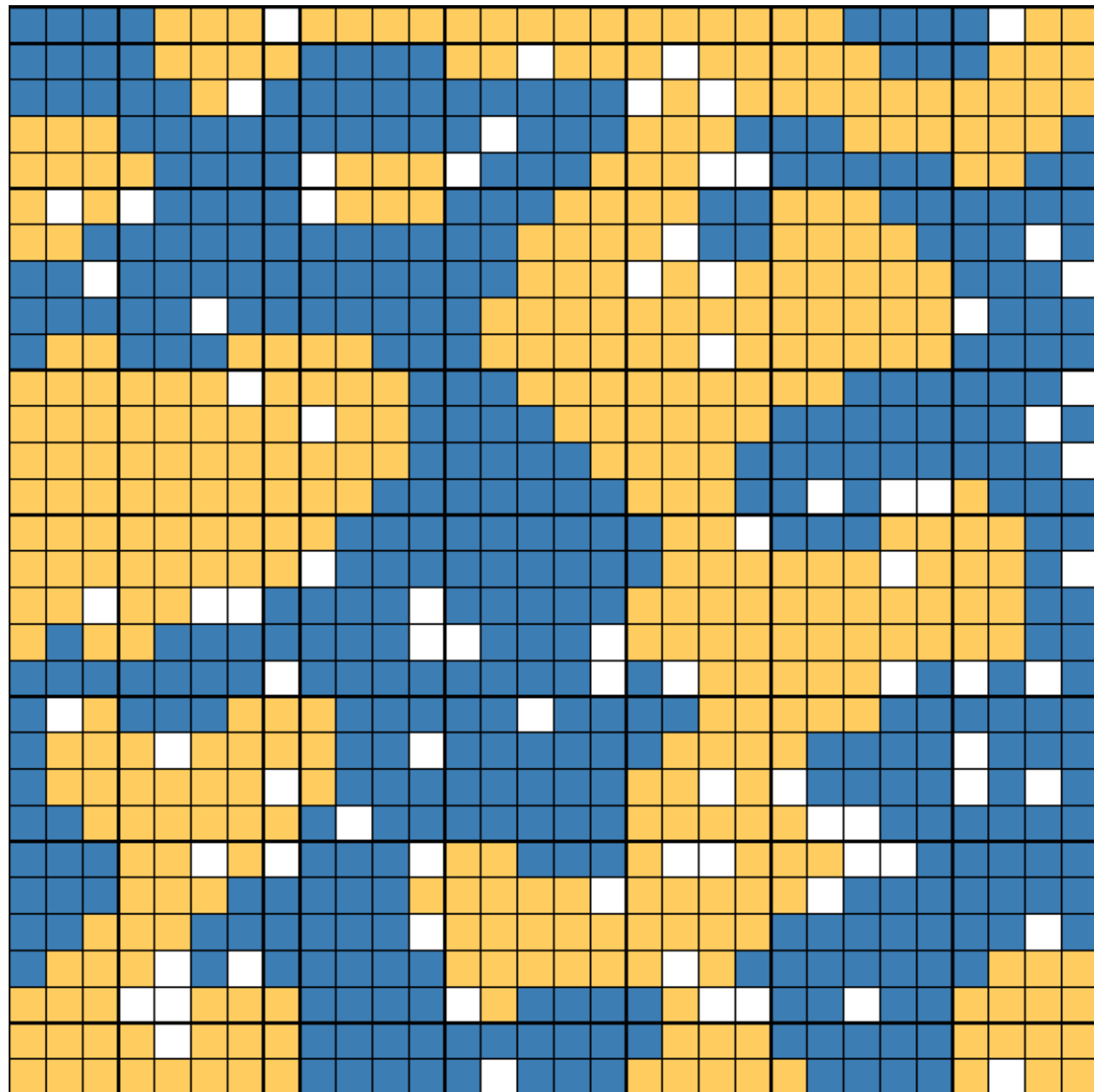
Flexibility:

- swap with another student
- move from last 3 seminars to first 2 (2 empty spots)

Students Seminars Format

- 20 minutes for each student
 - 15 minutes (strict) for presentation
 - 5 minutes for questions and discussion
- both me and other students will make questions
- it is normal not to always know the answer, the important thing is your ability to reason
- the written report summarizing the main points of the paper (up to 4 pages, minimum font size 11pt) must be submitted at the latest the day before the seminar
- grading is
 - 50% presentation
 - 30% report
 - 20% participation in discussions

Recap



Segregation

Can it emerge spontaneously or are discriminatory policies needed?

Schelling's Model

Segregation emerges spontaneously even if agents tolerate living in minority

Game of Life

Complex chaotic behavior can emerge from simple deterministic rules

Outline

1. Measuring culture
2. Measuring cultural similarity using Eurovision data
3. Axelrod's culture model
4. Language and the Naming Game



The background features a complex network diagram with numerous nodes (represented by small circles) and connecting lines. The nodes are arranged in a somewhat circular pattern, with some nodes being larger and darker (black) than others. The lines connecting the nodes are thin and light-colored (white or light blue). The overall aesthetic is clean and modern, typical of a corporate or academic presentation.

Measuring Culture

Cultural Values and Norms



"Culture is the collective programming of the mind that distinguishes the members of one group or category of people from others" - Geert Hofstede
Dimensionalizing Cultures: The Hofstede Model in Context (2011).

For example:

- Shared values and beliefs: tolerance of suicide, gender equality at home
- Artistic and symbolic norms: popular and folk music, dressing style, food
- Customs and other norms: walking speed, gender segregation norms, tolerance to nudity

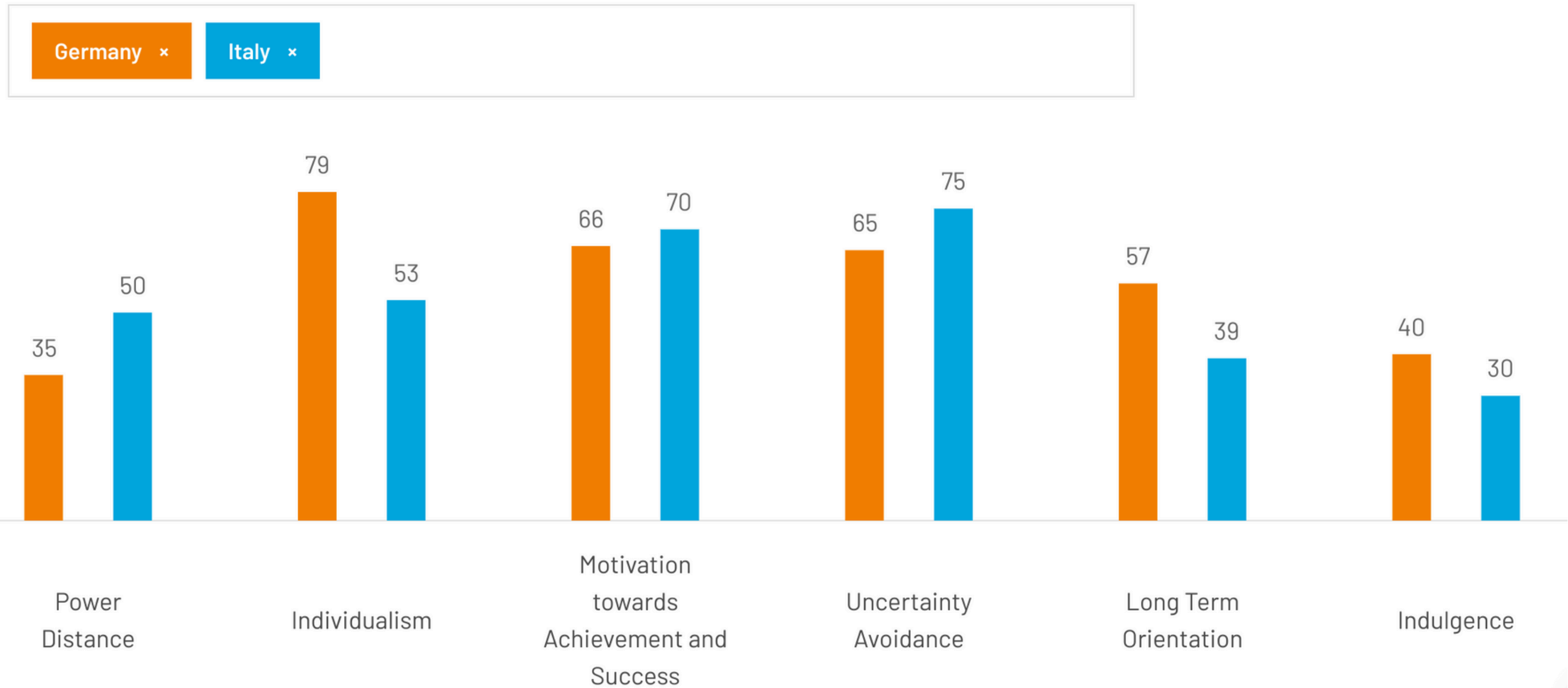
Work cultures: Hofstede's model

Model based on questionnaires of IBM workers around the world: captures cultural differences but is incomplete.

- **Power distance:** Norm of acceptance that power is distributed unequally
- **Individualism – collectivism:** Degree of interdependence among members of a society
- **Masculinity:** Society is driven by competition and achievement or by well-being and care for others
- **Uncertainty avoidance:** the extent to which people feel threatened by ambiguous or unknown situations and try to avoid these

<https://www.hofstede-insights.com/product/compare-countries/>

Germany vs Italy

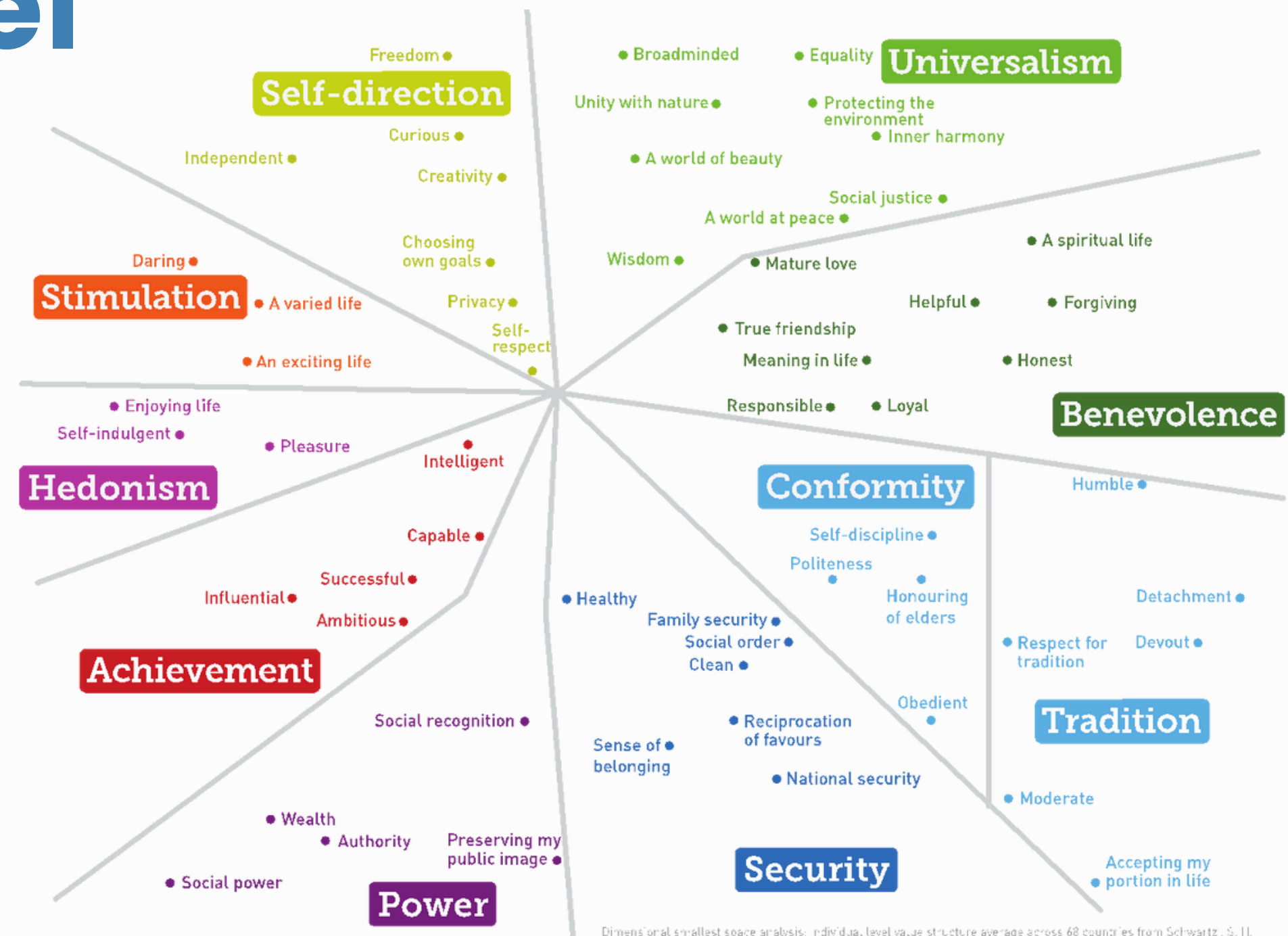


World Values: Schwartz's model

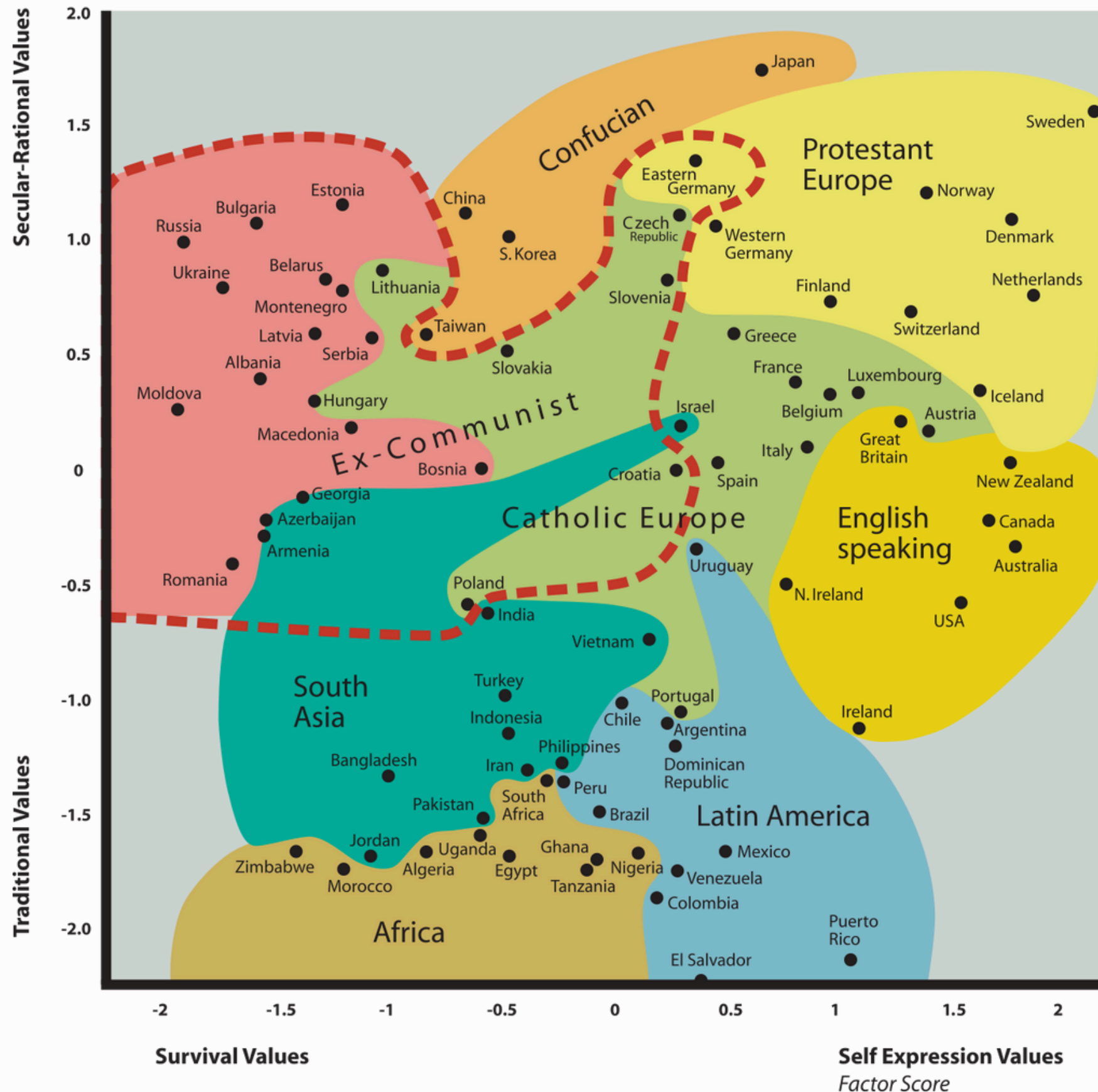
Theoretical formulation of the basic shared values that differentiate cultures

- Measurable through survey questionnaires
- Organized in larger dimensions
- Basis of World Values Survey

[An Overview of the Schwartz Theory of Basic Values \(2012\).](#)



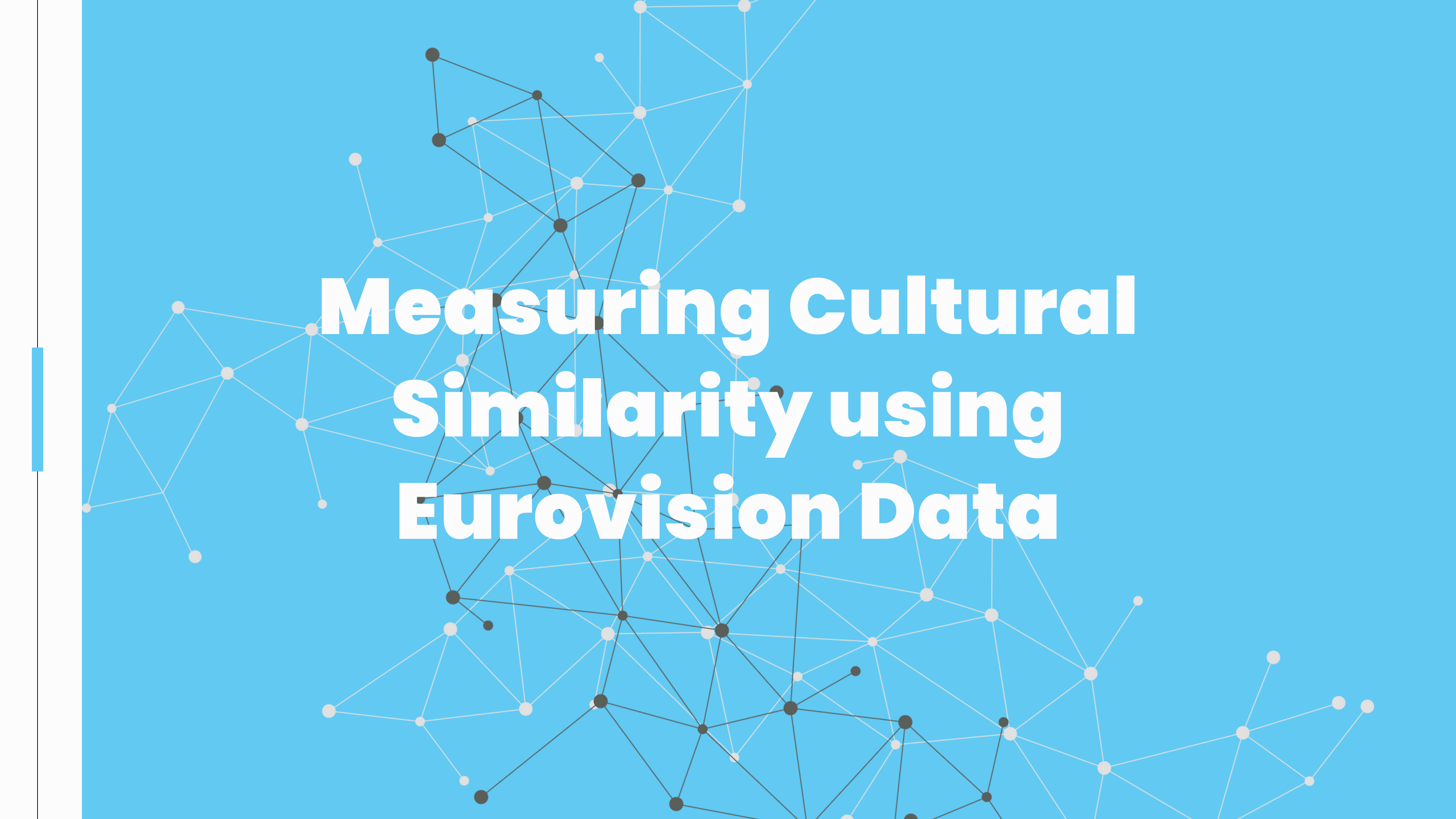
Dimensional smallest space analysis: individual-level value structure average across 68 countries from Schwartz, S. II. (2006). Basic human values: Theory, measurement, and applications. *Revue française de sociologie*, 42, 249-288.



The Ingelhart Welzel map

- Factor analysis of World Values Survey
- Two factors explain ~70% of variance:
 - Traditional-Secular values
 - Survival-Self expression values
- Clustering based on cultural history

[The WVS Cultural Map of the World, Inglehart & Welzel \(2010\).](#)

A network graph background with nodes and edges in white and black on a blue background. The nodes are represented by small circles, and the edges are thin lines connecting them. The graph is dense and interconnected, with some nodes having more connections than others. The overall structure is a complex web of relationships.

Measuring Cultural Similarity using Eurovision Data

Can we use Eurovision Song Contest voting data to determine the cultural similarity of countries?

- In Eurovision people can not vote for their own country
- Each country publicly announces which other countries receive points from 1 to 8, 10, and 12
- We can use cross-voting to determine how friendly is a country to the other countries
- We have to take into account the baseline (San Marino is expected to get few votes, Germany to get many)

[Measuring cultural dynamics through the Eurovision song contest. David Garcia and Dorian Tanase. Advances in Complex Systems, 16 \(2013\).](#)

The Eurovision Song Contest



The Friend or Foe coefficient

In order to measure cultural similarity we introduce the Friend or Foe $FoF(c_v, c_p)$ between country c_v and c_p

- voting country c_v
- participating country c_p
- $p_{v,p}$ is the number of votes country c_v gives to country c_p
- s_p is the total votes obtained by the participating country c_p
- N is the number of competing countries

Measures the
overvoting or
undervoting bias

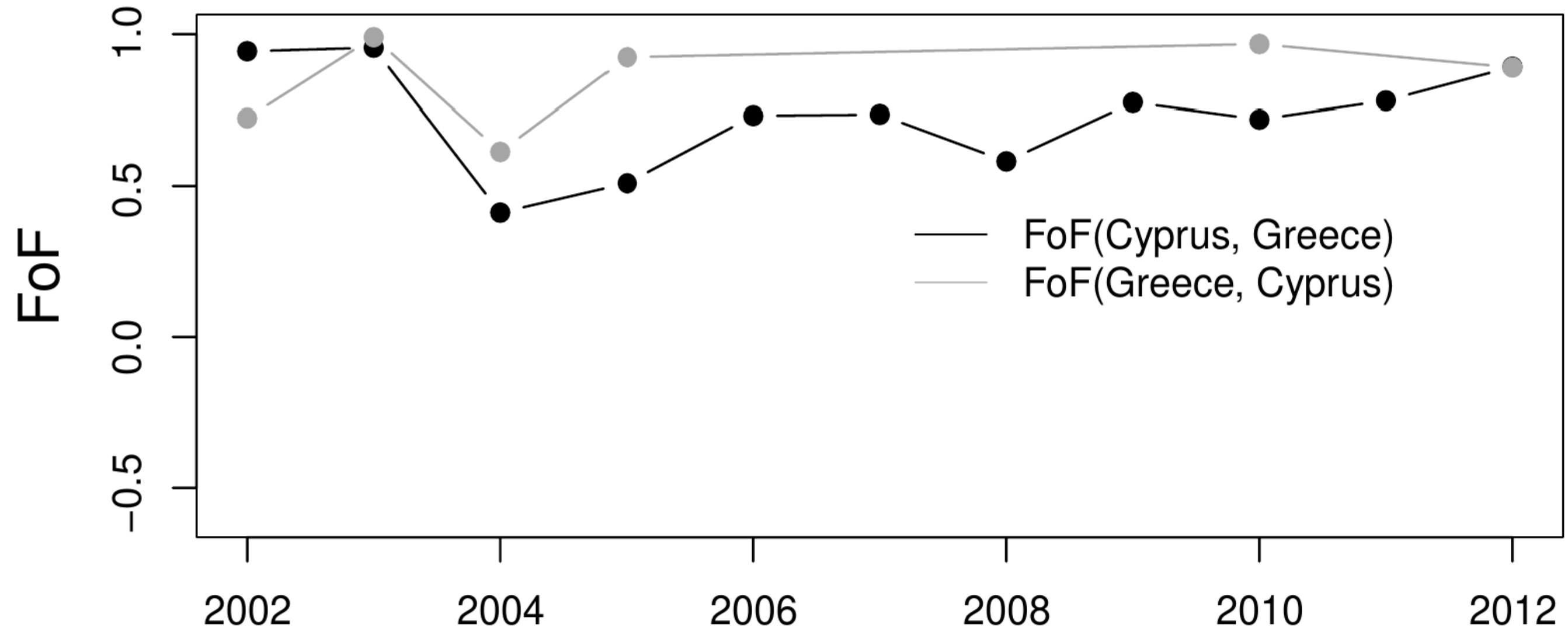


Corrects for song
quality and
country size

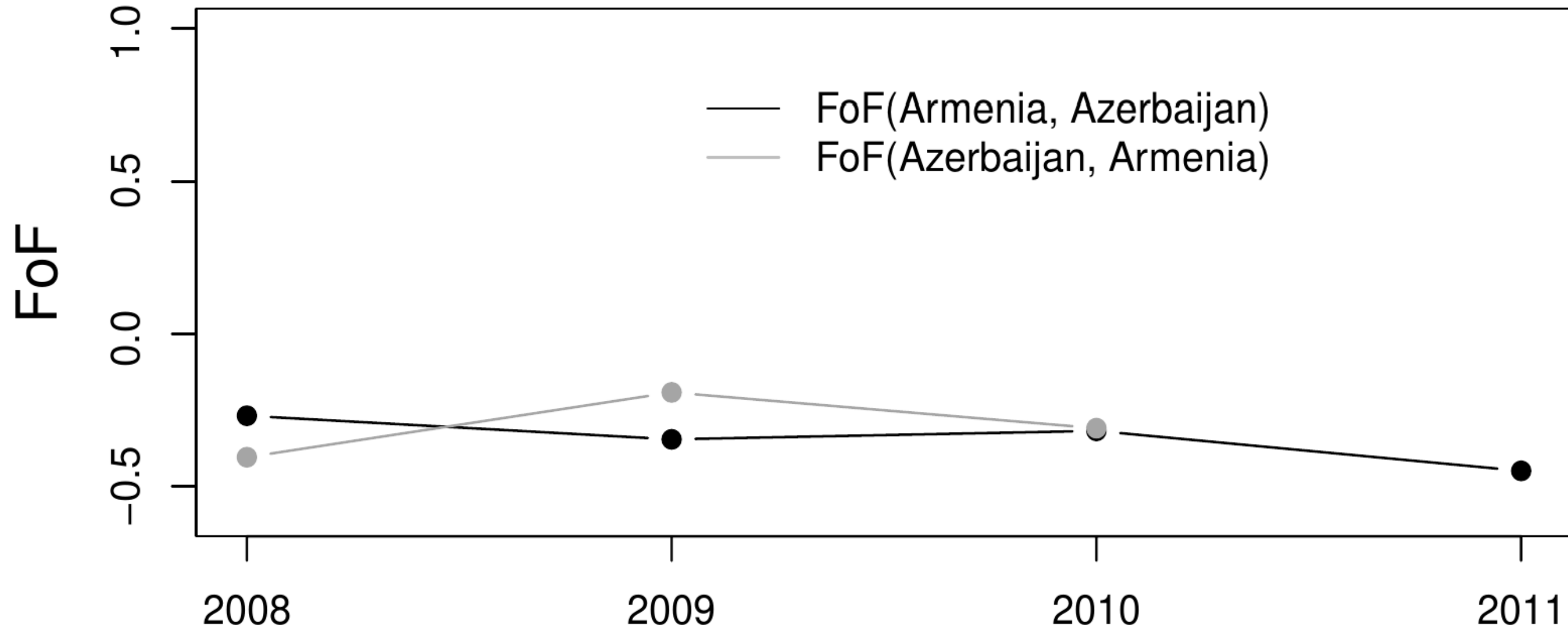


$$FoF(c_v, c_p) = \frac{p_{v,p}}{12} - \frac{s_p - p_{v,p}}{12(N - 2)}$$

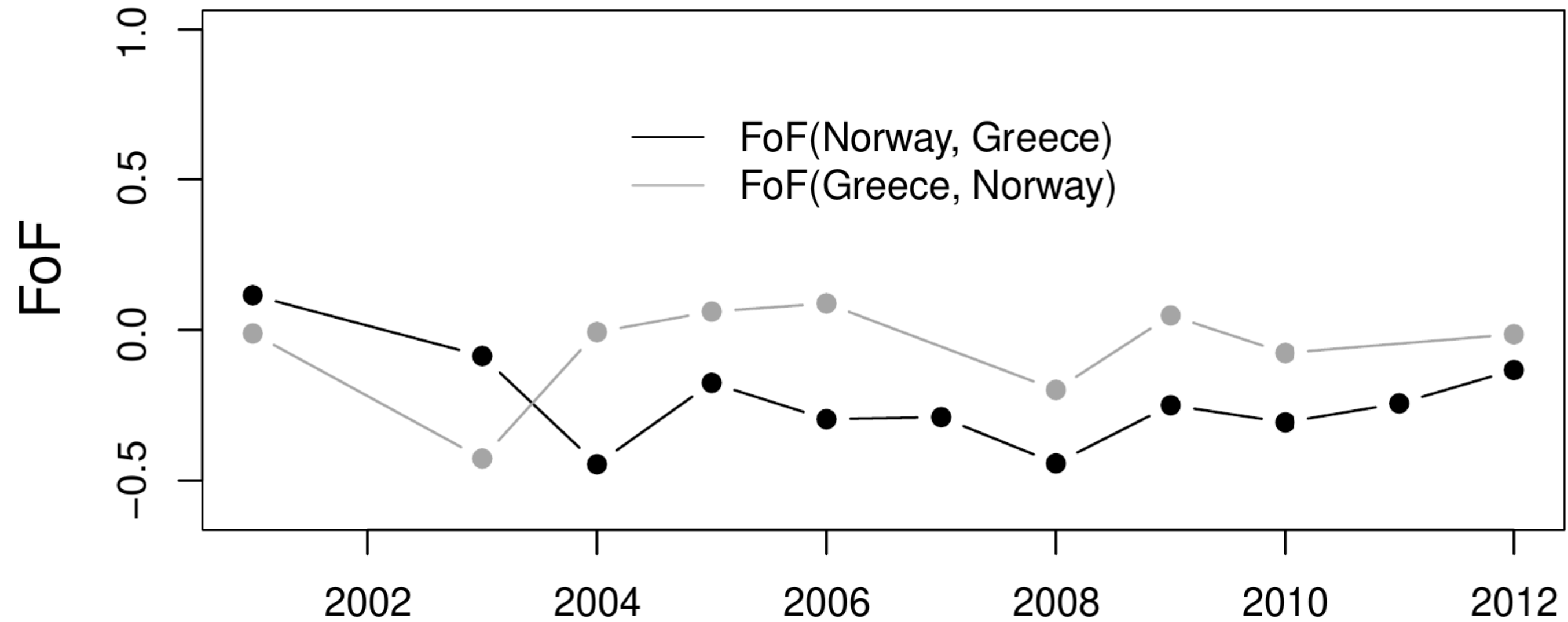
Example: Positive FoF



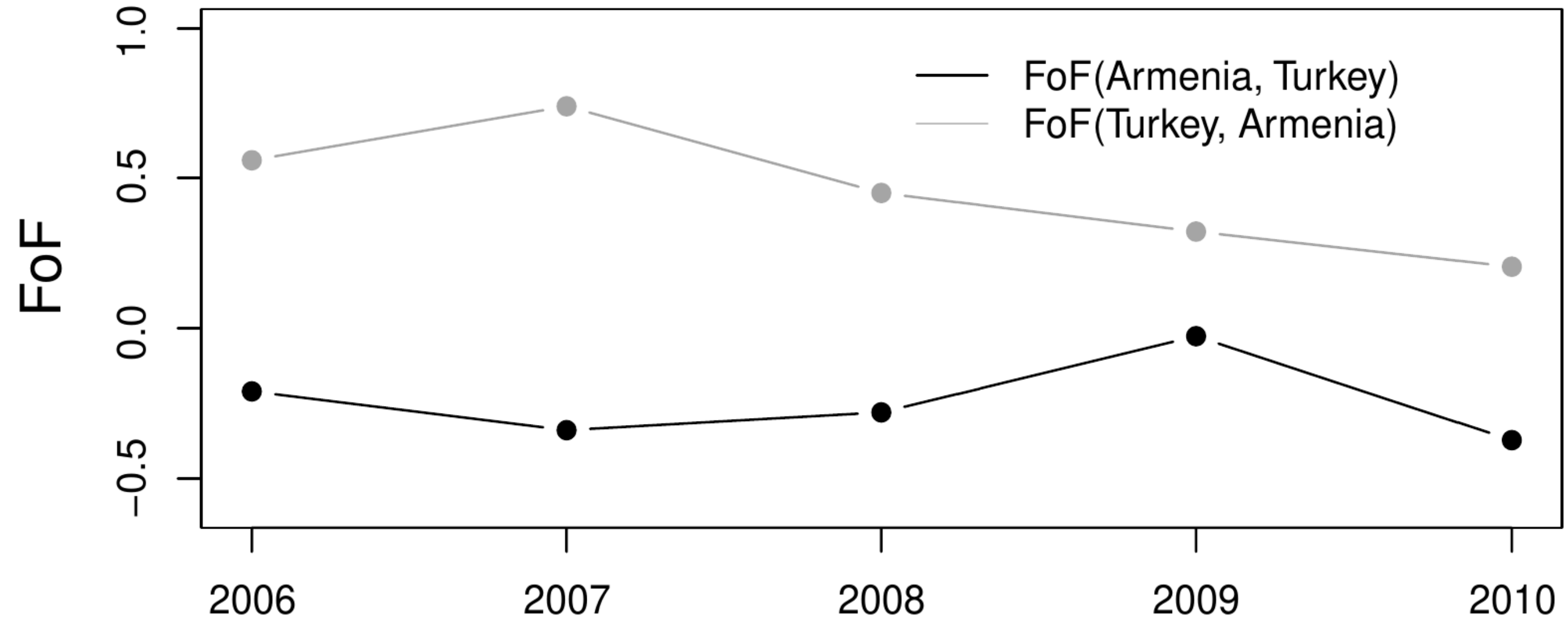
Example: Negative FoF



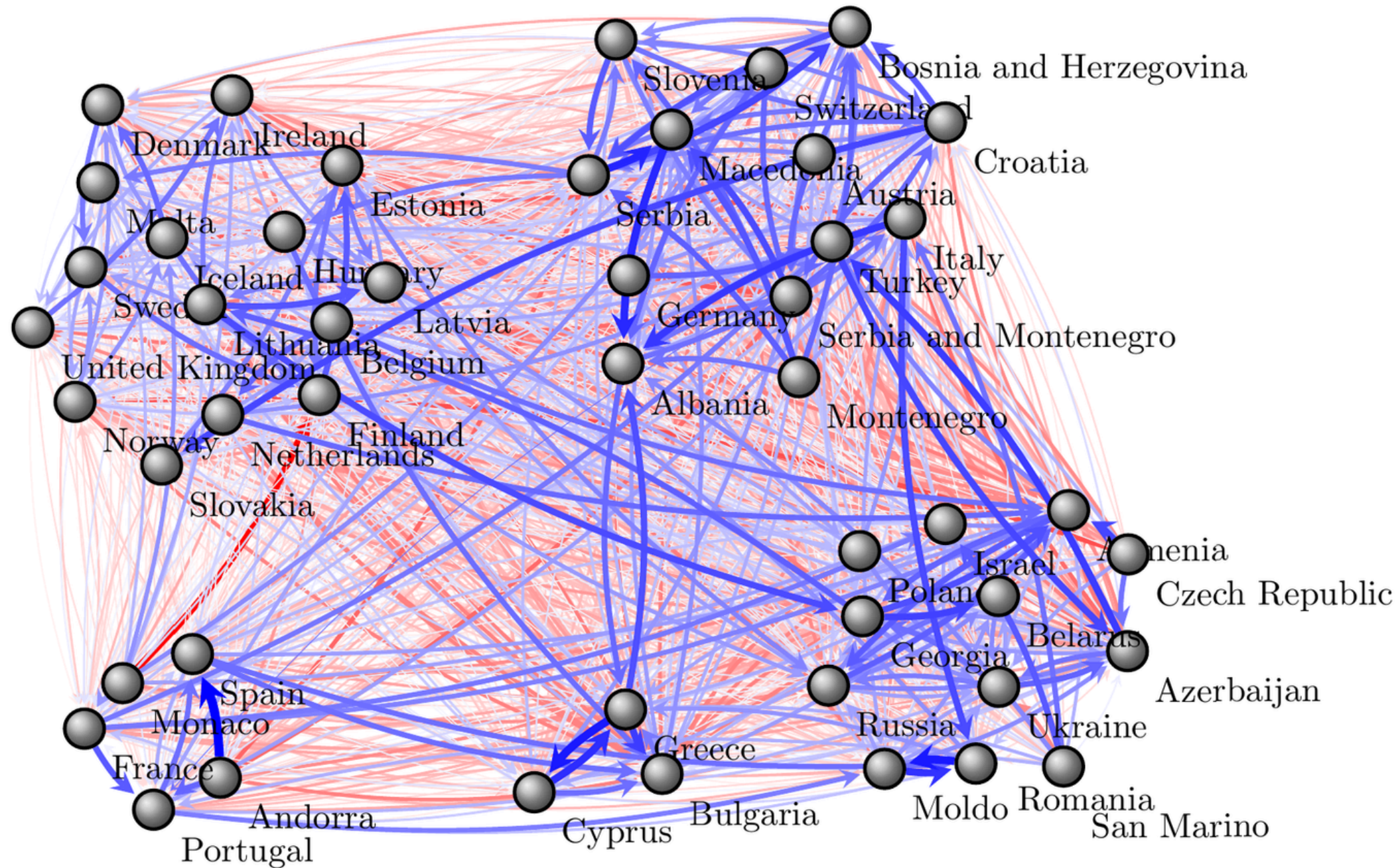
Example: Asymmetric FoF



Example: Asymmetric FoF



Mean FoF Network



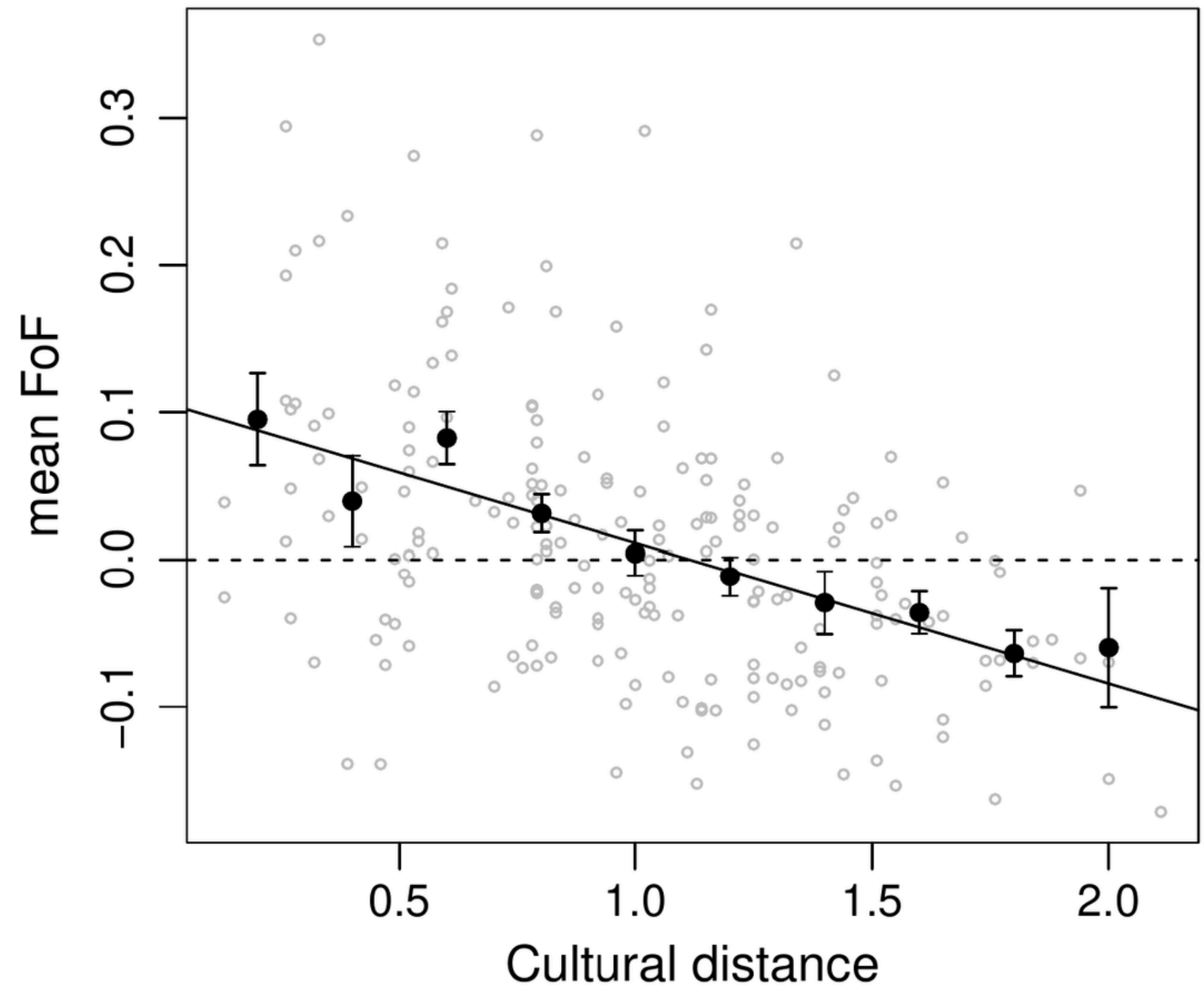
FoF network obtained averaging the FoF over the period 1997-2012

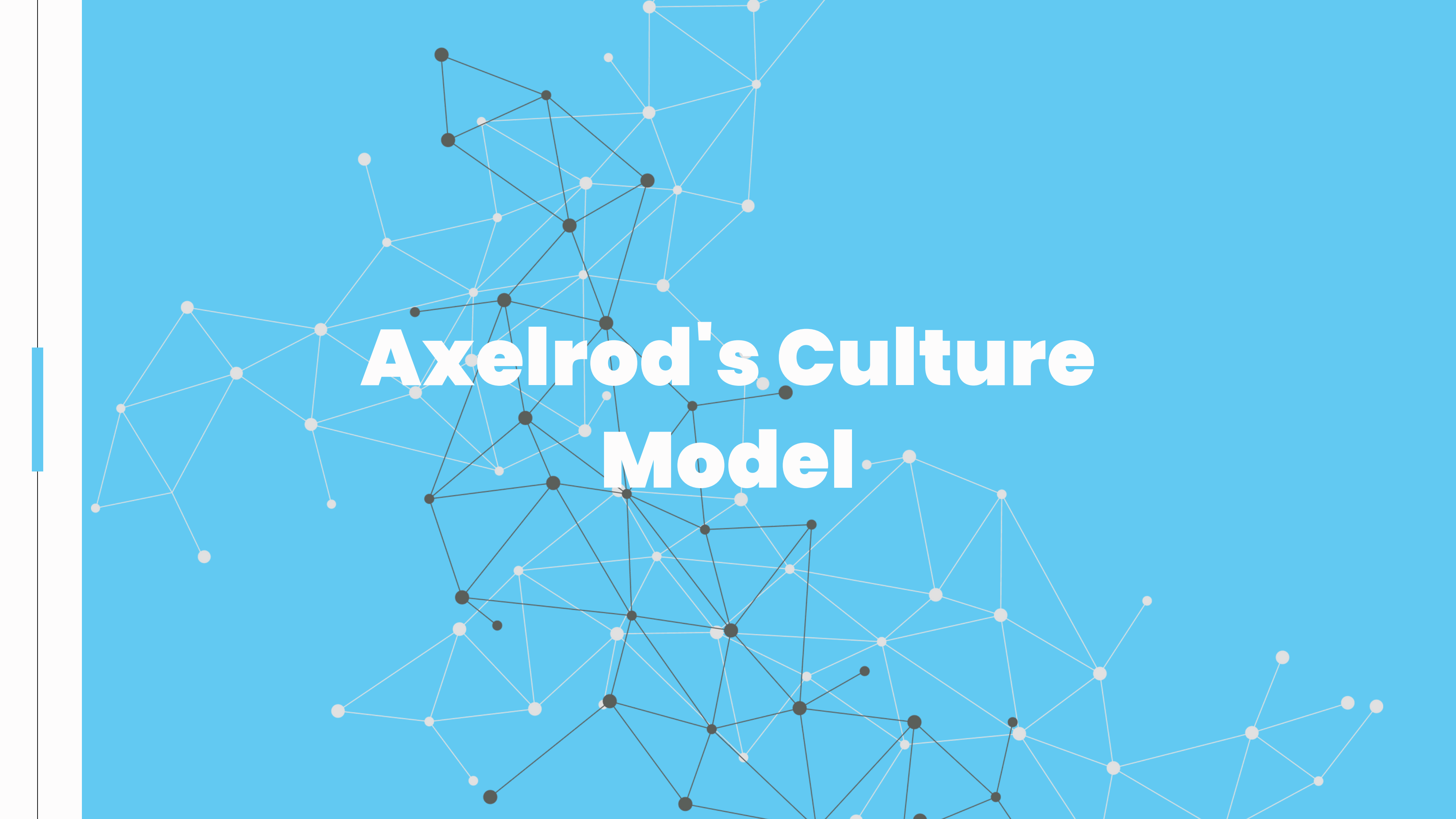
- negative FoF in red
- positive FoF in blue
- edge width and darkness are proportional to the absolute value of FoF

Nodes are arranged in five communities

FoF vs Cultural Distance

- Cultures measured with Hofstede's values
- Cultural distance measured as sum of absolute differences in four dimensions
- Linear regression: $R^2=0.1946$ ($p < e^{-10}$)



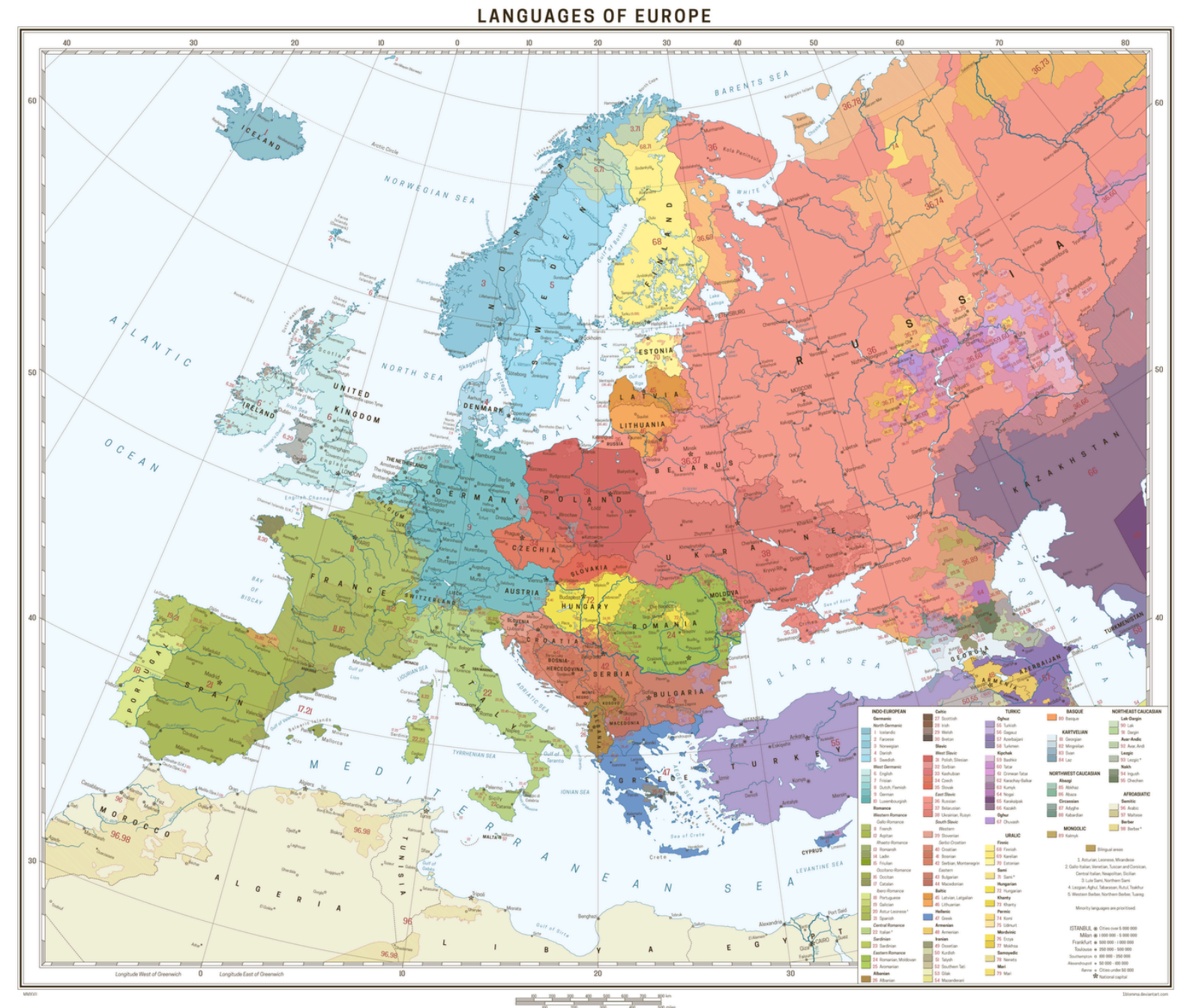
A network diagram with nodes and edges on a blue background. The nodes are represented by small circles, some of which are black and others are light grey. The edges are thin lines connecting the nodes, forming a complex web. The text 'Axelrod's Culture Model' is centered over the network.

Axelrod's Culture Model

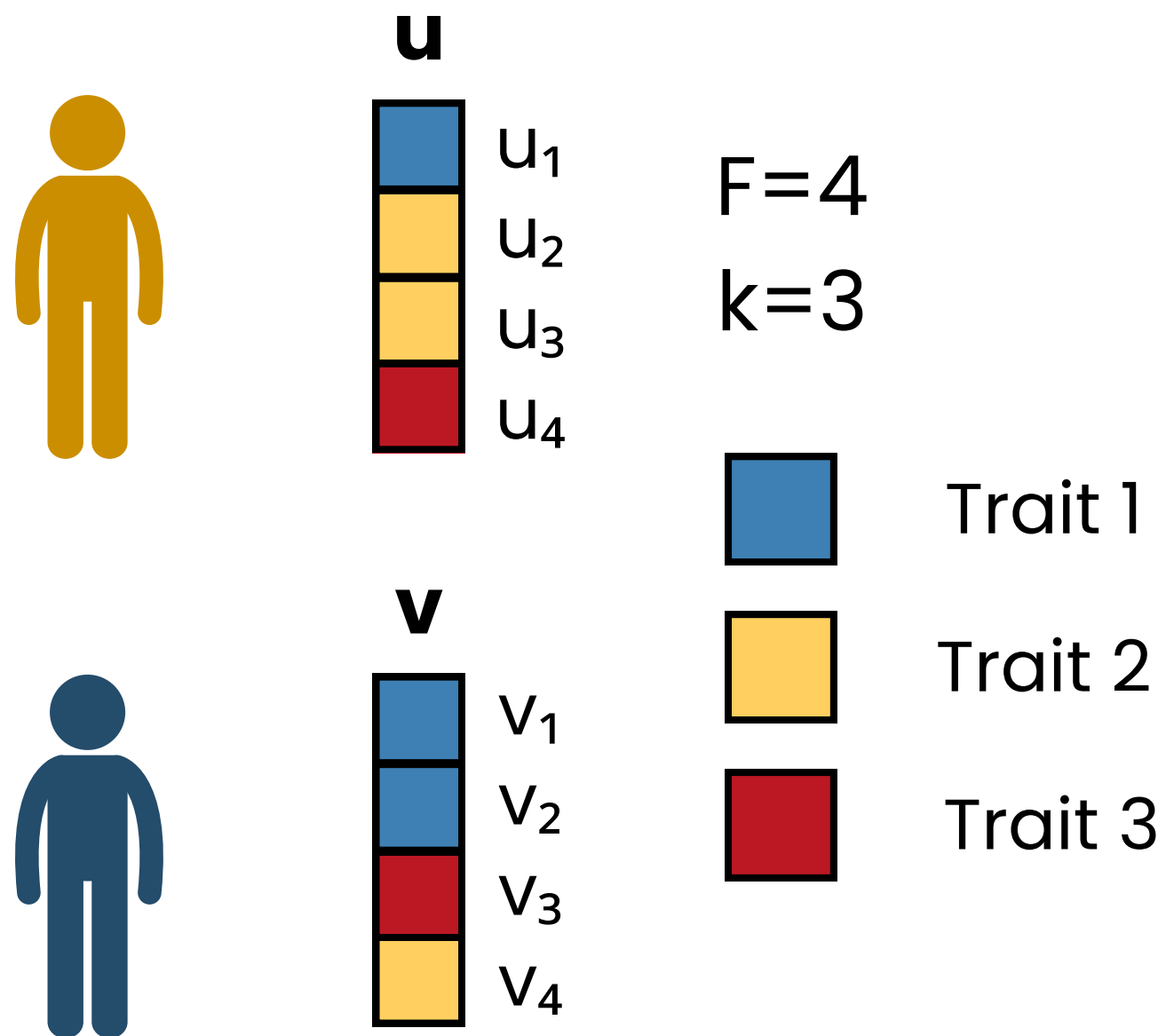
Questions about Cultural Dynamics

Cultures influence each other, sometimes forcefully and sometimes willingly.

- Why do different cultures persist under the presence of this kind of convergence dynamics? Is differentiation necessary?
- What is the role of diversity of cultural options, number of cultural features, and physical space in the coexistence of cultures?



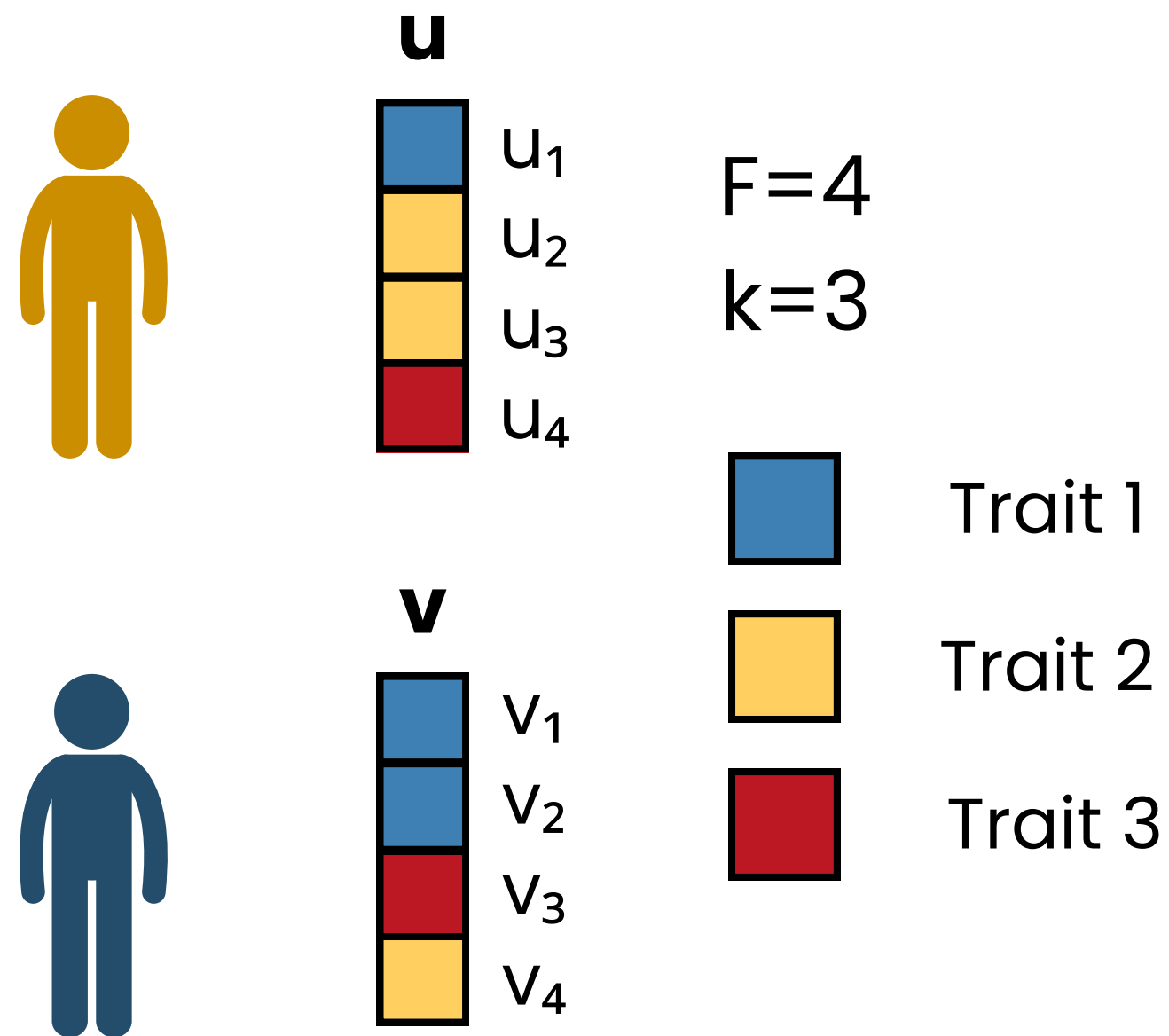
Axelrod's Model



Agents are characterized by cultural features and traits:

- each agent has F cultural features (e.g. religion, language...)
- each feature can assume one out of k possible traits (e.g. Italian, English, German)
- we can describe an agent u as a cultural vector with F components u_i , each corresponding to a trait

Axelrod's Model



The agents interact depending on their cultural similarity

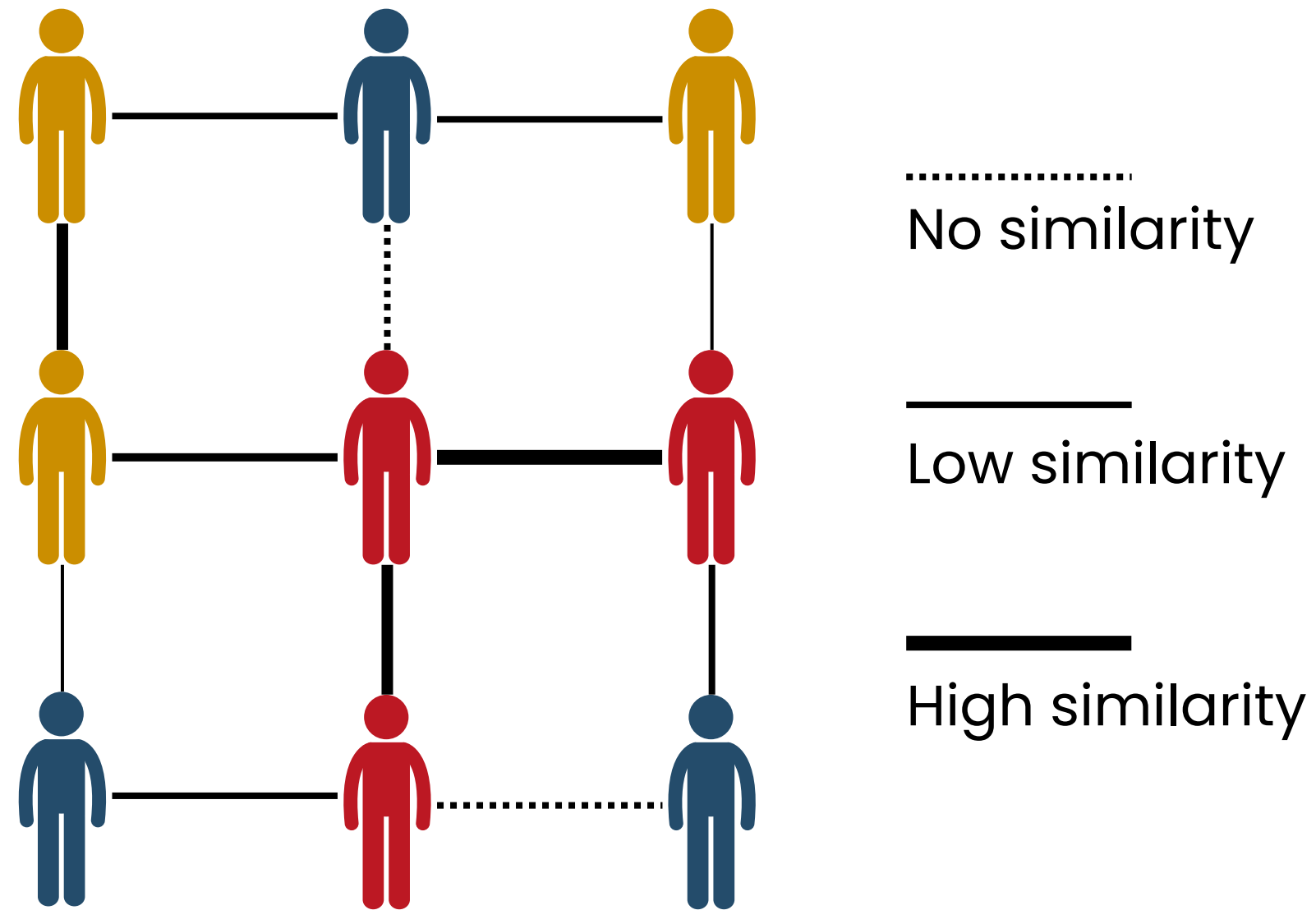
- Cultural similarity is calculated as fraction of features with the same trait over total number of

features:

$$\text{sim}(u, v) = \frac{\sum_i^F \delta(u_i, v_i)}{F}$$

- u and v are two agents with cultural vectors u_i and v_i
- $\delta(x, y) = 1$ if and only if $x = y$

Definition of Lattice



The model is defined on a 2D grid

- Von-Neumann neighbourhood: four neighbors in a cross
- Similarity is shown as edges between cells: lighter is less similar

Dynamics of Axelrod's Model

The model works by iteratively repeating the following steps

1. Choose a cell (agent) uniformly at random to be the active agent
2. Choose at random one of its neighbors
3. With probability equal to their cultural similarity the active agent copies a random feature of its neighbor in which they differ

Notes:

- Agents with zero similarity do not interact
- Copying only applies to features with different traits
- If they only differ in one, the active agent copies that one
- Simulation ends when all similarities are zero or one

Simulating Axelrod's Model

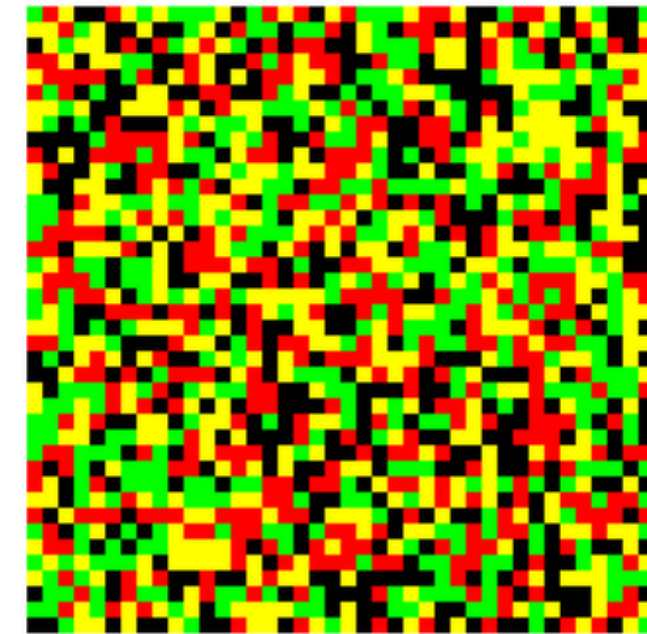
You can play with the model at:

<https://rf.mokslasplius.lt/axelrod-culture-dissemination-model/>

- Different colors represent different cultures.
- Two cultures are different even if they differ on a single trait
- Key parameters: size, F , k

Starting from size = 20, $F=2$ and $k=2$, what happens when we increase the size and k ?

size=20x20, $F=2$, $k=2$

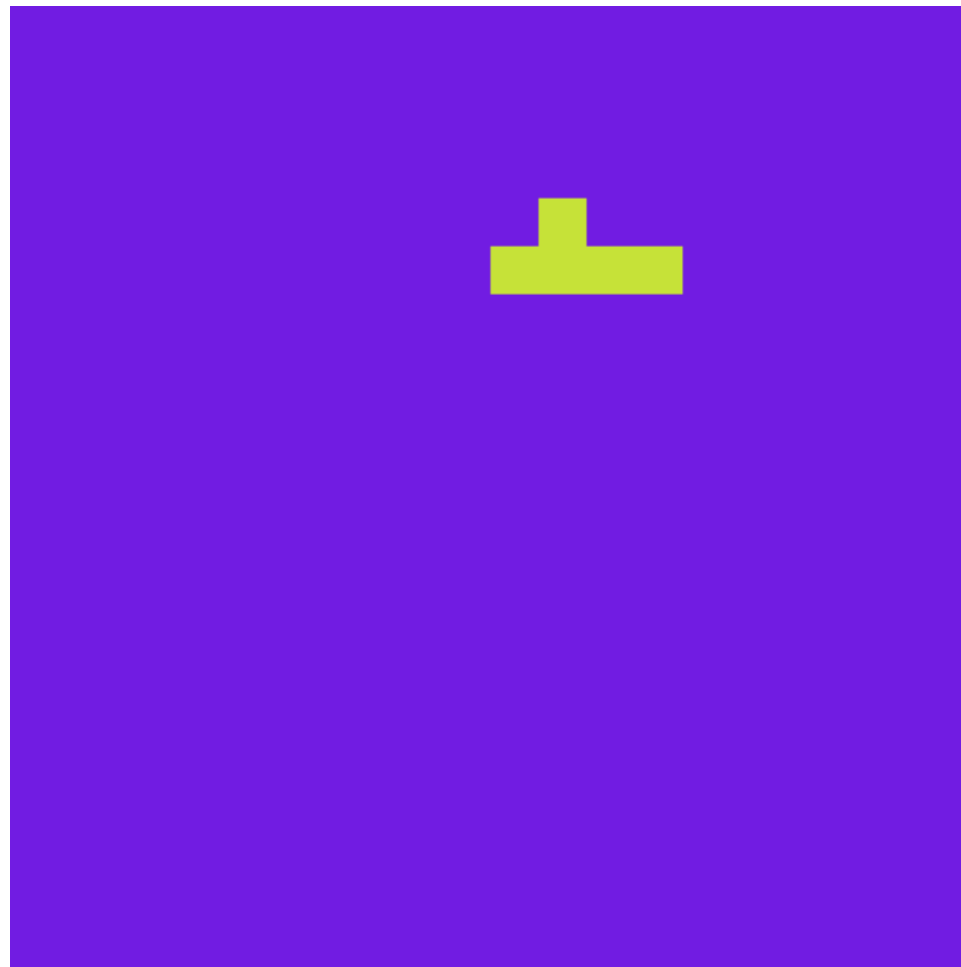


Many
Iterations

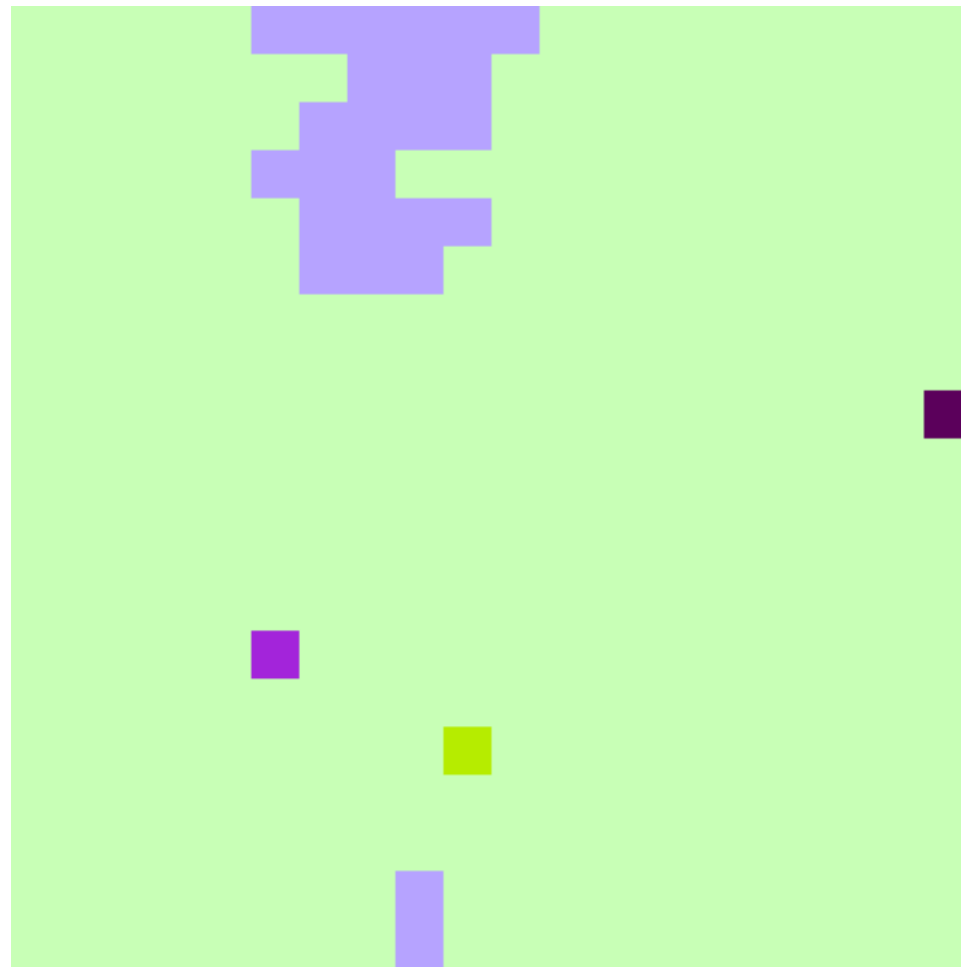


Asymptotic Configurations

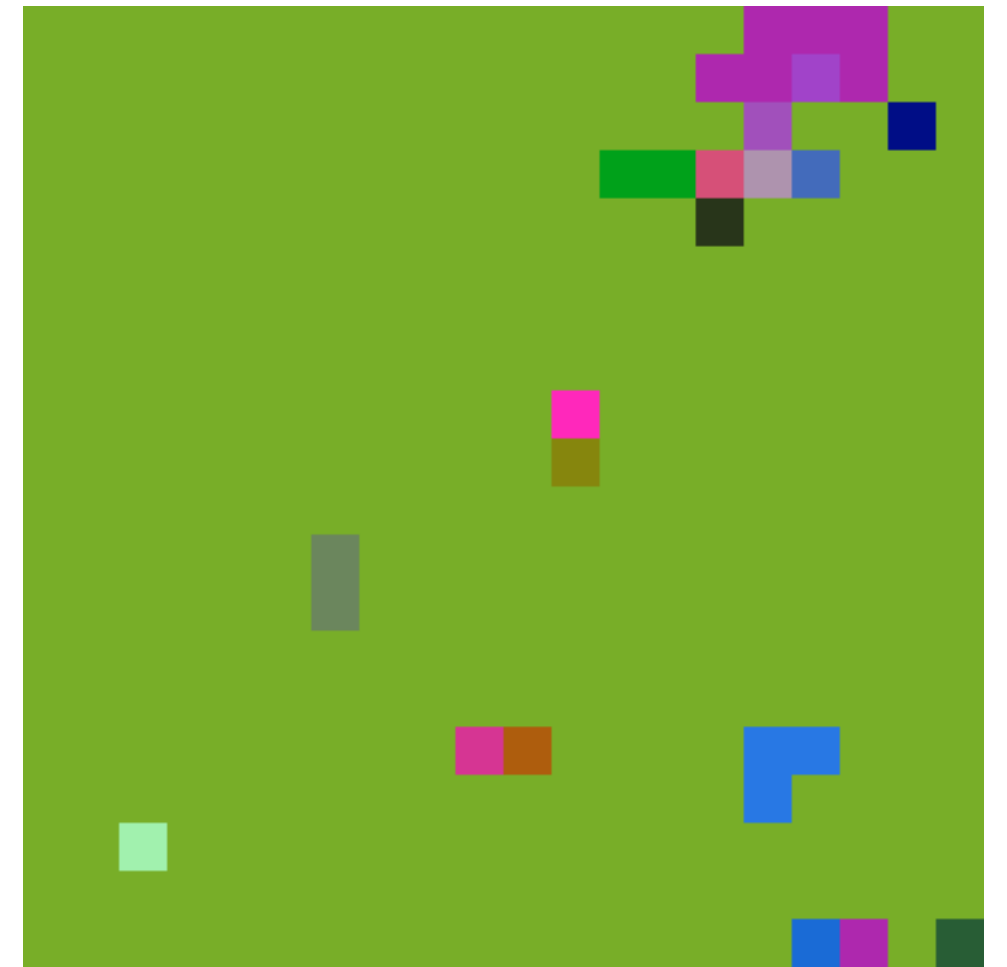
We study the effect of traits using size=20x20, F=5, and varying k



k=10
2 cultures

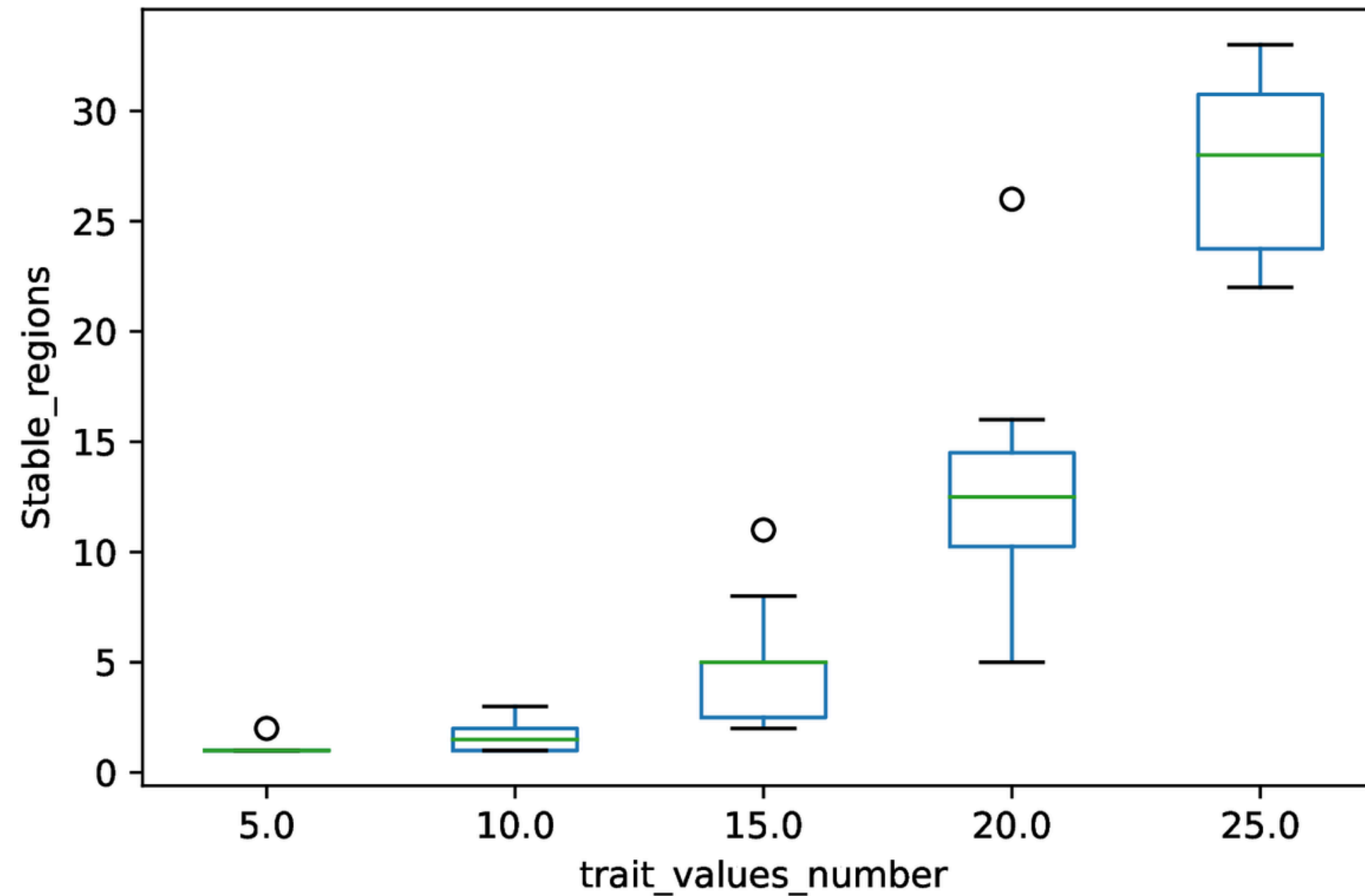


k=15
5 cultures



k=20
~20 cultures

The Role of the Number of Traits



We set 10x10 space, $F=5$. More traits per feature (higher k), more cultures!

Some Observations

What did we learn?

- No hardwired advantage of majority: hegemony emerges even if agents are equally likely to switch to minority cultural features
 - Opposite of functionalist theories of culture: the majority doesn't have to be better in any particular application or competition
- Heterogeneity is stable even though only imitation dynamics exist.
- Empirical predictions: larger territories have more homogeneous cultures than moderate-sized ones. Some evidence among small territories in the Solomon islands but hard to validate.


Why is this working?

- copying mechanism to reach local consensus
- similarity based interactions to get global polarization

Axelrod was ahead of his times!

"In the near future, electronic communications will allow us to develop patterns of interaction that are chosen rather than imposed by geography. If individuals are linked together at random, one could expect substantial convergence over time. In the more likely case that the interactions will be based on self-selection, people will tend to interact with others who are already quite similar to them on relevant dimensions (Resnick et al. 1994; Abramson, Arterton, and Orren 1988). An implication of the model is that such self-selection could result in an even stronger tendency toward both "local" convergence and global polarization. Only then the "local" convergence will be based not on geography but on emergent patterns of more or less like-minded communication. The implications for resolving the tensions inherent in a multicultural society are problematic."

Robert Axelrod, 1997

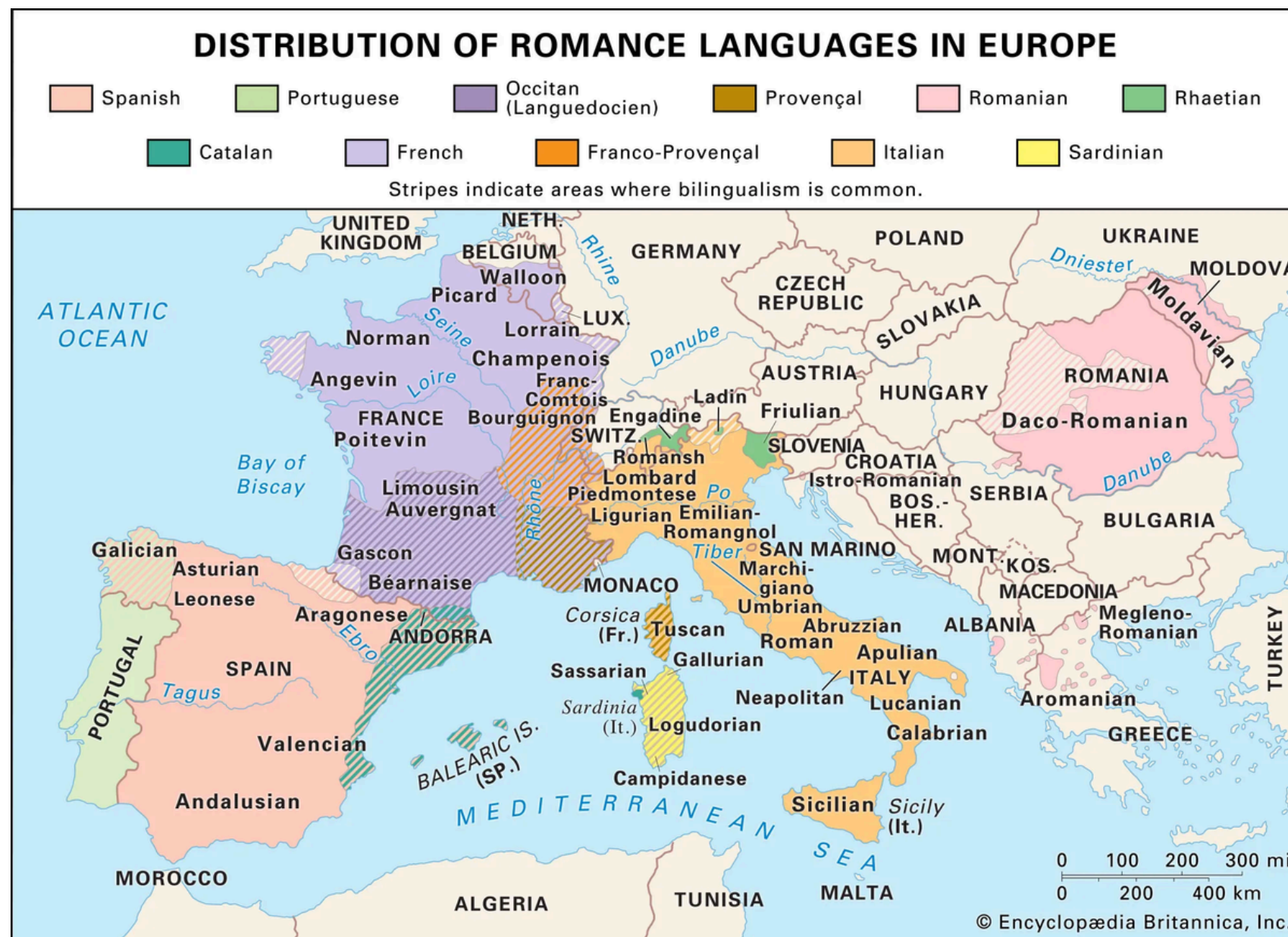
A network diagram with nodes and edges on a blue background. The nodes are represented by small circles, some of which are black and others are light gray. The edges are thin lines connecting the nodes, forming a complex web. The text is centered over this network.

Language and the Naming Game

The Emergence of Languages

Language is a dynamic and complex adaptive system:

- **Pidgins:** Arise for practical needs such as trade, where no common language exists. Ex. Tok Pisin in Papua New Guinea
- **Creoles:** pidgins became the first language of a community. Ex. Haitian Creole
- **Dialects and Languages:** Over time, dialects may diverge significantly becoming recognized as distinct languages. Ex: The Scandinavian languages from Old Norse.



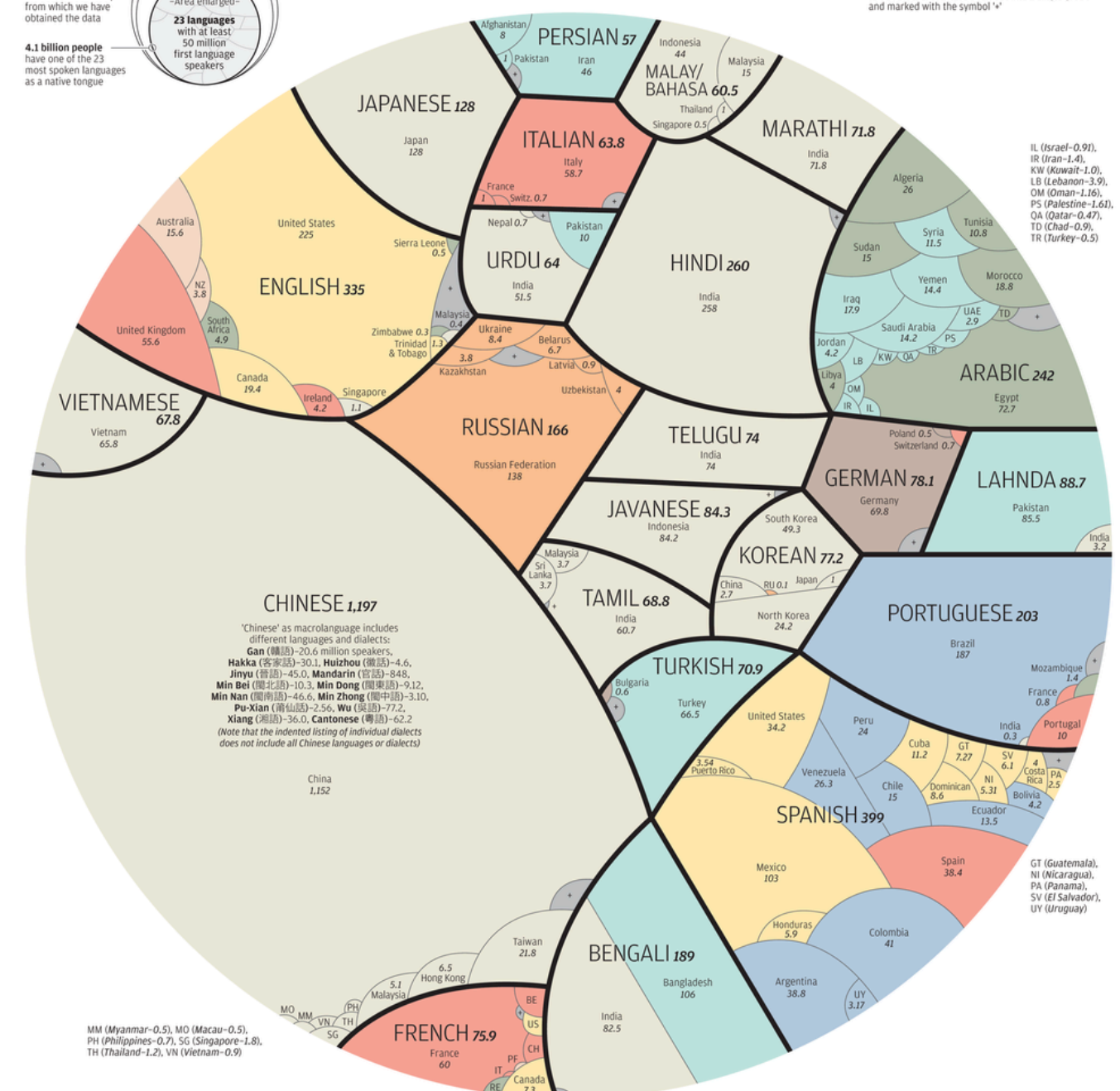
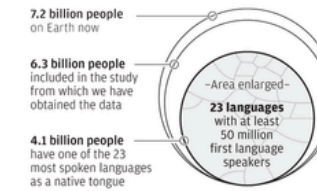
Questions about Language Dynamics

Languages influence each other and are in continuous evolution

- Can a language spontaneously emerge from the interaction of individuals without the need of a central governing entity?
- Under which circumstances can a group of humans develop a common language?

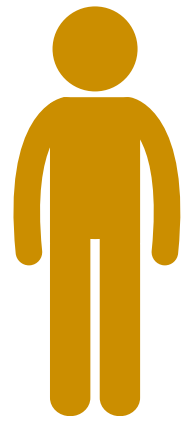
A world of languages

There are at least 7,102 known languages alive in the world today. Twenty-three of these languages are a mother tongue for more than 50 million people. The 23 languages make up the native tongue of 4.1 billion people. We represent each language within black borders and then provide the numbers of native speakers (in millions) by country. The colour of these countries shows how languages have taken root in many different regions

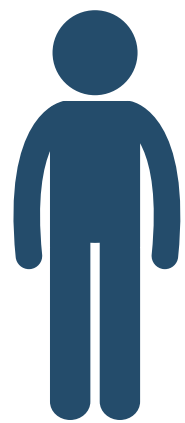


Note: The areas represented conform to the data provided by "Ethnologue: Languages of the World". These estimates are not absolute because the demography is constantly evolving. Some studies are based on data from old census and may date back more than 8 years

The Naming Game



tree
ricu
opes
netu



voga
tree
reso

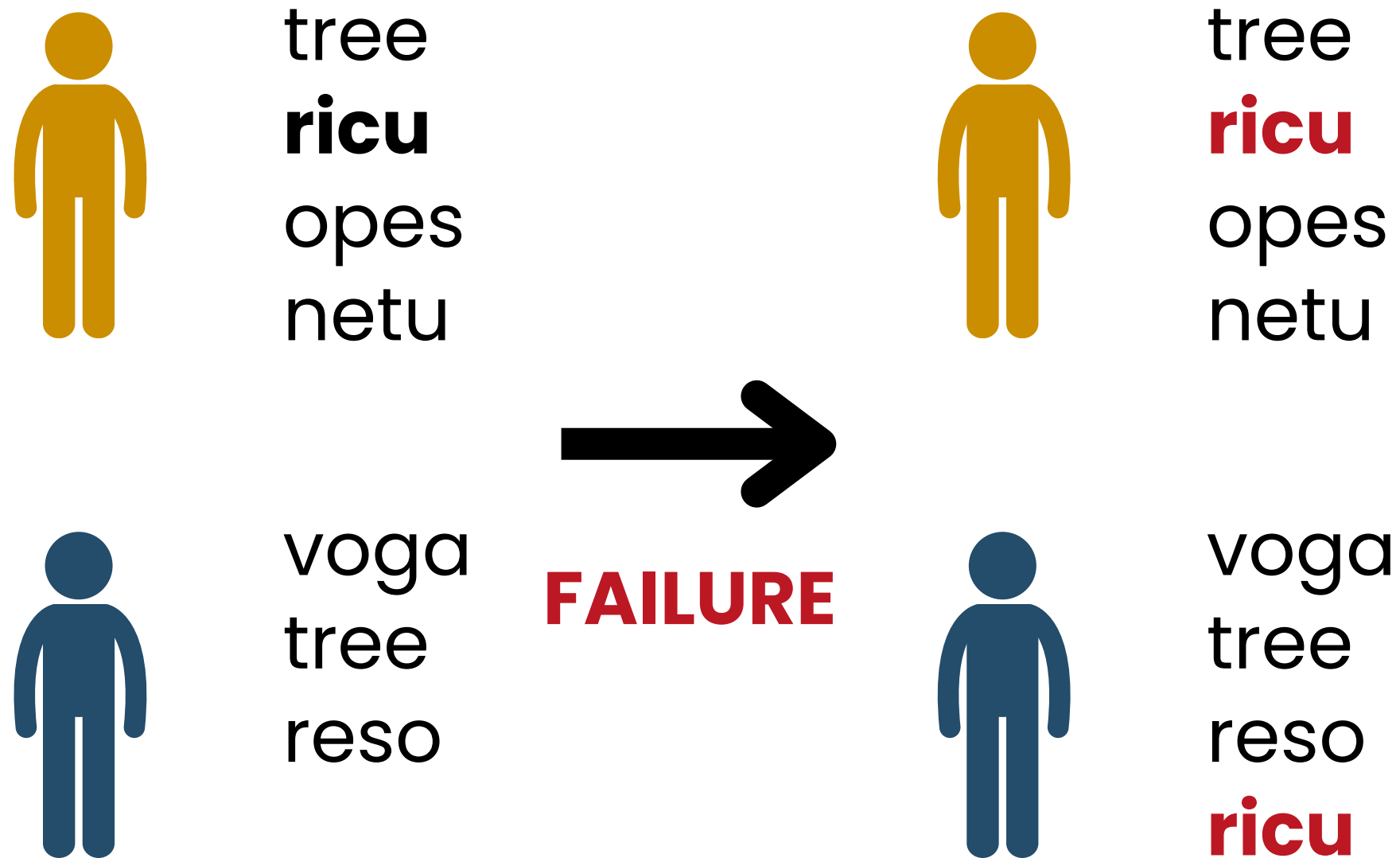


The (minimal) Naming Game models a group of agents trying to name an object

- each agent has an infinite inventory when it can store words
- initially each inventory is empty
- agents interact in pairs trying to determine a common word for the object
- only local interactions

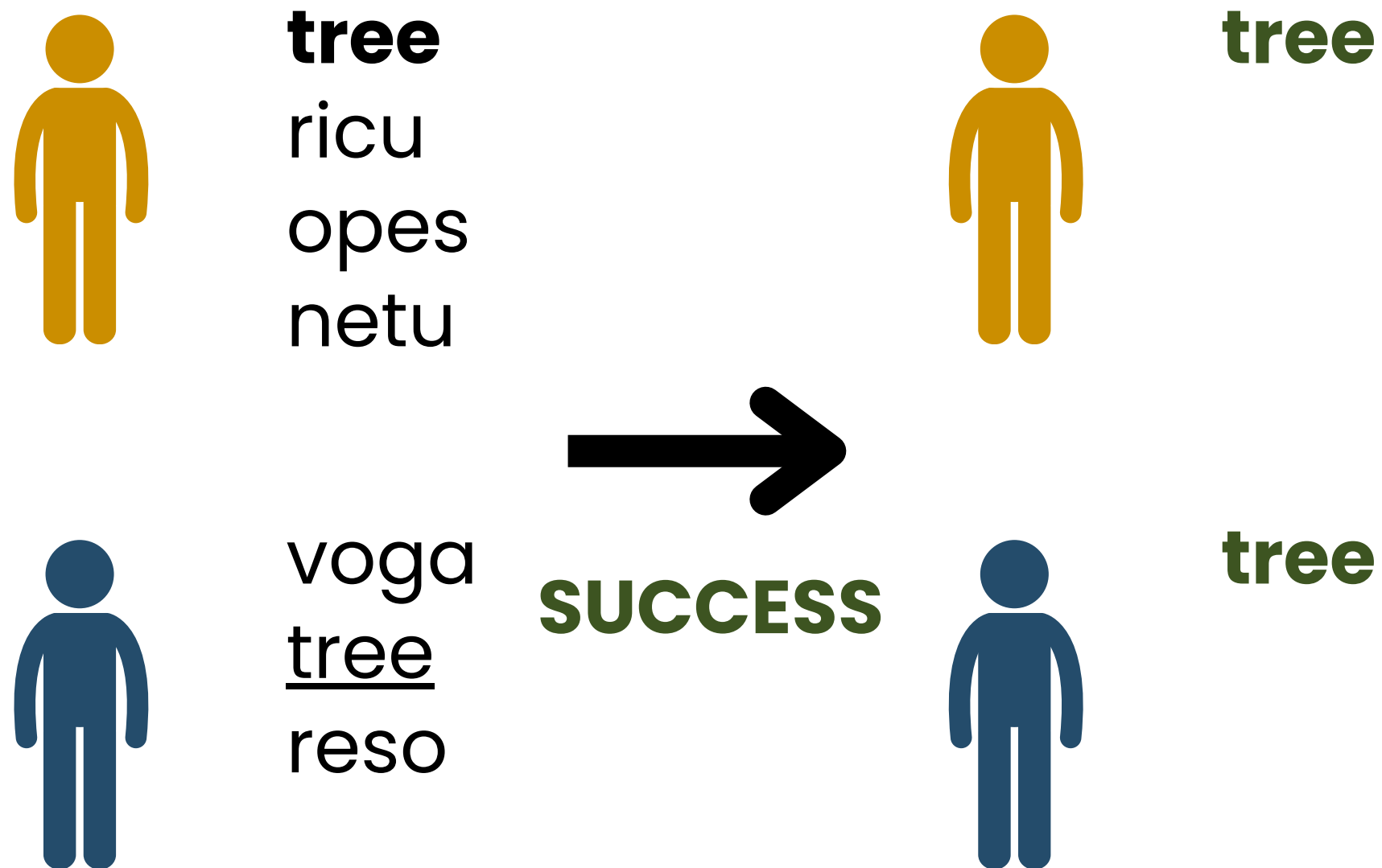
[A gentle introduction to the minimal Naming Game. Andrea Baronchelli \(2017\).](#)

Dynamics of the Naming Game



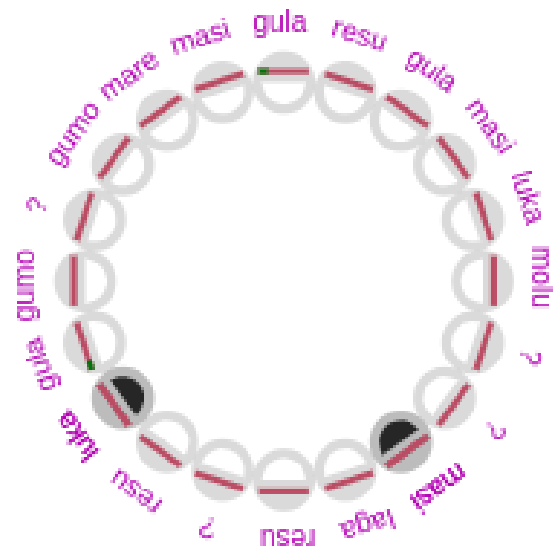
- at each time step we randomly select a speaker and a listener among the agents
- the speaker randomly selects a word from its inventory and communicates it to the listener
 - if the word is not in the listener's inventory the interaction is a **failure** and the listener add the word to its inventory

Dynamics of the Naming Game

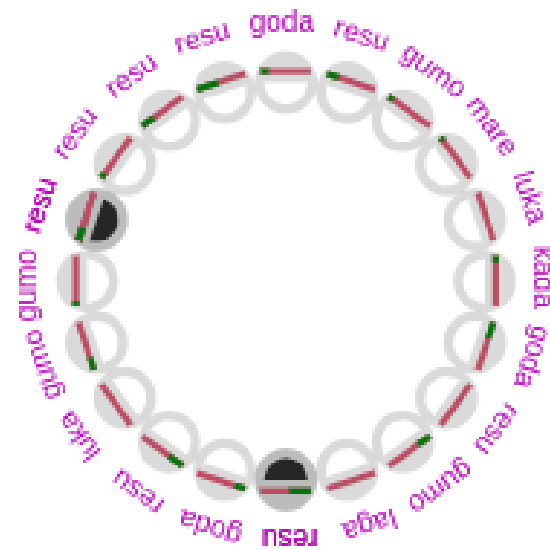


- at each time step we randomly select a speaker and a listener among the agents
- the speaker randomly selects a word from its inventory and communicates it to the listener
 - if the word is in the listener's inventory the interaction is a **success** and both agents only keep that word in their inventory

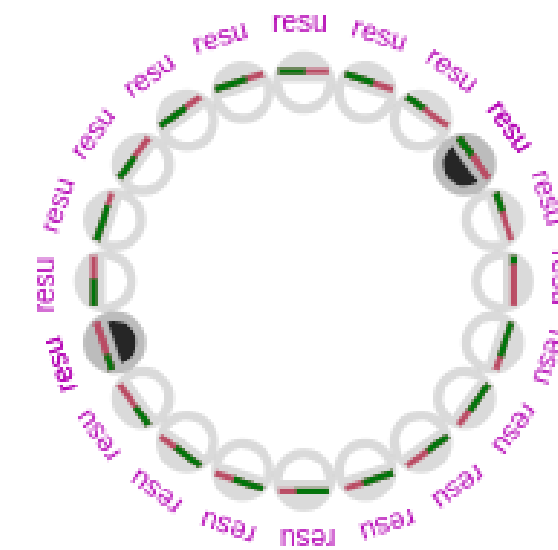
Example of Simulation



After few iterations



After more iterations



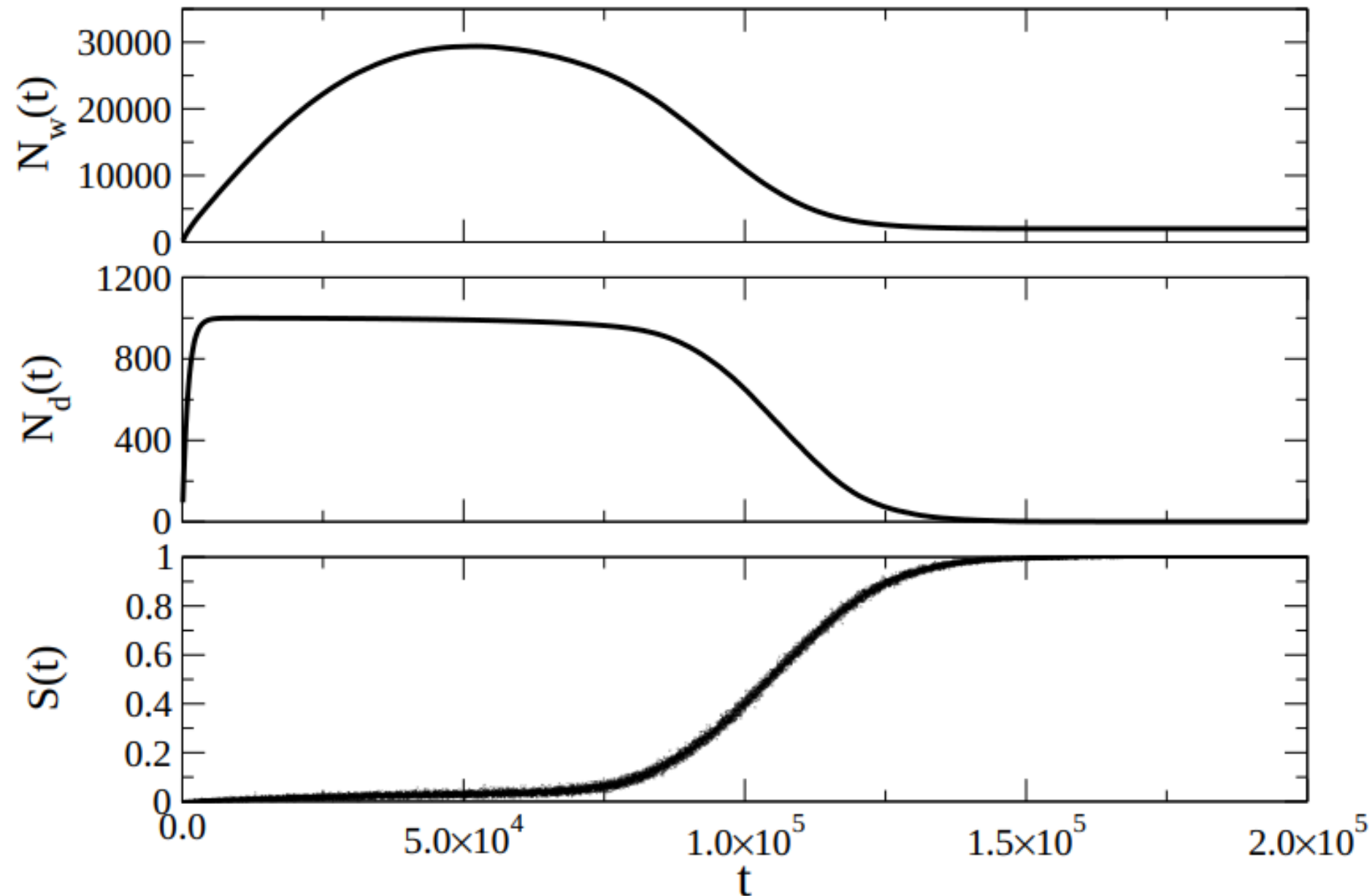
Final configuration

The system asymptotically reach a consensus configuration where only one word survives.

You can play yourself at

http://www.socialdynamics.it/topics/complex-systems-dynamics/language-dynamics/naming_game/

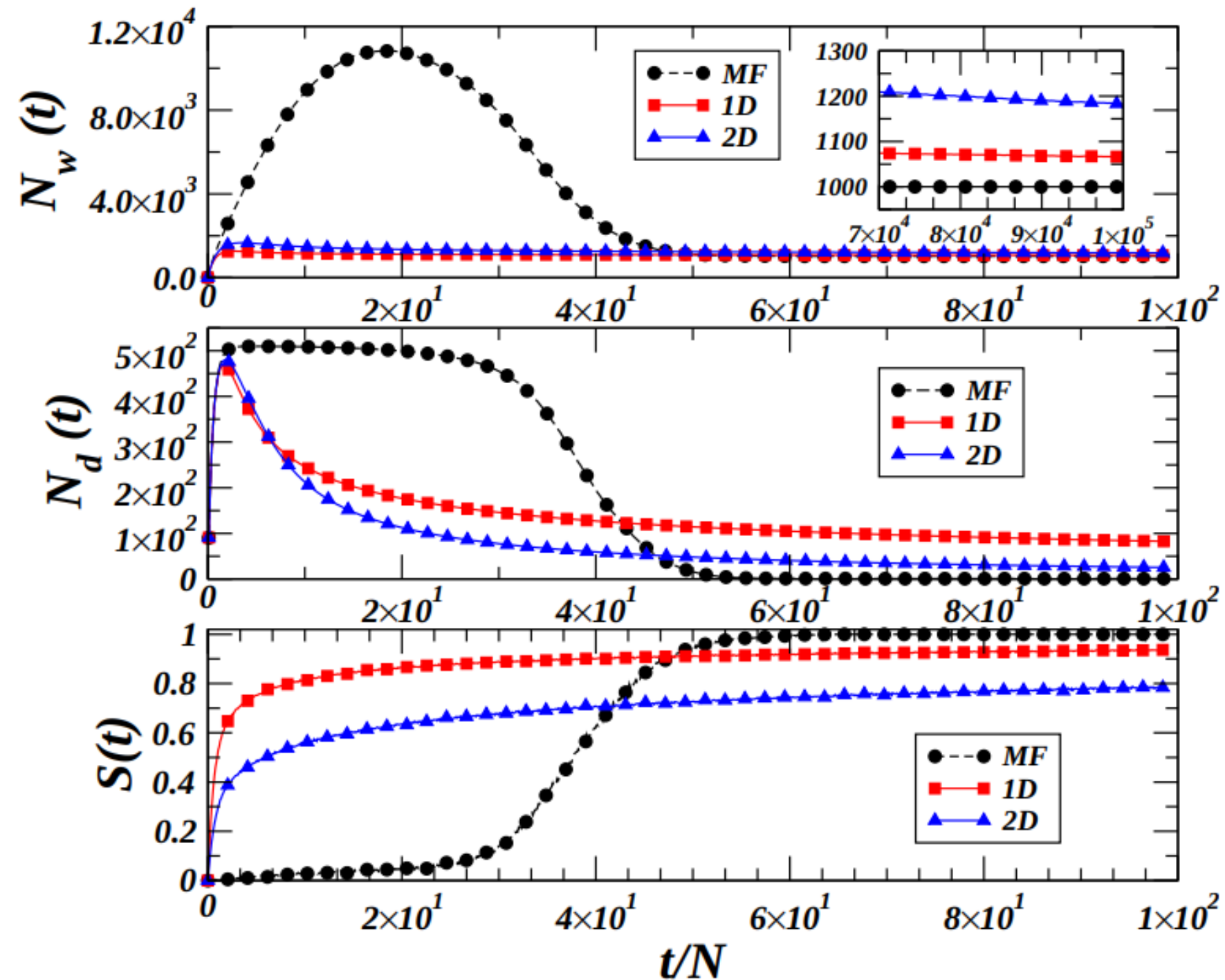
Metrics of the Naming Game



Consensus is reached!

- t number of interactions or time
- $N_w(t)$ total number of words in all inventories as function of time
- $N_d(t)$ number of different words as function of time
- $S(t)$ probability of a successful interaction as function of time

Behavior on Lattices



Consensus is reached!

- We compare different topologies
 - black fully connected
 - red 1D lattice (line)
 - blue 2D lattice (grid)
- on lattices N_w and N_d are much lower (agents need less memory)
- convergence to consensus is much slower

Some Observations

What did we learn?

- We observe three phases
 - a. initially the words are invented;
 - b. then they spread throughout the system inducing a reorganization process of the inventories;
 - c. this process eventually triggers the final convergence towards the global consensus
- Local pairwise interactions are enough for reaching consensus (find a common word)
- A common language can spontaneously emerge, but there are many strong assumptions
- On lattices consensus is reached, but slowly. However agents need less memory than in the fully connected case.

Conclusions

Dimensional models to measure culture

- Approaches based on questionnaires in surveys
- Hofstede and Schwartz combinations: cultural distance can be measured
- Cultural distance can be measured using Eurovision data

Axelrod's culture model

- Agents with culture vectors and copying dynamics
- More traits per feature lead to more cultures
- Nonlinear relationship between grid size and culture homogeneity
- Different cultures can coexist even with only copy dynamics (but there is a trick)

The Naming Game

- Agents with inventories of words and copying dynamics
- Local pairwise interaction leads to the formation of a common language

Quiz

- Which culture do you think is higher in individualism in Hofstede's model, Italy or Switzerland?
- What are the limit of using Eurovision Data to measure cultural similarity?
- What are the implausible assumptions of Axelrod's model?
- What would happen if neighborhoods were larger in Axelrod's model?
- What are the implausible assumptions of the Naming Game?
- What are the key differences between the Naming Game and Axelrod's model?
- Why does the Naming Game reaches global consensus while Axelrod's model does not?
- How could we generalize the Naming Game and Axelrod's model?

Play Yourself to Understand!

Axelrod's Model

<https://rf.mokslasplius.lt/axelrod-culture-dissemination-model/>

Naming Game

http://www.socialdynamics.it/topics/complex-systems-dynamics/language-dynamics/naming_game/