

A Simple Model of Coevolution for Macroscopic and Microscopic Levels

Matteo Morini^{1,2}, Sarah de Nigris¹

¹Université de Lyon, Inria, UCB Lyon 1, Laboratoire de l'Informatique du Parallélisme UMR 5668, DANTE, CNRS, Institut Rhône-Alpin des Systèmes Complexes, ENS Lyon

²Department of Economics and Statistics, University of Torino

IMT, Lucca, 22-23 February, 2017

Outline

Introduction

Segregation Metric

Palatability Map

Influence

Relocation rule

Preliminary Results

References

Future lines of research

Questions

Introduction

- ▶ The Schelling Model of Ethnic Residential Dynamics

Introduction

- ▶ The Schelling Model of Ethnic Residential Dynamics
- ▶ **Measured**

Introduction

- ▶ The Schelling Model of Ethnic Residential Dynamics
- ▶ **Measured**
 - ▶ Segregation metric (spatial autocorrelation)

Introduction

- ▶ The Schelling Model of Ethnic Residential Dynamics
- ▶ **Measured**
 - ▶ Segregation metric (spatial autocorrelation)
 - ▶ Detection of Stationary States

Introduction

- ▶ The Schelling Model of Ethnic Residential Dynamics
- ▶ **Measured**
 - ▶ Segregation metric (spatial autocorrelation)
 - ▶ Detection of Stationary States
 - ▶ Intrinsic tolerance

Introduction

- ▶ The Schelling Model of Ethnic Residential Dynamics
- ▶ **Measured**
 - ▶ Segregation metric (spatial autocorrelation)
 - ▶ Detection of Stationary States
 - ▶ Intrinsic tolerance
 - ▶ “Social” tolerance

Introduction

- ▶ The Schelling Model of Ethnic Residential Dynamics
- ▶ **Measured**
 - ▶ Segregation metric (spatial autocorrelation)
 - ▶ Detection of Stationary States
 - ▶ Intrinsic tolerance
 - ▶ “Social” tolerance
 - ▶ Expectation: segregation reinforcement

Introduction

- ▶ The Schelling Model of Ethnic Residential Dynamics
- ▶ **Measured**
 - ▶ Segregation metric (spatial autocorrelation)
 - ▶ Detection of Stationary States
 - ▶ Intrinsic tolerance
 - ▶ “Social” tolerance
 - ▶ Expectation: segregation reinforcement
 - ▶ Apparent outcome: alter transition towards segregation in form of mixed patterns (not segregated)

Introduction

- ▶ The Schelling Model of Ethnic Residential Dynamics
- ▶ **Measured**
 - ▶ Segregation metric (spatial autocorrelation)
 - ▶ Detection of Stationary States
 - ▶ Intrinsic tolerance
 - ▶ “Social” tolerance
 - ▶ Expectation: segregation reinforcement
 - ▶ Apparent outcome: alter transition towards segregation in form of mixed patterns (not segregated)
- ▶ **Augmented**

Introduction

- ▶ The Schelling Model of Ethnic Residential Dynamics
- ▶ **Measured**
 - ▶ Segregation metric (spatial autocorrelation)
 - ▶ Detection of Stationary States
 - ▶ Intrinsic tolerance
 - ▶ “Social” tolerance
 - ▶ Expectation: segregation reinforcement
 - ▶ Apparent outcome: alter transition towards segregation in form of mixed patterns (not segregated)
- ▶ **Augmented**
 - ▶ Palatability Map

Introduction

- ▶ The Schelling Model of Ethnic Residential Dynamics
- ▶ **Measured**
 - ▶ Segregation metric (spatial autocorrelation)
 - ▶ Detection of Stationary States
 - ▶ Intrinsic tolerance
 - ▶ “Social” tolerance
 - ▶ Expectation: segregation reinforcement
 - ▶ Apparent outcome: alter transition towards segregation in form of mixed patterns (not segregated)
- ▶ **Augmented**
 - ▶ Palatability Map
 - ▶ Networking

Introduction

- ▶ The Schelling Model of Ethnic Residential Dynamics
- ▶ **Measured**
 - ▶ Segregation metric (spatial autocorrelation)
 - ▶ Detection of Stationary States
 - ▶ Intrinsic tolerance
 - ▶ “Social” tolerance
 - ▶ Expectation: segregation reinforcement
 - ▶ Apparent outcome: alter transition towards segregation in form of mixed patterns (not segregated)
- ▶ **Augmented**
 - ▶ Palatability Map
 - ▶ Networking
 - ▶ Influence

Introduction

- ▶ The Schelling Model of Ethnic Residential Dynamics
- ▶ **Measured**
 - ▶ Segregation metric (spatial autocorrelation)
 - ▶ Detection of Stationary States
 - ▶ Intrinsic tolerance
 - ▶ “Social” tolerance
 - ▶ Expectation: segregation reinforcement
 - ▶ Apparent outcome: alter transition towards segregation in form of mixed patterns (not segregated)
- ▶ **Augmented**
 - ▶ Palatability Map
 - ▶ Networking
 - ▶ Influence
 - ▶ Informed relocation decision

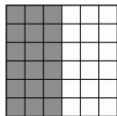
Spatial Autocorrelation Metric

- ▶ Moran's Global I (Anselin, 1995)

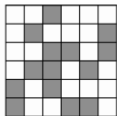
$$I = n/S_0 \frac{\sum_i \sum_j z_i w_{i,j} z_j}{\sum_i z_i z_i}$$

$$z_i = y_i - \bar{y}$$

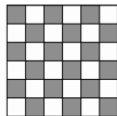
$w_{i,j}$ = spatial weight



Positive spatial
autocorrelation



No spatial
autocorrelation



Negative spatial
autocorrelation

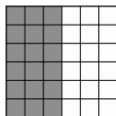
Spatial Autocorrelation Metric

- ▶ Moran's Global I (Anselin, 1995)
 - ▶ "Queen" contiguity

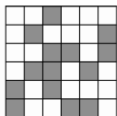
$$I = n/S_0 \frac{\sum_i \sum_j z_i w_{i,j} z_j}{\sum_i z_i z_i}$$

$$z_i = y_i - \bar{y}$$

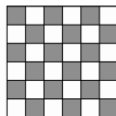
$w_{i,j}$ = spatial weight



Positive spatial
autocorrelation



No spatial
autocorrelation



Negative spatial
autocorrelation

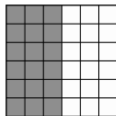
Spatial Autocorrelation Metric

- ▶ Moran's Global I (Anselin, 1995)
 - ▶ "Queen" contiguity
 - ▶ Missing neighbors

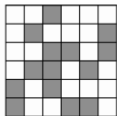
$$I = n/S_0 \frac{\sum_i \sum_j z_i w_{i,j} z_j}{\sum_i z_i z_i}$$

$$z_i = y_i - \bar{y}$$

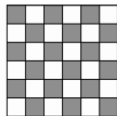
$w_{i,j}$ = spatial weight



Positive spatial
autocorrelation



No spatial
autocorrelation



Negative spatial
autocorrelation

Palatability Map

- ▶ Individual “world” map pM_i

Palatability Map

- ▶ Individual “world” map pM_i
- ▶ Tiles rating updated tick after tick

Palatability Map

- ▶ Individual “world” map pM_i
- ▶ Tiles rating updated tick after tick
- ▶ Time spent

Palatability Map

- ▶ Individual “world” map pM_i
- ▶ Tiles rating updated tick after tick
- ▶ Time spent
 - ▶ **on tile:** increase tile value (*incrementally*)

Palatability Map

- ▶ Individual “world” map pM_i
- ▶ Tiles rating updated tick after tick
- ▶ Time spent
 - ▶ **on tile:** increase tile value (*incrementally*)
 - ▶ **moving away:** decrease tile value (*one-shot*)

Influence at a distance

- ▶ Networked Agents

Influence at a distance

- ▶ Networked Agents
 - ▶ Spatial Neighbors become Network Neighbors

Influence at a distance

- ▶ Networked Agents
 - ▶ Spatial Neighbors become Network Neighbors
 - ▶ Time Persistence

Influence at a distance

- ▶ Networked Agents
 - ▶ Spatial Neighbors become Network Neighbors
 - ▶ Time Persistence
 - ▶ “Type” Distribution according to **Tolerance Parameter** $\tau/2$

Influence at a distance

- ▶ Networked Agents
 - ▶ Spatial Neighbors become Network Neighbors
 - ▶ Time Persistence
 - ▶ “Type” Distribution according to **Tolerance Parameter** $\tau/2$
 - ▶ $\tau = 0$: same-type “friends” only

Influence at a distance

- ▶ Networked Agents
 - ▶ Spatial Neighbors become Network Neighbors
 - ▶ Time Persistence
 - ▶ “Type” Distribution according to **Tolerance Parameter** $\tau/2$
 - ▶ $\tau = 0$: same-type “friends” only
 - ▶ $\tau = 1$: equal share of types

Influence at a distance

- ▶ Networked Agents
 - ▶ Spatial Neighbors become Network Neighbors
 - ▶ Time Persistence
 - ▶ “Type” Distribution according to **Tolerance Parameter** $\tau/2$
 - ▶ $\tau = 0$: same-type “friends” only
 - ▶ $\tau = 1$: equal share of types
- ▶ Stubbornness: $\sigma \in [0, 1]$

Influence at a distance

- ▶ Networked Agents
 - ▶ Spatial Neighbors become Network Neighbors
 - ▶ Time Persistence
 - ▶ “Type” Distribution according to **Tolerance Parameter** $\tau/2$
 - ▶ $\tau = 0$: same-type “friends” only
 - ▶ $\tau = 1$: equal share of types
- ▶ Stubbornness: $\sigma \in [0, 1]$
 - ▶ Incorporating *Palatability maps* from networked agents

Relocation rule

- ▶ Final decision

Relocation rule

- ▶ Final decision
 - ▶ ${}_pM_i$ [*Personal matrix, a.k.a. palatability map*]

Relocation rule

- ▶ Final decision
 - ▶ ${}_pM_i$ [*Personal matrix, a.k.a. palatability map*]
 - ▶ ${}_pM_j (j = 1, \dots, n)$ [*Connected agents matrixes*]

Relocation rule

- ▶ Final decision
 - ▶ ${}_pM_i$ [*Personal matrix, a.k.a. palatability map*]
 - ▶ ${}_pM_j (j = 1, \dots, n)$ [*Connected agents matrixes*]
- ▶ ${}_fM_{i,j(u)} = \sigma {}_pM_i + (1 - \sigma) \sum_{j=1}^n {}_pM_j$

Relocation rule

- ▶ Final decision
 - ▶ ${}_pM_i$ [*Personal matrix, a.k.a. palatability map*]
 - ▶ ${}_pM_j (j = 1, \dots, n)$ [*Connected agents matrixes*]
- ▶ ${}_fM_{i,j(u)} = \sigma {}_pM_i + (1 - \sigma) \sum_{j=1}^n {}_pM_j$
- ▶ Hop to **best, empty** tile

Segregation **without** influence

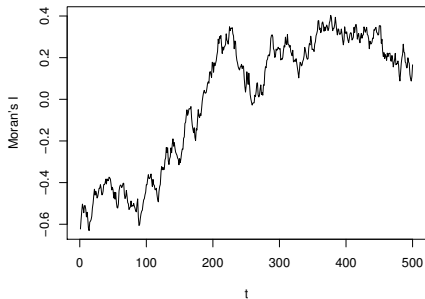


Figure 2 : Standard model.

Segregation **with** influence

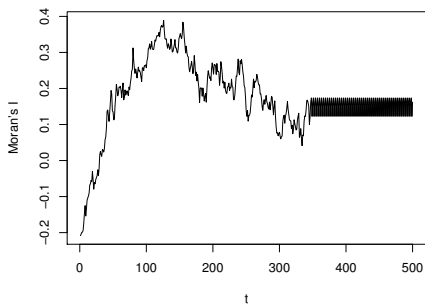


Figure 3 : Augmented model.

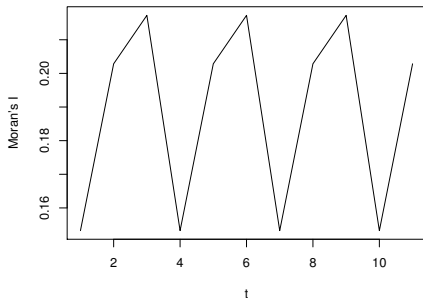
Segregation **with** influence (Zoom on steps [400:410])

Figure 4 : Augmented model cyclic behaviour.

References

1. Schelling T.C., *Dynamic models of segregation*, J Math Soc 1.2 (1971): 143-186
2. Grauwil S. et al., *Competition Between Collective and Individual Dynamics*, PNAS 106(49) (2009): 20622-20626
3. Erez H. and Benenson I., *The Schelling Model of Ethnic Residential Dynamics: Beyond the Integrated - Segregated Dichotomy of Patterns*, JASSS 15 (1) 6 (2012)
4. Anselin L., *Local Indicators of Spatial Association*, Geogr An 27(2) (1995): 93-115
5. Lee S.-I., *Developing a bivariate spatial association measure: an integration of Pearson's r and Moran's I* , J Geogr Syst 3 (2001): 369-385.
6. Gandica, Y., Gargiulo, F., & Carletti, T., *Can topology reshape segregation patterns?*, Chaos, Solitons & Fractals 90 (2016): 46-54.

Segregation Metric Refinements

- ▶ Moran's Global I (Anselin, 1995)

Segregation Metric Refinements

- ▶ Moran's Global I (Anselin, 1995)
- ▶ Refined measure (Lee, 2001): *L statistic* integrating

Segregation Metric Refinements

- ▶ Moran's Global I (Anselin, 1995)
- ▶ Refined measure (Lee, 2001): *L statistic* integrating
 - ▶ Pearson's r as an aspatial bivariate association measure

Segregation Metric Refinements

- ▶ Moran's Global I (Anselin, 1995)
- ▶ Refined measure (Lee, 2001): *L statistic* integrating
 - ▶ Pearson's r as an aspatial bivariate association measure
 - ▶ Moran's I as a univariate spatial association measure

Questions

Questions