Urban Dynamics in Latin American cities: an agent-based simulation approach

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Presentation outline

- Latin American cities
- Research question and methodology implemented
- The Peripherisation Model
  - Peripherisation module
  - Spontaneous settlements module
  - Inner city processes module
  - Spatial constraints module
- Limitations and contributions

Latin American cities

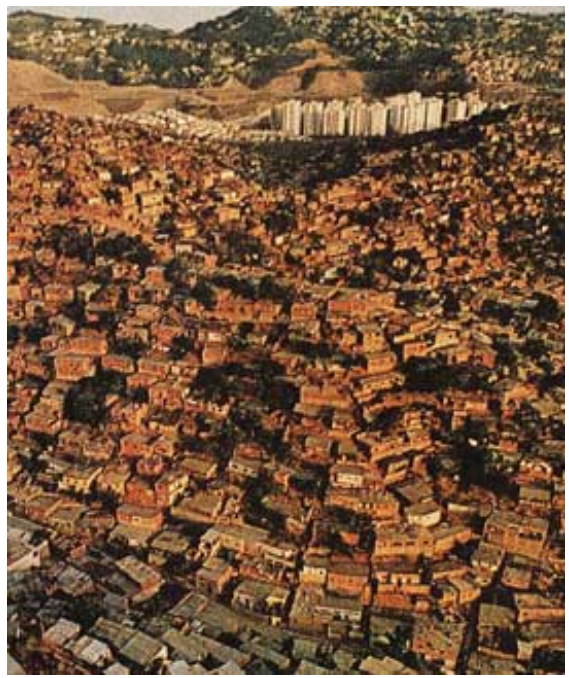
- High speed of urban growth (urbanization)
- Poverty + spontaneous settlements
- Poor control of policies upon the development process
- Spatial result: fragmented set of patches, with different morphological patterns often disconnected from each other that mutate and evolve in time.

Peripherisation Phenomenon

Process in which the city grows by the addition of low-income residential areas in the peripheral ring.

These areas are slowly incorporated to the city by spatial expansion, occupied by a higher economic group while new low-income settlements keep emerging on the periphery.

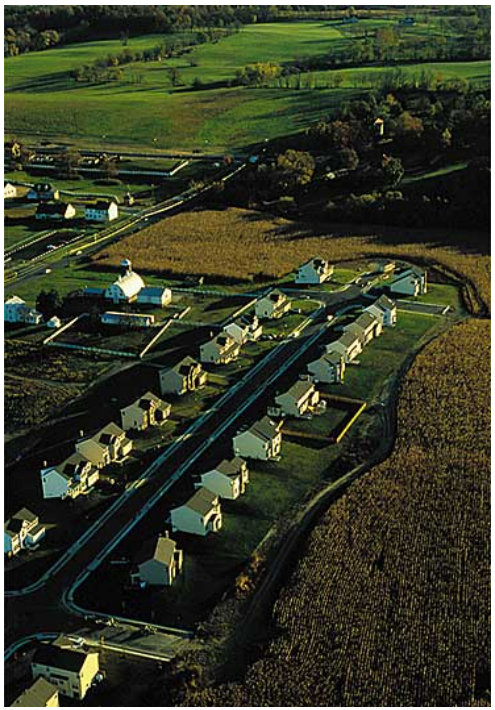
São Paulo - Brazil



Caracas - Venezuela

Urban growth

Urban sprawl in the United States



Urban sprawl in Europe (UK)

Peripherisation in Latin America (Brazil)

Research question and methodology

How this process happens in *space* and *time*?

⇩

DYNAMICS

⇩

modelling and simulation

- How space is shaped by individual decisions? → Complexity approach
- Time + Space → automata model
- Social issues → agent-based simulation

The Peripherisation Model

- exploratory agent-based model for urban growth in Latin American cities
- *JAVA* - software framework RePast

Four modules:

- Peripherisation module
- Spontaneous settlements module
- Inner city processes module
- Spatial constraints module

For each module:

- Sensitivity analysis tests → the study of the relationships between input and output of a model or, in other words, the study of the effects that changes in the parameters have on the output
- Simulation experiments → analyses of the model's outcomes and from these results, the chapter attempts to provoke discussions and draw conclusions about the reality of Latin American cities

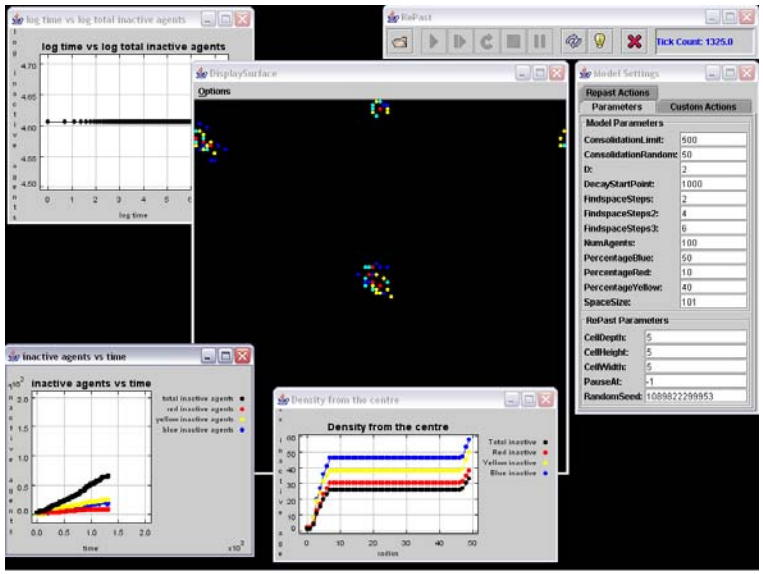
Sensitivity Analysis Tests

The study of the relationships between input and output of a model or, in other words, the study of the effects that changes in the parameters have on the output.

- Demonstrates the typical behaviour of the model
- Identifies the role of each parameter for the formation of the spatial pattern
- Allows the modeller to understand the typical behaviour of the model and to distinguish the features that are result of the behaviour of the parameters within the model from those that can be observed as proxies for the real behaviour of the system modelled .

- Visual analysis of spatial patterns
- Measurements along the simulation (graphs and charts):
  - Total number of active agents
  - Total number of occupied cells
  - Logarithm of number of occupied cells
  - Derivative of number of occupied cells
  - Density from the centre
- Landscape metrics → FRAGSTATS

Sensitivity Analysis Tests



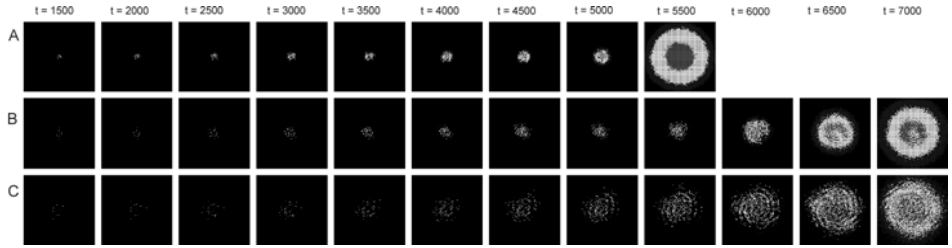
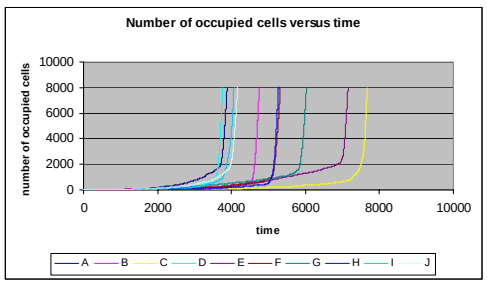
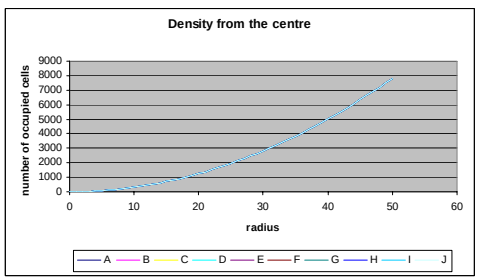
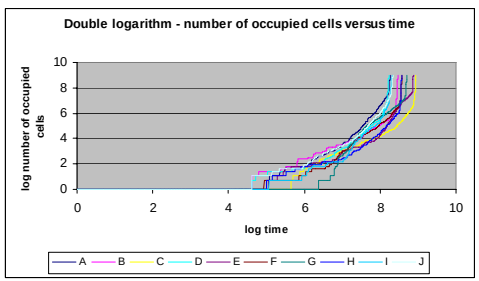


Table 1: Landscape metrics results for tests with steps.



	PAFRAC	*CONTAG*	*IJI* (%)
steps = 2	1.3950	39.3278	59.4799
steps = 4	1.5579	37.9115	63.9479
steps = 8	1.6809	20.5978	77.4128



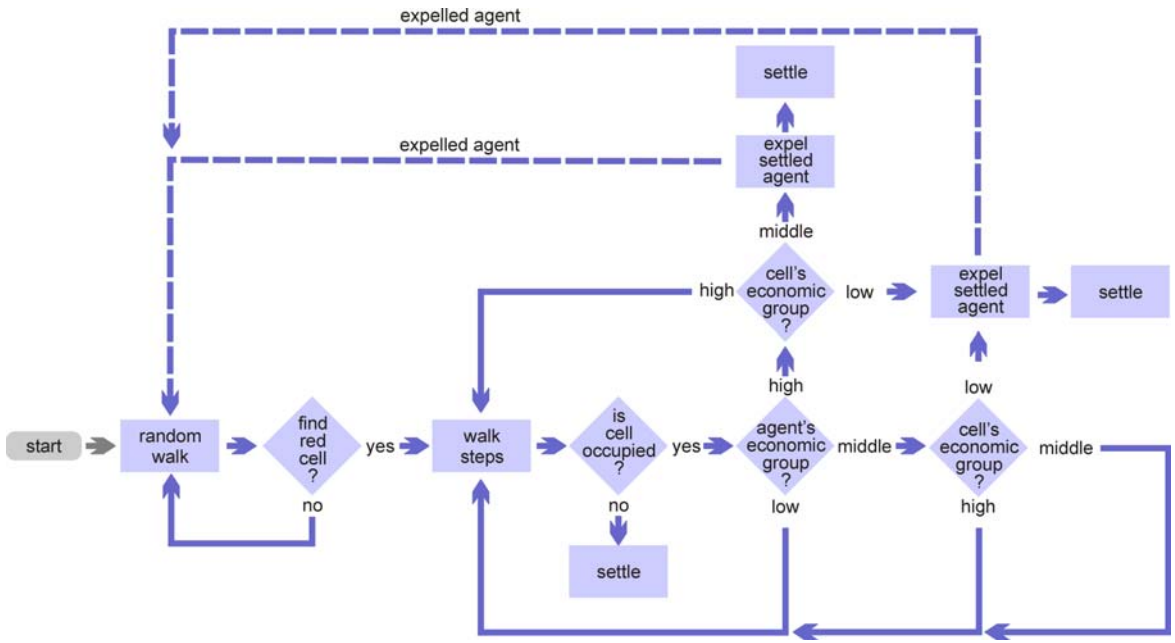


Peripherisation module

- reproduces the process of expulsion and expansion by simulating the residential locational processes of 3 distinct economic groups.
- assumes that despite the economic differences all agents have the same locational preferences. They all want to locate close to the best areas in the city which in Latin America means to be close to high-income areas
- all agents have the *same preferences* but *different restrictions*

Agent's rules:

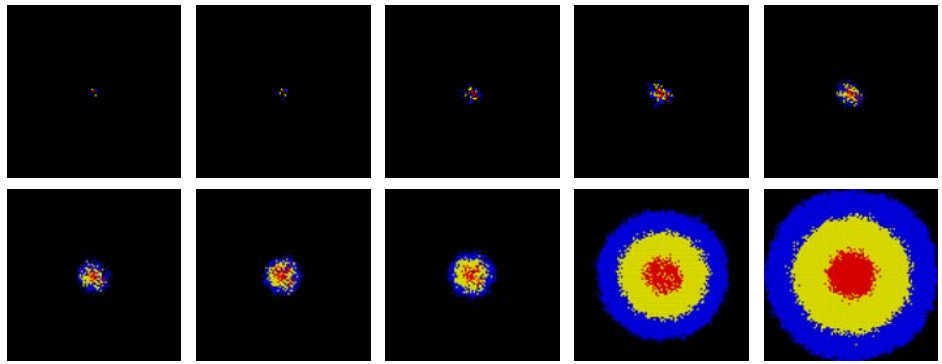
- proportion of agents per group is defined as a parameter
- high-income agent – can locate anywhere
- medium-income agent – can locate anywhere except on high-income places
- low-income agent – can locate only in the vacant space
- agents can occupy another agent's cell.
- then the latter is evicted and must find another place to settle



Peripherisation module – simulation exercises

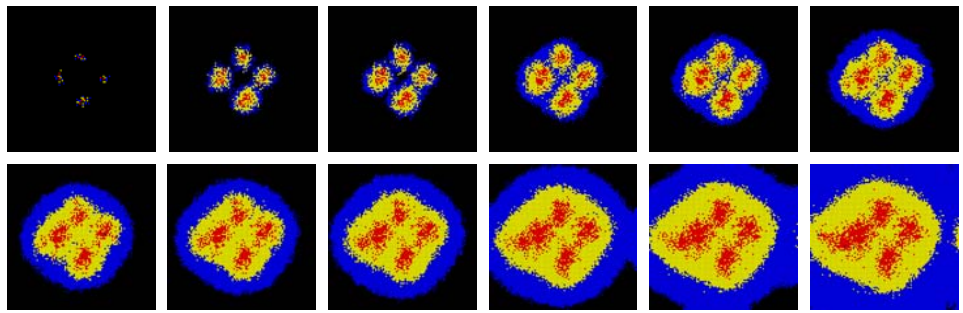
Spatial pattern:

- the rules do not suggests that the spatial outcome of the model would be a segregated pattern or that high-income groups should be located in the centre surround by buffering rings of middle and low-income cells



- approximates to the spatial structure found in the residential locational pattern of Latin American cities

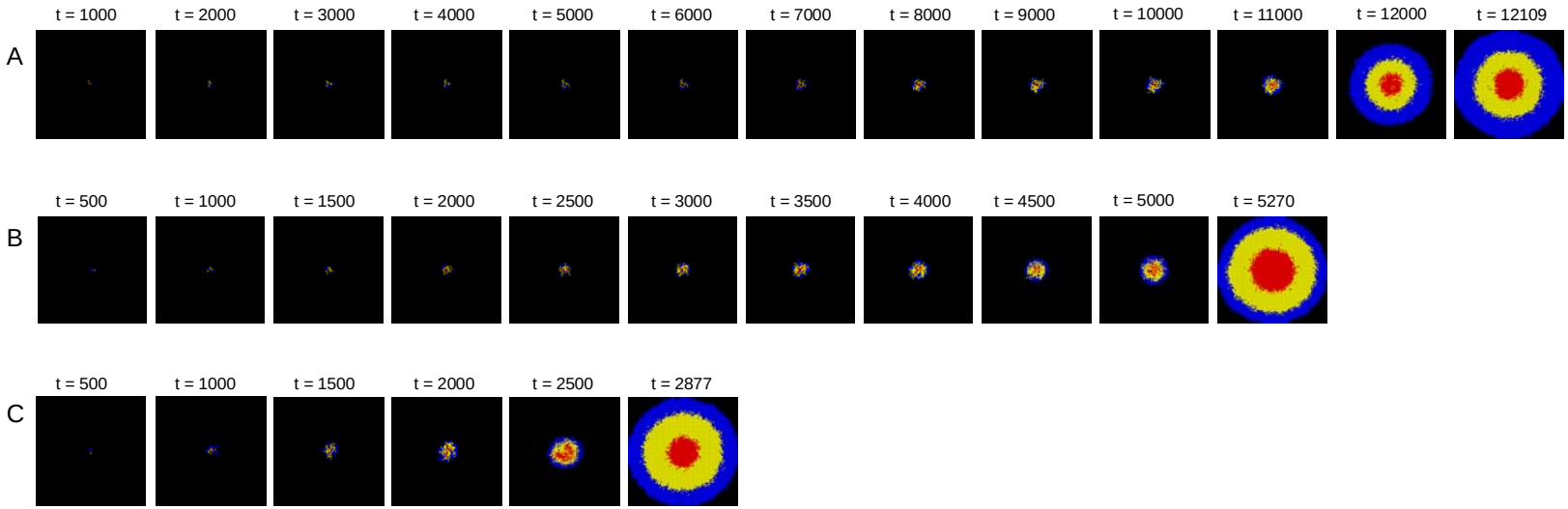
- multiple initial seeds - resembles certain characteristics of metropolitan areas



Peripherisation module – simulation exercises

Speed of growth:

- literature: speed is seen as an essential cause of the spatial patterns
- the rules of the model are related in any sense to the way locational decision takes place in reality, then speed has little, if any, influence on the generation of the core-periphery spatial pattern
- increase in the number of agents within the simulation does not affect the spatial pattern → the role played by speed in the formation of the spatial pattern must be questioned



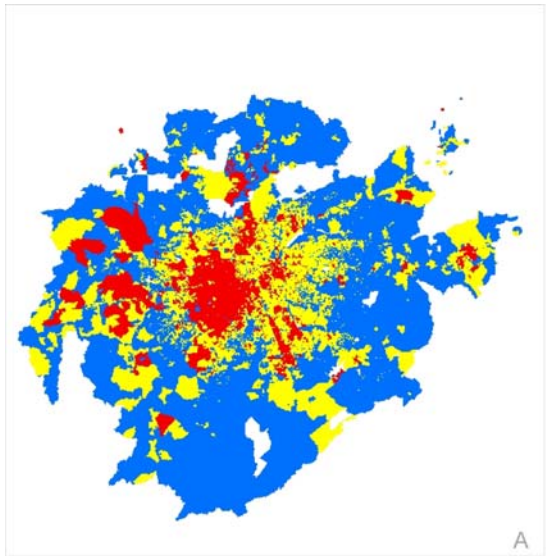
Comparison with reality

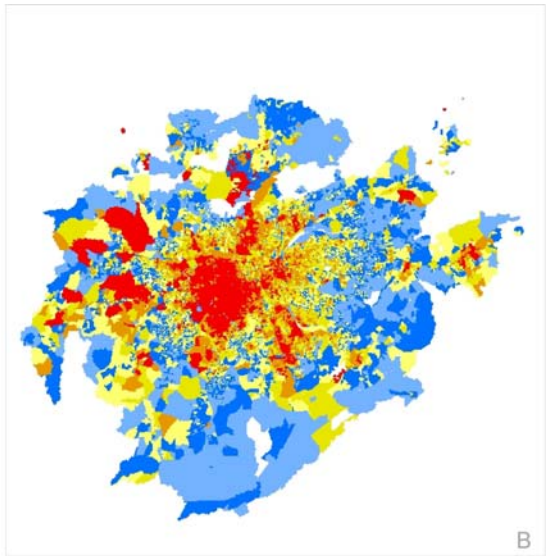
Maps of income distribution for São Paulo, Brazil (census 2000)

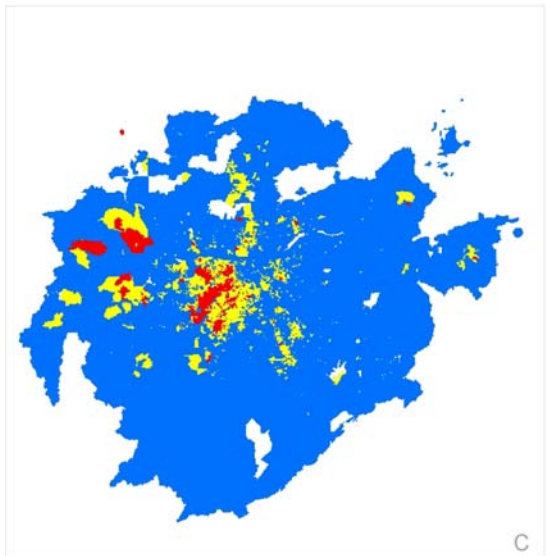
Maps A and B: quantile breaks (3 and 6 ranges)

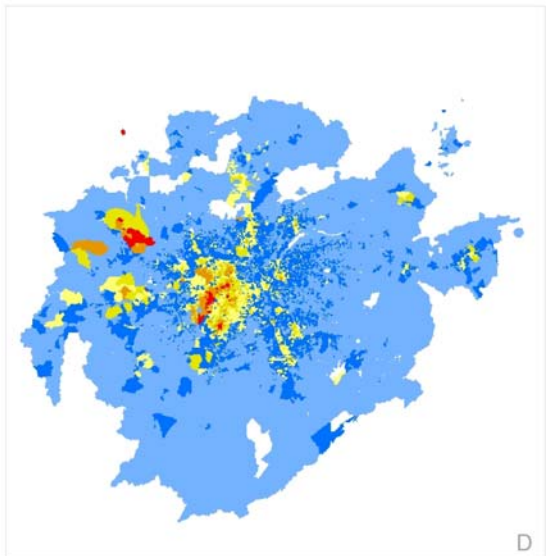
Maps C and D: natural breaks (3 and 6 ranges)

No definition of economic groups or social classes







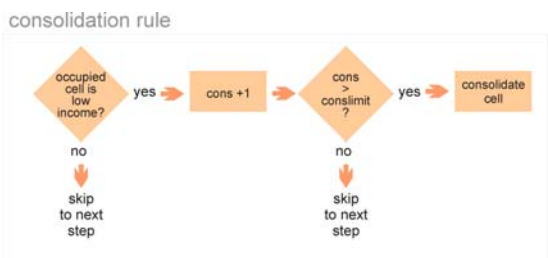


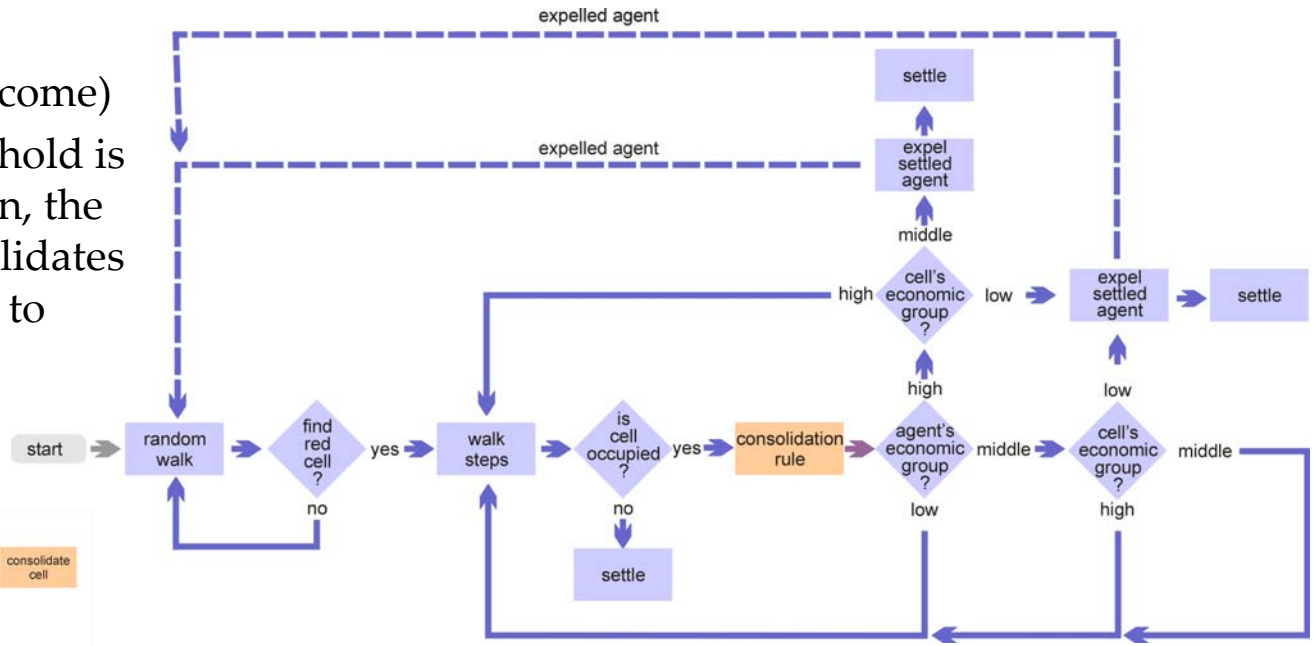
Spontaneous settlements module

- simulates the process of formation and consolidation of spontaneous settlements as part of the urban growth dynamics
- consolidation: process in which spontaneous settlements are gradually upgraded, and, as time passes, turn into consolidated *favelas* or, in other words, settlements that are harder to evict

Agent's rules:

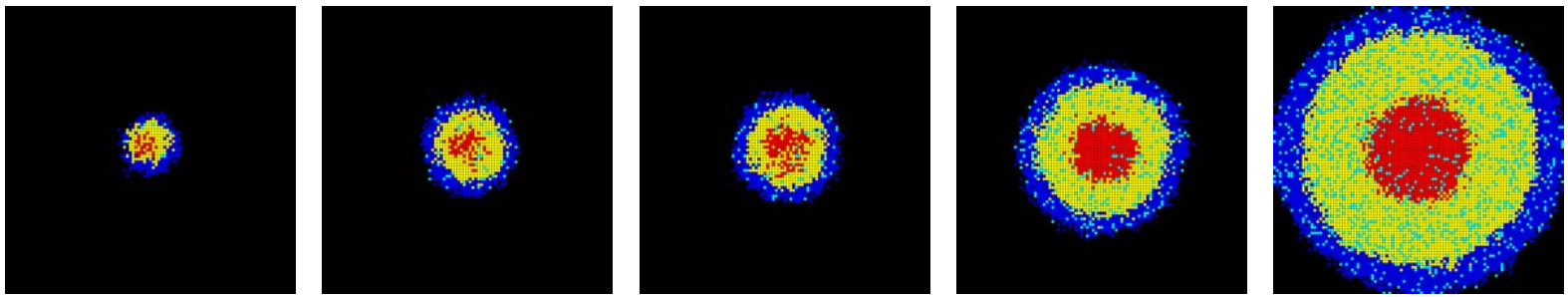
- *cons* variable (low income)
- if the *consLimit* threshold is reached before eviction, the low-income cell consolidates and becomes immune to eviction





Spontaneous settlements – simulation exercise

- generates a more fragmented landscape - consolidated spontaneous settlements are spread all over the city
- resembles what actually happens in Latin American cities - 'fragments' of low-income residential areas within higher-income zones



→ dynamic perspective - makes evident that spontaneous settlements that once were on the urban periphery are recontextualised and become located in central areas

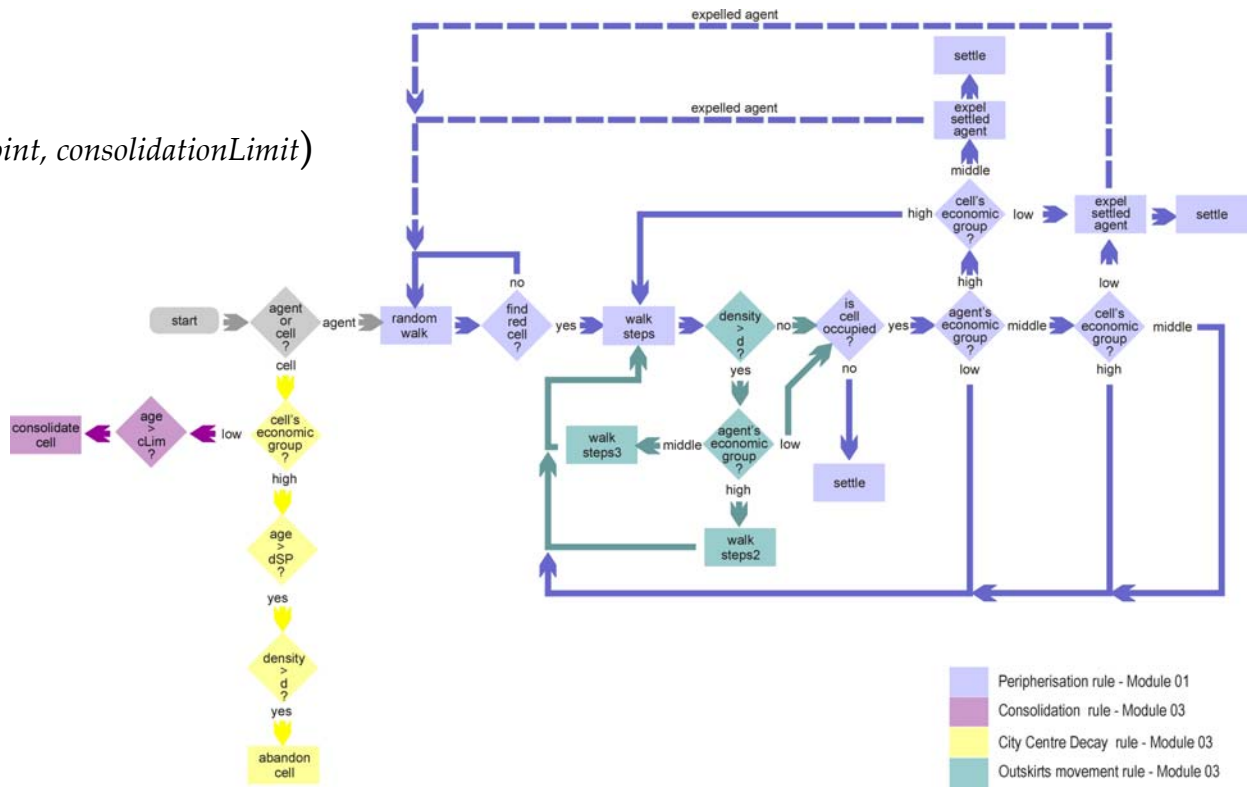
→ spontaneous settlements are part of the dynamics of those cities and their locational process must be further investigated

Inner city processes module

- attempt to reproduce some of the main dynamic processes in cities: *inner city decay*, *movement of elites towards the city edge*, *filtering*, and *gentrification*

Agent's rules:

- age (*decayStartPoint*, *consolidationLimit*)
- density (*d*)



Inner city processes – simulation exercises

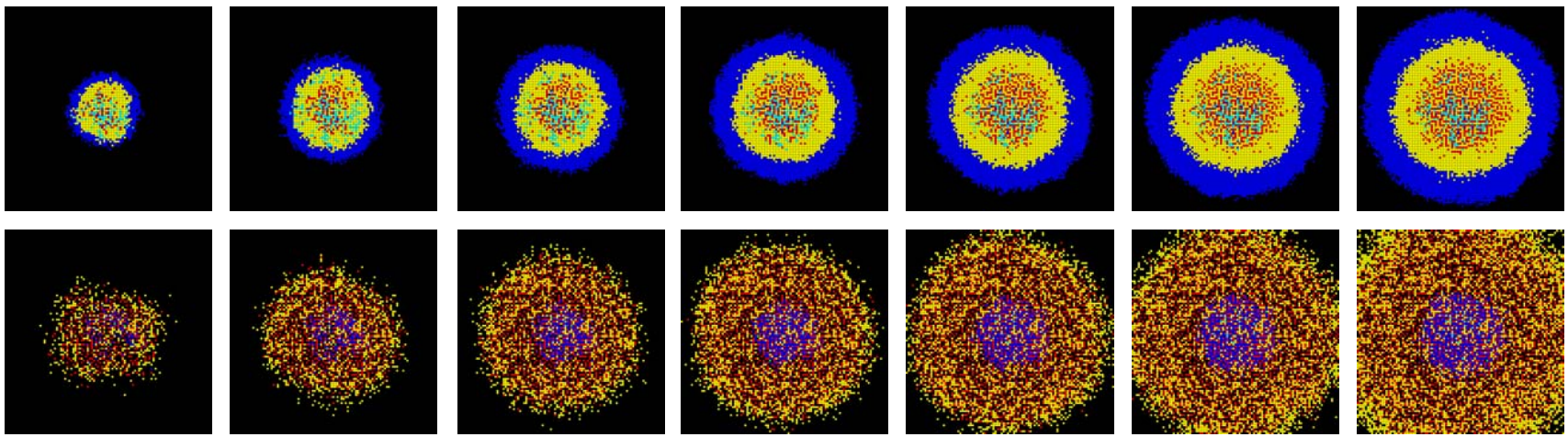
- comparative study of two different patterns of urban development: urban sprawl in Western cities and rapid urban growth in Latin American cities
- tests hypotheses (or theories) about inner city processes of residential change and their applicability to cities across cultures

Latin American city

10 40 50
d = 3
steps = 2
steps2 = 4
steps3 = 2
decayStartPoint = 800
consolidationLimit = 600

Western city

steps3 = 8
decayStartPoint = 400
consolidationLimit = 400
40 50 10
d = 2
steps = 2
steps2 = 7



Inner city processes – simulation exercises

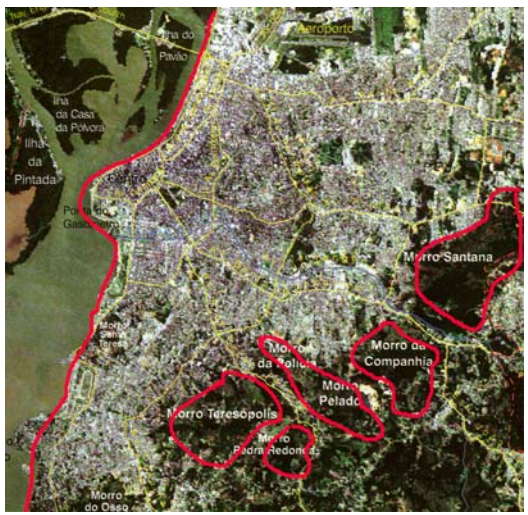
- the 'reversed' spatial pattern of location seems to be caused by a combination of differences in degree in processes of similar nature
- processes of filtering, core decay, and movement of high-income groups towards the city's outskirts are of *similar nature* in both Latin American and Western cities, and that they differ mainly in *degree*
- strong differences in the composition of the urban societies of these countries, which change the actual impact of these processes on the urban spatial pattern

Spatial constraints module

- introduce spatial constraints to the simulation model
- spatial constraints → bodies of water, steep slopes, or any other area where urbanisation is not possible
- implemented by the introduction of "grey" areas as initial conditions

Agent's rules:

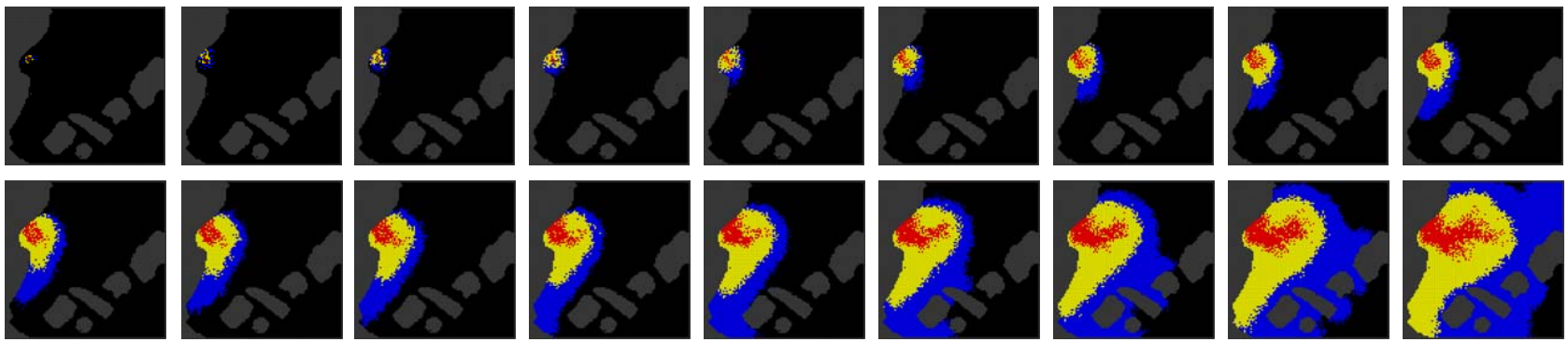
- agents do not settle or even walk on grey areas
- for every movement agents make towards new cells, they check if the new position is a grey cell or not and, if it is, they return to their previous position and change direction in order to avoid returning to the same cell



Spatial constraints exercises

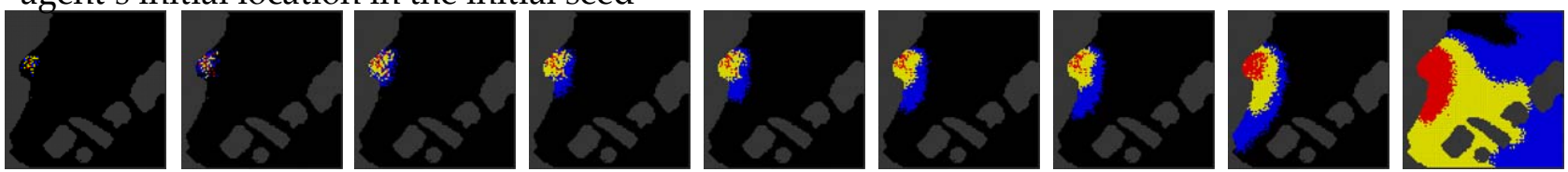
- objective : to check the impacts of spatial constraints on the tendencies shown by the model in previous experiments, and how they can be related to reality
- shows how the simple introduction of unreachable areas within the grid can shape the spatial development in such different ways

Exercises with Peripherisation module



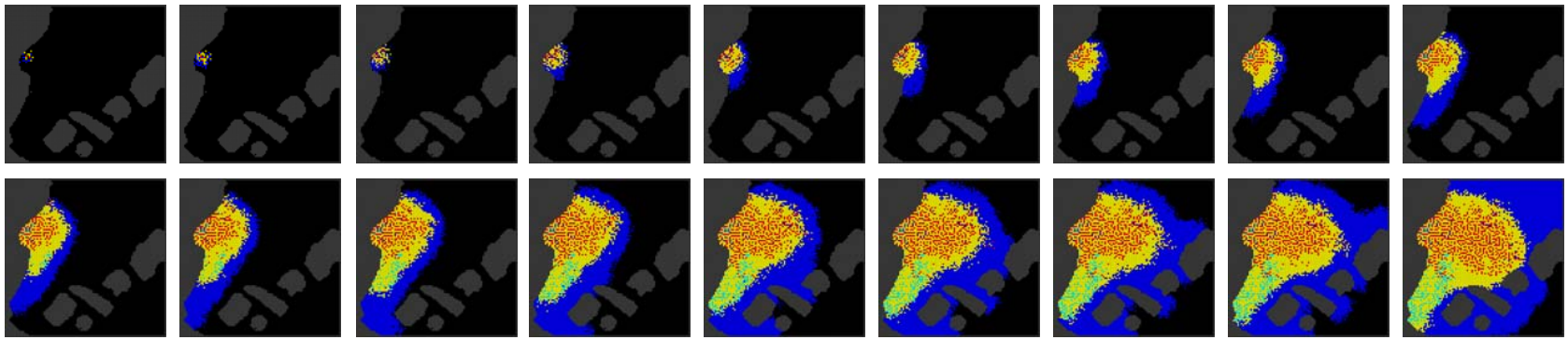
agent's initial location in the centre of the grid

agent's initial location in the initial seed



Spatial constraints exercises

Exercises with inner city processes module



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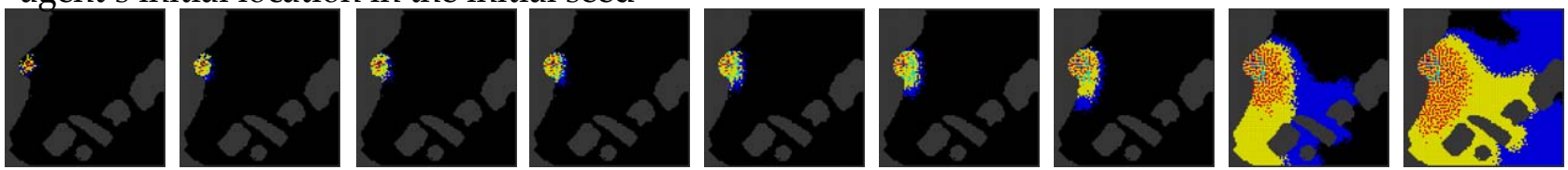

→ importance of spatial constraints for a more realistic simulation outcome

→ the role of spatial constraints in shaping urban morphology

Comparison with reality

Maps of income distribution for Porto Alegre, Brazil (census 2000)

Maps A and B: quantile breaks (3 and 6 ranges)

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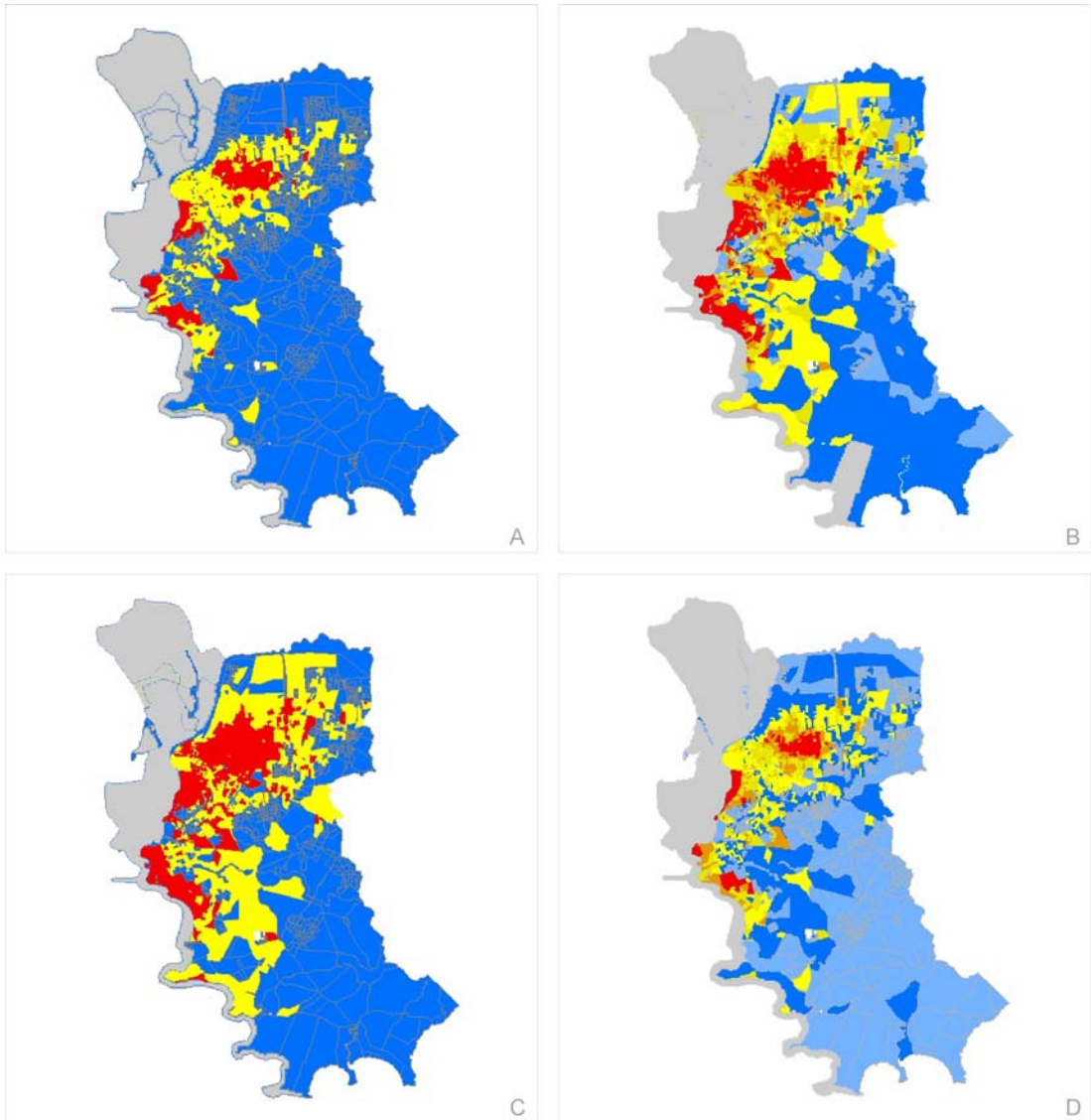
No definition of economic groups or social classes



Limitations

1. Experimental study → intends to provoke further enquiry rather than be definitive about the nature of dynamics and spatial patterns in Latin America

2. Generalisation attempt → sacrifices the ambition to reproduce the nature of the process going on in any specific city in the cause of trying to understand them all better

3. Oversimplification → the simulation model which reproduces aspects of reality through very simple spatial interaction rules. It therefore ignores a whole set of theories and socio-economic implications, and much of the complexity that characterises the real urban system.

Contributions

Despite making an oversimplification of a complex reality, the Peripherisation Model allowed the analysis of dynamic processes and made it possible to draw hypotheses about the dynamics of urban growth and change in Latin American cities.

On the simulation of urban dynamics

The Peripherisation Model is a good example of an exploratory simulation model and the simulation exercises seem to be an effective way to explore aspects of reality. In addition, agent-based simulation proved to be a suitable technique to explore urbanisation issues at the conceptual level, and allowed spatial patterns, dynamics and social issues to be handled within the same conceptual and modelling framework.

Contributions

On Latin American cities

- the theoretical framework for Latin American urban dynamics (Part I) - relates processes to global spatial patterns and urban morphology.
- change of perspective from statics to dynamics (morphology)
- the experiments with the model made clear that the actual process of development of Latin American cities is determined by socio-economic inequalities that are reproduced in space by the locational process
- also allowed the identification of similarities and differences in real-world inner city processes when comparing Western and Latin American cities
- the composition of the urban society is a key factor for the understanding of spatial patterns and processes in cities, and seems to play a major role in producing differences between different kinds of cities

→ the study of cities as complex systems provides a different perspective - how new planning policies could *drive* the urbanisation of Latin American cities along a different path, rather than simply trying to *control* it

→ identification of points that offer opportunities for intervention

Future work

Extensions of the Peripherisation Model

- introduction of an economic framework
- introduction of the housing ladder concept
- development of a matrix of change in land value
- introduction of the effects of historical change
- use of real data (input)

Variations in the evaluation method

- use of time-series data
- use of landscape metrics to compare results with reality

Applicability for other Third World cities

Thank you!

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