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

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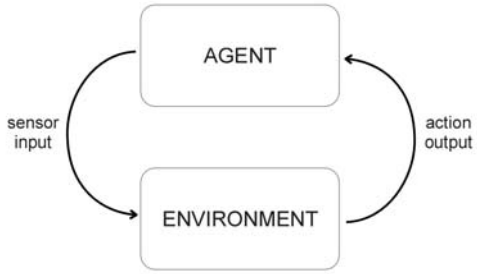
The complexity approach

- New approach to the study of *systems' dynamics* → permit the understanding of systems to go beyond description (in static terms) towards capturing the internal essence of the phenomena of change
- Cities are systems where historical events also shape the evolutionary process and each event brings about change through system feedback, possibly driving the evolution in a different way.
- The morphological structure (form) of the city is built from the interplay of different dynamics, adding an extra level of complexity to these systems.
- "a city's coherence is somehow imposed on a perpetual flux of *people and structures*" (Holland, 1995: page 1)
- The study of complex systems is largely built upon the use of computer simulations, using the computer as a *silicon laboratory* for urban studies as well as other social systems.

Agent-based Model

- Consists basically of a number of agents and an environment.
- Feedback mechanism:



- Simulation environment can be defined as “a medium separate from the agents, *on* which the agents operate and *with* which they interact” (Epstein & Axtell, 1996, page 5) → *geographic landscape*
- Allow modellers to explore three distinct layers or interactions:
  - *agent-agent*,
  - *agent-environment*, and
  - *environment-environment*

ABM in Spatial Studies

- Interaction between *agents and environment* (landscape be studied)
- Two main research streams:
  - focus on the ***agent's behaviour*** → how agents react to and within a given spatial configuration (landscape)

    Pedestrian movement models that investigate issues like crowd dynamics and shopping behaviour
  - focus on the ***landscape's behaviour*** → simulate spatial change

    Based on the understanding that human decision-making plays a major role in the process of spatial change and must be an explicit part of the model framework

    Agent-based models for land use and land cover

MAS/LUCC

- Multi-Agent Models for Land Use and Land Cover (MAS/LUCC)
- Combines two key components into an integrated model:
  - A cellular model that represents the landscape over which actors make decisions
  - An agent-based model that describes the decision-making architecture of the key actors in the system under study
- The cellular module is commonly misunderstood as a cellular automaton model but may draw on a number of spatial modelling techniques (including cellular automata), such as spatial diffusion models and Markov models
- It also may not have any kind of autonomous dynamic behaviour and simulate a static landscape modified by agent behaviour only

Why use an agent based model?

- “there are a number of systems where population dynamics and environmental interaction are so fundamentally interrelated that a modeller cannot satisfactorily represent one without the other” Box (2002, page 60)
- Cases in which a suitably dynamic representation of interactions between agents and environment interactions is necessary.
- It is essential to study the population effects on their environment, and on the effects of changes in the environment on the population’s actions

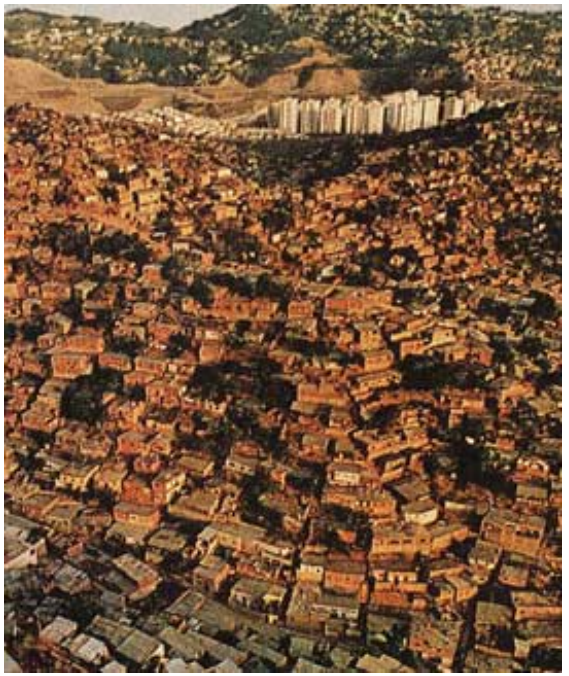
- **Urban growth in Latin American cities** → socio-economic component!

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

Assumptions behind the model

- Problem: formation and continuity of an specific dynamic spatial pattern

- Hypothesis: it is possible to improve the understanding of this phenomenon by simulating the process of residential location

- Economic ‘logic’:
  - Preferences/choices x restrictions
  - Division of agents in different economic groups
  - Inclusion of very low economic group (no budget)

The Peripherisation Model

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

Four modules:

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

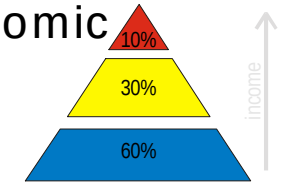
For each module:

- 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

The Peripherisation Module

Simulates a specific mode of growth: Peripherisation

- Reproduces the process of expulsion and expansion by simulating the residential locational process of 3 different economic groups according to the pyramidal model of distribution of income in these countries
- It is assumed that, despite the economic differences, all groups have the same locational preferences
- The difference on the behaviour of the three income groups is related to the restrictions imposed by their economic power



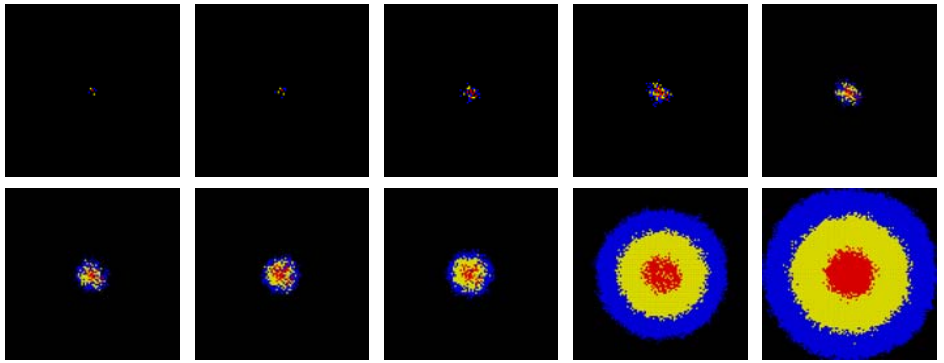
Model's rules

- Randomly walking agents over a cellular space divided into three breeds (economic groups)
- All the agents have the same preference/objective that is to be as closer as possible to the red patches but they present different restrictions to the place they can locate
  - Red agent – can locate anywhere
  - Yellow agent – can locate anywhere except on red patches
  - Blue agent – can locate only in the vacant space
- agents can occupy another agent's patch, when this happens the latter is evicted and must find another place to settle (run the process again)

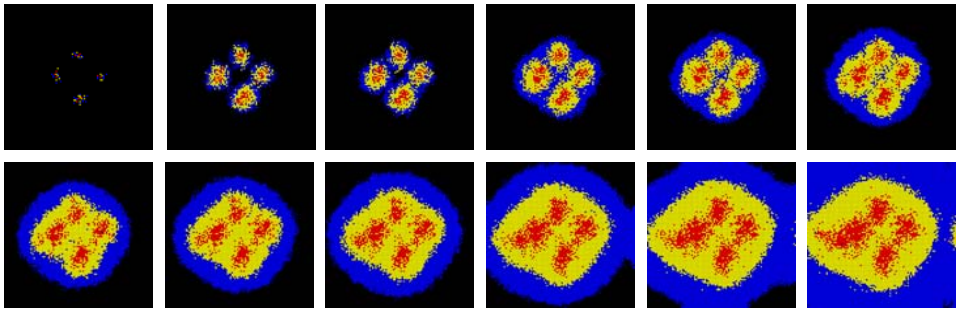
Peripherisation module – simulation exercises

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



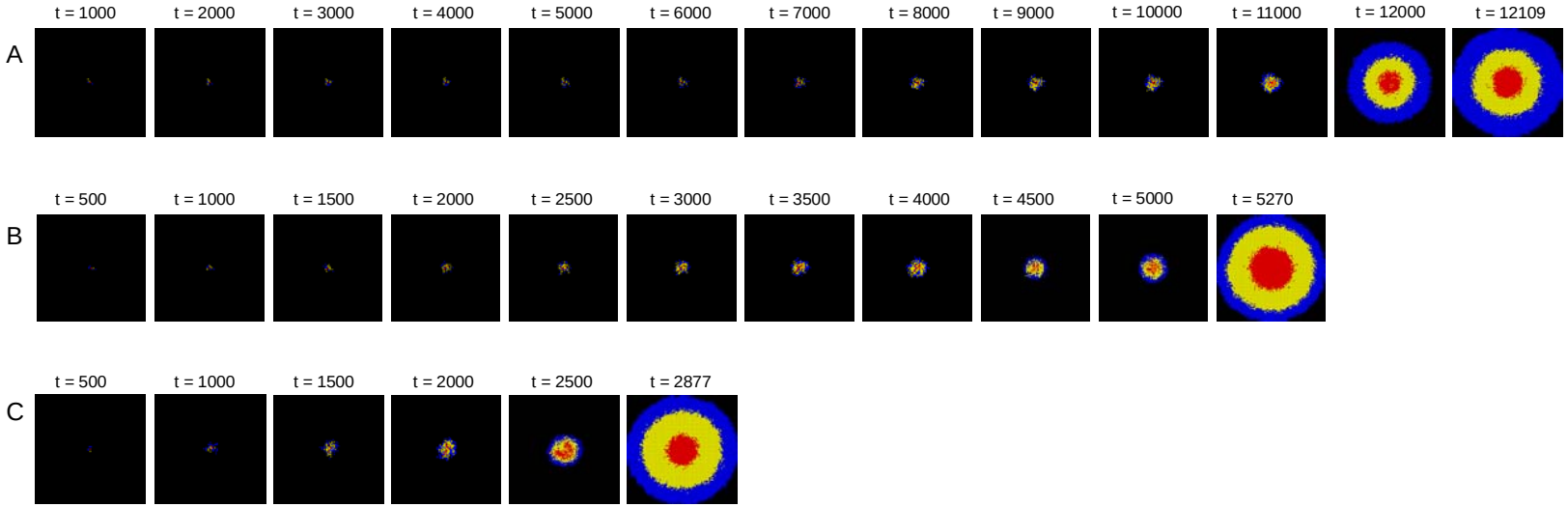
- approximates to the spatial structure found in the residential locational pattern of Latin American cities
- multiple initial seeds - resembles certain characteristics of metropolitan areas



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



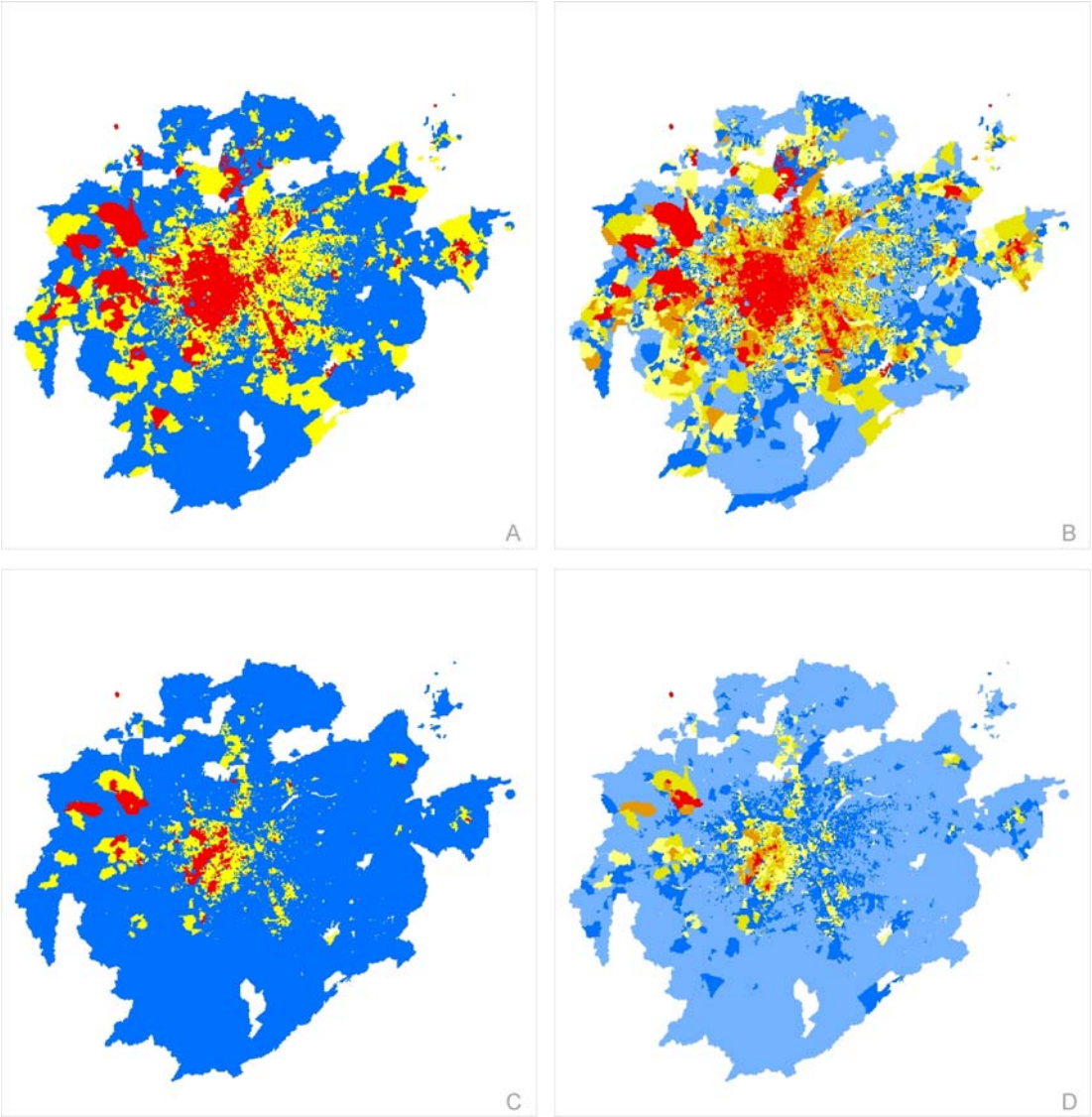
Comparison with reality

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

Peripherisation logic + *consolidation rule*

- 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

Peripherisation logic

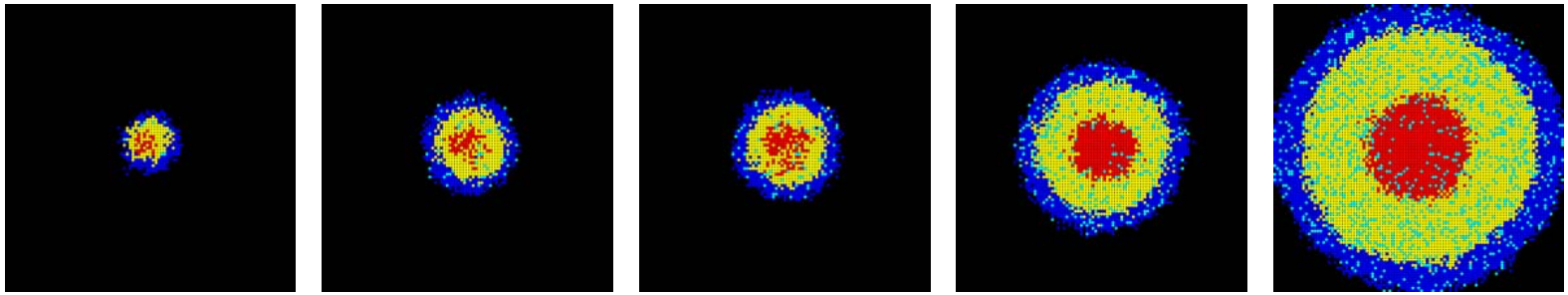
- Randomly walking agents divided into 3 breeds (red, yellow and blue)
- Agents have the same preferences but different restrictions
- Agents can be evicted from their patches when higher income agents occupy their patches

Consolidation rule

- ***cons*** variable (blue cells)
- When a *consLimit* threshold is reached before the patch turns into yellow or red , the blue patch consolidates (turn cyan) 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

→Chris Webster: How to manage spontaneity?

→Respectful attitude towards the existent dynamic?

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
  - Gentrification

- tests hypotheses (or theories) about inner city processes of residential change and their applicability to cities across cultures

Inner city processes

- Gentrification and Filtering

  Processes of neighbourhood change that involves its housing passing from one social group to another

- Inner city decay / suburbanisation

  The movement of high income groups to the urban outskirts is seen as interrelated process with the decay of the city centres

- Upgrading and succession:

  Most of the Latin American low-income groups lives in self-build houses either in ‘pockets’ within the city centre or in the urban periphery.

Comparison Study

Comparative study between two different patterns of urban development:

Latin America - **Urban Peripherisation**

Urban growth process is characterised by the expansion of the borders of the city through the massive formation of peripheral settlements, which are, in most cases, low-income residential areas including spontaneous settlements

Western countries - **Urban Sprawl**

Low-income groups live in the centre and high-income groups in the suburban areas which is always characterised by low-density but may vary between contiguous suburban growth, ribbon or strip development, and scattered or leapfrog development.

Inner city processes – simulation exercises

Latin American city

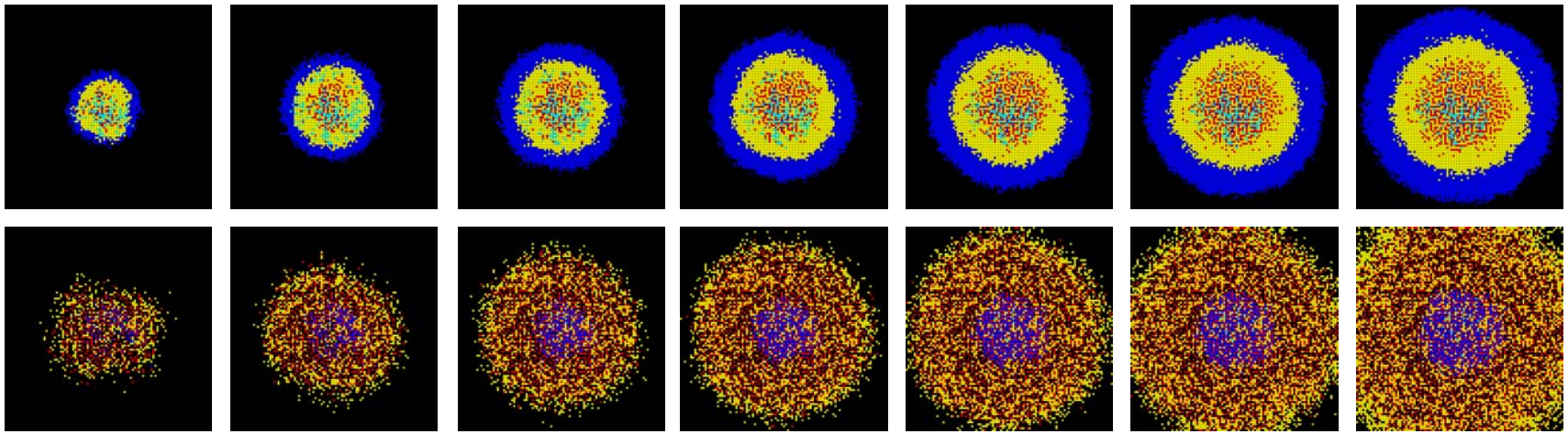
10 40 50
d = 3
steps = 2
steps2 = 4

steps3 = 2
decayStartPoint = 800
consolidationLimit = 600

Western city

40 50 10
d = 2
steps3 = 8
decayStartPoint = 400
consolidationLimit = 400

steps = 2
steps2 = 7



1000 cells | 2000 cells | 3000 cells | 4000 cells | 5000 cells | 6000 cells | 7000 cells

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

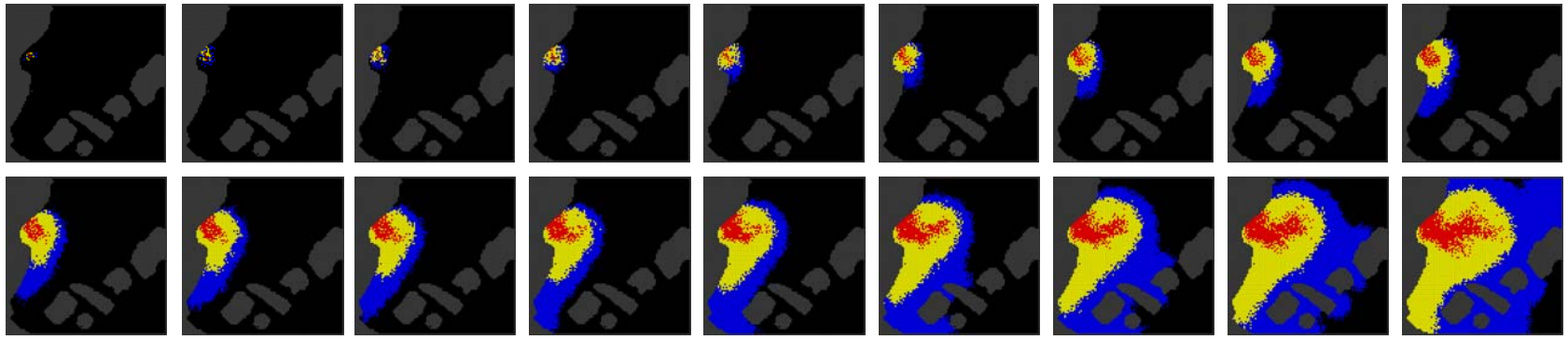
Agent’s rules:

- 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

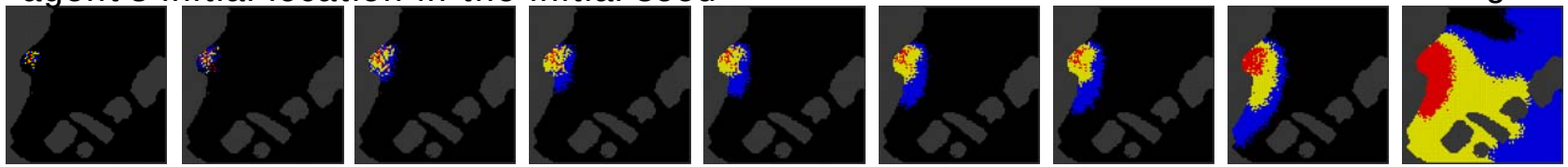
- importance of spatial constraints for a more realistic simulation outcome
- the role of spatial constraints in shaping urban morphology

Exercises with Peripherisation module



agent's initial location in the centre of the grid

agent's initial location in the initial seed



Conclusions

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.
- 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.

Conclusions

On Latin American cities

- 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

Complexity and Planning

- 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 → minor changes that impacts on the global system

- How agent-based models can be useful for support planning decisions?
- Do they have to be predictive models to serve planning?
- How can exploratory models serve to give basis for planning actions and policies?
- Can MAS/LUCC models be used in practice (like Nottingham Hill Carnival)? 'Informed speculation' - as a tool *to think with* or *to decide upon? Visualisation tool…*
- How the understanding of urban dynamics can change the planning perspective in Latin American cities?

Thank you!

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