Session 4: Lecture 5:

Development of a CA Urban Growth Model

Kiril Stanoliv
CASA, UCL and Architecture, University of Cambridge

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The Idea

dev elopment of a CA urban growth model
The Idea

Kiril Stanilov, June 2010

CASA

Past               present             future
40 – 50 years

traditional land use models
The Idea

Past               present             future

40 - 50 years

traditional land use models

Past           present           future

130 years

West London model

Kiril Stanilov, June 2010
study area
data

Ordnance Survey
County Series 1:2,500

1875

Kiril Stanilov, March 2010 CASA
data

Ordnance Survey
County Series 1:2,500

1875

1:10,000

Kiril Stanilov, March 2010 CASA
data

Ordnance Survey
County Series 1:2,500

Kiril Stanilov, March 2010 CASA
data

Ordnance Survey
County Series 1:2,500

1875

1:2,500

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Kiril Stanilov, March 2010  CASA
data

Ordnance Survey
County Series 1:2,500

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1875

Kiril Stanilov, March 2010 CASA
data

Ordnance Survey
County Series 1:2,500

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Kiril Stanilov, March 2010  CASA
data

Ordnance Survey
County Series 1:2,500

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Kiril Stanilov, March 2010 CASA
data

Ordnance Survey
County Series 1:2,500

1:2,500

1875

1:10,000

Kiril Stanilov, March 2010 CASA
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<th>used in model</th>
<th>digitized in GIS</th>
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Kiril Stanilov, March 2010 CASA
1875-2005 residential development

- Terraced housing
- Semi-detached housing
- Detached housing
- Multi-family housing

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1915 spatial structure

Kiril Stanilov, March 2010  Casa
Kiril Stanilov, March 2010
1960 spatial structure

1875 development
1875-95 development
1895-15 development
1915-35 development
1935-60 development
Industrial uses

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1985 spatial structure

1875 development
1875-95 development
1895-15 development
1915-35 development
1935-60 development

1960-85 development

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Kiril Stanilov, March 2010

1875 - 95 1895 - 15
1915 - 35 1935 - 60
1960 - 85 1985 - 05

nucl eation

diffusion

infill
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Residential development by distance from CBD

% cells developed as residential of total cells vacant in preceding period
NORMALIZED BY RATE OF GROWTH

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1935 Distance to rail stations

residential development 1915-35
rail station
1935 Distance to rail stations

- Residential 1915-35
- Developed land 1915
- Rail station

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1915 accessibility

distance to arterial roads

distance to connector roads

distance to rail stations

distance to rail stations
Identification of suburban centres

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40 – 50 years

traditional land use models

Past               present             future

40 - 50 years
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Past               present             future

40 - 50 years

traditional land use models

Past     present     future

130 years

West London model

Past               present

40 - 50 years
The Idea

Past               present             future

40 - 50 years

traditional land use models

Past     present     future

40 - 50 years

West London model

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CASA
The Idea

Past               present             future

40 - 50 years

traditional land use models

West London model

130 years
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The Result

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The Result

2005 actual

1875

2005 modeled
The Result

Kiril Stanilov, June 2010

CASA
Why Metronamica?

- Ability to model urban land uses (not available in SLEUTH)
- Intuitive interface – no need for programming
- Speed – “real time” interaction
Why Metronamica?

- Ability to model urban land uses (not available in SLEUTH)
- Intuitive interface – no need for programming
- Speed – “real time” interaction

Background

- White and Engelen (1997) Environment and Planning B
Applications
Applications
4 determinants

- **Neighborhood effect** - cellular automata
- **Accessibility** - calculated for each land use relative to the distance of the cell to each of the infrastructure elements
- **Suitability** - elevation, soil type, air quality, noise pollution, etc.
- **Zoning** - specifying which cells can and cannot be taken by particular land use
4 determinants

- *Neighborhood effect* - cellular automata
- *Accessibility* - calculated for each land use relative to the distance of the cell to each of the infrastructure elements
- *Suitability* - elevation, soil type, air quality, noise pollution, etc.
- *Zoning* - specifying which cells can and cannot be taken by particular land use

\[ P_k = r \cdot N_k \cdot A_k \cdot S_k \cdot Z_k \]

- \( P_k \) – transition potential
- \( r \) - stochastic perturbation factor

The model calculates for every simulation step the *transition potential* for each cell and each land use.

Cells change to the land use for which they have the highest transition potential until regional demands are satisfied.
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The Concept

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Kiril Stanilov, June 2010  
CASA
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Model input

- Land use maps
  - ASCII files
  - spatial reference and demand
Model input

- Land use maps
  - ASCII files
  - minimum of 2

- Accessibility
  - vector shape files
Model input

- Land use maps
  - ASCII files
  - minimum of 2

- Accessibility
  - vector shape files

- Suitability maps - one for each land use
  - weighted linear sum of several factors
  - values normalized in the range of 0–1
Model input

- Land use maps
  - ASCII files
  - minimum of 2

- Accessibility
  - vector shape files

- Suitability maps - one for each land use
  - weighted linear sum of several factors
  - values normalized in the range of 0–1

- Zoning maps - one for each land use
  - each cell is associated with a set of codes
    (permitted, not permitted, permitted from certain year)
Land use classes

Land uses are broken in three categories treated differently by the model

1. *Active functions* – respond to exogenous demand
   - Residential
   - Industrial
   - Commercial
Land use classes

Land uses are broken in three categories treated differently by the model

1. Active functions – respond to exogenous demand
   - Residential
   - Industrial
   - Commercial

2. Passive functions – not driven by exogenous demand, appear or disappear as a result of land being taken or abandoned by the active land uses
   - Vacant
   - Soft – Allotment gardens, nurseries
Land use classes

Land uses are broken in three categories treated differently by the model

1. **Active functions** – respond to exogenous demand
   - Residential
   - Industrial
   - Commercial

2. **Passive functions** – not driven by exogenous demand, appear or disappear as a result of land being taken or abandoned by the active land uses
   - Vacant
   - Soft – Allotment gardens, nurseries

3. **Fixed features** – do not change but affect other land uses through their attraction or repulsion effect
   - Recreational
   - Large institutional
   - Airport
   - Railways
   - Water
Calibration

Hot topic
No adequate automated methods (ANN good but black box)
Metronamica relies on common sense, geographical knowledge and intuition

The steps

I. Qualitative calibration
   1. Qualitative calibration of parameters defining neighborhood influence
   2. Calibration of random perturbation coefficient
   3. Introduction of Suitability, Accessibility, and Zoning
   4. Fine tuning neighborhood interactions

II. Quantitative calibration
Qualitative Calibration

Kiril Stanilov, June 2010

CASA
Step 1: neighborhood influence

- keep the number of influence functions to a minimum
- influence functions are remarkably stable across context

(a) res-res
(b) res-ind
Step 2: stochastic parameter

controls the degree of scatter in land use patterns

impacts

- density gradient of land uses
- seeding of new clusters
- degree of irregularity of cluster boundaries
Step 2: stochastic parameter

controls the degree of scatter in land use patterns

impacts

- density gradient of land uses
- seeding of new clusters
- degree of irregularity of cluster boundaries

fractal dimensions

- the radial dimension
- the cluster size – frequency dimension
- the perimeter scaling dimension

All of three dimensions are measured serving as the reference for the calibration.
Random coefficient = 0.9
Random coefficient = 0.2
Step 3: accessibility

Two types of parameters:

- **weighting parameters** - the relative importance of various network elements for particular land use
- **distance decay parameters** - specify the rate at which the inherent desirability of a cell for a particular land use declines as distance from the network element increases.
Qualitative Calibration

No accessibility
Access to CBD
Access to CBD + arterial roads
Access to CBD + arterial roads + connector roads
Access to CBD + arterial roads + connector roads + rail stations
Access to CBD + arterial roads + connector roads + rail stations + suburban centres
Qualitative Calibration
Qualitative Calibration
Step 4: Zoning

- Somewhat rigid integration – allows for little change over time
- Still better than most other CA-based systems

Kiril Stanilov, June 2010
no zoning
protected open space
Qualitative Calibration Summary

What features/patterns are relevant to look for:

- Dispersal
- Scatteration
- Number of clusters
- Cluster sizes
- Cluster shape
- Raggedness of edges
- Land uses adjacencies

These are all qualities of pattern which cannot be captured in pixel by pixel comparisons.
Quantitative calibration

Evaluation of the degree of fit between two maps using the comparison matrices method,
Provides a basis for choosing between calibrations which, according to a visual comparison, are of similar quality.

Main techniques

▪ Kappa statistics
▪ fuzzy Kappa statistics
▪ polygon based fuzzy map comparison

The MAP COMPARISON KIT is an instrument enabling the pair-wise comparison of the many maps generated in particular runs of METRONAMICA.
To Do list

- Fine-tuning the calibration
- Sensitivity analysis
- Spatial resolution analysis
  - cell size
  - land use classification
Conclusions

- METRONAMICA is cool ... and it works!
- Strong evidence that the complexity of urban land use patterns is generated by underlying processes which are relatively simple in qualitative terms and consistent across time