Theoretical Basis for CA

Late 1940's, John von Neumann credited with being first to formally investigate the concept of self-replicating machines. He was interested in the logic, the processes, and algorithms necessary for machines to produce copies of themselves. Von Neumann explored these concepts using relatively simple 'machines', the system of cellular automata:

- an array of cells
- each of which can be in one of a finite number of states
- all cells in array are updated synchronously in discrete time steps (i.e. parallel)

→ These basic mechanisms appear very similar to those of biological life discovered in the 1950's.
Watson and Crick described DNA structure in 1953.

1966 John von Neumann published his paper on 'Theory of Self-Producing Automata'.
1960's John Conway's Game of Life popularized the CA model.
1994 John Koza showed that spontaneous emergence of self-replicating systems was possible.

1995 Gianluca Tempesti produced a self replicating CA capable of computation → demonstrated by computer code that printed out LSL (Logic Systems Lab).

New Book: *Evolution of Parallel Cellular Machines: The Cellular Programming Approach* by Moshe Sipper concludes "parallel cellular machines can attain high performance of complex computational tasks, and that, moreover, such systems can be evolved rather than designed." (parallel → the array of cells updating synchronously)

Assumption of SLEUTH: application of the CA rules of the model will yield meaningful patterns (i.e. it is a decentralized system capable of evolving emergent patterns of land use change).
Will the patterns reveal anything of the underlying processes of land use change?

How SLEUTH Works

Raster Based array of cells where each cell can exist as alive or dead.
Growth commences with an initial set of conditions for a given study area.

Recall that all the cells are updated synchronously in discrete time steps and
the state of each cell depends on the previous state of its surrounding neighbors.

Rules of birth, death, and growth are applied.

John Conway's rules:
A dead cell with exactly three live neighbors becomes a live cell (birth).
A live cell with two or three live neighbors stays alive (survival).
In all other cases, a cell dies or remains dead (overcrowding or loneliness).

The **original Urban Growth Model**, which depicted only urban development, has been coupled with the **Deltatron** Land Use Model, which depicts urban expansion into the landscape produced by the UGM.
[??The Deltaron Model somehow extends representation capabilities to allow multiple land cover class transitions; using transition matrices or transition grids??]

Data input consists of urban extent depicted as land cover at different time periods.

Slope
Land Cover
Exclusion – a masked layer of lands that cannot be developed
Urban extent
Transportation network
Hillshade – used for visualization

A **Growth Dynamic** implemented in UGM is defined through 4 steps:

Spontaneous Growth – a new type of land use can be introduced into an otherwise homogeneous area of a different land use type. E.g. a single retail entity springs up in a residential area. (dispersion, slope)

New Spreading Center Growth (Perpetuation of Change) –

Determines whether any new spontaneously created urban cells will spread or 'attract' more of like kinds of land use. E.g. build one house, someone else will build another one nearby. (breed, slope)

Edge Growth (Adjancent Expansion) – where two land uses meet, one grows into the other. E.g. riparian woodlands adjacent to ag lands can easily be converted to more ag lands. (spread, slope)

Road Influenced Growth – tendency for ubanization to spread along lines of transportation. (road-gravity, random walk defined by dispersion coefficient)

5 coefficients are applied to the Growth Dynamics:

Dispersion Coefficient
Breed Coefficient
Spread Coefficient
Slope Coefficient (Resistance to growth)
Road Gravity Coefficient

Deltatron Space

Urban Growth dynamics drive changes in the non-urbanized land cover. Deltatron space tracks the spatial and temporal transitions. The age of a deltatron determines whether its associated land use class is available for propogating change or staying the same.

Dynamics in the non-urban classes occur through a 4 step process similar to those that are applied to urban classes:

Initial Change
Cluster Change
Propogate Change
Age Deltatrons

SLEUTH products:

Forecasts of land cover change are simulated through a number of Monte Carlo iterations; this produces a probability growth map.

A second map describes the uncertainty related to any cell's predicted land cover.

Paper says the maps are imported into a GIS to give it a spatial context, but if they're already maps they already have a spatial context???

SLEUTH Ratings by CIPEC Evaluation Standards:

Spatial Complexity: very flexible; could potentially fit any spatial extent or scale.

Temporal Complexity: again very flexible; could potentially be used over any temporal extent with any time step from daily, to annual, to decadal.

Human Decision-Making Complexity: rated a level 2 by the authors --> Human decision making assumed to be determinately related to population size, change, or density.