A CELL-DEVS MODEL FOR LOGISTIC URBAN GROWTH

Bruno St-Aubin
Department of Systems and Computer Engineering
Carleton University
1125 Colonel By Drive
Ottawa, ON, Canada
bruno.staubin@carleton.ca

Gabriel Wainer
Department of Systems and Computer Engineering
Carleton University
1125 Colonel By Drive
Ottawa, ON, Canada
gwainer@sce.carleton.ca

ABSTRACT

As society moves towards sustainable urban growth, urban planners and city officials require tools that support spatial decision-making. Modeling and simulation (M&S) has been shown to be an adequate tool in this case. Cell-DEVS offers an optimized method of spatial simulation that can tackle computationally complex scenarios such as urban growth. To demonstrate this, we implement and discuss a well-known model, logistic urban growth (LUG), using the Cell-DEVS formalism. We show that this implementation supports the standard characteristics of LUG models by studying the variation of different parameters of the model such as restricted growth areas, spatial configuration and distance to features of interest.

Keywords: DEVS, Cell-DEVS, Visualization and Analysis, Logistic Urban growth.

1 INTRODUCTION

Modeling and simulation of urban growth patterns has shown to be an efficient tool to support decision-making when planning future urban development. In this context, M&S allows planners to easily evaluate different scenarios. However, urban growth modeling is data intensive and involves complex processes; it can be computationally prohibitive. The Cell-DEVS (CD) approach offers a potential solution to this problem. In this demo, we show that CD can represent urban growth by implementing a well-known method of urban growth modelling, logistic urban growth. We demonstrate that a CD model can consider distance to important geographic features, neighborhood urbanization and variations in spatial configuration.

2 BACKGROUND

Cell-DEVS is an extension of DEVS that can be used for modeling and simulation of systems in a cell space. Each cell is an individual atomic model and the cell space is a coupled model where all the cells are linked to their neighbors through input and output ports, as in classic DEVS models. CD has been used to model a variety of systems, forest fires, tumor growth, pedestrian traffic, volcanic ash propagation, etc.

A common approach to simulate urban growth over time and space is to use the logistic cellular automata model. The transition rules for this model are based on the logistic equation developed by Pierre-François Verhulst in the early 19th century. Briefly put, the equation states that population growth, unimpeded by external factors, will follow an exponential curve that will diminish as population grows and completely stop at population maturity (see equation below). This equation is used in a large range of fields including chemistry, biology, ecology, demography, economics, etc.

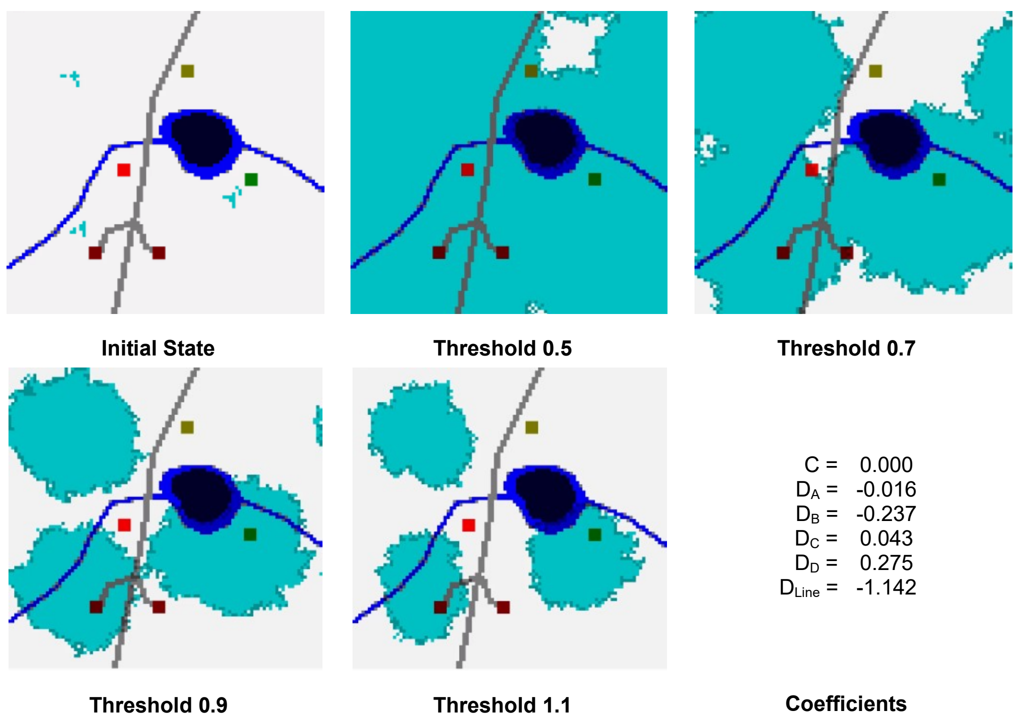
$$P_{ij}^{t} = \frac{1}{1+e^{-\left(a_0+\sum_{n=1}^{m} a_n x_{n,ij}\right)}} \times \frac{\sum_{x,y=1}^{x,y=n} con\left(S_{xy} = urban\right)}{n^2-1} \times Bin(cell_{ij} \neq restricted) \times (1+(-\ln r)^{a})$$

Where

$\frac{1}{1+e^{-(a_0+\sum_{n=1}^{m} a_n x_{n,ij})}}$	Probability of transition contributed by distance to geographical features
$\frac{\sum_{x,y=1}^{x,y=n} con(S_{xy}=urban)}{n^2-1}$	Probability of transition due to urban neighbors
$Bin(cell_{ij} \neq restricted)$	A binary function that returns false is the cell cannot be urbanized.
$(1+(-\ln r)^{\alpha})$	Stochastic disturbance applied to the probability of transition

3 RESULTS

For this project, a parameter variation study was conducted to determine if the model was able to consider the different parts of the logistic equation. To achieve this, we ran multiple simulations while varying one parameter at a time. The different parameters we evaluated are the probability of transition threshold, the distance to geographical features, the stochastic disturbance, the restricted cells and the spatial configuration of the map. The below image shows a sample result of the simulation where we varied the probability of transition threshold for a given spatial configuration and set of coefficients associated to geographical features of the map.



Variation of the probability of transition threshold. Top-left frame shows the initial state of the cell-space. Each following frame shows the final state of the cell-space for a given threshold.

4 CONCLUSION

DEVS based tools are uniquely positioned to provide a flexible process to generate reusable models and simulations. Through its decoupled and modular approach, DEVS could act as a generic platform for users to model various phenomenon related to city planning such as vehicle traffic, pedestrian behavior, pollution dispersions and, as this research as shown, urban growth. Increased ease-of-use and adaptability to different scenarios is one way to provide decision makers with more varied and better decision-making tools.