Visualization Tool for SLEUTH

1. Proposal Narrative

A. Abstract

The purpose of conducting this project is to create visualization tools for an urban growth simulation model called SLEUTH. Used all over the world to help predict future urbanization, SLEUTH runs and produces output during two main phases, calibration and prediction. The statistical data produced by the model during these two phases is challenging for users to understand in its current form. By creating visualization tools users will be able to better understand their results and be allowed to focus their efforts on interpretation of results instead. Expected outcomes of this project subsequently are new visualization tools to be produced during the calibration and prediction phases. These tools will help users both analyze their calibration results from phase to phase and also visualize the statistical output from the prediction phase. These results will be produced by following the software development lifecycle to generate the best possible tools. The goal of this project will greatly reduce post-processing time and will make SLEUTH easier for users to understand and interpret.

B. Background/Statement of the Problem/Significance of the Project

As the trend of urbanization continues to grow across the globe, careful urban development becomes a critical aspect of building a sustainable future. Globally, 68% of the population is projected to live in urban areas by 2050, and in the US as much as 89% of citizens are expected to reside in cities (United Nations 2018). Urban growth simulation models have been essential in the process of tracking, modeling and predicting urban development (Barredo and Kasanko 2003; Solecki and Oliveri 2004; Chaudhuri and Clarke 2012). By calibrating past urbanization from geospatial data, these models are able to predict future urban growth. Output from these models are essential for discovering the factors that impact urbanization (Jantz et. Al 2014;

Tayyebi et al. 2013) and help inform policy decisions regarding land management (Yang et al. 2011).

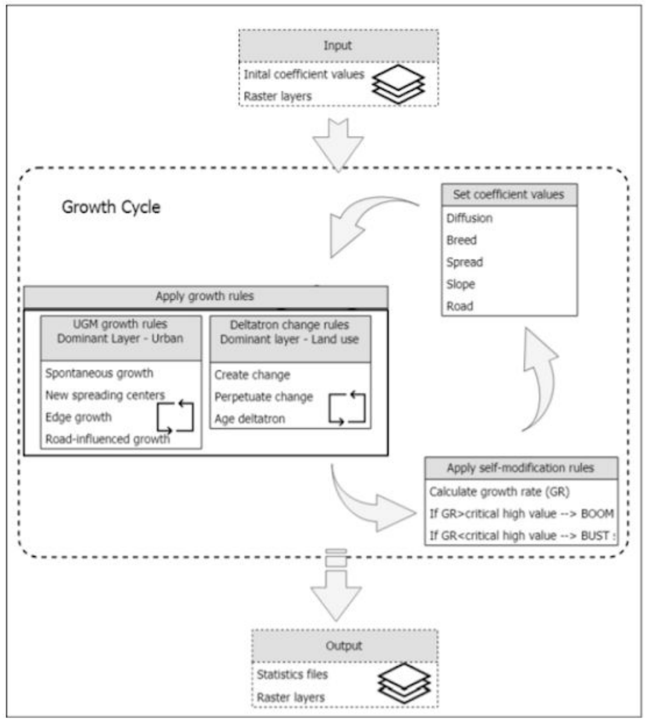

Figure 1: Overview of SLEUTH model (Source: Chaudhuri and Foley 2019)

One popular model of urban growth is SLEUTH, an open source land use change simulation model based on cellular automata. Using historical spatial data in the form of raster maps, SLEUTH simulates past urban growth in order to predict future urbanization within the area, as shown in Figure 1. The most time consuming aspect of using SLEUTH lies in the calibration phase. The goal of this phase is to find the set of control parameters values (from the dispersion coefficient, breed coefficient, spread coefficient, slope resistance factor, and road coefficient) that best fit the historical data for an urban area. Spatial data representing land-use, roads, and more from multiple time points are used by the model to see how closely the urban growth patterns fit the parameter values. Multiple calibration runs are used to refine the set of parameters to single values used for predicting future urban growth, typically coarse, fine and final (Silva and Clarke 2002). While SLEUTH provides a variety of benefits (from minimal data requirements to its ease of adaptation) the model suffers from long calibration times of days to even weeks (Guan and Clarke 2010; Chaudhuri and Foley 2019). Long calibration times increase the overall time it takes for urban modelers to study the past urbanization of an area and then predict future growth.

Both calibration and prediction phases of SLEUTH produce visual and statistical output. Statistical data, such as the control log file, details how well the parameters fit the historical data. Visual animations show past growth and urbanization within the studied location. The Optimal SLEUTH Metric (OSM) is used to calculate which parameter combinations best fit the data and sort the results. The results from the OSM are then used by an expert to setup the next calibration phase, or in the final step, the prediction run. This process of calibrating the control parameters and finding the best-fit data to predict future urbanization is critical, but can be complex and difficult for users to understand. The statistical data produced by SLEUTH is intended to help users understand this process, however without a deeper understanding of the log files the data can be challenging to sift through.

C. Objectives / Specific Aims

The overall goal of this project is to develop visualization tools that can be integrated with the SLEUTH model to help model users understand their results. The objectives of this project are to:

(i) Develop a visualization of OSM data to assist users with their analysis of calibration results.

(ii) Update and develop tools to visualize the statistical output of the prediction phase.

D. Methods

The software development life cycle involves the following stages: requirements gathering, design, implementation and testing (Modi, Singh & Chauhan, 2017). This project will follow this best practice over the course of the fall semester. The first two weeks will be spent setting up tools, determining what users need visualized from the statistical output data and then documenting those requirements. In addition to requirements gathering, output data will also be collected so that there are values to work with and test in the next phases. Weeks three to four will entail designing different visualization tools based on the requirements. Weeks five through ten will be spent working to implement the tools into the existing SLEUTH program. Documentation and validation of the new software will take place from weeks eleven and twelve. Finally, the last two weeks of the semester will be spent writing up the work for both dissemination at appropriate venues and for users of SLEUTH.

The first objective will help SLEUTH users, especially new users, to gain some insight on what parameter ranges are to be used for calibration phases. The process of narrowing the search space for the next calibration phase is complex and requires experience working with the model and the process of urbanization in the given area. It is assumed that the model users are already aware of the urbanization pattern and process of the given study area, therefore model generated visualizations of the OSM after every calibration phase, as proposed by the first objective, will help users to quickly identify useful parameter choices for the next calibration stage. The second objective of this project, will update and build new visualizations based on the statistical output from the prediction phase. Currently, output from the prediction phases includes predicted future maps, an animation of the future urban growth, and statistical data in text files. A variety of visualizations are developed by each user based on those results. In this project, we will review the recent literature for common forms of visualizations that users generate to interpret and showcase prediction results, and develop tools that can be integrated with the model so that those visual outputs can be automatically generated after the prediction phase. Additionally, web maps will be developed to show the predicted images and animation overlaid on satellite images. Current predicted maps do not have any geospatial information, thus the users cannot overlay them on real world satellite images to compare with the current urban extent. Thus automatically generating predicted maps with embedded geospatial reference information will reduce the post-processing time and will help users to focus their effort on interpretation of results.

E. Final Products and Dissemination

The final product of this proposal will be the software which will be integrated with the current SLEUTH model which is shared on github. The software and visualizations produced using it will be presented at UWL's Research & Creativity Symposium. Additional venues for dissemination include MICS, a regional computer science education conference that happens in the spring, as well as GIS venues as the tool is used to produce visualizations by the rest of the SLEUTH research group at UWL.

F. Budget justification

Scholarship funds are requested at $1000 for completing the design, development, and testing of the visualization tool. No other funds for supplies are requested.

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