An Agent-Based Modelling Study of Persistent Segregation in Metropolitan Cape Town

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Abstract

The history of the South African city was shaped more by a turbulent political past than by the inherent dynamics of urban growth. From the early 20th century national law brought forth legislation for racial and spatial segregation, especially within the South African urban environment. More than twenty years after democracy, segregation is persisting in the major cities and emphasizes the substantial influence social and political factors had on the urban development of the South African city. The present research project aims to extend the research into the spatial distribution and economic exclusion of the segregated urban areas of South Africa and aid to improve the understanding of the foundations of segregation in the urban environment in the country. The objective of the research study is to develop an agent-based model in Netlogo that can replicate the dynamics of segregation in the city of Cape Town. The aim is to construct a model, which will provide for the ability of producing alternative 'what-if' scenarios to study the impact of complex dynamical mechanisms on the persistence of racial and socio-economic exclusion in the study area. This will serve as theoretical foundation on which the specification and development of modelling methodology is based for the research study.

Model Overview

The segregation model of Cape Town focusses on the spatial distribution and degree of separation of the households of different population groups (races) in the city's residential areas. Thus, a combination of census and land-use data is applied to provide for more detailed development of the agents and spatially explicit modelling environment.

GIS data of Cape Town is used in the model and consequently a variety of data types were required for the development of the components of the model. Figure 1 provides an outline of the three main data suppliers, the types and description of data acquired and the format it was received in. Zoning data not only specified the location of residential land use, but also the types of residential dwellings that are present and other land uses not accessible to households. Census data from the 2011 South African census was then applied to establish distribution of population groups and household sizes.

SOURCE	DATA	FORMAT	DESCRIPTION
City of Cape Town Council: Strategic Development Information (SDI) and Geographic Information Systems (GIS) Department	Land Use (Zoning) Data	GIS (Shapefile)	The land use data represents the zoning and land use rights of all land within the study area/urban extent of the city.
City of Cape Town Council: Planning Portal	Urban Edge Boundary Data	GIS (Shapefile)	The urban edge boundary stipulates the boundary which controls development within the city.
	Agricultural Land Data	GIS (Shapefile)	The agricultural land data stipulates all land within the municipal boundary of Cape Town that is zoned for agricultural use only.
	Proposed New Development Data	GIS (Shapefile)	Proposed new development areas are stipulated in terms of the Spatial Development Framework for Cape Town and forms part of future planning of the city.
Statistics South Africa	Municipal Boundary Data	GIS (Shapefile)	The municipal boundary data provides the legislative council boundary for all municipalities in South Africa.
	Census (2011) Small Area Layer (SAL) Data	GIS (Shapefile)	The Small Area Layer for the 2011 Census provides boundaries of all the enumeration areas known as "small areas".
	Population Group (Race) by Census Small Area	Excel (Numerical)	The Population Group data provides figures for all population groups by small area for the 2011 Census.

Figure 1: Data Acquired for Model Development

The structure of the model consists of a modelling environment, which is represented by the geographical extent of Metropolitan Cape Town and three types of agents, represented by households of the three largest population groups in Cape Town (Black African, Coloured and White). Figure 2 shows these households in the residential areas of the city, with Black African households in red, Coloured households in blue and White households in brown. Each agent is an aggregation of a number of households and consists of the following characteristics: type of population group (race), household size, level of income and residential dissonance (tolerance) and happiness. The model environment is characterised by land use type (residential or non-residential), dwelling type and occupational status.
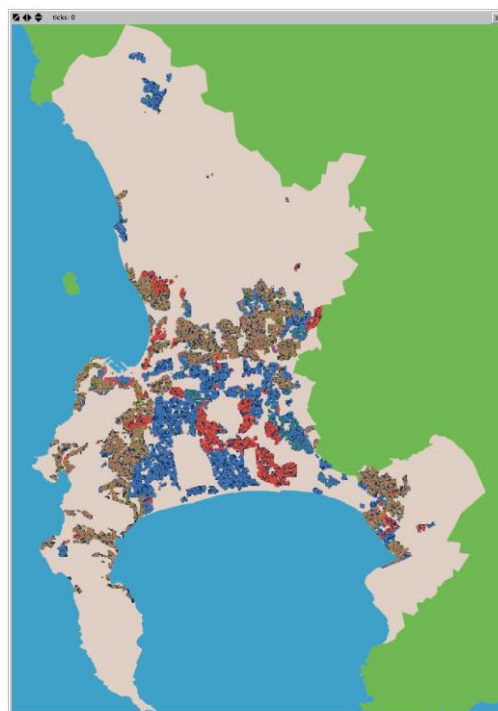

Figure 2: Model Environment and Agents

The main drivers of the current model are household satisfaction and neighbourhood preference. The model is based on the general concept of inhabitants of the city striving to improve their circumstances and economic opportunities when given the choice by future planning policy. At the same time, Schelling's segregation model forms part of the foundation of decision-making, where households might reflect a level of preference to their own culture rather than intolerance of another. At sub-model level households assess their current location and circumstances against several criteria and then do the same for a potential new location. Finally, the agent variables are updated at the new location. Agent to agent and agent to environment interaction are modelled at a local scale to test for pattern emergence at a larger scale. The model reflects standard decision-making theory and employs multi-criteria evaluation to enable the decision making of agents. The decision model of the agents is based on the assumption that they seek to better their economic and social circumstances, while reflecting a mild preference for their own culture. For the purpose of this study agents have limited knowledge of the world and reflect bounded rationality. They also rely on heuristics to undertake the process of determining better preferred locations to settle. The decision-model is based on real-world heuristics of persisting urban segregation in Cape Town. Theoretical consideration was given to numerous studies undertaken by the African Centre for Cities and other researchers to address the phenomenon of continuous disparity.

Further Development

It is intended to enhance the parameters and variables for both the agents and the environment of the model. Additional land use types and property value will be added to the environment and income and family size will be assigned to households. The next step will be to develop a well-defined and ordered evaluation process for the research model. It is intended to undertake continuous verification of the model to ensure consistency in output, followed by exploring methodology for the calibration of model parameters and finally the validation of model outputs. Following model process evaluation, the introduction of various segregation measurement indices will be considered and applied to the model. It is hoped to formulate a methodology whereby segregation can be measured before and after a simulation run to test the degree of change in spatial distribution of different population groups. Finally, it is also the intention to construct the model in a way that would allow for the introduction of various proposed developments. Hence, it is planned for the model to be able to incorporate additional land use to the model environment and test the effect these changes may have on household decisions and movement patterns. As the composition of the model evolves and the complexity increases, additional discourse will be generated on the construction and functionality of the final model.