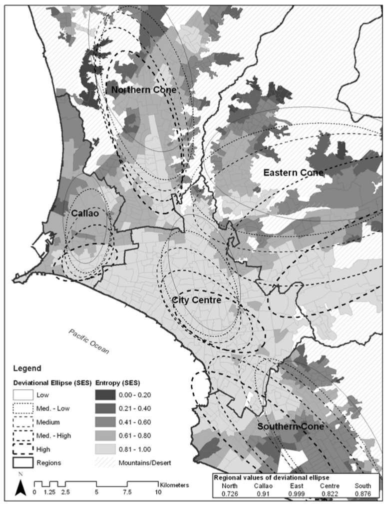
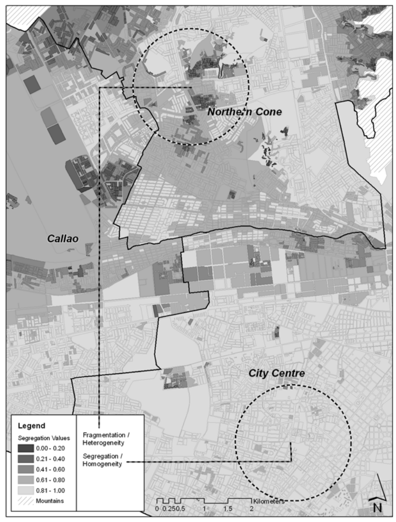
Fragmentation of Urban Space in Latin America: A GIS approach to the analysis of segregation in Lima





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Abstract

The complex nature of urban space within Latin America's major cities limits the applicability of many empirical measures of segregation. However, the development of integrated spatial measures allows for the measurement of highly localised patterns of segregation between multiple groups across multiple dimensions. This paper presents a methodology for integrating spatial analysis and GIS tools as an explicit part of investigating the nature and patterns urban segregation. Using Lima, Peru and an example, the related processes of segregation and fragmentation are unpacked across multiple social dimensions and spatial scales. Additionally, this paper empirically tests the theoretical proposition that social groups in Latin America are becoming increasingly fragmented rather than segregated.

Keywords: Spatial Segregation, GIS, Latin American Cities

Introduction

The history of urban development and planning in Latin American cities has led to divergent forms and highly localized patterns of urban spatial segregation. Despite this, Latin American metropolitan regions do not empirically indicate high levels of spatial segregation between social groups. However, when examined in greater detail at the regional and local levels, extreme values of segregation are indeed evident. This gap suggests that the scale and nature of segregation in Latin America is such that social groups are more fragmented within the urban environment rather than segregated. While much research has addressed segregation in Latin America from a theoretical perspective, little empirical evidence has been produced that measures the nature and extent of segregation in the regions major cities. This gap between theory and empirical evidence is due in large part to the lack of appropriate analytic tools employing relevant measures for the measurement of segregation in this context.

The primary objective of this paper is to present a general methodology for the analysis of segregation in Latin American cities using custom GIS tools. First, a broad outline of segregation analysis is presented, adapting the significant literature on empirical methods and applications to the Latin American context. In particular, the use of GIS as an appropriate tool for the analysis of segregation is highlighted and previous examples of such research are cited. Second, the development of a general GIS tool for the analysis of urban segregation patterns is outlined, specifying the data requirements, analytic process, and functional requirements. Third, the application of this tool within Metropolitan Lima is presented. Building upon existing literature on the nature of segregation in Lima, the scale of segregation within the region is tested. The outcomes of this analysis highlight the possibility for integrating complex analytic procedures within a common framework, resulting in a usable tool for the analysis and planning of changing urban centres.

Analysis of Segregation with GIS

The most widely used definition of segregation is "the degree to which two or more groups live separately from one another, in different parts of the urban environment" (Massey and Denton 1988: 282). This definition encompasses segregation as between different racial/ethnic groups, different social classes, or some other unique population characteristic such as education or employment status. Importantly, segregation is not uni-dimensional and five key characteristics of segregation are often cited: evenness, exposure, isolation, clustering, and centralization (Massey and Denton 1988). This definition recognises that segregation operates across a variety of dimensions and through multiple processes. In the Latin American context, this definition is limiting in how it is applied to the structure large urban centres, underemphasizing the relationships between space and social processes (Peters and Skop 2005). In this paper, the inherent spatiality of urban segregation is recognised, and thus, space and spatial processes are an explicit component of the analytic methodology. Segregation is taken to be a socio-spatial phenomenon with complex connections between unequal social groups. As such, places are shaped by social processes, which, in turn, are influenced by the nature of physical space (Giddens 1984). Reardon and O'Sullivan (2004) note that with the traditional definition of segregation, evenness and exposure are taken as aspatial, while clustering, centralisation, and clustering are explicitly spatial. However, this distinction is an artefact of reliance on census sub-areas for analysis rather than explicit locations of individuals in space (Schnell 2002).

Rethinking segregation in explicitly spatial terms, two primary definitions can be developed. First, spatial exposure is the extent that members from one social group encounter members of other social groups in their local spatial environments. Second, spatial evenness is the extent to which different social groups are similarly distributed across space. In this manner, spatial exposure and evenness are distinct from each other, while related to clustering and isolation. Unlike with the Massey and Denton definition, centralisation and clustering are subcategories of spatial unevenness. This definition, which stresses not only the social distance between social groups, but the ways in which social environments are visibly demarcated across the urban landscape, better reflects the realities in Latin America mega-cities. The explicit role of social processes and the recursive and influential nature of physical space is thus included within the analytic framework and thereby, measurement tools.

Measurement of Segregation

The choice and use of appropriate indicators is widely debated in segregation literature. While little firm consensus has been achieved on what specific indicators are best able to capture desired aspects of segregation, several effective approaches to the measurement of socio-spatial segregation have been identified (Massey and Denton 1988; Reardon and Firebaugh 2002; Reardon and O'Sullivan 2004). Many segregation indices have been developed in the context of the United States to measure the degree of separation between two racial/ethnic groups across one dimension. However, measures of segregation between two-groups can only capture partial interaction between the target population; although this can be addressed to some extent by using multiple trials of two-group populations (Fischer, Stockmayer, Stiles, and Hout 2004). Given that segregation typically occurs between multiple groups, many traditional measures have been adapted for multi-group environments, some of which will be presented in this paper.

Accompanying multi-group methods are multi-level approaches that measure segregation at various levels of urban structure. Social groups cluster not only in specific subdivisions and neighbourhoods, but also is different communities, areas, or regions (Peters and Skop 2005). These approaches assume that individuals interact within and between communities at the neighborhood, district, and regional levels, not necessarily defined by political boundaries. Thus, individual action reinforces the processes that lead to segregation, but these processes are also reinforced by social groups and actors at higher geographic levels, interacting not only within, but also between each level. Thus, using a multi-level approach will address the important influences of local-level group interactions at higher levels of geographic aggregation (Peters and Skop 2005).

Of particular importance to this paper, there has been increased recognition of segregation as an inherently spatial phenomenon, manifested simultaneously across physical and social space (Grannis 2002; Wong 1993; Wong 2003a). Given this, the analysis of segregation and selection of analytic measures must take into account the spatial nature of the urban environment in which social interaction occurs. Conventional aspatial measures of segregation may mask these characteristics as only within a local context does the extent of fragmentation between different groups become apparent (Wong 2002). This paper addresses this shortcoming by placing the framework for measuring segregation directly within a spatial analytic tool.

Each of the indicators selected for this analysis relies on detailed population data at a specific spatial analytic scale. Most commonly, analysis is conducted within statistical packages that are capable of processing large datasets efficiently and accurately. However, the inclusion of spatial interaction requires software that is able to incorporate spatial data for the analysis of proximity, adjacency and the like. Thus, the use of GIS tools for analysing segregation is a logical move, allowing researchers to easily incorporate tabular data that are linked directly to spatial data (Wong 2003b). Additionally, unlike in statistics packages that include spatial objects, results can be viewed via a common interface and general patterns easily compared. The following section elaborates on this with the presentation of a GIS decision support tool for the analysis of urban spatial segregation.

GIS Decision Support Tool

GIS data structures that link spatial information and custom databases, powerful scripting languages, and advanced visualisation capabilities make GIS a logical platform for analysis of urban segregation. Despite this, few tools have been developed to fully incorporate spatial segregation measures into a computing environment (see Apparicio 2000; Wong 2003b; Wong and Chong 1998: for important exceptions). While GIS software has become easier to use over time, developing custom scripts to analyse segregation patterns and integrating results with tested statistical measures has remained difficult. To address this shortcoming, this paper presents results from an integrated analysis tool within the GIS package ArcGIS, incorporating both traditional aspatial measures of segregation with advanced spatial measures. This section outlines the conceptual framework for a GIS-based segregation tool and a basic analytic process for exploring segregation at the metropolitan level. A generalised GIS-based segregation analysis tool integrates tabular and spatial data with combined tabular and visual outputs. The first and perhaps most time-consuming step in undertaking GIS-based analyses is the preparation of both tabular and spatial data. Most recent census datasets in North and South America have complete summary results available at small spatial scales and individual-level results available as samples at higher-levels. Additionally, since the early 1990s many government agencies have produced corresponding spatial datasets down to the city block level that can be linked to census tables. Table 1 presents the available data for Lima as an example of what data are available for other urban areas and to provide a basic outline of what data cleaning and conversion are required to perform a detailed empirical analysis of segregation at the local level.

Data Type	Dataset	Description	Data Type
Tabular	Population	Basic population demographics	DBF Table
	Household	Household characteristics	DBF Table
	Housing	Housing characteristics	DBF Table
Spatial	City blocks	Double-line urban block network	Polygon shapefile
	Census zones	Contiguous census enumeration zones within municipalities	Polygon shapefile
	Municipal districts	District boundaries for Metropolitan Lima	Polygon shapefile
	Regions	Regions of Metropolitan Lima	Polygon shapefile
	Street network	Major roads for Metropolitan Lima	Line shapefile

Table 1: Available tabular and spatial data for Lima, 1993.

For the analysis of segregation, tabular information can include information on nearly any comparable population characteristic. For the segregation indicators presented in Table 1, all population characteristics are summarised at the group level, although some measures are available that utilise individual-level characteristics (Schnell 2002; Schnell and Benjamini 2001). Most commonly, segregation is measured along racial / ethnic lines, such as the white / black division in the USA. In Latin America where racial divisions are less clear and census data is not collected on ethnic origin, other social divisions such as poverty, education, housing quality, and employment status are used (Luco and Vignoli 2003; Peters and Skop 2005; Sabatini 2003). Data are summarised by geographic level and calculated on raw population counts or population proportions, depending on the indicator used.

The amount of conversion required for spatial data is dependent upon the level of analysis and the indicator employed. In general, two different types of spatial data are required for aspatial or spatial analyses. For the analysis of aspatial segregation, where measurements of adjacency and proximity are not calculated, double-line polygon layers are sufficient. For analysis of segregation at the metropolitan or municipal district level, contiguous census zones are sufficient for most indicators. Each district contains a minimum number of census zones, all of which are contiguous to other tracts allowing for the measurement of adjacency, boundary length, area, and perimeter.

However, for local spatial measures that include elements of polygon adjacency, proximity, or shared boundaries, a single-line, contiguous polygon block layer is required. For many indicators city blocks polygons as provided are satisfactory, allowing comparison of population characteristics within census tracts or within districts. However, to include many spatial measures at the local level, a contiguous single-line city block network must be created. In the absence of a single-line block network provided by official sources, there are many options available for creating a single-line block network; however, for this paper and the GIS-based tool described, the thiessen polygon approach is used.

The analytic flow for this analysis begins with the input of tabular and spatial data; specification of indicators and variables; further analysis of tabular output; and, visualisation of outputs. Starting with an input population table that contains either population counts or proportions, combined with either a single- or double-line polygon layer, a selection of indices can be calculated. The software developed for this paper uses raw population counts and re-calculates field values as proportions as required. Likewise, if a single-line contiguous polygon layer is not available, a function for calculating thiessen polygons from block centroids is available. From these inputs, all the available indices can be calculated, allowing tabular results to be exported to software such as Excel or SPSS for further analysis and visualised in ArcGIS using basic mapping techniques. The following section presents an analysis of urban segregation in Metropolitan Lima, using a variety of indicators and techniques to measure the nature and extent of socio-spatial segregation.

Context and Case Study

Lima provides an interesting case for the analysis of urban segregation processes in Latin America. While the city grew along similar patterns as other cities in the region, changing state controls and uneven economic development have changed the structure of the urban environment. Like many cities in the region, rapid population growth from the middle of the 20th century due to rapid rural-urban migration and high fertility created intense pressure on urban governments to provide even basic infrastructure and control for residents. Given the lack of adequate housing or effective land controls, many new residents opted to look outside the formal markets and settled land through informal means, either constructing new residences within the existing urban area or invading new lands at the periphery.

At the same time, the growing middle-class and elite populations in Lima continued to develop lands in the Central and Eastern Cones of the city, moving in a linear pattern along major transportation routes. This pattern of development has led to large areas of middle-class and elite housing concentrated in only a few areas of the city, with the remaining population making up the majority of the urban space. Elite and middle-class populations are relocating to traditionally popular areas, creating "pockets" of poverty and wealth which can be seen in localised patterns of segregation.

Table 2: Metropolitan-level segregation

Dimension	D	D(adj)	SD(m)	S	H
SES	0.516	0.405	0.417	0.790	0.213
Education	0.172	0.117	0.230	0.408	0.049
Employment	0.173	0.127	0.208	0.350	0.051
Tenancy	0.672	0.574	0.414	0.693	0.293
Primary complete or less as compared to all other categories Self-Employed as compared to all other categories Invasion as compared to all other categories Low and Med.-Low SES vs. as compared to all other categories					

Using a custom GIS tool, this paper outlines the analysis of segregation across multiple social dimensions, reducing the scale of analysis from the metropolitan to the local level. At the metropolitan level, Lima displays relatively low levels of segregation via many standard measures when compared to North American cities. In the Latin American context where segregation does not centre on racial/ethnic lines of Black/White/Hispanic, generalised measures at the metropolitan level may be misleading as to the actual degree of segregation experienced across the city. Thus, to further describe the nature of segregation, several other measures are included that address multi-group, multi-level, and spatial components of urban social segregation.

Figure 1: Elliptical distribution of SES, entropy score of SES.

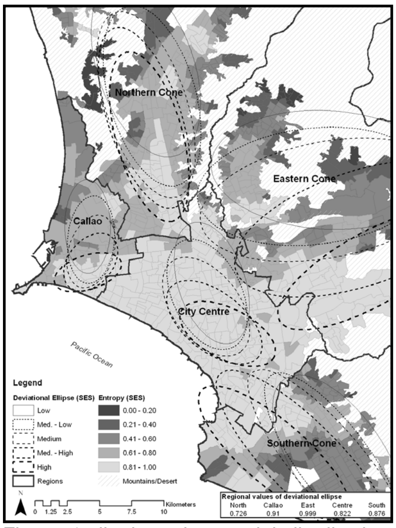
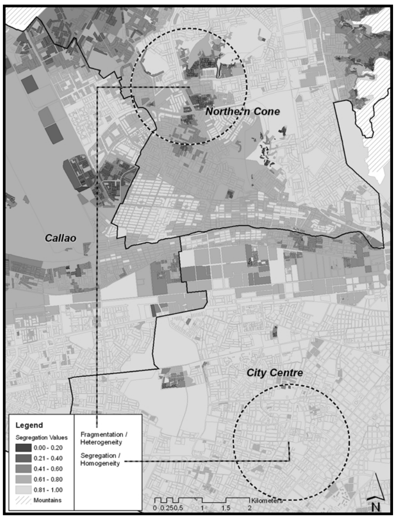


Figure 1 displays the spatial distribution of segregation at the regional level. The elliptical rings correspond to the spatial distribution of SES at the household level as measured by the national census. The S indicator provides a purely spatial view of segregation, measuring the difference between different SES groups as the intersection between the elliptical distribution of individual groups across a region (Wong 1993). This index of spatial segregation expands upon the common statistical measures of the D- and entropy-indices, allowing for a visual comparison of different social groups across different spatial regions. While at the metropolitan level the selected indicators do not necessarily indicate a high level of segregation, it is apparent that there are broad differences at smaller spatial scales. Combined with the spatial entropy score at the census tract level, the pattern of segregation between regions is clearly evident.

Figure 2: Local fragmentation and segregation of SES using spatial entropy index.



Further reducing the scale of analysis, Figure 2 presents a view of fragmentation at the local level in several areas of the Metropolitan region. From this overview, pockets of local-level fragmentation are clearly evident segregation values differ widely from those in immediately surrounding blocks. The case illustrated here displays pockets of low segregation, suggesting greater potential for the mixing of SES groups, amongst high segregation levels. When compared to the metropolitan, district, or even tract level, this picture of segregation illustrates the degree to which different social groups cluster within space, either due to formal development processes or informal means. By methodically reducing the scale of analysis, it is possible to detect local-level differences in population characteristics.

Conclusion and Discussion

The research presented in this paper supports the hypothesis that the nature of segregation in Lima is such that social groups are fragmented within the broader fabric of urban space. At the metropolitan level, empirical segregation values are relatively low as compared to other world cities; however, segregation values are quite high at smaller spatial scales with pockets of fragmentation or segregation visible across the region. By reducing the scale of analysis, using multi-group measures, and including social interaction across space, segregation is indeed evident across the metropolitan region.

The methodology for analysis presented here allows for complex data sources to be integrated easily within a GIS-based environment. This integration allows for the analysis of segregation using both statistical and visual methods, available within commonly available GIS software. Additionally, results of segregation analyses can be linked directly to statistical software for further analysis. It is hoped that this tool can be used to further measure segregation in other Latin American cities and empirically test common theories of urban development.

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