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Mapping changes in spatial patterns of racial diversity across the entire United States with application to a 1990–2000 period

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ABSTRACT

Changes in racial configuration patterns are affected by uneven population growth of different racial/ethnic groups and by modification of social attitudes. A comprehensive assessment of these changes is important for effective policymaking. Conventional assessments, which rely on tabular census data, are restricted to a handful of major metropolitan areas and do not provide spatial information. Here we propose using high resolution categorical demographic grids to assess and map spatio-temporal changes in racial configuration patterns over the entire United States. Recently published demographic grids for the years 1990 and 2000 are classified into neighborhood types based on the local level of diversity and the dominant race. Codifying the 1990–2000 transitions of neighborhood types for all grid cells yields a transition grid, which provides raw information for all subsequent assessments. The change is evaluated from three different perspectives: overall statistics, mapping, and neighborhood topology. A change diagram visualizes diversity change from statistical perspective using transitions collected from the entire U.S. Change map reveals complex spatial transitions between different neighborhood types; examples of change maps for metropolitan areas of Chicago, San Francisco, and Houston are shown and described. Topologies of spatial change for various neighborhood types are also visualized showing the specific manner of transition from one type of neighborhood to another. Presented methodology opens the door to much more comprehensive and in-depth assessment of changes of racial and diversity patterns.

1. Introduction

Spatial segregation along racial and ethnic lines is a continuing reality of American social structure, but shifting social attitudes results in a gradual increase of residential racial diversity (Iceland, Weinberg, & Steinmetz, 2002). In addition, changes in the U.S. demographic makeup, in particular, significant increases of Hispanic and Asian populations (Iceland, 2004), transforms America's racial configuration from a binary paradigm (for example, a Black/White dichotomy) to a much more complex multi-racial pattern (Iceland, 2004). Thus, a thorough geospatial analysis of the U.S. racial configuration dynamics requires tracking temporal changes in a multi-class spatial pattern over the entire country at a high spatial resolution. No such analysis presently exists because the long-standing methodologies of measuring residential segregation and diversity are not designed to address the problem in as comprehensive a fashion as stated above.

Because of a significant interest in the issue of racial configuration there exists a significant body of literature on the topic. A common thread to all previous analyzes is a demographic data model based on the U.S. Census Bureau aggregation areal units, such as census tracts or blocks. Consequently, the scope of previous investigations, analytical tools developed for these investigations, and even the nomenclature used, are heavily influenced by the character of this "tabular" data model. We submit that tabular data model impedes analysis of racial segregation and diversity as summarized in the next three paragraphs.

Residential racial segregation – the physical separation of two or more groups into different neighborhoods (Massey & Denton, 1988) – has been the major focus of previous research, with segregation indices being the analytical tool of choice. A large number of segregation indices, later shown (Massey & Denton, 1988) to measure five independent aspects (evenness, exposure, centralization, concentration, and clustering) of two-group segregation, were proposed. These indices characterize a region (most

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often a metropolitan statistical area or MSA) and are calculated using demographic data assigned to the region's sub-divisions (most often census tracts or blocks). Most proposed indices are aspatial (Massey & Denton, 1987, 1988; White, 1983, 1986) although some do incorporate spatial relations between sub-divisions (Brown & Chung, 2006; Dawkins, 2004; Jakubs, 1981; Morgan, 1982; Reardon & Sullivan, 2004; Wong, 2004). The shortcomings of segregation indices include dependence on the scale of sub-divisions (for example, tracts vs. blocks) (Parisi, Lichter, & Taquino, 2011) and difficulties with change assessment due to census-to-census changes in delineations of sub-divisions (Reardon et al., 2009). Also, indices-based analysis does not address the issue of diversity at a neighborhood scale, as diversity is defined only at a regional scale. Given the character of segregation indices analysis, a typical result is in a form of a table that compares the values of indices between different MSAs or between different years for the same MSA.

As the U.S. is a multi-racial rather than a bi-racial society, two-group measures of segregation were recognized as insufficient, and multigroup indices, the most prominent of these being the Theil information theory index (Theil, 1972), were developed (Reardon & Firebaugh, 2002) and applied to characterize diversity at regional scale (Farrell, 2008; Iceland, 2004). In comparison to the segregation indices the Theil index provides additional and often more relevant information on racial configuration within a region, but it still suffers from the same limitations as segregation indices due to the reliance on the tabular data model. As the Theil index and two-group segregation indices are region attributes, they are predominantly calculated for prominent regions, such as MSAs (Farrell, 2008; Farrell & Lee, 2011; Frey & Farley, 1996; Johnston, Poulsen, & Forrest, 2007; Logan, Stults, Farley, & Stults, 2004) with only a few analyzes quantifying rural areas and small towns (Cromartie & Kandel, 2004; González Wahl & Gunkel, 2007; Lichter et al., 2007; Lichter, 2012).

Recent research (Holloway, Wright, & Ellis, 2012; Wright, Ellis, Holloway, & Wong, 2014) breaks away from the reliance on indices as a tool to assess and quantify the U.S. racial configuration and moves toward a more cartographic approach to the problem. In such an approach, neighborhoods (census tracts) are classified into a number of types on the basis of a combination of segregation and diversity criteria. The results are presented in the form of thematic map that explicitly shows the geography of racial diversity and segregation. Temporal change can be assessed by comparing maps constructed from data gathered at two different times. This method is a major step forward but still inherits the limitations of the tabular data model: poor spatial resolution outside MSAs and the possible incompatibility of areal units as delineated at different years.

In this paper we propose studying racial configuration in the U.S. and its temporal change using a raster data model instead of a tabular model. This is feasible due to recent availability of high resolution demographic grids for the entire U.S. (Dmowska & Stepinski, 2014). Cells in these grids have categorical values corresponding to several diversity/dominant race types (DDRTs). This allows us to think about the underlying data in terms of “human cover” in an analogy to the concept of a “land cover” in the field of remote sensing. Thus, we can analyze human cover patterns and their temporal change using robust methods already developed for the analysis of land cover. This method of analysis, intrinsically different from previous approaches, yields an in-depth assessment of racial configuration dynamics in a lucid form that could be used to inform decision makers responsible for the efficient allocation of economic, health, administrative, and law enforcement resources to a population going through changes in its racial makeup. We focus on analyzing change during the 1990–2000 period as the grids are presently available only for these two years. However, the more recent 2000–2010 change could be analyzed using the same method once 2010 grid becomes available.

2. Data and methods

2.1. Population and diversity/dominant race grids

The U.S.–wide high resolution demographic grids by Dmowska and Stepinski (2014) constitute an input to our analysis. We refer a reader to that paper regarding detailed information on the method used to construct those grids. In the rest of this sub-section we briefly recount the computational process leading to obtaining DDRT grids.

Dmowska and Stepinski (2014) start by applying dasymetric modeling (Wright, 1936) to coarse, 1 km grids previously developed by the Socioeconomic Data and Application Center (SEDAC) (Seirup, Yetman, & Razafindrazay, 2012). SEDAC grids are products of a simple areal weighting interpolation from census blocks. They are disaggregated from 1 km to 90 m resolution using dasymetric model with the National Land Cover Dataset (NLCD) land cover 1992 and 2001 data as an auxiliary variable. Because 1992 and 2001 editions of NLCD have different legends, a dasymetric model does not use the main land cover categories of each NLCD edition. Instead, it uses the NLCD 1992/2001 retrofit product (Fry, Coan, Homer, Meyer, & Wickham, 2009) which classifies land cover into a smaller number of more generalized classes which, however, are common to 1992 and 2001.

Dasymetric modeling works for disaggregating total population because of the correlation between the type of land cover and the total population density. However, there is no robust correlation between land cover type and the density of population belonging to a given race/ethnicity group. Thus, members of race/ethnicity groups located within a coarse 1 km SEDAC grid cell are disaggregated using weights established for the entire population. This means that in each populated 90 m cell the relative percentages of different race/ethnicity groups is the same as in the entire coarse 1 km cell, but the disaggregation improves information on the spatial distribution of different groups inasmuch as it shifts people away from uninhabited or sparsely inhabited areas.

Using population and race grids all inhabited grid cells are classified into 11 diversity/dominant race types (DDRTs) taking into consideration the level of diversity and the dominant race. Demographic information in a cell is encapsulated by a normalized histogram whose bins represent the proportions of a cell's population belonging to different racial/ethnic groups. Five race/ethnicity groups: white, black, Hispanic, Asian, and other are considered. Following (Holloway et al., 2012) the racial diversity of a cell is classified on the basis of the standardized informational entropy E of its histogram with modifications made to ensure agreement between obtained classes and customary notions of group dominance (Farrell & Lee, 2011).

All inhabited cells are classified into three diversity types:

- ***Low diversity*** type if the histogram fulfills two conditions: (1) $E < 0.41$, and (2) the dominant race constitutes more than 80% of a cell's population.
- ***High diversity*** type if the histogram fulfills three conditions: (1) $E > 0.79$, (2) the dominant race constitutes less than 50% of a cell's population, and (3) the sum of the two most dominant races constitutes less than 80% of a cell's population.
- ***Moderate diversity*** type if the cell does not belong to either high or low diversity types.

Two of the three diversity types (low and moderate diversity)