Development of a High Resolution Population Dynamics Model

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Biography:

Dr. Budhendra Bhaduri is the research leader of the Geographic Information Science & Technology (GIST) group at the Oak Ridge National Laboratory. He is actively involved with ORNL's Global Population projects and is leading the research initiatives for the development of LandScan USA, a high resolution population distributing modeling project. Dr. Bhaduri's responsibilities include conceiving, designing, and implementing innovative computational methods and algorithms to solve a wide variety of geospatial problems involving land cover modeling, natural resource studies, and emergency management, using various geographic information systems (GIS) and remote sensing techniques. He is actively involved with research efforts with The Department of Energy (DOE), several Department of Defense agencies, the Department of Homeland Security, US Environmental Protection Agency, US Geological Survey, and the Department of Health and Human Services.

Abstract:

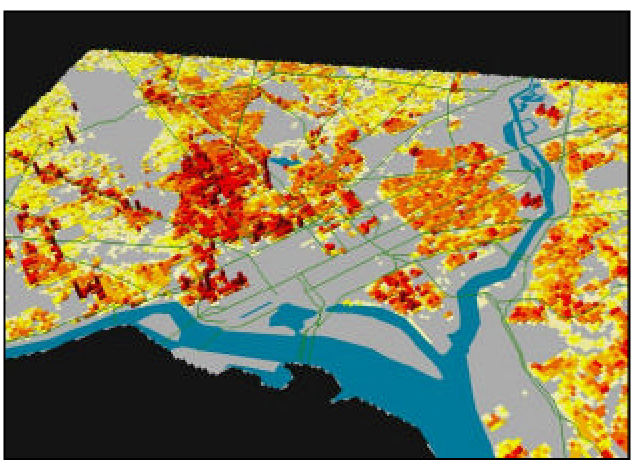
High resolution population distribution data is critical for successfully addressing critical issues ranging from socio-environmental research to public health to homeland security. Commonly available population data from Census is constrained both in space and time and does not capture the population dynamics as functions of space and time. This imposes a significant negative consequence on the fidelity of event based simulation models with sensitive space-time resolution. From a spatial perspective, Census data is limited by Census accounting units (such as blocks), there often is great uncertainty about spatial distribution of residents within those accounting units. This is particularly appropriate in suburban and rural areas, where the population is dispersed to a greater degree than urban areas. From a temporal perspective, Census counts represent "residential" or "nighttime" population and its usage in a daytime event simulation is illogical. Because of this uncertainty, there is significant potential to misclassify people with respect to their location from, for example pollution sources, and consequently it becomes challenging to determine if certain sub-populations are actually more likely than others to get differential environmental exposure. For the US, the source for population data is the US Census Bureau, which reports population counts by census blocks (smallest polygonal unit), block groups (aggregated blocks), and tracts (aggregated block groups). At the highest resolution (block level), a uniform population distribution is assumed and the population values are typically an attribute of the block (polygon) centroids. Similarly, population values for block groups and tracts are reported at the centroids of the block group and tract polygons. In geospatial analyses, these points are used to represent the population of a census polygon. For

example, calculation of travel time to health care providers considers these centroids as the starting points for travel. For exposure and risk analyses, these centroids often serve as "receptor" points for calculating exposure or dosage from any dispersed agent.

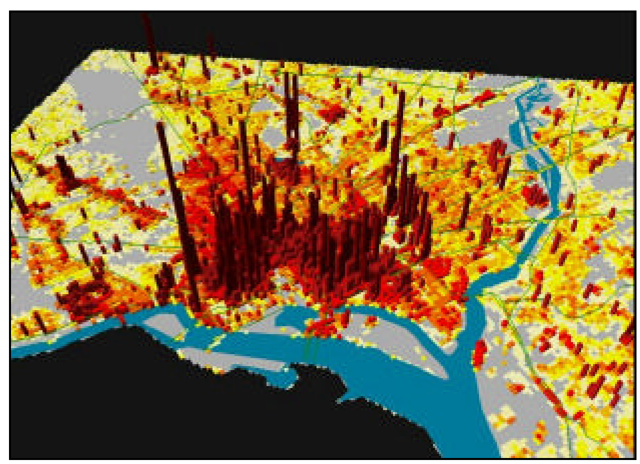
In common practice, census data are intersected with buffers of influence (such as those from emission sources) using two primary approaches to quantify population at risk:

a. tally the entire population (if the centroid is inside the buffer) or zero population (if the centroid is outside the buffer)
b. an area weighted population accounting approach (based on the ratio of the areas of the polygon included in and excluded from the buffer).

These limitations, to a large degree, can be overcome by developing population data with a finer resolution in both space and time at sub-Census levels. Geodemographic data at such scales will represent a more realistic non-uniform distribution of population. Using an innovative approach with Geographic Information System and Remote Sensing, Oak Ridge National Laboratory (ORNL) has made significant progress towards solving this problem (Bhaduri et al., 2002; Dobson et al., 2000). ORNL, as part of its LandScan global population project, has developed a high resolution (1 km cell) population distribution model (LandScan Global) for the entire world. LandScan is the finest global population data ever produced and is 2400 times more spatially refined than the previous standard. As an expansion to global LandScan, ORNL is currently developing a very high-resolution (90m cell) population distribution data (LandScan USA) for the US. At this resolution population distribution data includes nighttime (residential) as well as daytime distributions.



Washington DC Nighttime



Washington DC Daytime

LandScan is a dasymetric population distribution model. It collects best available census counts (usually at sub-province level) for each country, calculates a "likelihood" coefficient for each cell, and applies the coefficients to the census counts which are employed as control totals for appropriate areas. For LandScan USA, census blocks serve as the polygonal unit control population. Census blocks are divided into finer grid cells (90m) and then each is evaluated for the likelihood of being populated based on a number of relevant spatial characteristics (including land cover, slope, proximity to roads, and nighttime lights). Criticality of such spatial indicators from remotely sensed data has been well recognized (Elvidge et al., 1997; Sutton et al., 1997). The total population for that block is then allocated to each cell weighted to the calculated likelihood (population coefficient) of being populated. Large volumes of satellite derived spatial data including land cover and nighttime lights are used in developing LandScan databases and verification and validation (V&V) of the population model. Locating daytime populations requires not only census data, but also other socio-economic data including places of work, journey to work, and other mobility factors such as daytime business and cultural attractions/populated places datasets. The combination of both residential and daytime populations will provide significant enhancements to geospatial applications ranging from homeland security to socio-environmental studies.

This paper will describe ongoing development of the computational framework for spatial data integration and modeling framework for LandScan. A large number of disparate and misaligned spatial data sets are spatio-temporally correlated and integrated in the modeling framework to understand, model, validate, and visualize dynamics of population. Discussions will cover development of algorithms to utilize population infrastructure datasets (such as residences, business locations, academic institutions, correctional facilities, and public offices) along with behavioral or mobility datasets for representing temporal dynamics of population. In addition, we will discuss development and integration of transportation, physical and behavioral science computational algorithms; the integration of these models that address different scales and different time frames; and the development of dynamic optimization routines to take advantage of real-time data from sensor networks. We will also demonstrate utilization of such high resolution population distribution data within an integrated modeling and simulation framework of a transportation network creation model, a demographic model generator, and a traffic simulation model to enhance the fidelity of an evacuation model.

References:

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