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GIS Automated Delineation of Cancer Service Areas: Implications for Cancer Control in the U.S.

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1. Background

The assessment, planning, and management of cancer care for effective cancer control and prevention require a standardized system of geographic units on which reliable analyses can be performed for different regions and populations to address many challenges facing the U.S. health systems. Health and cancer researchers have devoted great efforts to defining various service areas, such as the popular Dartmouth Hospital Service Areas (HSAs) and the National Cancer Institute (NCI) catchment areas. However, these geographic units and their corresponding methodologies suffer from some limitations, including a lack of scientific rigor, not being representative of the highly specialized cancer care markets, or a failure to address where to have discrete or overlapping service areas in the context of the increasingly interwoven cancer care markets. Using 2014-2015 Medicare enrollment and claims data, the study discussed how to develop innovative GIS and spatial network optimization models in automated GIS tools to delineate discrete and overlapping cancer service areas (CSAs), respectively, to help advance the U.S. cancer control and prevention efforts from different perspectives.

2. Goals

The discrete CSAs were delineated for major cancer centers extracted from the Association of American Cancer Institutes (AACI) in the U.S. The study used localization index (LI), population, population density, income, average travel time, and other metrics to evaluate and compare the CSAs with AACI cancer centers and CSAs without AACI cancer centers using statistical analysis.

The overlapping CSAs were defined in six representative areas with different degrees of urbanicity. The study used LI, population, population density, and travel time to compare overlapping and discrete CSAs. It also used the belonging coefficient to measure the degree of overlapping in different study areas. The overlapping CSAs were further compared with the NCI catchment areas to inform potential collaborations and coordination among leading cancer centers and local hospitals.

3. Solutions and Methods

We developed two geospatial network optimization methods, termed spatially constrained Leiden (ScLeiden) and spatially constrained Speaker-Listener Label Propagation (ScSLPA) algorithms to delineate discrete CSAs and overlapping CSAs, respectively. We used Python to code both methods as tools in ArcGIS. The ScLeiden method is a discrete network community detection algorithm that accounts for spatial adjacency and other constraints. We applied it to delineate coherent CSAs within which the service flows between patients and providers were maximal and they were minimal between different CSAs. In this case, each patient belonged to one CSA. The ScSLPA method is an overlapping community detection algorithm that accounts for spatial adjacency and other constraints. The method mimics human pairwise communication behavior to propagate speaker and listener labels between patients and providers. A patient who has multiple labels would belong to multiple CSAs, thus the CSAs are overlapping.

4. Outcomes

We delineated 110 discrete CSAs which had a high mean localization index (LI = 0.83) with a narrow variability (standard deviation = 0.10). The variation of LI across the CSAs was positively associated with population, median household income, and area size, and negatively with travel time. On average, patients traveled less and were more likely to receive cancer care within the CSAs anchored by AACI cancer centers than their counterparts without cancer centers.

The overlapping CSAs tended to form in areas that were more urbanized, with higher localization index (LI) values, larger populations, and shorter travel times than discrete CSAs. Two CSAs in Los Angeles and San Diego were consistent with the catchment areas of the National Cancer Institute (NCI)-designated cancer centers, and other CSAs were much smaller than the catchment areas of their anchoring cancer centers.

5. Lessons Learned and Future Directions

Instead of using the Dartmouth HSAs, our newly derived 110 discrete CSAs can be used as a reliable unit for studying cancer care and informing more evidence-based policy in the United States. The value of discrete CSAs and the scale-flexible GIS method would be very high for many stakeholders, such as federal agencies, health systems, cancer centers, private insurers, and researchers if using this approach to evaluate cancer-specific care both nationally and within smaller areas.

The delineation of overlapping CSAs captured the increasingly interwoven and integrated cancer care markets in the U.S., particularly for the highly urbanized areas. The overlapping CSAs not only provide cancer patients with multiple choices but also expand their access without traveling longer distances. The intersection of the CSAs and the NCI catchment areas has important implications for public policy. It suggests where and how the leading cancer centers and local hospitals can collaborate and coordinate, rather than compete, to improve cancer care delivery and outcome.

Our current study is using 2014-2025 Medicare data that only cover cancer patients aged 65+ at the ZIP code level. Future research may consider using more recent medical data that cover both younger (aged 65-) and older (aged 65+) cancer populations at finer spatial resolution to test the generalizability of CSAs.

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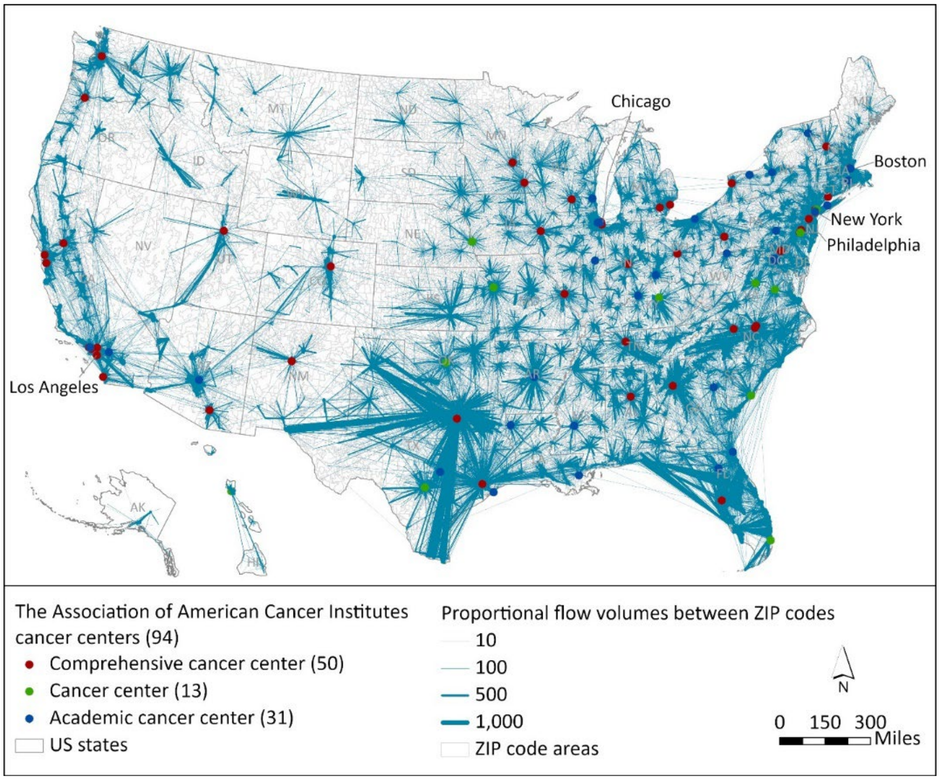
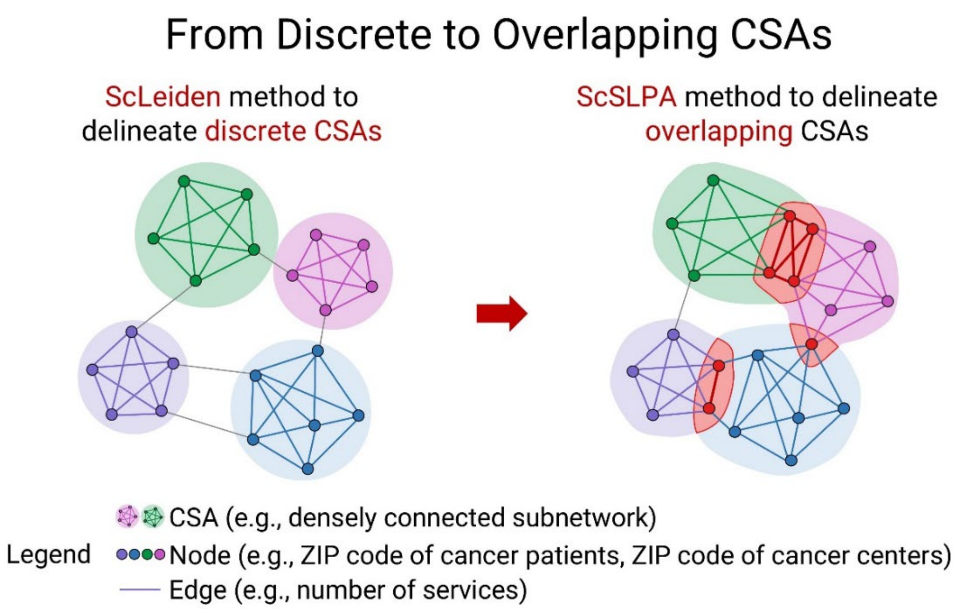
Figures





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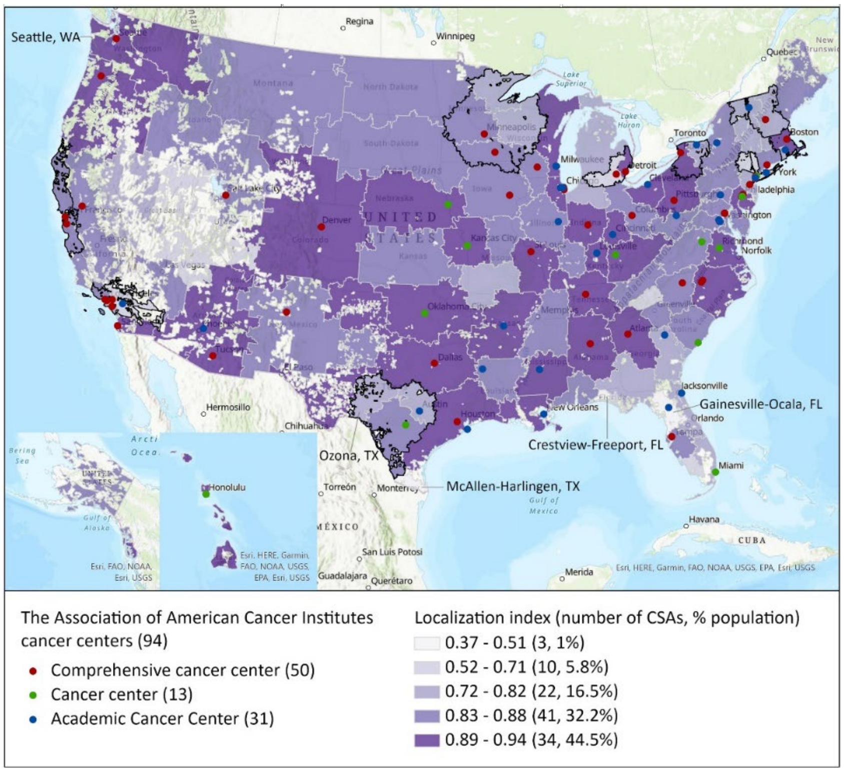

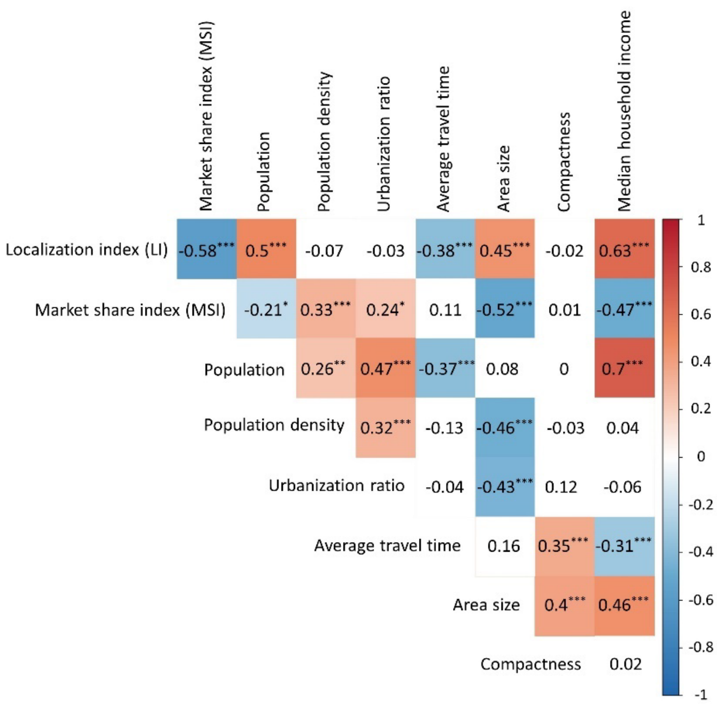

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