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An Innovative Geographical Approach to Spatial Epidemiology: Dasymetric Refinement of Disease Location Data in Switzerland

Spatial epidemiology is concerned with the study of health outcomes in geographical spaces. This scientific field is broadly divided into three research areas: descriptive disease mapping, exploratory disease hot spot and cluster detection, and etiology driven geographic correlative studies (Lawson, 2006). In disease mapping, disease data are first assembled and pre-processed for subsequent cartographic visualizations of disease distributions. With hot spot and cluster detection studies, spatially aggregated disease outcomes are statistically described and identified. Finally, geographic correlative studies assess potential relationships between disease outcomes in space and possible causal environmental factors. All epidemiological studies currently face the same fundamental challenges in terms of availability and quality of georeferenced disease data potentially suitable for the specific analytical task at hand (Beale et al., 2008).

Due to privacy concerns, human disease data are typically available only in aggregated form, based on administrative enumeration units (Lawson, 2006). The choice of the spatial unit and its aggregation level will influence subsequent visualization as well as statistical analysis and inference in modeling to understand disease patterns under study. In the spatial modeling and visualization steps of geographical disease studies, the use of administrative enumeration units might emphasize disease patterns that are specific to the arbitrary areal zones and thus impede data-driven exploratory analysis, and disease pattern identification (Eicher and Brewer, 2001). Spatial analysis and inference based epidemiological studies on aggregated disease data are subject to the modifiable areal unit problem as the geographical manifestation of the ecological fallacy (Openshaw, 1984).

For the above-mentioned reasons, the choice of the analytical spatial unit and its aggregation level should be considered carefully, paying special attention to the consequences on the quality of subsequent analysis steps in the epidemiologic study. Despite their known fundamental importance, aggregationrelated issues are frequently neglected in epidemiological research to date, as efforts are mostly concerned with improving disease measurement and statistical modeling methods (Beale et al., 2008). While this has been proven to be effective in increasing the quality of epidemiological analyses, the propagation of uncertainty and bias due to the choice of reference spatial units and their respective levels of aggregation has not been investigated in depth in the field of spatial epidemiology.

A long-standing and widely used method to model and depict statistically aggregated disease data by means of administrative areal units is the ubiquitous choropleth map. Our proposed approach to spatial epidemiology draws from an equally longstanding, alternative cartographic method, which is considered to represent aggregated data in a more meaningful way (Mennis and Hultgren, 2006). This method is known as dasymetric mapping, a type of areal interpolation that uses ancillary spatial variables to refine administrative units. Applications of this method are common in the mapping of demographic data, where populations are typically aggregated at an administrative level, and these discontinuous areal units are used to approximate the spatial distribution of populated land (Mennis and Hultgren, 2006).

To investigate the effects of a dasymetric refinement of aggregated data in epidemiological research, we are currently carrying out a set of studies on different aspects of spatial modeling and visualization as well as statistical analysis and inference using veterinary disease data. We first assessed the consequences of a simple binary refinement of administrative enumeration units to the portion of residential land. Changes in the spatial structure of the data are observed and result in differences in size and distance measures between units (Figure 1) if unrefined and refined data are compared. The research team developed some Generalized Linear Models of dog tumor incidences to test statistical inference under refinement scenarios, and found improved predictive power when using spatially refined outcome and explanatory variables.

Spatial analysis of model residuals made possible to carry out a more realistic evaluation of spatial autocorrelation patterns when using dasymetrically refined spatial units.

We conducted our studies on comprehensive dog tumor and dog population data in Switzerland for the year 2008. Using pets as sentinels in epidemiological analyses is of great interest, as human tumor registries are still today often unavailable at a national level. Besides, future studies on possible environmental risk factors for human health will greatly benefit from comparative studies as companion animal dogs are considered sentinels for environmental pollutants at the community level (Reif, 2011). Our preliminary findings on dog tumor data indeed justify the implementation of a dasymetric framework in spatial epidemiology. These results should be considered more broadly as a way for popularizing GIScience and respective spatialanalytical methods in a translational context as to improve the quality of spatial epidemiological research.

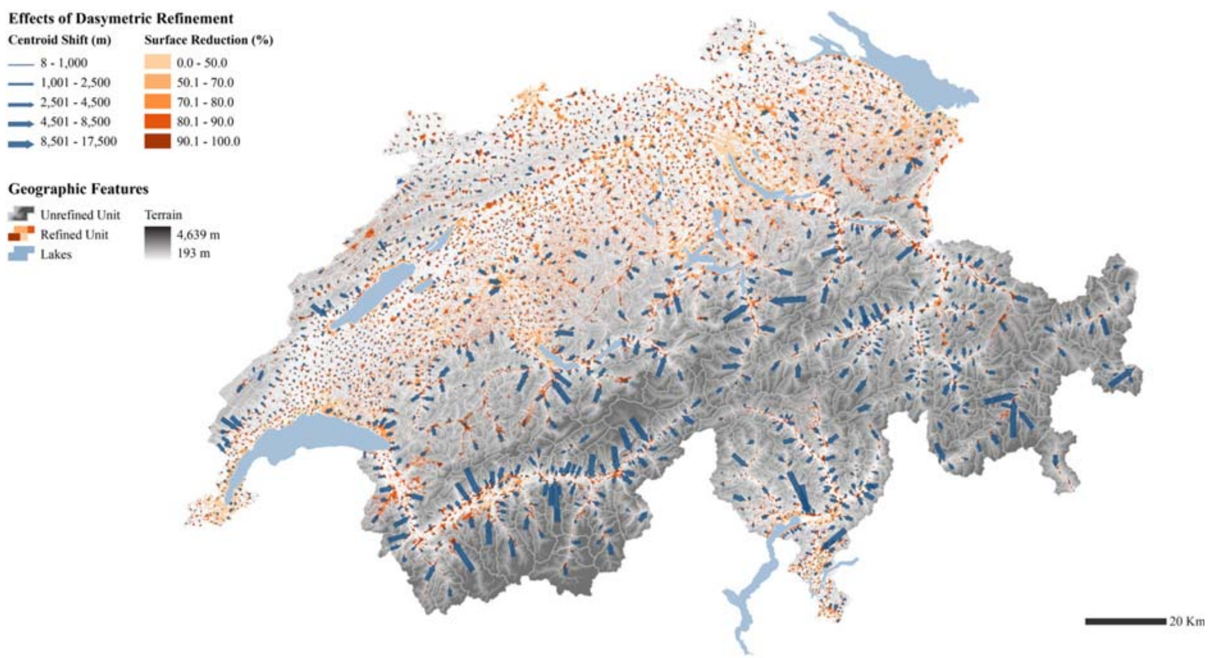

Figure 1. Binary dasymetric refinement of Swiss municipality units using residential land. The arrows show the centroid shifts from unrefined units to dasymetrically refined units as an indicator of the individual units displacement. The refined units classes indicate the area loss due to dasymetric refinement of the individual units. Switzerland's specific topographic setting creates regions with distinct effects of dasymetric refinement (data: SFOT, SFSO).

References

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