Position Paper for UCGIS Workshop on Computation and Visualization
for the Understanding of Dynamics in Geographic Domains

Spatio-Temporal Information Technology for Environmental Health Research

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My research interests concern the intersection of exposure to environmental contaminants and human health effects, with particular focus on the spatial, temporal, and spatio-temporal patterns of the exposure-disease relationship. My recent research has addressed development and application of spatio-temporal technologies to account for human mobility in an environmental epidemiologic analysis of human exposure to arsenic in drinking water and bladder cancer in Michigan. In this work, I developed a method for integrating sources of spatial, temporal, and spatio-temporal variability in an assessment of lifetime exposure to inorganic arsenic. More specifically, the method I developed integrates individual residential histories with time-varying maps of arsenic concentrations in drinking water to estimate individual-level exposure.

Recent generations have seen a striking increase in human mobility and a global shift in the population distribution such that cities and developing countries are growing the fastest. Geographical space has collapsed and travel times have fallen dramatically from the 1800's to the present. Improved transport and population growth have contributed to changing mobility patterns of increasing size and complexity. Residential mobility histories compared across several countries in the early 1980s found nearly 13 moves per person over a lifetime in New Zealand, 11 in the U.S., 7 in Great Britain, 6½ in Japan, 5 in Belgium, and 4 in Ireland (Long, 1992; Population Studies 46: 141-158). Approximately 50-70% of the moves occurred within localities (e.g., counties), 20-35% between localities, 10-15% between regions (e.g., states or provinces), and 0-10% between countries. Until now, however, most methods for addressing environmental health problems have been based on a static world-view (Goodchild, 2000; GeoInformatica 4: 127-139) in which individuals are considered immobile and migration between populations does not occur. As a result, many of the applications in the published literature suffer from violations of fundamental assumptions that are inherently unrealistic.

As part of my research, I am working with colleagues at BioMedware, Inc. to develop new Space-Time Information System software (called Space-Time Intelligence System™ (STIS™) and distributed by TerraSeer, Inc.) for applications in environmental health. STIS™ extends the functionality of GIS software by incorporating temporal data structures into maps and analyses. This technology is ideally suited to the representation, visualization, simulation and analysis of disease patterns and processes. An example of output from the STIS™ technology is shown in the Figure. Clearly noticeable is the time associated functionality, the statistical capabilities (histograms, box plots and scattergrams) and map property tools for zooming, querying, and changing display properties. The STIS™ has been built with the user's interactivity in mind. Users are able to query, select, drag, and create subsets of their data. Most importantly the user can interact with the time slider bar to visualize changes in attribute data (such as specified age categories) and geographic shapes (such as land parcels) through time. The 'static' map view of GIS is replaced by linked, animated maps in the STIS, allowing users to visualize change through time. This technology is a functioning example of a next-generation computation and visualization tool for understanding dynamics in geographic domains.

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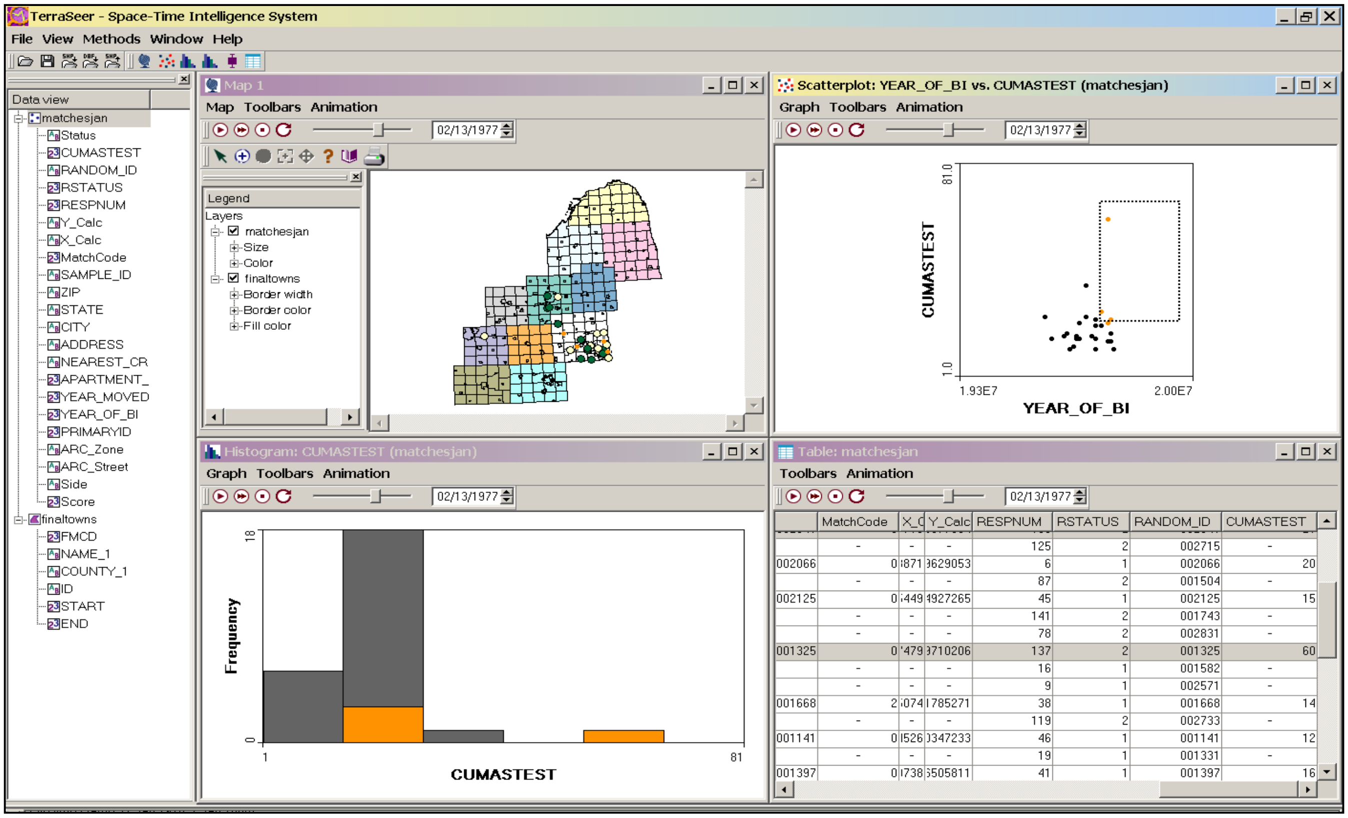

Figure 1: *The STIS user interface in a study of individual lifetime exposure to arsenic. The user has selected young individuals with high cumulative exposure to arsenic and has time-linked the windows (all windows above are shown for 1977). These same individuals are also selected in the map, table and histogram views.*

One area of current scholarship is the characterization of residential and industrial histories for use in cancer cluster analyses. This work extends the conceptual models of the space-time paths formed as individuals move throughout their days and lives developed by Hagerstand (1970; Papers of the Regional Science Association 24: 7-21). In the context of human health studies these space-time paths have been called "geospatial lifelines", and their mathematical representation, properties, and means of analysis have become important research topics, especially within the arena of cancer cluster investigations. Despite the interest in cancer clusters in the popular media, few studies have examined spatial patterns of past residences and even fewer have examined if cancer clusters occur near former industrial facilities. Dozens of approaches for quantifying pattern on disease maps are available, but most of these rely on assumptions that stem from a static world-view that individuals are immobile, and that the latency between causative exposures and health events (e.g. diagnosis, death) is negligible. That risk of disease may vary from one geographic sub-population to another, and that this risk is time-dependent, is a fact for almost all human diseases, including infectious as well as chronic diseases such as cancer. Colleagues and I have recently developed new spatio-temporal clustering statistics (called Q-statistics; Jacquez et al., 2005; Environmental Health 4(1):4). These statistics can evaluate if a cancer cluster is statistically significant using calendar year, age, or years prior to diagnosis as a measure of time. In other words, these clustering tools can be used to display cancer clusters of similarly-aged participants, as well as clusters based on the years a participant lived at a residence. In this manner, clusters of children can be investigated, whether they were born in the same generation or in different generations. I have recently submitted two grant proposals to apply these statistics to search for cancer clusters over the life-course: a Non-Hodgkin's lymphoma study with colleagues at the National Cancer Institute, and a testicular cancer study with colleagues at the Danish Cancer Society.

Another area of scholarship involves development of methods to integrate spatio-temporal raster datasets (e.g., remote sensing images of land use patterns or pollution dispersion maps) with spatio-temporal vector datasets (e.g., individual-level residential histories) so that researchers can more easily compute metrics and statistics that capture the spatio-temporal intersection of these datasets. Currently, there is no method available for easily integrating changes across vector and raster databases. For example, a researcher may want to know the proximity of a person to farmland over the life-course, incorporating changes in residence and changes in land cover. A new tool is necessary to integrate these databases and calculate each individual's proximity to farmland over time. I have recently submitted a grant proposal to support the development of this spatio-temporal application within the STIS™ platform.

I am a young scientist actively developing and applying spatio-temporal theory and tools for addressing environmental health problems. I am affiliated with the University of Michigan as a graduate student although that affiliation will officially end later this year since I graduated with my Ph.D. in Environmental Health Sciences this Spring. I am in the running for a tenure-track position in the Geography Department at Michigan State University, another UCGIS-affiliated institution. I currently serve as a research scientist at BioMedware, Inc., the research and software development firm responsible for developing the STIS™ software. As a participant in this workshop, I hope to offer my experience in spatio-temporal analysis, modeling, and visualization to discuss potential applications of spatio-temporal information technologies in environmental health research and in fields other than my own. I believe that my experience in the following four areas will be an untold asset to the workshop: (1) developing analytical algorithms for environmental health research in spatio-temporal information technology, (2) integrating information from spatio-temporal datasets of individual mobility and time-varying maps of environmental contaminants in STIS™, (3) applying spatio-temporal statistics to detect where and when cancer clusters occur, and (4) investigating how maps of cancer clusters change when using alternative measures of time (e.g., individual's age vs calendar year). I expect the resulting publications from the workshop to include a summary of the state-of-the-art spatio-temporal information technologies, an outline of a research agenda for key challenges in achieving and disseminating spatio-temporal information technologies, and examples of applications of spatio-temporal information technologies in fields such as public health, demography, natural resource management, climate change, etc. I look forward to working with other workshop participants to discuss next-generation computation and visualization models needed for understanding dynamics in geographic domains.

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