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Spatial Turn in Health Research

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Abstract

Developments in geographic science and technology can increase our understanding of disease prevalence, etiology, transmission, and treatment.

Spatial analysis using maps to associate geographic information with disease can be traced as far back as the 17th century. Currently, the widespread diffusion of geospatial data acquisition technologies is enabling creation of highly accurate spatial (and temporal) data relevant to health research.

New approaches in geography and related fields, capitalizing on advances in technologies such as geographic information systems (GIS), the Global Positioning System (GPS), satellite remote sensing, and computer cartography, are often referred to collectively as geographic information science (1, 2). GPS and related systems make it possible to integrate highly accurate geographic location and time with virtually any observation. GIS provides the means to store, share, analyze, and visualize real-time and archived spatial data. It also permits the integration of multiple layers of interdisciplinary spatial data, such as health, environmental, genomic, social, or demographic data, for interactive spatial analysis and modeling.

Spatial and spatiotemporal statistical methods (3), such as multilevel analysis, spatial data mining, and agent-based modeling, provide ways of relating health and disease to specific genetic, epigenetic, and environmental factors (4). The density, accuracy, and specificity of current geospatial data also facilitate sophisticated spatial and spatiotemporal analysis and the modeling of complex spatial health processes at the level of the individual rather than the aggregate (5, 6) (see the figure). Research based on data-intensive real-time GPS/GIS methods with miniaturized "wearable" environmental and biomedical monitors is generating advances in exposure assessment, as well as in mobility and obesity studies (7). In addition to individual interventions, this research can lead to outcomes such as the design of healthier environments which enhance access to parks and quality foods, and better treatment programs for a wide range of health conditions, from asthma to diabetes.

GIS visualization and analytical tools also enable researchers to identify spatial patterns and to model specific processes of disease diffusion or contagion, such as of pandemic influenza viruses, or evolving genetic strains of hepatitis or tuberculosis. Researchers have integrated patient demographics, daily activities, and HIV viral concentrations to map and model changing spatial patterns of HIV infections and their relationships to health care treatment programs (8), or to social risk factors (9). Researchers have also used GIS data, spatial statistics, and interactive mapping to identify HIV concentration hotspots near the Mexico–U.S. border (10). This kind of GIS-based analysis enables proactive and timely delivery of tailored prevention and treatment strategies, such as HIV testing, antiretroviral therapy intervention, and education to the affected communities.

Geospatial data on health and social environments have also been used to provide information about health disparities. Using GIS-based ethnic density measures and spatial data on mothers' residential locations, a recent study of infant health inequalities among Bangladeshi immigrant women in New York City found that their infants were most vulnerable to poor health outcomes, such as low birth weight, when living either in very isolated settings or in areas of the highest ethnic density (11).

With real-time interactive GPS/GIS functionality (12) now increasingly embedded in cell phones and low-cost navigation and other mobile devices, individual citizens also are contributing to the flow of health-related geospatial data. These activities are variously referred to as participatory GIS, crowd-sourcing, or volunteered geographic information (x). Despite unresolved issues of privacy and quality assurance, the ability to access georeferenced data from millions of people could be transformative.

For example, by analyzing data from 15 million mobile-phone subscribers, Wesolowski *et al.* (13) could examine the complex interactions between human and animal movements and the spread of malaria in Kenya. From Japan to California, volunteers with GPS-enabled real-time air-quality monitoring systems are assessing exposures to air pollution and radiation at spatial resolution levels and data densities not previously feasible (14).

Better institutional and educational models for successfully integrating the spatial dimension into health research and practice are needed to achieve the full benefits of these new capabilities in a timely manner (15, 16). There is also an urgent need for the creation of distributed, interoperable spatial data infrastructures to integrate health research data across and within disparate health research programs. In addition to fostering standards and scientific access, such large-scale spatial data infrastructures are themselves powerful new resources for generating and testing hypotheses, detecting spatial patterns, and responding to health threats.

Ongoing collaborations between the NIH and the Association of American Geographers are addressing key technical and institutional challenges (e.g., standards, interoperability, common terminology, data confidentiality) to facilitate the generation, coordination, and use of the rapidly growing body of geospatial health data (17). Research agendas that systematically incorporate spatial data and analysis into global health research hold extraordinary potential for creating new discovery pathways in science (18).

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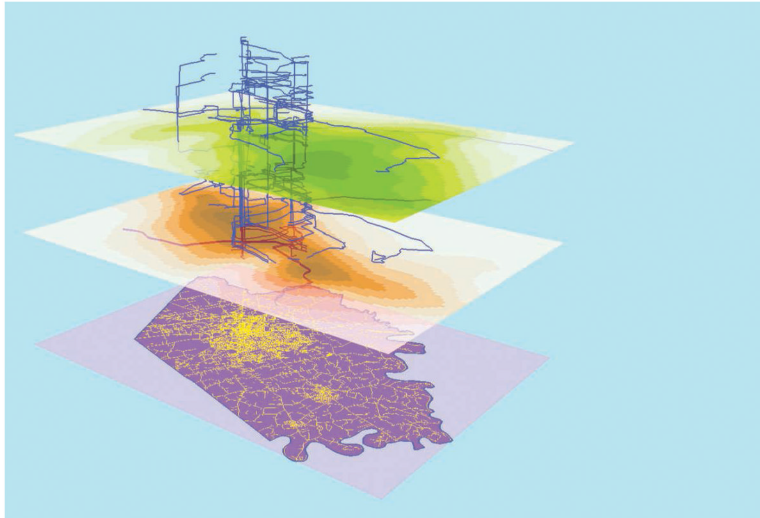

Figure. Exposure assessment with GPS/GIS data of individuals

Life paths of individuals collected with GPS/GIS methods can provide more accurate assessment of exposures to environmental or social risk factors when integrated with detailed GIS data about the spatial and temporal variations of these risk factors (19). Life paths of individuals are shown as trajectories that unfold along the vertical axis, which represents time; the bottom horizontal plane represents the spatial extent and transportation network of the study area. The green and orange horizontal planes illustrate the spatial distribution of risk factor concentrations (e.g., traffic-related air pollution, carcinogenic substances, liquor stores) for two time points.