Geographic Information Systems and Public Health: Mapping the Future

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Looking toward the 21st century, we anticipate that health planning, particularly at the community level, will be substantially improved by developments in informatics—that is, through the application of information science and technology to public health practice and research. Ideally, each community will have the capability to link together health information from a variety of different data sources and to recognize spatial data patterns that suggest where cost-effective public health interventions can be applied.

We believe that geographic information system (GIS) technology will be an important part of the toolkit to support this capability, but only if epidemiologic principles and methods provide the foundation for the data analyses to be displayed in GIS maps. Here, we provide our thoughts about current trends and future directions for GIS technology in public health and the challenges to institutionalizing this technology as a standard part of public health planning and practice by the Year 2010.

Current Trends

During the 1990s, local government use of GIS technology has grown substantially. A national survey in 1997 of a sample of 200 cities and counties concluded that use of GIS technology in at least one department of local government had increased from 20% of jurisdictions in 1990 to a predicted 87% by the end of 1997. Respondents named planning departments as the most frequent local government users (almost 80% of respondents in all jurisdictions).

Based on informal discussions with representatives of many local public health departments, the National Association of County and City Health Officials (NACCHO) reports that interest in GIS technology has increased during the 1990s, but many local public health departments still do not have the software, hardware, or trained staff that would enable them to apply GIS technology. Local public health departments would like to see GIS components added to NACCHO’s community planning tools such as the Assessment Protocol for Excellence in Public Health and its new iteration, Assessment and Planning Excellence through Community Partners for Health, scheduled for release in year 2000 in electronic format (for more details about these tools, see NACCHO’s website at www.naccho.org). NACCHO is currently developing plans for a national survey to document local public health departments’ GIS activities.

One of the initial steps in any GIS project is to geocode (georeference) each data record to the desired level of accuracy (for example, county, Census tract, Census block, US Postal Service zip code, or street address). (The smallest area of US Bureau of Census geography is the Census block. In urbanized areas, a Census block typically is a quadrangle bounded by four streets (a city block). In sparsely populated areas, a Census block has a population of about 70 people and is bounded by visible features such as roads, streams, or railroad tracks or by invisible boundaries such as city or county limits. In rural areas, a block may encompass many square miles.) During the 1990s, geocoded public health data have been in relatively short supply, limited to states with initiatives to geocode vital statistics data or to individual investigators who could geocode their own data. In a 1997 survey of state Vital Statistics Project Directors, only 21 of 49 respondents reported that their states had some type of automated geocoding of vital statistics.

The growing interest in GIS applications in public health is illustrated by the Third National Conference on GIS in Public Health, held...
in San Diego in August 1998. Participants addressed a wide variety of topics, ranging from the use of satellite images to measure ocean temperatures and forecast cholera epidemics in India to the use of global positioning system (GPS) technology to determine latitude-longitude coordinates for locations of billboards with cigarette advertisements in relation to school bus routes.

Epidemiology and GIS Technology

Epidemiologic principles and methods provide the foundation for public health and preventive medicine. To avoid drawing false conclusions from maps, users of GIS technology need to understand and apply these principles and methods in formulating study questions, testing hypotheses about cause-and-effect relationships, and critically evaluating how data quality, confounding factors, and bias may influence the interpretation of results. Conversely, epidemiologists need to be able to understand and critically evaluate maps prepared using modern GIS software, data, and spatial statistical methods.

A recent special issue of the Journal of Public Health Management and Practice was devoted to GIS technology. (A second special issue is due out in July 1999.) In an editorial, Melnick and Fleming discuss the "promise and pitfalls" of GIS technology. They note that "perhaps the greatest potential of GIS lies in its ability to quickly, clearly, and convincingly show the results of a complex analysis.... The greatest strength of GIS is that its product is a picture." They go on to say, "Ironically, the power of the GIS tool may also be its biggest pitfall. The consequence [of integrating] complex data into a visually easy to understand picture ... is a setup for misunderstanding and misuse." Users, including policy makers, they point out, may be tempted to infer causation from correlation and to make inferences about individuals from population data (the ecologic fallacy).

Another potential problem with drawing conclusions from maps is that, as Monmonier writes, "Not only is it easy to lie with maps, it's essential...." The cartographer's paradox is that "to avoid hiding critical information in a fog of detail, the map must offer a selective, incomplete view of reality." Public health practitioners need to be alert for "lies" that can range from "little white lies" (suppressing details selectively to help the user see what needs to be seen) to more serious distortions in which the visual image suggests conclusions that would not be supported by careful epidemiologic analysis. For example, when some geographic units of analysis have small denominators, disease rates computed for these areas may appear extremely high if any cases have occurred in these areas. When the rates for these geographic locations are displayed on a map, readers may incorrectly conclude that these are "hot spots," high priority locations for targeted interventions. More appropriately, these areas should be labeled to indicate that rates are statistically unstable due to small numbers and therefore not shown.

With advances in desk-top computing, it will become easier to produce multiple maps using different data sources and different methods, each offering a unique perspective on an issue. Again, the principles and methods of epidemiology need to be applied to evaluate the strengths and limitations of the data and the science "behind" the maps, in order to identify the map (or maps) that convey the most truthful messages.

The ability to invest in GIS hardware, software, and data may enable those with greater resources to be more influential in communicating their "selective, incomplete view of reality" to community decision makers. In the future, as advocacy groups, community organizations, hospitals, managed care organizations, and the news media increasingly use GIS technology with health-related data, the need for education about epidemiologic methods and principles becomes even more essential.

Definition

The phrase "geographic information systems" was first used in the 1960s to refer to a computerized system for asking questions of maps showing current and potential land use in Canada. Since that time, a number of definitions have been proposed, with variations that depend on the perspective of the author, the specific application, the software available at a given time, and the level of complexity appropriate for the intended audience. Some authors have begun to suggest that a different term, "geographic information science," might be advantageous in order to place greater emphasis on the underlying general principles and science and to be more independent of developments in software technology.

From a community health planning perspective, the Federal Geographic Data Committee (FGDC) definition provides a useful starting point: A computer system for the input, storage, maintenance, management, retrieval, analysis, synthesis, and output of geographic or location-based information. In the most restrictive usage, GIS refers only to hardware and software. In common usage, it includes hardware, software, and data. When organizations refer to their GIS, this latter usage is usually what they mean. For some, GIS also implies the people and procedures involved in GIS operation.