ORIGINAL ARTICLE

GIS IN EPIDEMIOLOGY: APPLICATIONS AND SERVICES

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ABSTRACT

There is a growing understanding and appreciation regarding the power of health and health-related information in planning and implementing health programs. Given these points and the fact that most health information is tied in some way to geography, it is becoming increasingly important that health professionals, organizations, and communities create systems that empower them to really take advantage of the many different types of information that is available and that can be brought to bare on health issues and program management. There are countless layers or types of health and health-related data for a given population or place. GIS allow people to organize, visualize, and analyze these data layers more effectively. GIS and related spatial analysis methods provide a set of tools for describing and understanding the changing spatial organization of health care, for examining its relationship to health outcomes and access, and for exploring how the delivery of health care can be improved. Geographic information systems (GIS) provide ideal platforms for the convergence of disease-specific information and their analyses in relation to population settlements, surrounding social and health services and the natural environment. They are highly suitable for analysing epidemiological data, revealing trends and interrelationships that would be more difficult to discover in tabular format. Moreover GIS allows policy makers to easily visualize problems in relation to existing health and social services and the natural environment and so more effectively target resources. This study highlights the application and relevance of GIS for improving the efficiency of public health services.

Key Words: Epidemiology, GIS, Health Services, Mapping, Public Health

INTRODUCTION

The prevailing model of understanding health is a medical, focusing the individual and physiological systems. But understanding the total environment in which people live is being accepted increasingly as a means of action for the promotion of improved health and disease prevention. The total environment includes the physical setting and the social context. A wide range of observations about the physical, social, economic, and political and environment can be oriented in a widespread geographical base. Analysts and policy makers have begun to deal with issues relating to the most effective ways to bring spatial knowledge into the public health domain, but considerable work remains to be done before the understanding of geographical and epidemiological perspectives are on a par with clinical knowledge

As health phenomena have revealed strong spatial aspects, maps can show spatial distribution and spatial patterns of diseases. Analyzing and mapping the spatial aspects of disease can improve our understanding of disease etiology, facilitate work with therapists to educate the public, and enhance decision-making on programs that aim to prevent illnesses.

Epidemiologists, public health professionals, medical geographers have traditionally used maps when analyzing associations between location, environment, and disease. Thus, spatial analysis and mapping have a historical association with epidemiology. However, until recently, their use in public health practice has been limited. Recent advances in Geographical Information System and Mapping Technologies and increased awareness have created new opportunities for public health administrators to enhance their planning, analysis and monitoring capabilities.

The ability of GIS to manage and retrieve georeferenced data has demonstrates its value in the integration of complex epidemiological models through visualization of spatial and temporal relationships.The investigation of space and space-time epidemiological patterns often gives rise to the explanation of factors that might create an unfavorable health condition. GIS has several advantages over conventional methods used in health planning, management and research

LOCATION MATTERS

Historical Background,

The concept that location can influence health is a very old one in medicine. As far back as the time of Hippocrates (3rd century BC), physicians observed that certain diseases tend to occur in some places and not others. In fact, different locations on Earth are usually associated with different profiles: physical, biological, environmental, economic, social, cultural and sometimes even spiritual profiles that do affect and are affected by health, disease and healthcare. These profiles and associated health and disease conditions may also change with time (the longitudinal or temporal dimension).

The health applications using spatial components of diseases can be traced back to 1854 when Dr. John Snow combined geospatial information to analyze the cholera deaths and found clusters around water pumps. [1]

The work of John Snow during the cholera epidemics that ravaged London in the mid-1800s is an early example of an epidemiological investigation.[2] Snow's groundbreaking work was made possible by the registers of births and deaths maintained by local authorities in every English parish from the early 1880s. Without information on numbers of deaths from cholera and the street address of each victim, Snow's mapping of mortality in relation to the siting of water pumps would not have been possible. By plotting each known cholera case on a street map of Soho district (where the outbreak took place), Snow could see that the cases occurred almost entirely among those who lived near the Broad Street water pump. By using a map to examine the geographical (spatial) locations of cholera cases in relation to other features on the map (water pumps and cemetery of plague victims), Snow was actually performing what is now known as spatial analysis.[3]

This has been recognized by the World Health Organization (WHO): Geographical information systems (GIS) provide ideal platforms for the convergence of disease specific information and their analyses in relation to population settlements, surrounding social and health services and the natural environment. They are highly suitable for analyzing epidemiological data, revealing trends and interrelationships that would be difficult to discover in tabular format. Moreover GIS allows policy makers to easily visualize problems in relation to existing health and social services and the natural environment and so more effectively target resources. Since 1993, WHO's Public Health Mapping and GIS programme has been leading a global partnership in the promotion and implementation of GIS to support decision-making for a wide range of infectious disease and public health programmes. [4]

FUNCTIONS OF GIS

There are three important functions of Geographical Information System (GIS) in health research and policy analysis: a) Spatial Database Management, b) Visualization and Mapping, and c) Spatial Analysis[2]

a) Spatial Data Management: Data management include linking,integrating and editing many kinds of data that are located on the Earth's surface, such as health, social, environment data. GIS facilitate the integration of quantitative determination and control data with data obtained from maps, satellite images, and aerial photos. Frequently, socioeconomic data and qualitative information on health facilities have a spatial basis, and can also be integrated.

GIS allows analysis of data generated by Global Positioning Systems (GPS). Combined with data from surveillance and management activities, GIS and GPS provide a powerful tool for the analysis and display of areas of high disease prevalence and the monitoring of ongoing control efforts. The coupling of GIS and GPS enhances the quality of spatial and nonspatial data for analysis and decision making by providing an integrated approach to disease control and surveillance at the local, regional, and/or national level. Spatial and ecologic data are combined with epidemiologic data to enable analysis of variables that play important roles in disease transmission. This integration of data is essential for health policy planning, decision making, and ongoing surveillance efforts

b) Visualization: GIS can provide spatial dimension to epidemiological research (visualization modeling). Visualization is also an important tool for showing the change in disease patterns over time. Animation, embedded within a GIS, is highly effective in give a picture of the spread or retreat of disease over space and time.It offers powerful tools to present spatial information to the level of individualoccurrence, and conduct predictive modelling. It determines geographical distribution and variation of diseases, and their prevalence and incidence. Visualization and mapping can explore the spatial patterns and correlations of diseases and many factors such as census and environment. Visualization can be used in novel ways to explore the results of traditional statistical analysis. Displaying the locations of outlier and influential values on maps and showing variation in values over space can add a great deal too epidemiologic research. GIS keeps track of the geographical locations of service providers, customers, resources, and health plans and programmes. It allows policy makers to easily understand and visualise the problems in relation to the resources, and effectively target resources to those communities in need. GIS permits dynamic link between databases and maps so that data updates are automatically reflected on the maps.Visualization can be used in new way to explore the results of traditional statistical analysis. Although such tools are being developed and explored, they would benefit greatly from a closer and more seamless link between statistical packages and GIS.[5]

c) Spatial Analysis: Spatial analysis refers to the "ability to manipulate spatial data into different forms and extract additional meaning as a result".[5] It encompasses the many methods and procedures, developed in geography, statistics, and other disciplines, for analyzing and relating spatial information. Spatial relationships, those based on proximity and relative location, form the core of spatial analysis. Spatial analysis utilizes the spatial relationship to generate new health patterns. For instance, Kriging is a popular method used for interoperating health data. When a disease appears, GIS can represent disease information rapidly and analyze the spread of disease dynamically.

Location of clinics or other new health carefacilities, regional health planning (e.g., plan emergency medical servicesacross a city, several district), plan for efficient transportation of patientsuse to plan a network (of hospitals, of healthcare organizations, otherhealth related variables of interest are often spatially distributed), facilitate prompt implementation of prevention and intervention efforts, identification of clusters of disease such as TB, Diarrhea **,** Malaria or other notifiable diseases and its location. Spatial analysis assists to identify areas with high prevalence of certain diseases.

i) Overlaying: Involves superimposing thematic plane of GIS features containing geographically and logically related data two or more map layers to produce a new map layer. Map overlay operations allow us to compute new values for locations based on multiple attributes or data "layers" and to identify and display locations that meet specific.This allows the analyst to compute new values for locations based on multiple features or data "layers". GIS can overlay diverse layer of information. This helps in decision making and medical research through multi criteria modelling (for example, in understanding the association between prevalence of certain diseases and specific geographic features).

ii) Buffer Analysis: GIS can create buffer zones around selected features.The user can indicate the size of the buffer and then join together this information with disease incidence data to establish how many cases fall within the buffer. Buffer or proximity analysis can be used to map the impact zones of vector breeding sites, where control activity needs to be strengthened.The buffer analysis capabilities of GIS are used for computing the health events located within a specified radius of each grid intersection

iii) Location-allocation Analysis: GIS is increasingly being used in “location-allocation” problems to inform the optimal allocation of finite resources. Health planners can identify potential locations for new primary health care facilities and evaluate each competing locationfor their effects on clinic access by using the power of GIS to incorporate information on the demand for care as well as the supply of that care. Poorer population is more likely to exclusively use the nearest health care facility regardless of discrepancies in standard of care. This makes the optimal placement of health care facilities in lower-income settings particularly important, and it is therefore vital to site facilities in such a way as to maximize access by the population.

iv) Exploratory Spatial Analysis: These methods allow the analyst to sift meaningfully through spatial data, identify "unusual" spatial patterns, and formulate hypotheses to guide future research.[6] The quantity and diversity of spatial data in GIS can be overwhelming: exploratory methods help the analyst make sense of data and address "what if" questions. Advances in computing and graphics technology have made this one of the most active areas in GIS/spatial analysis research.

v) Spatial Statistical Modelling: For instance, Kriging is a popular method used for interoperating health data. Kriging has become perhaps the best embedded into proprietary GIS.[7, 8] Here, an attempt is made to model the value of a spatially continuous covariate at locations where it has not been sampled; the weights of a linear estimator are derived from a modelled variogram. This describes the way the pattern of spatial dependence declines with distance, or spatial lag. Among the most important exploratory methods for epidemiology and public health are methods for identifying space-time clusters or "hot spots" of disease.

vi) Spatial Interaction Model: It analyses and predicts the movements of people, information, and goods from place to place.[9] The flows of people between rural areas, villages, cities, and countries are all forms of spatial interaction that are central to disease transmission. By accurately modelling these flows, it is possible to identify areas most at risk for disease transmission and thus target intervention efforts.

vii) Spatial Diffusion Models: The spread of phenomena over space and time and have been widely used in understanding spatial diffusion of disease.[10] Such models are quite similar to spatial interaction models except that they have an explicit temporal dimension. By incorporating time and space, along with basic epidemiologic concepts, the models can predict how diseases spread, spatially and temporally, from infected to susceptible people in an area[11] and aid in understanding the emergence of infectious disease[12]

CONCLUSION

While it holds distinct promise as a tool in the battle against emerging infectious diseases and other public health problems, GIS can be seen as a new approach to science, one with a history and heritage, a finite and well researched suite of methods and techniques, and a research agenda of its own. With the base of research and intellect, application of GIS in the health sciences cannot be ignored. GIS should be seen as improving the set of tools to promote public health. The future of GIS has already retained a role for the geographically literate public health expert. Epidemiologists should seize the opportunity to set their own agenda and influence the technology and science toward the goal of public health.

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