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Monitoring Physician Locations with GIS

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This case illustrates the use of a geographic information system to monitor and analyze spatial patterns of physicians' multiple locations. Physicians practicing a more than one location on a regular basis are considered multiple-location practitioners and amounted to about 16% of instate (North Carolina) physicians during 1992. The pattern of primary locations (Figure 1) and secondary and tertiary locations (Figure 2) coalesce in metropolitan centers such as Asheville, Charlotte, Greensboro, and Raleigh-Durham-Chapel Hill, North Carolina (Albert 1995). However, 15 counties had ratios of primary to secondary and tertiary locations greater than one suggesting that the contribution of multiple locations to nonmetropolitan counties might be substantial (Figure 3). Monitoring the percent of physicians with multiple locations might serve as an indicator of organizational changes occurring within the health care industries during the 1990s. This case highlights data location, acquisition, and assessment, join and relational operators, geocoding and distance calculations, and standard query language. More technical descriptions of these terms can be found within *The NCGIA GIS Core Curriculum and Technical Programs*. For more information on geomedical applications of GIS see "Synopsis and Bibliographic Resource of Medical-GIS Applications," Albert (1994) or Albert, Gesler, and Wittie (1995).

Data Location, Acquisition, and Assessment

The physician database is from the North Carolina Board of Medical Examiners (NCBME 1992) via the North Carolina Health Professions Data System (Sheps Center for Health Services Research 1992). The North Carolina Health Professions Data System collects and disseminates data on chiropractors, dental hygienists, dentists, doctors of medicine and osteopathy, licensed practical nurses, nurse practitioners, optometrists, pharmacists, physical therapists, physical therapy assistants, physician assistants, podiatrists, practicing psychologists, psychological associates, and registered nurses. From a larger number a fields from the physician database, 22 were chosen for this geographic analysis:

<u>Physician Characteristics</u>

gender
race
primary specialty

<u>Primary, Secondary, and Tertiary Locations</u>

ZIP Code
city
county
state
hours per week in medicine
employment setting.

These 18,253 records and 22 fields were in ASCII format (tab-delimited) and 2.3 megabytes in size (Table 1).

These data were from the 1991-92 application of medical license registration with the North Carolina Board of Medical Examiners (1992). Collection is via self report. This raises concerns over potential errors and missing observations within the physician database.

- First, some corrections were made with respect to misspellings and variant spellings (i.e., misspellings Madion and Manor of Marion, North Carolina).

- Second, efforts were made to assess completeness. Eleven of the 22 fields were over 90% complete. The city, county, and state fields for primary, secondary, and tertiary locations were between 98-99% complete. However, the ZIP Code fields for primary, secondary, and tertiary locations were, respectively, 97%, 66%, and 54% complete.

Overall assessment of the database is fair to excellent depending on the combination of fields under review (Table 2). Software/hardware configurations for this illustration include MapInfo® 2.0.3 for Macintosh on a Quadra 840AV with a 16 inch color monitor, Tektronic 220e color printer, and a LaserWriter as peripheries.

Results

This case illustrates join and relational operators, geocoding and distance calculations, and standard query language. The findings are set out according to these headings so as to conform to specific units within Part I of *The NCGIA GIS Core Curriculum for Technical Programs*.

Join and Relational Operators

Additional attributes such as a physician classification scheme (i.e., the 105 primary specialties in the database were coded into either General and Family Practitioners, Medical Specialists, Surgical Specialists, or Other Specialists), metropolitan status (metropolitan county or nonmetropolitan county), and population size (U.S. Bureau of the Census 1990) were brought into the physician database through join and relational operators; such operators made the following analyses possible. Multiple-location practitioners were less apt to be medical specialists, 27% vs. 32% ($p < 0.001$), and more apt to be other specialists, 32% vs. 27% ($p < 0.001$), than single-location practitioners. Further, multiple-site practitioners were moving down the urban system to secondary and tertiary locations indicating a redistribution of physicians to smaller-sized places. For example, 24% of secondary locations and 35% of tertiary locations were in places under 5,000 compared with 15% for primary locations. Fifty-four percent of physicians have urban primary and secondary (including tertiary) locations, 19% urban primary and rural secondary locations, 5% rural primary and urban secondary, and 20% rural primary and rural secondary locations.

Geocoding and Distances Calculations

Observations within the physicians primary, secondary, and tertiary ZIP Code fields were geocoded using a centroid coordinates file (latitude and longitude). Straight-line distances between location orders were found using the program syntax within MapInfo® (Table 3). On average, there were twenty-four miles between primary and secondary locations (N = 1,741), 30 miles between primary and tertiary (N = 292), and 35 miles between secondary and tertiary locations (N = 286). Note that distances between the locations of general practitioners and family practitioners (GP&FP) were less than between other specialists (OS). Further 90% of primary to secondary distances were between 45-50 miles apart; 90% of primary to tertiary and secondary to tertiary distances were over 60 miles.

Standard Query Language

Standard query language (SQL) provides a means to search a database per specific user requests. Here, an accounting of physician hours gained and lost to individual counties is possible because of SQL. For example, a search of the database for "Greene" within "Primary County", "Secondary County", and"Tertiary County" fields retrieves a set of physician records. Remember, the records contain the fields "Primary Hours", "Secondary Hours", and "Tertiary Hours" that provide physicians' hours. The search found that 18.17 hours per week were brought into Greene County, North Carolina, from secondary and tertiary locations (NCBME 1992).

Health Care Policy Implications

The case illustrates the usefulness of geographic information systems to monitor and analyze patterns of health care providers. However, it is important to place these findings in terms of health care policy implications (Albert and Gesler 1997). Some implications include concern over data quality (missing observations and errors), monitoring of health care personnel (consider multiple locations, otherwise under or over estimate personnel resources), access and availability (consider redistribution of physicians via multiple locations), shortage designations (multiple locations change population-to-physician ratios that determine federal shortage designations), and physician recruitment (target multiple-location practitioners for full-time commitment to shortage communities).

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Table 1. Data, Hardware/Software, and Functions

Data Source:	NC Board of Medical Examiners, 1992	
Data Quality:	Fair to Excellent	
File Size:	2.3 compressed to 200K with Compact Pro®1.33	
Data Fields:	Race	Tertiary City
	Gender	Tertiary County
	Primary Specialty	Tertiary ZIP Code
	Primary City	Tertiary State
	Primary County	Primary Hours
	Primary ZIP Code	Secondary Hours
	Primary State	Tertiary Hours
	Secondary City	Primary Setting
	Secondary County	Secondary Setting
	Secondary ZIP Code	Tertiary Setting
	Secondary State	In-/Out-of-State

Software:	MapInfo® 2.0.3 for Macintosh
Hardware:	MacIntosh Quadra 840AV with 16" Color Monitor Tektronic 220e Color Printer,Laser Writer
Analyses:	Join and Relational Operators, Geocoding, Distance Calculations, Standard Query Language, Maps, Graphs, Tables

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Table 2. Data Completeness, NCBME, 1992

Field	**Percent**
Demographics	
1. Race	100
2. Gender	100
Specialty	
3. Primary Specialty	99
Primary Location	
4. city	100
5. state	100
6. county	100
7. ZIP code	94
8. hours/week in medicine	84
9. setting	76
Secondary Location	
10. city	98
11. state	100
12. ZIP code	66
13. county	100
14. hours/week in medicine	86
15. setting	77
Other Location	
16. city	98
17. state	100
18. ZIP code	54

19. county	100
20. hours/week in medicine	79
21. setting	70
22. in-out-of-state code	100

Table 3. Mean Miles Between Practices			
	P to S	**P to T**	**S to T**
General and Family	23	30	32
Medical Specialists	22	26	34
Surgical Specialists	21	26	30
Other Specialists	27	36	40
Total	24	30	35
P = Primary, S = Secondary, T = Tertiary			

Table 4. Distances Between Locations: 20%, 50%, and 90% Cut-Off			
Cumulative %	**P to S miles**	**P to T miles**	**S to T miles**
20	0-5	5-10	10-15
50	15-20	20-25	25-30
90	45-50	60+	60+
P = Primary, S = Secondary, T = Tertiary			

Synopsis and Bibliographic Resource

of Medical-GIS Applications

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There is a small, but growing number of applications of geographic information systems towards health-related issues. This review provides a synthesis and bibliographic resource on emerging applications within this realm (see also Albert, Gesler, and Wittie 1995; Siebert 1994; Barnes and Peck 1994; Davenhall 1993).

Disciplines

Medical geography is "the application of geographical concepts and techniques to health-related problems" (Hunter 1974, 3). Two divisions within the field include the spatial patterning of health services and the spatial patterning of disease (Overhead 1). Geographic information systems integrate spatial data to support decisions (Cowen 1990). Star and Estes (1990) coined the term the "four M's" in reference to the measurement, mapping, monitoring, and modeling capabilities of geographic information systems (Overhead 2). This review encompasses the intersection between medical geography (MG) and geographic information systems (GIS).

Medical Geography and GIS

The literature encompassing the intersection between MG and GIS represents four distinct groups of articles - potential, cautionary, preliminary, and application (Albert, Gesler, and Wittie 1995) (Overhead 3). Connecting these orientations is a dialogue, an academic and professional exchange through workshops, conferences, and journals that facilitate communications between these groups.

The potential group (Verhasselt 1993; Gould 1992; Fisherden 1991; Nicol 1991; Scholten et al. 1991; Twigg 1990; Wrigley 1991; Mohan and Maguire 1985) suggests the benefits of geographic information systems for hypothesis generation, crossing geopolitical boundaries, and small area analysis. Quoting Verhasselt (1993, 121), GIS "open up new possibilities in ecological associative analysis."

The cautionary group argues for a critical approach to using GIS (Matthews 1990) for the following reasons. First, GIS suffers from definitional vagueness; there is no definition having universal acceptance. Second, techniques often overshadow research questions. Third, data suffer from the four (in' s): intensive, inaccessible, incompatible, and inaccurate data (Taylor 1991; Heywood 1990; Twigg 1990).

The preliminary group suggests potential disease/health applications of geographic information systems. One suggestion involves assessing danger to lead poisoning through neighborhood risk scores attributable to socioeconomic status (0 = high; 3 = low), soil contamination (0 = clean; 3 maximum), and air contamination (0 = no effect; 3 maximum). Exposure rates (number of cases /number of blocks) are found for each risk score (Wartenberg 1992). The second suggestion (Stallones et al. 1992) involves producing a composite map of water wells and associated residences using a contaminated aquifer. The third suggestion is to use geographic information systems to analyze patterns of stomach and esophageal cancer for ecological association because of the enormous environmental data requirements (Lam 1986).

The application group uses geographic information systems to examine spatial patterns of health care services and disease. These have been set apart into the following subdivisions: distributions; location/allocation; catchment areas; monitoring and prevention; surveillance, modeling, and simulations; and cluster analysis (Overhead 4).

Albert (1995) and Albert and Gesler (1997) provide analyses of physicians' primary, secondary, and tertiary medical practice locations using a geographic information system (MapInfo®). The physician database (18,253 records with 22 fields) and attribute data on settlement size and county-level designations on metropolitan and health professional shortage status were input within GIS. Some findings include: secondary and tertiary medical locations have lower population thresholds than primary medical locations; and, higher-order physicians (more specialized) travel greater distances between locations than do lower-order (less specialized) physicians.

Van Creveld (1991) describes an ambulance service application. The "Command and Control Program" presents a status report on the nearest 24 rescue vehicles to a monitor. Planned upgrades include a radio beacon system to dispatch and track the optimum vehicle to the accident location. Another example of an emergency response application is the use of a geographic information system to conduct search and rescue activities during the collapse of a section the Nimitz Freeway in October 1987 (Tyler 1990).

Zwarenstein et al. (1991) demonstrate the use of Thiessen polygons to assess the effect of removing race restrictions on hospitals in Natal/KwaZulu, South Africa in 1985. The results indicate that the population/bed ratios for blacks were still high even after removing race restrictions on hospital admissions.

Other applications include a geographic information system to monitor measles epidemics (Solarsh and Dummann 1992), HIV/AIDS (Fost 1990), and access to health care resources for the homeless (Lee 1996).

Some applications present modeling and simulations of health hazards. For example, isopleths were drawn around an industrial plant producing toxic emissions to indicate areas having an excess risk for cancer (Moore 1991). Another project found geographic information systems useful in comparing observed versus expected patterns of lead exposure among children (Guthe et al. 1992).

Several projects examine the incidence of cancer using geographic information systems (Tobias et al. 1996). Fitspatrick-Lins et al. (1990) found that potential radon exposure is highest in areas with metamorphic rocks and that sandstone and shale have a mediating influence on potential radon levels. Oppenshaw et al. (1987, 1988) found age-sex adjusted incidence rates for various cancers corresponding to circles drawn around points of a superimposed grid. Those circles with significant incidence rates were drawn to indicate the location of major cancer clusters.

Classroom Linkage

The instructor can use some of the research articles cited in this review to illustrate certain concepts and functions of geographic information systems. For example the following GIS capabilities can be referenced with specific research (Figure 1): database attribute queries and report generation (Tyler 1990), database queries (Fost 1990), overlay operations (Fitspatrick-Lins et al. 1990; Guthe et al. 1992), exploratory data analysis (Fitspatrick-Lins et al. 1990), Thiessen polygons (Twigg 1990; Zwarenstein et al. 1991), isopleths (Moore 1991), radii searches and cluster significance (Openshaw et al. 1987), network routing (Van Creveld 1991), scale (Solarsh and Dummann 1992), and modeling (Moore 1991; Guthe et al. 1992). Further, since most GIS courses have a term project of some sort, this review provides students with ideas and direction that can be used to develop a project more in line with improving on previous research or identifying new avenues of research.

Conclusions

This review represents a resource and reference guide to current health and disease applications of geographic information systems. Similar reviews exist documenting applications of geographic information systems for other geographic subdisciplines and other disciplines.

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National Council for Geographic Education for permission to adapt "Geographic Information Systems and Health: An Educational Resource (Albert et al. 1995).

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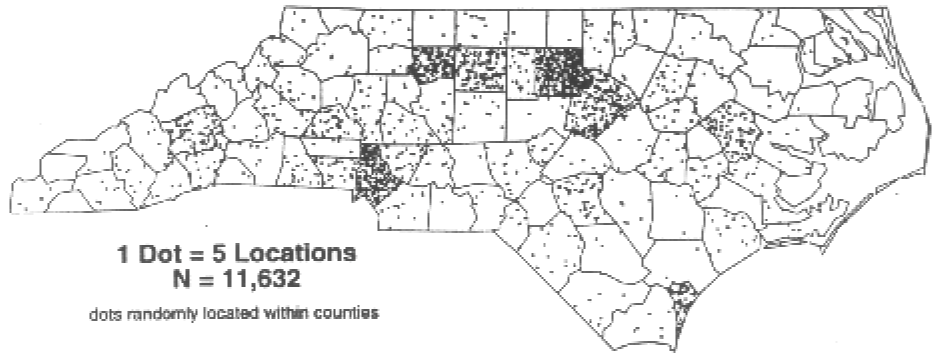
Figure 1. Applications of Geographic Information Systems to Health Research

Author(s)	Application	Geography	Variables	Concept Illustrated	Software
Tyler 1990	Search and rescue	Micro scale San Francisco and Alameda County	Vehicle registration Power lines	Database query reports	Unspecified
Van Creveld 1991	Automated emergency response	West Midlands 345 square miles	Real-time tracking of 24 rescue vehicles	Network routing	West Midland's Command and Control Program
Fost 1990	AIDS surveillance	San Francisco	Street network Questionaire data	Database queries	MapInfo
Twigg 1990	Assessment of GPs and clinics relative to school catchment districts	Enumeration district approximation using Thiessen polygons	Households without WC and bath GP surgeries and clinics School districts	Thiessen polygons	ARC/INFO
Zwarenstein et al. 1991	Measuring accessibility	Defining hospital catchment areas using Thiessen	Persons/bed ratios	Thiessen polygons	ARC/INFO

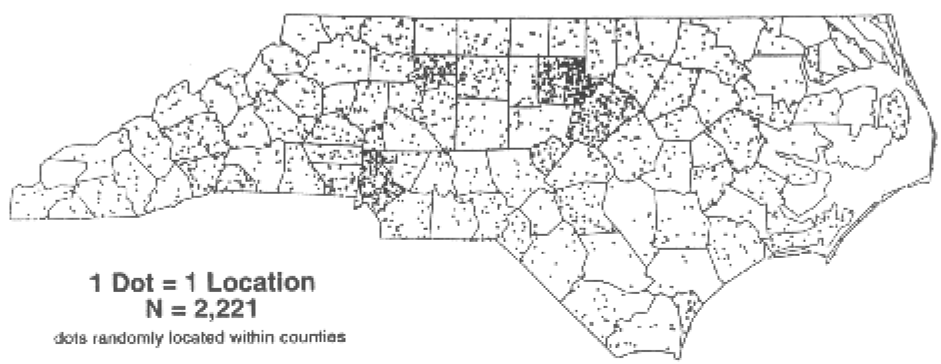
		polygons			
Moore 1991	Degree of public exposure Assess health risks from emissions	Isopleths of cancer risk	Carcinogenic and noncarcinogenic health risks	Isopleths Modeling	PC ARC/INFO
Guthe et al. 1992	Prediction of high levels of lead in blood of children	Identification of high-risk census tracts	Blood screening records Local sources of industrial and hazardous wastes Traffic volume	Overlay operation Modeling	ARC/INFO
Fitspatrick-Lins et al. 1990	Regional variations in radon potential	Within county	Underlying geology soils Indoor radon data	Overlay operation Exploratory data analysis	ARC/INFO
Openshaw et al. 1987	Significance of cancer clusters	Point locations	childhood leukemia incidence	Neighborhood operation-search using radii	GAM
Solarsh and Dummann 1992	Measles surveillance	Subdistrict (Edenal Health Ward, southern Natal)	Hospital inpatient data	Scale	dBase III PLUS Epi Info (v. 3 CDC)Harvard Graphics

Figure 1. Primary Practices, 1992



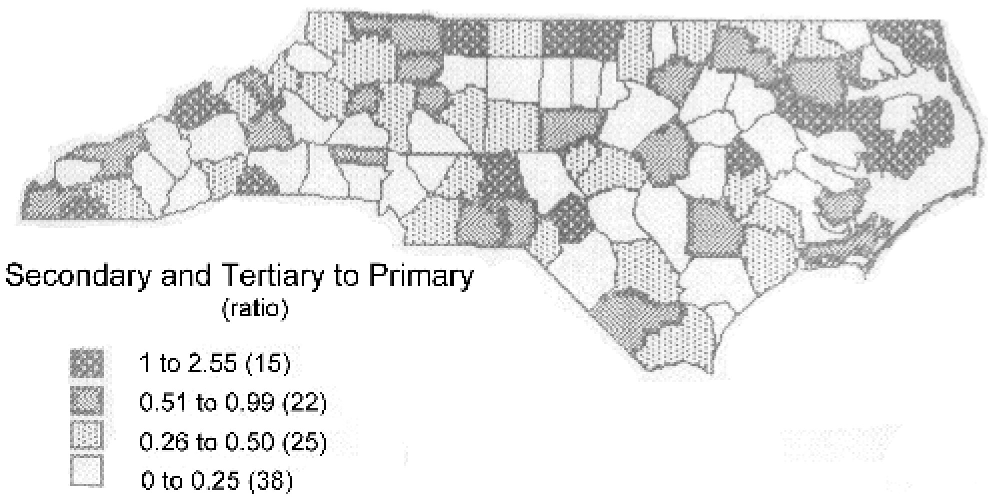
1 Dot = 5 Locations
N = 11,632
dots randomly located within counties

Figure 2. Secondary and Tertiary Practices, 1992



1 Dot = 1 Location
N = 2,221
dots randomly located within counties

Figure 3. Secondary and Tertiary to Primary Locations



Data Source: NCBME, 1992.

Overhead 1

Medical Geography

spatial patterning of health services
spatial patterning of disease

Overhead 2

"Four M's" and GIS

measurement

mapping

monitoring

modeling

Overhead 3

Four Groups

potential

cautionary

preliminary

application

Overhead 4

Application Group:
Subdivisions

distributions

location/allocation

catchment areas

monitoring and prevention

surveillance, modeling, and simulations

cluster analysis