GIS Queries for Population Data Analysis and Management

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ABSTRACT

It has been confirmed that one of the most vital requirements necessary for planning and decision-making in any field of human endeavour is the quality of information available on its human resources. This is needful because most daily decisions revolve around the people that populate or make up the system. Thus the implementation of an effective population management system, will determine largely the success rate of most decision and planning processes anywhere in the world.

The paper has been able to harmonize and display sample implementations of this phenomenon using a Geo-reference Information System (GIS). It serves as a sequel to an earlier presentation. Results have further confirmed the suitability of this application.

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1. INTRODUCTION

The time required for the population of the world to reach its first billion had stretched through all of human pre-history into the early 1800s. The second billion was added in a little more than a century, and the 3-billion mark was reached in 1960, less than 50years later. The additional billions since then were accumulated in time spans of about a dozen years each.

Even though the world birth rate had been declining gradually, the population continued to climb at a record rate in excess of 90million people each year. More than 90percent of this growth was in the developing countries of Africa, Latin America, and Asia (with the exception of Japan).

This tremendous spurt in population growth requires a carefully designed management tool/system that would be able to relate these figures to the existing spatial entities in the environment for an efficient management process. The succeeding sections give a lucid documentation of these processes.

2. THE GIS REQUIREMENTS FOR CENSUS APPLICATION

2.1 Requirements

The key requirements for population management have been enumerated to include, maps, census data and GIS tools in Ayeni et al, (2001). Maps and map data, and the GIS tools have been given enough prominence in the aforementioned paper. A brief re-cap is made here for the understanding of this presentation.

2.1.1 Census Maps

The map data is either of two types:

(1). The paper/analogue maps

The categories of maps needed for an accurate census may be enumerated as follows:
- National Administrative maps (1:5000,000:1,500,000)
- States Administrative maps (1:50,000 - 1:500,000)
- Maps of local government areas (1:25,000 - 1:50,000)
- Urban maps (1:10,000 - 1:25,000)
- Maps of settlements (1:5,000 - 1:10,000)
- Maps of Administrative units within towns (district maps) - 1:5,000 - 1:10,000

Other beneficial analogue maps from which any of the above could be gotten or directly used

include;
- Photomaps (at suitable scales)
- Orthophoto maps (at suitable scales)
- Image maps.
- Census map, which is an already delimitated map and could be any of the listed above.

These maps provide necessary information, particularly at the local government/cities/towns levels, for delineating the population Enumeration Areas (EA). Thus apart from supporting census data gathering, they can form the respective base maps upon which the development of the database system for population management is based depending on the scope of coverage; for instance, at the national level, the national administrative map will form the base map and vice-versa.

The maps could cover different themes, such as utility land use, planimetric and/or topographic maps. In current digital environment, remote-sensing images can be used to generate the needed maps, even in large scales because demarcation of administrative boundaries is faster with remotely sensed imageries.

(2). The digital maps

Digital maps are maps that are in softcopy format and are stored electronically in computer files. Examples of these satellite imageries, digital photographic imageries, digitized or scanned analogue maps.

Remotely sensed data could be from either aerial photography or from the Earth Observation Satellite System (EOSS). These data cannot be used in their raw form in census gathering and population management. They have to be processed and information needed for a realistic census extracted. This processing in a digital environment is known as digital image processing (DIP).

In case of aerial photography, the analogue photographs will have to be converted to digital form by scanning. Digital cameras can also produce digital aerial photographs for on-line processing and analysis. Digitized aerial photographs can be processed in digital photogrammetric workstations to produce a set of orthophoto maps needed for delimitation of the enumeration areas.

The thematic information required for census exercise belongs to either of a Point, Line or Area feature classes. These are known as topological entities. Examples of the point feature objects are, buildings, bridges, road junctions, etc; Linear: roads, street rivers, etc; and Area: districts, towns, settlements, etc. These features are very vital in census mapping exercise because it is upon them that demarcation of Enumeration Areas is based. Required non-spatial features - the population data - can be extracted based on the above spatial features.

2.2 GIS Components

In its simplest form, a GIS may be viewed as a database system in which most of the data are

spatially indexed, and upon which a set of procedures operates in order to answer queries about spatial entities in the database.

2.2.1 Hardware And Software Requirement

As a decision support system, the components of a GIS include Hardware and Software. The system can be designed to function as stand-alone or in a network environment. The latter is recommended for population management. The hardware and software components of a GIS for population management can be clearly identified after a detailed user requirement study (feasibility study).

For optimal performance, each of the computer unit or workstation, apart from having high processing speed and memories (e.g. Pentium III, 1000MHz clock speed minimum), should possess a full multi-media capability as minimum configuration. Recommended peripherals that could be networked with these workstations are; Plotters, Digitizers, Scanners (preferably 800-1800 dpi resolution), and Printers.

Apart from acquiring any of the high grade raster/vector GIS software available in the market, other software platform that could be incorporated may include any of the Multimedia software such as, Macromedia Director 5.0, Macromedia Flash 3-5, Window's Media Player 7.0 or latest upgrade, etc.

2.3 Population Census

A population census is a total process of collecting, compiling and publishing demographic, economic and social data pertaining, at a specified time, to all persons in a country or delimited territory. This involves the collection of data on the total number of persons, their composition (age, sex, marital status, etc.), dynamics (fertility, mortality, migration) and their spatial distribution (location).

The planning and administration of any census exercise must be related to its objectives. The conduct of the 1991 population census of Nigeria was predicated on the following objectives (PAN, 1990).

(a) To undertake the enumeration of the nation's population and universal registration of birth and death;
(b) To establish and maintain the machinery for continuous and universal registration of birth and death;
(c) To prepare and maintain a National Frame for the delineation exercise for census and sample surveys;
(d) To collect, collate and publish data on migration statistics.
(e) To research and monitor the National Population Policy and set up a National Population Information Data Bank;
(f) To arrange for the appointment and training of enumerators and all other categories of staff of the National Population Commission;
(g) To provide information and data on population for purpose of facilitating national

planning and economic development;

(h) To advise the Federal Government on other population and population related programmes and problems;

(i) To disseminate information and educate the public about the work of the National Population Commission.

2.3.1 Census Activities

Census activities can be broadly categorized into these main functions:

(1) Production of Enumeration area maps
(2) Enumeration, (Including pre - and post - enumeration exercises).
(3) Storage, retrieval and processing of census data
(4) Data Analysis and dissemination of population data

2.3.2 Results of Census Exercise

The characteristic of population data defines the type of information collected. During the exercise, individuals are asked to give information concerning their characteristics. Such as: Name, Sex, Age, Citizenship, Place seen on census day(s), State where seen on census day, Place of birth, Place of origin (ancestral home), Local Government Area of Place of Birth, Local Government Area of Place of Origin, Relationship with the head of household, Marital Status, Literacy, Educational Attainment, Employment status, and Occupation.

From the answer received on the above population characteristics, the following data are usually obtained:

(i) Size of the population, its distribution by rural and urban areas, by local government areas and by states.

(ii) Patterns and trends of demographic events i.e. births, deaths and immigration and the associated growth rates for the country and its political sub-divisions.

It is pertinent to note that, these are only a few examples of the type of data about a country's population that result from a census exercise. Many more tabulations can be derived from census data depending on the needs of individuals, organizations, the various levels of government (local, state and federal), or others who use data for research, planning and administrative purposes.

The GIS tools could be applied in the implementation of all the stages of census activities as enumerated above i.e. right from the production of enumerating area maps to the final analysis and dissemination of population data. This paper focuses on the latter stages.

3. MODELLING OF SPATIAL DATA

The first step in developing a database for a GIS is to acquire the data and place them into the system. The database system of a geographic information system provides the means to organize the spatial and non-spatial attributes for efficient storage, retrieval and analysis. Since population data are numerical values defining the spatial entities of interest, a tabular

format for data recording will be the best choice of form of database to use. This informs the reason for adopting the relational database structure for this presentation (Ayeni, et al, 2001).

The GIS database would consist of the spatial and non-spatial (attribute) data. Often the non-spatial data are embedded in the spatial database in form of descriptive information about the stored spatial objects or the relationship existing between them. The map is perhaps the most familiar form in which geographic data are represented. The information required of a geographic feature will be made of the following characteristics:

- Its location with reference to a standard coordinate system.
- Its spatial attributes
- Its relationship with other geographic features and
- The epoch of the feature.

The data (attributes) collected from the field on spatial and census entities can be geo-referenced with respect to the graphic data (defined by the administrative maps of the area). The different classes of data, using chosen criteria, can then be structured into layers of diverse information called themes. A set of slightly different themes from the part 1 of this presentation was abstracted from the 1991 census figure. These are presented in Fig. 1.

Tables Themes
1 Nuptial Indices by States of the Federation.
2 Distribution by age classification
3 Population distribution by States of the Federation.
4 Growth rate.
5 Literacy rate and household headship rate

Fig. 1: Table showing themes abridged from results of Nigerian 1991 Census.

4. ON–SCREEN PROCESSING

The ArcView for Windows (Version 3.1) used for this research added extensions possess enough capabilities for geospatial querying of the component population data. The tables were created in Microsoft Excel and converted to Dbase IV format before exporting to the ArcView project environment. The tables were later joined to the theme table of the administrative map of Nigeria that was earlier stored in Arc View's shape-file. The results of these merging are different spatial themes represented in Fig.1.

Different queries could be built to obtain needed information in order to reflect different areas of application and management requirements. In retrospect, sample queries were drawn to explain the capabilities of the GIS tool. These apart, other supportive tasks that can be performed will include, but not limited, to the followings:

1. Size and spatial distribution of the population across the country.
2. Patterns and trends of demographic events, such as births, deaths, migration, the associated growth rates for the country and its political sub-divisions. This will for

instance provide information necessary for structuring a birth control programme.

3. Planning and Location of Infrastructures, Agricultural/Farm settlements, industries, Educational Institutes, etc.
4. Transportation planning and traffic routing.
5. Manpower developments & planning.
6. Determining the pattern of early or late marriages across the country.
7. The spatial extent of a unit area and information on adjacent areas.
8. Estimate of projections for School enrollments at designated intervals.
9. Disease control: mapping and control of diseases and epidemic outbreaks, and
10. Other population related management issues.

For example, figures 2 to 4 are the products of sample queries on the available data from figure 1.

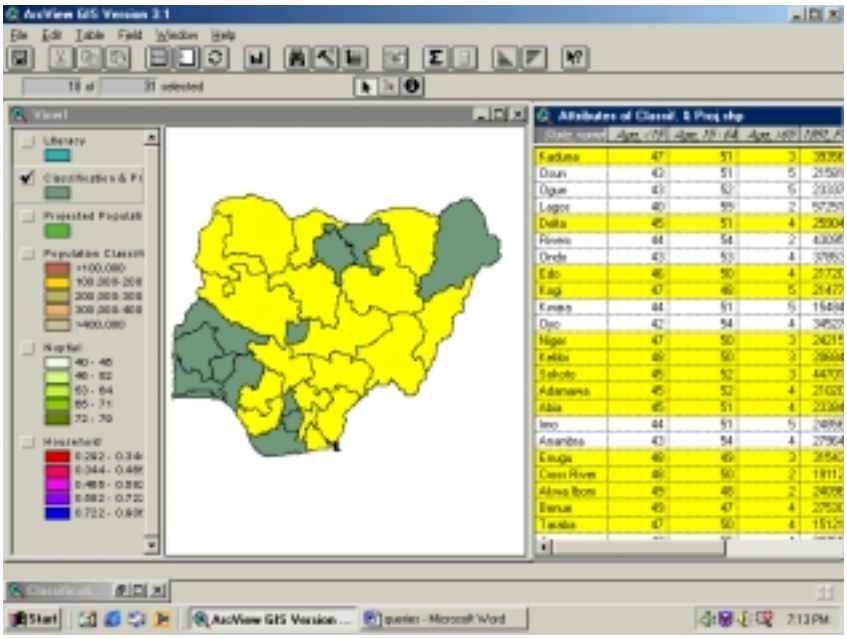

Fig. 2: States with more than 45% of its Population Under 15 years of Age.

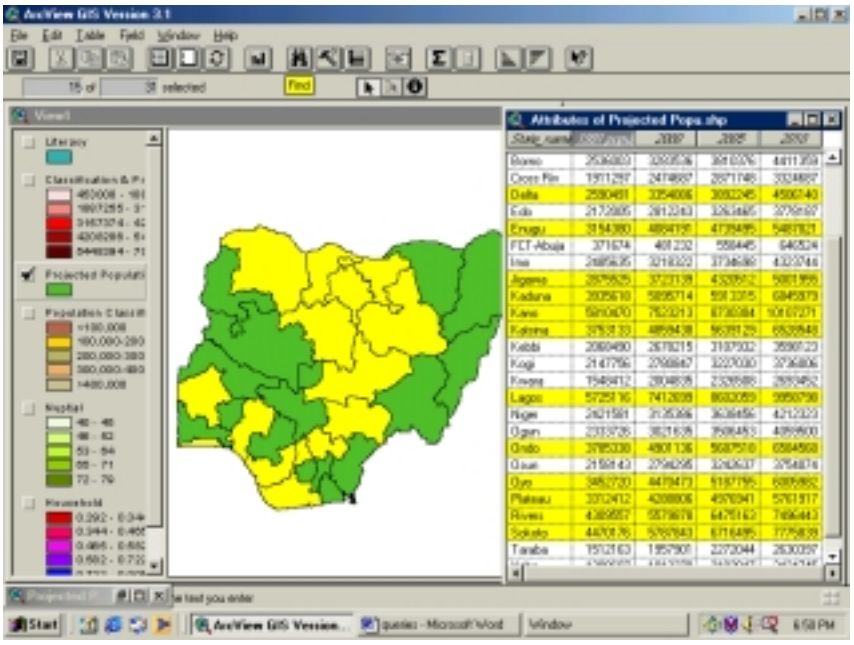

Fig. 3: States with likely population of more than 4.5m by year 2010.

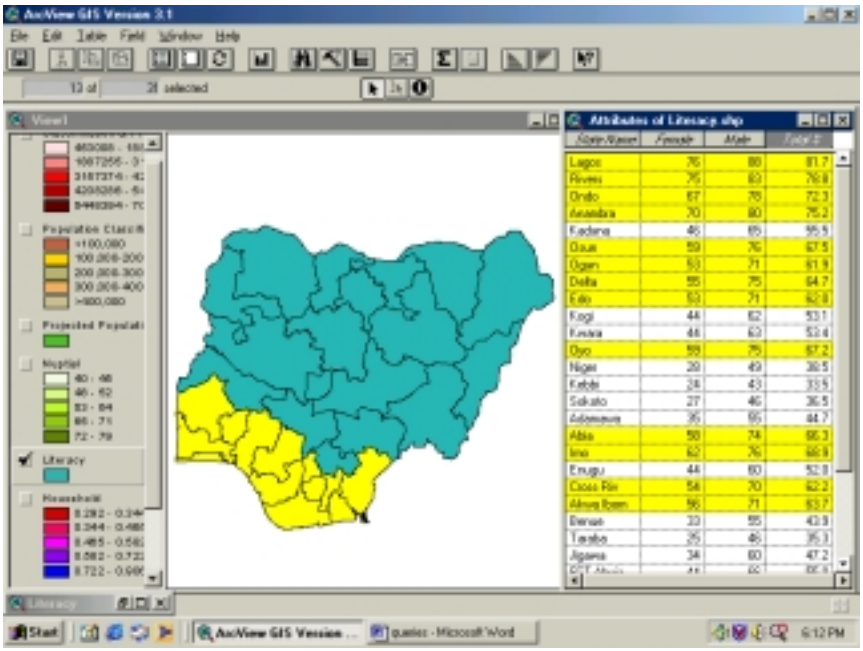

Fig. 4.1: States considered as highly literate (literate rate > 60% of its population)

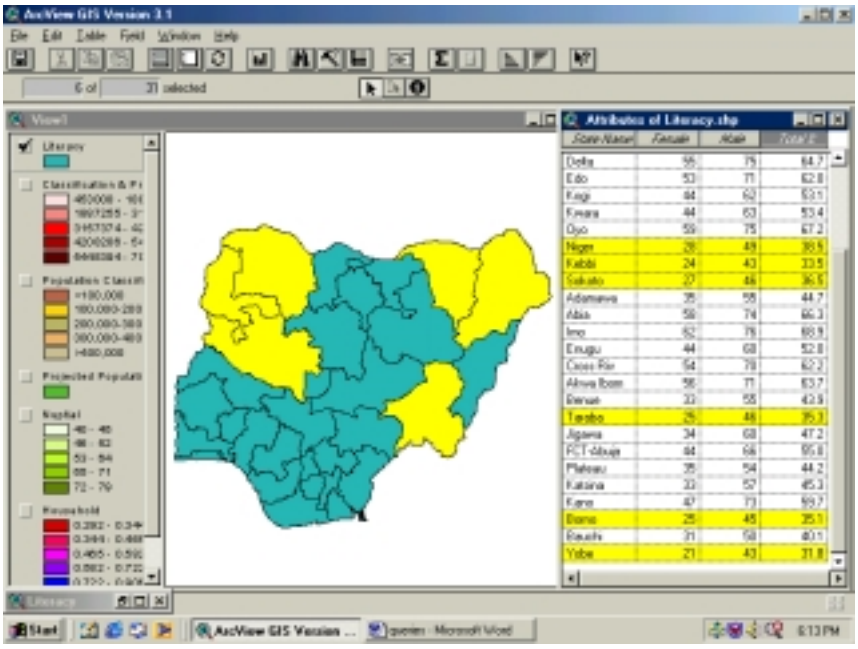

Fig. 4.2: States with literacy level of less than 40% of its total population.

5. CONCLUSION

A fundamental requirement in the planning, development and management of the human population and other economic resources of a state is the knowledge of the population and its characteristics as obtained from census exercises. Census is a fundamental source of basic demographic data, without which any attempt at managing these resources would be futile. Thus for a successful system using the GIS, a sound and accurate database need be put in place.

Nigeria experience shows that past census exercises and the figures obtained have always been a subject of contention in Nigeria. This means that projections and planning on unreliable data will adversely affect the effectiveness of such a system. The present Geo-referenced Information System is able to, given available data, provide the environmental planner with all useful spatial data and program development tools needed to produce results that should enhance the planning and other management processes of governance if and only if the 'base' data are right; i.e. Information will only be as accurate and reliable as the data that produce it.

The GIS spatial queries on population data can be utilized to detect gross errors in field or compiled census data. Such queries can also be used to detect attempts by census officials to manipulate census results in Nigeria and other nations, particularly in the third world countries.

6. GIS APPLICATION AND FUTURE OUTLOOK

The effectiveness of a population management system will determine to a reasonable extent, the degree of success or failure of further hybrid programmes designed to provide and manage related projects. This paper has shown the effectiveness of the GI System in the capturing, storing, checking, retrieving, integrating, analyzing, and displaying the appropriate spatial information.

However, due to the very large nature of data involved in population data acquisition and processing such as tabular, texts, graphics, imageries, video clips, audio, animation, and others; It is becoming obvious that the existing traditional GIS software will in no time be unable to meet the requirements for the management of these and other data that are expected to yield a set of useful information for intelligent decision-making required of the 21st century. An advanced research will explore the application of two emerging technologies in Information Science: Multimedia and Object-oriented approaches.

Unlike other GIS data, multimedia objects are very large in data volume and usually unformatted with complicated spatial relationships and rich semantics. However, they play a much better role in communicating and explaining the results of spatial analyses, and in handling data of a more qualitative nature that are more critical in decision-making process. Because of these characteristics, multimedia objects are best queried through other objects. This supports such Object-oriented features as – long transactions, versioning, very large continuous databases, images as first class objects, etc.

Future research should focus on the techniques of modeling the various attributes, geographic and multimedia 'population' data using the object-oriented GIS approach. The results will enhance a more sustainable development of resources of nations of the world, especially the poorer ones who incidentally are presently overwhelmed with 'unhealthy' population growth.

REFERENCES

Ayeni, O.O. & O.S. Adewale (2001), *A Geo-referenced information System for Population Management*, Proceedings of The International Conference on Spatial Information for Sustainable Development, Nairobi, Kenya. Oct. 2001.

Dangermond, J. (1983), *A Classification of Software components commonly used in GIS.* Proceeding, U.S. - Australia Workshop on the design and Implementation of Computer based Geographic Information System, pp 70-91, Honolulu, Hawaii.

Knapp E. (1978), *Landsat and ancillary data inputs to an Automated Geographic Information System.* Report No CSC/tr78/6019, Computer Science Corporation, Silver Springs, Maryland.

PAN (1990), *Everybody's Guide to the Nigerian Census*, The Population Association of Nigeria, Ibadan.

Shyllon, E.A. (1993), *Mapping Information System: Spatial Data Management for Offshore Oilfield Services*, M.Phil Thesis.

BIOGRAPHICAL NOTES

Prof. Olubodun Ayeni (1941): A Professor of Surveying, He was engaged as a Senior Lecturer in 1979 at the University of Lagos, Nigeria. He became a Professor in 1983. Between 1985 and 1991, he was the Director of RECTAS (Ile-Ife, Nigeria), and has since been back to the University where he lectures at the Department of Surveying and Geoinformatics. He has many published works in Remote Sensing, Photogrammetry, Geographic Information Systems, and Adjustment Computation & Statistical Analysis of Survey Data. He has also been involved in numerous international projects.
Professor Ayeni is a Winner of International Prizes and Awards such as; Talbert Abraham Award (ASPRS, 1983), Instrumentation of America (1975), and Edward Dolezal Award (ISPRS, 1996).

Oluwaseun S. Adewale (1966): Received his first degree in 1988 and in 1998, a master's degree in surveying both from the University of Lagos. He has over ten years of professional experience in engineering surveying, seismic survey data acquisition, GPS applications, Geographic Information Systems and Remote Sensing Data applications. He is presently an Assistant Lecturer at the Department of Surveying and Geoinformatics, University of Lagos, Nigeria where he is pursuing his MPhil/PhD program. His research interest is in Spatial Information Systems, Digital Mapping and Remote Sensing.
Mr. Adewale has won many scholastic awards such as, The Best final Year Student in Additional Mathematics (MHSO, 1983), Best Graduating Student in Geodesy (UNILAG, 1988), Best Student in the field of Photogrammetry (UNILAG, 1988).