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Satellite Remote Sensing Technology in Spatial Modeling Process: Technique and Procedures

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ABSTRACT

This paper aims to give insights into the origin, applicability and basis of remote sensing (RS). It focuses on image technique and procedures which includes image acquisition, processing, validation, classification and image-data presentation. This paper also considers digital image processing (DIP) software and geographic information system (GIS) in terms of compatibility with image-data modeling process. This is aimed at outlining the standard procedure for spatial data modeling via satellite remote sensing (SRS).

Keywords: *Satellite remote sensing, image acquisition, processing, validation, classification and image-data presentation.*

1. INTRODUCTION

Today a variety of earth observation satellites are in space for various intent and purposes. Remote sensing (RS) is the science of using electromagnetic radiations (EMR) to identify earth surface features and estimation of their geo-bio physical properties through analysis and interpretation its spectral, spatial, temporal and polarization signatures using EMR. Scientific satellites serve as space-based platforms for observation of earth, the other planets, the sun, comets, and galaxies [1]. Therefore, accurate and detailed geospatial data can be generated from these earth orbiting satellites are useful in a wide variety of other applications. The use of satellites remote sensing (SRS) products (data) for solving real world scenarios is thickening by the day. However, the technology of the generation of these SRS products and the implementation for spatial modeling process requires special skills in information handling process. The procedures and techniques for acquisition, processing, validation, classification and presentation of image and or image data that is compatible with GIS will be in focus.

A discussion of RS technology would not be complete without the mention of geographic information system (GIS). SRS represents a technology for synoptic acquisition of spatial data and the extraction of scene-specific information. GIS provides a computer-implemented spatially oriented database for evaluating the information in conjunction with other spatially formatted data and information that may be acquired from remote sensor data, maps, surveys, and other sources of spatially referenced information.

This article however examines only some of the conventional digital modeling techniques. It describes various procedures and techniques for acquisition, processing, validation, classification and presentation of image and or image data that is compatible with GIS.

1.1 Overview of Satellite

The origin of this new space technology can be traced to the launching of SPUNTNIK-1 on October 4, 1957 by the former USSR. Researchers at the Applied Physics Laboratory, John Hopkins University in the United States (US) who monitored the satellite were intrigued by the substantial Doppler frequency shift of the radio signals from this first artificial satellite orbiting the earth [2]. Every satellite sends data to the receiver in form of signals, having some information about satellite and orbital information.

Consequently, the U.S. developed interest in research into the use of space technology for both military and civil purposes. This marked the beginning of research for global mapping from space which eventually led to the thematic mapping of resources with the use of 80m resolution US-LandSat MSS in 1972 [3]. Further improvement was made with Land-Sat TM in 1982 at 30m resolution. Subsequent higher resolution earth observation satellites were based on camera technology from manned and unmanned space platforms and digital optical sensors. Since the SPOT in 1986, continuous improvements have been recorded on the ground resolutions of satellites (table 1). The suitability of SRS as a mapping tool derives from its characteristics of comprehensiveness, timeliness, repetitiveness, regularity, reduced dependence on weather and improved cost-effectiveness [4].

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Table 1: High Resolution Optical System History

YEAR	SYSTEM	RESOLUTION	IMAGE	REMARK
1968	Corona	3m	Film	Stero
1972	Landsat MSS	80m	digital	-
1982	Landsat TM	30m	digital	-
1983	Metric Camera-SL	10m	film	Stero
1984	Large Format Camera	5m	film	Stero
1986	Spot P	10m	digital	Stero
1987	KFA 1000	7m	film	Stero
1991	KVR 1000	2m	film	TK350 (stero)
1993	MOMS 02	5m	digital	Stero
1996	MOMS 02-P	6m	digital	Stero
1996	IRS 1C/D	6m	digital	Stero
1999	Ikonos 2	1m	digital	Stero
2000	EROS A1	1.8m	digital	Stero
2001	Quickbird	0.6m	digital	Stero
2002	Spot 5	2.5m	digital	Stero
2003	NigeriaSat-1	32m	digital	-
2005	Kompsat	2m	Digital	Stero
2007	IndianSat	0.5m	digital	Stero
2008	Geoeye 1	0.41m	Digital	Stero
2009	DigitalGlobe's World View-2	0.46m	Digital	-
2011	NigSat-2	2.5m	digital	

Source: Modified after [5].

2. BASIS OF REMOTE SENSING

It is often said that a photograph does not lie and it is a fact."Remote sensing" is a method of acquiring information about an object (target) without making physical contact with the object [6]. Information about target characteristics is obtained by measurements using electromagnetic energy (EME). Thus, there must be interaction between a recording device and the object (fig.1). The major medium of contact is the EME either reflected or emitted by such objects. Such EME are collected by a suitable sensing device and recorded in digital or analogue form. By studying the patterns and distribution of such recorded radiation, it is possible to infer the characteristics of such objects in terms of their physical dimension and nature [7].

RS systems were broadly classified into passive and active system. The ***passive type*** of remote sensing is such that sun's energy is the only source of radiation, while the ***active system*** transmits out microwave which are either; reflected, transmitted, absorbed or scattered (fig.1). It can be said that the active system emits pulses of microwave radiation to illuminate the areas to be imaged. Images are formed by measuring the microwave energy scattered by reflection from the target. It is a physical law that all objects having temperature above 0k or -273^{0}C or -460^{0}F radiate EME. This is the physical basis of remote sensing that makes it a viable and reliable tool for earth resources management [7]. This is so because no two distinct targets will have the same spectral signature. Thus, the basis of information extraction (interpretation) in RS [8].

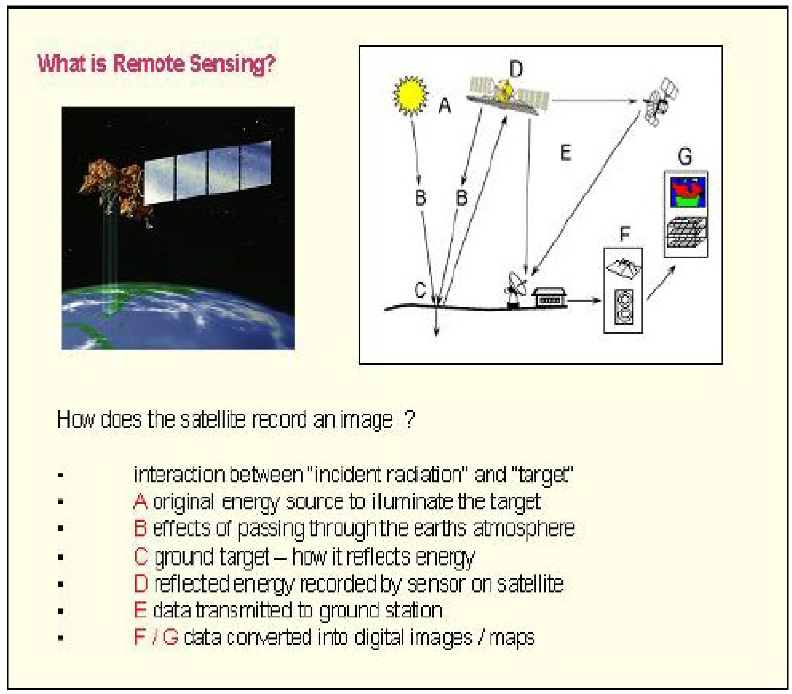

Fig 1: Energy/Object Interaction Mechanism and Remote Sensing Model – Showing the major components. Source: [5]

RS is no longer confined to the visible portion of the EMR. With multispectral scanner subsystem (MSS) image scenes can now be recorded with various wavelengths (fig. 2). Scanners (push/whisk broom) have charge couple device (CCD) for image recording. The CCD is more sensitive than photographic material [9]. Another important instruction associated with image (data) capture in spatial modeling process is the aerial camera and airborne passive sensor (using EMR) and the active airborne sensor (using Radar System). The aerial camera employs light materials (film), to record topo information that is later processed as aerial photos.

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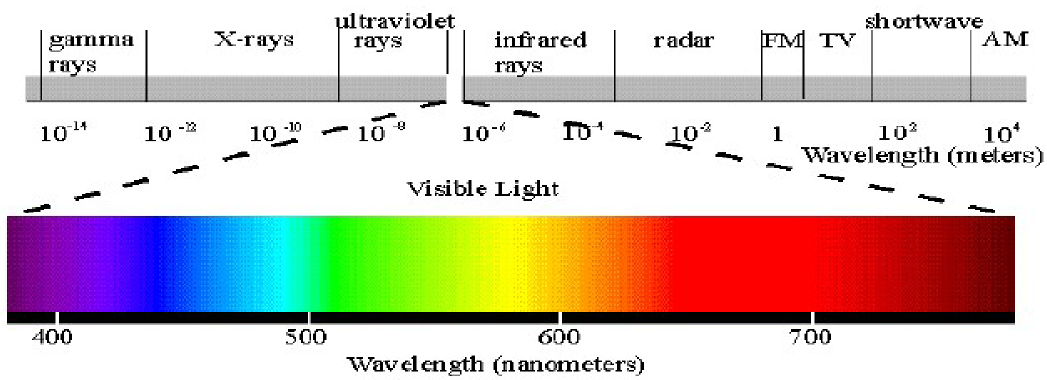

Violet:	0.4	-	0.446µm
Blue:	0.446	-	0.500µm
Green:	0.500	-	0.578µm
Yellow:	0.578	-	0.592µm
Orange:	0.592	-	0.620µm
Red:	0.620	-	0.7µm

Fig 2: The Electromagnetic Spectrum. Source: [5]

The actual difference between the airborne sensor and aerial is that of information recording technology. While the aerial camera uses visible light and sometimes Infra-Red radiation, the airborne sensor employs microwaves [7]. Microwave imaging is wholly associated with digital techniques, because the technology is such that spectral signature portray spatial (topo) information characteristics. These signatures are coded as numeric and relayed to a ground processing station, in case of orbiting imaging satellite where they are decoded as topo images.

Most satellite remote sensing sensors detect EMR electronically as a continuous stream of digital data [5]. The data are transmitted to ground reception stations, processed to create defined data products, and made available for sale to users on a variety of digital data media. Once purchased, the digital image data are readily amenable to quantitative analysis using computer implemented digital image processing (DIP) techniques [6; 10]. Such techniques as: data error compensations, atmospheric corrections, calibration, and map registration, essentially involve pre-processing the data for subsequent interpretation and analysis [9].

Another group of techniques is designed to selectively enhance the digital data and produce hard-copy image formats for interpreters to study. For these images, some of the principles and techniques of air-photo interpretation can be applied to manual analysis of the image information content [11]. A third major group of digital processing techniques involves information extraction through the implementation of a wide range of simple to complex mathematical and statistical operations on the numerical data values in the image. The results of these operations provide output such as derived information variables (that might relate to terrain brightness or vegetation condition), categorized land and water features, or images showing changes over time [12; 8; 13].

3. IMAGE TECHNIQUE AND PROCEDURES

The procedures and techniques for acquisition, processing, validation, classification and presentation of image and or image data that is compatible with GIS will involve:

3.1 Image Acquisition

Images can be acquired using three platforms, namely: Ground based (terrestrial) - e.g. ladder, crane, human hand, house top, etc; Air-borne – e.g. aero-planes, balloons, and

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Space borne – e.g. space shutter or STS. The different between air-borne and space remote sensing is that the air-borne type has sensor mounted in an aircraft, while the space borne may be manned or unmanned. Space borne systems acquire data of the terrain at higher altitude. The ground based images are acquired with sensor or camera mounted on elevated platforms such as tower. Information are extracted from the image data processing, such processing can be manual or DIP that is computer assisted [12; 6].

3.2 Image Processing

Image processing techniques are employed to enhance the image for visual interpretation and to correct (restore) the image where it has been subjected to geometric distortion, blurring or degradation by other factors. Manual or Computer assisted image processing (DIP) could involve the following stages:

- **Manual Processing:** In manual processing the stages include: examination and detection; recognition, identification and classification; and ground or field truthing. In these stages, non-geometric parameters used for image interpretations are employed, such as pattern, shape, tone, shadow, size, location and texture [14; 15; 6].

- **Computer Assisted:**The computer assisted (DIP) entails; Image restoration and rectification (image processing), Image enhancement, and Image classification.

In the process the conventional aerial photographs in panchromatic produce continuous images, scanners record images in bits (digits known as pixel - picture elements). The digital data are encoded in 8-bits and 10-bits of 0-255 and 1024 respectively. In panchromatic (black and white) mode, zero (0) stands for black while 255 stands for white. It means that the graphic voltage (VGA) in a particular hardware can be varied integer-wise to produce 255 range of black to white [14; 13]. On the other hand, Red, Green and Blue (RGB) colours has a total 255-x-3 range of composite colour. If the VGA is varied integer-wise, the result is a 3-x-3 diagonal matrix [6]:

$$\begin{matrix} RGB \\ RGB \\ RGB \end{matrix} \begin{pmatrix} 256 & 0 & 0 \\ 0 & 256 & 0 \\ 0 & 0 & 256 \end{pmatrix}$$

There are four types of analytical image processing namely; point, area, frame and geometric [16]:

- **Pont Processing:** A pixel by pixel operation that alters the digital number (DN) of a pixel in an image due to its original value or location, without consideration to its neighbouring pixels. Point processing includes negative, image brightening or darkening, contrast stretching and thresholding.

- **Area Processing:** A pixel by pixel operation that considers the original value of a pixel in relation to pixels that surround it (neighbourhood). Area processing includes spatial frequency, convolution kernels and spatial filtering.

- **Frame Processing:** A frame processing changes the value of an image based on the value(s) of a pixel(s) in another image. A frame process can be used to overlay images to form new image. This technique can be used to detect any change(s) that has occurred between two or more images of the same place. Therefore, in order to process frame image the following operations will be performed: (i) ***Subtraction*** **–** the difference between the values of pixels in two or more images, and (ii) ***Boolean operation*** **–** such operations as AND/OR/XOR/NOT will be performed to combine the pixel(s) of two or more images.

- **Geometric Processing:** This is carried out by altering the value(s) or location of pixel(s) using geometric calculation or transformation. Operations on images associated with geometric process include: image rotation mirroring, and image translation. Since all satellite images come in raster format [17]. The orientation of the cells (pixels) is determined by the x- and y – axes of the coordinate system. The pixels are always referenced by x, y locations in the map coordinate space and not by a row-column location. Therefore, the process of rectifying a raster image to a camp coordinates or converting a raster image from one geometric projection to another is generally referred to as geometric transformation.

3.3 Image Validation

Images are acquired with errors which are either internal (hardware) or external [5]. These errors includes; variation in satellite altitude, deviation in satellite attitude, velocity variation of satellite, panchromatic effect, earth's

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curvature atmospheric refraction, relief displacement, earth rotation beneath the satellite during imaging, non-linearity in sweep of a sensor's instantaneous field of view (IFOV) and inclination of the satellite orbit to the earth's axis. These errors have been modeled and two methods may be used to identify radiometric and geometric distortion on image that is: ***Mathematical Modeling Method***, and ***Mapping Polynomial Method.***

After these errors (noise) are removed or reduced in image, they are registered, and the registration process involves relating each pixel coordinate in image space to its corresponding coordinate in object space (eastern and northern). This process is used mostly in multi-temporal analysis of satellite images, to identify changes on the ground or for the purpose of overlaying the two images [17]. The process involves: (a) ***Image-to-Map Registration*** **–** this entails addressing each pixel in an image in terms of map coordinate. This process is known as geocoding, and (b) ***Image-to-Image Registration*** **–** entails simultaneous processing of two or more images acquired at different dates or resolutions.

3.4 Image Classification

A process of image features categorising based on their remittance and reflectance to properties (spectral signature). In order words, it is a process of converting semantic information found on the image scene into a thematic map. This thematic map can be combined with other databases of a test area for further analysis and utilization. It is an operation of looking into the image, recognising identifiable patterns in the data and grouping the data into distinct classes [7]. By the use of existing information about the area represented by the image (ground truth or control information) the recorded patterns can be translated into the surface they represent. Digital image classification is a pattern recognition operation that is of two types: **(a)** ***Supervised Classification*** – It involves classification of images using available spectral data to label pixel as being made up of a particular spectral class, and **(b)** ***Unsupervised Classification*** – In this approach partitioning of features is performed by cluster analysis which is used to identify natural grouping of pattern.

3.5 Data Presentation

Remote sensing data must be presented in a format that is user-compatible (according to the desired use). Image-data could be presented in the following formats: maps or graphics, statistical tables (e.g. histogram), and digital data file (DDF). It could also be in form of alpha, numeric, alpha-numeric, and or softcopy/hardcopy formats [5].

4. DIGITAL IMAGE PROCESSING SOFTWARE

Digital image processing (DIP) is the use of computer algorithms to perform image processing on digital images. In this case, the DIP software is the software used for the implementation of the DIP. A software is a collection of instruction (programs) carefully written in a particular computer language and of which controls the hardware [18]. Therefore, a DIP software should be able to make the hardware accept, process, display and or store information approximately to the desired application. For this purpose the software must be able to basically interact with the operating system, device drivers and third party programs or plug-ins [16]. Apart from the libraries that are available in the platform with which DIP software is written. The software should be able to link to dynamic libraries and other resource files provided by the operating system (OS) at run time (fig 3). The dynamic link libraries (DLL) are the engine power of non trivial software such as the one under discussion. The windows DLL contains native application programming interface (API). API is made up of routines (functions) most of which are hardware specific in which an application could call when required. In order words the software should contain modules (sub programs) that deal with OS as well as core application [19; 9].

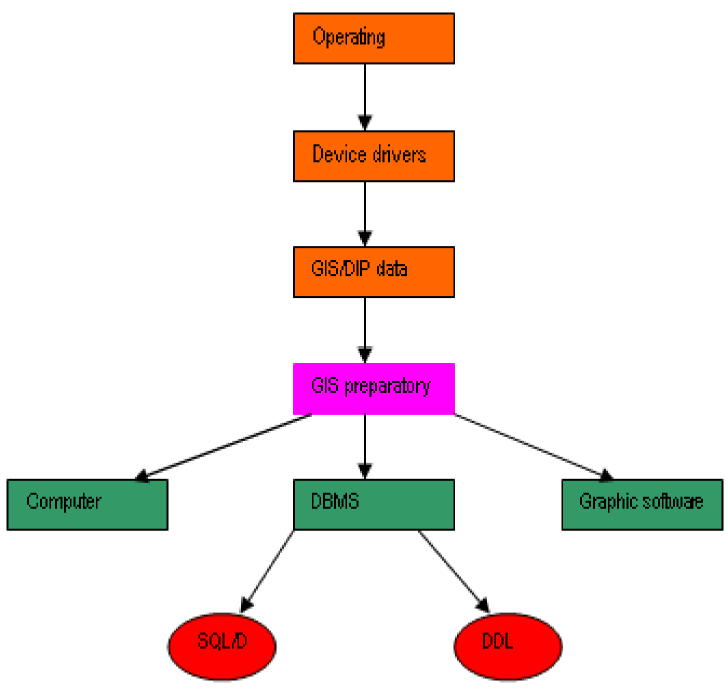

Fig 3: A Typical GIS/DIP Software Architecture Source: [5].

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5. GEOGRAPHIC INFORMATION SYSTEM

A discussion of RS technology would not be complete without the mention of GIS. SRS represents a technology for synoptic acquisition of spatial data and the extraction of scene-specific information. GIS provides a computer-implemented spatially oriented database for evaluating the information in conjunction with other spatially formatted data and information that may be acquired from remote sensor data, maps, surveys, and other sources of spatially referenced information. The concept of spatial data integration in a GIS is well described by [20] and [21]. Thus, [22] defined GIS as a system of computer hardware, software, and peripherals designed to support the capture, management, manipulation, analysis, …, and display of spatially referenced data for solving complex planning and management problems. [5] contends that, this definition can be debated for want of exhaustiveness over time, as successes recorded since the inception of GIS, qualifies its features as being good potential for the application of object 'oriented' non spatial reference database. [9] noted that GIS is no longer a tool for specialists. This is because in recent years, developments of the user-friendly interface, powerful and affordable computer hardware and software, and public digital data have brought GIS to mainstream use.

[23] asserted that GIS comprises of a set of sophisticated technology made up of four major components as; data input (capture), data storage and retrieval, data manipulation and analysis, data reporting (display) subsystems. Depending on the design of a particular GIS, a complete GIS module with the necessary subsystem could still be a part of a networked GIS. In this case, part(s) of the network is dedicated to a particular task. In its simplest form, a GIS may be viewed as a database system in which most of the spatially indexed, and upon which a set procedures operates in order to answer queries about entities in the database. In its professional context, a GIS may be viewed as being made of the following five sub-systems: data encoding and input processing, data Management, data retrieval, data manipulation and analysis, and data display. The order of listing is indicative of the procedural steps or operational modalities inherent in existing GIS software packages [24].

6. CONCLUSION

This article has described some of the basic techniques of image-data modeling process. These methods range from image-data acquisition to modeling in digital image process. It describes various procedures and techniques for acquisition, processing, validation, classification and presentation of image and or image data that is compatible with GIS. Satellite remote sensing represents a technology for synoptic acquisition of spatial data and the extraction of scene-specific information. GIS provides a computer-implemented spatially oriented database for evaluating information in conjunction with other spatially formatted data. Such information may be acquired from remote sensor data, maps, surveys, and other sources of spatially referenced information.

REFERENCES

[1] Encarta Encyclopedia, 2007, Microsoft Encarta Encyclopedia, Standard Edition, 2007.

[2] J.O. Ehiorobo, 1998, *"Global Satellite Systems and their Impact on High Precision Engineering Surveys Resources Exploration and Management*". Private Communication.

[3] J.O. Akinyede, and R.A. Boroffice, 2003, *"Geoinformation, Space Application and Sustainable Development"*. A paper presented at the 38th AGM of NIS at Lokoja, May, 2003.

[4] S.O. Ihemadu, 1997, *"Impact Expectation of Current Satellite Surveying and Aerial Mapping Practices in Flood and Erosion Monitoring and Control"*. Paper presented at the NIS 32nd AGM and Conference, Uyo, 7th-9th May 1997, page 58.

[5] C.G. Eze, 2008, Application of Remote Sensing and GIS for Creation and Management of Enumeration Areas in Enugu State, Nigeria. PhD Dissertation Submitted to the Department of Surveying and Geoinformatics, Nnamdi Azikiwe University, Awka, Nigeria.

[6] K.N. Ndukwe, 1997, *Principles of Environmental Remote Sensing and Photo Interpretation*. New Concept Publishers, Enugu, Nigeria. 278pp.

[7] J.B. Olaleye, 1998, *Data Acquisition by Remote Sensing Method*, In: Ezeigbo CU, (Ed). Principles and Applications of Geographic Information System, Panaf Press (Nig), Bariga, Lagos. Pp 90-104.

[8] J.I. Igbokwe, 1996, *Mapping from Satellite Remote Sensing*, EL'DEMAK Publishers, Enugu.

International Journal of Science and Technology

http://www.ejournalofsciences.org

[9] K. Chang, 2007, Introduction to Geographic Information Systems, Fouth Edition. McGraw-Hill Publications, a business unit of the McGraw-Hill Co.

[10] Sabins, 1987, Digital Image Processing in Remote Sensing Principles and interpretations.

[11] T.M. Lillesand, and R.W. Kiefer, 1987, Remote Sensing and Image Interpretation. John Wesley & sons, New York, 2nd Edition.

[12] P.R. Wolf, 1983, Elements of Photogrammetry McGraw-Hill Book Company, New York. 2nd Edition.

[13] K.N. Ndukwe, 2001, Digital Technology in Surveying and Mapping: Principles, Applications and Legislative Issues. Rhyce Kerx, Publications, Enugu, Nigeria. 250pp.

[14] R.O. Onyinloye, 1993, Handbook on Digital Image Processing. Unpublished Lecture Notes, Regional Centre for Aero-Space Survey (RECTAS), Ile-Ife, Nigeria.

[15] E. Amamoo-O'tchere, 1991, *"Remote Sensing Materials for Census Cartography"*. Paper Presented at the ECA Sub-regional Training Workshop on Census cartography. RECTAS Ile-Ife, Nov 11-12.

[16] A.A. Adeoye, 2001, Geographic Information Systems – Operations and Management. Information Mgt Consultant, Lagos, Nigeria.

[17] J.I. Igbokwe, J.C. Ojiakor and M.N. Ono, 2004, *"Georeferencing for Satellite Mapping in Natural Resource Management"*. Paper presented at the NIS 39TH AGM and Conference, Port-Harcourt, 4th – 7th May 2004, pp 34-40.

[18] AutoCAD SQL Extension, 2000, Reference Manual. Autodesk, Inc. Publication May, 15th 2000.

[19] T. Pavlidis, 1982, Algorithms for Graphics and Image Processing. Spring-Varilag, Berlin.

[20] ESRI, 1992, Environmental Systems Research Institute 1992 Report on the Potential Application of Geographic Information System and Environmental Information System.

[21] M.F. Worboys, 1998, Geographic Information System: The Computing Perspective. Taylor and Francis Publications. 376pp.

[22] UN/ECA, 1994, United Nation Economic Commission for Africa, 1994. *"A Framework for the Establishment and Utilisation of National Geographic Information Systems"*.

[23] D.F. Marble, 1984, *"GIS: An Overview"* Proceedings of Pecoras Conference, Sioux Falls S.D.

[24] O.O. Ayeni, and O.S. Adewale, 2001, *"A Geo-referenced Information System for Population Management"*. International Conference on Spatial Information for Sustainable Development, Nairobi, Kenya. 2-5 October 2001