SPATIAL DATA MODEL FOR REGIONAL INTEGRATION IN AFRICA

Dr. Christian U. EZEIGBO, Nigeria / Kenya

Key words: data model, integration, geo-referencing, technologies.

ABSTRACT

Two standard spatial data models, object-based and field-based data models are considered relevant to the regional integration in Africa. The spatial data type and the model would in general depend on the level at which the integration is envisaged. However, the realization of the relevant data model will only be possible if a unified geodetic reference system is established in the continent.

1. INTRODUCTION

For many decades, African leaders have tried to establish and maintain some degree of cooperation among African countries at different levels. Quite recently, at the last conference of African heads of states, such efforts have resulted in the resolution by the Heads of states, to transform the Organization of African Unity (OAU) to African Union, in line with the European Union. Co-operations at regional levels, such as the East African Community, the Economic Community of West African States (ECOWAS), etc., also exist. The goals of these co-operations, no doubt, have always been, to identify and pursue areas of common interests for the social and economic benefit of the peoples of those regions. To what extent these goals have been achieved, or have been pursued with commitment, is not the subject of this paper. Instead, we want to consider one of the basic requirements for the success of such integration. In this regard, we will be considering the role of spatial information towards the success of the regional integration in Africa. We shall be interested in the availability of spatial data types relevant to the goals of the co-operation, their management and application to regional projects. We shall also be looking at the appropriate models of such spatial data and their contributions to the successful execution of the projects. The issues of relevant technologies and the geodetic framework required for successful execution of such projects are also analyzed critically.

In the next section (section 2), we shall consider the definition and specification for the required spatial data. In section 3, we outline the concept of spatial data modelling. Section 4 deals with modelling approach for the regional integration. Section 5 looks at the spatial data type required for successful implementation of the projects. In section 6, we consider the issue of technologies needed for the spatial data modelling. Section 7 examines the geodetic framework needed in the spatial data acquisition. Section 8 considers the expected benefits and problem areas. In sections 9 and 10, we make our conclusions and recommendations.

2. DEFINITION AND SPECIFICATIONS OF THE REQUIRED SPATIAL DATA

Spatial data, in a broad sense, imply all objects in space in which some interests are attached, or as Worboys (1995) puts it: Spatial objects are called "spatial", because they exist in space, called embedding space. Without delving into the realms of abstract space, defined as "a relation defined on a set of objects (Worboys, 1995)", we shall understand space to mean the physical space, that is, the Euclidean space, in which we exist and carry on our regular activities. In this space, we are able to develop conveniently our sense of distances and directions. It is called the Euclidean space or the "co-ordinatized" space. In it, we are able to transform properties of objects, such as positions, distances, areas and volumes into properties of tuples of real numbers (x, y, z), which are amenable to digital processing. Hence, by setting up a co-ordinate frame, consisting of a fixed point, called the origin of the co-ordinate frame, and three orthogonal axes, which intersect at the origin, we are able to refer all objects in this space to the co-ordinate frame. See Figure 2.1 below. Objects so referenced are called spatially referenced objects.

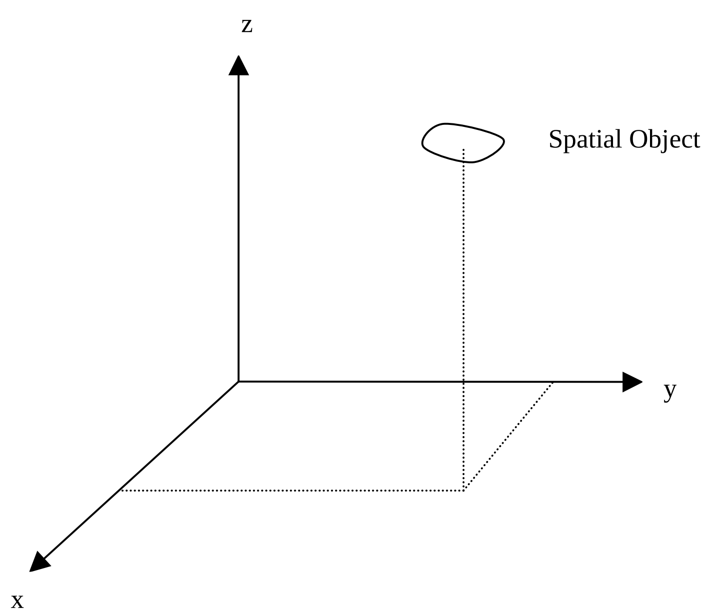

Fig. 2.1. Referencing Spatial Objects

When this co-ordinate frame is earth-based, objects referred to it are said to be geo-referenced. The objects that will be of interest to us in this paper belong to this group. These objects will include: geodetic control networks, infrastructures, natural resources, international and administrative boundaries, human settlements, digital terrain models, industrial establishments, environmental projects, and geodynamic phenomena, etc. The relevance of particular spatial data, and the specific data model to the various co-operation arrangements will be dealt with in the later sections of this paper. It is however pertinent to note that the type of spatial data and the required data models will depend on the level of co-operation desired in each regional grouping and the specific interests of the participating members of the group.

3. THE CONCEPT OF SPATIAL DATA MODEL

A model is an artificial construction in which parts of one domain (source domain) are represented in another domain (target domain) Worboys (1995). The transformation is achieved by means of structure-preserving function, called morphism, The constituent of the source domain may be entities, relationships, procedures, or any other phenomena of interest. An alternative definition, which agrees well with the present application, is by Kufoniyi (1998), who considers a model as a representation of human conceptualization of reality. The view of reality is represented in a simplified manner, which still satisfies the information requirement of the user. A data model is thus defined as an abstraction of the real world data that incorporates only those properties of the data considered relevant to the application at hand. A spatial data model is therefore a data model of information with spatial components.

Spatially referenced information may be modelled using either field-based or object-based spatial data modelling approach. These are methods of imposing structures and patterns on spatial data for convenience of operations. The field-based spatial data modelling approach treats the information space as a collection of fields; where each field is a function from a spatial framework to a finite attribute domain. A spatial framework is a partition of a given region into a finite tessellation of spatial objects called locations. Figure 3.1 below shows the spatial framework A, consisting of 6 locations; and the attribute domain B, consisting of three fields (f_i, i=1, 2, 3). For instance, if we take the spatial framework to be the African continent, the distribution of banking services, hotels, or weather conditions within the various countries in the continent will constitute the fields. That is, each field maps each country to the number of banks, hotels, or weather condition within that country. The spatial fields here will be the variations in the distributions of the bank and hotel facilities as well as weather conditions, with the countries in the continents as spatial locations, while the function values are the number of banks, hotels, etc. As can be expected, the spatial framework will always be a finite structure, while the target domain may not be finite, or may be too large for practical purposes. In such a case sampling is adopted with its inherent problems.

On the other hand, the object-based spatial data modelling approach treats the information space as being populated by discrete, identifiable and relevant entities, each of which is referenced to the given co-ordinate system (Worboys, 1995). The underlying space, as we have seen, is the Euclidean space and each spatial object is specified by a set of co-ordinates, or rules (formulas), to compute the co-ordinates. See Fig. 3.2. A process of discretization will often be required to convert continuous or infinite functions to computationally tractable functions. The object-based approach is preferred over the field-based approach in most applications because of its economy of memory requirement. In our model, the objects may be the countries in the continent, cities and districts in a particular country, whose attributes could be; the number of airports, banks and hotels, as well as the international and administrative boundaries, etc. In general, the appropriate data model for the co-operation at continental level and some of the regional groupings, is the object-based data model, where large portions of spatial locations in the framework are often sparsely populated.

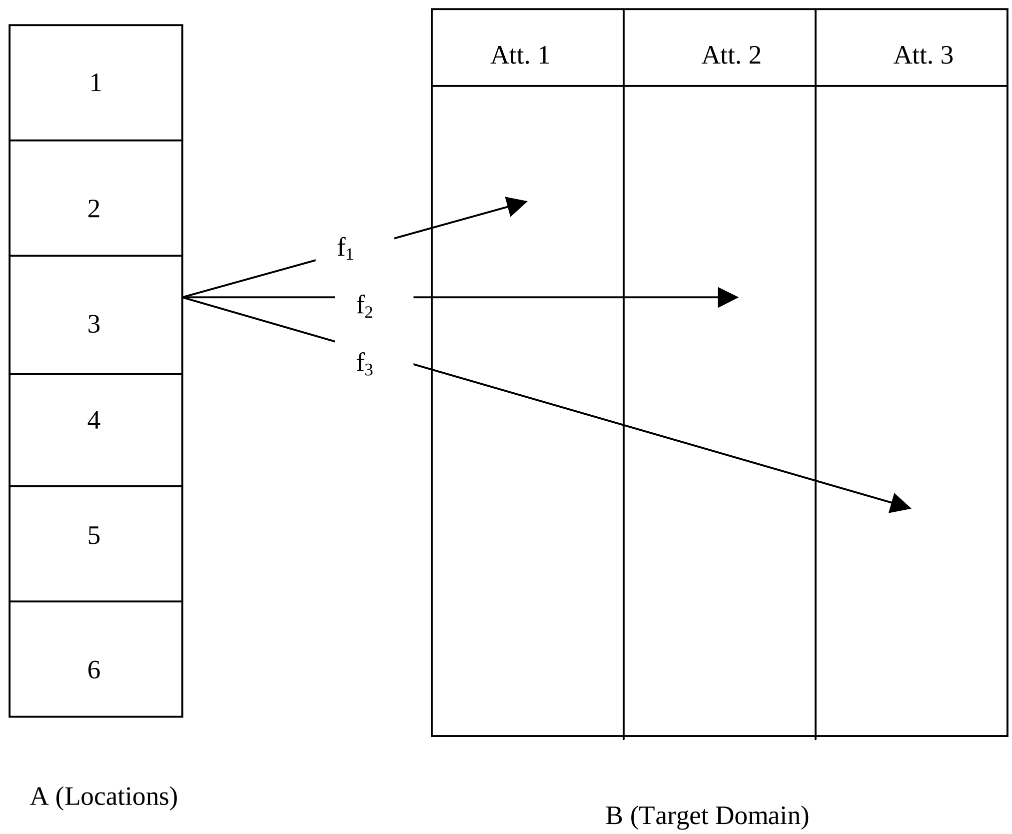

Fig. 3.1: Field-Based modelling

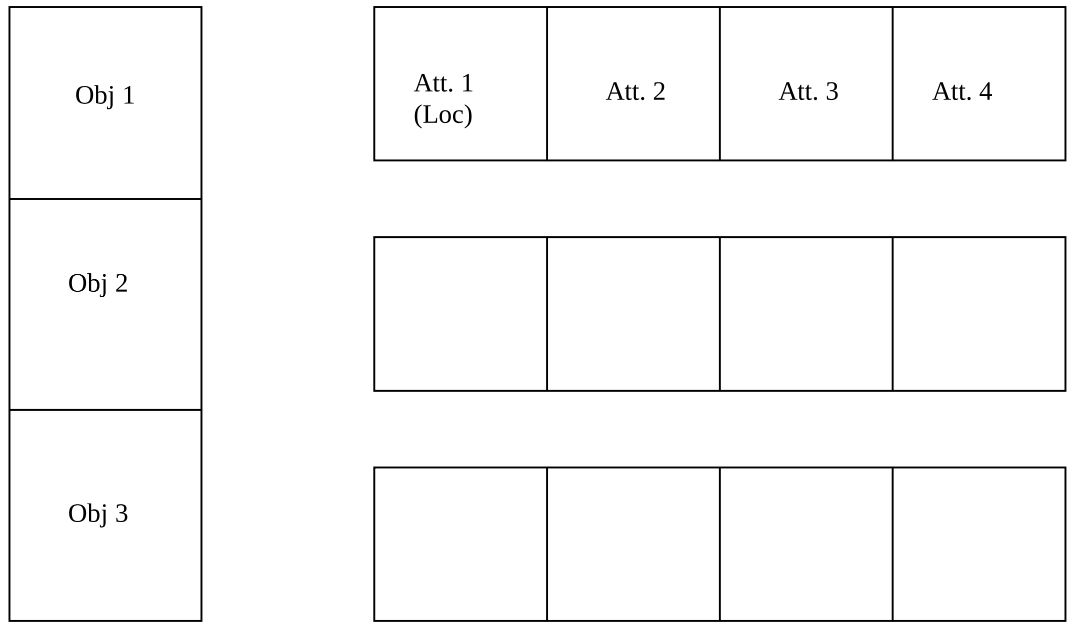

Fig.3.2. Object-based modelling

4. MODELLING APPROACH FOR REGIONAL INTEGRATION

We recall here, for easy reference, the definition of a model. A data model is an abstraction of the real world data, which incorporates only those properties of the data, considered relevant to the application at hand. Based on this definition, the spatial data models for the integration at the continental level would concern data of a general and global nature. For instance, it would be sufficient to know the number of international airports in member countries; their distribution, flight schedules and safety standards. It would not be necessary to include information on local airports. The reason of course is that transactions at that level may often end at the major cities, where the international airports are usually located. Again, we consider hotel services, or climatic conditions. At the continental level, we would be interested in international and top standard hotels and mean climatic conditions in the respective countries. On the other hand, if we are dealing with sub-regional groupings, detailed information on hotels and weather conditions, down to the rural communities, would be needed. We might in addition be interested in cultural and farming activities, among others.

Therefore, the two principal conceptual modelling procedures would be relevant to the design and implementation of spatial databases for regional and sub-regional integration in the continent, depending on the level of co-operation envisaged. As a general rule, the object-based model would be applicable to spatial data for integration at continental level, where spatial distribution of information is not required in great details. On the other hand, for sub-regional groupings, field-based model would be an ideal choice.

5. SPATIAL DATA TYPE FOR REGIONAL INTEGRATION

The choice of spatial data type for regional integration will depend on the level at which the integration is considered and the preference of the groups concerned. However, some general guidelines will be appropriate here. At the continental level, and for policy makers, a representative data type will often be sufficient. In cases of sub-regional groupings, where closer interactions between individuals in those communities are required, there will be a need for more detailed information. The following data types will often be required at different levels of generalization, depending on the level of cooperation considered. They include:

(i) Locations and grades of airports
(ii) Locations and facilities of seaports
(iii) Highways
(iv) Railways
(v) Banking and hotel facilities
(vi) Postal and Telecommunication services
(vii) Health and educational facilities
(viii) Power and energy supplies
(ix) Major cities and commercial activities
(x) Major recourses and industries
(xi) Tourism and cultural activities
(xii) Data on climate and environment

A database of these data types together with relevant attribute model, which will include position information, will be created. From the database, digital maps, and as the need arises, hard copies of these maps, providing instant information concerning any of the required services will be produced. As we indicated earlier on, the data type above will in general serve the different levels of co-operations, but at different levels of generalization, and of course the preference of the groups involved. It is the level of cooperation and the preference of the groups that will determine the emphasis on the data types to be included. For instance, a cooperation that is limited to cultural activities may not require detailed information on industrial activities.

6. THE ISSUE OF TECHNOLOGIES

The relevant technologies, such as Global Positioning System (GPS) and Geographic Information Systems (GIS), which are crucial to the establishment and management of spatial information system for the regional co-operations are already available in the continent. There are also many people who are quite conversant with the operations of the GPS and GIS tools. Unfortunately, every aspect of these technologies has to be procured at exorbitant prices from outside the continent. As Coleman (1998) succinctly put it: "rather than crawl up the same learning curve, new users in the developing nations (*mainly African nations*) understandable wish to take advantage of the most advanced and effective systems obtainable through their lines of credit". The Italics are mine.

This unhealthy approach to the application and utilization of new technologies has remained with the continent for many decades. Instead of contributing to the development of technologies she needs, the continent is contented with the habit of spending her non-existent lines of credit in buying the products of technologies, which, more often than not, have left her in worst conditions. If we take the case of satellite positioning, which has been with us for over three decades, it becomes obvious that our approach to the issue of new technologies leaves much to be desired. One of the objectives of the African Doppler Survey (ADOS) project, which was initiated by the international Association of Geodesy (IAG) in 1981, was to enable the continent establish a common geodetic datum for the continent (Mueller, 1982; Ezeigbo, 1994). This project was completed in 1986(ADOS, 1987). Fifteen years after the project was "completed", neither the datum nor a unified geodetic network for the continent has been realized.

From Doppler to GPS, geodetic networks remain undeveloped. GPS is said to have attained unprecedented level of accuracy. We have not benefited from such an opportunity, instead, most countries in the continent rely on datum information provided by the instrument manufacturers as the answer to their datum problems. It is appropriate to pause here, and ask our-selves some pertinent questions. What would happen to the projects which depend on these technologies, if the technologies were withheld from the continent for whatever reasons? The answer of course, is that we would be completely grounded. We have not been able to produce any of the software let alone the hardware needed in the implementation of the project. It is therefore right for us to assume that the technologies for this integration are not really in place, and hence, start to address the problems.

7. GEODETIC FRAMEWORK AND SPATIAL DATA

Geodetic framework is a basic infrastructure in the development of a reliable spatial data model (Ezeigbo, 1990a). At the moment, hardly any country in the continent can boast of a well-defined geodetic datum for her geodetic operations. The determination of a common datum for the continent to which the said spatial data can be referred is therefore a priority project. This is because a common datum has to be established first to assist in collecting consistent spatial data to develop a spatial database to manage spatial information for the regional integration. For instance, a common datum will be required in handling joint projects, such as, the boundary issues, construction of international highways, railways, etc. The production of accurate maps to aid the planning and execution of joint projects among African states will require a well-defined common geodetic datum for the continent. However, before a common geodetic datum for the continent could be realized, the problem with the individual geodetic networks in the continent must be addressed. For instance, over half a century after the Nigerian triangulation network was observed, the country is still living with provisional coordinates and sizeable distortions in the geodetic networks (Ezeigbo, 1990b). In Kenya, a provisional mapping arrangement, called Preliminary Index Diagrams (PID), adopted at the independence to handle a peculiar problem, has remained with the country for nearly four decades after independence (Mulaku, 1995). Worse scenarios abound in many other African countries. There is, therefore, the need to solve the geodetic framework problem in each country in the continent as a prelude to the determination of a common geodetic datum required in the spatial data model for the integration.

8. ENVISAGED BENEFITS AND THE PROBLEM AREAS

The establishment of spatial information system for regional co-operations among African countries holds many potential benefits for the people of the continent. Such benefits will include the promotion of tourist industry in the region. This will be assured by the provision of the information on cultural and recreational facilities, transport infrastructure and hotel accommodation in the region. Furthermore, by providing resource inventories and agricultural and industrial potentials of the continent, business activities in the region will receive a boost. The possibilities of realizing such a noble objective at the moment are quite slim, going by the internal and external crisis tearing the continent apart. There is a great deal of mistrust among African leaders, leading to lack of genuine commitment to the growth and development of the continent. Even if the political will is there, the necessary geodetic framework and relevant technologies are of course not there.

The determination of a common geodetic datum, as a first step in the establishment of spatial database, is an expensive project. A continent with the level of poverty experienced by her people, occasioned by mismanagement and technological backwardness is ill equipped to fund such an expensive project. Furthermore, since every bit of the technology required is imported from outside the continent at great expense, maintenance will also be a serious problem as has always been in the past. The chances are there, that the project may be started, but may not reach a successful completion.

9. CONCLUSIONS

Two conceptual data modelling approaches, namely, object-based and field-based, with the object-based model playing a more prominent role, have been identified as being relevant to the establishment of spatial information system, required in the regional integration in Africa. A list of sample data types has also been identified. The major factors militating against early realization of the project are of scientific and economic nature. The absence of a unified datum for geodetic networks, coupled with lack of the right technological culture in the continent compounds our problems. These problems have to be addressed before any meaningful results could be expected in the direction of the proposed integration.

10. RECOMMENDATIONS

Two crucial issues need to be tackled in an effort to realize a spatial information system for regional integration in Africa, namely:

(a) African nations must change from the current habit of merely consuming products of technologies to actively contributing to the development of these technologies. Then it will be possible for the continent to develop and maintain the required spatial information system for the integration.

(b) Each country in the continent must, as a matter of urgency, solve her geodetic network problems, so that the unification of geodetic network for the continent would become a reality.

REFERENCES

1. ADOS(1987): "African Doppler Survey(ADOS)", Proceedings of Int. Geodetic Symposium on Satellite Doppler Positioning, New Mexico State University, Los Cruces, New Mexico.
2. Coleman, D.J.(1998):"Academic Geomatics into the twenty-first century: A north American perspective.", Geomatica, Vol. 52, no.1, pp 11-24.
3. Ezeigbo,C.U.(1990a): "A Doppler satellite-derived datum for Nigeria.", Acta Geod. Geoph. Mont. Hung., Vol. 25(3-4), pp.399-413.
4. Ezeigbo,C.U.(1990b): "Nigerian geodetic networks- The control question", The mapmakers, Vol.25(3-4), pp 399-314.
5. Ezeigbo,C.U.(1994): "On the choice of a suitable datum for a unified geodetic network for Africa.", South African Journal of Surveying and Mapping, Vol. 22, part 6, pp385-392.
6. Kufoniyi,O.(1998): "Basic concepts in GIS", in Ezeigbo, C.U.(1998)ED: *Principles and applications of Geographic Information Systems*, Series in Surveying and Geoinformatics, Department of Surveying, Unilag.
7. Mueller, I.I.(1982): "African Doppler Survey(ADOS)", Proceedings of Int. Geodetic Symposium on satellite Doppler positioning, New Mexico state University, Los Cruces, New Mexico.
8. Mulaku, G.C.(1995): "Concept for preliminary index diagrams improvement", PhD thesis, University of New Brunswick, Canada.
9. Worboys, M.F.(1995): "*GIS: A computing perspective*", Taylor & Francis Ltd, London.

BIOGRAPHICAL NOTES

C. U. Ezeigbo is a visiting professor at the Department of Surveying, University of Nairobi, Kenya. He is on sabbatical leave from University of Lagos, where he has been with the Department of Surveying and Geoinformatics for the past 24 years. In 1991/92, he spent 7 months of this with the Department of Surveying, University of Nairobi, as his first visit to the University, under the UNESCO visiting staff fellowship. Before he joined the services of the University of Lagos in 1977, he had worked as a field officer with the Federal Surveys Department, Lagos for about 7 years. He graduated from University of Nigeria in 1971 with BSC(Mathematics), and obtained his MSC and PHD degrees in Surveying from University of Lagos. He is a member of International Association of Geodesy(IAG) and Nigerian Institution of Surveyors(NIS).

CONTACT

Prof. Christian U. Ezeigbo
Department of Surveying
University of Nairobi, P.O. Box, 30197 Nairobi, KENYA; or
Department of Surveying and Geoinformatics
University of Lagos, NIGERIA
Email: chrisezeigbo@yahoo.com