NEW DATA STRUCTURE MODEL FOR DIGITAL CARTOGRAPHIC DATABASE

Dr. Ing. Vishit SATHARANOND
Topographic Survey Division, Royal Irrigation Department
Thailand
Commission IV

ABSTRACT

Digital Cartographic Database is one of the subject that had been discussed in almost every international conferences where cartography is is involved. Many researches and experiments were carried out in several mapping organizations and institutes but the result came out unsatisfactory. The difficulties are due to the lack of powerful model for data structuring. Therefore important informations like topology and non-cartography are lessly incorporated in most of operational cartographic database.

The Hypergraph-Based Data Structure (HBDS) is a new model that enables users to incorporate any types of information into the database. The database is dynamically extensible, easy to manipulate and independent from the storage structure and the computer concept.

INTRODUCTION

It is almost unbelievable that the computer technology will go as fast. We are now approaching the 5th generation computer where the world will be mostly computerized. This include of course cartography which is at present being developed. Though the computer hardware is fantastically developed, the computer software specifically a powerful database management system is not yet at the same speed. Existing data structure models like hierarchy, network and relational provide incomplete structure of sophisticated information particularly in cartography. This is due to the fact that the cartographic phenomenon is composed of various complex informations which are densely related. To structure this phenomenon, it is essential that a powerful data structure model is needed.

The Hypergraph - Based Data Structure model, proposed by Prof. Dr. Francois BOUILLE (BOUI 77), University of Pierre and Marie Curie,Paris, France has been considered as a universal model for data structuring. Those three existing models appear as sub-structures of this new model and since it is defined from the mathematical basis it is capable to express entirely the relationships between data. Therefore it is believed that the HBDS model will be the one we are looking for realizing our digital cartographic database.

SHORT RECALL OF HBDS CONCEPT

HBDS is a topological data structure model which based upon the set theory and the hypergraph concept. According to the set theory, a set is composed of elements that have properties and that can form relationships with other elements of the same or of another set (BOUR 39). If we represent elements by points named vertices and relations by arcs we may represent graphically the definition of the set theory by Figure 1.

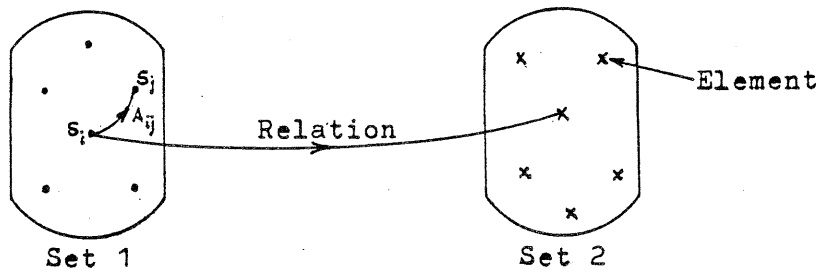


Figure 1

Now looking to the vertices S_i , S_j and the arc A_{ij} , if we put an arrow on the arc A_{ij} we may define using the graph theory that the vertex S_i is related to the vertex S_j by an arc A_{ij} in a direction starting from S_i to S_j . This graph is called a directed graph and defined as follow:-

$$G = \langle S, A \rangle \quad , \quad S = \left\{ S_i \right\} \quad , \quad A = \left\{ A_{ij} / A_{ij} = (A_i, A_j) \right\} \in S^2$$

There are still some more types of graphs. For example, if an arc A_{ij} is always associated with another arc A_{ji} in a reverse direction we called a directed symmetrical graph (Fig. 2a). If between the two vertices, there are more than one arc joining, the graph is called a multigraph (Fig. 2b). Each vertex as well as each arc may carry a valuation (Fig. 2c). The number of valuation may be from one to many. In case of one valuation, the graph is called valued graph and in case of many valuations it is called multivalued graph. If the graph is a multigraph, it is called a valued multigraph and a multivalued multigraph respectively.

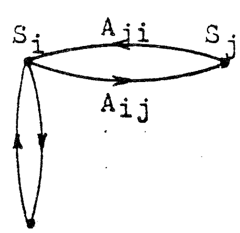


Figure 2a

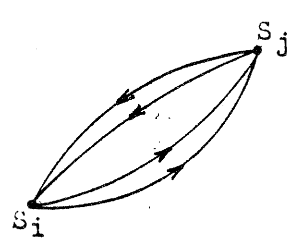


Figure 2b

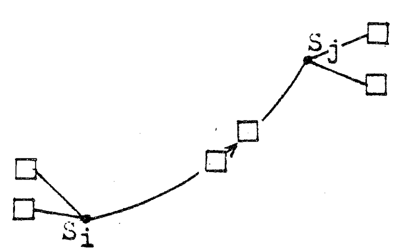
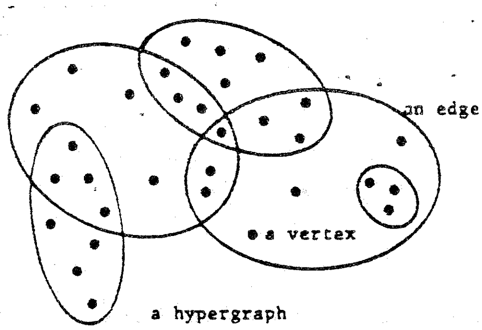


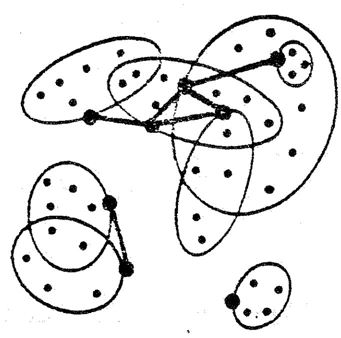
Figure 2c

The graph concept may use successfully to define relation between elements but not between the sets. In 1970, C.BERGE (BERG 70) had introduced the hypergraph concept which is nothing else but the generalization of the graph concept. The definition is that on the vertices S_i of the set of vertices S , we build parts P_k . Each part denoted by a line, called an edge, surrounding the vertices belong to the part defining that it is grouping all elements that have the same properties. Now we consider the set P of parts P_k and the set S of vertices S_i , the hypergraph H is defined as:-

$$H = \langle S, P \rangle \quad , \quad S = \{ S_i \} \quad , \quad P = \{ P_k \}$$

The different parts may have common elements corresponding to the intersection of edges. This aspect is represented by the so-called "Representative Graph of Edges of the Hypergraph"





the Representative Graph of the Edges of the Hypergraph

Figure 3

With the help of the graph and hypergraph concepts, we may easily represent in graphic form the entire structure of any phenomenons, no matter how complex it may be. Further, we know that there are four fundamental components in the set theory namely: set, element, property and relation. In HBDS these four components had been respectively named: class, object, attribute and link and are called abstract data types (LISK 74). Link is nothing but a representation of a relation by an arc. Figure 4 shows the graphical form of the four components.

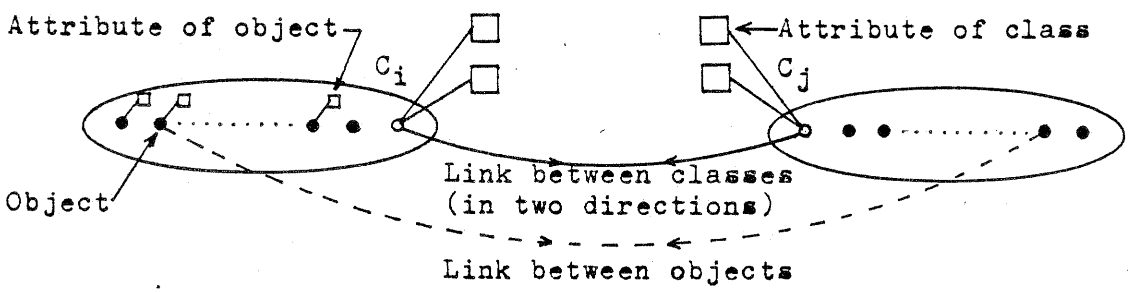


Figure 4

From the figure 4, we see that four components are not enough to express complete structure of any phenomenons. Therefore, two more abstract data type are designated, namely; attribute of object and link between objects. thus there are together six basic abstract data types in HBDS: class, object, attribute of class, attribute of object, link between classes and link between objects.

HBDS is made of two parts corresponding to two substructures: hierarchized and non-hierarchized.

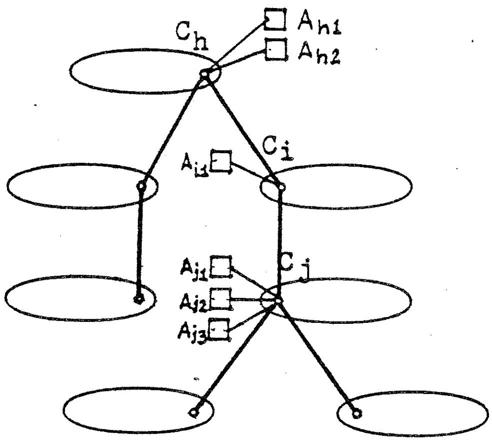


Figure 5

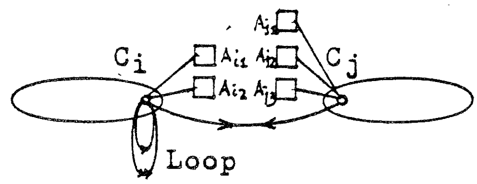


Figure 6

In case of hierarchy (Fig.5), a class may have one upper class called "Predecessor" and one or several lower classed (or none) called "successors". The attribute of each class is composed of its own and all attributes of all its classes predecessor. For example:-

$$\text{Attribute of class } C_j = (A_{h1}\ ,\ A_{h2})\ ,\ (A_{i1}),\ (A_{j1},\ A_{j2},\ A_{j3})$$

Therefore care should be taken to consider any hierarchized sub-structure such that no duplication of attribute is possible. Further there exists only two type of relations namely: predecessor and successor represented in the figure by solid straight line.

In case of non-hierarchy (Fig.6) each class like C_i may join to another class, for instance C_j, by one or several arcs called link(s) carrying valuation(s) which is (are) relation(s). If the link is going out and come back to the same class it is called "loop" verifying the relation between objects in the same class.

These two sub-structures will enable us to define a global structure of any informations. The obtained graphical representation composed of classes, attributes of classes and links between classes called the "skeleton structure" will visualise how the data are related. All data to be manipulated must correspond to this structure only strange data will be immediately rejected by the system.In some case the built-in skeleton structure may be over crowded and difficult to visualise due to the complexity of concerned phenomenon. HBDS had extended in that case several new components called: hyperclass, hyperlink, hyperattribute, multilink and hypermultilink which will reduce the overcrowded problem into visualisable structure again (Fig.7)

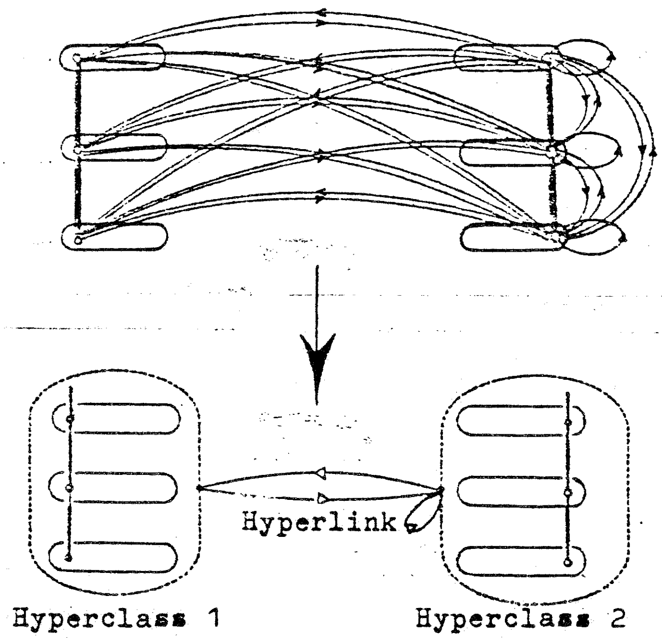


Figure 7

This is only short recall of the HBDS concept, more details may be founded in (BOUI 77).

STRUCTURING CARTOGRAPHIC DATA WITH THE HBDS MODEL

As it had been mentioned earlier that the cartographic phenomenon composed of various complex informations. Therefore, it is impossible to present it all here, only some of them will be shown in order to give an idea how these informations may be easily structured using the HBDS model

STRUCTURE OF OROGRAPHIC PHENOMENON

The structure of the orographic phenomenon may be recognized by the following example (Fig. 8a,8b).

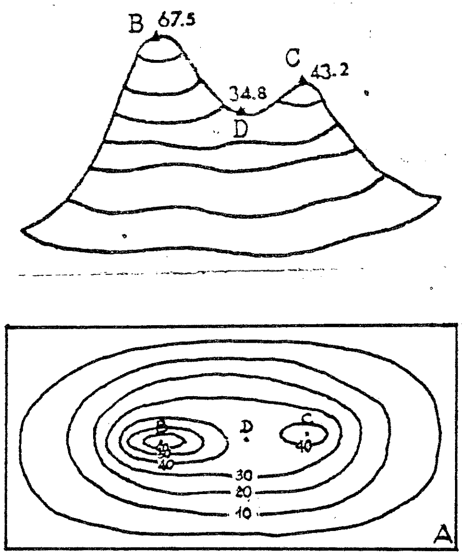


Figure 8a

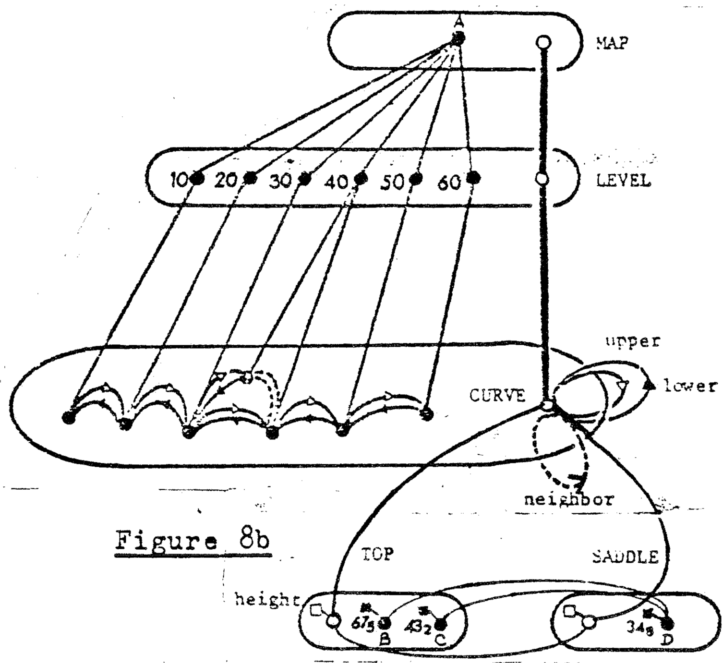


Figure 8b

Let A be an orographic map containing four isolines, two tops B, C and a saddle D. Each isoline has three kinds of possible topological relationships to others which may be: of upper height, of same height (then a neighbour) and of lower height (Fig. 8a). The topological structure of this orography is represented by a set of five classes: MAP, LEVEL, CURVE, TOP, SADDLE (Fig.8b). The first three classes are hierarchized. The class CURVE carries three loops materializing the three mentioned relationships between curves. The metrical aspect (i.e. coordinate x, y, z) comes only in form of the attribute named "COORDINATE" carried by the class CURVE and it is a numerical bidimensional array corresponding to a series of coordinates of auxiliary points issued from the digitisation phase.

STRUCTURE OF NATUREL AND ARTIFICIAL DOMAINS

Naturel and artificial domains delimited by topological boundaries like area of village, town, forest, cultivation, etc., may be assimilated to a direct graph (BOUI 73) as shown on Figure 9.

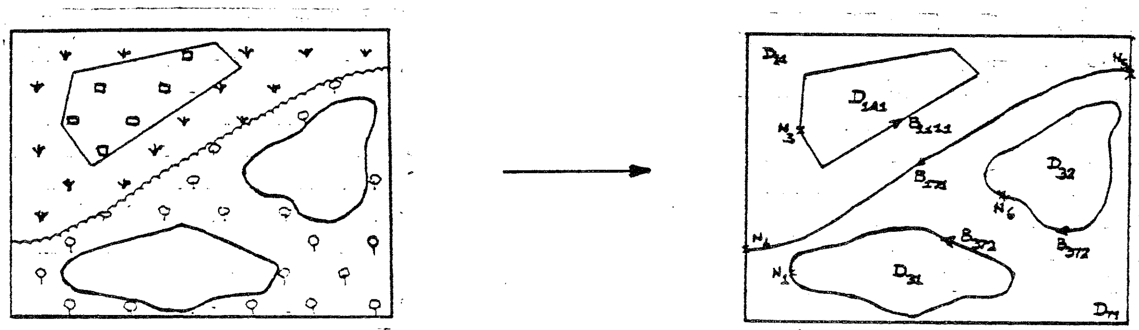


Figure 9

At the right hand figure, an arc is associated to the boundary of each domain. Different types of domain are distinguished by using different codes says, D_{im} where i is the index for domain type and m is the distinguished index for domains having the same type i. Similarly, each boundary is coded by B_{ijk} where i and j are indices of domains on both side of the arc, k is the distinguished index for arcs having the same index ij. The orientation of arcs may be given by following a pre - esta blished method, for example, the positive direction is going on keeping the domain with lower index on the right.

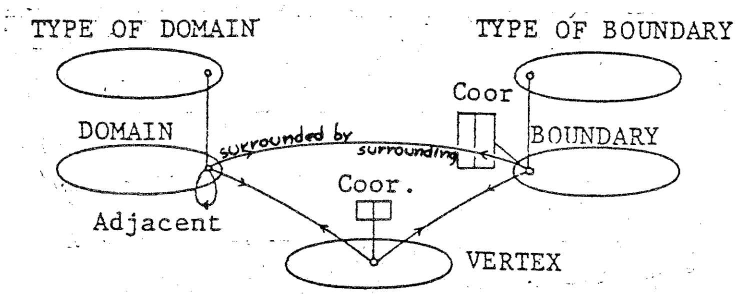


Figure 10

The topological structure of this phenomenon composes of two sets of hierarchized classes, one for the domain type and the other for the domain boundaries (Fig.10). The relation between them is materialized by two links carrying the relation "SURROUNDED BY" and "SURROUNDING"

STRUCTURE OF HYDROGRAPHIC PHENOMENON

There are two sets of object concerning the hydrographic phenomenon. Firstly, a set of waterly elements which may not be able to assimilate to a simple thickness line. These objects, for example; lakes, swamps, ponds, etc., have some certain width and therefore may be treated as in the case of naturel and artificial domains. Secondly, a set of waterly elements which may be assimilated to a simple thickness lines, for example, stream, river, canal, and so on. Let us consider a river (Fig. 11a), it is composed of segments which are connected through nodes. Each node may be it self a fork and / or a join, it may also be an origin or an end. Each segment,determined by a series of auxiliary points, has three possible relations : predecessor, collateral, successor. Further, the river itself may be connected to others and may be itself the main river or the affluent.

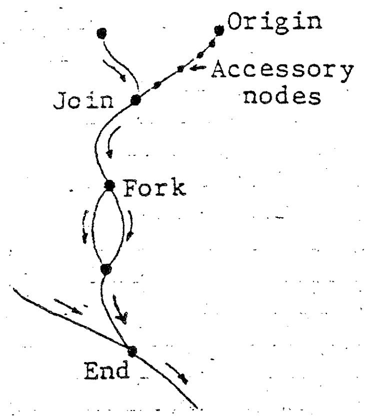


Figure 11a

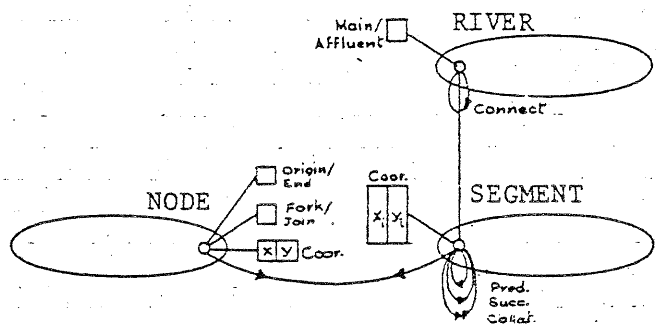


Figure 11b

The topological structure of the river is composed of three classes : RIVER, SEGMENT, NODE (Fig.11b). The first two classes are hierarchized. The attribute "COORDINATE" is a numerical bidimensional array containing a series of X, Y coordinates of auxiliary points issued from the digitisation phase.

STRUCTURE OF URBAN DATA

Urban data present one of the most important elements in human and land use planning. Among these data, streets, blocks, land percels are considered to be the basic components which other informations are attached to. Therefore they should be totally resided in the database, totally in this case means their topology and topometry. However, this is not the case since existing systems like DIME (USA) and RGU (France), etc., present only part of it (SATH 82) and the exact topology was lost! This is due to the unadaptability of existing data structure model to the scientific information. The HBDS model is in contrary well-adapted to any sophisticated phenomenon thus the complete topological urban structure (including topometry of course) was obtained as follow (SATH 82) :

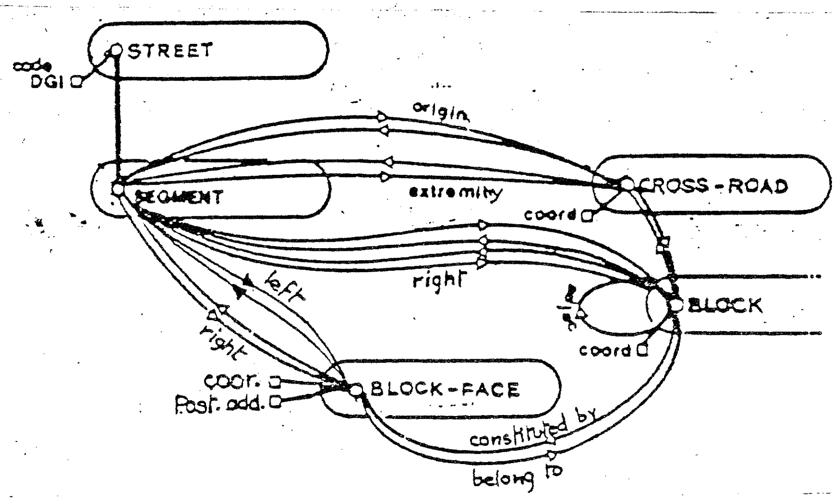


Figure 12

Figure 12 shows only the structure of streets, cross-roads, blocks and block-faces. The street is determined by connection of several segments thus the class "STREET" has a subclass named "SEGMENT". Now, looking deeply to the street structure we see that each segment is composed of block-faces therefore, instead of digitizing straight or curved lines represented the street axis like others did, we digitize block-faces. With the relation between segments and block-faces we may easily identify the street segment. The attribute "Address" is a so-called compound attribute because it groups together other simple attribute which is in this case one is for the beginning address and other is the end address on each segment.

CONCLUSION

Due to the allowed limited number of pages, only short part of the HBDS concept concerning the data structuring had been presented. More interesting subject like data manipulation and data retrieval do not have chance to be included. To manipute these data, the database management system is needed. The HBDS - DBMS had been developed in such a way that these two activities are in simplest form. The only task the user has to do is to communicate with the DBMS through several subprograms without needing to know how data are organized in the database. Therefore he may prepare application programs freedomly according to his needs without any disturb from the database sublanguage. Moreover, the HBDS concept offers several possibilities that no other existing models can do among these are : data structure transformation, fuzzy data processing, distributed shareable data structure, data protection, etc. All data are organized in characters therefore it ensure the portability of the data structure and independent from computer concept. These interesting subjects may be found in (BOUI 77) and (BOUI 79).

The author is very sure that the paper interests the reader and also very sure that the reader is still not clear. Therefore, the author will be very pleased and very honour to have discussion with anyone who wants to.

REFERENCES

(BERG 70) BERGE, C., 1970 : Graphes et Hypergraphes; Dunod, Paris, 2nd edition.

(BOUI 73) BOUILLÉ, F., 1973 : Contribution à la digitalisation et à l'analyse des cartes géologique; Thèse de 3eme cycle de Géologic, Université Pierre et Marie Curie, Paris.

(BOUI 77) BOUILLÉ, F., 1977 : Un modèle universel de banque de données, simultanément partageable, portable et répartie; Thèse de Doctorat d'État es Sciences Mathématique, Informatique, Université Pierre et Marie Curie, Paris.

(BOUI 79) BOUILLÉ, F., 1979 : The Hypergraph - Based Data Structure and its applications to data strueturing and complex systems modelling.

(BOUR 39) BOURBAKI, N., 1939 : Théorie de ensembles ; Livre I, Hermann, Paris.

(LISK 74) LISKOV B., ZILLES S., 1974 : Programming with abstract data type; ACM Sigplan Symp. on very high level languages. 28 - 29 March 1974, Santa - Monica, California, pp.

(SATH 82) SATHARANOND, V., 1982 : Méthodologie de structuration des connaissances et de saisie de Répertoire Géographique Urbain - Implémentation et mise en oeuvre; Thèse de Docteur Ingénieur, Université Pierre et Marie Curie, Paris,

BIBLIOGRAPHY

(SATH 81a) SATHARANOND, V., 1981 : Automatic Searching of Terrains for the Rice Agriculture; HBDS'81. 9 - 13 March 1981, Richmond, Virginia, USA, pp.

(SATH 81b) SATHARANOND, V., 1981 : An Application of the Hypergraph - Based Data Structure (HBDS) in an Agricultural Suitability Study; ASP - ACSM Fall Technical Meeting. 9 - 16 September 1981, San Francisco - Honolulu, USA, pp.

(SATH 83a) SATHARANOND, V., 1983 : Structuring of Urban Data with the Hypergraph - Based Data Structure Model; 10th United Nations Regional Cartographic Conferenced for Asia and the Pacific. 17 - 28 January 1983, Bangkok, Thailand, pp.

(SATH 83b) SATHARANOND, V., 1983: The Hypergraph - Based Data Structure: A New Approach to Cartographic Database Design, Management and Maintenance; International Cartographic Association Seminar on Computer Assisted Cartography. 22 - 30 November 1983, New Delhi, India.