DETERMINING AN INTERCHANGE STANDARD FOR THE NATIONAL SPATIAL DATA INFRASTRUCTURE OF TURKEY

Çetin CÖMERT Gürol BANGER

Karadeniz Technical University
Department of Geodesy and Photogrammetry
61080 Trabzon / TURKEY

Commission II, Working Group 5

KEYWORDS: Spatial, Data, Standards, Spatial Data Infrastructure, Spatial Data Interchange.

ABSTRACT:

Geographic Information Systems (GIS) have been receiving a growing interest from both public and private sectors in Turkey. Nevertheless, nationwide organizations dealing with spatial data have to have an effective way of sharing data to timely and economically meet ever evolving requirements. A National Spatial Data Infrastructure (NSDI) would greatly improve the accessibility, communication, and use of spatial data and enable nationwide data sharing. One of the most important technical requirements in building and maintaining the NSDI is a spatial data interchange standard. Due to the fact that designing a spatial data interchange standard is a colossal and long-term operation and acceptance as a "standard" in the end is not guaranteed, it would not be reasonable to design a new standard from scratch. Instead, a worldwide spatial data interchange standard could be adopted. To this end, a number of evaluation criteria which examine a spatial data interchange format in terms of its data model, implementation, and interchange environment have been determined. And DIGEST (Digital Geographic Information Exchange Standard), SAIF (Spatial Archive and Interchange Format), and SDTS (Spatial Data Transfer Standard) have been examined by the evaluation criteria. As the result of the evaluation, SAIF has been found to be the most appropriate. Identifying the need for NSDI in Turkey, this paper briefly presents the evaluation criteria and the evaluation.

1. INTRODUCTION

In spatial data handling, as well as other areas where Information Technology is employed, the need for computerized systems being "open", "integrated", "distributed", "interoperable", "corporate", "federated" have long been pronounced with some success, yet more to be achieved. The implications of these terms can be generalized as "distribution of tasks", "sharing of resources", and "cooperative processing" within and between systems. The deriving force behind all these has been to meet ever evolving requirements in an easy, fast, and cost-effective manner. Essentially meant with the "sharing of resources" here is the sharing of the software, hardware, and data. The particular interest of this paper is on the sharing of data.

Often overlooked in the context of building and maintaining a Spatial Data Handling System is the timely provision of required data, which may cost much more than software and hardware together (Dickinson and Calkins, 1988; Frank, 1992). Collecting spatial data firsthand is a costly and time consuming operation no matter what particular method is employed. On the other hand, stimulated by ever increasing availability of digital spatial data, today's challenging applications require data with very different qualifications. The result is as phrased by Coleman and McLaughlin (1992):"..Information requirements for administration, resource management and environmental programs in countries around the world now outstrip the information collection capabilities of any single organization."

Data sharing implies that the same digital data can be used by different users. Through data sharing, data collection costs can substantially be reduced since duplicate data collection activities of different organizations is avoided. Therefore, data sharing has been accepted as the way of providing timely and cost-effective solutions in spatial data handling (MSC, 1993; McLaughlin and Nichols, 1994; Frank, 1992; Calkins, 1992). However, the success in the data sharing practices around the world has been rather limited (MSC, 1993; McLaughlin and Nichols, 1994). Due to the technical and institutional problems involved, it has often been hard to obtain the required coordination and cooperation for data sharing. Therefore, the scopes of spatial data sharing programs have been limited to several agencies at the federal, state, or local levels (Coleman and McLaughlin, 1992). Institutional problems have been more difficult to overcome with respect to technical ones (Frank, 1992; Calkins, 1992; McLaughlin and Nichols, 1994; MSC, 1993).

In this study, the need for a NSDI in Turkey is identified and a spatial data interchange standard which will be one of the most important components of the NSDI is proposed. Until a consensus is reached on the terminology, the term "spatial data" will be used in this paper to colletively refer to the data held in a Spatial Data Handling System (SDHS) which refers not only to GISs but also to other types of computerized systems dealing with spatial data. Also, the shorthand "IF" will be used for "spatial data interchange format". And the sides of an interchange will be refered to as "supplier" and "client".

2. NATIONAL SPATIAL DATA INFRASTRUCTURE

As mentioned above, to date, the scopes of spatial data sharing programs have been rather limited. However, integrated and interdependent nature of the new challenges and issues require integration of spatial data both horizontally (accross environmental, economic, and institutional databases) and vertically (local to national and eventually to global levels) at a much larger scale (McLaughlin and Nichols, 1994). National Spatial Data Infrastructure (NSDI) has recently been proposed in the US to enhance the accesibility, communicaton, and use of spatial data nationwide. NSDI will create an "information highway" and thus enable horizontal and vertical integration of data. NSDI will, at the same time provide a solid foundation to handle technical and institutional problems in its implementation (MSC, 1993).

The components of the NSDI are data sources, spatial databases, institutions, technology, policies and standards, data networks, and finally users (figure 1). At the heart of the NSDI are policies and standards required for resolving both institutional and technical problems. Metadata will be a very important ingredient within various environmental, economic, and institutional databases. Data networks connect spatial databases and users employing the communication technology (McLaughlin and Nichols, 1994).

Concerning the variety of organizations involved, building and maintaining a NSDI will be highly challenging. It involves resolving technical and institutional issues such as "who needs and produces what data, what the best networking schemes are" how much a dataset or service cost, how open an organization's information will be to the others". The main technical issue is the development of standards which within the context of NSDI is not only limited to data interchange but also to hardware, software, communications, and data sets (Coleman and McLaughlin, 1992). The scope of this paper is limited to the spatial data interchange standards.

In Turkey, Geographic Information Systems (GIS), have been receiving a growing interest from both public and private sectors. Many public agencies have already set up such systems while others are either trying or planning to have one soon. Nevertheless, the challenge is not to set up but, to maintain these systems, which will require timely provision of data. That is, the need for data sharing as mentioned above, is equally valid in the case of Turkey. For instance, the duplication of data collection activities especially among public agencies dealing with spatial data has traditionally been a headache in Turkey as well. Turkey has to start building its own NSDI immediately if she wants to build an "information society". In doing this, Turkey has the chance of benefiting from the experiences of other countries.

3. METHODOLOGY

To design a new spatial data interchange standard from scratch could not be justified; Let alone the fact that designing a spatial data interchange standard is a formidable and long-term undertaking, acceptance as a "standard" is never guaranteed in the end, no matter how "well" the design is. Furthermore, spatial data handling communities around the world have similar requirements concerning data interchange. Therefore, it is much more practical to evaluate spatial data interchange standards recently proposed worldwide and adopt an appropriate one for Turkey.

To this end, a number of evaluation criteria, to be outlined in the following section, have been identified. And after a pre-evaluation of a number of spatial data interchange formats, three formats have been found appropriate for the final evaluation. These were DIGEST, SAIF, and SDTS. Evaluation of these formats by the evaluation criteria is summarized in Section 5 .

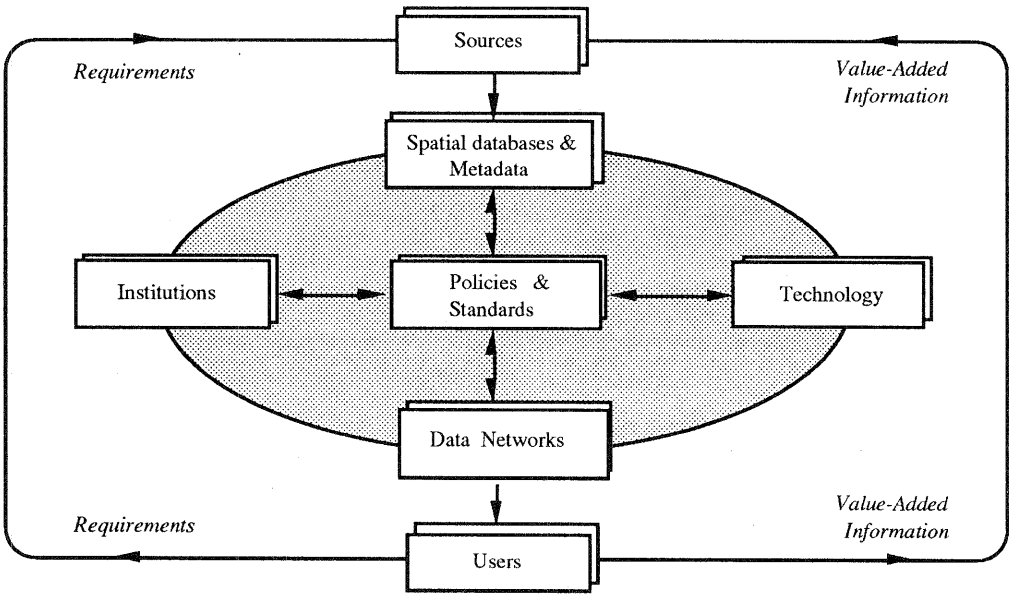

Figure 1. NSDI components (after McLaughlin and Nichols, 1994).

4. EVALUATION CRITERIA

Since there will be so many divergent groups involved, NSDI requires more than what current spatial data interchange standards offer. Therefore, needed was a more detailed criteria than those suggested earlier noticeably by the works of Lee and Coleman (1990) and Kottman (1992). Therefore, an evaluation criteria which examine a IF in terms of its data model, implementation, and interchange environment have been determined. In very general terms, what the evaluation criteria looks for are generality and extendibility in terms of data model, flexibility and hardware independence implementationwise and availability of services and tools which would facilitate the development of translators and enable efficient interchange of data considering interchange environment.

4.1 Data Model Criteria

Data model type: Spatial data models may be either "Feature-based" or "Record-based". IF's data model should be general and flexible enough to enable complete translations between as many different data representations as possible.

Raster data: Raster data may be represented in many different ways yielding various formats such as TIFF, GIF, Landsat TM, SPOT, RLE, JPEG, PICT, TARGA and many others. IF's data model should support various raster representations.

Cartographic representation: Cartographic representation of spatial information may take very different forms. For instance, in one form river names can follow the curvy shape of the river while in another, names might be through straight lines only. Similarly symbology, projections used in supplier and client may be rather different. IF should allow various cartographic representations.

Coordinates: IF should allow 1-, 2-, 3-, or 4-dimensional coordinates with varying resolution, and recognize different reference and projection systems.

Topology-geometry separation: If the client has topology builders and its topological data structure is rather different from that of the supplier then only geometry may be transfered and topology can be rebuilt in the client. However, topology may be used to verify the geometry of the transfered data. Also, a real-time application may prohibit topology building. Therefore, IF should allow the transfer of topology or geometry alone as well as both.

Complex objects: IF should enable direct representation of complex objects. Complex objects should be able to be treated as single units like simple objects.

Object sharing: Object sharing is the capability that an object can be shared by a number of other objects. For instance, two polygons may refer to the common boundary instead of each dupplicating it. Object sharing is very valuable especially when polygonal data is involved. Therefore, it is highly desirable that IF's data model supports object sharing.

Metadata: Metadata is needed to determine the fitness of the data for a specific application. Metadata can be specified *generally* for the entire transfer data set or *specially* on the basis of individual features. IF should allow both general and special metadata specification in varying levels of detail.

Feature-based interchange: Traditionally, spatial data interchange has been practiced over the transfer of an entire file corresponding to a map sheet, data set, or coverage. Interoperability requires that interchange be performed at the individual features level (Herring and Pammett, 1992), which is called "feature-based interchange" here. Feature-based data models would more readily offer feature-based interchange support since their fundamental modelling unit is a "feature".

Temporal data: Conventional GIS databases represent only a one-time snapshot of the reality (Vrana, 1989). This creates problems for the applications requiring temporal data. "Temporal Topology" (Vrana, 1989; Edwards et al., 1993; SAIF, 1994) has been proposed to handle the incorporation of temporal data into GIS databases, which is not a resolved issue yet. With the availability of temporal data, queries like "when the building was established on this parcel, what was the situation in the neighbouring ones?" could be answered. It would be most unfortunate if both sides of the interchange but the IF can handle temporal data.

Multimedia data: IF should support multimedia data types such as voice.

Extendibility: It is widely accepted that a general spatial data model which would meet any requirement is not viable (Pequet and Marble, 1990). Unpredictability of the requirements at the outset due to the diverse backgrounds and ever evolving requirements of the spatial data users renders the design of an all encompassing spatial data model very difficult, if not impossible. That is, modifications or extensions over time are unavoidable (Lee, 1990; Pascoe and Penny, 1990). Nevertheless, changes have to be carried out with mimimum side-effects. This is possible only if the data model of IF is extendible. Extendibility is perhaps the most important of the data model criteria for the fact that even if an IF does not have sufficient provisions for some criteria, required extensions can be done easily if it is extendible.

4.2 Implementation criteria

Profiles: Since a general and flexible IF will necessarily be rather complex, its implementation via a single large translator would be inefficient and impractical: A large translator would require a considerable development time (Friesen et al., 1993), which may contradict the time constraint of the project at hand and contain much more than what is needed for specific data transfers. Therefore, it is more practical to implement a general format through its special purpose subsets called *profiles* (Fegeas et al., 1992; Friesen et al., 1993). For instance, for an IF capable of handling both vector and raster data, a vector profile can be defined for just vector data. Profiles are also useful for harmonizing general and specific IFs.

Feature/attribute coding: Traditionally, Feature Codes (FC) are used to differentiate between the features of a geographic database. FCs may be hierarchical generated with respect to the hierarchy of a classification of features or non-hierarchical. Feature coding is another area where standardization is needed. Several standards, like FACC (Feature and Attribute Coding Catalogue) (NATO, 1993), have recently been proposed for this purpose. An IF may have its own classification scheme or allow external feature coding standards to be used with. IFs offering both options are desirable. Also, IF should enable the transfer of features/attributes which may not be covered by internal or external standards through a data dictionary.

Encoding scheme: For the interchange, supplier data has to be encoded into a series of bits and bytes and transmitted to the client. Transmission may be on-line over communication lines or off-line via magnetic and optical transfer media. Encoding of the data with an underlying schema and data model is carried out according to an encoding scheme such as ISO 8211 (ISO 1985) and ASN.1 (Abstract Syntax Notation One) (ISO, 1987). To understand the encoded data, the client has to either know the codes (tags) used in encoding or underlying supplier schema if a tagless encoding was applied. In addition to tagged/tagless encoding, an encoding scheme may offer ASCII or binary encoding options. Encoding scheme should enable a condense encoding and be hardware independent.

4.3 Interchange environment criteria

Documentation: Since a general format would be rather complex and require a certain level of expertise (SAIF, 1991; Altheide, 1992), its documentation must be clear and easily understandable. As is the case with many traditional IFs, data model and implementation concepts should not be mixed. The documentation will play an important role for an IF to obtain a widespread use.

Services: By "services" we mean translator, encoder, decoder, and communicator rutines or modules, which would enable constraction of interchange interfaces easily, in a modular fashion. Translations between two digital data representations may be *simple* or *complex*. Encoder and decoder rutines are for encoding/decoding the transfer data according to an encoding scheme. Finally, communicator rutines are needed for physically moving the data between supplier and client. Conventional methods have been accepted unsuccessful in producing extendible software (Meyer, 1988). A high degree of reusability and extendibility can be provided through object-oriented approach. Methods or services are already an inherent part of the object-oriented data model. Thus, services can be encapsulated within the objects and can be re-used for various interfaces. Through a "good" initial design extendibility can also be ensured.

Tools:
- *Compiler/Interpreter tools* : Since the translation between two digital data representations is similar to the one between programming and machine languages, compiler/interpreter techniques can be benefited from in spatial data interchange (Pascoe and Penny, 1990). That is, if data representations can be expressed formally, translators can be developed automatically. This is especially valuable for rendering direct translators a feasible approach against traditional neutral translators. Direct translators are preferable over neutral translators mainly for providing more complete translations. Even in the case of neutral translators, compiler/interpreter tools namely parsers, scanners, code generators, and executors accompanying an IF will be an important asset in its promotion as a standard.

- *Formal Description Language (FDL)* : To prevent misinterpretations, the abstract definition of IF should be in an FDL. A textual FDL is needed for both expressing extensions to the IF standard schema and compiler/interpreter tools. A graphical description language would also be helpful for users in understanding the abstract definition. Ideally, translation between the textual and graphical languages must be automatic.

- *Selection tools* : In an ideal interchange environment, the client should, desirably via a GUI, be able to query supplier data and then import only what is needed. Selections should be able to identify either individual features or a sub-group of features Selection tools may involve query languages, browsers, visualization tools, and proper organization of data.

5. EVALUATION

DIGEST (Digital Geographic Information Exchange Standard) (NATO, 1993), has been developed by the Digital Geographic Information Working Group (DGIWG) of NATO. NATO has formally adopted DIGEST in 1993 as its interchange standard. It has been designed for producer to user and user to user. spatial data the interchange. Either feature-based or relational implementation, which are referred to as DIGEST-A and DIGEST-C respectively may be applied.

SAIF (Spatial Archive and Interchange Format) (SAIF, 1994), has been developed by the Geomatics Unit, Surveys and Resource Mapping Branch (SRMB) of the British Columbia (BC) Ministry of Environment, Lands, and Parks. Current version (V3.2) was released in 1994. SAIF has been used to deliver SRMB data since 1992. Canadian General Standards Board, Committee on Geomatics has approved SAIF in 1991 as the National Standard for geographic data interchange (SAIF-FAQ, 1995). SAIF has an Object-Oriented data model and supports Object-Oriented implementation.

SDTS (Spatial Data Transfer Standard), is the culmination of approximately 9-years work of the development team (Fegeas vd., 1992). US Geological Survey (USGS) is currently the maintenance authority for SDTS. All the Federal agencies in the US were legally required to release their data in SDTS starting from February 1994. USGS and US Census Bureau now offers their DLG and TIGER data in SDTS (GIS-L, 1994). On the other hand, Australia and New Zeland have been working on adopting SDTS. SDTS has a feature-based data model implemented relationally.

The evaluation of DIGEST, SAIF, and SDTS by the evaluation criteria is summarized in Table 1. In terms of data

Table 1. Summary of the evaluation of DIGEST, SAIF, and SDTS by the evaluation criteria.

Criterion / Format	DIGEST	SAIF	SDTS
Data model type	Entitiy-based (DIGEST-A) and Relational (DIGEST-C)	Object-Oriented data model, multiple inheritance supported	Entitiy-based ("entity-attribute-attribute value"), not Object-Oriented
Raster data	Various raster data representations are supported, some are missing(e.g. quadtrees)	Raster data support is extensive	Only four different types of raster representation is recognized at the moment
Cartographic representation	Relatively weak support	Powerful enough. support, Sembol librarires can be referenced	Quite powerful support
Coordinates	2- and 3-D, 4-D is not supported, practically unlimited resolution	1-, 2-, 3-, and 4-D are allowed, 64-80 bit of resolution by design	2- and 3-D, 4-D is not supported, practically unlimited resolution
Topology-geometry separation	Supported	Supported	Supported
Complex objects	Supported at features level	Supported at objects level	Supported at geometry level
Object sharing	Supported at features level	Supported at objects level	Supported at geometry level
Metadata	Supported, general and special metadata specification is possible	Supported, general and special metadata specification is possible	Supported, general and special metadata specification is possible
Feature-based interchange	Not supported	Supported	Not supported
Temporal data	Not supported	Supported	Not supported
Multimedia data	Not supported	Not supported	Not supported
Extendibility	Limited	Highly extendible	Limited
Profiles	It is already a "defined" standard	Supported, 4 profiles for raster and vector data, first one ready, the others and a DIGEST profile are under develepment	Supported, TVP (Topological Vector Profile), profiles for DIGEST and DX-90 have been developed, raster profile is to be finalized
Feature/attribute coding	FACC (Feature and Attribute Coding Catalogue)	Does not acknowledge feature coding approach, however external coding standards may also be used	Internal coding scheme, external coding standards may also be used
Encoding Scheme	ISO 8211, ISO 8824, and VRF (Vector Relational Format), ASCII/Binary, telecommunications media supported	SAIF/ZIP; Taggless, ASCII encoding, telecommunications media supported	ISO 8211; tagged, ASCII or binary encoding, not suitable for telecommunications media
Documentation	Hard to understand, inconsistent use of terminology, data model and implementation concepts are mixed, not well organized	Especially SAIF 3.2 is well documented	Hard to understand, not standard terminology, data model and implementation concepts are mixed
Services	Not supported at data model and implementation levels	Supported with *SAIF Toolkit*, services are not included in the current SAIF Standard Schema, they can be added when needed	Not supported at data model level, CSP (Common Software Platform) is under development
Tools	Not supported yet, *Digest View* is under development. DCW, comes with a GUI	Supported; *SAIF Toolkit* and *SAIF Tools*, *SAIFTalk* data definition languages	Not supported

model, SAIF is more general and superior in a number of areas compared with SDTS and DIGEST. Using an object-oriented data model, SAIF promises a much higher degree of extendibility than the other two. This is crucial for the NSDI where so many divergent parties will be involved. Claiming superiority is not that easy concerning implementation. Nevertheless, SAIF offers an alternative approach to traditional feature coding by allowing different users to define features in their own way. Thus, the formidable task of creating and maintaining standard feature coding catalogs of the traditional approach which is used by SDTS and DIGEST is avoided. Finally, SAIF is supported with an interchange environment of broader facilities. Therefore, SAIF has been found to be the most appropriate for the NSDI of Turkey. A number of extensions will be needed for the adoption of SAIF. For instance, additions for the vertical and horizontal reference systems, and projections used in Turkey have to be made to the SAIF Standart Schema.

Choosing SAIF will not make SDTS and DIGEST invalid for the NSDI since these three standards are now harmonized (O'Brien et al, 1994). On the other hand, International standard bodies, namely European Committee for Standardization, Open GIS Consortium, and International Standards Organization's Technical Committee 211 have been involved in developing "interoperability" standards (CEN, 1993; Farley, 1994; ISO, 1995). However, when and how these efforts will end is unclear at the moment. Even they all succeed, there would still be three different standards in place. Should SAIF be replaced with an internationally accepted interoperability standard, it could still be used within NSDI for archieving.

6. CONCLUSION

Turkey has to start building a NSDI immediately if she wants to build an "information society". NSDI will make nationwide horizontal and vertical spatial data integration possible. One of the most important technical requirements in building and maintaining the NSDI is a spatial data interchange standard. To meet this requirement, DIGEST, SAIF, and SDTS have been evaluated by the evaluatuion criteria determined in this study. As the result of the evaluation, SAIF has been found to be the most appropriate for the NSDI of Turkey. Using an object-oriented data model, SAIF promises a much higher degree of extendibility than both SDTS and DIGEST, which is very valuable for the NSDI.

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