Vancouver
British Columbia
Canada
February 10 - 13, 1992

Sixth annual GIS symposium

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FRDA REPORT 173
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Acknowledgements

GIS'92, an International Symposium on Geographic Information Systems, is sponsored by Forestry Canada, the Province of British Columbia and Polaris Learning Associates, Inc., with funding provided under the Canada-British Columbia Forest Resource Development Agreement.

GIS'92 acknowledges additional support from
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Symposium management and planning by
Polaris Learning Associates Inc.
305 - 1040 Hamilton Street,
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Welcome message

International attention has focused on natural resource management. Fiscal expectations have necessitated increased efficiency, and the guiding principle of sustainable development has placed greater pressure on resource management. Geographic Information Systems (GIS) are being used to arrive at solutions to these new demands.

Exploring and promoting the applications of GIS to natural resource management has been the goal of the five major conferences held in Canada, from 1987 to 1992, in which Forestry Canada has participated. This conference is now widely recognized as the world’s premier GIS event for forestry and natural resource management applications. I am pleased that Forestry Canada is once again participating, in the 1992 edition of the GIS conference and its presentation of ways to Work Smarter with GIS.

GIS applications revolve around people in an organizational context. Its advocates deal with organizational questions such as sponsorship, budget strategies and technical conservatism.

This year’s conference continues in the tradition of its predecessors, focusing on GIS applications. The high quality of the GIS symposia have attracted delegates and vendors from increasingly further afield, attesting to the rapidly expanding awareness of the technology, the event, and Canada’s preeminence in this area.

I am proud that Forestry Canada continues to champion GIS and encourage greater awareness of the benefits of its technology.

Honourable Frank Oberle

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Designing British Columbia’s land information infrastructure: from vision to reality
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Designing British Columbia’s land information infrastructure: from vision to reality

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Abstract
The Government of British Columbia has recognized the importance of exchanging and sharing its land-related data both internally and with outside client groups. To this end, it has created the Corporate Land Information Strategic Plan (CLISP) to enable the integration of diverse government land information systems while maintaining the autonomy of the individual ministries in managing those information systems.

As a key part of the CLISP, the Ministry of Environment Lands and Parks has been given the task of establishing a land-related data access and management system called the Land Information Infrastructure (LII). The LII will be developed in stages over the next seven years and will involve the active participation of several key ministries and other government agencies that are custodians, providers and users of land-related data.

A vision of the function and architecture of the target LII system in 1998 has been defined. The target system will provide prompt, consistent and flexible access to land-related data maintained throughout the BC Government as well as a means for exporting the data to user application systems. The system will use a versatile heterogenous multi-database architecture.

A migration strategy has been prepared that charts a development path from the current situation to the target system. It takes a phased approach that will provide early benefits to users while minimizing development risk. The strategy includes a plan for the involvement of the participating groups and a description of intermediate implementations of the LII system.
Introduction

The Government of British Columbia is a large, diverse organization. Like many other government jurisdictions it manages large amounts of dispersed, land-related spatial data. Through the 1980's, with the rapid development of land information systems, various government agencies automated their existing major data collection programs to more effectively deliver their mandates. These developments were undertaken as independent, single business purpose initiatives resulting in a heterogeneous, multi-database environment which includes differences in hardware, operating systems, database architectures and database management systems. Although many of these systems meet the business needs of the custodian agencies for which they were first built, they all contribute to a common problem that must be solved: how to provide efficient access, and effectively exchange and share land-related, spatial data from these many disparate sources.

In 1989, the Government of British Columbia adopted the Corporate Land Information Strategic Plan (CLISP) to enable access to, and facilitate the sharing and exchange of the diverse land-related data holdings in Government. CLISP is a strategic plan for managing land-related data and systems in the B.C. Government. It is corporate, extending across ministerial boundaries. It is also strategic providing both a target vision for land-information and supporting systems and an overall strategy for achieving that vision.

The implementation of CLISP is being overseen by an inter-ministerial Land Information Strategic Committee (LISC) chaired by the Ministry of Environment Lands and Parks. The Ministry of Environment Lands and Parks was mandated as the central agency for land information systems and has the responsibility to create and coordinate standards for the management of land-related information and systems with a focus on enabling access to and facilitating the exchange and sharing of data between government agencies. The Government Land Information Data Exchange (GLIDE) Unit was created to manage CLISP and to provide information on its progress and operation.

CLISP has three main aspects: organization, policy and system. Each aspect involves the development of plans and specific tasks to meet the B.C. objective of servicing the land information needs of government as a whole in a standard, transparent and convenient manner. This paper focuses on one aspect; system. For more information on organization and policy refer to (Hofmeyr et al., 1991).

The central deliverable of CLISP is a physical infrastructure system including computer hardware, software, communications and standards, referred to as the Land Information Infrastructure (LII). The LII is being developed within a corresponding policy framework referred to as the Land Information Management Framework (LIMF). The LII will provide the technology and information required to enable the sharing of land-related information among the various agencies of the Provincial Government.

The vision

The past decade has made us more aware of our finite resources, the costs associated with managing them effectively and we have come to realize the extreme interdependency of our actions and the numerous physical and biological processes which govern the world around us. Those responsible for managing and developing our resources are being forced to manage more intensively and develop new skills requiring better use of available information. Planning and management will become more geographically specific. Each and every land or resource management issue will be resolved with a wide variety of information. Applications for supporting the business activities of government such as the management of timber supply, maintenance of land status, oil-spill response and other complex decision support will be developed. To be successful all such applications will require access to a wide variety of land-related information. Currently this is not possible, however because it is beyond the scope of any individual system or individual to deal with the problems of "global" data access and data translation.

To this end, the vision of the LII of the future, 1998, is a system that efficiently and effectively meets the needs of its users by providing easy, prompt, consistent and flexible access to land-related data, irrespective of where the user is located or where and how the data are stored and to have that data presented in a form most beneficial to the user and/or application to which it will be applied, Figure 1. The target system will serve both groups within and outside the B.C. Government, including private corporations, other levels of government and the public.

The LII will provide its users with a single window into the land-related information sources in Government and not compromise the security and integrity of the data it accesses. Ministry custodians of data sources will retain autonomy in managing their databases. Users or user applications will gain access to the LII via User Access Terminals (UAT's), which are software components running on their local hardware platform. The UAT provides the means, via access to LII services and the required information about data sources (contained in the LII Repository), by which the user can find out what land-related data is accessible using the LII, to order data, and to receive the retrieved data. The UAT will enable users to join, superimpose and manipulate data from directly linked (on-line) disparate digital data sources and deliver it for use on their local system or application program with minimum effort. The user will also be able to formulate requests for data from off-line data sources not directly linked to the LII. In this latter
Figure 1. The Land Information Infrastructure Concept
case, the LII dispatches the request to the custodian of
the off-line source who then physically fills the order.
This may be for hardcopy products not available in
digital form. The user will formulate his requests using
a rich text and graphics interface provided by the UAT
that will support queries by forms, graphics or example.

Because the LII mediates between data sources and
users, and undertakes the management of data access
and delivery, in addition to data linking from disparate
data sources, it will appear as if the user is ordering data
from one, or a few, databases, each of which in reality
is an integrated view of more than one database. For
example, there are at least five databases in Government
which show legal encumbrances on the land. In the
vision, the LII would provide a single integrated view
to these databases. If the user, via his/her UAT were to
define a geographic area and queried the LII for all legal
encumbrances within that area, the user, to this single
query, would receive a composite of consistent data,
derived from all the databases, in a form suited for use
on his/her application. To the user, the data would have
appeared to have come from one database.

The LII will enable the valuing (and pricing, if
desired) of land-related data by recording transactions
and so allowing those who capture source data to
understand by who, how, and to what extent, the data is
being used. The target system will provide distributed,
automated support to allow data and database managers
and administrators to maintain the information the LII
requires about their data and systems, check data
integrity and to report problems. The system will also
report on its performance and health to operations
personnel.

Systems support to the business environment in
which the LII will operate in 1998, will be distinctly
different than it is now. It is likely that the trend towards
vertical integration of business systems will continue with
the emergence and maturity of “enterprise or corporate”
systems. These are systems in which all applications, at
all levels within an organization, supporting a particular
business area are managed and integrated in one system.
Such business systems will evolve in the British Columbia
Government spanning entire ministries and even cross
ministerial boundaries. These systems will support day-
to-day transaction activities, provide statistics and reports
to regional and central managers and put key geographic
information derived from land-related databases at the
fingertips of decision makers. Examples to illustrate
include an Environmental Management System
supporting the vetting, issue and management of all types
of Environment tenures; management of the processing
of referrals; wildlife inventory, habitat and suitability
monitoring; and reporting at all levels. A similar
Integrated Forest Management system could evolve
supporting the management of all types of forestry
tenures; forest inventory management; forest growth,
yield and harvest modelling; and reporting at all levels of
management from operational to consolidated reports
to the Chief Forester. The LII although not an enterprise
system, as defined here, will play a major role by
providing the means of exchanging timely, specific and
consistent land-related information within and between
such enterprise systems.

Although the LII will provide GIS-like functionality
to facilitate the ordering of data in the context of a spatial
(e.g. graphic, map, or geographic) view, it should not be
confused with providing a corporate-GIS meeting the
many and varied ministry specific business requirements.
The LII is not a forest management system, nor is it an
environmental monitoring system, nor is it a system for
analyzing competing land use policies. The LII is the
system whereby the land-related data resources of the
Province can be made available to and shared among
such systems.

**Charting a course**

The previous section described the vision from a users
point of view of the target system. User expectation is
difficult to manage and it must be realized that the target
system is not intended to be fully operational until 1998.
Figure 2 shows the timeline for the phased development
of the LII. The phased migration strategy must balance
the needs of users against the reality of limited time,
resources, technical limitations of existing data sources
and government communication networks, and the
readiness of organizations to make effective use of data
provided by the LII. With that in mind, a phased
migration strategy has been charted which provides early
benefits to users, provides increased functionality with
each implementation to match expanding requirements
and to minimize development risk.

Phase I is complete. Its output was a conceptual
design for the Phase III system and the high-level design
for the Phase II operational prototype system.

At this time three major versions of the LII are
envisioned before emergence of the target system in
1998. The Phase II prototype system will be operational
in early 1993. It will be a limited implementation
intended to be both useful, but also a platform from
which the first full system will be developed. It will enable
access to a small number of on-line databases and a
wider set of off-line databases. The distribution of UATs
will be limited to approximately a dozen key locations in
participating ministries. The intent is develop a system
which provides useful service to a sizeable number of
users to demonstrate the capability of the system and to
demonstrate to its developers and custodians that the
design and architecture are capable of being extended
into a Phase III production system.

Requests will be formulated using a Common Data
Manipulation Language as graphical formulation of
requests will be rudimentary. Most on-line data will be
delivered electronically and it will be possible to display graphically, spatial data delivered in the LII's common data interchange format, but a custom translator may have to be supplied by the user to put the data in a form usable by his/her application. The system will have full transactions and resource accounting, standard security and access control, on-line help and support for the LII Data Administrator to update the LII Repository.

The Phase III system will be operational in early 1995. It will allow access to more on-line databases and will permit coherent retrieval and joining of data from multiple on-line databases. The Phase III system will be a true transaction processing integrated multi-database system. It will be able to support in the order of 100 concurrent users. Users will be able to use a comprehensive interactive graphics-based method for defining the data they require. For example a user could start with a map of B.C., draw an arbitrary closed shape and then request data from a number of sources falling within that boundary. Spatially-based queries will be supported. For example a user could identify an area displayed on a topographic base map and ask which Crown tenures apply to it. Users will have personal storage space within the LII allowing them to build their own body of information over time to facilitate their use of the LII.

The Phase IV system, which will be operational early in 1997 will be an extension to the Phase III system and will be more easily extensible and database update may be possible.

The ultimate success of this migration strategy depends on the close cooperation with all participating groups. Participating ministries must be willing and able to commit the resources to make their key land-related data available for access via the LII. Ministries must be willing to make changes over time to effectively use data provided by the LII. The hardware, communications and software technology, and its management, must be in place to support use of the LII. The custodians of the LII must provide the management, liaison, consulting, training and other services necessary for the day-to-day use of the LII.

**Figure 2. The Migration Strategy Roadmap**

**Designing for success**

**System requirements**

The LII is a system that provides transparent integrated access to sources of land-related data. For the most part, these sources are databases on digital computers connected on-line to the LII via communications networks. Users of the LII are able to find out what land-related data are available for access, and then request selected spatial and attribute data without having to know where or how the data are stored (see Figure 1). For example, someone might require the names of lessees of Crown tenures that border a given road. A query could be issued to the LII to obtain this information assuming it is accessible via the LII. To fulfill this query, the LII might need to retrieve and process Crown tenure polygon data from a GIS, road segment data from a digital map file system and attribute data from a relational DBMS, each of these being separate systems in different locations. Spatial data are transferred and manipulated within the LII in the Spatial Archive and
Interchange Format (SAIF), the draft national standard for interchange of geomatics data.

These are the key requirements of the LII:

Extensibility: The LII will evolve in stages. It is important that connecting new source databases does not require redevelopment of the existing system.

Flexibility: The LII will have an operational life of many years and will serve the needs of a large and diverse organization, namely the B.C. Government. The system must be flexible so that changes in its operating environment (e.g. changes in organizational structure, physical locations, policy, issues of concern) can easily be accommodated.

Expandability: When the LII becomes operational, the demand for its services is likely to be modest initially, but will increase substantially as its benefits are realised and as new databases are connected. Also, there are likely to be requests for additional services. The LII design must be such that system performance can be increased and the services it provides can be expanded to meet rising demand.

The design for the LII addresses these and other requirements and is based on a federated heterogeneous database system (FDDBS) architecture (see Sheh and Larson, 1990, for a description of the reference architecture) expressed using a client-server model. Below, is a brief description of the LII architecture followed by how it is applied in the system design.

The LII schema hierarchy

The LII system architecture is founded on a multi-level schema hierarchy which is an extension of the standard ANSI/SPARC three-schema architecture (see Figure 3).

The local schema is, in effect, the data dictionary of the participating source database. Its data model is that of the database management system (DBMS) (e.g. if the source database is managed using Oracle, then the data model is relational).

The export schema is a representation of the local schema in a Common Data Model (CDM) used by the LII. The CDM will not, in general, be the same as that of a source database. The export schema describes only those parts of the source data that will be visible to the LII. Thus, confidential data in a source database can be obscured from access by the LII simply by not describing the data in the export schema.

The conforming schema is a representation of the export schema, again in the Common Data Model, but in a form that is semantically consistent with a globally conforming view of all source data described in the LII. This means, for instance, that if a property tax database and a Crown tenure database both contain data types called LandParcel, but they are not identical data types, at the conforming level they must be differentiated (e.g. perhaps into TaxLandParcel and CrownParcel).

Federated schemas can be thought of as virtual databases that represent data from more than one

![Figure 3. Multi-level Schema Hierarchy](image-url)
physical source database. In other words, they are integrated views of more than one conforming schema. A user of the LII viewing a federated schema and ordering data based on its descriptions need not be aware that the data are being retrieved from different sources. So, for instance, a cadastral federated schema might consist of Crown cadastral data, private land title data, forest tenures and mineral tenures, each set of information being stored and managed in separate databases using different kinds of DBMS software and located in different places.

Although not shown in Figure 3, a complete schema hierarchy would, in general, show external schemas at the highest level. These are just like those defined in the ANSI model: different views of data maintained for different groups of users according to their needs. Typically, there would be one or more external schemas for each conforming schema and federated schema. The current design for the LII takes a simplified approach and disallows multiple user views, and so external schemas are collapsed into the conforming and federated schemas.

The LII components

Figure 4 shows the main components of the LII. Users interact with the LII via User Access Terminals (UATs) which act as clients to a number of servers. A UAT is a suite of software that can run on a variety of platforms. In addition to providing a human user interface, the
UAT software may be invoked directly by application programs. They do this by calling services provided in a linkable object library of UAT services.

An LII user must hold an account on the system. These are much like user accounts managed by an operating system. In the case of the LII, accounts are maintained by the Account Server and its associated database. An account is a set of information about the user, including access privileges and quotas to system resources such as the processor and disk space, current levels of expenditure, and preferences for style of use.

An important component of the LII is the Repository and its server. This is, in effect, a global database of meta-data which describes at a number of levels the land-related data contained in the participating source databases and how the data can be retrieved. The Repository contains both textual descriptions of data, which the user may browse to learn about what land-related information is available (e.g. its subject areas, currency, geographical extent, custodial group) and also schema descriptions (e.g. data types and associated services, attributes and their domains), which enable the user to formulate queries for source data and enable the LII to process these queries. The former information is contained in the LII Directory and the latter information is contained in the LII Dictionary. The schema descriptions are those of conforming and federated schemas; these being at the top of the schema hierarchy and so the only ones visible to the LII user.

The Network Query Processor (NQS) handles the validation, manipulation and routing of queries from the UAT client, as well as processing land-related data retrieved from source databases and forwarding it to the Account Server for delivery to the UAT client. Queries are expressed in a Common Query Language (CQL). The database associated with the NQS contains export schema descriptions and provides temporary working storage for retrieved source data. The LII user does not have access to this database.

The Data Access Servers (DASs) are the interfaces between the rest of the LII and participating source databases. There is a DAS for every database connected to the LII. It handles syntax conversions between queries in the LII CQL that it receives from the NQS and the query language of the source database (e.g. SQL or a proprietary language of a particular DBMS or GIS). It also receives retrieved data from the database, repackages it if necessary, and routes it to the NQS for further processing. The cost of development of a DAS depends on the kind of source database to which it is connected and the level of data access required. Take for example, a DAS connected to a digital map database. If the DAS is required only to retrieve whole mapsheets, it will be simpler than if it were required to retrieve individual features within mapsheets.

How the LII design meets key requirements

The LII design meets the key system requirements identified above in the following ways:

**Extensibility:** New land-related databases may be connected to the LII by adding new DASs. The Repository must also be updated to describe the new land-related information available for access. In principle, no other components need be changed.

The LII is also able to provide additional services for access to existing data sources. Assuming that the source DBMS is able to support the required level of access, a new service can be implemented simply by upgrading the attached DAS and updating the Repository accordingly.

**Flexibility:** At one level, the LII provides flexibility by shielding users from the physical and structural aspects of source data storage. This means, for instance, that if a government branch with a database connected to the LII moves to a different location, upgrades its computing facilities, or switches from a hierarchical DBMS to a relational DBMS, LII users will not need to know anything about the changes. (The Repository and/or the particular DAS may have to be updated, but this is not the concern of users of the LII.) One would hope that the only changes LII users see would be better response time and perhaps additional services for accessing this data set.

At another level, the LII provides flexibility by allowing the creation of custom data federations that answer the needs of specific user communities. This is done by creating federated schemas that provide integrated access to a number of data sources. As mentioned above, these simply appear as single databases to users. Federated schemas can be tailored to specific application areas, describing only the types of data required. As issues emerge and evolve, the federated schemas can be created and modified accordingly.

**Expandability:** The conceptual design for the LII outlined above may be translated into a variety of physical designs according to the size of the LII's user base, the number of source databases connected, the physical locations of users and databases, and the level of performance required. The first implementation of the LII will be modest, so a number of its components will reside on a single central host. However, as user demand develops and as more source databases are connected to the LII, it is likely that many of the LII functions will be distributed. Initially, this may mean expanding the host to provide symmetric multiprocessing. In time, better performance and reliability can be provided by distributing the server functions across many physical platforms, using perhaps some of the concepts of distributed DBMSs such as data replication management and data partitioning. In the longer term,
the expandability of the LII may be limited by the communications infrastructure of the Province. Because it will manage the transfer of large amounts of data, the LII will need to use communications resources efficiently, and as the system expands, its physical design will reflect this need.

**Conclusion**

The LII will provide the necessary services and information to enable access and facilitate the exchange and sharing of land-related data from many disparate sources in a heterogeneous multi-database environment. It will provide useful services to users in the short term and will evolve to play a major role by providing the means of exchanging timely, specific and consistent land-related information within and between ministry enterprise systems.

The federated heterogeneous database system architecture supported by a client-server technology architecture provides for the extensibility, flexibility and expandability requirements for the LII necessary for the long-term viability of the system. It also ensures the autonomy of individual ministries in the management of their own databases.

The development of this physical infrastructure will require an understanding of both the organizations involved in the information sharing as well as the nature of the information shared. In addition, the sharing of information is only possible if there is a common semantic framework which encompasses all the ministries and Crown corporations of the Government. Sharing is a cooperative enterprise where success can be achieved only through the support and continued cooperation and participation of the agencies involved.

**References**


MacDonald Dettwiler (1991) for the B.C. Ministry of Crown Lands: *Land Information Infrastructure Statement of Requirements (High Level)*, Victoria, B.C.


MacDonald Dettwiler (1991) for the B.C. Ministry of Lands and Parks: *Land Information Infrastructure System Architecture*, Victoria, B.C.

MacDonald Dettwiler (1991) for the B.C. Ministry of Lands and Parks: *Land Information Infrastructure Target System and Migration Strategy*, Victoria, B.C.

Efficient land information use within the province of British Columbia: Policy development based on need.

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Abstract

British Columbia is developing a Land Information Infrastructure system that will facilitate the sharing and exchange of land-related data within the Province. The sharing and exchange of land-related data is vital to support integrated resource management and the resolution of referrals within the Province. In order to manage and maintain the infrastructure and to ensure the consistent development of land-related information systems, the Ministry of Environment, Lands and Parks has developed operational policy, procedures, guidelines and standards for land-related information and technology management.

To determine what policy was required, the actual use of land information in government at an operational level was examined. From this study, what was needed at a management and policy level was ascertained. In order to develop policy that would work in a multifaceted government environment, it was necessary to: identify vendor-independent standards, permit varying levels of adherence, recognize the need for new organizational structures to mediate conflict resolution, accept the policy development as evolutionary and build upon existing government policy. The resultant land-related information and technology policies will enable the Ministry of Environment, Lands and Parks to fulfill its responsibility for ensuring the coordinated development, implementation, and approval of land-related information systems of government-wide interest and to develop an effective land-related data access and management system.
Design and operation of a Meta-GIS

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Abstract

Constructing spatial databases for resource management and mapping can be costly and
time consuming. Systems integration, technology transfer, and efficient data collection can
each be enhanced when private and public agencies cooperate in exchanging spatial data.
The Northwest Land Information System Network (NWLISN), a consortium of federal
and state agencies in Washington and Oregon, has contracted with researchers at Portland
State University to build a Spatial Data Index (SDX). As a “meta-GIS” the SDX
catalogs spatial data holdings by both subject theme and spatial extent. Queries and
reports utilize both graphical and attribute descriptions of the data holdings of contributing
members. Technical metadata issues addressed by this project include: 1) determining a
suitable taxonomy for classifying data sets to facilitate description and querying, 2) graphic
and topological approaches to the cross referencing of agency data tiled in differing
geographic formats, and 3) tracking lineage, data quality, and currency of data sets.
Institutional and organizational issues include: 1) coordinating funding and data reporting
among multiple agencies, 2) determining a long-term strategy for the institutionalization of
the index, and 3) implementing standards for meta data reporting.

Introduction

A catalog and indexing tool to help locate spatial data has been developed
at Portland State University. This Spatial Data Index (SDX), supports
graphical and tabular queries to locate GIS and digital mapping data for a
given areal extent and thematic subject. It is in effect, a meta-data GIS applica-
tion, since it records descriptions of data sets which reside elsewhere.

Virtually all approaches to cost justifi-
ation for GIS and LIS implementa-
tion recognize the characteristically high
start-up costs associated with database
development. (Dickinson and Calkins
require geodetic referencing and/or
digital map conversion that can take
months or even years to fully imple-
ment. (Epstein and Duchesneau 1984,
Parent et al. 1989) Similarly, land
records modernization and the building
of large attribute databases for land
information systems also is costly and
time consuming. Reduced uncertainty
in management decision-making, better
planning data, and automated facilities
management, are a few of the benefits
digital geographic databases. Because
testes are somewhat generic benefits,
many agencies with interests in the
same geographic region could poten-
tially benefit from databases originally
developed in another organization.

Despite the potential for sharing the
benefits of commonly developed
resources, a number of organizational and institutional impediments exist. (Dueker 1987) In particular, governmental organizations may replicate each other's spatial databases because organizational mandates and agency priorities differ even when areal extent and thematic subject matter are similar. (Chrisman and Niemann 1985) This results in many CAD, GIS, and LJS projects developing common base map and other data layers which have already been digitized or acquired by another agency. Therefore, as the technology matures, similar geographic databases proliferate throughout many levels and agencies of government within a region.

In the US pacific northwest, Oregon and Washington state agencies as well as federal agencies with regional headquarters in Portland or Seattle frequently require access to digital spatial data for mapping and geographic analysis. Because these data are expensive to generate, and duplicate copies of common themes are accumulating, it is increasingly important that digital map and attribute data be shared and/or traded whenever possible. The Northwest Land Information Systems Network (NWLISN) was established in 1988 as an ad hoc consortium of federal and state agencies to facilitate this exchange and inventory the state of geographic data processing in the Pacific Northwest.

Acting through the Oregon Department of Energy, a member agency, NWLISN has contracted with Portland State University to design, test, and initially to operate a database system that can assist its members in locating appropriate data sets from governmental agencies throughout the region. Such a system has several objectives.

- Avoid costly duplication of previously digitized map data.
- Promote inter-agency cooperation on data acquisition projects.
- Provide information on “most compatible” source products.
- Facilitate data standardization efforts and data transfer procedures.

By referring first to this index system, users identify data sets from other organizations that may be available for sale or trade in lieu of digitizing a source document. Planned data acquisitions are also cataloged to facilitate cooperation in obtaining and processing new digital data for areas of common interest. When more than one digital source is located using the index, additional attributes allow users to select the data which are most compatible with their system. Standardized methods of data description and reporting will assist the regional user community with adopting uniform data definitions and transfer methods based on the SDTS model. (USGS 1990)

Since the nature of the data is geographic, the index has been implemented with a GIS. In this way, SDX can be queried spatially or by attribute. When a geographic region of interest is specified, data holdings for that area identified by member agency and thematic content. Conversely, data themes such as land use, or soils, can be specified by query and all areas for which these data exist can be identified. In most instances, a query will consist of both location and thematic criteria, for example, when land use/land cover data are requested for an area defined by a list of USGS 7.5' quadrangles.

This paper summarizes the essential characteristics of the design and operation of the NWLISN Spatial Data Index, herein referred to as SDX. Following this discussion, several more detailed points are offered concerning insights this project has provided for the technical and organizational management of spatial metadata.

**Basic architecture of SDX**

The SDX can be thought of as three separate databases; the Agency Database, the Thematic Holdings Database, and the Spatial Cross-Reference Database. All are implemented in Arc/Info rev. 5.0.1 on a SunSPARC 1 workstation at the Portland State University. Urban and Public Affairs computer applications lab. The Agency and Thematic Holdings databases are also backed up as .DBF compatible files on a Macintosh PC running FoxBase 2.0. Copies of these relational files have been sent to the Washington State Library in Olympia to support some tabular queries and reporting from that location.

**Agency database**

The Agency Database provides information on participating agencies, their location and designated technical contact person. The agency contact is someone who has been identified as responsible for reporting data holdings to the SDX and is available to handle follow-up inquiries about data availability from interested parties.

In addition, all GIS and mapping systems in use at an agency are listed here, together with information concerning their computing platforms and operating systems. Preferred export formats and supported magnetic media are listed in the index so that persons contacting these agencies know what logical and physical formats to request.

Agencies with data holdings reported to SDX consist primarily of NWLISN members. In a few cases, non NWLISN member agencies affiliated with the Washington Geographic Information Council have been incorporated as well. For the most part all these agencies are either federal/regional or state-wide in scope but at least one county and another two-county regional planning agency is currently represented. Not all agencies contained in the Agency Database list data holdings with SDX. Some agencies are participating with the expectation that future database building efforts might be cooperatively arranged with others seeking similar data.
Figure 1 provides a summary of agencies listed with SDX and the GIS or CAD systems in use. Note the particular dominance of one vendor's GIS product among agencies in the Pacific Northwest. This is not as monolithic as it seems, however, when it is remembered that data are still structured and referenced quite differently from one installation to another. In addition, there are enough other systems in use to require that SDX incorporate non-vendor-specific descriptions for data holdings and extents that could be readily understood by this heterogeneous user community.

### SDX Agency Database

<table>
<thead>
<tr>
<th>Agency</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Federal</td>
<td>12</td>
</tr>
<tr>
<td>Oregon</td>
<td>7</td>
</tr>
<tr>
<td>Washington</td>
<td>9</td>
</tr>
<tr>
<td>Other</td>
<td>1</td>
</tr>
</tbody>
</table>

Total Agencies = 29

<table>
<thead>
<tr>
<th>System</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arc/Info</td>
<td>25</td>
</tr>
<tr>
<td>Intergraph</td>
<td>9</td>
</tr>
<tr>
<td>MOSS</td>
<td>4</td>
</tr>
<tr>
<td>GRASS</td>
<td>2</td>
</tr>
<tr>
<td>AutoCad</td>
<td>1</td>
</tr>
<tr>
<td>Synercom</td>
<td>1</td>
</tr>
<tr>
<td>I2S</td>
<td>1</td>
</tr>
<tr>
<td>MapInfo</td>
<td>1</td>
</tr>
<tr>
<td>EPPL7</td>
<td>1</td>
</tr>
<tr>
<td>In-house...</td>
<td>2</td>
</tr>
</tbody>
</table>

Total Systems = 47

![Figure 1](image)

SDX agencies and spatial data systems in use

### Thematic holdings database

The Thematic Holdings Database consists of records describing individual data sets reported by participating agencies. Data sets are uniquely identified by a combination of owning agency, the data set name, and completion status. (Figure 2) Additional attributes of each data set include:

- Thematic subject code (see below)
- Up to three keyword identifiers
- Tiling method
- Compilation data (when data were originally made digital)
- Compilation source or provider
- Compilation scale
- Revision date
- Host system

#### SDX Thematic holdings database

- Identified by name, agency, status

#### Attributes:

- Subject coded by theme
- Additional key words for search
- Compilation/Revision dates
- Source map or base data

#### Status Codes:

- C Completed
- I In Progress
- P Planned (Budgeted)
- D Desired (Wish-list)

![Figure 2](image)

Thematic holdings database: principal attributes and status codes

The status field is an important one for two reasons. A high priority of NWLISN is the ability to utilize the system to identify planned data acquisitions in other agencies, in order to find partners for shared co-development. Also, by using this field as part of the unique identifier, an agency can list two data sets with identical names, one complete and one planned. Four valid codes for the status field exist, corresponding to "Complete", or "In progress", and two categories of future acquisitions, "Planned" in the sense of budgeted in the current cycle, and "Desired" for those acquisitions on the planning horizon but not yet budgeted or prioritized. Agencies therefore can get a short and long term view of future data developments in the region.

The Thematic Holdings Database is a relational file and is linked to the Agency Database through the agency acronym fields of the two databases. When used alone, these two databases can provide information about the existence of individual data sets and who to contact to learn more about them. What is not contained in these listings is a description of the areal extent covered by individual data sets.

### Spatial Cross-reference database

The extent of an individual data set is maintained in the Spatial Cross-Reference portion of the SDX. Contributing agencies manage geographic data in a variety of tiling...
SDX

Spatial cross-reference database

Geographic Tiling

USGS Quads

PLSS Townships

HUC Basins

Figure 3. The function of the spatial cross-reference database

schemes. USGS quadrangles, Public Land Survey System (PLSS) townships, and Hydrologic Unit Basins are some of the more prevalent views of geography used by NWLISN agencies. When a data set is reported to SDX, the tiling system used to reference it is contained as an attribute. For each listed data set, areal extent is provided as a list of these quadrangle, township, or basin units. In cases where one of these three tiling systems are not employed, an approximation, usually in terms of 7.5' quadrangles, is used instead.

The function of the Spatial Cross-Reference Database is to find data sets meeting the thematic and geographic requirements of a user even if these data are cataloged in another tiling system. Given a list of quads, for example, the index can locate data for that area which are available from an agency reporting its holdings only in terms of townships. (see Figure 3)

Some implementation details of this cross-reference system are addressed in the technical issues section of this paper. It is a problem that is characteristic of the SDX user community, which is composed of agencies with widely differing views of the same geographic space. Users locating the data meeting their needs can contact the appropriate agency and request data in terms familiar to the holder. This facility enables participating agencies to report data holdings in accordance with the tiling schemes used in-house. Extent reporting thus remains in user-native terms when possible, and for GIS installations where a data set is referenced to a set of tiles, it can be accomplished by simply obtaining a list from the database.

Operation of SDX

Design and initial data collection for SDX has been completed, although additional query and reporting procedures are still being developed, particularly where frequent transactions can be automated. In its first phase, the SDX is a single site application, residing at Portland State University. Inquiries are handled via telephone or written communication and tabular and/or graphic results are provided within a short turn-around period. In addition to the query service, quarterly reports of the index contents are issued to subscribing agencies.

Query service access to SDX is not limited to NWLISN members at this time. There has been some discussion of a fee for access by non NWLISN agencies after the initial trial phase. Further details for the future of SDX are addressed in the institutional issues section, below.

When someone who needs information about geographic data calls the service, a staff person translates the request into a query to SDX. This is done as a three step process consisting of a specification of the geographical extent to be searched, the subject coding or other thematic attribute to be matched, and the type of reporting format desired by the user. These are summarized in figure Four.
Querying SDX

Step 1. Specify geographical extent to be searched
A. Oregon, Washington, both
B. List of quads, townships, basins
C. County
D. General Geographic area (approximate w/ quad list)

Step 2. Specify thematic attributes to search
A. Subject code
B. Status (Complete, In-progress, Planned, Desirable)
C. Agency owning the data
D. Tang unit
E. Scale
F. Combination of above &or data, source

Step 3. Specify desired reporting format
A. Report on data set information
   (by agency, status, code, scale, etc.)
B. Listing of geo. extent by tang units
C. Plot of geographic extent of data set
D. Print-out of related Agency Information

Figure 4.
Steps in querying the spatial data index

Technical metadata issues for spatial index systems

SDX is a GIS application that handles descriptions of GIS and cartographic databases residing at separate sites. A broad view of metadata defines the concept as data that describe other databases. (Elmarsi and Navathe 1989, p.489) Most metadata management systems are in the form of data dictionaries and catalog applications that store structural and semantic information about individual databases as schema descriptions and object definitions. Comprehensive information integration between two databases requires a detailed look at these metadata in order for the meaning and structure of data to be preserved. (Nyerges 1989) SDX is not such a tool. Rather, it can be viewed as a region-wide metadata tool, providing the first step toward better data integration by identifying relevant aspects of data sets for consideration.

What then, are some of the metadata constructs embodied in the SDX? They involve definitions and structural constructs that facilitate thematic, locational extent, and data quality description of whole data sets.

Taxonomy for data set subject classification

Developing a standardized approach to describing the thematic content of GIS and cartographic data is not a terribly straightforward task. Descriptions of data tend to be couched in terms familiar to specific software user communities and will vary considerably among agencies with distinctly different mandates. A coverage to an ARC/INFO user may hold quite different thematic data than a design file to an Intergraph user.

A typology for thematic data layers was developed after examining a number of data cataloging efforts in several other states. Although no one uniform scheme has been widely adopted, the two basic approaches describing thematic data are the use of subject codes and keywords.

Subject codes have the advantage of being hierarchically ordered and can support range specified queries, thus adapting to the level of specificity requested by a user. As with any hierarchical coding scheme, (SIC, SLUC etc.) inevitably there will be cases that are difficult to classify. The intent is to be complete and exhaustive.

Every listed data set must be identified with a single subject code. Subject coding of data sets is done by the reporting agencies according to a code sheet developed by SDX staff. Three digit integer codes depict seven main divisions of thematic data: Base Reference, Natural Features, Cultural Features, Socio-Economic, plus Areal, Satellite, and other Imagery. Each subject code within a main division, such as hydrology within natural features, or State and County Boundaries within Cultural Features, begins with the same digit. Each division may be further broken out into broad classes ending in zero and more specific subsets of those classes, (Slope = 215 of Topography = 210, of Natural Features, 2 - 7) Synonyms, explanations, and comments accompany each class to help users adopt a fairly uniform approach to categorizing their data. It is recognized that this is an imperfect method, but one which retains strong user participation.

Keywords are additional descriptive ‘tags’ for each data set. Keywords are not hierarchically ordered and so present difficulties for automating database searches for general to specific ranges, but they have the advantage of being intuitive and mnemonic. The SDX provides up to three keyword identifiers for each data set. In a sense they are a compromise, and can be used either to further specify the subject code (225 wetlands + “Estuarine”) or data source information (213 DEM + “DMA” and “250K”) or important related tabular items or files associated with the spatial coverage, (328 Census Tracts + “Income” and “Education”).

Extent description and cross-referencing spatial tiling schemes

Several possibilities for metadata describing data set extent exist. Spatial index systems in Santa Barbara, California and Columbus, Ohio employ polygonal descriptions to which thematic data attributes are tied. (RLG News 1989, Marble 1991) Catalogs in some other states are relational files only and do not feature a graphical description of the extent of data holdings, only listing counties or quadrangles for which data exist.
It was recognized at the outset of the NWLISN project that neither of these approaches would suffice. Polygonal boundaries are most useful for small project GIS applications and most NWLISN agency work involves very large areas in the two states or small areas that are widely scattered. (Much public landholding in alternate PLSS townships and/or sections). Building a relational database alone would forgo the graphical query and reporting that was desired, as well as make cross-referencing between tiling schemes very cumbersome.

Tiling spatial data refers to the partitioning of extensive map coverages into files of convenient size for storage and processing. Automated mapping and GIS have adopted previous map sheet partitioning strategies to the digital tiling equivalents. The result is that much digital cartographic data have been converted from map sheets directly into digital tiles with accompanying positional and attribute mismatches along the edges. (Chirsman 1990) Nevertheless, even as computing platforms and software advance in capability and speed, there are institutional and practical reasons why most geographic information professionals continue to think of geography in terms of the tilings appropriate to their agency mandates. Virtually all USGS Mapping Division products are can be described in terms of the basic 7.5' quadrangle building block. Meanwhile, hydrologic databases at the Water Resources division of USGS is stored in hydro basin files from the state HUC map series. Much Census Bureau data, while tiled by counties, can be referenced to the original quadrangle DLGs used to create the 1990 TIGER files. Other state and federal agencies use the Public Land Survey system townships as a tiling method.

Forcing all data set extent descriptions to conform to a single standard such as quadrangles would create an extra burden on some agencies to translate only for the purpose of contributing a listing. SDX users finding those data potentially useful would then call back, requesting data sets in terms of a non-native format, causing another round of work.

The solution to this problem was to use GIS overlay processing to enable data encoded in one spatial tiling form be cross referenced to data coded in another. (Figure 3) A practical limit was imposed, however, because if a large number of tiling schemes were employed, or if irregular polygonal boundary descriptions accepted, the integrated cross-reference coverage layer would contain and unmanageable number of reference polygons. Therefore, the three most prevalent tiling methods in use among NWLISN members were chosen. These are the USGS 7.5' quadrangles, PLSS townships, and HUC basins. Coverages defining these units are intersected into an integrated cross-reference layer which contains over 13 000 reference polygons for the state of Washington and over 10 000 for Oregon. (see Figure 5)

![Integrated layer of the cross-reference database](image)

- Cross Reference Polygons link to parent quad, township/range, hydro-basin
- Thematic data set IDs tied to individual quads, township/range, hydro-basin

Figure 5. Cross-referencing various tiling schemes describing spatial data sets

An individual data set record from the Thematic database is related to a link list of many quads, townships, or basins. An individual reference polygon is linked only to its parent quad, township, and basin and not directly to all metadata records in the thematic database that may occupy that sliver of geographic space. The reference tile lists are then related to the link lists for the thematic metadata to accomplish the cross-referencing. (see Figure 6) This method accomplishes the cross-referencing with a minimum number of separate data records (still considerable!) and results in reasonable query response times. It does this at the expense of spatial precision, however. f, for example, a query for all data is expressed as a list of townships, whole basins with those data that happened to correspond with even a corner of one of the townships will be selected. In most cases, this discrepancy is not very severe. Since the method cautiously errs on the side of over-, rather than under-reporting, the added benefit of presenting the inquiring user with query results which directly reference the native tiling scheme of the originating database is desirable.

Metadata describing data quality

A third major technical issue to be addressed in a spatial metadata indexing system is how to catalog and report data quality and accuracy information. In this regard,
SDX has not implemented a satisfactory "solution". In part this is a consequence of the nascent stage of standardization in reporting data quality. Furthermore, since the index is operated by a third party without direct access to the data, there is no independent way to verify statements about the quality of data sets listed by member agencies.

A standard for conveying useful information concerning data quality most likely will emerge from efforts to implement the national Spatial Data Transfer Standards (SDTS) (USGS 1990) The standard specifies that statements accompany file transfers concerning five components that document data quality.

- The lineage of the data; source documentation and processing.
- The integrity of positional accuracy in the data.
- The accuracy of attribute classifications in the data.
- The logical consistency of the data; how well the data conform to the model schema.
- The completeness of the data as described in accompanying documentation.

While the standard has undergone many iterations of review and comment there does not yet exist a practical software tool to implement SDTS. SDX’s caveat emptor approach to data quality therefore, reflects the state of the discipline with regard to this issue. But a "fitness for use criteria" can be employed only if metadata contain enough attributes to form an expectation of the integrity of the data. Certain fields in the SDX Thematic Holdings database can be evaluated in just such a way. Source document, compilation scale (of the smallest scale component that went into the digitizing), and compilation and revision dates, are all attributes that can be queries for any data set description and reviewed by prospective users.

Institutional metadata issues for spatial index systems

The technical considerations discussed above, for the most part describe how SDX works as a GIS metadata handling application. How SDX functions in the social and political milieu of spatial information sharing raises several interesting institutional metadata issues for consideration. Three of these are: how to coordinate the many individual agencies contributing to SDX, the closely related issue of how SDX is to evolve in the future, and the wider issues of the standardization of spatial metadata.

Coordination among multiple agencies

Informal arrangement for data sharing have persisted among users since the dawn of digital cartography, but the scale and scope of the current activity far exceed the ability of informal constructs and personal contacts to rationalize it. Nolan and Nyerges (1991) note that this cooperation is successful only to a point, beyond which, some coordination is required in the form of more formal efforts. These researchers proposed a Land Information System Network to establish organizational and technical linkages between local and regional agencies with interests in managing land records and geographic data. Such a network would not only exchange digital data but allocate responsibility for maintaining layers among participating entities.

The NWLISN is a less ambitious undertaking, relying on the voluntary cooperation and good-will of interested parties within participating agencies. The consortium established through a memorandum of understanding where each agency sends a representative to a Steering Committee which establishes policy. Technical working groups implement these policies; one of which is SDX. PSU was adopted as a contractor to design and initially operate SDX, and a NWLISN Index subcommittee meets periodically to oversee the venture. Thus, contacts among NWLISN member agencies and between them and PSU occur at a variety of levels. Managers and administrators at the Steering Committee level are enthusiastic about the index due to government mandates to cooperate on data acquisition. Representatives at the technical and index subcommittee levels are also enthusiastic but realize that the project involves a good bit of work. Each agency names a contact person to handle inquiries and data reporting. For the first year of the project, reporting has been slow since the project is lower on the horizon of people who have not been involved in planning and design meetings and are also working on day to day production.

Managing the SDX therefore has required some vigilance to keep participating members motivated and informed of progress. That this has come as far as it has in the absence of a strong central unifying organization is a tribute to the recognition that a regional metadata resource on spatial data will be beneficial to many.

Planning for long-term deployment of SDX

After the initial development of SDX, what organizational structure can maintain and operate it in the long run?

Currently the Washington and Oregon portions of SDX reside as separate and identical applications at PSU. The NWLISN has decided to seek a more permanent home for the application in an Oregon and a Washington State institution. SDX staff and the index subcommittee have formulated a redeployment plan based on incremental steps using in-place technology to transfer the facility to the Oregon State Service Center for GIS in Salem, and the Washington State Library in Olympia. Researchers in Portland remain interested in further developments, NWLISN wishes to continue its
Thematic to Spatial Cross-Reference
Database Link Schema

Thematic Database Records
- DATASET.NO
- AGENCYACRONYM
- DATASET_NAME
- STATUS
- TILING

One-Man

QUAD.LIST
- LIST.NO
- QUAD_NAME
- QUAD_CODE

Many-One

TOWN.LIST
- LIST.NO
- TOWNSHIP

Many-One

BASIN.LIST
- LIST.NO
- BASIN_HUC#

WASPATX.PAT
- Cross-reference database polygon record

WASPATX-ID
- TOWNSHIP
- QUAD
- BASIN-NAME

BASIN.LINK
- LIST.NO
- DATASET.NO

QUAD.LINK
- LIST.NO
- DATASET.NO

THEM.DAT
involvement to insure standardized access and reporting procedures for both states, and some redesign and co-
ordination will still be necessary in the beginning phases. Therefore, redeployment will include transaction logging
and evaluation in order to direct further development.

In Olympia, SDX will be initially a relational database
application without graphic query capability or spatial tile
cross-referencing. Evaluation of this service will de-
monstrate the need for more spatial processing and visualization. Depending on user demand, the index could then
be supported on a GIS at the State Library, or elsewhere,
with the Library acting as an interconnected node.

In Oregon, the State Service Center for GIS is also an
ARC/INFO site and can already support SDX as is. This agency is interested in establishing a state-wide network
of Arcview (browse only) nodes to support use of its
many services, including a version of SDX.

Additional policy decisions concerning non-NW LIS
access fees, subscriptions, and restrictions may be appro-
riate and will be made in accordance with open records
laws in both states.

**Development and Implementation of spatial metadata standards**

The NW LISN Spatial Data Index is one implementation
of a data cataloging system on a regional level. It has
involved the participation and cooperation of many
agencies which use different automated systems, data
definitions, and geographic partitioning strategies.
Methods of collecting, representing, and disseminating
spatial metadata have been central to the technical and
institutional decisions discussed above. As a more
integrated culture of geographic information processing
emerges, the need for metadata describing spatial
databases will expand. Interest in the role and utility of
metadata is rising in many disciplines. (Medley-Scott
et al. 1992) It is not too early to consider the require-
ments for a generic standard for spatial metadata
databases and applications.

Momentum has been building in recent years for a
standard approach to spatial data exchange. Metadata
to describe cartographic and geographic databases is
therefore a crucial part of the SDTS (Spatial Data
Transfer Standard), currently in the process of becom-
ing a federal information processing standard (FIPS)
(McDermott 1991). The standard has contributed much
to the definition of a language describing geographic
and cartographic entities, and provides a means to address
data quality issues. It prescribes formats for data transfer
modules and the metadata to describe their contents.

Because the principal focus of SDTS is the actual
data transfer process, another standards process has been
initiated to complement SDTS with a comprehensive
specification for spatial metadata. (ASTM 1991) This
effort, which is being moved through the ASTM stand-
ards process, may evolve as a voluntary guideline rather
than a national processing standard. Nevertheless, it has
provided a convenient forum for the discussion of spatial
metadata issues.

Discussions regarding this draft specification in part
have clarified the scope of how spatial metadata is useful
in geographic information processing. Several interests
related to spatial metadata imply slightly different points
of view regarding the use and development of a spatial
metadata standard. These are:

- Metadata for cataloging and indexing spatial data
  from a variety of agencies.
- Metadata to accompany an individual data transfer
  (SDTS)
- Metadata to document internal processing and
  operations on data, and
- Vendors of GIS and other software who many
  implement parts of the standard.

The SDX project corresponds to the first of these
four interests. The essential question to be addressed
by this aspect of spatial meta-data is, "What constitutes
a description of a spatial data set?" Yrana (1991) has
proposed a series of records to describe aspects of a data
set for indexing purposes. It contains ten categories of
information with nested subcategories indicating informa-
tion relating to the "who, what, where, and how" of
spatial data. (See table 1) The author participated in
discussions with a variety of individuals either engaged
in data indexing tasks or involved with organizations, like
NW LISN, which have a serious interest in developing
metadata to facilitate data exchange. For the most part,
these recommendations reflect these conversations and
the experiences and lessons of the SDX project regarding
spatial metadata.

**TABLE 1**

Spatial Meta-Data Fields to Support Data Indexing and Catalogs

1. Data set identification
   a. Each data set to be referenced by name or numeric ID
   b. Individual data sets may be uniquely identified by a compound key composed of
      the data set name, owner (agency), and possibly its availability status code (see
      below, 4e)

2. Thematic description of the data set
   a. Data theme represented by subject code
      — and/or
   b. Data theme represented by keyword descriptor
3. Earth location description of the data set
   a. Generalized text description. (i.e. “North east Oregon”)
   b. Polygonal boundary of area for which data set exists
   c. Method of tiling or partitioning to store/manage the data (e.g. 7.5' quads, Townships, etc.)
   d. Listing of all tile units covered fully or partially by the data set
4. Temporal description of the data set
   a. Availability status code (e.g.: C= completed, I= in progress, P= planned, D= desired.)
   b. Date of original compilation as a digital data set
   c. Date of latest revision
5. Source characteristic of the data set
   a. Source document type (i.e. map, air photo, other)
   b. Agency responsible for original compilation or survey
   c. Date of source document
6. Spatial framework of data set
   a. Spatial Model
   b. Scale of compilation (smallest scale from which data were derived/confabed)
   c. Coordinate system
   d. Projection
7. Quality characteristic of the data set
   a. Data lineage availability
   b. Positional data accuracy check
   c. Attribute data accuracy check
   d. Check for logical consistency
   e. Check for completeness
8. Media/product characteristic of the data set
   a. Program or software that created the data set
   b. CPU and operating system
   c. Format availability (if supplier has a choice, indicate preferred, or native format)
   d. Data set size
   e. Information on cost, licensing, restrictions etc.
9. Supplier/producer characteristic
   (Contacts for more info and/or exchange)
   a. Agency name and division
   b. Address/routing
   c. Contact person and telephone.
10. Additional characteristics pertaining to image data sets
    These elements pertain to digital imagery in addition to the elements that apply for all spatial data.
    a. Type of digital imagery [I. = aerial photography; II = multispectral scanned imagery, radar, etc.]
    On I.
    b. Scanned image, or digital rectification
       c. Scale
       d. Flying height (focal length)
       c. Film type (B&W, IR, Color, CIR, etc.)
       f. Film format (size)
       g. Sensor aspect (vertical, oblique, stereo, panoramic)
       h. Clarity (% cloud cover, dust, etc.)
       i. Date of exposure
    On II.
    b. Platform (Landsat, Spot, others, etc. possibly airborne)
       c. Minimum resolution (pixel size in ground units)
       d. Flying height/altitude
       c. Spectral band(s) (in wavelength units OR another common band reference scheme)
       d. Scene identifier (as referenced by source. Data set identifier may be more mnemonic)
       d. Scene size (frame reference as “earth-location” above. This is file size)

Conclusion

The NWLISN Spatial Data Index project has developed an application that can reference a variety of data holdings from agencies with different mandates, thematic subjects, and geographic views. Designing the application and making it work among a heterogeneous user base has required an examination of a number of technical and institutional issues discussed in this paper.

SDX and other prototype data indexing systems can be considered partial models for the development of regional and larger metadata handling systems. To accomplish this, the lessons and experiences of projects such as SDX should be examined with the intent to establish generic and uniform methods for representing spatial metadata, perhaps leading to a specification of a standard.

The ten categories offered above are put forward as the basis for discussion among parties interested in the spatial metadata question. Increased access to the data resources of public domain and other agencies on a quid-pro-quo basis will be facilitated with a standardized approach to data set description such as this.
Acknowledgements

The development of SDX came about through the efforts of many individuals connected with Portland State University or NWLISN member agencies. The author wishes to express his special gratitude and appreciation for the assistance and direction provided to the project by Cary Lorimor, Margo Blosser (especially for figure 6), Steve Sherer, and Dick Lycan. Funding for the project was obtained from member agencies and administered through the offices of the Oregon State Service Center for GIS, a unit of the State Department of Energy.

References


The use of GIS as a dynamic multiple-use management tool by the U.S. Bureau of Land Management on federal public lands in Colorado

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Abstract

The United States Bureau of Land Management (BLM) currently administers more than 270 million acres of public lands under the management principles of multiple use and sustained yield, as mandated by the Federal Land Policy and Management Act of 1976 (FLPMA). A wide variety of natural resource management techniques have been used over the 45-year history of the agency and new methods are constantly being evaluated for their potential to improve overall efficiency and meet increasing demands.

In 1982, responding to the dramatic increase in energy development activities for coal and oil shale resources, the Colorado State Office of the Bureau of Land Management initiated the use of Geographic Information System (GIS) technologies to support the resource management planning process. As this state-of-the-art technology has evolved over the years, the BLM has continuously incorporated new automated procedures to assist in the development of management strategies and in the production of public documents containing detailed maps and statistical reports.

As a result of the successes and frustrations of GIS implementation in Colorado, the BLM is learning new ways of efficiently incorporating this technology into its standard operating procedures. The knowledge and experience gained from past GIS projects are currently being used to develop new and comprehensive plans for a fully integrated Land Information System (LIS) that will provide managers with automated resource analyses and decision support capabilities.

Introduction

America’s “frontier”, the vastness was glamorized in the movies, neglected because of its emptiness and thought to be worthless. However, less than four decades ago Americans realized that the 440 million acres of the western “frontier” was important — that it contained vast natural resources and wealth, and should be retained in federal ownership.

Thus, in 1946 the Bureau of Land Management (BLM) was created from a merger of the Grazing Service and General Land Office. The BLM is one of the agencies in the United States Department of the Interior. It is responsible for the multiple-use management of the Nation’s largest system of federal lands, known as “Public Lands.”
Covering nearly one-eighth of the United States, including Alaska, these Public Lands represent all that remains of our Nation’s original public domain. Today, more than 270 million acres of BLM-administered Public Lands span the entire American landscape, ranging from tundras to coastlines, alpine meadows to sand dunes, raging rivers to subterranean caves. These lands offer Americans a great diversity and wealth of natural resources.

BLM is mandated by the Congress of the United States to manage the Public Lands under the principles of multiple use and sustained yield. Some of the multiple use programs include: protection and preservation of cultural and historical resources; opening lands for oil and gas, coal, and geothermal development; timber production; fish and wildlife habitat; cadastral surveys; plus a variety of recreation activities, such as development and maintenance of mountain biking and hiking trails, designation of off-highway vehicle and watchable wildlife viewing areas, and promotion of whitewater rafting and scenic driving routes. A vital support function for all programs is lands records data base management.

The majority of Public Lands are located in the western U.S. (plus 30,000 acres managed within 31 states east of the Mississippi River). To bring our offices and employees close to the lands we manage, and in turn better serve our constituents, the BLM administration areas are divided into state offices, district offices, and resource area offices. On-the-ground natural resources program management is developed and monitored by district and resource area offices. It is at these local offices where land management decisions are made, based on sound planning through citizen participation and staff resource specialist recommendations.

The fundamental principles of the BLM lie in the knowledge and mission to wisely manage “land.” BLM is responsible to know where the land is — who owns it — what’s on it — what’s under it — and how to manage it.

Technological advancements that enable managers to make better, more informed decisions about the natural resources within a particular parcel of land, are paramount to successful management. With the increasing complexity of managing resources, the use of technology to facilitate the decision process is essential. Geographic Information Systems (GIS) applications consolidate information previously scattered — from paper maps, files, and memories, and accesses up-to-date spatial data for immediate use.

Continued technological advancements in GIS provide BLM with opportunities to more efficiently research, record, retrieve, update, and interpret pertinent and complex information data bases. GIS is the common thread to facilitate in Public Land administration efforts. The GIS greatly enhances a broad distribution of spatial data to the public and, in turn, facilitates the job of a manager in explaining or defending a decision.

Land use planning documents
BLM is responsible to determine the best use of the land while accommodating competitive and often conflicting interests, such as wilderness designation versus off-highway vehicle use, or prehistoric cultural sites versus minerals extraction. GIS applications are dynamic. Information must be updated periodically, whenever land status, natural resources, or boundaries change. The BLM’s planning process is also dynamic. Comprehensive land use planning is the catalyst of a sound GIS data base.

Guided by the National Environmental Policy Act (NEPA), the Federal Land Policy and Management Act of 1976 (FLPMA), and numerous other federal, state, and local laws, BLM balances development with protection of the natural resources to ensure their long-term productivity. In order to do this, BLM develops comprehensive land use plans called Resource Management Plans (RMP’s) to set guidelines for multiple-use land management decisions. Land use decisions based on an RMP form the foundation for a data base and reflect all future management actions.

Published in conjunction with each RMP is an Environmental Impact Statement (EIS), which analyzes the effects of implementing each management alternative presented in the RMP. Once all alternatives have been thoroughly analyzed, BLM selects a preferred, multiple use-oriented alternative; one that will best balance uses in an area. These are working documents that guide natural resource managers in complex land use management conflicts. Decisions in the RMP are monitored throughout implementation to ensure that impacts and effects were accurately assessed and goals appropriately met.

GIS-supported RMP’s are dynamic — they are constantly updated with new and changing data. Through routine implementation and subsequent plan amendments, there is little if any need to revise planning documents except for very long life cycles or newly emerging issues.

Another important role for GIS is in the development of an activity-specific plan. GIS facilitates the production of site analyses, facility placement, environmental assessments, surface reclamation plans, research projects, predictive models, conflict identification, suitability analyses, weighted composite analyses, acreage calculations, and graphic products among others.

Whether an RMP, EIS, or activity plan, these various planning documents are referred to on a daily basis by field-level managers. They may be prepared for each geographic resource area or individual site, and may vary in size from one acre up to several million acres. Because of topographic, natural, and issue diversity, each plan is unique to the area it addresses. BLM’s planning guides are both comprehensive and issue-oriented, and must
also include alternative discussions of all affected resources or concerns, which focus on real, on-the-ground problem resolution.

GIS beginnings

The BLM’s first GIS effort began just ten years ago when Colorado embarked on an ambitious planning project that included 603,000 acres of Public Lands in northwestern Colorado. Documentation was needed to be able to quickly analyze alternative development scenarios and to fully address the diverse natural resources with possible social and environmental impacts. The federal government’s proposed oil shale leasing program necessitated the development of a comprehensive environmental impact analysis document. This extensive planning project required a thorough analysis of site-specific and cumulative environmental and socio-economic impacts, taking into account the probable development effects of the oil shale resource.

In order to adequately assess most likely impacts, BLM realized that a new and innovative approach was needed to address the complexities of the potential impacts to natural resources associated with proposed land use decisions. The subsequent RMP and companion EIS incorporated acquired information and demonstrated the best multiple-use management direction for oil shale development. The BLM planning process encompassed two years and incorporated GIS in a thorough analysis for a timely completion. The project included digitizing (data entry) and an analysis of complex data using 128 base maps. When final, the RMP contained approximately 900 thematic maps.

Recently, pertinent information about livestock grazing, deer and elk migration patterns, etc., has assisted with management decisions regarding a proposed uranium mine lease, off-site waste disposal, and disposition of nearly 700 oil shale mining claims. Current efforts are now underway to amend and supplement GIS information to evaluate additional Public Lands in northwestern Colorado. Much of the preliminary work is complete, thanks to existing GIS technology.

Early GIS efforts demonstrated that, for efficiency and cost effectiveness and amortization of data collection results in using the data base on a daily basis over the long term. This comprehensive GIS data base is updated whenever necessary, so it does not become outdated. Initial data collected through GIS efforts in the early ‘80’s is continually being updated and used in a variety of planning documents.

GIS configuration

The GIS used in BLM is the Map Overlay Statistical System (MOSS) family of software developed by the U.S. Fish & Wildlife Service and BLM. The MOSS system includes Automated Digitizing System (ADS) for digitizing, MOSS for vector analyses, and Map Analysis and Processing System (MAPS) for cell (raster) map analysis, and the Cartographic Output System (COS) for finished graphics plotting.

The GIS configuration (both hardware and software) has been standardized throughout the BLM. This configuration will support data standards, and will assist in the implementation of interagency data standards as well. The intent is to systematically improve BLM’s current GIS (MOSS family) of software to a specific and limited threshold. Utilizing technological advancements was identified as the highest priority by field employees. The BLM will adopt an incremental approach for making needed improvements. GIS software and hardware will be replaced with a Land Information System (LIS) between 1996 and 1998.

Current GIS applications

Data requirements to meet planning needs are identified through pre-planning criteria and are limited to those that address key planning issues. If digital information is not available, on-the-ground inventories and/or studies may be conducted and entered into the data base.

To supplement general information in the RMP, specialists enlist the support of GIS “modeling.” A map of the geographic area is generated using multiple themes of data (elevation contours, roads, water, land status, mineral leases, etc.). For example, a cultural resources theme could be depicted on a map that also showed the geographic relationship with a number of additional resources also occurring throughout the area. GIS analysis is determined when the overlays are reviewed. Thus, more and more often, GIS is playing an important role in the “modeling” of natural resources information.

Often the analysis and/or combination of data themes provide more valuable information, similar to an inventory but actually an analysis, than the data provided in raw format. For example, if an inventory of elk calving in a particular area was unavailable, it could be modeled and created by combining the soils data with steep slopes, wetland vegetation, recent wildfires, and elevations above 6,500 feet. Acreage summaries and map graphics support the inventories and analyses described in the text. These individual data sets may be combined to derive new maps. Although no physical inventory of the area was conducted by field specialists, the modeling technique using derived data is usually sufficient to project management of the area.

For the past several years BLM’s Grand Junction Resource Area Office in west-central Colorado has been assigning resource values to thematic data layers to assist in determining appropriate oil and gas leasing stipulations. Sequential resource conflict analyses assist the manager by quickly focusing on potential conflicts. Resource values can be visually displayed and land use decisions quickly determined. Subsequently, as
Each resource theme considered in the management scheme may be ranked in some order of preference — that is compared to all other resources to determine the dominant or preferred use or uses within a given geographic area. If two resources existed in the same location, such as coal and waterfowl, the wisest and best use of the land would have to be determined. If the allocation involved compatible resource uses, the decision would be relatively easy. However, in many cases, competing interests are incompatible and must be mitigated.

In developing management alternatives, GIS is used to sort areas by compatibility. The theme of each alternative determines the ranking order for its component themes. Components most compatible with the main theme become the highest priority, while those least compatible become the lowest priority in use allocation. Map graphics allow visually portrayed complex data themes. Analysis of the plot relies largely on the ability of resource specialists and other professionals to interpret trends and predict outcomes of actions.

After potential impacts have been identified, a preferred alternative is selected. The alternative is intended to resolve planning issues and promote balanced multiple-use principles with acceptable levels of impact. The preferred alternative can be a combination of various aspects of several alternatives or in some cases might duplicate an original alternative.

GIS cannot and will not replace staff resource specialists' professional judgment. Knowledgeable individuals are required to formulate concepts that use GIS applications to interpret the end results of analysis. GIS users are able to analyze large geographic areas with vast amounts of complex resource data in an efficient manner. Analysis, which may be too expensive and time-consuming to perform manually, is often accomplished with GIS capability.

GIS does not and cannot replace the specialist's or manager's ability to quantify impacts, such as the effect clear-cutting timber will have on elk herd numbers, migration, and health. It can help to identify specific conflict areas geographically and quantify the acreage of conflict. For example, biologists know that clear cutting will displace elk herds from part of their traditional feeding areas and reduce desirable cover. They can determine the total habitat loss by intersecting the timber harvest areas with the elk habitat, then create acreage summaries that may tell them that 11 percent of the herd's habitat will be affected. GIS will not identify how last month's record snowfall and cold, or dramatic increases in the numbers of hunters will affect the herd. Biologists will take these additional factors into consideration, calculate the probable effect of habitat reduction, and then determine the cumulative impacts on the herd.
In some instances, a management decision may be controversial or challenged by a member of an environmental organization or the oil and gas industry. To defend their position, the manager can graphically show why the decision was made. Ultimately, any necessary changes or additions can be included into the database thereby keeping all information current and easily retrievable.

GIS serves as a tool to assist in problem resolution and is used to manipulate alternatives, combining various aspects of each. Impacts can be quantified more effectively, producing a higher quality product which can be easily understood by the public, thus reducing the probability of adverse comment or protest.

**Working smarter in wildfire suppression**

The following maps show land status with base information such as streams, towns, roads, and transmission lines. For example, in southwestern Colorado, the BLM Fire Management Officer may receive a radio report of a wildfire at a particular geographic point. Using longitude and latitude coordinates of the wildfire, a computer search is generated and plotted. Within minutes fire personnel plot a map that indicates water sources, access roads, potential helicopter hazards with powerlines, and land status. Wildfires do not recognize land boundaries. A lightning strike that ignited an isolated, uninhabited area on BLM lands could easily travel swiftly onto private lands where the possibility of lives and property could be threatened.

GIS becomes more cost-effective and is amortized when data entered for one project is used in other projects, as indicated in the preceding example. The more that data, equipment, and trained personnel are used, the further the costs, which may initially be high, are spread. This data can be reused for many projects — many of which will be required on short notice without added funding. Some of these include predictive models, conflict identification, acreage calculation, ownership identification, impact analysis, facility placement, and matrix development.

**GIS cartographic advancements**

Since most natural resource issues are geographically referenced, they are mappable. The data layers not already on a system, are mapped, then digitized from a preferred U.S. Geological Survey base map at a 1:24,000 scale. Once entered into the MOSS family, the digitized layers are then referred to as resource themes. Plan requirements vary with complexity of natural resource issues but an average of 50 themes is generally needed for most comprehensive RMP's.

GIS automation has greatly facilitated digital cartography as well as updating data already collected. Preparation of custom maps for specific resource themes or for specific activity plans is commonplace throughout all BLM offices. Automated maps that focus on particular uses may be quickly and efficiently produced. GIS-plotted maps are especially useful at citizen participation meetings when a BLM manager needs to illustrate a position or alternative management plan, or enlist public support for a project or decision.

Digital cartography is a costly technological process. The enormous data volume generated by the surveying
sciences creates a demanding work load. The highest costs are typically associated with the data bases. Collecting and maintaining data is an expensive, labor-intensive endeavor. Coupled with the fact that BLM is still in the early stages of developing data standards and consistency, there remain numerous problem areas with graphically correct data output. However, GIS-generated map costs can reduce the manual process costs by as much as 80 percent. Color maps using GIS can be produced in 20 percent of the time required by the manual process.

Although, BLM has partially automated the mapping process with GIS, the agency must still perform some manual tasks for creation of cartographically correct maps. This is especially applicable in the area of final map preparation when four-color printing is required.

**BLM challenges**

During the past 10 years, BLM in Colorado has incorporated GIS applications into a variety of natural resource planning documents. In fact, Colorado has been at the forefront in building data bases, and leads the agency in completed RMP’s, most of which used GIS.

While success stories continue to increase, there is also a lengthy list of problem areas, stumbling blocks, and resistance to using GIS. Namely, from the very beginning, GIS may have been advertised as a total solution to automating natural resource management applications. However, in some instances GIS efforts have been unrealistic and expectations too high. Learning the MOSS family of software is extremely complex and time-consuming. The lengthy learning process has been interpreted differently by individuals, also knowledge and consistency varies greatly. To become accustomed and comfortable with this technology requires GIS users to “use” the program on a daily basis.

We recognize that no matter how a program is developed, user interpretation will vary. Therefore, probably our greatest drawback to GIS has been user inconsistency. Some individuals in the agency believe that BLM “put the cart before the horse,” — that GIS was introduced without the necessary structural changes in work flow and practices that would allow new technology to work efficiently.

Occasionally, due to time constraints, lack of base digital information has delayed or stopped a project or analysis which could have been completed in a GIS environment. BLM is still in the learning curve of data collection. It is not uncommon for personnel to realize the specifics about their area of expertise; however, much of the knowledge resides in their minds and personal notebooks. Subsequently, one of the major goals of automating BLM records to incorporate GIS application is to educate natural resource specialists and managers to collect raw data and ensure that data are appropriately recorded for GIS. The gradual addition of GIS coordinators in all State and District Offices will facilitate and accelerate learning and using the system. We plan to position additional GIS specialists in all BLM offices nationwide.

While GIS coordinators are available to advise and orchestrate data collection and maintenance efforts, it is also each user’s responsibility to take “ownership” of acquired data. An automated system is only as good as the data maintained. Unfortunately, data maintenance is tedious and time-consuming. An additional challenge to BLM is to diligently pursue allocating appropriate time and sufficient funding to train personnel. The BLM believes commitment to employee education and training is the most important aspect of adopting the GIS program.

From a manager’s viewpoint — many managers do not understand GIS and are therefore reluctant to insist their personnel adopt it. As with any new and innovative program, “old habits die hard.” This is perhaps most evident with managers who are not familiar or comfortable with “automation.” Rapidly evolving technologies within GIS foster additional apprehension. This is perhaps enough reason to keep our automated efforts simple and user friendly. In a nationwide organization of more than 9,000 people, there will be an enormous variation in GIS interest, knowledge, and acceptance. BLM realizes that GIS applications will provide an improved automated data management system — one that integrates the multitude of natural resource programs BLM employees deal with on a daily basis. There is no denying the system works — but how do we get there from here? And how can we do it in a timely, cost effective, and efficient manner. The challenge is to prove the system through successful applications. During the last decade BLM in Colorado, as well as early GIS efforts in California, Montanas, Wyoming, and New Mexico, provided invaluable evidence of the successes and pitfalls encountered through the GIS learning curve.

As a federal government land managing agency whose budget must be appropriated by the Congress, it is imperative to not only find ways of doing our jobs more efficiently, but to do them at a cost savings too. Ultimately, BLM will be challenged to play a major role in standardizing GIS information for natural resource applications. As mentioned early in this paper, BLM is responsible for the multiple-use management of one-eighth of the land in the United States. Currently, BLM is in the forefront of developing automated data bases. Clearly, GIS meets our required needs and will produce long-term benefits.

BLM has recently initiated Data Standards Teams throughout the field offices. Specifically, these “teams” are organized by natural resource programs, for instance oil and gas, cultural, or forestry. Each team is charged with evaluating the current status of GIS applications, analyzing the information, then recommending agency-wide standards to ensure overall consistency.
Using GIS in the RMP process has created multiple themes of data across the state. There currently are voids in the data base due to collection methods and management priorities. Data themes developed independently by field offices are now being standardized to ensure consistent naming and labeling.

Summary

What began in the BLM as “humble GIS beginnings” only 10 years ago, have multiplied many times over through the education of our employees, sophistication of GIS applications, simplification of workloads, and increased monetary savings.

As the Federal government’s largest multiple-use land-managing agency, it is imperative for BLM to consistently strive for a balanced integrated resource management approach in our decision making. GIS provides us with an enormous and powerful data base. We now must harness this vast abundance of information and methodically transform it into an easily retrievable format.

GIS applications steadily increased throughout the offices in BLM. Many managers quickly realized that GIS was the basis for a dynamic system — a system of unrealized capabilities — and a system that will save time and money.

GIS fosters an interdisciplinary approach and causes people to work together to discuss related resources and conflicts. GIS overlays information and interfaces with natural resources. A wildlife biologist is not alone; dealing only with a specific area of expertise. GIS brings all resource specialists together to discuss current situations and how to evaluate and adjust land use practices for the betterment of not only wildlife, but perhaps recreational uses or enhanced riparian values.

Accurate and reliable land, cultural, and natural resource information is the foundation for successful management decisions. Progressive management strategies are essential to BLM — the Congress of the United States demands it — the American public expects it — and those who are employed by BLM believe in it. GIS is a dynamic multiple-use management tool that continues to reinforce and advance BLM’s mission of wisely managing “land.”

References


A2 Access to data: grief or relief?

The GRASS CD-ROM global data base and public domain GIS software
Scott Madry, Rutgers University, New Brunswick, NJ, USA

Access to data in support of local studies and global investigations
John E. Estes et al., Department of Geography, University of California, Santa Barbara, CA, USA

Geographic information system for multidata database management
Frank Indome, IBM - Bergen Scientific Centre, Bergen, Norway

Spatial information sharing spells grief or relief?
Diane Allen et al., Ministry of Environment, Lands and Parks, Victoria, BC, Canada
GRASS CD-ROM global database and public domain GIS software

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Abstract

Global data sets must be made more widely available to the research and teaching communities to support new directions in global scale research. These data must be made available on media that are easily used and must be affordable. The Cook College Remote Sensing Center of Rutgers University and the U.S. Army Corps of Engineers Construction Engineering Research Laboratory (CERL) have signed an agreement that will allow Rutgers to make available on CD-ROM the CERL Global GRASS 1 digital data set. The data set (about 500 Mb) consist of some 50 different raster global data files from various sources; including global elevation, vegetation, green leaf biomass (monthly 1988 AVHRR composites), national boundaries, soils, and marine productivity (Coastal Zone Colour Scanner), among others. Additional CD-ROMs will be developed on an annual basis. This paper describes the global database, the GRASS software package, and their ability to support global research and teaching.
Access to data in support of local studies and global investigations

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Abstract

Timely, responsive access to data is a crucial element for achieving the science objectives of the U.S. Global Change Research Program and NASA’s Mission to Planet Earth. Effective management and utilization of rapidly growing data spatial assets call for new approaches and significant modifications to the infrastructure for accomplishing research. Success will ultimately be measured in terms of the systems responsiveness to science user needs for access to data and the tools required to convert data into new scientific insights.

NASA is developing the overall architecture, policies, and implementation guidelines to ensure that data and information systems achieve necessary levels of connectivity and interoperability. A high-level Master Directory will provide open and uniform access to information about space research data. The goal is to provide “one stop shopping” for spatial and other datasets important to a wide variety of investigators. NASA has also initiated an information systems research program to apply advanced computer and information system technology to enhance science user effectiveness. For example, improving methods for: browsing large spatial databases and, visualization of spatial data are being examined. These investigations supported by NASA are intended to improve the overall infrastructure required at scales from local to global.
Geographic information system for multidata database management

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Abstract

Database systems (DBS) were a solution to the problem of shared access to heterogeneous files created by multiple autonomous applications in a centralised environment [JITM90]. Globally integrated databases were then used to replace the files for easier data usage. The creation of databases has however led to the collection of different types of data (multidata') for different applications captured using different techniques and at times residing in different formats. And as the world comes closer through computer networking and distributed databases there is the need to integrate some of the data types to support effective decision-making and inferencing that could result from managing multidata. Since traditional database management systems cannot handle all data types, this paper looks at multi-data type database systems (MdDBS) and particularly GIS (which is a MdDBS) as a tool for integrating three types of data — facts, statistics and images.

Introduction

Current trends indicate that databases in daily use now play a significant role for information analysis and decision-making in both government and private sectors. This can be attributed to the emergence of diverse low priced hardware and software systems, computer networking and a general interest in using computers that have made the process of managing computerised files or databases accessible to a wide variety of users.

The collection and management of data for different applications is common in such areas as business, engineering, medicine, law, education and library science. Traditionally each department or organization collects its information into a database (or file) for a particular application. Different applications however, accept different data types leading to the collection of data from different sources in different formats (types) and at times residing in different applications. The creation of files or databases are thus meant to capture the exact data type needed by the applications used by organisations or departments.

An administrative body like a municipal council, for example, will usually have stored information about individual inhabitants in a relational database, or a list of files and maps showing infrastructure and other related attributes (name of road, length, origin), and hand drawn sketches and aerial images of parts of the municipality. There might also be information showing population census and survey data in statistical formats such as charts or histograms etc.

In Norway, the medical birth registry collects information on all births and related birth defects and publishes monthly reports which includes statistical tables, histograms.
and maps indicating graphically the trends in births and birth defects for the municipalities of the country. It stores information in the form of personal information (e.g. mother and child), aggregation of birth defects by e.g. municipality and maps showing changes in rates of some defects by municipality, county defined period of time etc. The information stored is however not integrated in a single system. Flat files are used for some data and a statistical package is used in generating maps for graphical presentations. This example will be referred to as the medical database in this paper.

Typical application data used in the areas mentioned above (e.g. education, offices, etc.) can be classified into five main data types which are represented directly or indirectly in an information system, (in the computing context this means all types of digitally representative data) [DASK91]:

1. Facts: Name, address; unique identifier in the types conveniently handled by existing databases.

2. Statistics: Data that requires graphical (pie-charts or bar-charts) or tabular (spread sheet) representation i.e. the aggregation of the fact data type.

3. Images: i.Raster — derived from photographs, painting programs, video-disks.  
ii.Vector — line drawings derived from engineering, computer aided design (CAD) systems, vector graphics.  
iii.Moving — a sequence of the above with extra clues to 3-dimensional relationships, history, time-series, narrative. e.g. animation

4. Text: As in a book or magazine article

5. Sound: E.g. the human voice — narrations, comments, lectures, music and sound from nature.

Collections of different data types are termed multidata and information systems that integrate at least two different data types are termed multidata database systems (MdDBS).

Such an integration, for this paper, entails bringing together the different data types within a single coherent system such that users can have a unified view of their data.

Numerous advantages accrue if multidata collected by organizations can be effectively integrated within a single information system [SHEP91]:

- reduced costs associated with data acquisition through the elimination of duplications in collected data and conversion activities (i.e. from one data format to the other)
- more operations can be performed on an integrated data set than on disparate sets of data
- sharing of information by organisations leading to more cooperation
- better presentation of ideas and products to clients and the public
- effective decision-making
- better inferencing from collected data
- perceived seamless information environment by users.
- quicker retrieval of multidata

Traditional database management systems (DBMS) have been designed to handle facts only. The integration within these systems involves storing the fact data in single databases with no redundancy. They however do not create the environment for integrating multidata as they lack facilities for handling other data types. Their relational operations, for example, are not directly applicable to some data types.

Aggregation functions, for example, cannot be applied directly in cases of missing sample values. Some types of data may be collected or measured using various scales, measuring distances or coordinates which complicate the integration of the data.

Traditional DBMS in general do not have graphical capabilities. Histograms and pie-charts and three-dimensional visualization, as examples, cannot be created directly. They are also not particularly suitable for spatial (i.e. image data) applications because they do not efficiently support the type of operations required for graphical applications.

There is a great deal of research taking place with diverse ideas about the integration of multidata — some developments are in the prototyping and others might take some time before being marketed commercially. The problem for this paper then is, how can organizations integrate their multidata at this present moment? It is the belief of this paper that some existing systems can be used for such an integration. One such system is the geographic information system (GIS). GIS are DBMSs known to manage at least two types of data: fact and image data (vectors and rasters), and can thus be classified as MdDBS.

In the sections that follow a reference model for an ideal MdDBS is presented, the requirements for management of multidata are given and how a GIS could be used in integrating multidata is also presented. An assumption made is that the data types could have been collected for other applications and not specifically for a GIS.
Multidata DBS (MdDBS)\textsuperscript{2}

A database system (DBS) has been defined to be the set of data and some software for managing the data called a DBMS [SHET90]. The data referred to here represents the fact datatype. For the purposes of this paper this definition is extended to a set of multidata and a DBMS. This extended definition then refers to a multi-data (type) DBS (MdDBS).

The focus of database research and development has been more on databases that store fact data (structured data) with the conceptual representation of the data provided through the DBMS. Logical concepts like objects, their properties and their inter-relationships are used in the representation and users need not know details about how the data is stored physically.

MdDBS use similar concepts as above. They mainly differ from conventional DBMSs by their ability to handle more than one data type. The fundamental basis for the design of MdDBS is also based on the techniques used by traditional DBMSs. A MdDBS thus maintains knowledge about the underlying storage structure of different data types, and the ability to manipulate the actual database or files involved. A good database design therefore, needs to be supported for efficient and effective management of all the data types within the MdDBS. For example it should be possible to process, in an interactive manner, fact data into aggregates (i.e. statistical data) and present results in different formats (i.e. pie-charts, bar-charts or maps).

The reference model presented below tries to implement an efficient and effective integration of multidata. The model is an extension of that for a centralised DBS [SHET90] and combines data/schema integration with query processing through the following basic components:

- **data:** Facts, statistics, images i.e. vectors and rasters
- **queries:** Requests (or commands) for specific actions that are either entered by a user or generated by a processor
- **processors:** Programs or modules that manipulate commands and data
- **schemas:** Descriptions of data managed by the DBMS and consisting of objects and their inter-relationships.

There are three main processors in this model - accessing processor, transforming processor and the interpretation processor.

- **Interpretation processor:** This processor reconstructs commands and associated data that can be sent to another processor. It also serves to partition and/or replicate an operation from one processor into operations accepted by multiple processors. It decomposes queries and checks for syntactic/semantic constraints.
- **Transforming processor:** Translates commands that are expressed using the conceptual schema objects into commands using the integrated schema objects. This provides a type of data independence by which the data structures and commands used by one processor are hidden from the other processors e.g. transforming data from one format (image data) to another (fact or statistical data).
- **Accessing processor:** Executes commands against the database. This access can be based on different methods e.g. access to data based on value (i.e. name, building, address, county) or spatial location (by coordinates, latitude and longitude). It may accept commands from several processors and reschedule the processing of the commands. The functions of the accessing processor include:
  - The management of the file system and access to the data dictionary
  - Generating data required by a user through queries or to the processor generating the query or command

There are three schema levels which portray the levels of abstraction — external, conceptual and internal schemas.

- **External schema:** Concerned with the way the different data types are viewed by users. This forms the subset of the database that is accessible by a group of users
- **Conceptual schema:** Describing the logical data structures (i.e. the schema consist of objects that provide a conceptual or logical-level description of the particular data type) and the relationships among the structures
- **Internal schema:** Describing the physical characteristics of the logical data structures in the conceptual schema e.g. information about the placement of records on physical storage devices.

The reference model has a design that aims at the efficient integration and management of facts, statistics and images. The different external schemas are a way of having many users access the database and at the same time limit access to sensitive information. Some users, for example, may be able to access the whole database whilst others might have access to only statistical data (i.e. the aggregation of the fact data).

Even though users need shared access to the different data types their needs might be different. One user may need to access only images whilst another may want to manipulate facts into statistics then produce a graphical representation of the results through maps, charts or histograms. Filters are used by the interpretation processor for these multiple user views of the database.
The multiple internal schemas are quite unique for this model. The main reason behind these is to allow the system to take advantage of the best possible data model for each of the data types. Thus a complete MdDBS could comprise of two data models — a relational model for the facts and statistical data types and a network model for the images (i.e. a raster representation).

Relational database models are well developed for fact data but are not that efficient when used to represent image data types e.g. vectors or rasters. In the case of vectors, large amounts of data ought to be processed before features and maps can be drawn resulting in poor response time with querying. Data models can be developed e.g. through a hybrid of some existing models for better representation of e.g. image data. The multiple internal schemas, when they are all relational, however make this model resemble a centralized DBMS.

The representation of the different data types are then transformed to an integrated conceptual schema by the transforming processor. The accessing processor serves as an interface with the operating system for faster storage and retrieval of the data requested. This helps reduce the number of physical accesses necessary to retrieve data for a particular process e.g. drawings or conversions from one data format to the other.