AN INTEGRATED SPATIAL INFORMATION SYSTEM FOR ICE SERVICE

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ABSTRACT:

The Canadian Ice Service (CIS) of Environment Canada is responsible for providing sea ice and iceberg information under the Canadian Federal Ice Program. The mandate of the Canadian Ice Service is to provide timely information on ice conditions for navigational purposes, to warn marine operators of hazardous ice conditions, and to maintain a general historic knowledge of ice conditions and ice climatology. This paper presents the mission-critical application of Remote Sensing and GIS technology in the Canadian Ice Service for supporting the marine community.

The products are generated on a daily basis and products turnaround time is 24 hours. A typical day for our operation involves the real-time data acquisition, processing, and analysis of remotely sensed geographic data; the integration of vector, raster, and alphanumeric information; generation and dissemination of text, chart, image and spatially enabled products to clients and partners; clients making their decisions based on the information received from CIS. All products are deposited in a central repository and are made available to the public and partners via a geo-spatial web service.

1. INTRODUCTION

Each year, ships face many challenges traveling through North American ice and iceberg covered waters. Production and delivery of timely ice hazard warnings to ships, marine and Northern Canadian communities becomes very important for their safety and security. The ice forecast information is used by ships and marine community in their decision making and route planning. Transportation, oil exploration, environmental protection and research institutions rely on ice information for their planning, decision support and research purposes. Canadian Ice Service (CIS) works closely with Canadian Coast Guard (CCG), US Coast Guard (USCG) and US National Ice Centre (NIC) for providing ice and iceberg information to national and international clients.

CIS relies on geo-spatial information technology and information management technologies for producing ice products and disseminating to its clients. The production, mapping and dissemination systems, based on client/server and parallel computing architecture, use the latest remote sensing, GIS, web mapping and data warehouse technology. The servers acquires over 10 GB/ day data in real-time from Radar and camera systems on-board the aircraft as well as various satellites. The major data sources includes Radarsat-I, Envisat, NOAA-AVHRR, OLS, QuickScat, GOES and Airborne Radar Images. These servers also receive ice observation charts from CCG icebreakers and ice reconnaissance aircraft, environmental and weather information from Canadian Meteorological Centre, ice and GIS information from US National Ice Centre, and spatial data from other national and international partners. The received data is automatically processed and stored in a central geospatial data repository. The ice forecasters and analysts using highly sophisticated graphic workstations analyze and integrate information from various data sources to generate products and digital maps.

These products and maps are disseminated to partners and clients using satellite and terrestrial telecommunications. The clients and partners can also access this geospatial data repository using Internet and geospatial data networks. In the near future, a user will be able to generate maps interactively and on demand through our new CIS Archive. The CIS clients and Ice Service Specialists on board the CCG ships will be able to browse the data repository using standard browsers or Java based spatial browsers, select and download the required information or retrieve ordered digital maps.

The Integrated geo-Spatial Information System (ISIS) is a decision support system built on ArcGIS, ArcView, ERDAS Imagine, Oracle Relational Database, Blue Angel – Metastar and ArcSDE, ArcIMS technologies in Microsoft Windows, Linux and HP-UX operating environments. The emphasis of this paper will be given to the CIS Archive Subsystem. More details about the other subsystems can be found in [Ou Z., etc. 2002], [Koonar A., Scarlett B. and Ou Z. 2004].

2. SYSTEM OVERVIEW

The Integrated Spatial Information System (ISIS) consists of eight subsystems: Data Acquisition, Data Archive, Ice Analysis, Berg Analysis and Prediction, Product Dissemination, Field Decision Support, Climate Support, and Data Ordering. Each subsystem provides the following functions:

2.1 Data Acquisition Subsystem

The Data acquisition Subsystem receives data from different sources and platforms, distributes data to other systems, triggers ice models or classification tasks, performs automatic geo-

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location, performs image compression, enhancements, imagery and model outputs and stores everything in a central data repository. Load balancing, distributed databases and parallel computing are used to meet daily processing requirements and for meeting strict production and delivery deadlines.

2.2 CIS Archive Subsystem

The CIS Archive Subsystem is composed of a relational database management system (RDBMS) and a database based upon the Content Standard for Digital Geospatial Metadata (CSDGM) as defined by the US Federal Geographic Data Committee (FGDC). The repository ensures the metadata access to the records is controlled and constraints are strictly enforced. The repository is comprised of a catalogue which is streamlined for a daily production environment and long range catalogue for archiving and trend analysis. More detailed discussion about the CIS

2.3 Ice Analysis Subsystem

The Ice Analysis Subsystem is the high-end ISIS workstations that provide access to all data referenced by the Metadata repository. Custom tools are developed for sorting, displaying, and analyzing of data in order to generate electronic and hardcopy products such as navigation charts and bulletins. Analysts can enhance imagery and then annotate with text and line objects to reveal ice characteristics and iceberg targets. This client/server subsystem is based on high availability UNIX servers and Windows 2000 clients and makes extensive use of ERDAS Imagine, ArcGIS and ArcView3 software. There are three primary components of this subsystem;

- ***Geospatial Metadata Browser*** is a visual directory of the real-time data repository. A user can view metadata associated with a data object in a tabular format and/or graphical format showing the coverage 'footprint'. A variety of temporal and spatial data filters are available for data discovery and drilling. With geospatial metadata the footprint of the data can be superimposed on a globe which allows the user to see the geographic context of the data.

- ***Image Analysis*** component provides the user with multiple image display, analysis using ESRI shared libraries, mosaics and generation of annotated image products.

- ***Data Integration and Product Generation*** component integrates GIS data from various sources including model prognosis, previous or archived analyses, and analyses from partners and observations from ships, aircraft and remote operation offices. Topology and product generation as defined by World Meteorological Organization (WMO) standards and business rules are integral within this component.

2.4 Berg Analysis and Prediction Subsystem

The Berg Analysis and Prediction Subsystem is comprised of four software components; Geospatial Meta Browser, Image Analysis and Iceberg Product Generation. The ***Browser*** and ***Image Analysis*** are identical to the Ice Analysis Subsystem.

- ***Target Detection and Manual Editing Tools***: The Target Detection is running on server as a Data Acquisition component. The target detection algorithm takes a RADAR image, detects the possible iceberg targets, and generates an iceberg message and graphics (a set of shapefiles). The manual editing tools are used to edit and valid the detected iceberg targets.

- ***Iceberg Product Generation*** provides capabilities for validating and correcting iceberg locations received from aircraft and ships, integrating recently reported icebergs with Most Recent Observation File (MROF), generating now cast and prognosis products based on model outputs and MROF.

2.5 Product Dissemination Subsystem

The Product Dissemination Subsystem receives products generated by Ice Analysis Subsystem or from other systems, formats these products based on client profiles and then delivers via their preferred communication methods such as FTP, e-mail or Fax. A product database and client standing orders maintain all deliveries and provide tracking and performance details. The subsystem supports delivery in GeoTIFF, MrSid, JPEG2000, PDF, Encapsulated PostScript, JPEG, GIF, ESRI export files and ERDAS IMG, bundled Shapefiles or SIGRID-3 (A vector archive format for sea ice charts) [2003] formats.

2.6 Field Decision Support Subsystem

The Field Decision Support Subsystem is the low-end ICE-VU workstations that are deployed on Canadian Coast Guard (CCG) vessels, remote ice operation offices, on board reconnaissance aircraft, and at the IMSB. ICE-VU workstations were designed specifically as marine decision support applications and provide Coast Guard and Ice Service Specialists with the capability to receive real-time airborne Synthetic Aperture Radar (SAR)/ Side Looking Airborne Radar (SLAR) data or to download compressed MrSID or JPEG 2000 imagery and GIS products provided by the IMSB. ICE-VU is stand-alone system with a real time GPS data feed and has its own data acquisition, processing and catalogue functions to enable user to plan navigation routes and deviations.

2.7 Climate Support Subsystem

The Climate Support Subsystem provides access to operational analysis tools for meteorological and ice trend analysis and support for analysts producing long range forecasts and seasonal outlooks. This subsystem has direct access to long range archive repositories, based on CSDGM Metadata search criteria. It supports other tools for producing ice climate products and an annual ice atlas.

2.8 Data Order Subsystem

The Data Order Subsystem provides tools for planning aircraft flight paths, planning data transmissions during flights to ships and to Ice Reconnaissance Data Network (IRDNET) ground stations for subsequent broadcasts to CCG and MSC. This subsystem also provides tools for planning Radarsat and ENVISAT data acquisitions and for ordering data frames to meet CIS operational requirements.

3. CIS ARCHIVE SUBSYSTEM

The CIS archive is a repository of many different forms of data including raw imagery files, CIS products stored in their original format and derived layers which will become the data source for on-line mapping and analysis projects. The CIS Archive implements a hierarchy of level one and level two storage, often described as a 2-tier storage architecture. From the perspective of the user, the categorizing of data as level one or level two is transparent. Either level is available but level two data simply requires more time for retrieval.

For the CIS Archive, data categorized as level one is available on a continuous basis with the server and network being the determinant for the time required for query, access and retrieval. Objects such as analysis coverages, PostScript charts, data extractions, bulletins and browse graphics is stored using level-one storage. A combination of Oracle RDBMS and ESRI ArcSDE technology is used for level one data. Oracle provides the database for structuring the data and ArcSDE provides the associated gateway for on-line mapping and spatial analysis.

The number and size of Archive tables is limited by the capabilities of the underlying database. For an enterprise Oracle installation, a realistic limit is 1 billion records per table. Tables exceeding this record count are entirely possible but the performance degradation would be significant enough to prevent efficient on-line querying and display. One polygon requires one database record. As the regional analyses have the highest polygon count of all the products produced by the CIS, they require the most number of database records. The accompanying table indicates that in a six year span from 1997 to 2002, the total number of regional analysis polygons was 93,643 giving an average of 15,607 database records per year. Allowing for future expansion by increasing to 100,000 records per year, a 30 year regional dataset estimated at 3 million records is well within the capabilities of any Oracle database.

Only raw imagery files or processed imagery files will use level-two storage although other objects such as charts could be transferred from level-one storage if space usage warrants this. The CIS processes about 10 GB of raw imagery data per day from various sensors and platforms.

The Veritas Storage Migrator (VSM) system will provide the automated migration of data files to and from the tape library. The tape library contains 60 tapes and each tape can hold 400GB of data for a total of 24TB storage space. With help of VSM, the whole tape library is transparent to users. The delay required to retrieve data from tape is dependent on the actual VSM infrastructure. For the existing configuration of CIS Archive it takes only 1~2 minutes for a request of raw RADARSAT CEOS file (100BM) which is physically located on a tape.

The Archive System runs its own Data Acquisition Subsystem (DAS). All data are loaded into database by DAS automatically. The Figure 1 is the data flow diagram.

3.1 New Metadata Catalogue

The ISISi Metadata Catalogue is an evolution of the lessons learned with the mission-critical systems at CIS (e.g. ISIS and WebServer). The fundamental difference in implementation is that ArcSDE will become the primary storage mechanism for the data objects. For any data objects which are stored as on-line files (e.g. MrSID exe files), a Uniform Resource Locator (URL) which is the standard for the World Wide Web, will be used to provide the connection to the data file.

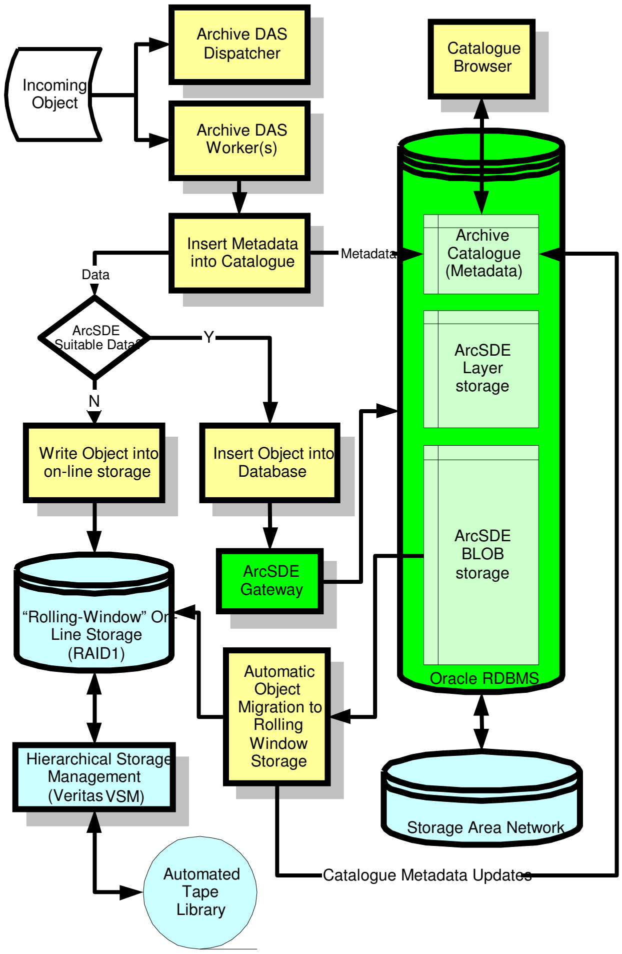

Figure 1: CIS Archive Data Flow

3.2 Metadata Format

The metadata supplied for each data object is complete, accurate. Users will be able to browse this metadata directly using ArcCatalog or via an ArcIMS and generic web browser solution. The ArcSDE metadata catalogue will be implemented using the ISO standard (TC211 Draft International Standard 19115). The content of the ISO standard is similar to the existing FDGC CSDGM but has improved documentation of scale, raster structures, temporal and vertical extent. The ISO metadata standard is easier to maintain than CSDGM since the number of mandatory fields is well defined and reasonable (approximately 30 elements). For this initial phase of the CIS Archive, the existing and proven FGDC metadata standard will be used. Tools for FGDC to ISO migration will be provided by ESRI.

This metadata standard will be compatible with Canada Federal Government data clearinghouses which currently support FGDC-CSDGM standard; such as the Discovery Portal (formerly CEONet), EC Gateway, and CRYSIS.

3.3 Metadata Population

As described in the previous section, the format of the metadata will be completely defined by international standards such as CSDGM and eventually ISO. Deviation from standards would hinder integration with other archives and would require effort to duplicate or modify the functionality already provided by software such as ArcCatalog and ArcIMS.

The creation of basic metadata for each data object will be automated as much as possible. For example, simple attributes such as scale, extents and structure will be extracted automatically from the data. Other attributes will require manual input. It is assumed that with most of the datasets, the provider of the dataset will also supply suitable metadata. Templates and examples will be available to be used as a guide for meta-documenting.

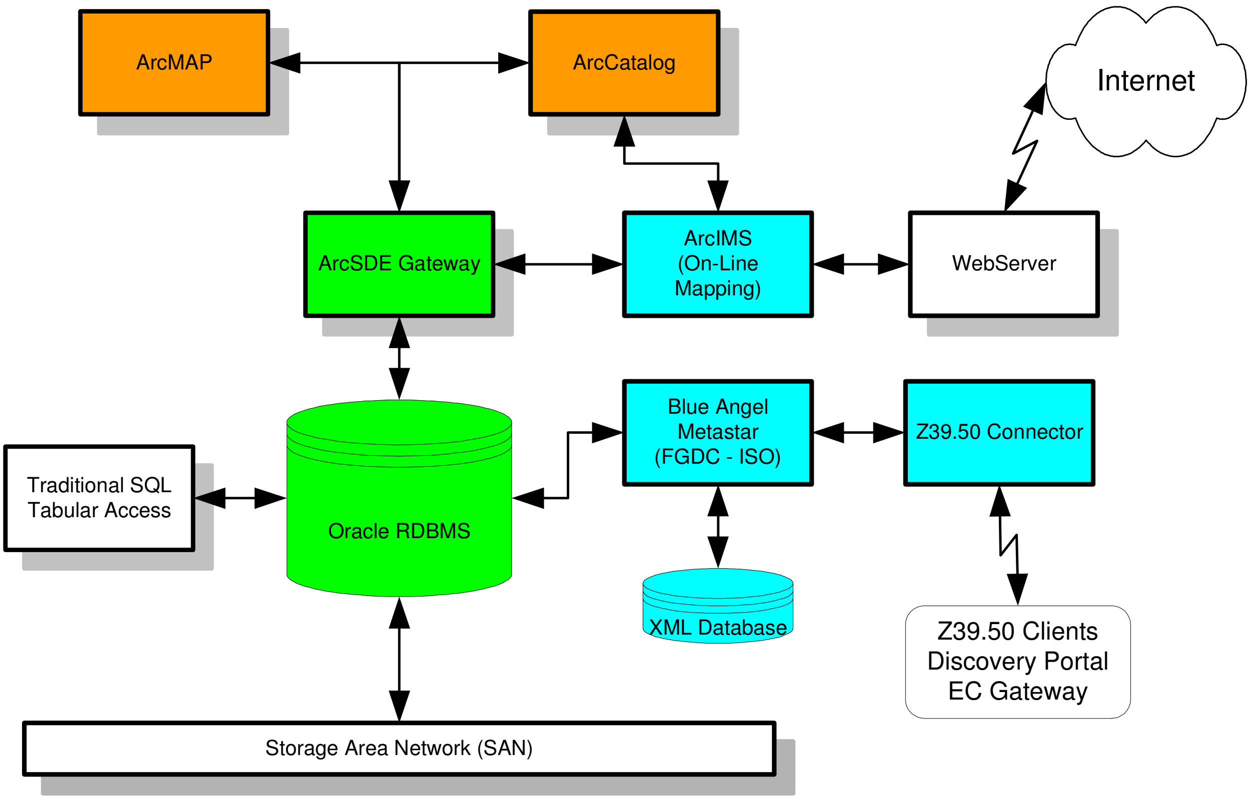

Figure 2: CIS Archive and Online Mapping

3.4 Geospatial Metadata and Footprints

The metadata required for the CIS Archive is geospatial. In general terms, "geospatial" indicates that a spatial reference (e.g. latitude and longitude co-ordinates) is a primary means of storing and accessing information in the database.

Geospatial metadata allows the "footprint" of the data can be superimposed on reference layers allowing the user to see the geographic extent of the data object and thereby helping to present more effectively the context of the data.

All data objects are loaded into CIS Archive through Archive DAS process automatically. A geospatial footprint and a browser graphics if possible are created while data is loaded into database.

3.5 Metadata Browse Graphics

The operational ISIS and WebServer databases have "quick look" browse graphics which support the visual selection of data objects. Browse graphics are typically small JPEG or GIF/PNG files which have just enough visual resolution to help the user evaluate the data object.

The CIS Archive Metadata Catalogue provides similar functionality through the use of standard URL references. Although technically possible, it is recommended by FGDC and ISO that browse graphics are not stored internally within the database (e.g. as BLOBs) due to their very small size and non-mandatory status. Furthermore, the use of file based browse graphics makes for easier integration with portals and data clearing-houses.

3.6 Metadata Catalogue Browser

The method of accessing the CIS Archive Metadata Catalogue is a Geospatial Metadata Browser. At least two types of Browsers will be supported; an internal Browser based upon ArcGIS technology and a pubic Browser based on generic Internet technology.

The internal Browser will be built as an application layer over ArcGIS technologies such as ArcMap with low level customizations provided by ArcObjects. The public Browser is light weight and user friendly application that runs within the client environment. The Browser is self-contained and does not require specialized hardware, extensive software resources or product licensing.

The public Browser, coupled with a Z39.50 component, presents the user with a consistent view of the repository and provides the tools necessary for displaying and manipulating selected sets of records from the Metadata Catalogue. Filtering metadata by theme, by location, by time and by attributes is provided along with the standard display functions for changing the area of interest (zoom-in, zoom-out, roam, etc.) At the same time, the Browser isolates the user from the implementation details of the repository and the data objects.

As the name implies, the Browser does not update the Catalogue. This allows Browsers to be distributed freely without the overhead of client administration and security concerns.

3.7 Online Mapping

Two CIS archive servers will be configured for the archive. The first server, inside the CIS firewall, will be a secure master copy of the data. The archived data will be loaded on this server. The second server will contain a copy of the archive database (exported from the server inside the firewall and imported outside the firewall). It will provide access to both internal and external clients.

Both servers will be implemented on the ISIS server platform. The data will be managed using ArcSDE (Spatial Data Engine) using Oracle 9i for the RDBMS storage and engine. All data objects will be stored as BLOBS (Binary Large Objects) within the RDBMS and will be physically located within database files on the SAN as shown in Figure 2 above.

For the archive located outside the CIS firewall, ArcIMS (Internet Map Service) will enable users to access ArcSDE using a generic web browser. Users will also be able to access the data directly using a variety of packages including ArcCatalog, ArcGIS, ArcExplorer or even custom applications based upon MapObjects (MO) or Java Server Pages (JSP).

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