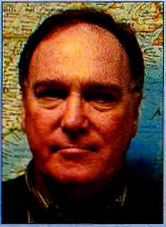


## Article



## A Model for Automatic Integration of Ice Information into Electronic Navigational Chart

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In ice-infested waters, the use of ECDIS as a stand-alone navigation system would not provide sufficient information for safe and efficient marine navigation. To overcome this problem, a number of agencies, including the Canadian Ice Service (CIS), are producing and distributing regional ice charts, which provide comprehensive information on the ice conditions. Unfortunately, however, although the ice charts are highly useful, they may not fulfil the requirements for safe and efficient marine navigation, even if they are used side-by-side with ECDIS. For example, a route may be identified as an ice-free or least hazardous through an ice chart, while it may not necessarily be a suitable route for marine navigation due to, e.g., shallow water. This suggests that, in ice-infested

waters, an integrated navigational chart system combining the ice information and ECDIS is vital. Ideally, the integration process should be done automatically, to save on time and cost, and provide consistency in processing multiple sets of similar data.

This paper proposes a model for automatic integration of ice information into an Electronic Navigational Chart (ENC). A prototype implementation of the proposed model is discussed. Technical issues associated with the integration process are addressed in detail.

### Introduction

The Electronic Chart Display and Information System (ECDIS) was introduced over a decade ago to provide mariners

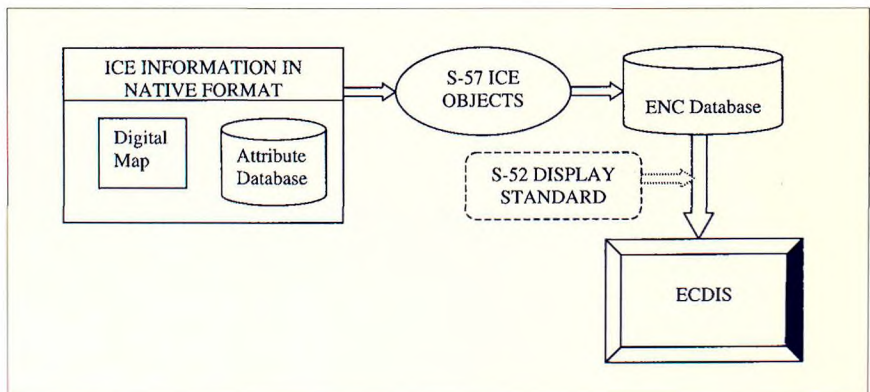


Figure 1: Diagram of the proposed model

with the required information for efficient and safe marine navigation. ECDIS is a computerised navigation system, consisting mainly of a computer processor and display, Electronic Navigational Chart data (a standardised database) and navigation sensors [Alexander 2000]. ECDIS is not only capable of displaying the navigation-related information in real-time but also supporting other advanced functions, such as route planning, route monitoring and automatic alarms. Unfortunately, ECDIS, in its current phase, cannot be used as a stand-alone navigation system in ice-infested waters as it lacks information about the ice conditions. To overcome this limitation, it is necessary that the ice information be integrated into ECDIS. The International Hydrographic Organization (IHO) has developed two special publications for electronic chart data classification, namely the IHO S-57 data standards [IHO 2000] and the IHO S-52 specifications for chart contents and display [IHO 1998]. Unfortunately, such standards are lacking for ice information, representing a major challenge for the Ice/ECDIS integration. The Canadian Ice Service (CIS) proposed the Ice Object Catalogue, version 3.0 [CIS 2001], which is used by our model. Another challenge is that the ice information is produced in a non S-57 compliant format. In our study, we used the CIS ice charts, which are distributed in ArcGIS Interchange format, though originally targeted for paper output.

The overall objective of our study is to develop a model that automates the integration of ice information into an ENC, following the IHO S-57 standards. The integrated chart system was produced using the CARIS Hydrographic Object Manager (HOM). When ice information is imported into the CARIS environment, some editing and preprocessing is necessary. This is done in order to regroup compatible data into various feature codes and layers, and before building topology. In this particular case where the original chart is targeted at paper output, editing is also necessary to remove the cartographic features that are specific for that purpose. For the sake of efficiency and consistency, a script was written to automate the preprocessing. For cost-effectiveness, we need to eliminate the requirement to have multiple systems, ArcGIS and CARIS in our case, for processing the information. Therefore, a script that runs solely in the CARIS environment is desirable. Arranging the chart's spatial features into relevant layers and configuring system files so that the process of forming feature

objects is fully automated in CARIS HOM is part of the objective.

### **Proposed Model for Integration of Ice Information in ECDIS**

An ideal model for integrating ice information into ECDIS is one that takes the ice information in its native format (as a digital chart, with or without an attribute database) and automatically converts it into the S-57 ice objects, and integrates it into the ENC database. The standard display is based on the IHO S-57 Transfer Standard for representing chart objects, and the S-52 Standard for presenting or displaying those objects in an ECDIS (see Figure 1). At present, there is no implementation of ice information integration that achieves this feat. The ice information that may come as a digital map (or paper chart converted to digital form), with possibly an attribute database, is converted to ice objects that comply with the S-57 Transfer Standard. The ice objects can then be displayed if standard symbols and colours are defined for them in the S-52 Standard. The S-52 should be expanded to include the symbols and colours for displaying ice objects.

Implementing a model that is capable of automatic conversion of ice information into ENC data, regardless of the GIS format (platform) used for collecting and storing the original data, is very unlikely. This is because of the lack of a single standard for the various GIS platforms coupled with the fact that mariners may not use the same platforms and techniques. As such, implementation of the model may involve data conversion to the format of the particular GIS employed locally in an ice service region. This is the approach used in the implementation of a prototype presented in the next session.

### **A Prototype Implementation for Integrating Ice Information in ECDIS**

Implementation of the proposed model for integrating ice information into ECDIS cannot be achieved by a unique solution. This is because of differences in representation and display of ice information in various regions of the world, for example, while the CIS uses the Egg Code method



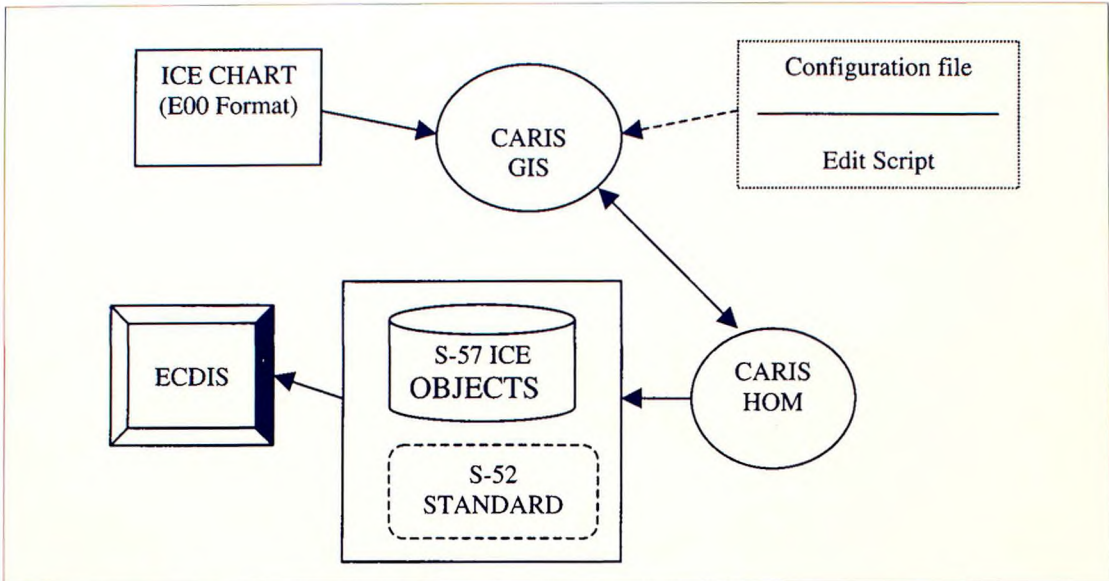


Figure 2: A prototype implementation model in CARIS

[Lapointe 2001; CIS 1997], the German Ice Service does not use the Egg Code, but uses the 'WMO Sea Ice Nomenclature' with fill patterns and additional symbols [Moggert 2000]. As such, implementation will have to take into account available technologies used in specific regions of the world. This paper presents an implementation based on the practice of the CIS. The reason for using this approach is because mariners are already used to the representation and display of S-57 compliant Electronic Navigational Charts in ECDIS. Such ENC's have been used side by side with ice charts produced by CIS. The challenge is to integrate the ice information into the same system that is based on S-57 and S-52 specifications. The prototype implementation model is shown in Figure 2.

The issues involved include the development of an automated procedure for importing an ArcGIS Interchange (E00) file, containing digital ice chart, into a CARIS GIS environment, editing and preprocessing the ice chart to comply with the S-57 standard, forming S-57 compliant ice objects and integrating the ice objects in an ENC. The groundwork for this project has been reported by Lapointe [2001]; Diarbakerly et al. [2002], and in an internal Project Report [2002]. The previous reports have stated some of the problems involved in importing ArcGIS Interchange data into CARIS GIS. These problems include the fact that the original

ice chart was produced to mimic paper output, therefore containing a lot of extraneous information like labelling lines, displaced or repositioned symbols and names, with the imposition of some unnecessary symbols and names suitable for paper output (see Figure 3a, with a magnified portion in Figure 3b). These constitute extraneous information in a purely digital context and create difficulties in processing the imported data in the new GIS environment. Another problem is the loss of semantics after data import into CARIS, as ArcGIS and CARIS use differing nomenclature and layering of information in identifying and classifying various spatial features. According to the previous reports on this project, these problems were tackled by employing a 'cleaning' script in ArcGIS environment to remove undesirable cartographic features, followed by manual editing in CARIS environment to rename and reclassify data. This process is slow, time-consuming, costly, inconsistent over multiple data sets, and prone to errors and data loss.

#### Input Data

The input data comprise:

- The E00 Interchange file containing the chart, which is based on the Clark 1866 Ellipsoid and the Lambert Conformal Conic Projection. Figure 3a shows an imported chart in its original coordinate system, while Figure 3b shows a portion of the chart with cartographic labeling.

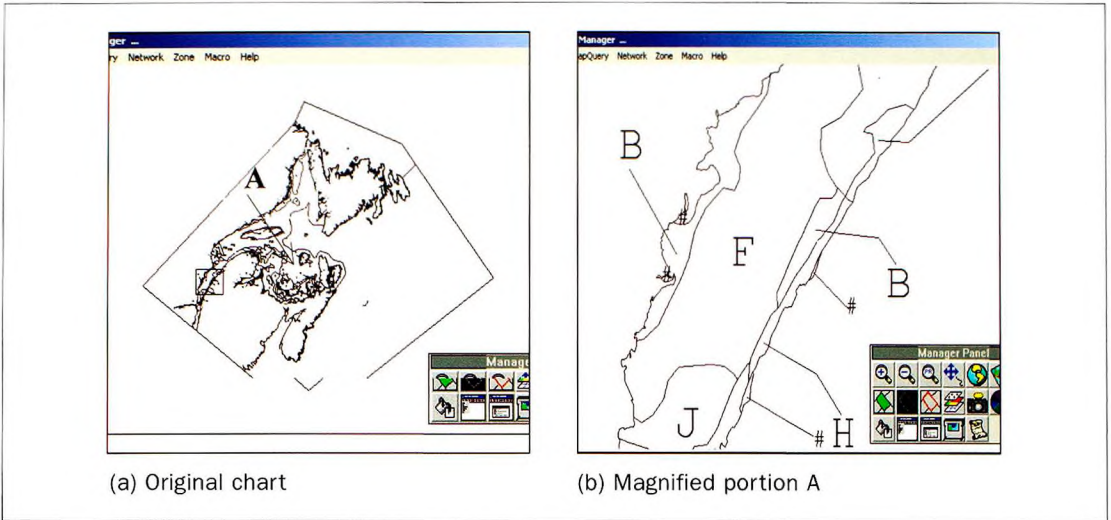


Figure 3: Imported ice chart from E00 file, in original form

- b. A header file containing the appropriate datum information (this is needed for the 'refcoe00' Import command to run correctly). The "header file" is an empty map in CARIS DES format for the chart coverage area.
- c. A database template (temp.mdb Microsoft Access template in our case) created using the ODBC (Open Database Connectivity) utility: this template is needed by the refcoe00 Import utility in generating attributes database tables.

translation control files to categorise the imported data in CARIS. The tables include AAT - Arc Attribute table and PAT - Point Attribute table (Figure 4).

**Import of E00 Interchange File and Processing in CARIS GIS**

A script invoking a combination of command line CARIS commands and CARIS macros has been developed to perform both the import of the E00 interchange file into CARIS and to carry out the editing and processing including building the network and polygon topology. Where necessary, the commands use the appropriate input parameter and/or option files that have been pre-configured. At this point of development, the script runs by typ-

Some database tables are formed during the process of importing the E00 file into CARIS. These tables contain some attribute information not directly linked to the resultant DES CARIS file. However, some of these attributes can be used in

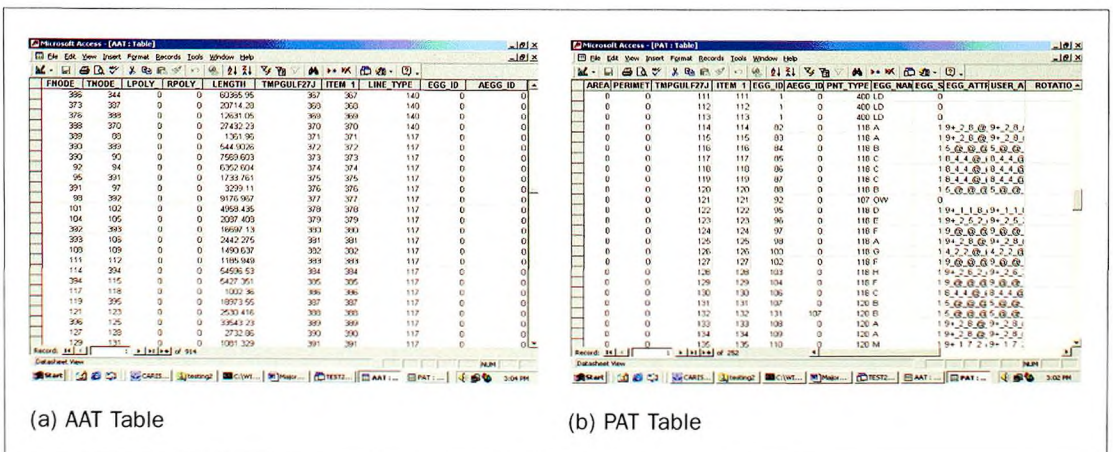


Figure 4: Imported database tables



ing "Processfiles e00filelist.txt" on the command line. The ProcessFiles batch file contains a line of command that invokes another batch file, process-Commands, which contains a sequence of CARIS commands. The e00FileList.txt file contains the name(s) of the E00 file(s) that is to be imported and processed in CARIS. The following sections describe the various segments of the import and transformation, editing and processing.

*Import of E00 File*

The import (refoe00 command) uses a header file and a translation control file. The header file is necessary because without it, the import routine encounters "Invalid Coordinate System" error and does not complete. The header file acts as a CARIS template that contains the correct datum for the imported chart data. A translation control file is

needed to map some of the features' spatial attributes to recognisable codes in CARIS. Without this control file, every line feature is given a unique feature code that is an integer number ranging from 1 to the maximum number of line features (e.g., 900) in the file. So also are the point features and symbols. In this way, one cannot digital-ly discriminate and categorise the data according to the features that have been mapped.

By scrutinising the ice chart in ArcGIS and checking for correspondence of attributes in the imported database tables (see Figure 4), some relationships have been established. These relationships are not visible within CARIS, without the use of an appropriate control file. The AAT table (Figure 4) contains an attribute field called LINE\_TYPE, which has values according to what features the lines

TABLE Field	Value Description	Remark
AAT Table (Lines): Line_Type	8 = boundary lines of the area containing data.  140 = Coastlines.  117 = Lines defining polygons for fast ice. 122 = Lines defining other ice polygons (not fast ice). 133 and 150 are also lines defining some ice polygons.  302, 307, 312, 316 and 399 are lines representing the special symbol features.	E.g., 302 lines represent the Arrow (Direction).
PAT Table (Points): Pnt_Type	400 = Point symbol that references land polygons.	Contains no Egg Code.
Note: These features are of the type SYMBOL in CARIS.	118, and 120 are points referencing ice polygons.  106 is used for some valid ice polygon reference points and some undesirable labelling points outside the polygons.  119 and 124 are points that are used with labelling lines outside the polygons.  100, 107, 112, and 115 are points referencing the special ice symbols.	Contain Egg Codes.  The invalid 106 points are identified by their 'KEY' having the value 3 or 31 in CARIS  These will be removed.

Figure 5: Relationships of features with the database tables

represent. For example, Line\_Type 8 has been used to represent coastlines in ArcGIS; Line\_Type 117 represents lines that bound the fast ice polygons; Line\_Type 122 represent lines that bound the polygons containing other ice polygons; and Line\_Type 302 represents lines that map the direction of ice (indicated by an arrow in the chart). Similarly, the PAT table (Figure 4) contains a field called PNT\_TYPE whose values represent the type of point features. For example, the reference points for land area polygons are of Pnt\_Type 400, while the reference points for ice area polygons are of Pnt\_Types 106, 118, and 120. A list of these relationships is given in Figure 5.

Using the translation control file with our `refoc00` command results in all features with the same Line\_Type or Pnt\_Type being given the same feature code in CARIS. For example, all coastline features will have '140' as the feature code, and all land area reference points will have the feature code of 400 after import. Afterwards, we use another command to change these feature codes to more semantic feature codes (e.g., COASTLINE, LANDPOINT, ICELINE) in CARIS.

#### *Transformation of the Imported CARIS File*

The resulting CARIS DES file needs to be transformed from the Lambert Conic projection and Clark 1886 Ellipsoid to the WGS84 (World Geodetic System 1984), in order to meet the ENC production specification. A segment of the script performs the necessary editing of a copy of the CARIS file, and the subsequent transformation of CARIS file based on the edited copy as a header template. The `editheader.txt` file has been supplied as the parameter input file in this project. The temporary copy of the DES file is removed at the end of the script.

#### *Removal of Undesirable Lines and Points*

The undesirable labelling lines and points are removed (cleaned out) from the ice chart. To achieve this, various visibility parameter files have been pre-configured, and used successively with the `makedisp` CARIS command, followed by the `remofeat` command. The configured input parameter files are:

- i. `viineremove.txt` – used to remove lines that are obviously labelling lines: Line\_Types (Feature Codes) 102, 103, 106, 107 as indicated in Figure 5.
- ii. `vpointremove.txt` – used to remove obvious labelling points: Pnt\_Types 119 and 124.
- iii. `vkeyremove.txt` – used to remove labelling points corresponding to when Pnt\_Type is 106 and Feature KEY is 3 or 31, as indicated in Figure 5.
- iv. `vnameremove.txt` – used to remove undesirable name or text features like the annotations of Egg Names.

#### *Changing the Feature Codes to Meaningful Codes in CARIS*

This segment of the script changes the feature codes from the integer values to more meaningful naming convention in CARIS. For example, the initial feature code 8 becomes NEATLINE, feature code 140 becomes COASTLINE, and feature code 117 becomes FASTICE. The `fcodchange.txt` file is given as input to the `chanfeat` CARIS command to achieve this.

#### *Layering of Features*

Features are categorised and moved into differing layers (user numbers and themes):

- (a) The COASTLINE, LANDPOINT and NEATLINE features are moved to Layer 200, using the `viscoast.txt` visibility input file on the `renu` CARIS command. This layer will later be used for creating the SKIN OF THE EARTH layer in CARIS HOM. The `annopoin` and `makelabe` commands are applied to this layer to convert the point symbols to polygon labels. CARIS uses the label points as display labels during the creation of polygon topology. This is necessary in order for the polygons to be automatically assigned the point KEYS. These keys are contained in one of the fields of the PAT table (Figure 4) and will be used to uniquely identify the polygons in later development.
- (b) The ice polygon lines and reference points are moved to Layer 201, using the `visice.txt` visibility input file. The `annopoin` and `makelabe` commands are applied to this layer also, to convert the point symbols to polygon labels. This is necessary in order for the polygons to be automatically assigned the point KEYS. These keys are contained in one of the fields of the PAT table (Figure 4) and will be used to relate the Egg Codes to their respective ice polygons.
- (c) Information regarding the special ice symbols is moved to Layer 300, using the `vissymbol.txt` visibility parameter,

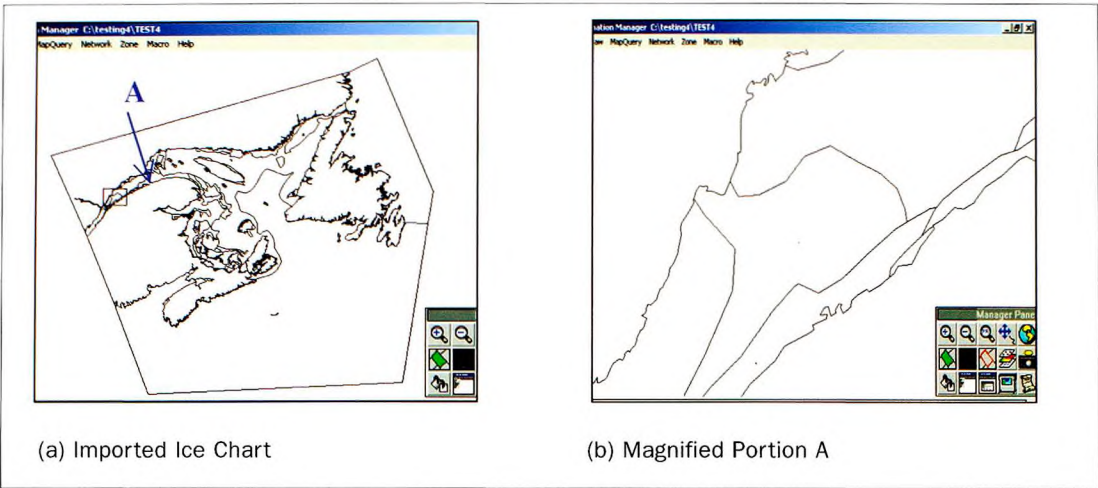


Figure 6: Imported ice chart - undesirable cartographic data removed

(d) All other data, which have been unused, are removed by supplying the `visunused.txt` visibility input file to the `remofeat` command.

This results in a clean and relevant CARIS file for further processing (see Figure 6).

*Creating the Neat Line and the M\_COVER Layer*

This segment of the script duplicates the NEATLINE feature (the boundary lines of the data area) into the other layers (Layers 201, 300, and 400), and creates a bounding rectangle in Layer 400. Layer 400 is created for the features that will be used for the Meta objects in CARIS HOM. This is achieved by supplying the import parameter file `cmd_dupli.txt` to the `wcared` CARIS Editor command. The `cmd_dupli.txt` file contains a sequence of CARIS macro commands and the necessary responses to prompts.

The coordinates of the map extent are used to insert the bounding rectangle in Layer 400 for the Meta objects. These coordinates are extracted from Field 20 of the map header information, and cover an area equivalent to the actual extent of the map data with a 5% allowance (see Figure 7). The map header information is displayed by using the command `disphead`, while the `dispcove` command gives the actual extent of data. The default display shows the coordinates in System Units, but the output of `disphead` can be saved to a report file, which shows the Ground and Geographic Units as well. The coordinates of any of the points defining the actual extent can be used as the anchor point for copying and pasting the NEATLINE feature in

the various layers (using the LAYA and LAPA macros). Figure 8 shows the result after applying this step.

*Building Network and Polygon Topology*

The next segment of the script employs the various commands leading to building the network topology for layers 400, 200, 201 and 300. After the first round of network topology, resulting in error messages for pseudo nodes, an attempt is made to remove pseudo nodes. Some are removed but others are not for valid reasons (a pseudo node is not removed when the two lines forming the node have different keys or feature codes or source identification numbers, and this is not an error). A second round of network topology is imposed, with the error messages suppressed. The next step builds the polygon topology for layers 400, 200 and 201. Polygon topology is not built for layer 300, which contains the special ice symbol lines and points.

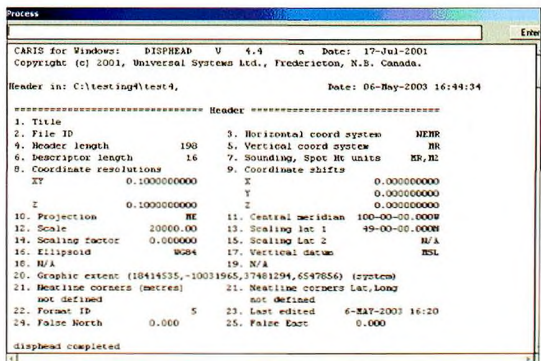


Figure 7: Extracting the coordinates of map extent





Figure 8: Ice chart showing inclusion of M\_COVR rectangle

**Processing for S-57 Compliant Objects**

The normal procedure for creating feature objects from CARIS spatial features is to use the CARIS HOM interface to interactively relate spatial features to object and attribute definitions in the object dictionary. This procedure requires extensive knowledge of CARIS HOM on the part of the user, and it is labour intensive and time consuming. The goal of this work is to provide a process for no or little user intervention in forming the S-57 compliant objects. We have explored the use of the Auto Create function of CARIS HOM, which poses its own challenge. Its success depends on how well one is able to customize the lookup files on which the Auto Create function depends. The first step in this process is to relate our polygons in the current CARIS file with the data set contained in the imported table described in Section 4.1. This has been done as follows:

1. A Visual Basic program (ICECHART) has been written to:
  - (a) Form a new database of the relevant spatial polygons from CARIS.
  - (b) Extract the 'Egg' attributes into the new polygon table from the imported .e00 database (PAT table) for the ice polygons, by matching the polygon keys in the new table with point number in the imported PAT table.
  - (c) Break down the Egg attribute values into indi-

POLYKEY	EGG_ID	EGG_NAME	PNT TYPE	EGG_ATTR	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14
10	11	FI	106															
100	1	LD	400															
101	1	LD	400															
102	1	LD	400															
103	1	LD	400															
104	1	LD	400															
105	1	LD	400															
106	1	LD	400															
107	1	LD	400															
108	1	LD	400															
109	1	LD	400															
11	12	FI	106															
110	1	LD	400															
111	1	LD	400															
112	1	LD	400															
113	1	LD	400															
115	93	A	118	5+2_5_@_@_@_4_9+2 0						4	1						3	X
116	94	B	118	5_@_@_@_@_@_@_1_5						1								
117	95	C	118	6+4_@_@_@_@_@_4_4						4	1						3	X
118	97	C	118	6+4_@_@_@_@_@_4_4						4	1						3	X
12	13	FI	106															
130	99	E	118	5_@_@_@_@_@_1_5						1								
121	92	OvW	107															
122	95	D	118	5+1_@_@_@_@_4_9+1 1 0						5	4	1					4	4

Figure 9: CARIS polygons showing feature attributes

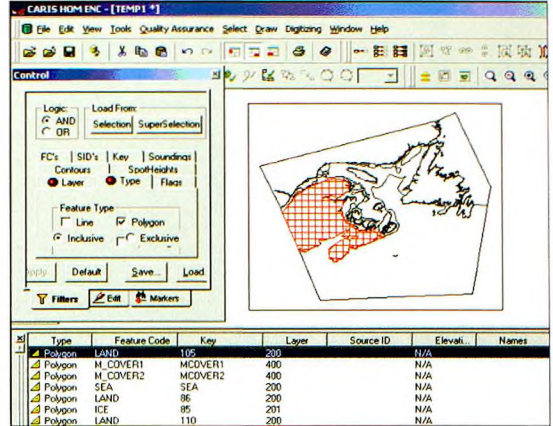


Figure 10a: Spatial features (Spatial View) in CARIS HOM

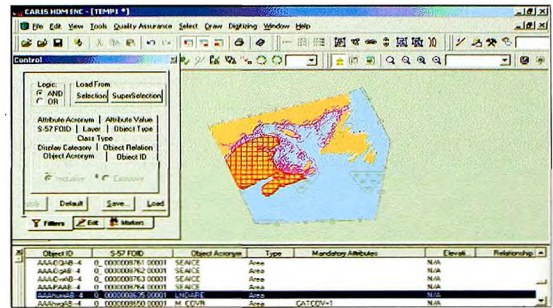


Figure 10b: Features objects (Feature View) in CARIS HOM

vidual Egg-Code values, each as a new field in the new table. There are seventeen Egg-Code values: ct (for total concentration), ca, cb, cc, cd (for partial concentrations), so, sa, sb,sc, sd, se (for stages of development), fa, fb, fc, fd, fe (for floe sizes) and cs (for the concentration of strips and patches). (See Figure 9 for the new table).

2. The lookup files in CARIS HOM have been modified and tested to generate the feature objects and assign attribute values automatically. The "Auto Create from Selection" function now works for all configured polygons. Ice object attributes (Egg Codes) are being assigned by the use of an attribute script (get\_eggcode.bat that uses set\_egg code.awk in %CARIS\_HOME%\HOM\ Scripts directory). The resulting ice chart in CARIS HOM can be seen in Figure 10a, b.

**Performance and Analysis**

An empirical performance measure has been conducted on the implementation of the prototype model in the CARIS environment. The first stage of the imple-



mentation involved the automation of the process of data import into the CARIS environment and the necessary preprocessing to have clean topological chart data in the spatial domain. The second stage is to link the ice attributes (in the imported database) to the topological ice polygons by running a Visual Basic program, using CARIS HOM and pre-configured lookup files to automatically convert the ice polygons into feature objects, and export to S-57 format.

The development environment consists of a DELL Pentium 4 - 3.0 GHz Processor, 1.0 GB RAM, 80 GB Hard Disk – running Windows 2000, CARIS GIS 4.4a, CARIS HOM ENC V3.2 and Visual Basic 6.0. The input data file is an E00 Interchange file of size 1.23 MB.

The script takes only about 20 seconds from the beginning to the end of producing a clean topological chart, on the system used. The resulting chart has been checked in CARIS HOM and found to be topologically clean, and ready for forming S-57 compliant objects. This is a significant improvement, in terms of efficiency, consistency and cost-effectiveness, over previous efforts. In manual processing and editing of an imported E00 ice chart in CARIS GIS, it could take many hours or days to produce a clean topological chart for the size of file used in this experiment. It also requires great knowledge of CARIS on the side of the user, and is subject to inconsistencies and user errors.

The script uses pre-configured input files fed directly to CARIS commands or macros. Thus, the script entirely runs in the native CARIS environment; hence, it does not impose any additional performance overhead that would have been the case, if interacting with additional programs. The pre-configured files eliminate the need for user interaction with the processing. It also eliminates the need for the user to be CARIS knowledgeable.

The only user action is in placing the name of the E00 interchange file (without the .e00 extension) in the e00filelist.txt input file. The other action is to insert the coordinates of the bounding rectangle and the anchor point (see Section 3.2.6) in the cmd\_dupli.txt input file. Both of these actions are carried out before starting the script.

The second stage of the development, which automates the process of forming the feature objects and assigning attribute values in CARIS HOM, has

also been achieved. Feature objects have been successfully formed, and feature attributes automatically assigned, from the CARIS polygons by running the "Auto Create from Selection" menu command in CARIS HOM. This way, there is a minimal user intervention in the feature object creation and attribute assignment process.

## Conclusion

A model for the integration of ice information in an ENC has been proposed. The success of this model can only be determined by implementing it in a logical production environment. A prototype of the model has been implemented in a CARIS GIS environment, which is the logical platform widely used in Canada for the production of ENCs. The input data is based on ArcGIS Interchange format, which is used by the CIS for collecting and disseminating ice information.

The implementation prototype was based on the proposed ice objects contained in the CIS [2001] report. Technical problems associated with exchanging data between the two GIS platforms, one for making ice charts, and the other for making ENCs, have been addressed. Automated processing of ice information from the initial stage of data import to the stage of forming S-57 compliant ice objects has been achieved. This saves time and cost, provides consistency and eliminates the need for the user to acquire great skills in GIS. User interaction with the CARIS HOM software in the conversion process has been minimised. This further offers savings in time, and provides consistency in processing multiple data sets.

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### Biographies

Dr Ahmed El-Rabbany obtained his Ph.D. degree in GPS from the Department of Geodesy and Geomatics Engineering, University of New Brunswick, Canada. He is currently working as an associate professor at Ryerson University in Toronto, Canada. He also holds an Honorary Research Associate position at the Department of Geodesy and Geomatics Engineering, University of New Brunswick, and an Adjunct Professor position at York University. His areas of expertise include: Satellite positioning and navigation, integrated navigation systems, and marine Geomatics. Dr El-Rabbany has recently published an easy-to-read GPS book,

which received a 5-star rating on the Amazon web site and listed as a best-selling GPS book. He also published numerous refereed journal and conference papers. Dr El-Rabbany holds a number of national and international leading professional positions, including, Councillor (Geodesy) to the Canadian Institute of Geomatics, and Chair, International Federation of Surveyors (FIG) WG-4.2: Vertical Reference Frame. Dr El-Rabbany received a number of awards in recognition of his academic achievements and was recently nominated for the "GREET" teaching award at Ryerson University.

Dr Benson Agi is currently engaged in research work at Ryerson University's Geomatics Program in the Department of Civil Engineering, Toronto, where he is working on the integration of Sea Ice information into an Electronic Chart Display and Information System. He graduated with a Ph.D. from the Department of Geodesy and Geomatics Engineering, University of New Brunswick, Fredericton, Canada in 1996, where he specialised in Geographic Information Systems. He had obtained M.Sc. in Photogrammetry from the International Institute for Aerospace Survey and Earth Sciences (ITC), Enschede, The Netherlands, and B.Sc. in Land Surveying in Nigeria. He has also acquired substantial training and experience in Information Technology.

Dr Agis's research and teaching interest is in Geographic Information Systems (GIS); Data Structures and Data Integration; Photogrammetry; Surveying and Mapping.

Dr David J. Coleman is Dean of the Faculty of Engineering and a Professor of Geomatics Engineering at the University of New Brunswick in Canada. Prior to obtaining his PhD, he spent 15 years in the Canadian surveying and mapping industry – as a project engineer, an executive in a national mapping company, and later as partner in a land information management consulting firm.

Dr Coleman has authored numerous papers on land information networking, operations management, and emerging national and global spatial data infrastructures. He is a past president of the Canadian Institute of Geomatics, has been a member of several national and international advisory bodies involved in geomatics, and has consulted to organisations on four continents.

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