Intelligent Chart Production System to Meet the Requirements of Modern Nautical Chart Production

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The rapidly increasing need for Electronic Navigational Charts (ENC) has led many Hydrographic Offices to a situation where there are two separate production lines – and two separate databases - for two products, ENC cells and printed charts. The existing *modus operandi* means that the same updates are done twice in two different databases. This paper starts with a description of the most challenging specific requirements of an application schema and production system supporting the production of ENC cells and printed charts from one common database. The paper outlines possibilities to expand the S-57 object catalogue by adding cartographic features and attributes which would enable presentation of the data according to the presentation requirements of printed charts. The paper then introduces the Finnish Maritime Administration's new chart production system, nSector, which uses these cartographic objects and attributes and increases remarkably the level of quality control during the production process.

Advances in navigation technology have set new demands on accuracy, reliability and the form of nautical charts. The positional accuracy of the chart should meet the increased accuracy of the positioning systems. To fully benefit from the dynamics of the modern positioning methods, high quality digital chart products should also be available. This allows real-time tracking of a ship's own position on the electronic chart display and also the development of more and more advanced integrated navigation systems.

Object: BUOY
Cartographic attributes:
Symbol rotation (Double)
Text string (String)
Text font (Integer)
Text visibility (Integer)
     0=invisible
     1=visible
Text position latitude (Double)
Text position longitude (Double)

Object: CARTO LIGHT
Cartographic attributes:
Visualisation method (Integer)
     0=symbol
     1=sectors
Sector arc range (Double)
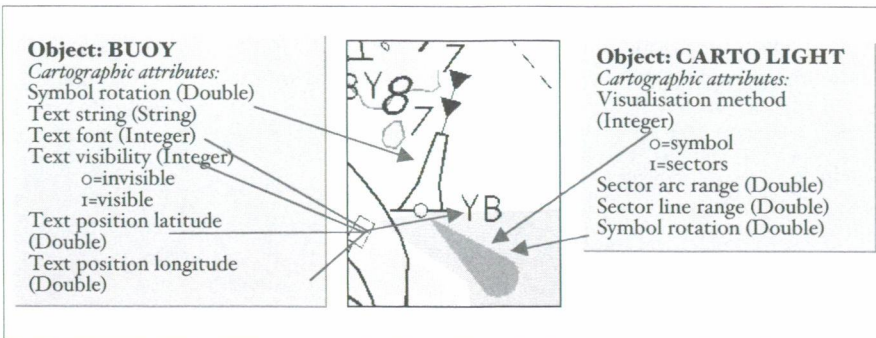Sector line range (Double)
Symbol rotation (Double)

Figure 1: An example of storage of the cartographic editing of a buoy. Cartographic attributes of a BUOY object could also be stored as separate cartographic objects, linked to a buoy (as object CARTOLIGHT)

New Challenges of Nautical Chart Producers

The production of ENCs truly started only a few years ago and the worldwide coverage of ENC data is still quite limited. However, it appears that the ENC production systems of chart producers are finally stabilising and the production plans and predictions promise improvement in the situation in a few years' time. In many Hydrographic Offices the rapidly increased need to produce ENCs has led to a situation where there are two separate production lines for ENC and printed charts. A common database would increase the level of consistency between the products and have a positive effect on the quality of the products. It would also save the time and effort required to do the same updates twice in two different databases. In many Hydrographic Offices research and development is now focused on the challenge of combining electronic and paper chart production efficiently and economically.

Differences between ENC and Printed Charts

Printed charts present all important information as chart features with appropriate symbology and descriptive cartographic information texts and symbols. One of the most important aspects in preparing data to be published on the printed chart is cartographic generalisation and cartographic editing. This includes displacement, aggregation, selection, rotation, inclination and text width, font and placement, etc. (Jatkola, M. & Tuurnala, T. 1998).

Apart from the purely informative text on the chart (e.g. the light character of a navigational aid) there is a need to give additional information about the chart to the user. Such additional information is, for example, mean sea level, buoyage system (IALA A/ IALA B), correction note, projection and horizontal datum. Such information is placed in the legend of the chart.

ENC data is presented on the display of the ECDIS, and the symbology of the chart objects is determined by the object class and its attribute values as well as by dedicated symbology rules. It is easy to add and remove information on the ECDIS display; the user can select which object classes he/she wants visualised on the display (except 'display base' object classes, see IMO, 1996). A large part of the attribute information does not affect the symbology, and the mariner can be given access to the information by a simple spatial query function. ENC data also uses so called 'meta object classes' in order to provide the mariner with information about the quality of the depth data or the direction of the buoyage system applied locally, etc. Tidal information or traffic restrictions, for example, can be presented as raster images or text files, which are stored as 'annexes' to the ENC file and opened by attribute query to the appropriate ENC objects on the ECDIS display.

As the user can select which piece of information is presented at each particular moment, the level of presentation detail in ENC information is not limited by the size of the display and its ability to read it in the same manner as in paper charts. The ability to zoom in and zoom out on the data and the possibility to select information presented on the screen are other reasons why there is no need for cartographic editing of the data. A good example of differences between ENC and printed charts is the displacement of depth figures (see Figure 2). On the ENC the depth figure has to be exactly in the correct position, but on paper charts this is sometimes not possible because of space limitations. Another good example of a
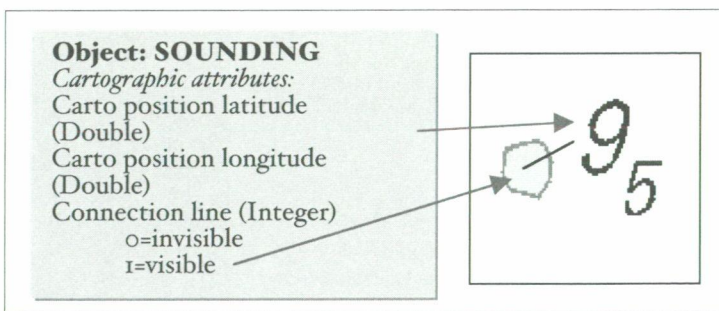

Figure 2: Cartographic attributes of displaced sounding (depth figure)

feature which requires cartographic editing is the sector light. The required cartographic editing operations are the positioning of sector arcs and lines and text placement.

Examples of Cartographic Attributes Needed for Printed Chart Presentation

The IHO Transfer Standard for Digital Hydrographic Data, S-57, defines five cartographic object classes. These are Cartographic Area, Cartographic Line, Cartographic Symbol, Compass and Text. The definition of Cartographic Area, Line and Symbol objects is as follows (IHO, 2000): 'An area (/ a line / a point) with a certain cartographic symbolisation'. The object Compass is to be used to transfer the parameters required to represent the magnetic and/or true compass cartographically. The Text object is a text string that is to be represented using a certain cartographic symbolisation. The S-57 standard does not define any rules for the presentation or display of information. Different applications must provide their own specific presentation models (The presentation model for ECDIS is defined in IHO's standard 'Specifications for Chart Content and Display aspects of ECDIS, S-52'). The underlying idea is that the concept of keeping information storage independent of presentation provides for greater flexibility and versatility. This should allow the same data to be used for many purposes, for example on the ECDIS screen and on the printed chart, without requiring any change to data model structure or content. However, the standard has been developed mainly for ENC and does not completely fulfil the requirements of printed chart presentation.

Examples of some important features of nautical charts which require cartographic editing to be presented on printed charts was introduced in the previous paragraph. The core element of the presentation of these features is to have presentation rules, provided by the application (printed chart production system), based on real world attributes. For example sector lights shall be presented by sectors based on light attributes (e.g S-57 attributes: COLOUR, LITCHR, SECTR1, SECTR2 etc.) and the texts, such as the name of the navaid, shall be deduced from the object name attribute (OBJNAM). In addition to real world attributes there must be some cartographic attributes to store cartographic appearance. Some of the cartographic appearances may be stored by using existing S-57 objects (e.g. $TEXTS, $COMPS) and attributes (e.g. ORIENT, $TXSTR). Some possibilities to expand the S-57 object catalogue with additional cartographic attributes and objects which would enable presentation of the data according to the presentation requirements of printed charts are presented in Figures 1, 2 and 3.

The cartographic appearance of the feature may vary in different products. For example two overlapping printed coastal charts of the same scale sometimes need to have a different cartographic appearance of a feature, if the location point of the feature is close to the edge of the chart. These are most frequently texts and light sectors. Thus a sector light may be presented with full sectors on one chart but on an overlapping chart it must be presented by a 'drop' symbol because of limitations of space. This is managed, for example, by having separate cartographic objects linked to real world objects and also by having a link to a product, if necessary.

nSector – State-of-the-art Nautical Chart Production System

The Finnish Maritime Administration (FMA) has developed a new data management and chart production system to meet the challenges of today. The first phase of the project was called the Hydrographic Information System (HIS) Project. The HIS system is used for entering new data to the database, editing and maintaining data, and for ENC production. The second phase, the printed chart production system development project has now been finalised and at the time of writing the new system – nSector - has just been accepted by the FMA. The system will be in full operation from the beginning of the year 2003 simultaneously with the introduction of INT symbology and the WGS-84 (EUREF-FIN) coordinate system on Finnish charts. Together with the HIS data management and ENC production system, nSector provides not only a modern chart production system but also a secure quality control tool for the reduction of human errors during the chart production process.

One of the key issues related to the nSector chart production system is its integration with the production of ENCs. This is accomplished by integrating the nSector system and its database into the existing
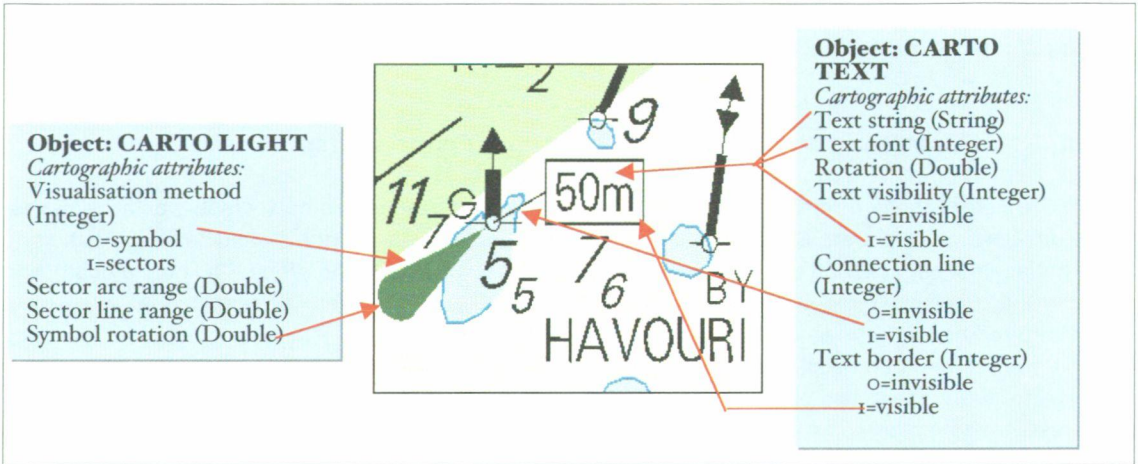
Object: CARTO LIGHT
Cartographic attributes:
Visualisation method
(Integer)
    0=symbol
    1=sectors
Sector arc range (Double)
Sector line range (Double)
Symbol rotation (Double)

Object: CARTO TEXT
Cartographic attributes:
Text string (String)
Text font (Integer)
Rotation (Double)
Text visibility (Integer)
    0=invisible
    1=visible
Connection line (Integer)
    0=invisible
    1=visible
Text border (Integer)
    0=invisible
    1=visible

Figure 3: A method of storing the cartographic appearance of an edge mark. The number inside the box denotes the distance to the channel border (deduced from real attribute of the navaid)

HIS system database. The same database will be the data source for both systems (HIS Client to produce ENC Cells and nSector Client to produce printed charts). The nSector system is based on the ESRI's ArcInfo8 technology and it will add cartographic editing tools and chart production functionalities on top of the ArcMap software. As a whole, the extension contains tools for the entire production line: product definition, layout design, high quality output and workflow control. It incorporates all the functions and features for producing the required products from the input data to a cartographically edited chart product. Intelligent cartographic editing tools together with a geodatabase[1] object model and specialised drawing methods offer a state-of-the-art nautical chart production environment. The system has been implemented by a specialised GIS applications company, Novo Meridian Ltd. of Finland. The following sections will introduce the most revolutionary parts of the system.

Cartographic Attributes and Presentation Rules

While the source data for both products will be the same, the cartographic appearance for paper charts cannot be achieved using traditional methods by editing the geometry of the data. Instead, the entire cartographic appearance of the features is stored to pre-defined cartographic attributes. All cartographic editing is in fact editing of these attributes. Editing the feature geometry is disabled and restricted. This approach ensures that actual data content and geometry are maintained and there is no possibility of defective discrepancy between various products.
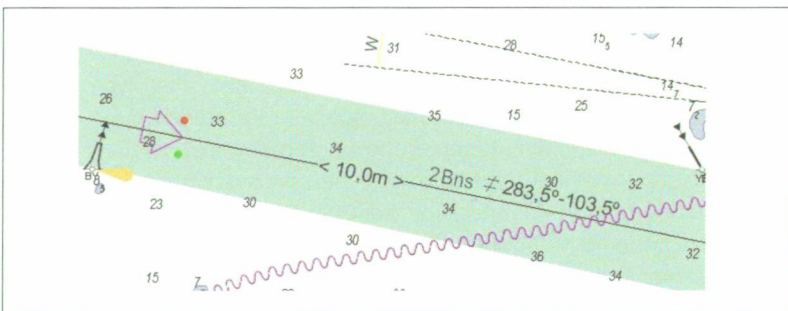

Figure 4: Navigation line (fairway) custom feature with additional text and symbol elements

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[1] The geodatabase is a new spatial data format, designed specifically for ESRI ArcGIS. Geodatabases are used with relational database management systems such as Oracle, Informix, Microsoft SQL Server, or DB2. (Ormsby, T et al., 2001).
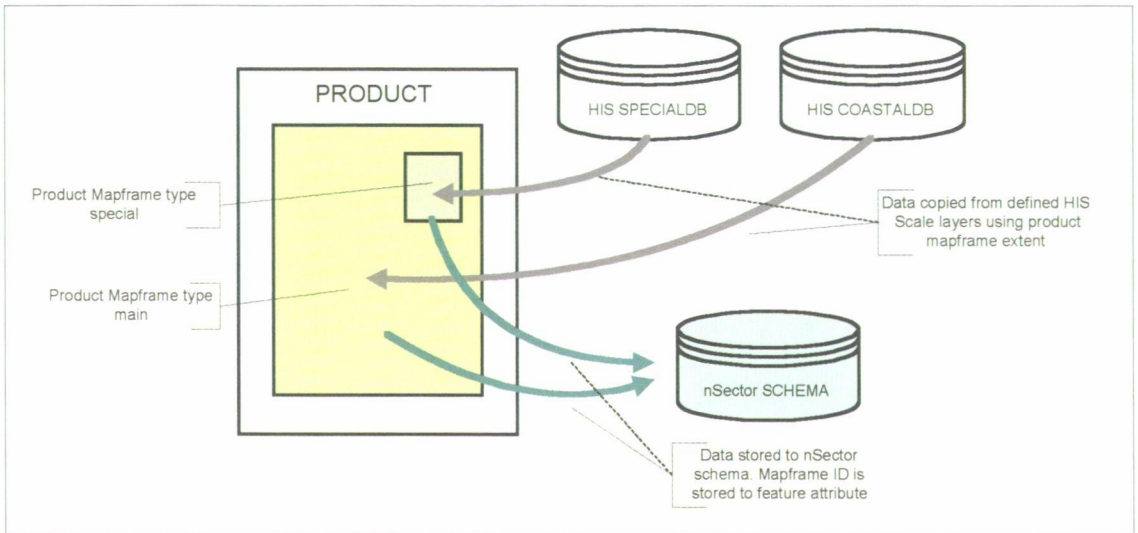
Figure 5: One chart product may consist of many mapframes, the data of which is derived from different HIS scale databases. (Chart Production System Functional Design, 2000)

Attribute based storing of cartographic edits has been in use at the FMA for several years. The previous printed chart production system, Fingis, has an extension for storage and editing of navaids cartographically. The settings for the cartographic presentation and cartographic corrections of navaids specific to each chart are stored in the RDB tables (Hirvonmäki, 1992).

The new nSector editing tools themselves have intelligence to help the operator with the editing process. 'Tools', for example, recognises the feature classes[2] automatically from the screen and acts as defined to this particular feature class. All complex custom drawing methods within feature classes are implemented by using draw methods. For example a fairway has the ability to draw itself using fairway depth and bearing. The texts derived from the 'real world' attributes are automatically aligned with the fairway line and can be freely located within the feature. The cartographic attributes of the fairway will store information about the content and locations of these elements. The depth and bearing texts will automatically mask the line under the texts as invisible (Figure 4).

In addition to presentation based on real world attributes and cartographic attributes, several other advanced presentation rules are provided by the application to avoid excessive interactive editing work. Whenever needed, the cartographer can change the settings separately for each object. The changes are stored in the database as cartographic attributes. These settings are for example:

- Sector arcs and lines have readable default cartographic range values, which will be changed only when needed
- Sector lights are visualised by full sectors, buoys with light are visualised by 'drop' symbols, without sectors
- Texts belonging to one feature have default positions, which are not in conflict with one another
- Text visualisation is based on object type. For example a default attribute value for the names of lighthouses is 'visible' and a default attribute value for the names of buoys is 'invisible'

Database Structure

The heart of the nSector application is the data model. The nSector database schemas are modelled using the Unified Modelling Language, UML. It combines an entity-relationship approach to modelling with

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2   A feature class is a group of points, lines or polygons representing similar geographic objects (Ormsby, T et al., 2001).

an object-component architecture. Perhaps, the most important concept of an object oriented data model is the ability to couple object behaviour and data using 'methods'. A 'method' is a property of an object that is bound to a behaviour. It is this behaviour that gives an object oriented database its power and flexibility. An example of a 'method' used in the nSector application is the draw method. When this method is selected by sending the draw instruction to the feature, the feature executes the corresponding behaviour. Physically the nSector database is a part of the HIS database in the form of three new user schemas. The Product geodatabase contains all product related tables, the Support geodatabase contains job and workflow process related tables and the Data geodatabase contains the actual feature classes. The nSector data model is based on the HIS data model, which is somewhat different from the S-57 data model. However, the nSector application supports the S-57 model as well, if required.

Product Management

In addition to storing all cartographic edits related to chart objects, the layout and product management is based on product information stored in the database. The main purpose of the Product Definition is to store uniquely referenced products, their definitions and properties in the database. A product is uniquely defined by its object ID, name and number. Each product consists of layout elements and several map frames. A map frame is a special kind of layout element, which contains the real data from the database. One product must contain one main map frame and it may contain several additional map frames. For example, the main map frame on a scale of 1: 50,000 and one special map frame on a scale of 1: 5,000. The data for these map frames can be derived from different HIS scale databases (see Figure 5).

As already mentioned in the previous paragraph, the cartographic appearance of the feature may vary in overlapping products. This is managed by storing a link for each feature to the mapframe it belongs to. This means that logically there are separate product databases for each product comprised of defined map frames, which include the cartographically edited data unique for each map frame. Each product is a temporal presentation of a certain timestamp of the HIS database. The operator has the possibility to do some final editing of the chart between the NtM date the chart is corrected up to and the printing/publishing date. At the same time the HIS database has to be updated in real time in order to enable the production of the ENC updating cell (ER) from the same area. When the next edition of the printed chart is to be published, the operator asks the system to update the product and he/she gets an update list, which contains all the changed features after the last edition and, if selected, the system automatically zooms in to the selected update (feature). The application also visualizes the updated features by colours: deleted features in red, modified features in green and new features in blue.

A product's Layout will usually be based on pre-defined layout templates. The layout templates are defined by a system supervisor. Existing templates can be used as a base when new products are defined. A layout template contains complete information about the product layout: paper size, mapframe information and all other layout elements needed for the final product. Layout elements are divided into three categories: static elements (which are generated automatically from the product information stored in the database), dynamic elements (edition related elements, which must be set by the operator, e.g. ISBN and NtM number) and other graphical elements (if needed). For the user, the layout of the product with its elements and their locations are constructed automatically based on element properties and locations defined in the database. During the cartographic editing process the operator only needs to do the necessary updates to the existing layout elements. The product's layout can be seen during the editing process in full WYSIWYG mode

Conclusion

The production of Electronic Navigational Charts has affected the production processes of Hydrographic Offices dramatically. Thus the existing production process, where ENC and printed charts are produced separately, is not a good solution in the long run. For several years, it has been the aim of the FMA to

create an integrated production system for the two products and research has been focused on this challenge. We can now report that the technical solution has been established. From now on we will pursue our next real challenge, the changing of the production processes and the sometimes conservative mindset of people in the production process.

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Biography

Tiina Tuurnala has a Master's degree in Surveying with a major in Geographic Information Systems (GIS) from the Technical University of Helsinki. She has worked for the Finnish Maritime Administration since 1994 and is currently manager of the ENC Production and System Development unit.

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