PRODUCTION AND APPLICATION OF DIGITAL CHARTS
----The Status and Development of Navigational Publications in China

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[Abstract]This paper covers the history of cartographic technology in China within the last fifty years. It lays stress on the status and scale of Chinese chart production, followed by the foreseeing of Chinese charting upon the global information-based trends.

[Key Words] digital charts, database, GIS

1.The History of Cartographic Technology in China within the Last Fifty Years

The Navigation Guarantee Department of the Chinese Navy Headquarters(NGDCNH) is the national authorized agency to publish navigational charts and publications. The agency has released a large number of charts and publications, aiming at ensuring the safety of various Chinese vessels and foreign merchant ships within China Sea Area. The period is approximately divided as the following:

1.1 Chart Production in the 1950's China began editing charts in1950including harbor charts of China coast and navigational charts. The total amount of the charts produced in th at period was up to 500, far beyond the one which had been produced before China's liberati on.

1.2 Chart Production in the 1960's and 1970's China has begun basic sea survey in 1958 that has offered the reliable proof for charting. From 1960 on, the newest survey data, universal depth datum and height datum have been adopted. The use of fair drafting and compilation together with drafting had improved the chart quality. The traditional pen-and-ink drafting was abolished in late 1970's, replaced by scribing on the polyester films. Meanwhile, navigational charts of foreign regions and for foreign vessels when navigating in China Sea Area began to be edited; moreover, a series of specifications and standards were formulated to regulate the chart production.

1.3 Chart Production in the 1980's At the beginning of the 1980's, the charting was subjected to the international standard. The new charts were specific, practical and numbered with a new method. Therefore, the accuracy and quality of charts were improved, and the print process was simplified. All these achievements helped cartography climb up to a new level.

1.4 Chart Production from the 1990's up to now GB-12319 and GB-12320 were formulated in early 1990's. The first international chart *INT5031* was published on trial in 1997 in order to intensify the international cooperation and undertake the responsibility according to IHO's relevant regulations.

For the sake of Chinese reform policy, perfection of the production structure and improvement of the service efficiency, new types of charts have come into being since 1998 to meet the need both domestically and overseas. The amount has increased from 100 to 400, and the covered region has spread from China Sea Area to adjacent sea area.

The notes in new charts are mainly in Chinese characters with the geographic names simultaneously in Chinese spelling. The titles, publisher, notes and cautions are printed bilingually (Chinese and English).

Computerized charting technology is accepted gradually. The time of charting is reduced great deal. Four-color drawing (black, blue, purple, green / brown) is used at present.

1.5 The Production of Thematic Charts and Nautical Publications Charts for special purpose, bathymetric charts, atlases, thematic charts and relevant publications have been produced along the different periods.

2.Production and Application of Digital Charts

2.1 The Development of Digital Charting Technology

"A/C Rams" (Auto Chart Resource Analysis Mapping System) was introduced in the middle of 1980's by NGDCNH. Paper charts were produced with the assistance of this system in 1988 and a breakthrough in automatic chart production was made. Meanwhile, computer typesetting was introduced in editing Chinese Characters and laser photocomposer was practised in 1989, which greatly shorten the time of edition.

ARC / INFO GIS platform was imported in 1994 to create database and to produce digital charts. An interactive Chinese editing interface has also been developed to facilitate the operation. This system has a high feasibility in the gathering, processing, analyzing and management of the spatial data. It can merge the data in databases or separate out any data layer for partial or whole storage and deletion. The classification, definition and indexing of data can be made to facilitate inquiring. The graphics and attributes can be interactively edited and various measurements, calculations, analysis and displays can also be made.

At the end of 1994, ORACLE(a kind of RDBMS) was introduced to deal with thematic feature data. MGE and Publisher of American Intergraph company are used in handling graphics, producing paper charts directly from the chart databases and automatic pre-print processing.

2.2 Hardware and software Employed:

The digital chart cartographic system is a bus-structured system with the network server as its hub, all equipments including digitizers, plotters, backup data memories being included in the network. It is a multi-platform, multi-agreement and multi-software local area network. Hardware employed includes servers, work stations, PCs, AO scanners, AO digitizers, color-drafters, etc. Software employed mainly includes ARC/INFO, ArcScan, GeoScan, MGE, Publisher, ORACLE, and Windows / Windows NT.

2.3 The Process of Charting The process is shown in **Figure Ⅰ.**

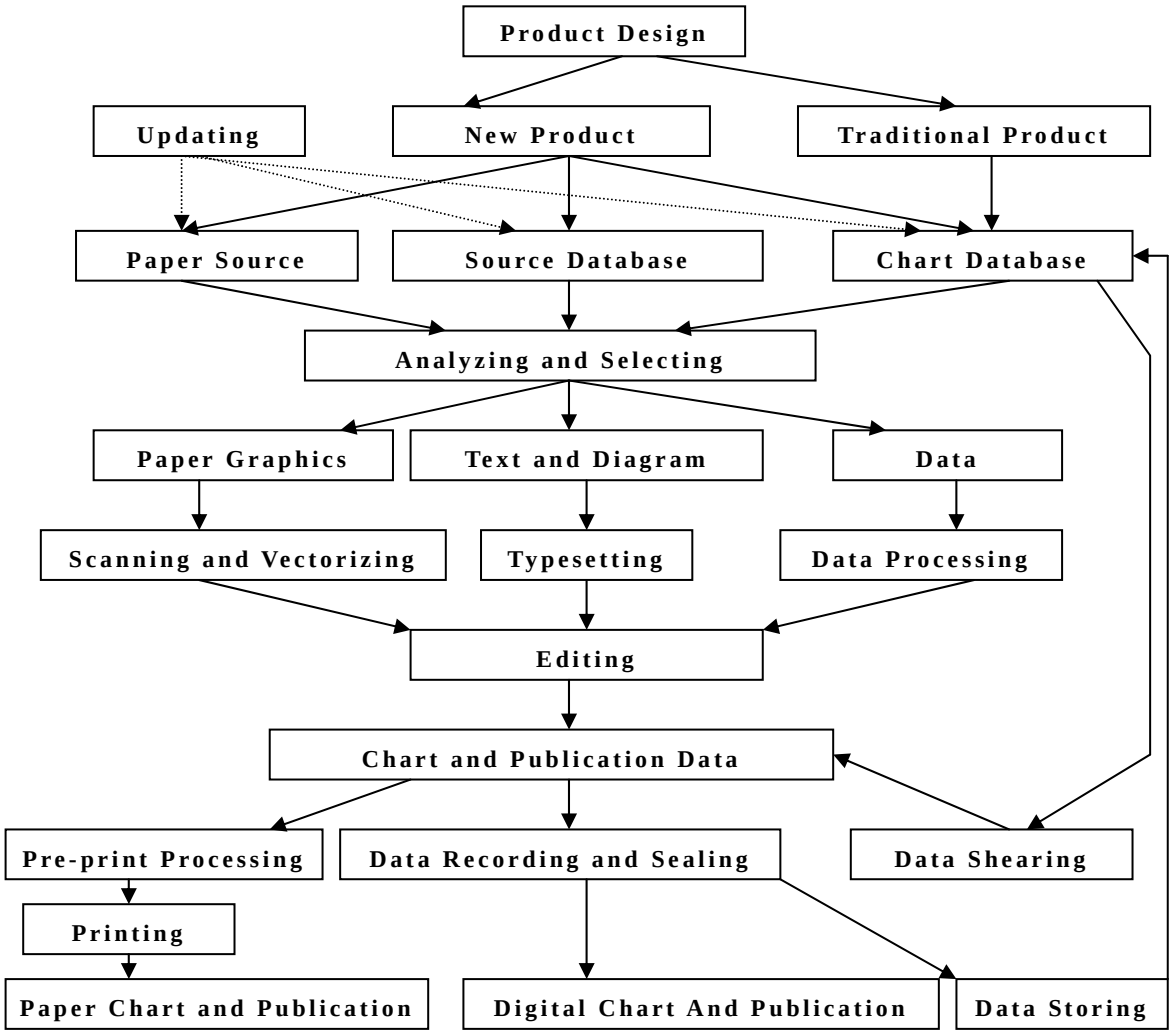

Figure Ⅰ

2.4 Data Structure of Digital Charts

2.4.1 For the controlling, calculating, processing and displaying on computers, the digital chart data should be organized according to certain rules. This kind of organizing form is called the data structure of digital charts. the data is generally organized into a layered structure, which can be divided into the following layers:

(1). Primitive

It is the fundamental graphic element which can be displayed and includes graphics such as points, lines, circles, arcs, etc., and characters such as Chinese characters, Chinese spellings, characters of foreign languages, etc..

(2). Entity

It is a group of fundamental graphic elements related logically. It is the logic unit in interacting and users can carry out with it such operations as deletion and correction, etc.

(3). Feature

It consists of many entities of the same nature, and each category of features should be laid in a sole layer. A single layer or overlaid multi-layer can be displayed.

(4). Sheet

It is made up of all features within certain topographic area divided according to certain rules. In map databases, a sheet is a work unit or work space.

(5). Region

The region of topographic maps based on administrative or geographic or other required divisions consists of certain sheets, which are objects of management in the digital map system. There is a sheet index diagram which can be displayed on the screen for the management, indexing and usage of the sheets.

2.4.2. Layering Method of the Chart Feature Data

(1). Basic principles

a. Practicality

For the computer management mainly involves the gathering of data, topological processing of features and displaying and transferring of data, the layering is closely related to the software. The ARC/INFO software used by us is the most perfect one in the field of today's GIS.

The chart features, described by spatial data and attribute data, are shown in three types of symbols: point, line and area. They should be laid in different layers for management.

The digital chart data are organized in a layer (or directory) structure according to a specified sheet area. In the computer, one sheet of digital chart is one directory, which is called "workspace". This workspace contains one or more data sets (subdirectories), and one incidence database which is used to record the attribute data. The data set under the workspace is our data layer, which is called "coverage".

The digital charts are mainly applied in navigation. So the layering must meet the oceanographic and navigational requirements. The features should be layered geographically while considering the navigational requirements. Those thematic features of the same or similar attribute should be put into the same layer for the convenience of displaying and usage in navigation.

b. Conformability

The classification and layering should be done in conformity with the geographic classification while referring to current GB12319-1998 *Symbols, Abbreviations and Terms Used on Chinese Nautical Charts and IHO Symbols, Abbreviations and Terms Used on Nautical Charts*. This makes it possible that the symbols in the database can be displayed incidentally and the feature codes will conform to the paper charts and international digital charts.

c. Clarity and Accessibility

The digital chart adopts a directory structure and, for the convenience of indexing and inquiring, the chart features are laid into a number of subdirectories (thematic layers). A digital chart can be simply considered as the overlaying of different thematic layers which are logically integral. Certain layer or category of features must be clear and accessible for indexing and inquiring.

(2). Layering Method

Based on the above principles, the chart features are geographically divided into land features and sea features by the shoreline. The sea features are emphases of the nautical charts and it is a key problem whether their classification is reasonable or not. When layering, the reasonable description of oceanographic and navigational informationed well-knitted structure should be considered.

a. Sea/Land

Those features having topological relations with both the sea and the land should be firstly classified through the shoreline which divides the sea and the land. The shoreline divides a geographical area into a land polygon(including islands) and a sea polygon which is further divided into certain isobathic areas(polygons) indicated by contours. The layer containing these related features is defined as sea/land layer.

b. Land Portion

Layering of the land portion is identical to its geographic classification which is logically clear. There are seven layers.

c. Sea Portion

This is the emphasis of digital charts. We can find that the features of the sea portion are plenty and have complicated relations with each other. Furthermore some features are classified too indistinctively. So when layering digital charts, we adopt two basic methods based on the

above major principles: distinctive features first and important features first. Using these two methods, we first put the navigational aids and obstructions, which have great influence on navigation, into two different layers. One is named navigational aids layer(ANVGPT) containing lights, buoys, beacons, fog signals, radars and radios, etc. Another is named obstructions layer(OBST××) containing rocks, wrecks and obstructions, etc. For the latter layer contains point and area features, it is further divided into two sub-layers respectively named OBSTPT and OBSTNT.

Then several other thematic layers such as fairways layer, area limits layer, port facilities layer, offshore installations layer and services layer, etc. by the same methods. Finally the other general features are synthesized. For example, the depths and natures of seabed are combined into one thematic layer named depths/natures of seabed layer; the tidal features and magnetic features are combined into another thematic layer named tidal/magnetic features layer. In addition, a sources file layer is defined for the purposes of indicating the sources adopted, analyzing the reliability of the sources and facilitating afterwards checks; and a index of next larger scale charts layer is also defined to indicate the interrelations of the charts.

d. File Portion

(3). Naming of the Feature Layers of Digital Charts

Each digital chart is divided into 17 thematic layers according to the categories of its features. The name of a layer consists of six letters, of which the first four are its English abbreviation and the last two are the spatial type identifier of features. The spatial type identifiers are defined as follows: point – PT; point and arc – PL; arc – PN; line, polygon and area – NT. For example, the sea/land layer containing point features is named OCLDPT and the sea/land layer containing line and polygon features is named OCLDNT.

2.5. **Digital Chart Database and Other Relevant Database**

2.5.1. Structure and Design of the Digital Chart Database

(1). Systematic Structure of the Digital Chart Database

a. Structure of the Library Entry

The digital chart database is created on the basis of chart data structure. The database is made up of a database definition file and a library entry file. The database definition file describes: *a).*database creation time and creator *b).* library entry's location(path) *c).* server's name *d).* sole database identifier *e).* character set definition. The file path specified for the library entry is called the root directory of the ArcStorm database which contains one arcstorm directory, one tmp directory and certain library directories. The arcstorm directory mainly contains system files and subdirectories for database management. The library directories contain data entities and related tables and files including partition directory, index directory, COVERAGE module and info table.

b. Data Structure of the Library Entry

In AcrStorm database, the spatial data are organized into one or more ArcStorm libraries corresponding to chart databases of various types and scales. The data are stored separately in the databases, each of which represents a specified geographic area. In order to facilitate the operation and access of data, the chart databases need to be two-dimensionally divided into certain Tile partitions.

ArcStorm offers two kinds of partition methods: one is to divide the geographic area of a library by certain power(s) of 2 into regular rectangle grids; the other is to divide the library area according to current or expectant data density(the number of features contained in each partition). In addition, each chart database may be divided into certain layers with identical tile partitions. It conforms to the layering scheme of digital charts combining logical layering with physical layering.

(2). Design of Digital Chart Database

We can begin to design the digital chart database in the following steps:

a. Determine the contents indicated: to determine the quantity of features to be indicated according to the different applications of various scale chart databases.

b. Determine the area scope: to determine the overall scope of area on the customer's requirement.

c. Organize and describe the data: to organize the data into certain layers according to their logical relations and classify and encode the data in each layer.

d . Partition: for the purposes of organizing and managing the data, the vast area involved by the database must be partitioned into certain smaller areas.

e. Determine the data source to digitize.

2.5.2 Digital Chart Database and Other Relevant Database The establishment of Chart database and the chart-product are carried out simultaneously. Chart database of basic scales has already been established, for example, database of General Chart of China Sea Area, database of 1∶1,000,000 scale, and database of 1∶250,000 scale. Database of thematic charts are being built.

In order to meet the needs of chart production, a large number of thematic databases have been founded: soundings database, management database for the Notices to Mariners, control points database, database of geographic names in China Sea Area, lights database of geographic names in China Sea Area, lights database, database of offshore oil platform, nautical information database, map database, database of harbor information, etc. Producing management database have been set up so as to coordinate the various charting segments, such as database of hydrographic survey and charting, distribution database.

2.6 Applications of Digital Charts

2.6.1 Paper Charting with the Assistant of Digital Chart Databases NGDCNH is responsible for the publishing and editing charts and publications, and for the release of Notices

to Mariners. Hundreds of charts and over 100 publications are produced annually. Its distribution network covers many countries and regions and the domestic regular users are up to 1,000. NGDCNH is also responsible for information exchange with IHO and other nations including America, Russia, England, Japan ,South Korea, etc..

2.6.2 ENCs An ENC is a kind of screen map based on chart databases. It is displayed kinetically with such functions as overlaying, indexing, data analyzing, process simulating, future forecasting, etc. About 100 digital charts have been produced which accord with CPF and S-57.

2.7 The Establishment of Standardization System

Chart Standardization and internationalization have been carried out along with the development of automatic charting. A series of standards have been released in recent years, including *Data Dictionary Used on Chinese Charts; Feature Attribute Codes for Nautical Charts; Specifications for The Notices to Mariners; Specifications for Fishing Charts; Symbols, Abbreviations and Terms Used on Chinese Nautical Charts; Specifications for Bathymetric Charts* and *Specifications for Chinese Nautical Charts.* These standards have regulated the chart processing and improved the chart quality. In order to adapt to the international standards of charting, a great deal of work has been done, for instance, *Symbols, Abbreviations and terms used on Chinese Charts* has been changed to meet with INT 1, and digital charts are produced under IHO S-57.

3.The Foreseeing of Charting

3.1 The Requirements of Charting in Information Society

The twenty-first century is an age of information when ocean research and exploitation become a focus of human beings. The international co-operations about oceans have increased with time goes on. Charting is facing new changes and challenges:

3.1.1 The consuming groups will enlarge, hence the demands for charts will reach an unprecedented number. Digital products will be in the leading position.

3.1.2 Charts will be made three-dimensionally with the development of space and computer technologies. Paper charts will only be the back-up when the vessels are installed with automatic navigation systems which result in the increasing demand of charts. Paper Charts will be out of date because three-dimensional information are required as to offer high-density and multi-layer data information.

3.1.3 The information-transferring media must be improved upon the available system and be closely connected with GIS, GPS and RS.

3.1.4 The universality of products and sharing of resources appear more important with the development of globalization.

3.1.5 The function of nautical publications, as the medium of basic ocean geographic information, will be more strongly enhanced.

3.2 Technologies Focused:

3.2.1 Automatic Charting Automations of editing and selecting of features are the key elements which affect the cycle of charting.

3.2.2 Virtual Ocean With the development of this technology, the service will be optimized.

3.2.3 Rapid Updating.

3.2.4 Space Data Engine (SDE) can improve the processing efficiency of data.

3.2.5 Internet Map Server(IMS) release the nautical products, charting technologies and service information on the internet and other public computer nets to offer on-line servers and to share the network resources.

3.2.6 The Technology of Digital Thematic Charts and Digital Chart Atlases The increasing demand of thematic charts and atlases requires us to produce comprehensive digital nautical publications, such as digital marine magnetic charts, digital marine gravity charts and digital chat atlases.

It is assured that the distribution and after-sale service will be carried out on the network very soon.

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