International Hydrographic Review, Monaco, LXIX(2), September 1992

THE ELECTRONIC CHART DISPLAY AND INFORMATION SYSTEM (ECDIS) IN CHINA

by The Research Group on ECDIS [1]

Abstract

This paper presents a prototype of ECDIS developed by the Research Group on ECDIS of the Dalian Maritime University, China, and describes briefly the configuration, function and characteristics of this system. Trials ashore and at sea have proved the good performance of the system.

INTRODUCTION

In the mid-1980s, China started research on ECDIS. At that time, research on ECDIS was limited to the transfer of information from the paper chart to the screen. Information from the paper chart was digitized and displayed with the ship's position. In the beginning of the 1990s, the Research Group on ECDIS (RGE) of the Ministry of the Communications of the People's Republic of China was founded, and progress was made in displaying the electronic chart, developing the information system and building up an Electronic Chart Data Base. In accordance with the requirements of the Provisional Specifications (Third Draft) for ECDIS, published by the International Hydrographic Organization (IHO), the RGE established the ECDIS. It consisted of subsystems for generating and displaying the electronic chart information. During September 1991, the RGE evaluated this system on the YULONG, which is the training ship of the Dalian Maritime University on a voyage from Dalian to Hong Kong.

THE MINIMUM SYSTEM CONFIGURATION

In compliance with the requirement of the minimum configuration in the Third Provisional Specifications for ECDIS (Third Draft), the Research Group

[1] Dalian Maritime University, China.

established the hardware system of ECDIS, as shown in Figure 1. The main controller was provided by an IBM compatible, 386 processor microcomputer. The output display system controlled by the main controller included two high resolution graphic displays (21", 1024x1024) and an alphanumeric display. Three displays were controlled by one Central Processing Unit: graphic displays were used for displaying graphic information and the alphanumeric display was used for displaying other information (menu, sailing directions, tide table, light list, etc). The input system consisted of a digitizer and a scanner taking data directly from the data base, which were connected with the main controller and generated electronic charts in different ways.

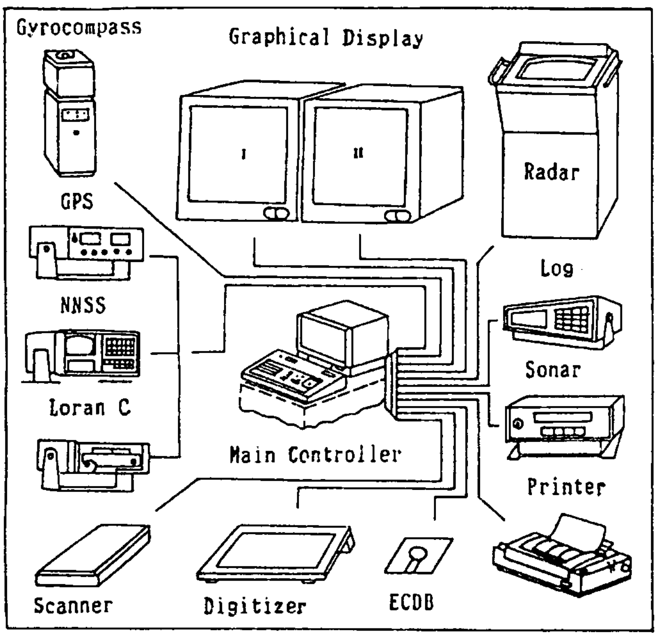

FIG. 1.- Constitution of ECDIS.

To obtain the position information and radar information when the vessel was underway, the main controller was connected to the navigation equipment and radar, both by means of an interface with the navigation equipment and an interface with the radar. The external inputs to the system were composed of navigational equipment and radar, which included GPS, NNSS, Loran-C, Gyro, Fathometer and Radar. The main controller can obtain information from this external equipment and display it in real time.

MINIMUM SYSTEM FUNCTION

1. Electronic chart generating system

This subsystem supplied chart information to user, and displayed it according to the requirement of the user. Because the information came from different sources, the methods of generating the electronic chart were different. The subsystem generated the electronic chart either from the paper chart or from the ECDB, and can be divided into digitizer method and scanner method when it generated an electronic chart based on paper chart.

(1) using a digitizer to generate an electronic chart

A digitizer was used to create an Electronic Chart Data Base from the initial data of the paper chart. When the paper chart was digitized, the coordinates were generally obtained in distance from 0.1 mm to 0.5 mm (range from one point to another point). The magnitude of error changed in accordance with the scale of the chart. The smaller the scale of the chart, the greater the level of error was.

(2) using a scanner to generate an electronic chart

In order to avoid the error resulting from the digitizer to generate the electronic chart, a scanner was chosen as a second method. The accuracy of the data obtained was increased by using a scanner. The scanning of a paper chart and the subsequent generation of a graphic file was a high-accuracy method for developing an electronic chart. But the file generated by the scanner ordinarily being a pixel file and requiring a large memory, the processing of the pixel file was very slow. It will undoubtedly bring about some inconvenience for managing an electronic chart. A reliable method was necessary to compress the pixel file so as to generate a file that was easy to manage and this was the pixel file's vectorization. When the scanner was used to generate an electronic chart, it was necessary to divide a paper chart into a number of A4 size paper charts, and to input each of them into computer separately. A number of pixel files, of 468526 bytes, were then generated. After linking up two of the A4 size pixel files, they could be cut out to generate six 1024x1024 pixel files of 1,310,372 bytes These pixel files could be used to generate vector files after vectorization, in accordance with the following format:

Head of file

segment 1
element 1
element 2
.
.
.
element n
segment 2
.
.
.
segment 3
.
.
.
segment n
end

The length of the header of each file was fixed to 48 bytes, including information on the features and standards of the file (for example, scale, longitude and latitude). The segment consisted of a head of segment and a number of elements. It could contain information, such as 2m depth contour, the 5m depth contour, symbols, etc. So, the information of the Electronic Chart could be divided into numerous layers, which could be displayed and presented. The vector file, after vectorization, was about 10 times shorter than the pixel file, and in conformity with ISO 7912 GKS Specification.

(3) using of ECDB to generate the electronic chart.

In accordance with the Third Provisional Specifications for ECDIS (Third Draft) developed by the IHO, the Electronic Chart should be generated from the ECDB. Preliminary research on the format of ECDB were subsequently made. As an ECDB was developed with the aim of generating Electronic Charts, emphasis was put on the speed and accuracy of the management. According to the present conditions in China, the chart was divided into a fixed portion and a variable portion. The so-called fixed portion included land and the coastline, and the variable portion included all variable information (e.g. depth contour, spot sounding, navigation marks, dangers, etc.). For the fixed portion, the first level vector file was generated using a scanner. On the basis of this vector file, the second level vector file was generated by an ECDB of variable portion, so as to use it when navigating the ship. The format of this ECDB of variable portion was as follows:

head of file
<number of type>
<number of base-cell>
<attribution>
<number of coordinate>
<longitude, latitude; longitude, latitude; ...>
<attribution>
<number of coordinate>
<longitude, latitude; longitude, latitude; ...>

.
.
.

(4) Electronic Chart's accuracy and error.

For the two graphic displays, the resolution is 1024 x 1024 pixels and the distance between points of the pixel is 0.28 mm. When representing charts at larger scale (1:120,000), one pixel corresponds to 48m. When representing charts at a small scale (1:230,000), one pixel corresponds to 1000m.

Error of the Electronic Chart is obtained from the calculation of the vector distance between a position in the chart and the corresponding one in the Electronic Chart. A statistical or "mean" error can be then calculated, supposing that the latitude and longitude of the original plotting points are xi, yi and that of the EC are Xi, Yi respectively:

longitude error : (Xi - xi) -->Δxi(m)
latitude error : (Yi - yi) -->Δyi(m)

total error: $\Delta i = \sqrt{(\Delta x_i)^2 + (\Delta y_i)^2}$

Thus the statistical error will be:

$$\sigma = \frac{\sum_{i=1}^{n} \Delta i}{N}$$

For a chart at scale 1:75 000, the statistical error will be:

$$\sigma_{7.5} = 42(m)$$

2. Electronic Chart Display System (ECDIS)

ECDIS consists of two high-resolution graphic displays (21 inch, 1024 x 1024, pixel size 0.3mm) and a Video Graphics Adaptor compilation display. The three displays work under the control of the same Control Processor Unit. The two graphic displays are used to display charts at different scales. One of them displays charts at small scale and is mainly used for chart retrieval, chart work, position and track presentation etc. It works in "absolute movement mode". When the ship position reaches the screen edge, it automatically moves to the next page. The time for this change is less than 10 seconds. The other is used to display at a large scale a part of a chart at small scale (the navigation area of the ship). The chart is displayed with more detailed information. In this case, it works in "relative movement mode", thus always keeping the position of the ship in the center of the screen to display the position and track as well as the superposition with radar image (Fig. 2).

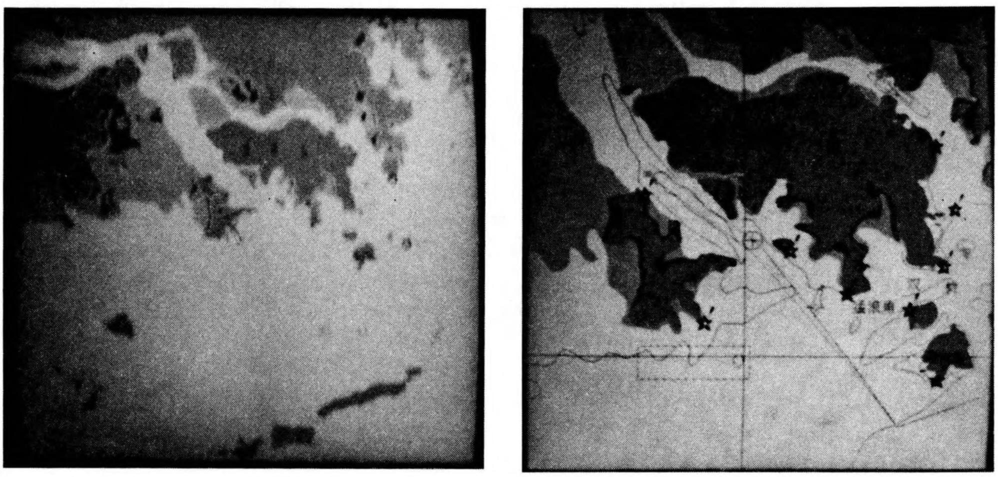

FIG. 2.- The two high-resolution graphic displays showing position in different movement mode.

In addition to the menu representation, the compilation display is used also for displaying the information from the Electronic Chart Information, mainly including route directory, tide table, buoy list, etc. The function of ECDIS is as follows:

(1) Display
Chart information is divided into 10 layers and each of them is displayed according to the requirements. The 10 layers are land information, the 2m contour line, the 5m contour line, the 10m contour line, the 20m contour line, the 30m contour line, depth point, symbols, Chinese characters, track line.

(2) Flashing
Apart from the land information, all the other information can be displayed with flashing on request.

(3) Ship Position and Track
The position and track of the ship are automatically displayed by processing the information received from the navigation equipment such as GPS, Sat-Nav, Loran-C, Compass, log, etc.

(4) "Zoom" effect
It can enlarge the display, step by step, or not, on a high-resolution graphic display.

(5) Representation of Navigation Information
The date, time, ship's position, course and speed are displayed on the CRT with digital number.

3. Chart Work

The Chart Work module in ECDIS is designed in accordance with all the routine work procedures currently done manually on paper charts as described in the Provisional Specifications for ECDIS (Third Draft) (Oct. 1988), and in accordance with the primary role of ECDIS in navigation. It has the following functions:

(1) **Chart Sorting.** Chart retrieval is carried out on the graphic display unit. When the departure port and destination port are input, the display unit will show all the chart frames covering this area. From these frames, the chart number is identified and used to determine which chart is to be chosen. Figure 3 is a chart diagram from a departure port (Dalian) to a destination port (Hong Kong).

(2) **Route Planning.** Routing in ECDIS utilizes the developing ship-based weather routing techniques, taking ship's navigational performance into account, regards the least time as a goal function, chooses an appropriate speed-loss function in seaway, uses the time-front isochromatic algorithm, the long and medium range weather data, and processed navigational data input from the keyboard, and designs the ship trans-ocean and offshore optimum route. Once a ship is under way, real-time observed weather data will be input, and the previous route may be modified. This ensures that the overall and local route is reliable, accurate and optimal. The route can be displayed on ECDIS whenever needed.

(3) **Navigational display.** This routine is used to read, at intervals, data from the interface with NNSS/GPS, log, and gyro-compass, and mark the fix of NNSS/GPS and the dead-reckoning position, calculated with the data from the log, the gyro-compass and the computer internal timer.

(4) **Plotting.** This function is designed, by means of inputing latitude - and - longitude data, cross cursor or bearing line, to take out the symbols specified by the

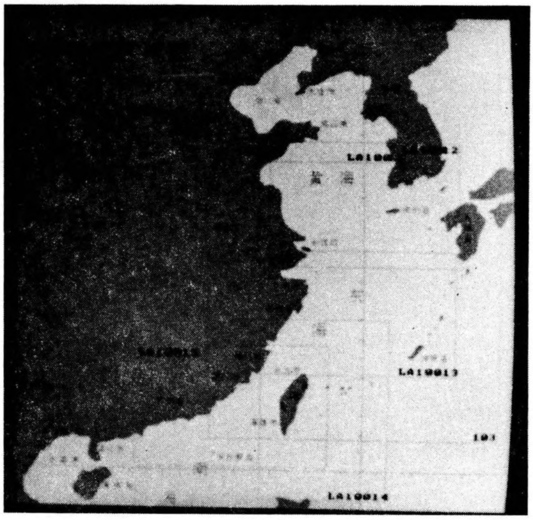

FIG. 3.- The diagram of chart sorting.

client from the symbol library and display them on ECDIS. Furthermore, users can make their own selected symbols and save them in the library.

(5) **Calculating.** This routine is based on the calculation of meridional parts. It computes Mercator's distance and bearing of any given two points, and also to reckons the set and drift, the ship speed and the course between two fixes.

(5) **Fixing.** This function processes the ship position and displays it on ECDIS with the given symbol, from the initial data of bearing and distance which are input from the keyboard and cursor (or bearing line).

(7) **Labelling.** This function enables the users to add their Chinese or English character on ECDIS, and to provide them with some functions such as translating, zooming and shrinking, rotating, deleting, etc..

The information data stored in the electronic chart can be displayed and deleted in due time according to the information provided by the Hydrographic Departments involved.

4. Updating

As a legal equivalent to the existing paper chart, the Electronic Chart Display and Information System should be able to perform the important functions of updating and correcting the displayed electronic charts, in conformity with Article 20 of Chapter 5 of the SOLAS. In this respect, there is a sub-system of chart correction, specially designed for that purpose.

Due to the fact that the format for transfer of data, for automatic or semi-automatic updating, has not yet been decided, information provided by Notices to Mariners are used for the electronic chart updating in the sub-system for chart updating. In accordance with the periodicity of such information, the subsystem of chart updating classifies data into the following categories:

(1) Lights,
(2) Buoys and Beacons,
(3) Dangers,
(4) Depth Contours,
(5) Ports and Harbours,
(6) Buildings,
(7) Various Limits,
(8) Miscellaneous Stations (life-saving, pilot, meteorology, etc.)
(9) Radio and Radar,

In the sub-system for Electronic Chart updating, data to be updated are manually input by the user. The functions addition, deletion, motion and displacement of the updating can be used to meet the need of point-updating.

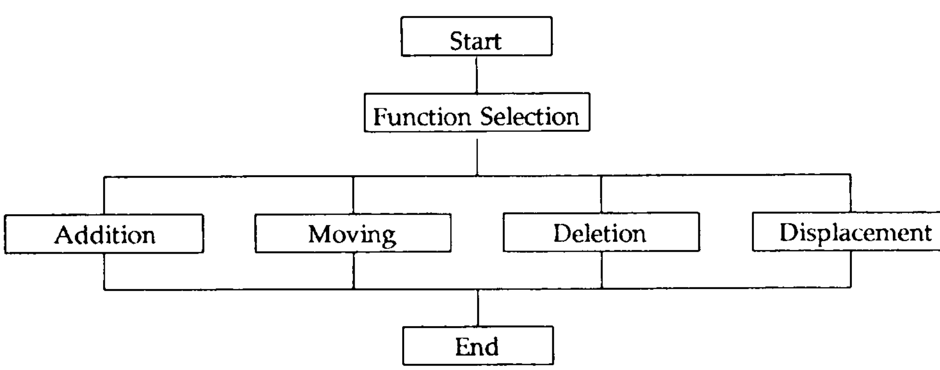

FIG. 4.- Block of software in sub-system of chart updating.

The hardware of the sub-system of chart updating is related to the main micro-computer of ECDIS, and the software is structured in modules for the use of main system. The block is as shown in Figure 4.

5. Interface with the navigation equipment

Information such as ship's position, ship's course and ship 's speed needed by the electronic chart system for displaying the ship's position comes from the ship's navigation equipment. For this purpose, there is a specially designed navigation interface. The navigation interface is of the intelligent type. It consists of a sub-microcomputer system which collects information from the navigation equipment, processes this information and produces navigation data. These data are transmitted to the main microcomputer at certain intervals. The interface is installed on a standard enlarged board, inserted into the enlarged groove in the main microcomputer. All these systems offer high accuracy and reliability.

Z-80 is used for the CPU of the interface, which can be connected to GPS, NNSS, Loran-C, Gyro-compass and Log. The interface fixes software and is able to process the data concerned and make control of itself. The block of the interface is shown below (Fig. 5):

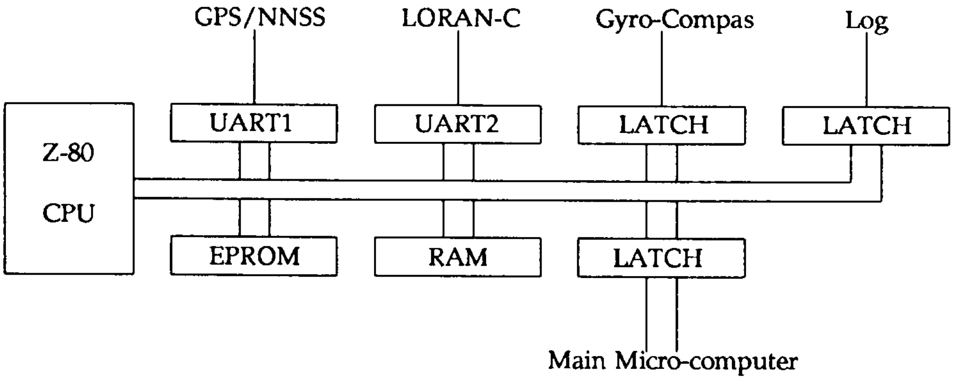

FIG. 5.- Diagram of the navigation interface.

The interface sends a group of navigation data to the main computer at intervals of 20 seconds. This group of data consists of 40 bytes, including ship's position in longitude and latitude, ship's course and ship's speed, provided by the navigation equipment connected to the interface. Therefore, the interface performs all the functions of collecting and processing the navigation data, automatically sends navigation data to the main micro-computer, without the main micro-computer control, and meets the requirement of an intelligent interface.

6. Connection to the Radar

The radar display provides important information in the electronic chart system. Since the electronic chart will be displayed on a high resolution display, the video-information from the radar receiver will be sent to, and stored, in the micro-computer memory, through the interface circuit. The radar interface mainly includes the following:

(1) The processing of the radar video signals
(2) The transformation of radar bearing signals
(3) The hardware and software of the radar picture transmission.
32 Kbyte of memory are necessary for a radar picture of 1024 units of bearing and 256 units of range. The function of the radar interface is to transmit a whole picture to a pre-established sector of 32Kbytes in the main micro-computer memory, at a certain interval.

A radar picture transmitted from the interface to the main micro-computer memory is stored in polar coordinates.

The radar display range consists of three ranges of 3, 6 and 12 miles. The relevant units of distance are 23.3m, 46.6m and 93.3m respectively, and the unit of bearing is 0.3515°.

After storing in memory a set of radar images, the computer will read the data as needed, calculating the orthogonal coordinates (x,y) of the unit, regulating the meridian part for the spheroid and then, adding it to chart.

OTHER FUNCTIONS

1. The image processing picture on ECDIS

The general navigational chart can provide three-dimensional navigational information on a two-dimensional plane. To achieve this objective using a nautical paper chart, one of the ways is making use of horizontal views. Photographs or sketches of mountains, islands, capes, points and lighthouses, conspicuous artificial buildings near the offshore river, port or important waypoint, are attached to the paper chart, and are adopted to help the observer to identify objects and seas.

In this system, the picture is stored separately as a of bit map file, and, when it is required, a frame can display the view in the graphical display. It is convenient to perform positioning and navigating, and to solve problems such as converting three-dimensional information into a two-dimensional display and the high cost of a three-dimensional work station. Figure 6 is a demonstration of view on an ECDIS.

2. Electronic Chart Information System (ECDIS)

An ECDIS system includes all the navigational information except the paper chart. It also includes sailing directions, tidal table, list of lights and fog signals, etc. They are respectively stored as data files on the external memory. Whenever necessary, it can be taken out and displayed.

ONBOARD TEST

The one-month test period was carried out on board the training ship YU LONG (10,000 ton class general cargo ship) of the Dalian Maritime University from September to October 1991, after the completion of the ECDIS research program in the laboratory, in order to test and verify the reliability in the application of the various performance indices of this system. The effectiveness of the position fixing accuracy on the Electronic Chart, the radar image accuracy, the updating of the Electronic Chart and the chart work on the Electronic Chart, the route planning design, etc, were checked. The test was carried out on a voyage between Dalian and Hong Kong. The results show that the system can basically meet the user's

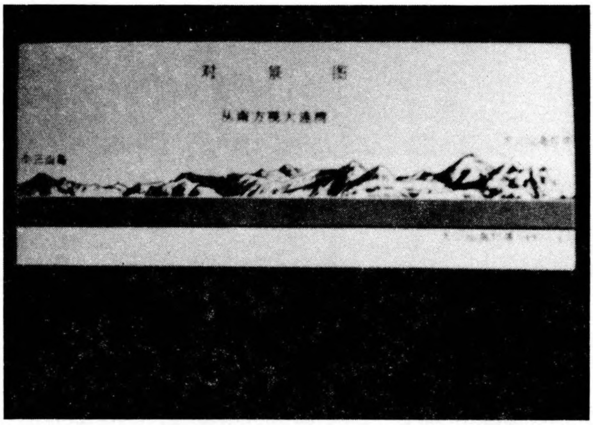

FIG. 6.- Demonstration of view on an ECDIS.

requirements. The external device interface equipment is stable and reliable, and the system operates satisfactorily.

CONCLUSION

With the steady development of navigation and computer technology, the function of ECDIS is close to, and even superior in some areas, to paper chart. At present ECDIS is mainly used aboard fishing boats, small offshore ships, survey ships, ferries and research vessels. But ECDIS not only offers plenty of navigational information, but also supplies integrated management information; it can be used both as a terminal of navigational display and information, and as a dynamic terminal of VTS (Vessel Traffic Service) for traffic control.