A development of GIS plotter for small fishing vessels running on common Linux

Yukiya Saitoh
Graduate School of Systems Information Science
Future University Hakodate
Hakodate, Japan
g2109018@fun.ac.jp

Masaaki Wada
School of Systems Information Science
Future University Hakodate
Hakodate, Japan
wada@fun.ac.jp

Abstract—In this paper, we propose a GIS plotter for small fishing vessels, with the objective of promoting effective coastal fishing and the sustainable use of aquatic resources in coastal fishing. Currently, various marine charts are created in support of coastal fishing operations. However, the charts are displayed on paper and cannot be used effectively on small fishing vessels. Therefore, we focus on GPS plotters that are currently the most widely used devices on small fishing vessels for navigation and for displaying bathymetric charts. We are developing a GIS plotter running on a common Linux system that can display various marine charts and automatically update marine chart data. First, we developed a GIS plotter that displays the vessel's position, a three-dimensional bathymetric chart, an isobathic line chart, a submarine geology chart and an aquatic resources distribution chart. From experimental results, we confirmed that these charts could be drawn at 1 fps or more. Next, the plotter was used to monitor, from land, small fishing vessels in real time by using a cellular phone network. Furthermore, data on schools of fish could be transmitted from small fishing vessels to land over a wireless LAN. We expect that the GIS plotter will support not only the fishing industry through the use of these new marine charts but also the sustainable use of aquatic resources through monitoring of small fishing vessels.

Keywords—*GPS plotter; geographic information system; Linux; navigation system for small fishing vessels; monitoring of small fishing vessels; marine information*

I. INTRODUCTION

The objective of this research is to promote effective coastal fishing and the sustainable use of aquatic resources through marine information mapping using sensing data shared among multiple small fishing vessels. From 1989 to 2008, the production volume of Japan's costal fishing industry decreased about 47%, and in that time, the number of people working in Japan's costal fishing industry decreased about 58%. To ensure effective coastal fishing and thereby to supply a stable amount of marine products, which are an important food source in Japan, the use of marine information has attracted considerable attention. However, because some bathymetric charts, for instance, were created over 30 years ago, and because mapping requires substantial time and costs, it is difficult to provide the latest information to fishermen. Furthermore, aquatic resources distribution charts are currently created based on the daily operation logs, but these charts cannot be supplied to fishermen in real time.

Therefore, we focus on the fact that small fishing vessels are mobile. By using the various measurement instruments installed onboard small fishing vessels, marine information can be acquired that is spread across a wide area. We have developed technology for effectively creating marine charts by sharing large amounts of sensing data among multiple small fishing vessels. For example, bathymetric charts and aquatic resources distribution charts can be created efficiently by sharing, over a wireless network, water depth information and fish catch information which has been collected by multiple small fishing vessels. One conventional example of marine information use is the construction of three-dimensional (3D) bathymetric charts by using a GPS device and an echo-sounder such as a multi-beam sounder or a fish finder [1]. The 3D bathymetric charts can then be displayed with software such as ArcGIS [2] in combination with geographic information and positioning information.

However, because of the lack of a high-speed wireless network at sea, the problems caused by the vibration of the vessels, the limited space and the damage caused by salt, generated marine charts cannot be used effectively in coastal fishing operations Therefore, this research focuses on GPS plotters, which are currently the most widely used navigation device on vessels, because this type of embedded device has been suitably adapted for use under maritime conditions. A GPS plotter displays vessel-positioning information on a digital nautical chart for navigation and a 3D bathymetric chart for fishing operations. However, the latest GPS plotters require manual collection of marine information, which is stored on CompactFlash (CF) cards. If the marine chart data stored on a GPS plotter can be updated automatically over a wireless network such as wireless LAN deployed in a coastal area (Marine Broadband Framework) [3] and over a cellular phone network, fishermen will be able to browse the latest marine chart in real time on a small fishing vessel. The latest GPS plotters can only display information such as the vessel's position and the water depth. If the submarine geology, the seawater temperature and the distribution of aquatic resources can be displayed on a map in addition to the currently available information, a wide variety of coastal fishing activities would be supported.

Accordingly, in this research, we developed a GIS plotter that can update marine charts in the real time on a small fishing vessel and that can display submarine geology charts,

seawater temperature charts and aquatic resources distribution charts. Moreover, by developing a GIS plotter that runs on a common Linux distribution, the navigation system can be provided to fishermen at low cost. In a previous study, we verified the feasibility of displaying a vessel's positioning information, 3D bathymetric charts, submarine geology charts and aquatic resources distribution charts. We also confirmed that GIS plotters can be used to monitor small fishing vessels from land. This can be accomplished by using a vessel's own positioning information display for navigation, and using this same information display on land for monitoring. As for the fish finder function, we confirmed that the developed GIS plotter can display real-time data about schools of fish on a small fishing vessel, as well as on land via a Web browser. For the system developed in this research, we aim for a display rate of 1 fps or more because the GPS transmission rate is 1 time per second. For the fish finder function, data on schools of fish are drawn at 3 fps or more because the data is transmitted to land 3 times per second.

II. DEVELOPMENT OF GIS PLOTTER

A. Existing GPS Plotter

At present, bathymetric charts are displayed on small fishing vessels by using electronic devices known as GPS plotters. The external display of a latest GPS plotter, SDP-300 (Koden Electronics Co., Ltd.), is shown in Fig. 1 (left) [4]. This device displays the vessel positioning information, two-dimensional (2D) bathymetric charts such as nautical and isobathic line charts, and a 3D bathymetric chart. Fig. 1 (right) also shows a 2D bathymetric chart and a 3D bathymetric chart from the SDP-300. Table 1 lists the specifications of the SDP-300, which has an internal CPU clock frequency of 200 MHz and 32 MB of memory. The SDP-300 stores data for 2D charts and isobathic lines as vector data, and stores 3D chart data for water depth as grid data. The chart data can be updated by using a CF card.

Because the latest GPS plotters do not have network functionality, they cannot share marine information and update marine charts in the real time on small fishing vessel. Moreover, they cannot display marine information such as submarine geology information and the distribution of aquatic resources, which is useful for sea cucumber dredge net fishing. Thus, we propose a GIS plotter that has the functionality listed in Table 2.
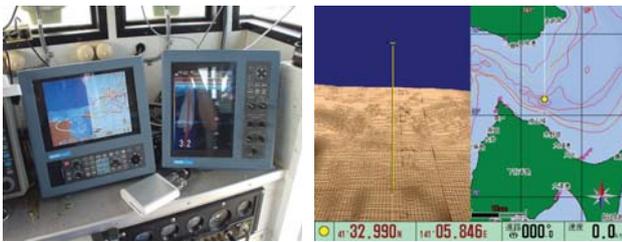
Figure 1. External appearance of SDP-300 (left) and screen capture of 3D and 2D bathymetric charts displayed on SDP-300 (right)

TABLE I. SPECIFICATIONS OF SDP-300

CPU clock frequency	200 MHz
Memory	32 MB
Connection ports	CF port, Serial port
Display contents	nautical charts (2D chart) Isobathic line charts (2D chart) 3D bathymetric charts(3D chart)
Chart data	2D chart data (approximately 300 MB) 3D chart data (approximately 500 MB)

TABLE II. FUNCTION OF GIS PLOTTER

Navigation Function	This is a function of existing GPS plotters. The function can display the vessel's positioning information on nautical charts using data from GPS.
Marine Information Display Function	In addition to the functionality present in existing GPS plotters, such as the ability to display nautical charts, bathymetric charts and isobathic charts, it can display additional information such as submarine geology charts, seawater temperature charts, and aquatic resources distribution charts.
Network Function	This is a function that shares information from measurement instruments that are installed on multiple small fishing vessels by using transmission over a wireless network. Also this function update created marine charts
Monitoring Function	This is a function that displays the positioning information about multiple small fishing vessels to be monitored in real time on land using a wireless network.
Fish Finder Function	This function that GIS plotter and WEB browser display image of school fish from fish finder.

B. Running Materials

In this research, we used a common Linux system to develop a GIS plotter. Fig. 2 shows the external appearance of the GIS plotter. Conventional personal computer (PC) boards emit high levels of heat that makes them unsuitable for use as embedded devices. However, with the increasing popularity of netbooks in recent years, and the release of Intel Atom processors, which have power consumption similar to conventional embedded CPUs, PC boards can now be used in embedded devices as well. Moreover, using a PC board for development simplifies application development and run simulations. Table 3 lists the specifications of the developed GIS plotter.

Figure 2. External appearance of GIS plotter

TABLE Ⅲ. SPECIFICATIONS OF GIS PLOTTER

CPU	1.6 GHZ
Memory	4GB
Connection port	Serial port×4 USB port×2, LAN port

C. Development Details

The Linux OS that we used for the GIS plotter has standard functions such as TCP/IP communications and 3D graphics functionality. Because the Linux OS is released under an open source license and free to distribute, we were able to develop the display application as free software. Thus, the GIS plotter can be provided to fishermen at low cost. We used Debian 5.0.3 as the OS, and to display 3D graphics, we used APIs for the graphics library Mesa7.0 (GLU) corresponding to OpenGL2.0 and freeglut2.4 (GLUT).

For the chart data, Surfer 8 [4] was used to make a 3 minute × 3 minute (5,556 m × 5,556 m) grid and a 15 minute × 15 minute (27,780 m × 27,780 m) grid based on data from The Digital Sea Chart in Japan [5]; the data was then converted into 3D chart data for SDP-300. For the 3 minute × 3 minute grid, square grid spacing of 0.005 minute (9.26 m) is used. For the 15 minute × 15 minute grid, square grid spacing of 0.02 minute (37.04 m) is used. In the same manner as existing GPS plotters, a 3D bathymetric chart and an isobathic line chart can be displayed. In addition, the submarine geology chart and the aquatic resources distribution chart are new types of marine information that can be displayed. The marine information is shown on an XGA display (1024 × 768 pixels). Fig. 3 shows bathymetric charts in 2D (left) and 3D (right). Moreover, to generate the isobathic line chart, latitude, longitude and water depth information are extracted from isobathic line data of The Digital Sea Chart in Japan.

The submarine geology chart display extracts the draw range data from a text file that consists of the latitude, longitude, and geographic attributes, and then the bathymetric chart surface colors are displayed in RGBA colors according to the color legend of the submarine geology chart, as shown in Table 4. In the aquatic resources distribution chart, the bathymetric chart surface colors are displayed according to the color legend of the aquatic resource distribution chart, as shown in Table 5.

Figure 3. Screen capture of 2D (left) and 3D (right) bathymetric charts showing the same information

TABLE Ⅳ. COLOR LEGEND OF SUBMARINE GEOLOGY CHART

Land	Coral	Rock	Fine sand	Sand	Coarse sand
Sand gravel	Gravel sand	Gravel	Mud	Shells	

TABLE Ⅴ. COLOR LEGEND OF AQUATIC RESOURCES DISTRIBUTION CHART

Color				
(kg/m2)	~0.005	~0.010	~0.015	~0.020

The flowchart of GIS plotter operation is shown in Fig. 4. The GIS plotter acquires NMEA sentences from the GPS daemon (GPSD), and accesses 3D chart data and geological data on the basis of the latitude and longitude. The 3D bathymetric chart and submarine geology chart are then drawn. The GPSD is the NMEA server, and sends and receives NEMA sentences using socket transmission. Therefore, the function to acquire the NMEA sentences from the GPS can be left completely to the GPSD. This allows the application to focus on graphics processing. Moreover, the GPS data can be acquired remotely if a wireless network is available. For example, if a wireless network has been constructed for Vessels A, B, and C, as well as a base station on land, by running GPSD on Vessel A, the positioning information from Vessel A can be displayed at multiple locations such as Vessel B, Vessel C and the base station on land. In this way, the positions of small fishing vessels can be monitored in real time from land.

Lastly, in the fish finder function, data on schools of fish can be displayed on a small fishing vessel and on land using a CVB-20 system (Koden Electronics Co., Ltd.), which is a fish finder that can be connected to a LAN network on a small fishing vessel. First, the data from CVB-20 is sent using the UDP protocol to OpenBlockS 600 (Plat'Home Co., Ltd.), a small server embedded in a wireless LAN base station. Next, the data is sent to a GIS plotter on land via the Internet. Because CVB-20, not the GPS plotter, is connected to the LAN, to receive data on land from CVB-20, some means are required to transfer data between CVB-20 and the GIS plotter onboard the small fishing vessel. Therefore, we developed software that sends and receives data between CVB-20 and the GIS plotter, and displays data about schools

of fish on land by using software running on the wireless LAN base station where OpenBlockS 600 is installed.
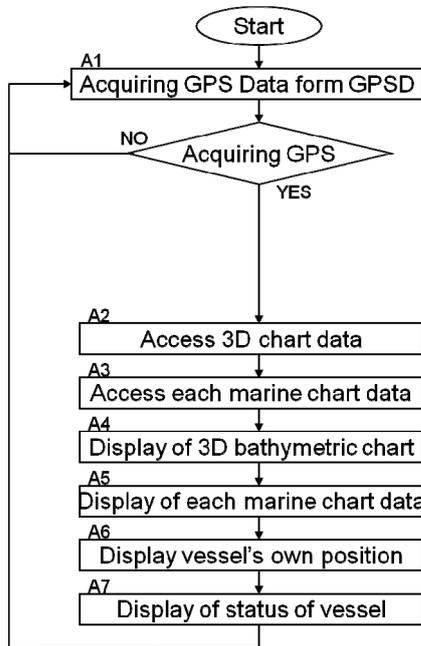
Figure 4. Flowchart of display on the GIS plotter

III.   EXPERIMNETS

A.   Bathymetric Chart And Submarine Geology Chart

In this experiment, we verify the display of 3D bathymetric charts, as well as the display of submarine geology charts with surface colors on 3D bathymetric charts. The vessel positioning information could be displayed on the 3D bathymetric chart as a navigation function, and the 3D bathymetric chart was drawn at 1 fps or more. Next, we discuss the results of displaying the submarine geology chart. The geographic attributes could be displayed by changing the surface color of the 3D bathymetric chart. No difference was observed in the drawing speed between the 3D bathymetric charts with and without submarine geology information. We also confirmed that the geographic attributes and display range could be changed in real time. Fig. 5 (left) shows a screen capture taken when the geographic attributes were changed. The area within the red square is the area within the range that was changed.

B.   Monitoring Function

In this experiment, we verified the display of small fishing vessel positioning information that was transmitted over a cellular phone network and displayed on land. As a result, we were able to confirm that W-CDMA transmission could be used for this purpose, and that we could monitor the positions of the small fishing vessels from Future

University Hakodate in real time. Fig. 5 (right) shows a screen capture taken while conducting this monitor. However, when the connection was interrupted, the movement of the small fishing vessels, as displayed on the screen, appeared to stop; thus, in future work, an appropriate process must be designed to handle an interrupted connection.
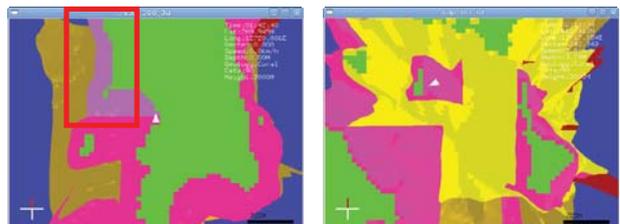
Figure 5. Screen captures of displays after changing the geology attributes (left) and during small fishing vessel monitoring (right)

C.   Isobathic Line Chart And AquaticRresources Distribution Cart

In this experiment, we verified the display of isobathic line charts and aquatic resources distribution charts using log data. As a result, we found that both types of charts could be drawn at 1 fps or more. Fig. 6 shows a screen capture of the isobathic line chart on the left and a screen capture of the aquatic resources distribution chart on the right. However, when the isobathic line chart displayed all data, the display became cluttered. Thus, in order to improve the display, we need to devise an approach to reduce the number of contour lines shown in this case.
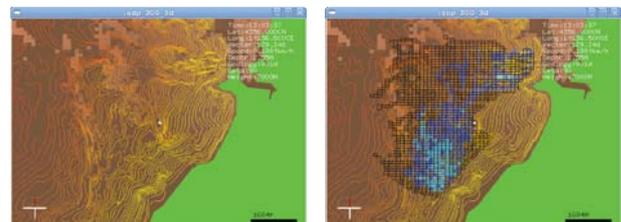
Figure 6. Screen captures of isobathic line chart (left) and aquatic resources distribution chart (right)

D.   Fish Finder Fuinction

In this experiment, we verified the display of data about schools of fish on a small fishing vessel, as well as on land for information transmitted over the Marine Broadband Framework from the CVB-20 system used as a networked fish finder onboard a small fishing vessel. The data on schools of fish could be displayed at both locations. Fig. 7 (left) shows a screen capture of data on schools of fish, as seen on land. However, when other processes were running, the display stopped being drawn. Thus, we improved the drawing speed, and conducted the experiment again. As a result, we found that data on schools of fish could be drawn

at 3 fps or more. Furthermore, we developed technology to display the data on schools fish in a Web browser so that fishermen can view the fish finder information. Fig. 7 (right) shows a screen capture the information displayed in a Web browser.
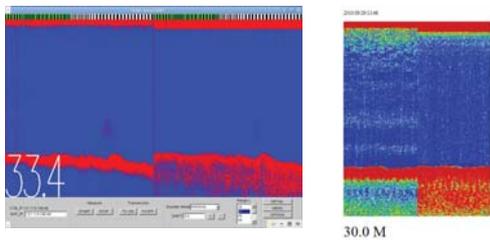
Figure 7. Screen captures of data on schools of fish (left) and Web browser display (right)

IV. DISCUSSION

Table 6 shows a comparison of the specifications of an existing GPS plotter and the developed GIS plotter. The GIS plotter has a clock speed that is approximately 5 times faster than that of the existing GPS plotter, and it has approximately 125 times as much memory. From the experimental results, we verified that the GIS system was capable of running the navigation, marine information display and monitoring functions. We display the 3D bathymetric chart, isobathic line chart, submarine geology chart and aquatic resources distribution chart. These charts were drawn 1 fps or more. We also verified that small fishing vessel could be monitored on land using data transmitted over a cellular phone network. Fig. 8 shows the drawing speed as a function of the amount of GIS plotter memory. When the memory was 1 GB, the drawing speed was 1.2 fps. Lastly, according to its specification, ArcGIS requires a CPU clock speed of 2.2 GHz and 2 GB of memory, while the developed plotter has less-demanding requirements. Therefore, we set the specifications that the GIS plotter requires a CPU clock of 1.6G Hz and 1 GB of memory for operation as an embedded device; the system is also required to have a serial port and LAN port.

TABLE. VI. COMPARISON OF SPECIFICATIONS FOR GPS PLOTTER AND GIS PLOTTER

Specifications	GPS plotter	GIS plotter
CPU clock	200 MHz	1.6 GHz
Memory	32 MB	1 GB
Connection port	CF port, Serial port	CF port Serial port LAN port
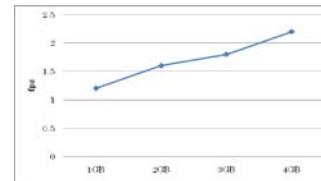
Figure 8. Drawing speed as a function of GIS plotter memory

V. CONCLUSION

In this research, we developed GIS plotter with the aim of supporting coastal fishing operations, and we verified the display of 3D bathymetric charts, isobathic line charts, submarine geology charts and aquatic resources distribution charts, as well as the monitoring function and fish finder function.

We expect that the developed GIS plotter can support, for instance, the sustainable use of aquatic resources in sea cucumber dredge net fishing. By monitoring small fishing vessels from land, fishing routes can be visualized and the submarine geology charts and aquatic resources distribution charts can be provided to fishermen. Moreover, through the use of the fish finder function, for example, schools of fish can be monitored in real time on land in support of fixed shore net fishing operations.

In an extension of the present work, we have since conducted experiments to verify the network function by which marine information is updated in the real time. We plan to report these results in the near future. We also plan to increase the basic performance of the GIS plotter in order to improve the productivity of coastal fishing operations.

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