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Method and Implementation to Overlay Radar Image on the Electronic Chart

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***Abstract*—Electronic navigation becomes increasingly more common, particularly onboard commercial vessels. As one of important elements in the electronic navigation, the electronic chart has introduced a new level of performance to navigation such as Electronic Chart Display and Information System (ECDIS). As a completely new and interactive navigation information system, it has an undisputable capability for displaying all necessary chart and navigation-related information required for the safe operation of a vessel. However, despite its many advantages, an electronic chart does not present the dynamic real-time situation within a certain area or cell of the chart. To overcome this problem many ships are equipped with additional marine radars to monitor the real situation around their actual positions. Current trends show that there is an increasing demand to complement the electronic chart with available radar image. This paper describes a method and implementation to overlay radar image into the existing electronic chart.**

***Keywords*—ECDIS, Electronic Chart, Radar Overlay, Navigation**

I. INTRODUCTION

Although relatively new and unfamiliar, electronic navigation is becoming more common, particularly onboard commercial vessels. The electronic chart, as one important element in the electronic navigation, has introduced a new level of performance to navigation. As a completely new and interactive navigation information system, it has the capability for displaying all necessary chart and navigation-related information required for the safe operation of a vessel [1][2]. Nevertheless, despite its many advantages, an electronic chart alone still does not present the dynamic real-time situation within a certain area or cell of the chart. Many ships are therefore equipped with additional marine radars to monitor the real situation around their actual positions. Current trends show that there is a growing demand to complement the static data provided by an electronic chart with dynamic radar data.

Electronic Chart Display and Information System (ECDIS), a standard application system dealing with electronic charts, is a real-time navigation system that integrates a variety of chart and navigation-related information. Thus, ECDIS is more than simply a replacement for a paper nautical chart. It is capable of continuously determining a vessel's position related to the land, charted objects, aids-to-navigation, and unseen hazards [2][3].

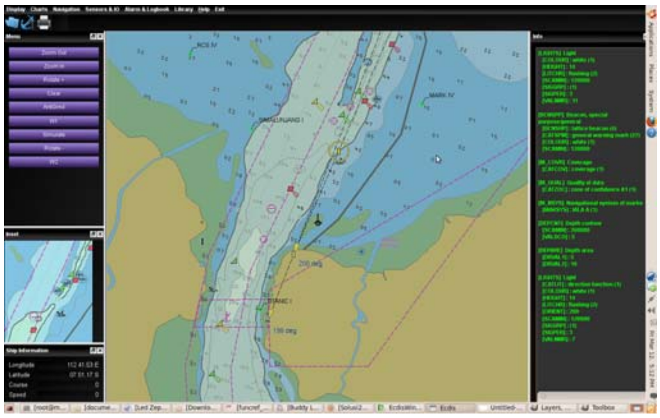

Figure 1. The main view of ECDIS application. It consists of three main windows. The main window, which displays the electronic chart, appears in the middle of the screen. The left window contains command buttons, chart inset, and information about the actual position of own ship. All related information about navigational objects or critical events during the seafaring are shown on the right window.

ECDIS displays the vector formatted Electronic Navigational Chart (ENC) – an equivalent of the paper charts produced by the Hydrographic Offices of the world. Because of its navigational and anti-grounding tool, as well as other sophisticated safety features, ECDIS can be regarded as the main safety tool onboard a vessel. Besides, ECDIS has several features not available on the paper charts, which release the navigators from many time-consuming tasks and let them concentrate on the navigational and ship management decisions (Figure 1). Among such features is the capability to display the timely variable objects, especially that of the non-cartographic information which represents the dynamics of the real world.

Marine Information Objects (MIOs) are used to encode time varying data in accordance with the S-57 standard. Their representations are implemented through overlays to prevent the chart clutter. By using this overlay technique all dynamic data from outside systems like radar or other environmental data from various sources can be integrated with ECDIS

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which in turn can assist in finding safe solutions to navigational problems, especially when the vessel was in the state of emergency. In this paper we will discuss a method and implementation to overlay radar image onto an existing electronic navigational chart. The result will be demonstrated on our own ECDIS application.

II. METHOD

All radar data and image used in this paper are provided by INDERA MX-2 radar which is produced by *Radar and Communication Systems* (*RCS*) in cooperation with the *Indonesian Branch of International Research Centre for Telecommunications and Radar* (*IRCTR-IB*). INDERA MX-2 is a low-power Frequency Modulated Continuous Wave (FMCW) marine radar operating at the X-band frequency with the carrier frequency of 9.4 GHz.

Figure 2. Radar INDERA MX-2 produced by *Radar and Communication Systems* (*RCS*). This FMCW marine radar is operating at X-band frequency with the carrier frequency of 9.4 GHz.

The low power consumption has an effect that the transmitted radar signal is very difficult to be detected by any radar scanners. By using dual antenna technology and with the support of modern signal processing this radar is capable of accurately detecting and localizing a target (Figure 2). According to its silent and stealth characteristics this radar is categorized as a Low Probability of Intercept (LPI) radar.

The high resolution radar image that is received from INDERA radars can be overlaid onto an existing electronic chart installed on a vessel. This overlay technique can yield impressive images and useful results. However, several problems must be first solved for its application. One of the main problems is the proper alignment of the chart with the actual latitude and longitude position of the vessel (geo-referencing).

The overlay technique used to embedding radar data onto an electronic chart is similar to that for the superposition of topographic maps. In a vector map, every contained geographic information, and also additional information for navigation purpose, of the same type is generally stored in separate layer (Figure 3). Every single object stored in this layer is accompanied with its coordinates or location related to the layer. Thus, when all data received from radar are also provided with their coordinates, we can embed the radar image or data onto an arbitrarily selected layer.

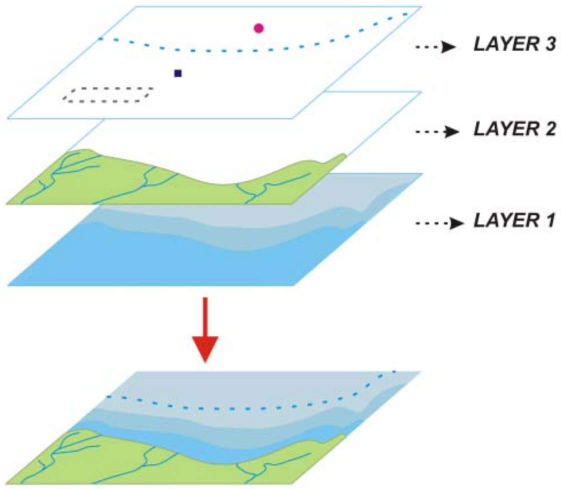

Figure 3. Principle of the overlay technique. This technique is similar to that for superposition of a topographic map. Every geographic data and additional information for navigation purpose is stored in separate layers. A complete map is herewith constructed from layers that are arranged on top of each other [4].

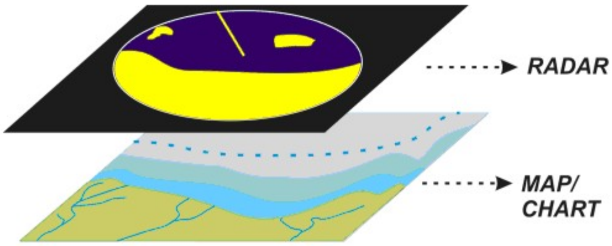

Figure 4. The overlay of radar image on the electronic chart. Since the chart contains only static data it can be handled as a common background image. In contrast to a dynamic background, such static image does not need any updates once it is uploaded into the video or graphic card's memory.

For the above mentioned purpose we have reserved a special layer to accommodate all data received from INDERA MX-2. This newly created radar layer is then placed over the existing layers of the electronic chart which solely contain the static geographic data (Figure 4). Other dynamic data, e.g. data from Automatic Identification System (AIS) device, will be inserted on the next layer over the radar image.

Every single data point making up an electronic chart must carry the information about its geographic position (longitude and latitude). Therefore, each series of radar data is always preceded by the information about the radar's geographic position with its actual azimuth data. Since we are dealing with a huge amount of data transmitted from radar in a short period of time, the method to display the radar image on the chart screen must be very efficient. For securing the overlay of radar image on top of the electronic chart, a reliable and efficient data communication among them must first be established.

Figure 5. Display of ECDIS in the night color mode. Various color modes are available depending on the environmental situation on the vessel.

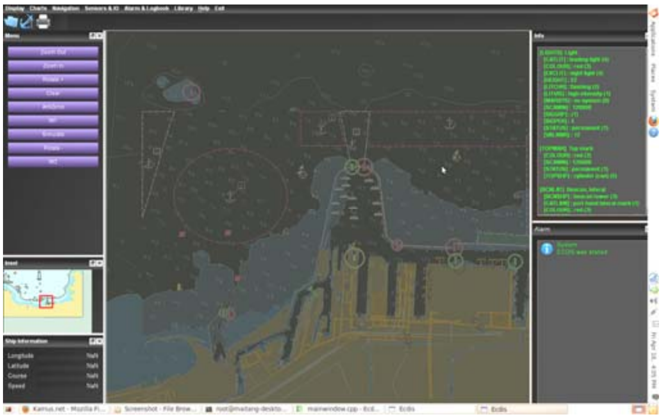

Figure 6. Display of ECDIS in the dusk color mode. The configurable chart display can be used to impressively enhance the effect of radar overlay technique.

Once we have established the communication link between ECDIS and radar we can show the result of the overlay on the monitor screen. In some situations, e.g. in a dull-light environment, the main display of ECDIS need to be changed so that the vessel's officers can work comfortably in front of the chart display for a long period of time. This configurable chart display can herewith be used to dramatically enhance the effect of radar overlay on the electronic chart (Figure 5 and Figure 6).

III. IMPLEMENTATION

In this section we will focus on how to display the overlay result to the screen. By using the overlay technique all of the data received from radar INDERA can be displayed in real time on top of the electronic chart. As previously stated, to support a smooth exchange of data between radar and the electronic chart, each data package transmitted by radar is accompanied by the latitude and longitude position of the radar. These are then followed by a series of intensity data captured on that actual radar azimuth position.

In the high resolution mode, the number of data received from the radar will reach the amount of 512 cells per 0.25 degree. Consequently, by a moderate radar antenna's rotation speed of 16 rpm we are dealing with more than 11.7 million data per minute. In order to be able to process a large amount of radar data on a computer with limited processing capability, it is important to design an efficient system for displaying radar data in real-time.

The reduction of the amount of data in the display is realized by re-sampling and averaging data received from radar sensor. The selection of proper data re-sampling is done by adjusting it with the display resolution whereas data averaging is performed on a series of data captured at each azimuth position.

For completing the display process, each data has to pass through two processing stages, namely mapping and drawing. Since ECDIS receives radar data only in streaming mode, the amount of existing data in the memory queue will accumulate and increase continuously. This will limit the available Central Processing Unit (CPU) resources that otherwise can be used to process next data. If this incident took place continuously, then the CPU would give only very slow responses. This phenomenon greatly affects an application like radar overlay that generally requires real-time information.

In designing a display system we have applied a multiple buffering technique which employs more than one buffer for storing blocks of data. Along with this design strategy the data store and calculation process are completed in the Graphics Processing Unit (GPU) of the video card, whereas the CPU continues processing other data. In the latest version of our ECDIS application we utilize three buffers consisting of two buffers as cache and a write buffer sent directly to the monitor screen.

To implement the above display technique we arrange the buffers in such a way that the radar data will be alternately transferred from one of the cache buffers into the write buffer. Thus, if the first cache buffer is empty, then the write buffer will require the next cache buffer to send its latest streaming data. In the mean time, as the data transfer took place, the first cache buffer would be filled with the next streaming radar data. Hence, the write buffer would give the computer enough time to provide cache buffer with the next data streaming.

In the programming level the previously mentioned strategy can be realized with multithreading. Multithreading is the ability of an operating system to execute different parts of a program, called threads, simultaneously. When practicing multithreading technique we must carefully design the program in such a way that all existing threads can run at the same time without interfering with each other [5].

In a well designed and structured interactive application, multithreading will allow a computer application to remain responsive even though some programs are being blocked or performing other long operations. Additionally, some threads that perform the same process will share available resources. This advantage will allow an application to have several different threads in the same location in the memory [6].

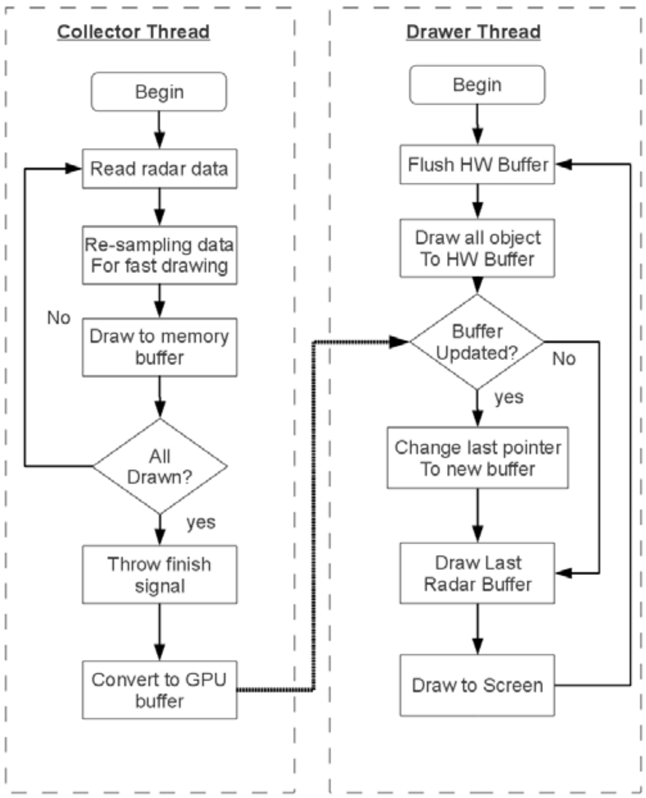

Figure 7. Multithreading strategy to handle large data streaming from radar. In order to overlay radar image on top of the electronic chart in real-time we have utilized two threads: collector and drawer thread. The first *collector* thread has a task to collecting, re-sampling and averaging data streaming from radar to be in line with the actual resolution of the display. The second *drawer* thread has a task to draw the final result of the overlay to the display screen.

By means of multithreading a complex process can be subdivided into several small processes. For our purpose the technique of multithreading is used for the calculation of many simple repetitive but critical processes. One of such processes is the process of writing data directly into the hardware (graphic card) buffer. The process of writing data to the graphic card's buffer is performed in one of the Graphical User Interface (GUI) threads. This direct access has allowed us to perform a faster data transfer from radar to our ECDIS application (Figure 7). Thus, it helps in improving the efficiency of processor performance in the drawing process.

IV. RESULTS

Using the above described method we can combine or overlay the radar image on the electronic chart. An example of this overlay method is demonstrated in Figure 8. On top of the radar layer we can still append new layers reserved for other dynamic variables supplied by the real-time sensors, models or other predictions.

Table I shows that the performance of the software can be improved by utilizing the previously described method. As shown in the above table, the usage of multithreading technique in the radar overlay has significantly reduced the time consumption per drawing cycle to be about 2.38%. At the same time, due to the nature of multithreading technique in sharing resources, we are also able to manage the usage of memory buffer more efficiently (less than 12.9%). It is obvious that the graphics processing speed will be accelerated when using the GPU [7].

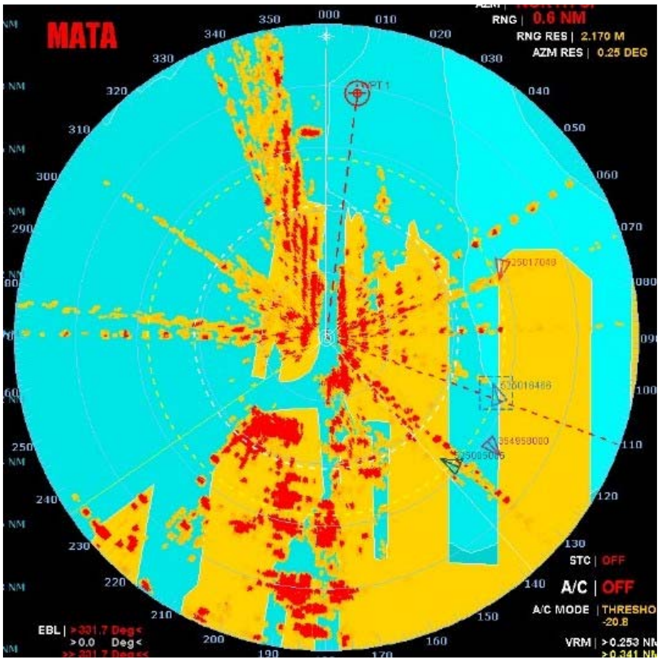

Figure 8. Result of the radar image overlay on the electronic chart. In this figure the overlay technique is applied directly on the PPI display of the radar INDERA MX-2. The overlaid radar (scattering) image is shown in red.

TABLE I
SOFTWARE PERFORMANCE BEFORE AND AFTER MULTITHREADING

Measured parameter	Before	After
Time consumption per frame (*ms*)	4,250	101
Memory buffer usage (%)	6.0	2.6

With its simplified menu structure, the radar overlay technique shares the new insightful user interface of our ECDIS application. This kind of display technique has opened a new possibility in the marine navigation and can significantly increase the seafaring safety. The consistent visual appeal and intuitive usage is of great importance on the vessels bridge, especially on being a working and living environment for thousands of vessels' officers on a day to day base.

Obviously the radar overlay technique can enhance the ECDIS performance, and offer priceless value in providing safety to navigation. It is predictable that in the near future ECDIS will become a fully-fledged Marine GIS rather than a simple electronic chart.

V. CONCLUSION

At present Electronic Chart Display and Information System (ECDIS) is regarded as the best navigational system available. As an inseparable part of ECDIS, the electronic chart plays a significant and key role. In this paper we have demonstrated a method of overlaying radar image on the existing electronic chart. This overlay technique requires a reliable communication channel between the ECDIS application and radar. Since data obtained from the radar sensor is very large to be processed in a short time, the overlay process should guarantee a rapid response. The responsive process will make a real-time display within the ECDIS application affordable.

In this paper we have also introduced an efficient technique for displaying radar image over the electronic chart. The optimization of the display technique was focused on the generation and retrieval of data. It is shown that buffering, multithreading, sampling and averaging play key roles in the radar overlay. The introduced multithreading technique in the radar overlay can improve the software performance by reducing the execution time per frame to 2.38%, and the usage of memory buffer to be less than 12.9%.

REFERENCES

[1] L. Alexander, Harmonizing chart and navigation-related information on ECDIS, *Proceedings U.S. Hydrographic Conference 2001*, Norfolk, 2001, pp. 1-13.

[2] R. I. Goralski and C. M. Gold, The Development of a dynamic GIS for maritime navigation safety, *Proceedings of ISPRS Workshop on Updating Geo-spatial Databases with Imagery & The 5th ISPRS Workshop on DMGISs 2007*, Urumchi, 2007, pp. 47-50.

[3] B. Pillich, Towards the next generation of ECDIS, *Proceedings U.S. Hydro Conference 2003*, Biloxi, 2003, pp. 1-9.

[4] D. Yulian, W. Sediono and A. Lestari, Implementasi peta dinamis pada Radar INDERA, *Proceedings Seminar Radar Nasional 2009*, Bandung, 2009, pp. 114-118.

[5] Wikipedia the Free Encyclopedia, *Multithreading*. [Online]. Available: http://en.wikipedia.org/wiki/Multithreading

[6] K. Chaichoompu, S. Kittitornkun, S. Tongsima, MT-ClustalW: Multi-threading multiple sequence alignment, *Proceedings of the IEEE International Parallel & Distributed Processing Symposium 2006*, Rhodes Island, 2006.

[7] G. Lupton and D. Thulin, Accelerating HPC using GPU's. [Online]. Available: www.hp.com/techservers/hpccn/hpccollaboration/ADCatalyst/downloads/accelerating_HPC_Using_GPU's.pdf

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