Design and Development of Information System Template Prototype for Maritime Transportation

Felipe P. Vista IV1, Bo Long2 and Kil To Chong1,3,*

1,2 Electronic Engineering Department, Jeonbuk National University, South Korea
3 Advanced Electronics and Information Research Center, JBNU, South Korea
1 felipe.p.vista.iv@gmail.com, 2 longbo1978@gmail.com, 3* kitchong@jbnu.ac.kr
*Corresponding Author

Abstract

This paper details the step-by-step production of a real world scenario and modular template for a marine information system from the theories involved to its design, development, implementation and tests. Data and information from the global positioning system (GPS), digital compass (DC), automatic identification system (AIS) and electronic navigational charts (ENC) were utilized to display map, map data, directional, location and ship related information. The data and other information display orientation remains in legible horizontal manner even if the base map is moving or transforming while several utilities such as serial device connection configuration and data retrieval was written for technical and testing purposes. This work was done to come-up with a template for developing a marine vehicle system that will serve as a reference or basis for future system developmental works. The modular and compartmentalized design of the system makes it very easy to customize for further specific development such as a Marine Vehicle Monitoring System or Marine Navigation System.

Keywords: Marine vehicle monitoring system type template; navigation system development; civilian operations research; GPS; AIS

1. Introduction

The design and development of a software system is a long and tedious process that can be done in several ways depending on the requirements and skills of a developer or programmer[1]. These systems could be information systems[2], utilities[3] or security[4]. This paper describes the design and development process for a Marine Information System type template involving software-hardware integration, data processing and visual representations for an industry-academe partnership project. It includes the steps done in designing and developing the system from the methodology, system design flow, algorithms, and all the way to the technical specifics of the GPS and DC data and connectivity.

The global positioning system (GPS) is undoubtedly one of the most common and widely-used tool in use at present to check for one’s location specific to the earth’s spherical coordinate system such that applications and systems specific to it have been developed[5]. While vital information can be retrieved through the automatic identification system (AIS) as a situational awareness tool[6] that is very useful to keep track of other ships in the area. It is worthy to take note that the AIS is mandated to be installed aboard ships by the International Maritime Organization, a United Nations’ specialized agency responsible for improving maritime safety and preventing pollution from ships[7]. GPS, AIS plus the digital compass
(DC) and electronic navigations charts (ENC) are the source of information and data utilized by our template system.

The paper is laid out in such a manner to easily follow the way the system was developed. The second section gives a background of the system and then explains the system design and development process. The third section describes the implementation setup after the system prototype has been developed while the conclusion and implications of the work done is discussed in the fourth section.

2. System Design and Development

The system is robust and flexible enough to utilize data from the GPS and DC as well as any other type of data that may be needed or introduced in the future such as radar or mobile locations. GPS, Digital Compass, AIS and ENC data as well as maps generated from ENC were used in the design and development of a prototype marine tracking system template. It utilized efficient and effective algorithms and methods to achieve the objective of a working Marine Information System. The system is composed of several sub-systems or major components namely the map base, ship plotting, map lateral movement, map label display and GPS/DC data processing.

The system has the following components as its core processes: (1) a method of using an image map file to serve as the base display of the system instead of drawing a base map, (2) an image-manipulation algorithm used in extracting a specific part of the image base map given a set of geographical coordinates (geo-coordinates), (3) a method of displaying the map details information around a specific location, in a proper horizontal orientation even if the map is rotated, (4) method of displaying the own-ship and any other ships in the vicinity with the correct direction and whose sizes can be set to be reflective of the actual ship dimensions, (5) robust and efficient algorithm in extracting and processing the GPS data, (6) collection of data from several devices, and (7) the processing of several types of data and the display of pertinent information on-screen as chosen by the user.

The system can be designed and developed by using some of the existing methodologies such as Waterfall [8], Prototyping [9], Incremental development [10], Spiral development[11], Rapid Application Development [12], Agile [13], Lean [14] and Dynamic Systems Development Method (DSDM) [15] or any other ones that the programmer may prefer as utilized in several previous research works [16, 17]. A relatively different method called System Design, Development & Deployment Using Rapid by-Customer Demand with Business Principles Approach (RBCDwBPA) [18] was chosen. RBCDwBPA is the formalized and more detailed version of the Rapid, Non-Formal and By-Customer-Demand Approach [19] which was used in Wang [20]. The system was developed on a per-component basis which has to be working satisfactorily before going on to develop the next one. The diagram in Fig. 1 shows the general system flow of the Marine Information System which starts with the configuration of the serial device connection parameters (GPS and Digital Compass) for proper data retrieval. The image map and its corresponding data are loaded into system memory and then the main window is displayed which gives the user several options in manipulating the display and its features. The user can start or stop the GPS and Digital Compass data capture and also disable or enable the logging feature. The system also allows the user to toggle between displaying or hiding the base map, ships in the area, map details, and grid (4 or 8 lines). There is also the option of switching the center of map being displayed between the GPS reading or a given coordinate and then zooming in or out. The user can also choose what to display between the main window or a bearing/heading of the ship based on the DC reading. The key components of the system are the following: (1) ENC Data Processing, (2) ENC-based base map processing, (3) map labels and details, (4) ship
diagram representation and plotting, (5) GPS data retrieval and processing, and (6) DC data retrieval.

2.1. Pre-development ENC Processing

An ENC is an official database created by a national hydrographic office for use with an Electronic Chart Display and Information System (ECDIS) which conform to standards stated in the International Hydrographic Organization (IHO) Special Publication S-57 [21]. The ENC is not just a plain image map but it contains important data such as names of places, contours and soundings (depth). The ENC data are pre-processed in two steps before it can be used with the system.

The first step generates image and data files from the ENC file and it must be noted that this step is only done when there is raw ENC data to be used or the ENC data needs to be
updated. The second step deals with the extraction of necessary information from the generated image and data files of step one and displaying them in the system developed. For the first step, the individual ENC files are loaded into the Global Mapper System Software [22] which is configured to display a map containing only the desired vector area data of land mass, water mass and contour lines. This generated map is then into exported into an image file in JPG format with a relationship setting of 2880 x 2880 pixels for a 1 x 1 geo-coordinate square degree. This generated map will then serve as the source of the base map that will be displayed by the system. At the same time, the data or information from the ENC to be used in the system developed are selected for extraction such as feature labels, names of places, buoys, spot soundings (water depths at specific area) and are then exported with their corresponding geo-coordinates into a common data format (CDF) file.

2.2. Base Map Processing

The map base serves as the main “base” or background of the system where the map labels, details, ships and grid lines are superimposed. The base map processing is a core operation of the proposed system therefore the development of an efficient algorithm to be able to satisfactorily perform this operation. It extracts a part of the image file a portion whose size and location depends on a given set of geo-coordinates using the algorithm shown in Figure 2.

The image file is loaded into system memory in the initialization phase of the system and the actual base map processing starts by checking whether the geo-coordinate center point of the map to be displayed is taken from the GPS or manually inputted by the user. This geo-coordinate center point is checked if it is a valid value and if it is different from the current

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**Figure 2. Algorithm for Base Map Processing**

[Diagram showing the algorithm for base map processing]
geo-coordinate center of the system. The new and validated geo-coordinate center point will then serve as the new center point of the base map to be extracted from the main image map whose specific dimensions would depend on the current magnification or zoom factor and pixel to geo-coordinate relationship. Calculations are then performed to pinpoint the pixel coordinate equivalent in the main map of the given geo-coordinate center which then serves as the center point of the display map to be extracted from the main map. The system then performs the same procedure whenever there is a valid change of the system geo-coordinate center.

2.3. Map Details Processing

The map labels and details are not integrated into the base map when it was exported to an image file but is superimposed by the system during operation depending on the orientation and current geo-coordinate of the system. The map label details are retrieved from the CDF format file and corresponding information for the map are shown with respect to the current map area displayed by the system. The details are shown in their respective locations with respect to the map and are easily legible if the map moves sideways, upwards, downwards, or even rotates. The procedure that was used in the map label display involves setting up the current geo-coordinate center of the system as the origin of the coordinate system of the display. The map details are shown in their respective locations with respect to its relation in the original map. A method was used that was effective in enabling the system to display the map details and related information correctly in a horizontal orientation even if the base map was being rotated. The following are the formulas and relationships used for this particular method using the coordinate system given in Figure 3.

![Figure 3. Map Details and Display Coordinate System](image)

For label originally in $Q_1$: $\beta_1 = \theta_1 - a_1$
- moving label to $Q_2, Q_4, Q_3$: $d_{2_{\text{long}}} = dh \sin \beta_1, d_{2_{\text{lat}}} = dh \cos \beta_1$
- moving label to $Q_1$: $\beta_2 = 180 - \beta_1, d_{2_{\text{long}}} = dh \sin \beta_2, d_{2_{\text{lat}}} = dh \cos \beta_2$

For label originally in $Q_2$: $\beta_1 = \theta_1 + a_1$
- moving label to $Q_4, Q_1, Q_2$: $d_{2_{\text{long}}} = dh \sin \beta_1, d_{2_{\text{lat}}} = dh \cos \beta_1$
- moving label to $Q_4$: $\beta_2 = 180 - \beta_1, d_{2_{\text{long}}} = dh \sin \beta_2, d_{2_{\text{lat}}} = dh \cos \beta_2$

For label originally in $Q_3$: $\beta_1 = \theta_1 + a_1$
- moving label to $Q_1, Q_3, Q_2$: $d_{2_{\text{long}}} = dh \sin \beta_1, d_{2_{\text{lat}}} = dh \cos \beta_1$
- moving label to $Q_3$: $\beta_2 = 180 - \beta_1, d_{2_{\text{long}}} = dh \sin \beta_2, d_{2_{\text{lat}}} = dh \cos \beta_2$
For label originally in $Q_3$: $\beta_1 = \theta_1 - \alpha_1$

-moving label to $Q_4, Q_1, Q_2, Q_3$: $d_{2\text{long}} = dh \sin \beta_1, d_{2\text{lat}} = dh \cos \beta_1$

Where:

$(OS_{\text{long}}, OS_{\text{lat}})$ - Own-ship geo-coordinates

$(L_{1\text{long}}, L_{1\text{lat}})$ - Map label geo-coordinates

$d_{1\text{long}} = L_{1\text{long}} - OS_{\text{long}}$, - long distance bet own-ship & label

$d_{1\text{lat}} = L_{1\text{lat}} - OS_{\text{lat}}$, - lat distance bet own-ship & label

$dh = \sqrt{(d_{1\text{long}}^2 + d_{1\text{lat}}^2)}$, - hypotenuse

$\theta_1 = ACos (d_{1\text{lat}}/dh)$, - ccw angle, w/ respect to (+) X-axis

$\alpha_1$, - change in bearing

$\beta_1$, - the new angle

$(L_2, L_2)$, - map label new X/Y coordinate

$(OS_x, OS_y)$, - own-ship X/Y

2.4. Ship Representation and Plotting

The ship can be represented a number of ways in the system either as a small circle, a diamond or any other design that is needed. One method used in displaying the ship representation of a ship in the system is described by plotting individually the specific vertices of the ship and then connecting these points to create a five-point polygon symbolizing the ship itself as shown in Figure 4. This method takes minimal computational time with great accuracy that even plotting several ships on the system does not greatly affect the performance of the system. The other-ship information such as its bearing, length, breadth as well as it geo-coordinate locations are available from the AIS signals that they are broadcasting.

Equations that were used are given below taking into account the actual length and width of the other-ships as well as the other-ship’s bearing or direction. The “+/−” operator refers to the orientation of the Y-Axis depending on the XY orientation of the display. The upper operator “+” will be used if the Positive X-Y plane is in the 2nd Quadrant, while we use the lower operator “−” if the Positive-X/Y plane is in the 1st Quadrant.

$$X_B = O_X + L_F \sin \theta$$  \hspace{1cm}  $$Y_B = O_Y +/− L_F \cos \theta$$

$$X_{BS} = O_X + B/2 \cos \theta$$  \hspace{1cm}  $$Y_{BS} = O_Y +/− B/2 \sin \theta$$

$$X_{BP} = O_X - B/2 \cos \theta$$  \hspace{1cm}  $$Y_{BP} = O_Y +/− B/2 \sin \theta$$

$$X_S = O_X - L_A \sin \theta$$  \hspace{1cm}  $$Y_S = O_Y +/− L_A \sin \theta$$

$$X_{SP} = X_S - B/2 \cos \theta$$  \hspace{1cm}  $$Y_{SP} = Y_S +/− L_F \sin \theta$$

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$$X_{BS} = O_X + B/2 \cos \theta$$  \hspace{1cm}  $$Y_{BS} = O_Y +/− B/2 \sin \theta$$

$$X_{BP} = O_X - B/2 \cos \theta$$  \hspace{1cm}  $$Y_{BP} = O_Y +/− B/2 \sin \theta$$

$$X_S = O_X - L_A \sin \theta$$  \hspace{1cm}  $$Y_S = O_Y +/− L_A \sin \theta$$

$$X_{SP} = X_S - B/2 \cos \theta$$  \hspace{1cm}  $$Y_{SP} = Y_S +/− L_F \sin \theta$$
\[ X_{SS} = X_S + B/2 \cos \theta \quad Y_{SS} = Y_S +/ - B/2 \sin \theta \]

Where:
- \( \theta \) - Ship bearing in radians
- \( O_X, O_Y \) - Set as center of the cartesian coordinates of the ship
- \( L_F \) - Length of forward part of ship
- \( L_A \) - Length of aft (back) part of ship
- \( B \) - Breadth (width) of the ship
- \( X_B, Y_B \) - (X,Y) coordinates of center-bow (forward)
- \( X_{BS}, Y_{BS} \) - (X,Y) coordinates of bow-starboard (front-right)
- \( X_{BP}, Y_{BP} \) - (X,Y) coordinates of bow-port (front-left)
- \( X_S, Y_S \) - (X,Y) coordinates of center stern (aft/rear)
- \( X_{SS}, Y_{SS} \) - (X,Y) coordinates of stern-starboard (rear-right)
- \( X_{SP}, Y_{SP} \) - (X,Y) coordinates of bow-port (rear-left)

### 2.5. GPS Data Processing

The GPS data processing for the own-ship is used for plotting the present location of the ship on the ENC-based map while the AIS data will be utilized in plotting the other ship or ships in the immediate vicinity depending on the current display magnification factor. An algorithm, shown in Fig. 5, was designed to efficiently and rapidly process the data received from the GPS. Data from the GPS receiver are retrieved and fully segregated accordingly aside from the latitude and longitude values. For the particular GPS receiver used in this research, an ASCEN GPS Logger, it has the GPRMC (Recommended Minimum Specific GPS/TRANSIT) data, GPGGA (Global Positioning System Fix) data, GPGSA (GPS DOP and active satellites) data, and the GPGSV (GPS Satellites in view).

The algorithm developed to read, segregate and process the data from the GPS device can be easily tweaked or modified to process any other data that other types of GPS might give. It is the reason why this GPS data processing algorithm is considered robust and very handy. The algorithm for identifying and segregating the GPS data is described by the following steps:
Check header if GPRMC", "GPGSA", "GPGGA" or "GPGSV"
Check for a valid value after the first delimiter
Extract data if present or set the corresponding variable as null if none is available
Continue checking until end of string.

In the case of "GPGSV" data, since it has multiple lines of data per set, the same procedure is followed with the addition of a way to check if it is the first, second or third line of "GPGSV" information. The process threading routine of Microsoft Windows VC#.Net was utilized to be able to continuously read and display the data from the GPS receiver and at the same allow the user to interact with the system.

2.6. Digital Compass Data Processing

The Digital Compass data is retrieved from the device and the values are then processed to reflect the bearing of the own-ship. The data retrieved from the device is checked if it has a valid value and then compared if the retrieved value is different with the present one in the system. This new and validated data is used for showing the bearing of own-ship as well as the digital compass representation. A tool, Figure 6, was written for reading in, identifying and properly segregating the DC and GPS data. It is used in testing the accuracy and effectiveness of the device connection, data identification and data separation algorithms utilized in the system.

3. Implementation

3.1. System Prototype Implementation Setup

The system was developed using Microsoft Visual C#.Net of the Microsoft Visual Studio 2008 Suite and were tested on a Windows XP (SP3), Windows Vista (Basic Home and Ultimate), and Windows 7 Ultimate environments running on a personal computer with 2GB RAM, Intel Core2-Duo Processor, and 512MB NVIDIA GeForce G210 graphics card. It was tested on a notebook with Windows 7 Ultimate operating system on a 3GB RAM, AMD Athlon X2 Processor with shared memory NVIDIA GeForce 8200M graphics card during the test phase. A USB Ascen GPS device and a Serial Port Digital Compass connected to a serial-to-USB adapter used in the simulations and tests done. A screen capture is shown in Figure 7 of the template system in action.
3.2. System Prototype Testing

Tests showed that the procedures and algorithm performed as designed where there were simultaneous continuous polling of data from the Digital Compass and GPS. Any update in the values processed triggers a change in the orientation display of the bearing, map and data displayed. The system was tested using actual ENC data files for the Republic of Korea purchased from the National Oceanographic Research Institute of the Republic of Korea and dummy AIS test data.

The description for the graphical user interface (GUI) shown in Figure 8 is described as follows:

- **A** - Open window/form to configure device connection parameters
- **B** - Load base map into memory for later use
- **C** - Start/stop retrieving data from GPS
- **D** - Start/stop retrieving data from DC
- **E** - Show/hide own-ship and other ships in the area
- **F** - Show/hide the base map dependent on the zoom factor & coordinate of center display
- **H** - Show/hide grid with four (4) lines
- **I** - Show/hide grid with eight (8) lines
- **J** - Start/stop logging of current time, geo-coordinates and bearing data into a file
- **K** - Exit the System
- **L** - Choice of setting center of map displayed between GPS & user-given geo-coordinate
- **M** - Button to change the center of map being displayed
- **N** - Digital Compass reading (in degrees)
- **O** - Speed of own-ship (in knots)
- **P** - GPS reading (in decimal & sexadecimal format)
- **Q** - Buttons to zoom-in and out of the current display
- **R** - Graphical bearing display, switch main display between the map and the bearing
- **S** - Current scale of the map display

The system can connect and configure connectivity to various serial-devices.
- **T** – Check boxes to enable update of the device connection parameter
- **U** – Drop down list box of available Serial COM ports
- **V** – Drop down list box with choices to select the Bits per Second setting for the device
- **W** - Drop down list box with choices to select the Parity setting for the device
X - Drop down list box with choices to select the Data Bits setting for the device
Y – Button to refresh the list of available COM ports in the computer unit
Z – Accept connection parameters chosen and close window/ form
IA – Cancel Device Connection Settings and close window/ form

4. Conclusion and Implications

The use of robust algorithms and methods produced a template Marine Information System for actual application that performs satisfactorily and comply with all the requirements set. The system utilized data and information from the global positioning system (GPS), digital compass (DC), automatic identification system (AIS) and electronic navigational chart (ENC). An example of its robustness is the ability of the system to incorporate other sources of information for localization such as radar or proximity sensors. One can easily retrieve, identify, separate and process this information by doing some tweaking and modifications in the device data retrieval algorithms to adapt to its specific technical details. The modular design makes it even possible for the system to accept information and data from other systems such as underwater intruder detection [23] or from a situational awareness tool [24].

The authors believe that the algorithms and development method presented is a good reference for those who want to develop similar marine tracking system that might be web based [25] and running on other platforms [26]. They can modify and try to improve some parts of the system such as the image processing component by using tools such as openGL [27]. It can even be applied in a classroom setting wherein teachers and students doing an activity by recreating the scenario is even better, reinforcing the idea that hands-on experiences increase the learning efficiency and performance of students [28]. This in turn will help increase the quality of the resulting output which could score higher on the DeLone and McLean Information System success model [29] while assessment and evaluation [30] of the output can be done to check on the synaptic errors and such. Previous research work have stated that working with real data instead of simulated data may induce higher levels of motivation[31], the authors of this work would to venture forth by stating that working with real-world and actual instead of theoretical situations or scenarios will encourage researchers to a higher degree of motivation in solving the problem at hand and delivering a much better working system.

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References


Authors

Felipe P. Vista IV, received his Bachelor of Science in Computer Engineering from University of St La Salle, Bacolod City, Philippines in 1998 & Master of Engineering from Western Institute of Technology, Iloilo City, Philippines in 2005. He is currently working for his Ph.D. at the Electronic Engineering Department of Jeonbuk National University, South Korea. His research interests include system design & development, networks, fuzzy logic and navigation systems.

Bo Long received his B.S. and M.S. degrees from Petroleum University in Xian last 2001 & 2004, Ph.D. from Xi’an Jiao Tong University in June of 2008. He is a full-time lecturer in the School of Mechatronic Engineering at the University of Electronic Science & Technology of China in Chengdu. His current research interests include high-performance motor drives, renewable energy generation, distributed generation systems, micro-grid & unified power quality conditioners. He is currently doing post doctorate work in the Department of Electronic Engineering at Jeonbuk National University, Jeonju, South Korea.

Kil To Chong received the Ph.D. degree in Mechanical Engineering from Texas A&M University, College Station in 1995. Currently, he is a Professor and Head of the Department of Electronic Engineering, Jeonbuk National University, Jeonju, Korea. His research interests are in the area of motor fault detection, network system control, time-delay systems, and neural networks.