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THE ELECTRONIC CHART IN AN EFFECTIVE VESSEL TRAFFIC SYSTEM

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INTRODUCTION

The Vessel Traffic System (VTS) described herein is established on total exploitation of the flexibility afforded by today's computer technology, and provides a comprehensive traffic monitoring system for the marine environment. Computer technology makes possible the electronic chart, which is a basic ingredient of any modern VTS. Beyond this, by digitizing sensor-derived information, such as radar video, which was previously used only as analog signals displayed on a PPI, it is possible to create an interaction between digitized navigation chart and digitized target data which significantly advances the goal of vessel traffic management.

For many years air traffic has been monitored by computers which generate the graphic situational display of air targets and their tracks. These computers were tied to the radar systems by interface equipment that digitized the radar return. The management of the total air picture is readily handled by the computer once the radar information is converted into digital form. The computer-assisted traffic management system automatically plots target movements and checks collision avoidance criteria, thereby increasing operator performance and reducing operator fatigue.

It is effective to apply the same technology within a Vessel Traffic System (VTS) which consists of operation centers and radar stations and provides both traffic monitor and shipping management. The traffic monitor system provides automatic target acquisition and tracking, collision avoidance management, and anchored vessel and buoy watch functions. The shipping management system allows quick access to ship information, such as previous port entry, inspection checklist, etc., and may be connected to other data bases for additional information.

As a VTS monitors activities occuring on a surface plane, it is apparent that by introducing a digitized depiction of the affected surface - an electronic chart - the computers are able to provide a comprehensive, and infinitely useful, view of the traffic situation in real time.

The electronic chart serves a number of important functions. First of course, it shows the geography of the area on which the traffic occurs. Second, it accomodates immediate modification of the natural and cultural geography, enabling the system to take into account and to monitor new harbor facilities, piers, buoys, anchorages, and channels. Third, as the electronic chart is digital data, it can be integrated into a system such as we describe as an active participant.

To clarify this function, we can cite this important example. If, as we say, the radar information is transposed to digital data before it is introduced into the system, it is possible to manipulate the digital data in any way necessary to enhance the VTS. One such manipulation is the elimination of a large number of returns which are not significant, such as piers and other charted areas which are already shown on the resident electronic chart. Through software, it is possible to arrange that all radar returns representing charted areas are suppressed.

Another important advantage offered by the electronic chart is the facility for instantaneous adjustment of the situation depiction. In the system described, a touch of the finger on any point on the operator's screen "zooms" the area to any desired scale for greater definition.

To fully exploit the myriad advantages presented by the electronic chart, a conscious effort is needed to eliminate data generated from sensors which is unnecessary, to extract the target information which is important, and to correlate the information received from separate sensors to preclude duplications.

Radar information from one to several transceivers can be incorporated into the system we describe. The individual radar stations are connected to any number of operation centers, and the separate centers are linked together for coordination between them. The radar stations can communicate with the operation centers through direct cabling, telephone lines, UHF radios, or microwave links. The operation center displays are connected through a local area network (LAN), which permits fast operator response. The centers may be connected through land lines, or through a wide area network.

The operation center is equipped with several workstations, consisting of high resolution color graphics monitors showing vessel traffic and ship management information. The operator has access to information from all radar stations, through the central target correlator mentioned above, which combines all the targets reported from all the radar stations into one target table. Targets that are detected by multiple radar stations are resolved into a single target by the target correlator.

The high resolution graphics monitor displays an electronic navigation chart superimposed with target positions. The touchscreen on the monitor permits fast and friendly interaction between the operator and the computer. For example, to obtain information on a specific target, the operator only has to touch the target on the monitor. The data monitor allows the operator to query stored information, such as name and telephone number of local agent for an incoming vessel, or to create information for future reference, such as a defects list.

The radar station, designed for unmanned operation, provides ship movement information to the operation center. The equipment at the radar station consists of the radar(s), a "Radar Data Unit (RDU)", communication equipment, and ancillary equipment, such as weather station instruments, or intrusion alarms.

In air search radars, the radar information conversion normally takes advantage of clutter elimination by use of a "Moving Target Indicator (MTI)." The doppler shift from aircraft at normal speed provides discrimination between targets and clutter, thereby allowing the computer to process relatively clean target information. Unfortunately, MTI is not adequate for surface radar since ship speeds are not sufficient to produce a discernable doppler shift. In addition, a doppler system would drop a ship target if the ship stopped during maneuvering. Therefore radar returns from ships are addressed in a different manner for the vessel traffic situation.

The Radar Data Unit (RDU) described herein serves two fundamental purposes. First, it converts radar video returns into a digital word that describes the location and relative size of each ship in the coverage area of a standard marine radar. Secondly, it automatically acquires those radar returns, and calculates the course and speed of each ship and assigns a unique identifier to it. Additional functions performed by the RDU are associated with the monitoring and control of all the equipment located at an unmanned radar station.

GENERAL RDU FUNCTIONS

The RDU is comprised of four basic functional elements, housed in two printed circuit card racks mounted in a standard 19-inch cabinet. The units contain the necessary power supplies, cooling fans, and interconnecting wiring. In general, the RDU first converts the complete radar picture to a digital bit stream and then discards all of the data associated with radar returns from land. Since the VTS radar is at a fixed location, the range and bearing to all land returns never change and only serve to interfere with processing of the data from ship targets. And, as mentioned, land returns are not necessary as they are available in the basic electronic chart.

Once the video in digital form has passed an established threshold test it is sent to the correlator which performs scan to scan integration and determines the size and shape of the target. The center of the target is calculated and used to establish a tracking window and target identity. A pretracker senses movement of each target and adjusts the tracking window accordingly. Final calculation of course and speed is done in the Site Controller and Tracker (SCAT), which formats all the information on each target and sends it to the center for integration with the other data in the VTS and for display superimposed on the electronic navigation chart.

RADAR INTERFACE

The RDU is designed to use predicted statistics of marine radar with a log video detector. The video signals are converted from analog to one of 128 digital levels for each range cell. This provides a very large dynamic range and allows processing to be done accurately. The synchro information for azimuth position of the radar antenna is converted to digital words and provides 4096 discrete azimuths. The synchro and trigger control many aspects of the processing since they are a reference for the system. A storage memory resides physically on the land mass blanker PC board and appropriate land mass chart information is downloaded from the SCAT to designate areas to be blanked.

A test target generator is also provided on the interface board. For maintenance the operator can create a simulated test target digitally and the analog test video will be injected into the front end to be processed through the system. This provides a convenient method of assuring RDU system integrity.

TARGET EXTRACTOR

The extraction process is performed on digital information that represents the video returns of the radar. The range of video derived in the video converter is dictated by the radar pulse repetition rate. The maximum range of short pulse can thereby be expanded beyond the normal radar short range. The limiting factor is the anticipated video return level considering the clutter and target characteristics. For instance, the pulse repetition frequency may allow short pulse returns out to 10 miles, but the video returns at that range may be too weak to distinguish the returns from clutter. The video converter can be programmed to stop video samples at six miles. A similar analogy is true for medium and long pulse.

The digital video for each range cell is compared to a digital memory stored in the land mass blanker. This memory is prepared unique to that radar location. Chart data for land mass in the radar coverage area is prepared on a chart digitizer and then converted from the mercator projection to a polar range and bearing. This now coincides with the actual radar returns. The tolerance on the land mass blanking coincides with one-half of the antenna beamwidth and range resolution of the selected radar pulse. Although this expands the blanking pattern and as such removes small sections of ocean, it is needed to preclude small video returns from sections of land being mistaken for stationary targets.

For points of land which provide desired reference, the blanking pattern can be shaped to allow tracking. A radar site established solely to provide detailed short range coverage of a harbor can use a blanker with resolution based on radar short pulse. Thus in constricted waterways, vessels transversing close to land can be tracked without the land mass being mistaken as a target.

Once the video samples are prepared they are passed through a two pole recursive filter which allows integration of the pulses over the beamwidth of the antenna. This filter determines the integrated value of the video target and clutter returns. Integration of video across azimuth builds up target returns and reduces spikey clutter, including radar mutual interference.

The digital value of the video at each range cell over the beamwidth of the antenna is now compared with a threshold level. This threshold is calculated for each range cell by first determining the average of the video cells that are distributed in the area around the cell of interest. This patch is selectable, and has a size of N by M range cells. The standard deviation (sigma) of the log video returns in the area of the target is calculated using a students-T distribution of the patch size. The mean and deviation computer is also known as the Log-T processor. The patch size can be modified to shape the distribution for best performance. An adjustable sigma factor changes system sensitivity (or threshold).

Once the threshold comparator checks the value of the video cell against the threshold level, it makes a pass/fail decision and sends a 1 or 0 reflecting the test results.

All range cells out to the selected range for 360 degrees except land mass, have now been determined to be either valid targets or not.

TARGET CORRELATOR

Assuming the pattern of range cells from the extractor are valid target cells, the remaining problem is to determine the size of the target (i.e., how many range cells make up each target), the center of the target (in X, Y format) and the direction and speed at which the center is moving. Also, the target which has been built or defined must have a unique identity which is remembered and associated with the same target scan after scan.

The scan integrator stores each target and checks it against the video in the same region for subsequent scans of the antenna. Once the range cells have been integrated over sufficient scans so that any residual noise is eliminated the process of target size determination, identity, and center is performed in the pre-tracker. The better the scan correlation, the smaller the pre-track window becomes. The target quality monitor performs this analysis. The pretrack calculation of course and speed are used only to move the window with the target to prevent a lost target. This course and speed is rough but as long as the video cells stay in the window, the size, location of center, and target ID will be determined for every scan of the antenna. This information is passed to the SCAT for storage in memory.

SITE CONTROLLER AND TRACKER

The Site Controller and Tracker (SCAT) plays an important role in tying all of the functions at a remote radar station together and provides interface to the VTS. The SCAT receives target information from the correlator, assigns each target to a track file and processes new positions through a Kalman filter to produce a smooth course and speed. The target size is converted to eight relative levels, and placed in the target file along with the target identifier and position. Position is listed in distance X and distance Y from the radar location.

In addition to the tracking function, the SCAT provides direct input and output of both digital and analog signals. These control radar functions such as on/off or pulse width selection. Control of communications equipment, power generators, and cooling systems is also handled by the SCAT. Monitor and control of additional equipment, such as weather station instruments or radio direction finders, may also be accomplished by SCAT.

OTHER RDU CONSIDERATIONS

The Radar Data Unit is designed for independent unmanned operation of a remote radar station. Although the design considers temperature and humidity the site should contain air conditioning to assure maximum radar transceiver and RDU reliability.

Built-in tests and test target injection can be performed at the remote site by a maintenance technician with little test equipment or the operator can initiate tests from his console at the control station to isolate faults to a sub-module level.

Target information from the RDU can be distributed by a communications network to any number of consoles but control signals need to be limited to one master console. This prevents two console operators from issuing conflicting instructions to the RDU.

As the radar station is the primary sensor for the Vessel Traffic System, it is strongly recommended that an Uninterruptable Power Supply (UPS) be included as part of each radar station. The UPS ensures adequate power is available for the RDU and communication equipment for a short period of time until orderly shutdown can be completed. The UPS also increases the reliability of the radar station by suppressing power spikes and power surges.

Several configurations of remote radar stations are possible such as dual radars, or a single antenna with dual transceivers. The RDU functions with equal effectiveness in any configuration.

This approach accomodates the following primary objectives:

- Enhanced operational safety
- Improved operator effectiveness
- Accommodation of future system enhancements

To satisfy these paramount considerations and to fully meet the detailed specifications and requirements of a worldz-class port, this highly sophisticated and flexible VTS which provides the greatest possible ease of operation coupled with secure, redundant, and robust flow of information. Major system elements brought together to this end are:

- Optimal integration of the radar surveillance provided by existing installations, with provision for integration of additional radars.
- Integration of data received from existing or any additional VHF/DF sensors.
- Real time dissemination of all data, including processed radar target information to all system consoles, monitors, data loggers, hard copy printers, plotters, and supervisory stations via a robust, efficient token ring network.
- Raw radar data processing, which includes detection, dissemination, and management of essential target data.
- Simplified operator controls, utilizing modern touch

screen techniques to enhance the man-machine interface.

- Daylight viewable bright raster scan color displays.
- Automatic alarms generation for both system and vessel traffic monitoring.
- Data-logging facilities.

Efficiency during long hours of watch in a busy VTS Station, under stressful conditions engendered by the heavy responsibilities for the safe monitoring of vessel traffic can be improved by providing radar displays that do not require a darkened environment. This feature alone does much to alleviate eye fatigue and to improve operator alertness. Such daylight-bright displays are now widely available. In addition, the displays are provided in color to make the discrimination of various targets and geographic features more positive.

This significant enhancement in radar display technology is made possible through the exploitation of a number of newer technologies - as well as the application to the marine world of several technologies long used in other contexts, such as air traffic control, as already discussed.

In essence, however, it is the effective conversion of conventional analog radar display to digital data which accomodates the flexibility, integratability, expandability, and effectiveness required. As the radar signal is converted to digital data, it more readily interacts with the myriad other computer-supported digital messages and data bases which comprise a modern Vessel Traffic System.

The digitized radar signal is fast becoming standard in the industry: raster-scan radar. The radar image is produced in the same manner as in high resolution television. This image produces clarity and resolution comparable and in most cases superior to conventional radar PPI displays. It also can provide computer enhancements such as display of track history, normal ARPA calculations, buoy-watch, anchor-drag alarms, and a fully capable Data Base Management system. This system includes an electronic chart composite display of the entire harbor or other waterway area integrated with the other functions needed to manage the station.

To disseminate the data generated by the associated radar and other sensors to the various VTS elements which require it, a real-time token-ring network is introduced, whereby all data required resides within the network and is available for use by any other element or remote station.

All system sensors, including the radars, VHF/Direction Finders, and weather instruments, are integrated in the token-ring network. The network enables all necessary displays, workstations and support equipment to be linked. The resulting integrated system provides all necessary information at each operator's workstation. A major advantage of such a system is the capacity for future expansion, where additional radar, direction finder, or workstations may be added without any redesign of system hardware or software. This system can be linked to other networks by telephone lines through high speed modems.

Incorporated in this powerful array of computers is unique VTS software, which offers such effective capabilities as:

- Automatic target acquisition
- Automatic target tracking
- Automatic target correlation
- Target alarms
- Recording and playback of targets
- Composite display of all targets
- Touch screen operation of displays

With the addition of powerful data base management software, this system is further enhanced, enabling administrative officers and operators designated for non-VTS duties to have access to real- time target data as well as target historical data. The VTS operators also have access to all other data that may be required to support VTS operations. This link between the current on-going harbor status and historical or other data base information provides true flexibility and expandabilty.

SYSTEM ELEMENTS

The Vessel Traffic Management System (VTMS)

The VTMS provides digitized radar target information to a sophisticated computer system which produces a real-time color graphic composite display for over 500 target tracks. These target tracks are correlated from site-to-site so that duplication of targets is avoided, and then displayed in high resolution against a high definition electronic chart of the area.

The Track History Processor (THP)

The THP combines all sensor data (from radars and DFs) with any target identification information and logs it on a mass storage device. It affords playback of logged data, and accomodates an information processing and retrieval system as well as chart and target plotting.

The Information Processing and Retrieval System (IPRS)

The IPRS provides a database that includes current positions and background data for vessels under surveillance. This supports other operations such as Search and Rescue and is an analysis tool for general operations while providing a data base for summary reports.

The Raw Video Display

In addition to the VTMS color graphic displays, a raster-scan high definition radar display is incorporated into the VTS operators' consoles. This display allows the operator to observe sea clutter and rain squalls which are intentionally deleted from the graphic display. The raw radar raster-scan display provides back-up for the system should a fault occur in the primary VTMS color graphic display.

The High Speed Token Ring Network

A unique high-speed computer network is key to the flexibility and future expansion of the entire system. This network is used to pass target and other data to all elements of the system so that any authorized station has complete access to all data in the network. The proven advantages of the token ring over other data networks make this arrangement ideal for the integration of sensor-generated information, and provides for efficient combination of radar signal processing and computer technology.

GENERAL SYSTEM DESCRIPTION

The Vessel Traffic System (VTS) is comprised of three major sub-systems:

- The Vessel Traffic Management Station (VTMS)
- The Track History Processor (THP)
- The Information Processing and Retrieval System (IPRS)

The VTMS provides a graphic display and real time information concerning vessel traffic in the system coverage area. The THP integrates sensor data from the radars and direction finders with target identification information obtained from Watch Officers through the VTS consoles. The result is a complete real-time picture of the coverage area traffic. This picture is distributed to the various VTS consoles for display and analysis, is logged periodically in the THP for plotting and playback, and is sent to the IPRS for update of various database entries.

The IPRS contains a ship information data base including current positions as well as a general information data base. This system provides analysis in the form of summary reports of system traffic and supports Search and Rescue (SAR) functions if needed.

A complete Watch Officer's console comprises a VTS Management Station, an IPRS workstation, and a raster scan radar display. The VTS Management Station presents a chart of the coverage area overlaid with symbols representing ships and their motions. The chart may be centered and scaled over any point in the area. Its symbolic information is then part of the complete system picture. This display presents the Watch Officer with the current traffic situation. It provides for various analyses (target-to-target information: range, bearing, CPA, TCPA, etc.) and allows data entry as the operator identifies a particular target in the area.

The radar display provides raw radar information from which the VTS Management Station's symbolic information is derived. The raw radar display can be switched to select any radar in the system and then presents that radar's video output.

The IPRS workstation affords the Watch Officer full access to database information, and allows him to issue target history plotting requests. The IPRS has two distinct functions. First, it maintains a database which combines the static descriptions of vessels which traverse the coverage area with actual transit information generated by the VTS. Second, it supports the SAR activity by maintaining a database of supporting information in conjunction with incoming reports. The major component of the IPRS is a data base server. This serves the query and report requests for the various IPRS workstations.

The THP combines information provided by all system sensors to produce a single complete picture. This includes correlation of targets detected by more than one radar to present them as single targets to the system. It is responsible for maintaining a target's identity as it passes through the various radar coverage areas. Target information provided by any operator is passed to the entire system. The THP also generates any simulated targets which have been specified. In addition to the real-time picture generation, the THP retains the target history for playback and plotting. This is accomplished by periodically logging the real-time picture. Playback and plotting requests are handled by the THP which accesses the logged data. The THP comprises the Target Correlator computers and maintains the data log on the Network File Servers.

The VTMS is implemented as a distributed processing system with redundancy in crucial components. The communication medium is a token ring network. The network allows complete system information to be available to any of the nodes. The network also facilitates incremental expansion as new requirements arise. The system software is similarly designed for growth. The various nodes are based on standard IBM-compatible PCs, with each component having a standard interface. This allows computers to be replaced easily as processing demands increase or as components wear out. Another facet of the distributed design is resource sharing. Each operator's console can access the various system resources, such as printers, plotters, and TELEX equipment. In this way a few printers can be used to satisfy the entire system's needs. These printers can be placed in convenient locations to be accessible, through the system, to all. Similarly, all plotters and TELEX equipment can operate in this fashion.

TOKEN-RING NETWORK

The basic communication medium for the VTS is the a token-ring (4 Mega-bit per second) local area network (LAN). Each of the VTS components or workstations is connected to the network via a computer analog-to-digital conversion module called a network interface unit (NIU). This affords infinite flexibility and expandability. The PC-based NIUs contain interface cards which give direct access to the network. Other devices (e.g., printers, plotters, Telex devices) are connected to a PC through some type of parallel or serial port (e.g., RS-232) and are thus accessible over the network through a PC. This is convenient since such devices generally require a special interface program, like a print spooler, which resides in the host computer. The PC may, in some cases, be dedicated to hosting several different devices (as with the plotters and TELEX equipment), or it may allow resource sharing in a non-dedicated manner. Several IPRS workstations also serve as printer hosts.

MESSAGE PASSING

The Dover CNIS system requires two types of network traffic: (node-to-node) and (node-to-server). The node-to-node traffic is required in the THP processing and the THP-VTS interface. Information is provided by a node (e.g., the radar interface) to be processed by another (e.g., the target correlator). This transfer must be real time to satisfy system requirements. A system which meets these needs is based on the IEEE 802.2 standard and the software is independent of the physical layer.

FILE SERVICE

The other type of network traffic, node-to-server, provides for non-time-critical communication. This includes down-loading of system programs, data base access (should be fast but not time-critical), and data logging. For this service a standard network file service software will suffice.

NETWORK LOADING AND EXPANSION

An example of worst case loading on the network assumes an expanded system with six radars, five VHF-DF units, 13 IPRS workstations and five VTS Management Stations. In this configuration, with a maximum target loading of 250 per radar and 500 for the total system, the network shows a 38.79 per-cent loading. This is well within prudent operating limits and shows room for even further expansion. Future expansion can be easily accomodated.

VTS MANAGEMENT STATION

The VTS Management Station is the operator's interface to the rest of the VTS system. It is the main operational location for the VTS operator and provides both operator interface functions and inter-face functions to the other computers within the VTS system. In addition to the interface functions, the VTS Management Station provides the following vessel monitoring functions, system functions, and operational functions:

- Target alarm determination and notification
- Zone alarm determination and notification
- Target course and vector length calculations
- Range, bearing, Closest Point of Approach (CPA), and Time to Closest Point of Approach (TCPA) calculations for target to target, target to point, and point to point queries
- Waymark (Buoy) monitoring and alarm calculations

- Target Data Logging and Playback control
- Graphical presentation of Electronic chart and target information
- Creation and editing of electronic charts
- Status and control of remote sensors such as Radar, VHF-DF, Weather, and Generator equipment
- Video Blanking Map Generation and Down Load
- System setup and calibration

The VTS Management Station functionality is attained by integration of operator interface devices to a high performance computer. It is interfaced to the rest of the VTS system by the Token-Ring Network. The VTS system incorporates a high resolution color monitor display, which produces a high brightness, daylight viewable display. It incorporates a unique touch screen which allows all controls, with the exception of text entry, to be placed within the display area. Thus, the operator need not look away from the display to find the needed controls. The touch screen allows quick and accurate selection of targets or points for data display or monitoring by simply touching them. Numerous switches and control devices have been eliminated.

Reliability of the VTS Management Station is enhanced by several methods. First, the Management Station uses digital techniques to process and display the radar and control information. Highly reliable digital integrated circuits are used instead of analog circuits. Second, functionality of the VTS Management Station is identical from station to station. Software controlled security levels and software controlled configuration allow access to various functions within the system. Therefore, complete redundancy and operational flexibility are available from station to station.

Connection of the VTS Management Stations to the Token-Ring Network provides the link necessary for exchange of data between various components of the system. The main source of data provided to each Management Station is the correlated target table. This target table is provided by a Multiple Sensor Target Correlator (MSTC) which produces a composite of all targets from all sites into a single target data table. This table contains the entire list of actual targets within the radar coverage area. Each VTS Management Station is able to superimpose any or all of the reported targets in this table, on the displayed electronic chart.

Through software and touch screen control, each operator can independently display any section of the electronic chart with the superimposed targets. The display can be quickly zoomed or panned for greater detail in any area of coverage. Because each VTS Management Station is functionally the same, and because a true com- posite target table is provided to each Management Station, hand-off of target information from coverage area to coverage area is unne- cessary. In addition, this design provides the flexibility to modify the operator's coverage responsibility as operational workloads dictate.

The tasks associated with the VTS Management Station can be broken down into a number of major categories: operator interface functions, data interface functions, graphics, vessel and waymark monitoring, alarms, subsystem status and control functions, and data logging and playback functions.

OPERATOR INTERFACE

Each VTS Management Station uses a high resolution color monitor with a touch screen overlay and a keyboard as user interface devices. The color monitor provides the display of chart, target, waymark, menu, commands, user prompts, and text display. The touch screen and keyboard provide the user input to the system.

In the lower left hand side of the main VTMS screen are a series of twelve labeled rectangular areas. These are "Touch Keys" which are displayed at all times. Touch keys provide rapid, single touch access to commonly used functions without having to access the menu. When touched, each key is highlighted.

Similary, all the described functions, including screen manipulation, such as centering and zoom of any area desired, and interrogation of any specified target data is readily and effectively accomplished at the touch of a finger.

Now the technology which has provided Air Traffic Control for years can, with the addition of electronic charts, be put to the service of the maritime community as well.

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