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Integrated Vessel Traffic Control System

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ABSTRACT: Paper describes Integrated Vessel Traffic Control System realizing fusion of data received from the shore based station of the Automatic Identification System (AIS) and pulse and Frequency Modulated Continuous Wave (FMCW) radars and presenting information on Electronic Navigational Chart. Additionally on the Observation Post is installed Multi Camera System consisting of daylight and thermal cameras showing automatically object tracked by radar and selected manually by operator.

1 INTRODUCTION

Paper describes Integrated Vessel Traffic Control System realizing fusion of data received from shore based station of the Automatic Identification System (AIS) and pulse and Frequency Modulated Continuous Wave (FMCW) radars and presenting information on Electronic Navigational Chart issued by the Polish National Hydrographical Service – Hydrographical Office of the Polish Navy. Additionally on the Observation Post is installed Multi Camera System consisting of daylight and thermal cameras showing automatically object tracked by radar and selected manually by operator.

System was designed and built in the scope of research work financed by the Polish Ministry of Science and Higher Education as developmental project No OR00002606 from the means for science in 2008-2010 years.

2 MODEL OF INTEGRATED VESSEL TRAFFIC CONTROL SYSTEM

2.1 *System configuration and features*

Model of Integrated Vessel Traffic Control System has a modular architecture. This system has been subdivided into autonomous modules. Each of them can be individually maintained, upgraded and/or replaced. Presented system has been designed to make possible development of his elements and functions in the future. The structure of the system has been shown in Figure 1.

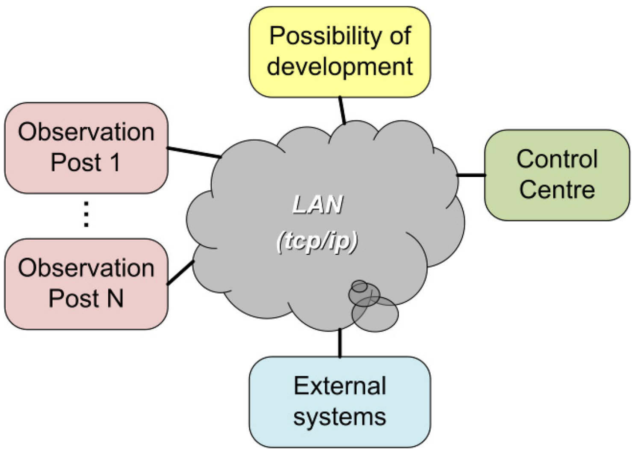

Figure 1. Scheme of Integrated Vessel Traffic Control System.

The Integrated Vessel Traffic Control System is an open-ended system, which is possible to integrate with external systems. The system consists of one Observation Post and one Control Centre. If required, there are abilities to connect to Control Centre several Observation Posts. All elements of the system are linked through the LAN (Local Area Network).

Figure 2 shows functional diagram of Observation Post. It consists of the following devices:

- Pulse radar in X band;
- Frequency Modulated Continues Wave (FMCW) radar in X band;
- Multi cameras system which comprise of daylight and thermal cameras; and
- Class A station of the Automatic Identification System (AIS).

The pulse radar as well as the FMCW radar includes plot extractor and tracker device.

The pulse NSC 25/34 Raytheon radar has been applied in the model of integrated system for the performance tests. This radar is characterized by the maximum range equal 24 Nm. However the CRM-203 FMCW radar, also used in the Observation Post, has been produced by Telecommunication Research Institute Ltd. This radar is able to detect objects at maximum distance equal 48 Nm. It is necessary to remember that range of radar destined to detection of sea surface objects, also depends on a height of antenna location and propagation conditions of electromagnetic wave.

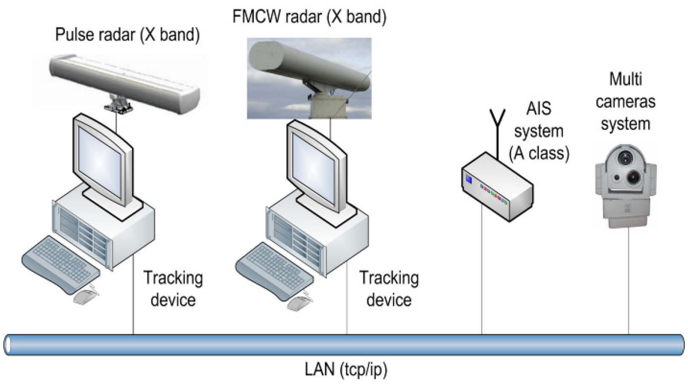

Figure 2. Functional diagram of the Observation Post.

CRM-203 is fully solid state radar. It makes use of modern technologies such as generation of emitting signals on the base of frequency Direct Digital Synthesis (DDS) and Fast Fourier Transform (FFT) processing implemented in signal processors TigerSHARC and Field Programmable Gate Array (FPGA) circuits VIRTEX. Described radar can detect sea surface targets and determine movement parameters of objects. It is equipped with modules realizing ARPA's functions and can cooperate like pulse ship's radars with external sources of information (GPS receiver, ship speed measuring device, gyrocompass, satellite compass, scanner of charts, etc.). CRM-203 is able to automatically tracking of detected targets and to pass information about tracked objects to command and control systems.

More detailed information about utilised FMCW radar was presented during the previous TransNav conference (Plata 2009).

Multi cameras system Sargas KDT-360 has been installed on Observation Post of integrated system. KDT-360 has been manufactured by the Polish company Etronika. Maximum range of the multi cameras system is in the order of several kilometers. If necessary, it is possible to apply in the integrated system cameras, which have better range features.

Moreover for performance tests purposes in Integrated Vessel Traffic Control System has been used as AIS coastal station AIS class A device produced by SAAB.

The main task performed by the Observation Post is supply information about sea surface situation in detection range of the radars and operation range of the AIS system. Moreover, remote controlled multi cameras system can make identification of objects detected by remain sensor or even external systems. All devices are able to work in the unattended mode.

The functional diagram of the Control Centre has been presented in Figure 3. The centre consists of equipment as follows:

- Server;
- Operator workstation; and
- Printer.

Server as well as operator workstation operate under control of Red Hat Enterprise Linux 5 operating system.

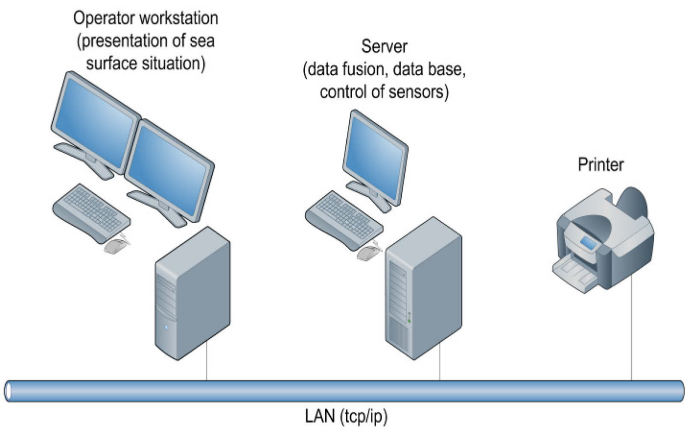

Figure 3. Functional diagram of the Control Centre.

The Dell Power Edge T610 server has been used in the presented system. This computer has two four cores and 64 bits processors Xeon X5570, 32 GB of RAM as well as five 300 GB hard disks. Hard disks are operating under matrix system RAID 6.

The Dell Precision T5500 computer has been applied as operator workstation. This machine has 64 bits processor Intel Xeon W5580, 12 GB of RAM, two 300 GB capacity hard disks and graphical card NVIDIA Quadro FX3800. Hard disks in the workstation are operating under matrix system RAID 1.

The Control Centre performs tasks as follows:

1 Generalization of information about current sea surface situation. The process relies on verification and data association collected from sensors, which operate on Observation Post.
2 Monitoring, collecting and updating of sea surface information within the scope of:
   - Tracking of all sea surface targets in range of Control Centre operation;
   - Identification and classification of detected object;
   - Distinguishing between stationary and movable objects;
   - Assertion of vessel entrance to areas temporarily or permanently prohibited and other areas defined by the operator;
   - Assertion of vessel descent from in forcing maritime routes; and
   - Cooperation with others services.
3 Archiving and play back of recorded sea surface situation.

Information received from radars and AIS are put to the database. Next, these data are subjected to fusion. Results of fusion are also written down to the base. Communication and control of the sensors, the database and the data fusion algorithms have been implemented in the server.

Data from the base and the sensors i.e. radars, AIS and even multi cameras system can be transferred automatically (in suitable range) to external systems. Information from these external systems can be received automatically, as well. Received data, such as targets tracks from radars and AIS are written down to the base and are subject to fusion with information obtained from local sensors of Integrated Vessel Traffic Control System.

Information from all local sensors and external systems are presented on two computer displays. Actual positions and movement vectors of targets, detected by radars and received from AIS devices installed on vessels, are presented in the graphical form on Electronic Chart Display and Information System (ECDIS) (Weintrit 2009). The picture from multi cameras system is presented in the separate window (daylight or thermal camera). Archived comprehensive sea surface situation can be playing back in any moment.

Presented configuration of the model of integrated system and its functions can be changed. Therefore, modifications and development of manufactured vessel traffic control system are possible in dependence on needs and requirements of a customer.

2.2 *Data fusion*

Multi-sensor data fusion is one of the most effective ways to solve problems of different groups, which have common characteristic features. It uses data from multiple sources to achieve a result which would not be possible to obtain from a single sensor. Data received from different sources can be associated by make use of specific procedures of signal processing, recognition, artificial intelligence and information theory. Many methods of data fusion have been developed and their common feature is an inclusion of multiple layers of data processing in the integration process.

Fusion process used in presented system can be divided into several main stages (Figure 4):

1 Unification of state vectors units of targets and bringing them to single timeline.
2 Association.
3 Determination of an updated state vectors.

The need to harmonize the time, results from the asynchronous operation of sensors. They operate with different frequencies and can be turned on at different times. For example the position of radar antennas working in the system can be different at any given time. Uniform period of time equal 1 second has been adopted. It allows easy synchronization of data received from sensors with different frequencies (typically: 2, 3, 6, 10 seconds).

Association is performed using the modified PDAF algorithm (Probabilistic Data Association Filter) (Bar-Shalom et al. 1995, Bar-Shalom et al. 2001, Krenc 2006). In the modification we assume that there are two (or more) sources of varying quality. The associated measurement can come from two sources, one or none. Additionally, there is one validation gate, inside of which are measurements from both sources. The modification relay on adding new innovation vectors v and association mass e of these vectors:

$$v_{ij} = \frac{e_i \cdot v_i + e_j \cdot v_j}{e_i + e_j}, \; e_{ij} = e^{-0.5 \cdot v_{ij} \cdot S^{-1} \cdot v_{ij}^T} \tag{1}$$

where: v - the innovation vector; e - association mass of innovation vector; S - innovation matrix; and i, j - indexes ($i \neq j$).

In this way has been assumed that data are received from both sensors and probability of such hypothesis is calculated. This allows several percent of improvement in the quality of estimation.

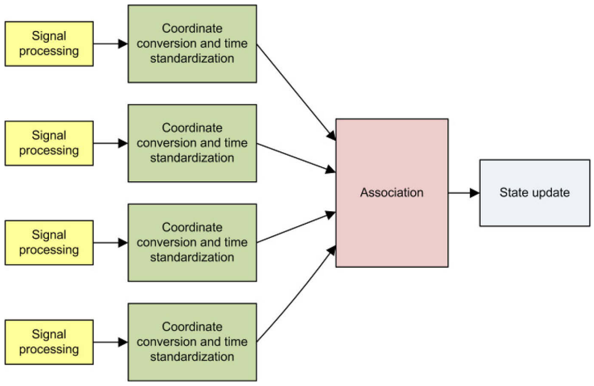

Figure 4. Diagram of data fusion process.

The state vector updates are assigned on the basis of calculated innovation vectors and association probabilities.

The algorithm allows for flexible operation, depending on currant conditions (adaptive assessment of interferences) and quantity of information sources.

2.3 *Sea surface situation picture*

As mentioned in paragraph 2.1, the function of presentation of sea surface situation has been implemented in the operator workstation. Picture is presented on two displays, which shows fully independent graphic information from the radars, AIS, multi cameras system and external systems. Positions and motion vectors are displayed with different accuracy, depending on the type of objects:

– Detected only by radars;
– Transmitting AIS data and not detected by radars;
– Detected by radars and transmitting AIS data, after data fusion.

Sea surface objects are presented on electronic navigation chart (Weintrit 2009). The situation can be displayed on full screen of two monitors simultaneously or one monitor or else in dedicated window. It is also possible to observe magnified area in separate window. Operator's console is presented in Figure 5. An example of costal sea surface situation picture is shown in Figure 6, whereas an example of data fusion working is presented in Figure 7.

Figure 5. Operator's console.

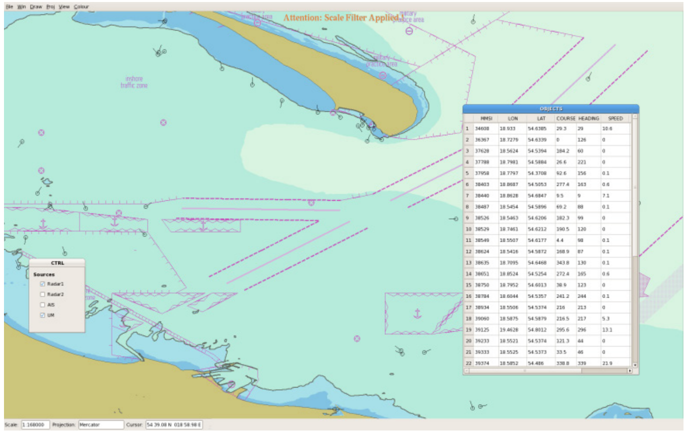

Figure 6. An example of costal sea surface situation picture.

On the left monitor there is the window displaying moving objects on the background of navigation chart. Above, on top of the screen, has been placed Menu Bar which make possible to choose the submenu for selection of actions or to open control windows. At the bottom of the screen has been placed Status Bar (see Figure 6).

The right monitor is designed generally to present windows with tables that contain descriptions of targets obtained from all sensors or external systems, additional descriptions of tracking objects and targets after data fusion as well as to present the picture from multi cameras system. An operator can shapes the view on the screen in suitable for him manner because any windows can be moved in the frame of main window.

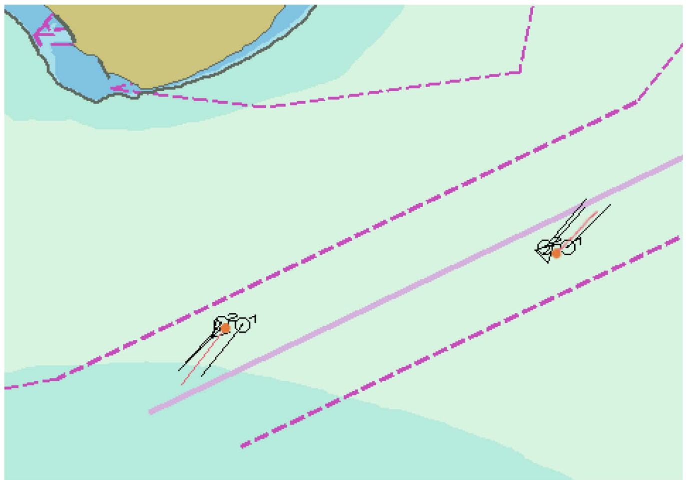

Figure 7. Two detected and tracked targets (circle 1 – FMCW radar, circle 2 – pulse radar, triangle – AIS, point – data fusion).

Software package EC2007 ECDIS Kernel developed by SevenCs GmbH has been used to build navigation charts background. The package allows the application of various types and formats of electronic digital charts supplied by different manufacturers.

The set of tools and libraries Qt developed by Nokia (formerly Trolltech) has been used to build controls elements of the picture and specialized windows, which present e.g. the list of sea surface parameters or the picture obtained from multi cameras system. Qt provides up-to-date components and mechanisms to build operator interface and tools to implement communication, processing of text documents or to use databases.

The use of both software tools, i.e. EC2007 ECDIS Kernel and Qt, allows to rapid implementation of the software which meet the requirements of IHO/IMO.

Some parts of the operator interface functions have been performed solely for research purposes, such as fusion algorithms and can not be found in the target Integrated Vessel Traffic Control System. Similarly, the units implemented in control parameters of multi cameras system are as required by this device. It has been done in order to facilitate operation tests and control of used multi cameras system. Units or scope of unit's description should be adapted to thinking ways and working procedures of an operator.

The solution of the picture displayed on monitors, which has been adopted in Vessel Traffic Control System, is flexible. Depending on the operator's needs, presentation of sea surface situation and other necessary information can be freely shaped.

3 CONCLUSIONS

Paper presents Integrated Vessel Traffic Control System designed and constructed in the scope of research work mentioned in the introduction. The system works and results of its performance tests conducted in autumn and winter 2010 are described in other paper presented on this conference.

REFERENCES

Bar-Shalom Y, Rong Li X. 1995. Multitarget-multisensor tracking: Principles and techniques. *University of Connecticut.*

Bar-Shalom Y., Rong Li X., Kirubarajan T. 2001. Estimation with Applications to Tracking and Navigation. *John Wiley & Sons Inc.*

Krenc K. 2006. Statistic methods of processed data evaluation for the purpose of information fusion in C&C systems. *MAST.*

Plata S., Wawruch R. 2009. CRM-203 Type Frequency Modulated Continuous Wave (FM CW) Radar. TransNav - International Journal on Marine Navigation and Safety of Sea Transportation, Vol. 3, No. 3, pp. 311-314

Weintrit A. 2009. The Electronic Chart Display and Information System (ECDIS). An Operational Handbook. *CRC Press, Taylor & Francis Group*