Knowledge based Information Evaluation for Integrated Ship Bridge Systems

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Abstract: The following paper describes a data fusion oriented approach for a novel information handling on integrated ship's bridge systems using agents. A Joint Data Laboratories based data fusion model was used for the ship navigational data handling. First experiments supported by data from a Voyage Data Recorder, external knowledge data bases and various defined information layers will be discussed. The goal of the investigation was the information relevance evaluation in the navigational process current circumstances. An applied example will be discussed.

1 Introduction

The most ship’s bridge equipment devices follow their own philosophy of displaying information and announcing warnings or alarms when determining safety- or operation-critical states. The technical navigation systems are used on board vessels in a different manner. Very often these systems have an integrative mode of operation. However, they have actually a life of its own depending of the equipment manufacturers. The sense and handling of the announced warnings or alarms in complex situations is not acceptable in ship handling procedures, because of the device-centric decision-making process. The nautical staff have not the ability to distinguish the acoustically and visually cognition of alerts due to the lack of classified or graduated critical information appearances. The currently used alert systems do not work in accordance to the state of vessel’s vitality neither with the technical periphery nor with the navigational situation or task.

A cross-system data management for process information harmonizing and weighting is necessary. Such a management system would be aimed to bundle sensor-information, warnings and alarms efficiently. Determined process-dependent information sets and hierarchies have to be carried out for handling this challenge. The goal of a new data and alert management should be the discharge of the nautical staff during the operational task by confining the permanent information overflow. The integrative load of the operator during sorting and prioritizing of process information and process handling has to be minimized by a vital display of significant and qualified process data. This dynamic needs a holistic approach which can be reached by the theory and methods of
Data Fusion (DF). The sensor data of vessel’s technical system like engine and bridge systems may be correlated with its current circumstances as the current maneuvering behavior of own ship, navigational conditions (spaces, targets and weather) and rules of collision avoidance and grounding. It is essential to associate the measured local states of solely sensors with the global overall situation and to post-process the data in respect to this focus.

2 Data Fusion in Ship’s Bridge Information Systems

The probably most complex system using methods of DF is the human being by itself. It is able to recognize and to evaluate different situations in shortest time frames because of its sense organs and its capability of cross-linking. At all times a decision tree will be running through in the background. The created result may be different every time due to the external influences or due to the growing number of the decision tree branches. The technical DF aims to reverse engineering of the human model. At this the measuring sensors will be connected to a net-working system which is able to recognize an event by additional aspects [BI98]. The pyramid tapering of a voluminous dataflow into process-depending knowledge is the central task of a data cross-linking on ship’s bridge.

2.1 The Architecture of the used Model

The theory of DF is summarized in the generic Approach of a DF System [Ha01], [Bi03]. The data of different resources will be pre-processed, linked and refined and will get a new and higher quality after each level of processing by using the generic architecture of a multi sensor fusion system like in [SGD99]. The performance of a DF System is also based in the prognostic of relevant data. The system may detect unsteadiness of the behavior rapidly. That means for the ship’s system, that the functionalities and the interrelationship of sensors can be treated by the methods of DF in a very efficient manner [Da07]. The goal is a cross-linked description of an operating ship of her movement, her load, her mission related to the interaction with the surroundings like the navigational space, the targets, the wind and water. The more exact and complete the accordant situation may be qualified the more accurate the data of technical system may be interpreted according to the given context.

2.2 The Knowledge based Information

The ship’s sensor system affords the technical measurement recognition of the environment in more or less complete manner. So, any situation may be interpreted as a structured extract from the real world and may be formed as information, which can be combined, abstracted and related to each other information. Putting expert knowledge into the investigation the result of a multi-sensor-system is a correlated and integrated outcome. The information η itself may be defined as η = {r, x, t, p, k}, with r as a relation between units, x as location, t as time, p as probability, and k as a class membership [St06].
The data of the Ship-Bridge Information Management has to be collected and to be sort according to a hierarchical structure. Therefore a multi-layer model [Ha06] based on a performed graph architecture is used. The first layer called Data Layer provides the origin sensor data to the next higher layer called Information Layer which handles the data by given processing functions. The resulted outcomes build up the Knowledge Layer. Each layer has included a restricted knowledge base containing the kind of data and operational tools. The integration and controlling of ship’s data is carried out in all three layers as a dynamical graph. Its building up depends on the operational result in every existing knot. That means, only the relevant connections of the knots inside the tree will be treated. The knots are implemented as special structures and are called as agents. They contain operational intelligence with respect to their controlling domain.

3 Implementation

The automatically estimation of the kinematical state of the own ship is a central intermediate process of the implemented DF methods for getting the reference to the context. Due to the use of a context information carried out by DF may be weighted in relation to their relevance. That means, not all displayed information is necessary in every situation of the navigational process. The opportunity is given for splitting off the information in temporary important or unimportant, necessary or needless and other groups by taking a context into account. Therefore \( f \) is the elemental function for mapping the parameter \( I \) used for describing the current kinematical state of the own ship into a real number \( R \). By means of a measurable set \( I \) of the parameter the integral of \( f \) is estimated by:

\[
s = \int f d\mu = \sum_{i=1}^{n} \alpha_i \mu(I_i), \quad \sum_{i=1}^{n} \alpha_i = 1
\]

with \( \alpha_i \in \mathbb{R} \) and \( \mu(I_i) \) is the measure. The identification of the weights \( \alpha_i \) was done in an empirical way. It based on interviewing of experts and analytic evaluation of data records of a real ship during voyage.

Beside the dynamical parameter of ship’s moving behavior like speed, rate of turn, drift and its derivatives the actuating elements like revolutions, rudder angles, thrusters and engine mode also belong to the parameter set for estimating the kinematical ship state \( s_{cin} \). with

\[
f : R \mapsto N_0, f(s) = s_{cin}, s_{cin} \in S = \{0,1,2,3\}. \quad (2)
\]

The different characteristics of the well-defined parameters are clustered into four introduced classes of the ship-state set \( S \): 3 – Underway, 2 – Maneuvering, 1 – Drifting and 0 – Moored. The cluster Underway consists of all the ship-states, which means the classical voyage of a vessel. An anchored vessel (harbor, anchorage), which are moving with very low or none velocities belongs to the cluster of Moored. If the moving behavior of the ship is solely resulted by external influences like wind and current the ship-state class is Drifting. All others ship-states like coastal or pilotage trade, maneuvering, positioning and tugging are clustered by Maneuvering.
4 The experimental Use

During the sea trail of a motor vessel before ship’s delivery the NMEA data were recorded by the Voyage Data Recorder (VDR) for about 36 hours. In the following figure the recorded sea trail NMEA – data are shown. The sea trail consists of the full required maneuvering program before ship’s delivery. The record includes engine, rudder and thrusters maneuvers as well anchor, tug and blackout maneuvers. An extract of the focused parameters are shown in the diagram as normalized values.

![Figure 1: Assignment of the cinematic ship-state based on dynamical parameter of moving behavior (3 – class Underway, 2 – class Maneuvering, 1 – class Drifting, 0 – class Moored)](image)

After the use of the implemented DF methods on the recorded data a mapping of the ship-states is carried out by the agents and marked by the red dots in the diagram for each time step. For example, in the time frame of about 40 minutes at 11 o’clock of the time scale the estimated kinematical state of the own ship alternates between the classes Drifting and Maneuvering. The mapping alternation here depends on the measured Rate of Turn, which is influenced by the switching use of the ship’s thrusters during the testing and adjusting period. The estimated kinematical ship-state influences the operational capability of the implemented agents and the priority of the processed data. The information will be evaluated and controlled in accordance to the current context in terms of their relevance, their availability and their quality. Thus, the temporary consideration of the parameter Heading in the cluster Underway has to be evaluated differently as in the cluster Maneuvering.
5 Results

The following figure shows the results of the applied DF approach for Ship-Bridge Information Management. The input data are real NMEA data. A 30 minutes time sequence of one navigational parameter POSITION is abstracted displayed. The diagram range is a color gradient from green to red, which reflects from a very good to a very low availability and quality of the data according the context shown by the color of the value marker. Each color describes one kinematical state of the own ship estimated by the algorithm. The origin data of position recorded by the Voyage Data Recorder are marked by the white triangle. For this data the kinematical state estimation and an agent controlling do not exist. Three times the position signal is lost each for 4.5 minutes. No position value is available, the quality is zero. A concert of acoustic alerts produced by each technical devise handling with position data like Track pilot, Conning Display, ECDIS, Weather Charts and Radar would be the consequence at the ship’s bridge.

![Figure 2: Comparing the quality and availability of origin and fused data, (One time step = 30 sec on the time scale)](image)

Looking at the second group of displayed values marked by colored quads, it is evident, that the missing origin signal is substituted by alternative data representing positioning data. This data may be delivered from a competitive sensor or estimated on the basis of a co-operative sensor. The quality of the substituted value is evaluated by the algorithm with respect to the context. The kinematical state of the own ship is estimated as a maneuvering behavior (brown marked quads) during the first and second period of signal missing. In this state the positioning data are appraised as necessary and the threshold of a satisfactory quality is higher than in the state Underway. So, the quality of the substituted data reaches lower in opposite to the third period of missing signal. There the quality of the substituted values is regarded as satisfactory good. Here, the consequences at the ship’s bridge could be an alert handling reduction by a centralized technical device. The exemplary diagram shows the different processing operations of the implemented algorithm in an effectual way. The lost information handling may be analyzed and controlled in a context depending method by the use of a DF approach for a ship’s bridge information system. This approach gives the possibility for a different and automatically adapted conditioning of bridge alerts.
6 Summary

Currently the data flow of an INS on ship’s bridges is characterized by a partly exchange of navigational data of special integrated bridge sub-systems. The technical components are directly connected with the necessary sensors. There is no cross-link or cross reference between the devices. A data pre-processing or checking is made only by the respective component of the technical system. In case of an operational fault of any sensor each technical sub-system depending on this sensor data will announce its own acoustical alert. The consequence is an alert distress of the nautical staff and acceptance failures to the technical systems. Taking the knowledge of the sensor architecture into account the alert frequency may be reduced by substitution of a sensor fault by competing or corresponding sensors. A second step in reaching a silenced bridge is a context depending evaluation of a sensor fault. Alerts without a relevance to the defined context may be quieted. During a four years lasting research project (“DGON-bridge” funded by the German Federal Ministry of Economics and Technology) it was shown that the goal of a differenced ship alert handling for reducing the overload of the nautical bridge personnel is reachable by the theory of DF using Agent Model. It was proved that the alert disturbances can be measurable reduced since the sensor data of the technical system ship are cross-linked and focused under identified circumstances. The implemented method is applicable in real-time and well-proofed by the good outcomes.

Literature

[Im09] IMO NAV CG on IBS: Draft Performance Standards for Bridge Alert Management (in progress)