# Multisensor Data Fusion in the decision process on the bridge of the vessel

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ABSTRACT: More and more electronic devices appears on the bridge of the vessel. All of them are supposed to help navigator in his work. Some of them are useful for exchanging data among vessels. Nowadays navigator can observe surroundings of the vessel on screens of some different systems of exchanging data. It is obvious that there are some advantages and some disadvantages of each of these systems. Proposal of the author is connecting data obtained from mentioned systems by means of data fusion technique. Joining few systems in one will be helpful at making decision on the bridge of the vessel. This paper is an introduction to consideration how to use the data fusion in the maritime navigation.

## 1 INTRODUCTION

### 1.1 *Systems of the exchange of data*

The scientific and technological progress is bringing some new solutions. There are more and more electronic devices on the vessel's bridge. That cause1 navigator has the access to various systems of the exchange of data. Some of them can receive data, other combines send-receive operation.

The navigator's assessment of collision risk depends on his knowledge about own ship's motion and other ships' motion. The available means for assessing the other ships' motion are for example: visual sighting, radar, ARPA, AIS and the voice communication with other ships. Each of enumerated systems possesses particular reliable features.

Voice communication, radar and visual sighting give real time information. Each of them is a separate system on the bridge of the vessel. The most difficult for the navigator can be predicting the situation in advance if the safety margins are small, as in congested waters. The same applies for Automatic Identification Systems (AIS) if only the text display is provided. It is appeared, that the AIS will be able to replace many of enumerated means of communication.

Very important question is possibility to switch off AIS receiver. Acts of piracy represent a serious threat to the lives of seafarers and the safety of navigation. In such situation switched AIS is making vessel to be sitting target. Of course sometimes AIS receiver should be switched off.

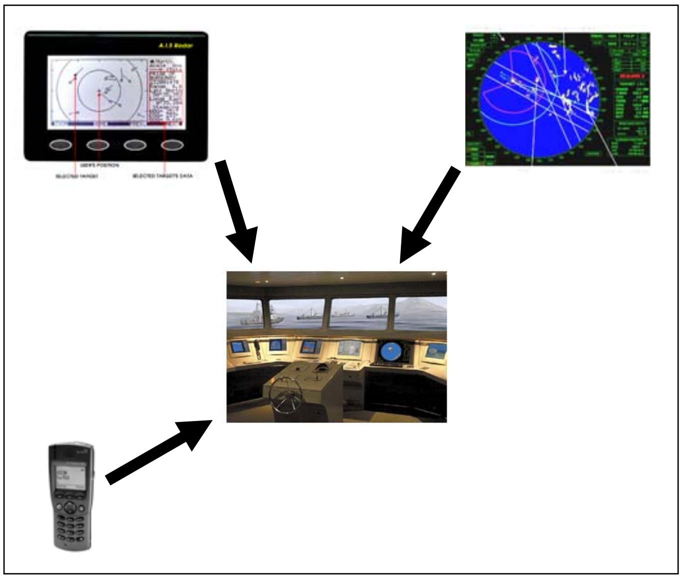

Fig. 1. Some systems of exchanging data on the bridge of the vessel

It is appeared, that the AIS and ARPA can collaborate with themselves. AIS, if works in the graphical mode, have the advantage that its results easy to interpret and it is easy to predict the other ships' motion based on the information available at the moment.

The AIS is known as a system providing other ships' course and speed in real time, in opposed to the ARPA system which calculates the course and speed from historic radar data. For this reason it may be suspected that information obtained from the AIS in many cases will be less reliable than information from the ARPA.

Of course, in some situation AIS can also provide incorrect data. In this system the course and speed over ground may be provided from a GPS with very slow filters. This may cause the AIS course and speed information to be more delayed and less accurate than the ARPA calculated information.

It is possible to connect all systems of the exchange of data which are found on the bridge of the vessel into one system. Each of enumerated systems will be still working individually.

This paper presents theoretical rules about joining similar data from different sources.

## 2 A DATA FUSION PROCESS MODEL

Data fusion means a very wide domain and it is rather difficult to provide a precise definition. Several definitions of data fusion have been proposed. Pohl and Van Genderen (Wald, 1999) defined " image fusion is the combination of two or more different images to form a new image by using a certain algorithm" which is restricted to image. Hall and Llinas (Wald, 1999) defined "data fusion techniques combine data from multiple sensors, and related information from associated databases, to achieve improved accuracy and more specific inferences that could be achieved by the use of single sensor alone". This definition focused on information quality and fusion methods. According to these definitions, it could imply that purposes of data fusion should be the information obtained that hopefully should at least improve image visualization and interpretation.

The basic definition of data fusion is as follow: "combining information to estimate or predict the state of some aspect of the world".

General steps in data fusion process are shown at fig. 2. In the process it is possible to appoint such steps as data receiving, pre-processing, fusion and visualisation.

There are several fusion approaches. Generally fusion can be divided into three main categories based on the stage at which the fusion is performed namely:

- pixel based,
- feature based,
- decision based.

In pixel based fusion, the data are merged on a pixel-by-pixel basis.

Feature based approach always merge the different data sources at the intermediate level. Each image from different sources is segmented and the segmented images are fused together.

Decision based fusion, the outputs of each of the single source interpretation are combined to create a new interpretation.

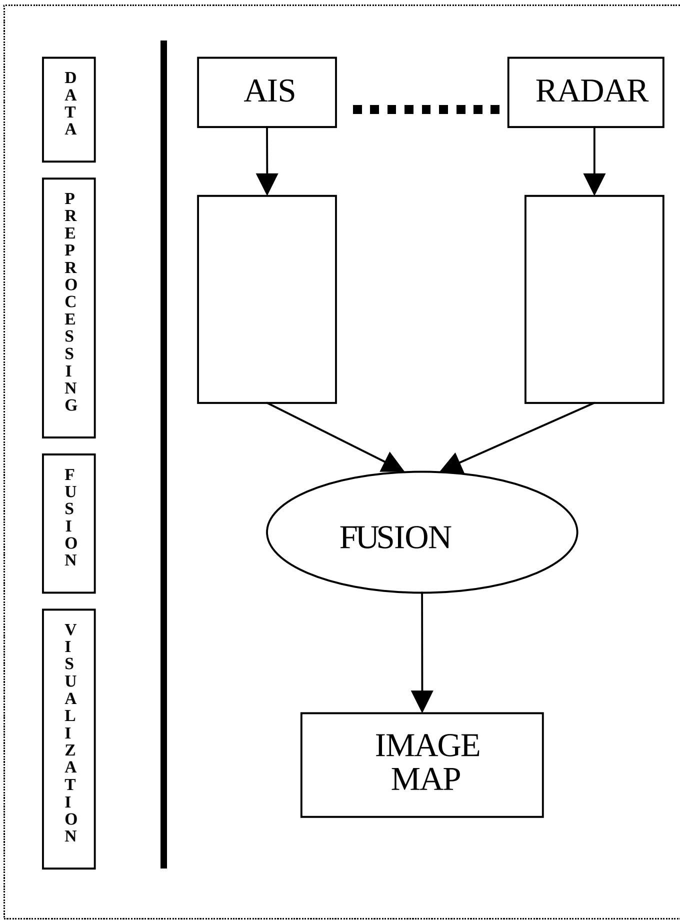


Fig. 2. Data Fusion Process

In the scheme, shown in fig. 3, the data fusion process is conceptualized by sensor inputs, human-computer interaction, database management, source pre-processing, and four key sub-processes. Sometimes data fusion domain includes two additional sub-processes (Level 0 and Level 5).

## 3 PHASES OF DATA FUSION PROCESS

The best known model of data fusion functions is the JDL (*Joint Directors of Laboratories*) model. Its differentiation of functions into fusion levels provides a useful distinction among data fusion processes that relate to the refinement of "objects," "situations," "threats," and "processes."

### 3.1 *Level 0 - Sub-Object Data Association and Estimation*

This level is not very often included in data fusion domain. There is a data processing on the signal level in this phase.

### 3.2 *Level 1 - Object Refinement*

The main task of this level is combining data from multiple sensors and other sources to determine position, kinematics, and other attributes.

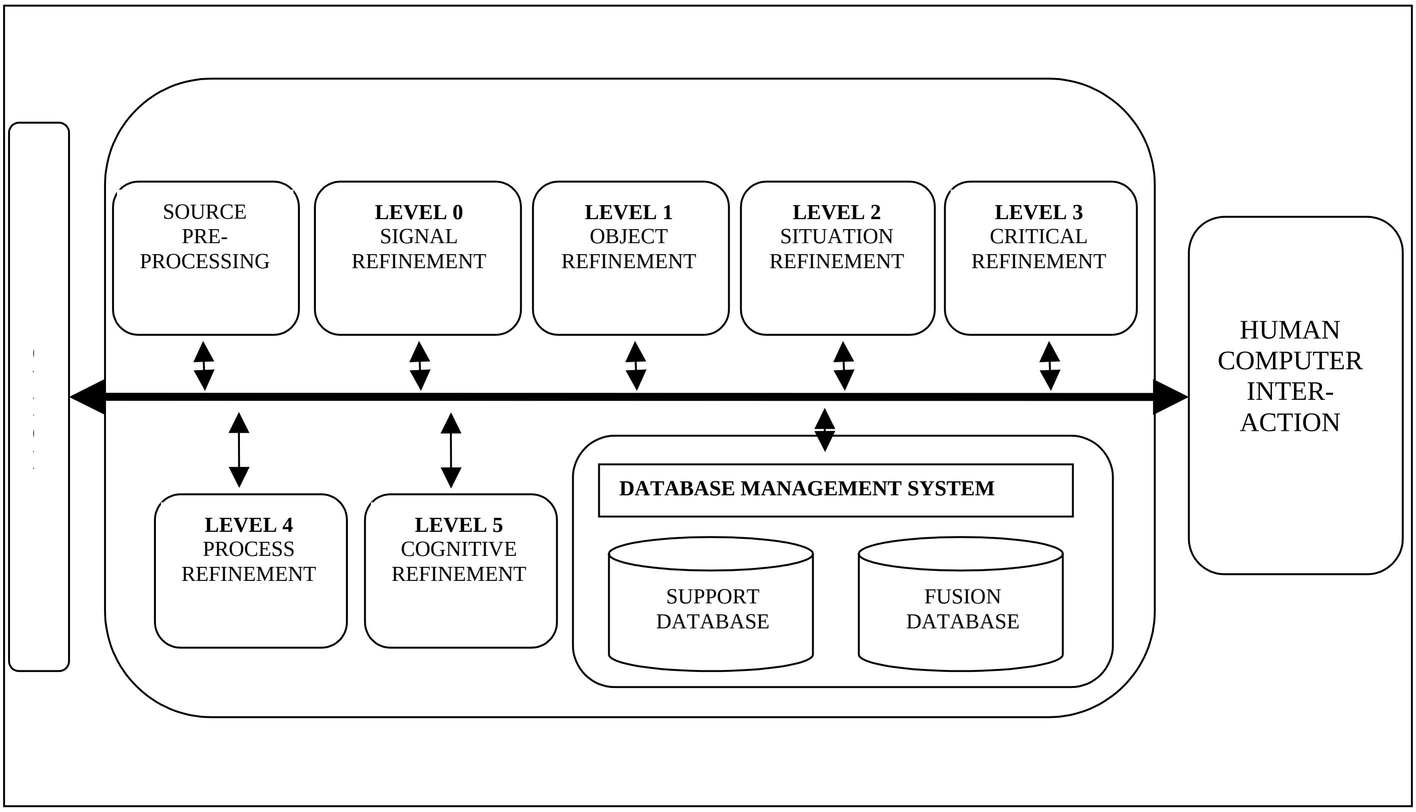


Fig. 3. The Joint Directors of Laboratories data fusion model (Adapted from Hall & McMullen, 2004)

The first general method of combining multi-sensor data, known as data association, correlates one set of sensor observations with another set of observations. As a result of this process, data association is able to produce a set of "tracks" for a target object. A track is an estimate of a target's kinematics, including such factors as its position, velocity, and rate of acceleration (Hughes, 1989). Thus, data association represents the initial step necessary for localizing a target; this can later be increased with the identification of other characteristics associated with the target.

In tracking targets with less-than-unity probability of detection in the presence of false alarms, data association is crucial. A number of algorithms have been developed to solve this problem. Two simple solutions are the Strongest Neighbour Filter (SNF) and the Nearest Neighbour Filter (NNF). In the SNF, the signal with the highest intensity among the validated measurements is used for track update and the others are discarded. In the NNF, the measurement closest to the predicted measurement is used.

Data association becomes more difficult with multiple targets where the tracks compete for measurements. Here, in addition to a track validating multiple measurements as in the single target case, a measurement itself can be validated by multiple tracks. Many algorithms exist to handle this contention. The Joint Probabilistic Data Association (JPDA) algorithm is used to track multiple targets by evaluating the measurement-to-track association probabilities and combining them to find the state estimate. The Multiple-Hypothesis Tracking (MHT) is a more powerful (but much more complex) algorithm that handles the multi-target tracking problem by evaluating the likelihood that there is a target given a sequence of measurements (Hall, 1989).

### 3.3 *Level 2 - Situation Refinement*

Level two data fusion represents an advance beyond the creation of raw sensor data, as occurs at the first level, and supports the synthesis of more meaningful information for guiding human decision-making. Bayesian decision theory is one of the most common techniques employed in level two data fusion. It is used to generate a probabilistic model of uncertain system states by consolidating and interpreting overlapping data provided by several sensors. It also determines conditional probabilities from a priori evidence.

On this level is used one of two most popular techniques which are:

- Bayesian Decision Theory
- Dempster-Shafer Evidential Reasoning

#### 3.3.1 *Bayesian Networks*

Bayesian networks are useful for both inferential exploration of previously undetermined relationships among variables as well as descriptions of these relationships upon discovery.

#### 3.3.2 *Dempster-Shafer evidential reasoning (DSER)*

The Dempster-Shafer method has several other advantages over Bayesian decision theory. Most importantly, hypotheses do not have to be mutually exclusive, and the probabilities involved can be either empirical or subjective. Because DSER sensor data can be reported at varying levels of abstraction, a priori knowledge can be presented in varying formats. It is also possible to use any relevant data that may exist, as long as their distribution is parametric.(Hughes, 1989).

### 3.4 *Level 3 - Critical Refinement*

Level 3 processing projects the current situation into the future to draw inferences about threats and opportunities for operations (Hall, 1989)

On this level is used one of three most popular techniques which are:

- Expert Systems,
- Blackboard Architecture,
- Fuzzy Logic.

#### 3.4.1 *Expert Systems*

An expert system is regarded as the personification within a computer of a knowledge-based component from an expert skill in such a form that the system can offer intelligent advice or take an intelligent decision about processing function.

#### 3.4.2 *Blackboard Architecture*

A blackboard-system application consists of three major components:

- The software specialist modules, which are called knowledge sources. Like the human experts at a blackboard, each knowledge source provides specific expertise needed by the application.
- The blackboard, a shared repository of problems, partial solutions, suggestions, and contributed information.
- The control shell, which controls the flow of problem-solving activity in the system.

#### 3.4.3 *Fuzzy Logic*

Fuzzy Logic is a mathematical technique for dealing with imprecise data and problems that have many solutions rather than one.

Fuzzy logic is derived from fuzzy set theory dealing with reasoning that is approximate rather than precisely deduced from classical predicate logic.

**Level 2 and Level 3** fusion are very challenging. They involve the attempt to emulate human reasoning.

### 3.5 *Level 4 – Process Refinement*

Level 4 was defined as a meta-process. The process monitors the data fusion process and tries to optimize the process by controlling the sensor resources in order to achieve improved fused results. Basically the purpose of sensor management is to optimize fusion performance by managing the sensor resources. It can therefore be considered as a decision making task, taking viewpoint from decision theory, determining the most appropriate sensor action to be taken in order to achieve maximum utility. (Xiong and Svensson, 2003).

### 3.6 *Level 5 – Cognitive Refinement*

According to Hall & McMullen (2004) human-computer interaction (HCI) research in the fusion domain has mainly considered interaction between the user and a geographical information display (based on a geographical information system) through menus and dialogs. However, the current research interest in this area is growing, and techniques such as gesture recognition and natural language interaction are currently of interest.

## 4 REMARKS

In this paper there were presented some different systems of the exchanging data among vessels. It contains also descriptions of situations when similar data coming from different systems can cause making wrong decisions. One method which can be used to analyze data in these situations is data fusion method presented above. It is appeared that using technique of data fusion can enable navigator to solve complex problems concerning choosing the most available route of vessel.

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