Information Sharing Concept in Ship Performance Management Systems

Wojciech Gorski, Enamor, Gdynia/Poland, wojciech.gorski@enamor.pl

Abstract

Modern Ship Performance Management Systems (SPMS) automatically collect large amount of diversified data and usually allow access also for users not physically present onboard. Typical scenario for this arrangement is ship crew access onboard and technical office onshore. In a most simple approach both users just have an access to the same dataset. However, providing access to the same data, does not ensure that SPMS efficiently supports vessel operation. Contrary it may easily create user confusion due to huge amount and diversity of data. Paper attempts to present means used to enhance user comprehension of ship data and collaboration between crew and owner office in a context of taking decisions towards ship performance enhancement. Variety of methods including data pre-processing and visualisation, transition of data towards information, information encapsulation, sharing and hierarchy are discussed based on Enamor's SeaPerformer SPMS.

1. Ship data digitalisation

Ship digitalisation is nowadays highly discussed topic. It is expected that process of digitalisation will reshape of maritime industry in coming years. Review of Maritime Transport provided by *UNCTAD (2018)* indicate that digitalisation process will be a key factor in transport optimisation. It however addresses also major threats connected with data safety and security which must be addressed. Report indicates also data sharing as the critical aspect since data transformation between systems is limiting factor for implementation of digital ship concept.

Digitalisation process has been already started by different initiatives described e.g. by *Schmode et al. (2018)* but yet have not converged into universal solution. The process, its tools and methods and data standards will develop and evolve however it is already visible two general approaches. First one is based on relatively low resources hardware onboard dedicated for data acquisition and transfer to cloud server. It has limited capability for instant data processing and visualisation thus is intended for decentralised systems where major processing is on remote server side and therefore rely on continuous data exchange. More traditional approach assumes high processing capabilities onboard which allows for data processing, visualisation and user interaction independent on cloud server. This paper presents SeaPerformer SPMS as an example of latter approach indicating its capabilities for ship digitalisation through support of user comprehension of data and collaboration between crew and owner office in a context of taking decisions towards ship performance enhancement.

2. Data sharing

Typical scenario of data sharing between ship and shore consists of single direction of data flow. Data collected onboard are send to onshore server. This scenario may however result in serious system limitations. It imposes that complete data set registered onboard must be send each time data are exchanged even in case some data are not important in daily operation. In case of data which changes seldom or high resolution data single direction data exchange results in increased data traffic and high demand for onshore server space. Bi-directional communication allows for data transfer optimisation. Some data may be excluded from data set periodically send onshore and kept onboard until they are needed. Such an approach may be efficiently used for data reflecting ship's system condition after failure. Until failure occurs these data do not provide useful information and may be retained onboard without impact SPMS performance. However, in case of failure these data contain critical information with respect to failure diagnostics and system recovery. Bi-directional communication allows onshore user to request specific subset of onboard data whenever needed. In most simple form onshore user may request onboard data based on situation description provided by ship crew. This simple approach requires crew to recognise failure, provide this information to onshore user (technical office, service support) which in turn requests appropriate data set to be send. This scenario may be however automated. SPMS may evaluate specific signals (triggers) as indicators of abnormal situation and, whenever this situation is recognised, automatically request additional relevant data set. This approach has been implemented in Enamor's SPMS system developed for one of the leading marine diesel engine developers. This version of system includes fast signal module which records each engine cylinder combustion pressure and other relevant information (valves positions) as a function of crankshaft angle. In order to maintain constant angular resolution of 0.1 degree irrespectively of engine rpm, cylinder signals are recorded at 10kHz frequency. Resulting data set exceeds few MB per hour of engine operation and is far too large taking into consideration onboard satellite communication restrictions. Therefore fast data set is excluded from data package send periodically to onshore server. High frequency data are kept only in onboard database for some time. Ship crew can use SPMS user interface to evaluate engine combustion signals and in case of need for assistance, select appropriate subset and send it onshore for consultancy. Moreover, SPMS allows remote engine monitoring. For this purpose set of standard engine key performance indicators (KPIs) are calculated based on high frequency cylinder signals for each engine stroke. These KPIs are send ashore and can be evaluated by competent personnel in order to detect abnormal situation. In case KPIs indicate situation which needs more detailed investigation relevant subset of high frequency data can be requested from the ship. Such request is automatically processed by onboard SPMS and appropriate data packed is send in return. Onboard SPMS can be also used for automated engine monitoring. Set of rules based on engine KPIs can be continuously monitored by the system and in defined conditions relevant subset of high frequency data is send ashore without onboard or shore personnel intervention.

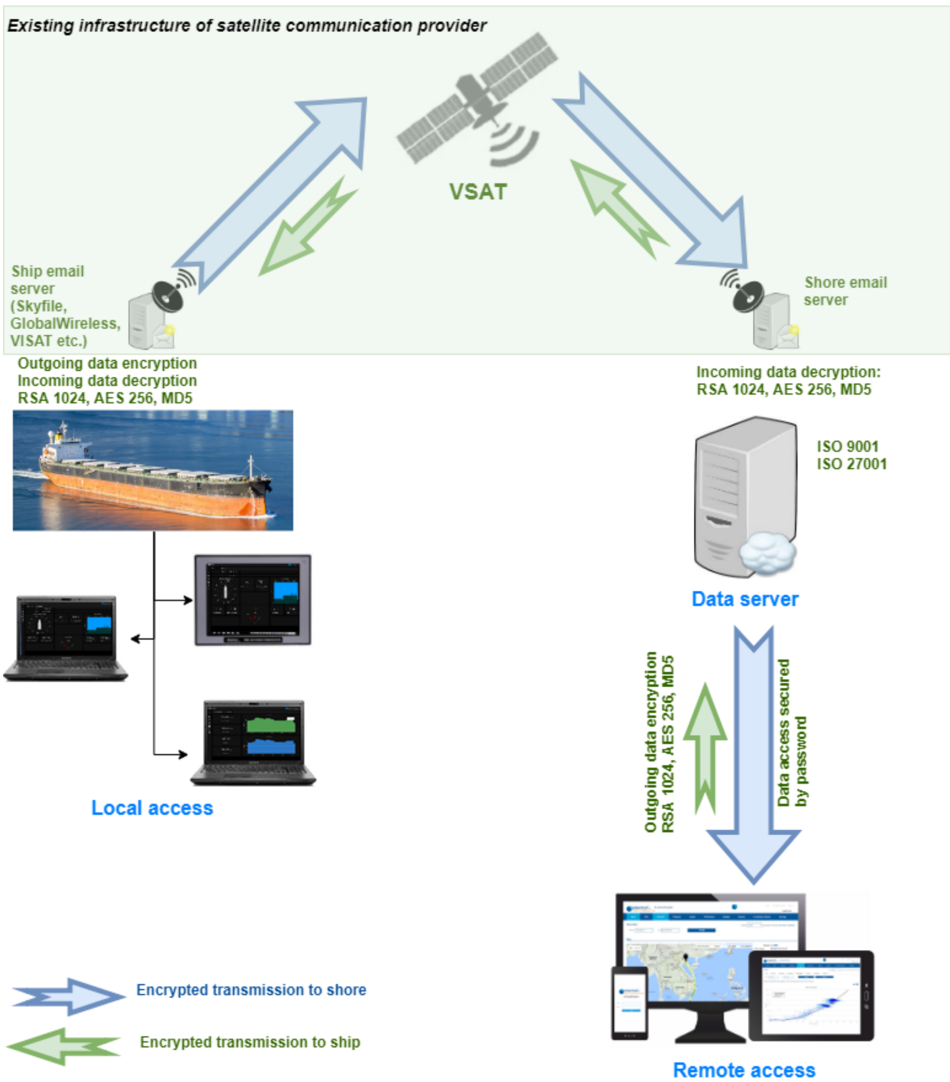

Fig.1: Scheme of data exchange implemented in SeaPerformer

Some of data exchange scenarios described in previous paragraph requires onshore user to interact with SeaPerformer SPMS onboard. Since typically vessels are not online due to limitations imposed by satellite communication systems or owner internal regulations, interaction with onboard system is realised with use of emails. General scheme of data exchange used in SeaPerformer is presented in Fig.1. SeaPerfrormer has been also furnished with remote diagnostic module (RDM) in order to allow safe channel of communication from shore to ship. RDM implements SMTP and POP3/IMAP client for receiving commands with data and sending responses. All the data exchanged with use of RDM are encrypted using combination RSA1024/RSA2048/AES/SHA256 encryption. Regardless the above the additional transport encryption is recommended between endpoints of email transfer. The onboard email clients support SSL/TLS when connecting to relevant server. This way data encrypted at source remains in that state until it reaches the destination. All commands sent to on-board system are encoded and signed. The on-board system checks the received message against the sender address, proper encoding, signature, the age, command syntax. Only verified commands are executed. The execution of commands requires an authorisation command to be executed first. RDM is therefore a great tool for secure remote diagnostic purposes. Onshore user can send onboard a command for SeaPerformer to prepare specific subset of data and send it back for further analyses. Although this feature is extremely useful, RDM can be also used for other purposes. Since, with use of RDM, remote user can get access to local files at authorised paths general operation system (OS) diagnostic can be handled. System or specific application log files can be downloaded from onboard computer and analysed onshore. Based on received information, maintenance commands can be executed remotely. This feature greatly simplifies OS maintenance minimising a need of IT expert’s physical presence onboard. Last but not least RDM allows for remote update of SeaPerformer software. Encrypted and zipped update files can be uploaded onboard and update process can be completed remotely without involvement of ship crew.

3. Visualisation and contextualisation of data

Data visualisation comprise one of prime functionalities of SPMS. It allows user access to recorded data but what is even more important provides context which is required for data interpretation. Visualisation is also a significant tool supporting transition of data into information i.e. makes data understandable for user and helps him taking rational decisions. Taking above into consideration it is largely insufficient to provide user possibility to build graphs with arbitrary data. Usual time trend data plots although provide access to data, may not be very helpful in providing context and building data understanding. Furthermore, building user defined graphs is quite involving and requires sufficient level of experience. Therefore, SeaPerformer provides number of predefined graphs and views which incorporate data pre-processing (i.e. data cleaning and grouping), contextual selection of graphic elements types and blending of data elements. Although these graphs are predefined in order to minimise user effort it allows for certain degree of customisation, especially in case visualisation combines multiple data sources. Good example of this approach is a map view. It provides geographical context of vessel operation by default and therefore helps comprehension of data. It also allows for combination of different data in one consistent view i.e. providing bathymetry or weather data as the supplementary information to ship operational data. This feature is a powerful tool in building understanding of physical processes associated with ship operation. Although map view is very helpful in building context and blending multiple information it does not allow for direct presentation of data values as in case of typical X-Y plots. Therefore, appropriate data representation are used in map view. SeaPerformer map view combines colour coding (i.e. value representation by appropriate colour) for scalar data (i.e. ship speed through the water or engine power), arrow representation for vector data and text boxes for providing direct access to data values. Furthermore, map view can be enhanced with supplementary information such as bathymetry overview, navigation aids or extends of emission control areas (ECA). Such versatile visualisation can be easily overloaded with information and final effect can hinder understanding of presented information. Therefore, in order to facilitate handling of visualisation, map view elements are associated with layers which can be managed by user. This way visualisation can be easily adjusted for the purpose and needs of user.

Fig.2: Different visualisation techniques used in map view

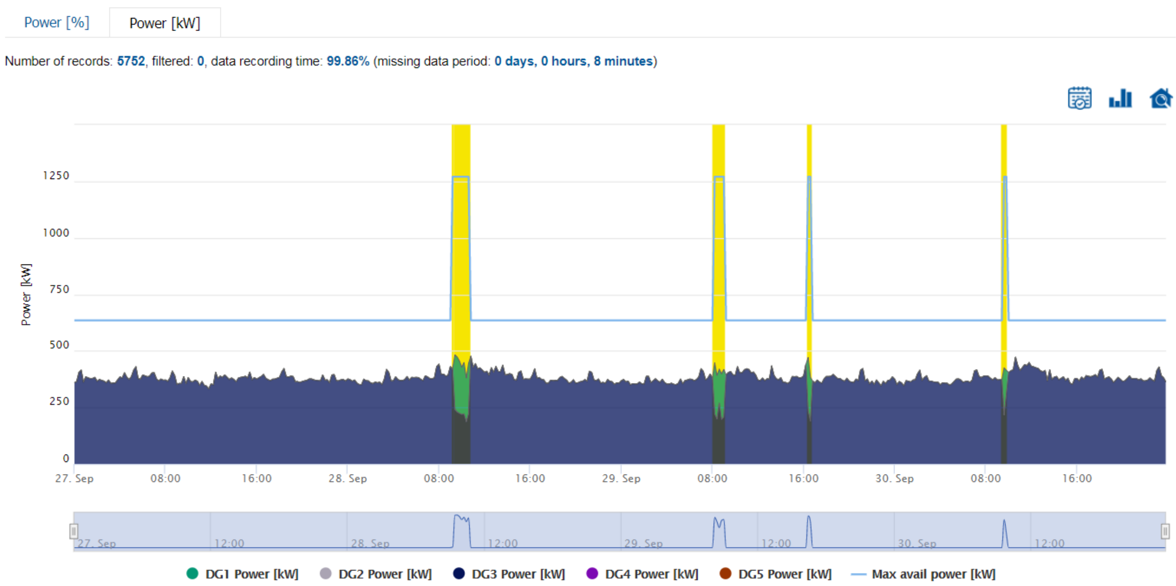

Fig.3: Time graph enhancements supporting data contextualisation

Sophisticated techniques can be also employed in more traditional visualisation such as time trend. This type of visualisation is probably the most common graph used in SPMS systems however in many cases does not sufficiently support user in understanding of presented data. An obvious advantage of time trend is visualisation of signal dynamics and providing easy access to data values either by use of axis and data grid or textual overlay (so called tool tips). Time trend graphs does not readily support visualisation of data which values are not numerical (i.e. binary data or system states) or which range is of different magnitude. Latter may be well handled by multiple Y-axis or re- scaling of data. Non-numerical data visualisation requires special techniques such as use of alternative graph background colour. Enhanced data comprehension can be also achieved by combination of different graph styles. An example of this approach in SeaPerformer is auxiliary engines load graph. This visualisation combines two principal graph styles; stack area graph for representation of individual genset load with colour differentiation of each unit, and line graph for indication of maximum output of gensets in operation. This type of graph is helpful in identification of concurrent use of many gensets resulting in low efficiency and excessive fuel consumption. Graph arrangement supports this task; colour layers identify number of active gensets, stack area graph provide actual output of gensets in operation, line graph define total available output. Large gap between line graph and stack graph identify usage of too many gensets resulting in low efficiency. Inefficient use of gensets is identified onboard and communicated to the crew. In order to illustrate crew response to the warning, time of unnecessary concurrent use of gensets is visualised by colour overlay on a graph. Yellow overlay indicate time span when warning message is presented for the crew until corrective measures are taken (see Fig.3). In case reaction time is exceeded, overlay changes colour to red giving clear visual indication to supervising personnel.

4. Pre-processing

Data pre-processing is an indispensable feature of any SPMS if the system is intended to be capable of transforming data into information. Well known, and already numerously quoted in past editions of HullPIC conferences, term “garbage in, garbage out” emphatically highlights importance of this process. Handling of unverified data which may include errors, data gaps or data context misinterpretation will lead to false conclusions. While, to certain extend, data reliability problems can be overcome by experienced user who based on his past knowledge, abstract thinking and problem generalisation can detect, neglect or regenerate problematic dataset, automatic handling of improper data pose serious challenge. In SeaPerformer development of data pre-processing mechanisms is treated as key feature. Some of advances with this respect have been already presented in past edition of this conference by *Gorski (2017)*. These concerned data redundancy and regeneration. Both techniques address problems of data gaps or identified false readings. However, very often reliable identification of data failure became a challenging task. Onboard equipment used as data source seldom provide self-diagnostic features and does not deliver clear identification of malfunction (e.g. failure flag) which may be automatically interpreted by the SPMS. Except obvious case of data gap (i.e. system reads NULL signal from a data source) identification of corrupted signal is a difficult problem which requires implementation of advanced processing techniques usually taking into account context of analysed signal. In order to clearly explain these difficulties two practical examples are discussed in details. Both concerns vital signals for performance evaluation. First example concerns ship static draft which is important for determination of vessel operation condition and is crucial in evaluation of required engine power. Static draft fore and aft is used to determine actual ship trim (her longitudinal inclination with respect to water plane) which is essential for trim optimisation. Secondly rudder deflection signal is discussed. This signal is used for identification of ship manoeuvring and allowing appropriate engine power correction to reference conditions.

Static draft can be read directly from ships loading computer (LC) however interfacing LC is sometimes challenging. In case LC is not available static draft can be determined with use of draft sensors i.e. pressure sensors scaled according to static head of the water and corrected for sensors position with respect to ship bottom. Draft sensors readings shall be however treated with caution since they are vulnerable to dynamic changes of pressure due to water movement with respect to ship hull. Furthermore ship changes her position at speed with respect to water plane (dynamic trim and sinkage) which impacts draft sensor readings as well. Therefore static draft can be read with use of draft sensors only at ship rest (in port after loading and ballasting procedure is completed). Obtained value shall be retained in SPMS and used until next port call. This method can provide practical information unless major ballasting operation is performed. If re-ballasting is done during sea voyage use of this method e.g. for trim determination is misleading and additional data input such as trim inclinometer is required. As explained above determination of such basic parameters as ship static draft and trim may be quite complicated in practical operational conditions. It requires special approach which includes data sources redundancy and special processing. However, in order to reflect reality of ship operation it must be noted that draft signal reliability often pose a serious problem. Author experience in use of draft data collected on more than 200 vessels of various type and equipment reveals frequent problems with draft sensors. These sensors are prone to failure providing awkward results which, if not recognised, may lead to problems in performance analyses or trim optimisation. It is often observed that draft sensors after failure continue to provide data. Therefore, most common and simple detection of malfunction by recognition of lack of data may not be sufficient. However, since draft signal after sensor failure changes its properties i.e. often exhibit lesser sensitivity and shift, failure detection based on data processing may be effectively used. For the purpose of draft sensor malfunction detection is based on parallel evaluation of four draft sensor signals (fore, aft, midship portside and starboard) and speed over ground signal. Detection algorithm works in two variants depending on ship speed. At higher speeds only signal lost or rapid shift uncorrelated with speed on any of single draft sensors is detected. At lower speeds above method is supplemented with calculation of hull trim, list and longitudinal deflection. Values obtained based on draft sensors are compared with typical operational ranges which allows for detection of possible failure. Algorithm automatically recognises port operations during which only signal continuity is verified.

Another signal which often poses difficulties in operation is rudder deflection. This signal is important since allows for detection of dynamic states during ship manoeuvres and thus enable proper signal filtering for performance analyses. Rudder deflection is usually taken from synchro transmitter/receiver as the analogue signal or, in modern equipment, already converted to digital NMEA format. Rudder deflection is often subject of errors, especially in case of analogue signal transmission. The most straightforward in processing is signal lost however often situation is more complicated. It has been observed that many cases rudder deflection transmitter continue to provide data but with significant error. Two types of erroneous signal patterns have been observed: signal stall and signal shift. Signal stall results in almost steady (sometime small oscillations can be observed) signal irrespectively of actual rudder deflection. Signal shift is characterised by appropriate reproduction of signal gradient but rudder neutral position is not preserved. It is important that SPMS is able to recognise not only rudder signal lost but also other errors. For this purpose, it should be able to continuously process data during acquisition process. SeaPerformer implements appropriate algorithms for detection of rudder signal stall and shift. Due to nature of these errors stall recognition algorithm works in shorter time window and offset in longer time window. Stall of rudder signal is recognised based on standard deviation. Small value of standard deviation indicates an error. Rudder signal offset error determination is based on 3% quantile calculation at extreme ends of signal distribution. Large value of quantile suggests problem with data source. Error determination based on statistical quantities proved to be efficient approach (see Fig.4) comparing to method based on signal comparison with expected range of signal variation since it copes also with signal having false analogue to digital scaling factors.

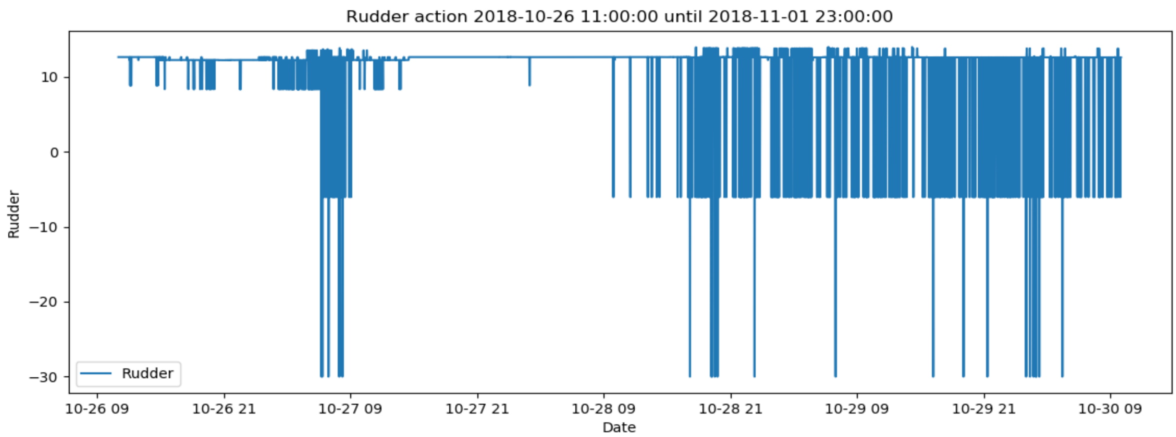

Fig. 4 – Erroneous rudder signal identified by signal processing module

As it has been highlighted in above examples, verification of signal quality and detection of possible data source malfunctions may involve special computational methods. It is usually not sufficient to relay on current value of signal or signal gradient. Due to scattered nature of signals registered onboard signal pre-processing is necessary. These methods include moving window averaging and statistical calculations (e.g. standard deviation and quantile calculations) on data subsets ranging from dozen of minutes up to couple of days. Data processing may apply to several thousands of records and therefore could be computationally demanding. It shall be noted that signal verification supposed to be realised in parallel to data acquisition and visualisation therefore it must be taken into account in SPMS hardware resources, mainly computing processor and memory.

5. Encapsulation

Data encapsulation, also known as data hiding, is a term used in programming and means mechanism whereby the implementation details are kept hidden from the user. In a context of SPMS it can be useful technique which simplifies user interaction and presentation of information. SeaPerformer system utilises encapsulation both in onboard and in web applications. System notifications can be taken as an example where this technique is employed. Onboard software processes multiple signals according to specific algorithms in real time. On this basis system detects situations which require ship crew action. However instead of presenting relevant signals system encapsulate them into warning symbol (bell icon as presented on Fig.5) and guidance information. This method allows to focus crew attention and minimises time to take necessary actions. Web application also uses encapsulation in case of system notifications but in different way comparing to onboard software. Instead of using bell symbol, warning information is encapsulated on ship track using colour. Yellow or red colours denote part of the voyage where unwanted situation occurred. This method allows for quick warning identification and at the same time provides larger context through map view.

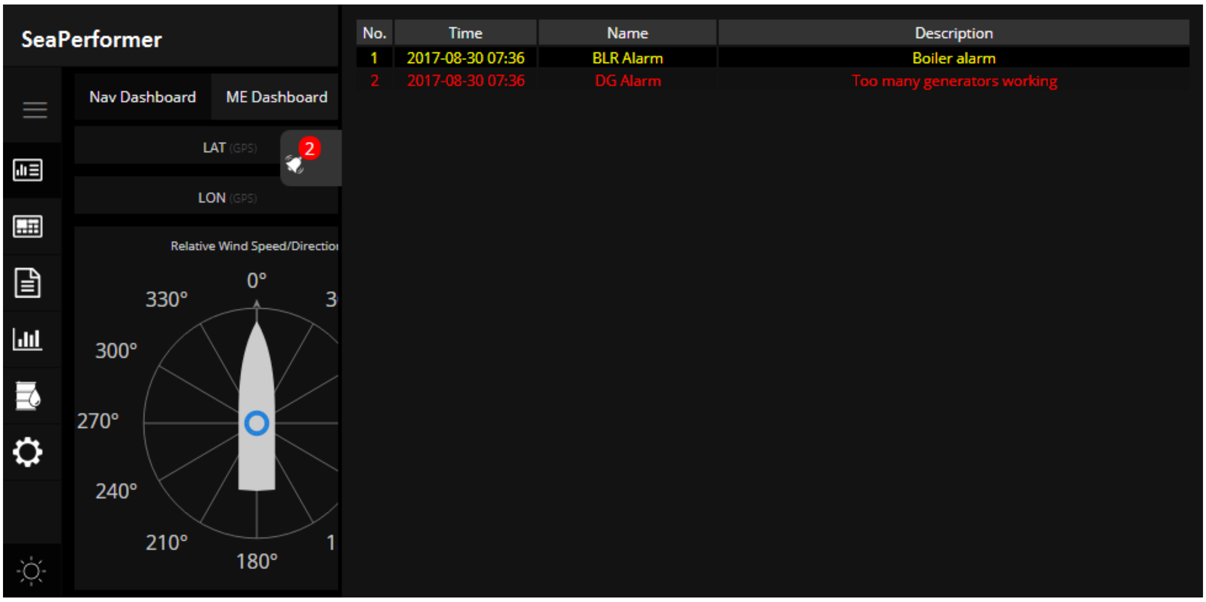

Fig.5: Information encapsulation in onboard application

6. Data hierarchy

Trim optimisation provides an interesting example of data hierarchy concept application. Ship hull trim is an important factor with respect to fuel consumption. Depending on hull form, selection of favourable trim setting may result in 3% to 8% savings in fuel consumption comparing to situation when trim is selected only with respect to stability and strength criteria. Due to complicated hydrodynamic phenomena of flow around hull geometry optimum trim vary with ship speed and draft and cannot be determined with use of simple methods. Traditionally hydrodynamic model tests performed in wide range of speed, draft and trim were employed for this purpose. For each combination of speed and draft, impact of trim on hull resistance or ship propulsive power was determined. Continuous interpolation of test results constitute a reference model upon which optimum trim can be determined during ship operation. Physical model tests can be nowadays substituted with methods of computational fluid dynamics resulting in lower costs and time of the reference model determination process. Another promising method for reference model elaboration is utilisation of operational data but this approach involves sophisticated data cleaning techniques and may be limited by range of parameters at which vessel is operated. Irrespectively of the reference model origin the method of optimum trim determination is the same. Initially vessel speed through the water, static draft and trim shall be determined. Local surrounding of operational parameters is searched for better solution (usually search is done for trim only while speed and draft is kept constant). If substantial improvement is recognised trim change is recommended. It must be emphasised that trim optimisation process is highly dependent on proper recognition of actual operation parameters. In case speed, draft or trim is determined inaccurately it will influence a starting point of optimisation and thus also final result. Unfortunately, it is difficult to determine all of important parameters for the process. Problems of accurate determination of speed through the water has been already discussed e.g. *by Bos (2017)* but also in case of draft and trim their proper identification is sometime challenging. It should be noted that usually reference model for trim optimisation is based on static draft and trim while direct measurement of draft (and recalculation of trim) by draft sensors provides dynamic parameters. These values may differ substantially especially on higher speeds where dynamic trim and sinkage effects are pronounced. Furthermore, as already discussed in previous chapter, draft sensors are sensitive for dynamic pressure around the hull. These effects may falsify readings especially for bow sensors. In order to counteract mentioned problems SPMS may use multiple sources of data arranged in hierarchy of accuracy and reliability. SeaPerformer uses following sources for draft and trim determination:

a) loading computer,
b) draft sensor readings in port corrected for actual trim measured by ship inclinometer,
c) direct draft sensor readings at speed corrected for actual trim as in b),
d) direct draft sensor readings uncorrected for dynamic effects.

Static draft and trim shall be determined with use of loading computer. Accurate modelling of hull and internal compartments allows for determination of draft with error less than few cm. However, LCs are usually separated systems, difficult to interface with. Furthermore, even in case SPMS is connected to LC data exchange must be initiated by LC user which is often forgotten. For this purpose, in parallel to LC data SPMS reads and process data from draft sensors. SeaPerformer monitors draft readings during port operations and retains values at the completion of loading operations (final static draft at departure). Static draft may however change during voyage i.e. due to ballasting operations which may not be easily recognised since draft sensors are burdened by dynamic effects. In order to take account for these effects ship inclinometer is used. During ship voyage inclinometer measures dynamic trim. This may be however recalculated to static value based on reference model (it must contain both static and dynamic trim). In case actual dynamic trim is outside of reference model range and cannot be recalculated to static value, SPMS can use directly draft sensor readings as they were static ones. The latter is the less accurate method and shall be only used at low speeds where dynamic effects are not pronounced.

6. Conclusions

As indicated in the introductory note there are two general approaches differing in allocation of computational resources. Preceding paragraphs illustrate important features of SPMS which increase data comprehension and supports operational decisions resulting in improvements of ship performance. Irrespectively of the SPMS concept these features shall be incorporated as they are vital for achieving required functionality. Both concepts theoretically allow supporting data pre-processing and visualisation, transition of data towards information, information encapsulation, sharing and hierarchy. It must be however confronted with existing ship data transfer infrastructure. Nowadays majority of vessels do not support data streaming. Data are sent in packages and therefore data processing on cloud server is delayed by data exchange period. It is serious limitation especially in case of signal pre-processing with respect to possible data source malfunctions. Cloud server-side processing makes it necessary that results shall be send back onboard in case they require crew attention. This scenario therefore increases data transfer which is nowadays critical due to costs. Taking this into consideration solution which secures sufficient computing resources onboard reveal certain advantage until satellite communication enables data streaming on reasonable costs.

Ship Performance Management Systems can effectively support increase of vessel operation effectiveness thus enable cost savings and lower environmental impact. However, in order to take full advantage of the system it must incorporate features that enhance user comprehension of ship data and collaboration between crew and owner office. These important features include data pre-processing and visualisation, transition of data towards information, information encapsulation, sharing and hierarch which were in details discussed in this paper. Available data transfer technology implies that solution allowing for local, onboard data processing pose advantage.

References

BOS, M. (2016), *How MetOcean Data Can Improve Accuracy and Reliability of Vessel Performance Estimates*, 1st HullPIC Conf., Pavone

GÓRSKI, W. (2017), *Automatic MRV Reporting with Use of Onboard Performance Management Systems*, 2nd HullPIC Conf., Ulrichshusen

SCHMODE, D.; HYMPENDAHL, O.; GUNDERMANN, D. (2018), *Hull Performance Prediction beyond ISO 19030*, 3rd HullPIC Conf., Redworth

UNCTAD, (2018), Review of Maritime Transport 2018, https://unctad.org/en/PublicationsLibrary/rmt2018_en.pdf