

Timestamp Discrepancies in Multisensor NMEA Environment during Survey Voyage

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Key words: marine electronic devices, information, reliability of data, navigational data, survey voyage

Abstract

The standard for interfacing marine electronic devices (NMEA – National Marine Electronics Association), does not provide unambiguous information regarding the reliability of data and its timing. In this paper, time delays in navigational data are investigated. For this purpose AIS and navigational data collected offshore and onshore are used. The investigations are concentrated on lags among various NMEA sentences recorded in a relational database during the survey voyage. The analysis is based on standard elements of descriptive statistics.

Introduction

Digital technology has an impact on every sector of world economy. Maritime traffic systems are no exception. As the computerisation of vessels continues, operating a fleet nowadays is less of a slow and easy crossing the oceans and more of a managing data and racing against time. This has led the International Maritime Organization (IMO) to define the e-Navigation strategy. Its aim is “the harmonized collection, integration, exchange, presentation and analysis of marine information on board and ashore by electronic means to enhance berth to berth navigation and related services for safety and security at sea and protection of the marine environment” [1].

High level application user need recognised by this strategy is the provision of integrity information describing the current usability of sensors, services and data. Nowadays integrated navigation systems on board vessels operate in a multisensor environment. In case of a combined use of data coming from various sources, it is important to determine a temporal validity of data, in order to make it usable in data fusion processes applied to evaluate the integrity of data products, as well as navigational systems in real time.

For many years NMEA has been the standard for interfacing marine electronic devices. It has

served its purpose well, because officers of the watch have worked with data on a visual perception basis. In the age of digital data processing the need for unambiguous information with assessed reliability grows. Furthermore, time attributes of data are often missing, and only their simple temporal synchronization is feasible. Therefore, it is important to investigate time delays in navigational data and to analyse their impact on surveying and assessment of the traffic situation. If lags among various NMEA sentences generated by the shipborne equipment are better understood, the most probable time delays can be applied during data fusion, thus helping the system reach proper synchronisation and error awareness.

Concept

Current research activities of DLR’s Institute of Communication and Navigation concentrate on the development of algorithms and techniques, which are able to provide integrity information describing the current usability of sensors, services and data used in the maritime traffic system. In order to collect appropriate navigational data, which the integrity processors can be fed with, it is necessary to complete parts of the project under real world conditions at sea. So, a practical measurement concept is necessary to proceed with the investigation of

time delays in navigational data. All data streams available on the bridge conform to the NMEA standard. They form a data exchange network, which enables different sensors on board to share their readings.

By attaching our own voyage recording equipment to various output nodes of the bridge network, it is possible to use a chain of serial port converters and to acquire NMEA data over Ethernet. The live data storage is controlled by a piece of software interfacing with SQLite database management system. The data chunks are stored as database records and timestamped in nanosecond resolution. In order to maintain stable timing throughout the whole survey voyage, the recording system is synchronised over local area network with a GNSS receiver running a network time protocol (NTP) server. The following diagram shows the onboard setup of the voyage data acquisition.

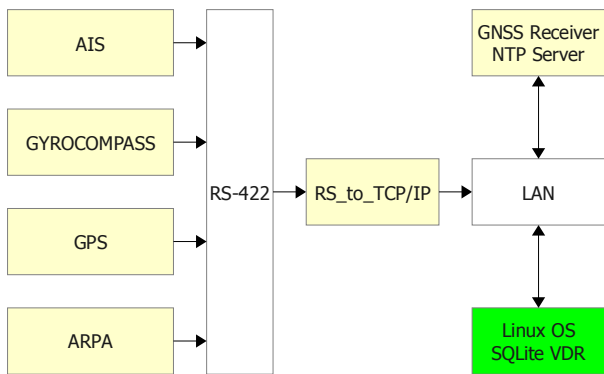


Fig. 1. The onboard setup of the voyage data acquisition

Besides assigned offshore data storage, it is necessary to have an insight into the overall traffic situation, with our survey vessel being one of the participants, as seen from onshore point of view. In order to accomplish this, similar data recording configuration is activated at the DLR onshore reference station in Rostock. It allows collecting and storing the AIS data transmitted by vessels operating in the Warnemünde VTS Area. The timestamp information is retrieved from a GNSS receiver running an NTP server. The following diagram shows

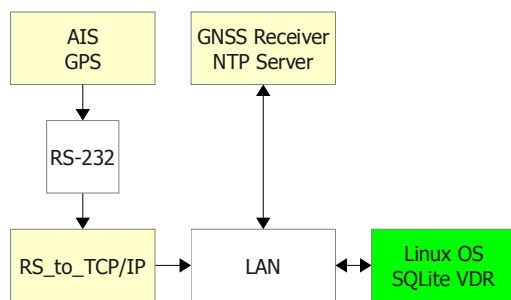


Fig. 2. The onshore station setup of the AIS traffic data acquisition

the station setup of the AIS traffic data acquisition.

With the above configuration it is possible to conduct a measurement campaign at sea and have a synchronised collection of data streams, which will serve as groundwork for analysis of timing discrepancies in multisensor NMEA environment.

Analysis

VDO versus VDM

A VDO sentence is a data package compliant with the NMEA standard and part of the Automatic Identification System. It contains a complete navigational dataset of own vessel, the copy of which is broadcast to other vessels over VHF by AIS transponder in form of a dynamic message packet. The data within VDO sentence is encapsulated according to the ITU R M.1371 specification. The VDO sentence is used internally and is output through a so-called pilot plug interface. It allows connecting an external chart plotter to the bridge network and visualisation of own position, course and speed.

A VDM sentence is identical to the VDO one in terms of data payload structure. The only difference is that VDM datagrams are output by an AIS receiver and contain dynamic navigational data of all vessels equipped with AIS transponders, which are within the radio range of the receiver.

During the survey voyage on board BALTIC TAUCHER II the VDO sentences generated by her AIS transponder were timestamped and recorded in the database. The same navigational content was broadcast over AIS link at the same time. The AIS receiver based at the onshore reference station in Rostock captured that data, timestamped and stored it in the local database in form of VDM sentences.

After joining both databases by using the values of time common to each, it was possible to find duplicates of dynamic data originating from our survey vessel and to query the timestamp differences between them. The following histogram shows the results of this analysis, computed with 5407 records.

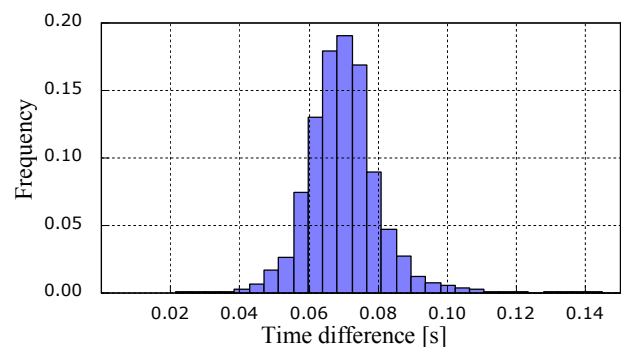


Fig. 3. Timestamp differences between the acquisition of VDO and VDM

As indicated on the chart, about 19% of all AIS dynamic messages from BALTIC TAUCHER II reaching the reference station in Rostock are delayed by 0.07 s, compared to the datagram creation timestamp on board. About 92% of observed time delays can be found in range between 0.05 s and 0.09 s. The rest of the cases are negligible due to their low occurrence. The delays around 0.07 s could be caused by the processing time needed to convert radio transmitted data into a usable NMEA compliant plain text format, as there is some computing power involved in the process. However, a precise assessment of the internal computation timing is beyond the scope of this research.

Acquisition of offshore VDM versus onshore VDM

During the survey voyage, the AIS data received from other vessels by onboard AIS transponder was timestamped and recorded. It led to creating a collection of VDM sentences describing the traffic situation in proximity of BALTIC TAUCHER II. At the same time the onshore reference station in Rostock acquired and timestamped the AIS data from the vessels navigating in the area of Warnemünde and approaches. As long as the radio ranges of both the survey vessel and the station overlapped, identical AIS dynamic messages could be obtained at both locations. Both databases were joined afterwards. The timestamps of duplicate VDM sentences were queried and their time differences were calculated. The following histogram shows the results of this analysis, computed with 103 337 records.

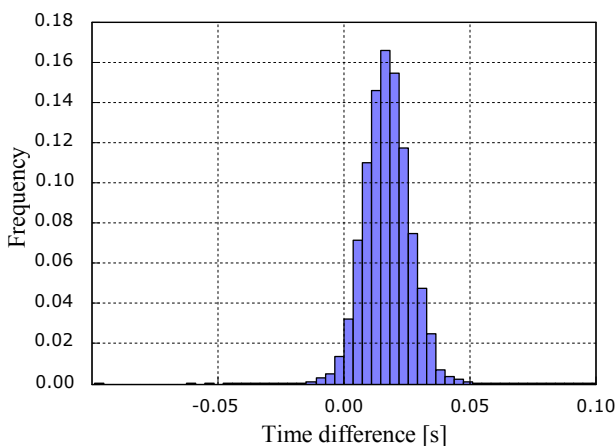


Fig. 4. Timestamp differences between the acquisitions of offshore VDM and onshore VDM

About 17% of VDM sentences received at the onshore reference station have a time delay of 0.016 s, compared to the shipborne acquisition of the same VDM data. In the majority of cases the time difference between the moments an AIS

dynamic message reached the station in Rostock and the survey vessel is positive, because during a deep sea voyage BALTIC TAUCHER II had more vessels in her AIS vicinity than the number of vessels moored in Rostock, and could receive their data first due to shorter distances. Moreover, as it is possible to relay the AIS dynamic messages via base stations in order to artificially increase their range, the time they needed to reach Rostock might have slightly prolonged. As the histogram shows, only about 1.7% of VDM transmissions reached the onshore station earlier than the AIS sensor on board the survey vessel. This could also be explained by a smaller number of vessels made fast in Rostock, compared to the number of those at sea, and their proximity to the reference station.

RMC timestamp versus database timestamp

The data recording software running at the onshore reference station in Rostock was capable of storing not only AIS data in form of VDM sentences, but additional NMEA data, too. The AIS receiver, used there as a data source, had an internal GPS positioning module, which could output NMEA compatible RMC sentences. The RMC format contains position, course, speed, and additionally UTC date and time, all available in plain text. It is possible to compare the RMC timestamps originating from the GPS receiver with the NTP synchronised database timestamps indicating the moment RMC sentence was inserted as a new database record. The following histogram shows the results of this analysis, computed with 46 858 records.

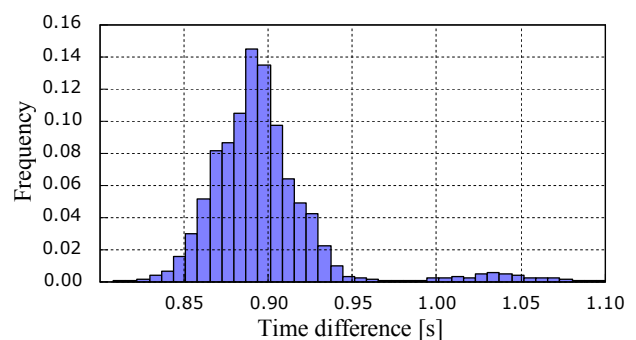


Fig. 5. Timestamp differences between the UTC of the RMC sentence and its database entry time

In about 14% of all cases, the RMC sentences were timestamped by the database time reference with a delay of about 0.89 s, compared to the time epoch indicated by the RMC time and date information. Another peak visible on the histogram marks all time delays of about 1.03 s. They occur within 1% of all analysed time differences. The

nature of the second delay cannot be explained straightforwardly. Since the AIS receiver processes and outputs a mixed set of NMEA and AIS data parallelly, it cannot be ruled out, that some elements of its internal software may contribute to interruptions of service, which could cause slightly longer time delays.

TTM timestamp versus database timestamp

One of the crucial tasks undertaken during the survey voyage on board BALTIC TAUCHER II was storage of TTM datagrams generated by her radar equipped with ARPA. The TTM stands for “tracked target message” and is used to output information about distance and bearing to an acquired radar echo. Every TTM sentence contains a UTC time, which indicates the moment, at which all data enclosed within a TTM datagram was calculated by the ARPA module. The TTM data is fed into ECDIS, which can overlay tracked radar targets on a nautical chart. Amid the measurement campaign the TTM data was timestamped and stored in the database aboard. Therefore, it was possible to compare the ARPA timestamps with the timestamps generated at the moment an end user received the data. The following histogram shows the results of this comparison, computed with 63 210 records.

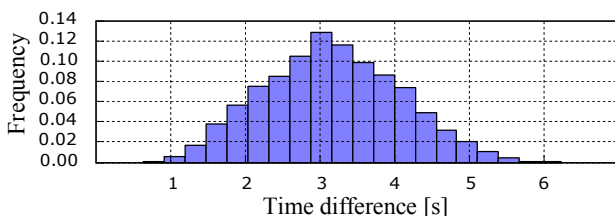


Fig. 6. Timestamp differences between the TTM sentence and its database time

In most cases the expected time delay of TTM data oscillates at around 3 s. However, this is represented by only 13% of all observed time differences, because they are triangularly spread over a time span of five seconds. Various reasons could have caused such distribution of time delays. In the course of the survey voyage two explanations are distinct enough to provide some interpretation of this histogram.

First, the onboard ARPA does not have its own source of time information, be it an internal GNSS receiver or any other suitable clock hardware. That is why it has to rely on an external timestamp feed, which is provided in form of an NMEA data stream wired to a GPS receiver. The time data transfer and its processing may introduce additional delays into the process of providing TTM data to other sensors. A good example of this type of GNSS timestamp

deferral is the analysis of RMC message delays mentioned previously.

Second, as it is impossible to output the TTM data of all radar targets at once, the data has to be output stepwise in small groups of TTM sentences. Every TTM datagram contains the parameters of one single ARPA target. The number of tracked radar objects and the speed of serial data connection may contribute to a noticeable time delay, before all computed TTM sentences are transferred to an end user.

AIS base station timestamp versus database timestamp

The AIS equipment on board the survey vessel and at the onshore reference station in Rostock was capable of receiving the AIS base station reports. Those messages contain geographic position of the broadcaster, UTC date and time, as well as its current radio slot number. According to the ITU specification, “mobile stations, which are unable to attain direct or indirect UTC synchronisation, but are able to receive transmissions from base stations, should synchronise to the base station” [2]. The AIS base station reports, marked “ID 4” in the specification, were timestamped and inserted into the database both at sea during the survey voyage and ashore at the reference station in Rostock. It was possible to compare the timestamps encapsulated in the base station VDM message with the internal database time of the recording software. The following histogram shows the results of the time delay analysis of AIS base station data retrieved on board BALTIC TAUCHER II at sea, computed with 4103 records.

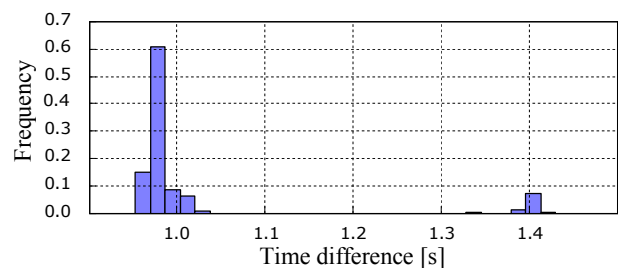


Fig. 7. Timestamp differences between AIS base station time and database time on board the survey vessel

The most frequent time delay occurs at 0.97 s and is common to about 61% of all analysed timestamp pairs. As the distribution shows, the prevailing part of time delays is shorter than 1 s. Another noticeable delay is located at 1.4 s, where about 9% of time delays are placed.

The histogram of time delays, which depicts the timing of AIS base station data recorded at the onshore reference station in Rostock and computed

with 7642 records, is similar to its offshore version above.

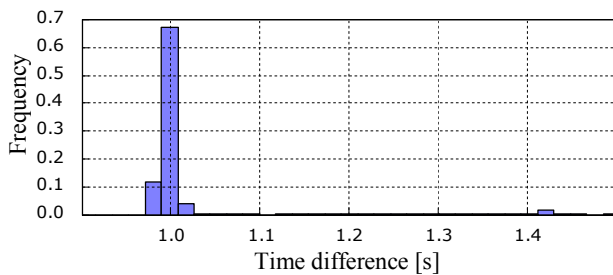


Fig. 8. Timestamp differences between AIS base station time and database time at the onshore reference station in Rostock

As the distribution plot indicates, about 67% of all recorded AIS base station reports are stored in the database with a delay of 1 s. In other words, a timestamp received from the AIS base station is one second old in reference to the NTP synchronised database time. Only 1% of all registered base station messages are delayed more than 1.4 s, which is less than the frequency of it observed at sea.

It is noticeable, that the distribution of delays computed both at sea and onshore has a significant degree of similarity. As the prevailing delay of 1 s seems to be reasonable, the second peak around 1.4 s occurred in both cases, although the AIS devices used on board BALTIC TAUCHER II and at the reference station in Rostock were not identical. This might suggest that the additional delay of 1.4 s may have been caused by the recording software or hardware, which was the same at both locations.

Conclusions

The time delays among various NMEA sentences were analysed, using a statistical approach. The data was collected on board the offshore supply vessel BALTIC TAUCHER II and at the onshore reference station at the Research Port of Rostock. In order to acquire the AIS data (VDO and VDM sentences), which were needed for the analysis, it was necessary to store the AIS transmissions both aboard and ashore. An experimental setup described in section *Concept* made it possible to store additional data, like navigational information, on the bridge. With the databases it was possible to compare time delays

between the dataset pairs: offshore–onshore, offshore–offshore and onshore–onshore.

The data analysis in section *Analysis* has shown, that the lags observed in the NMEA data recordings follow statistical distributions, which contain distinguishable ranges of time delays marked with clearly discernible frequencies of occurrence. The time difference between the acquisition of the VDO message stored on board and the VDM message stored offshore is at the order of about 0.07 s. The analysis showed that the most probable time delay was approximately 0.016 s after it had been sent.

The timestamp of the AIS message received at the base station was delayed by about 1 s, when compared to its reception time. The above results confirm that the time delays of AIS data received offshore and onshore are small and have negligible influence on creating inconsistent assessment of the traffic situation.

In case of navigational data acquired on board BALTIC TAUCHER II, the time delays of TTM sentences generated by ARPA were analysed. The most frequent lag oscillated at about 3 s. Considering the inability of the radar software to output all tracked targets at once, especially in dense traffic areas, this time delay does not have negative effects on safety of navigation and should be expected in the majority of ARPA–to–ECDIS links.

Additionally, a mixed data output was analysed at the onshore reference station using AIS receiver with GPS positioning module, which could generate RMC sentences. The most frequent time delay of RMC timestamps measured at the station was about 0.89 s. The value is not significantly high, but systems using RMC as their source of UTC should be aware of the lag.

The results of this study will support further research activities related to the sensor data fusion. Determining the most probable time delays in NMEA data and identifying their patterns can improve overall synchronisation and error awareness of the fusion processes.

References

1. IMO NAV54/25 Annex 12.
2. ITU R M.1371 4.