CHARACTERIZING THE AIS DATA OF PORT TUGS IN THE PORT OF BARCELONA

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Keywords

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Abstract

Tugs are an important part in port activity and navigational safety issues. Port tugs ensure the safety of large vessels while they are entering, maneuvering, mooring and unmooring, and are of huge importance during other port operations. They are also used for other important port functions and activities, such as fire protection and search and rescue operations. To achieve efficient tug operations, investigating the features of tug activities is of crucial importance. This study aims to characterize Automatic Identification System (AIS) data for further maneuver services identification and characteristics analysis of tug activities in harbor areas.
The AIS data from seven tugs in the port of Barcelona, Spain, in March 2023 were characterized for future identification of maneuvers. The finding of this research will help to improve the planning, timing, and assessment of tug services for docking and undocking vessels and evaluation of tug fleet operation. In this study, Speed Over Ground (SOG), Navigational Status of tugs (NS), ping frequency and data gap information on different variables are analyzed. Initial findings describe SOG ranging from 0-13 knots and a scattered use of the NS definition throughout the fleet. Ping frequency and data gaps are also initially described depending on the variable and the outcomes indicate that it relies on external factors such as the equipment used, technical issues, human factors, and dense traffic etc. Hence, investigating the attributes of tugboat operations can enhance the efficiency of tugboat fleets in port areas.

1 INTRODUCTION

Safe operations are very important to the normal functionality of ports. Among the most difficult operations in ports are ships entering ports, mooring and unmooring operations, where the tugs are of the utmost importance. Port tugs assist ships using the port channels, maneuvering of ships turning at basins, shifting to and from quay walls. Today, the tugs operated in ports are of a different type and capacity and mostly depend on ship size and port-external conditions (wind, waves, current and shallow water) [1].
The main risks at ports, which are pointed out by some authors [2, 3, 4] can be classified as follows: poor ship and port staff knowledge and training; the human factor in general; poor maintenance of port tugs; poor communication between all players during a ship's arrival at or departure from the port, as well as mooring operations (in the case that the ship's crew, port pilot and tugs masters communicate in different languages); poor or outdated tug equipment; poor safety culture, etc. By making an efficient tugboat schedule, the tugboat operator can reduce energy consumption and large vessels' waiting time. The efficient operation of tugboats requires an in-depth understanding of the characteristics of the maneuver services [5].
To identify vessels in maritime navigation, Automatic Identification System (AIS) is used. The AIS is a maritime navigation safety communications system, standardized by the International Telecommunication Union (ITU), and adopted by the International Maritime Organization. Their objectives for implementation of AIS are to enhance safety and efficiency of navigation, safety of life at sea, and maritime environmental protection. The motivation for adoption of AIS was its autonomous ability to identify other AIS fitted vessels and to provide extra precise information about target ships that can be used in collision avoidance. It has the ability to detect other equipped targets in situations where the radar detection is limited in conditions of restricted visibility by fog, rain, etc. AIS data comprised of three information: static data (information on ship characteristics), dynamic data (information on ship position and movements) and voyage-related data (information on a current voyage) [6].
This study aims to use AIS data to characterizing port tugs. The AIS data from seven tugs in the Port of Barcelona, Spain, in March 2023 are used as the case study. This is the preliminary study needed to start characterizing the tugs maneuvers to be able to later compute their fuel consumption and Greenhouse Gas (GHG) emissions.

2 STUDY CASE

Barcelona is located at West Mediterranean, Balearic Sea in Spain. Geo-spatial data used herein is the AIS data acquired through a Class B-AIS antenna (SeaTraceR AIS Class B Transponder S.287) located at the Barcelona School of Nautical Studies in Barcelona, Catalunya. The height of the antenna is 17 m above sea level and the average height of the antenna on an average container vessel is around 85-90 m. Thus, the AIS system is able to provide stable reception in a range of about 50 nautical miles (nm), with the maximum range being 120 nautical miles, weather permitting, see Figure 1.

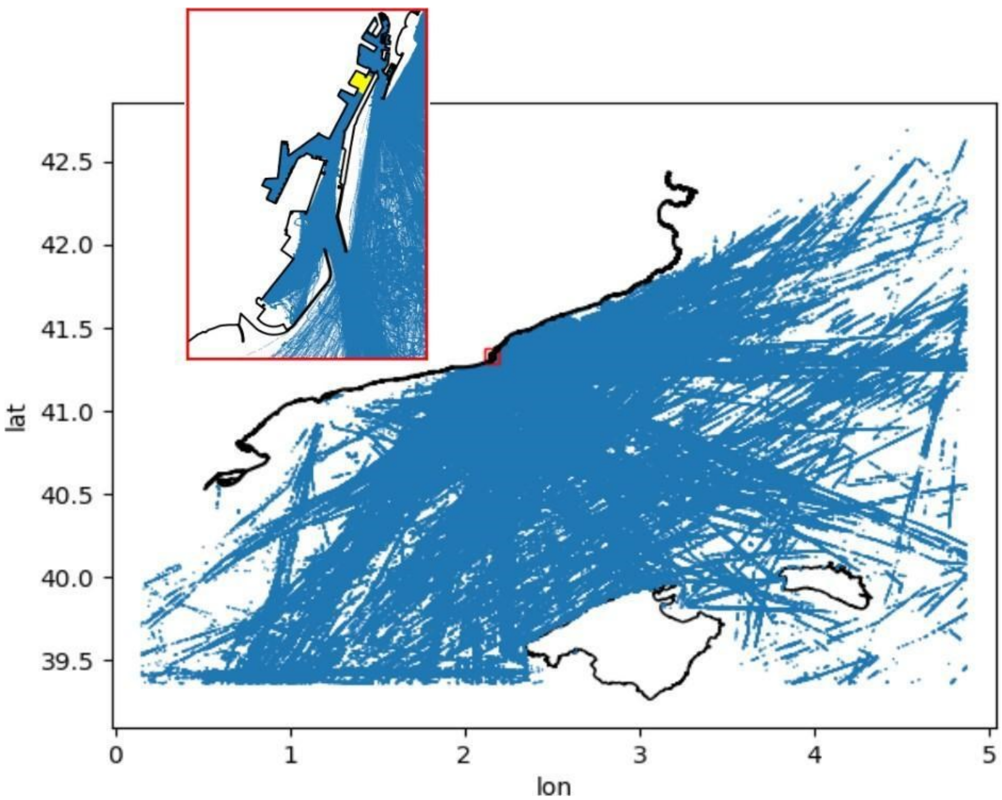

Figure 1. AIS data recorded by the Class-B AIS antenna located at the vicinity of the Port of Barcelona in March 2023.The port has 7 tugs officially operating in the area. Table 1 shows their names and characteristics values. Upper right figure presents

More than 10e + 6 AIS data from seven tugs in the port of Barcelona in March 2023 were analyzed. All of them are sailing under the flag of Spain and their characteristics can be found in Table 1.

Table 1. Characteristics of port tugs in the Port of Barcelona.

MMSI	Shipname	Length Overall (LOA) (m)	Vessel Type Detailed	Year Of Construction
225991180	Azabra	27	Tug	2020
224026000	Cala Gullo	31.5	Fire Fighting Vessel	2016

224746000	Cala Sequer	31.5	Fire Fighting Vessel	2017
224339000	Cala Verd	32	Fire Fighting Vessel	2020
224350720	Eliseo Vazquez	27.55	Tug	2008
224271630	Montbrio	29.5	Tug	2007
225394000	Willy T	27.55	Tug	2009

3 METHODS

Ship trajectory information is an ideal data for studying ship motion patterns and understanding ship behaviors. AIS data including frequency pings, status, MMSI, longitude, latitude, speed, turn, course and heading were analyzed. In this paper, we used Python 3.10.9 and the Jupyter Notebook 6.5.2 as the main tools for data analysis. We also used several Python libraries to create interactive notebooks that contain our code snippets, data, and visualizations. These libraries help us to read, clean, and summarize our data, as well as to perform some statistical tests. Moreover, we could generate and manipulate geometric objects. AIS information includes the date and time and the ship's name, Call Sign, Position (latitude and longitude), Speed Over Ground (SOG) in knots, Course Over Ground (COG), Heading (HDG), Rate Of Turn (ROT) and Navigational Status (NS), etc. The Maritime Mobile Service Identity (MMSI) is a unique nine-digit number assigned to vessels equipped with a radio communication system. Some MMSI errors can be more difficult to detect, including when they are set to manufacturer defaults or assigned to multiple vessels over time. It is suggested to validate the reported MMSI by cross-checking with other identifying values within the AIS report. Here we cross-validated the MMSI with the International Maritime Organization (IMO) number, which is a unique number assigned to the ship. SOG represents the speed of a vessel relative to the Earth's surface. COG refers to the direction in which a vessel is moving over the Earth's surface. The true heading of a vessel represents its orientation with respect to true north and ROT indicates how quickly a vessel is turning. Positive values denote turning right, while negative values indicate turning left. The NS is a form of a signal reported by the vessel, which describes the status of the vessel in real-time. The NS sets the ping frequency rate at which the AIS is broadcasting the messages (e.g. underway, moored, anchored, power-driven vessel pushing ahead or towing alongside).

4 RESULT AND DISCUSSION

After analyzing the SOG we can see that tugs typically operate at average speeds between 1 and 4 knot, see Table 2. Cala Sequer with a speed of 13.8 knots has the highest maximum SOG and Willy T with a speed of 11.9 knots exhibits the lowest maximum SOG. Table 2 also shows that for the studied tugs in whole month, March 2023, three out of the seven studied tugs report a NS=5 which indicates that they have been moored all, see Figure 2. According to the AIS navigational Status, a vessel is considered to be moored when it is secured at a pier or elsewhere by several lines or cables that restrict its movement. Additionally, it depends on the precision of the GPS, so as well on the presence of satellites at the moment and their coverage. Since NS is manually configured by the vessel's crew, when it remains unchanged during navigation, it indicates that the crew has not made any manual updates. Then NS might not be a reliable source of information.

In the context of several tug vessels, we have encountered instances of missing data, commonly referred to as "Not A Number" (NaNs), in both ROT and HDG information. Three vessels, Azabra, Cala Gullo; Cala Sequer, had no missing data. However, for the vessels Willy T and Eliseo Vazquez, 16.8% and 37.6% of the data points are absent, respectively. Additionally, for Montbrio and Cala Verd, all ROTs and HDGs are missing.

Our data analysis is conducted using the reporting intervals specified in Recommendation ITU-R M.13715 for Class A shipborne mobile equipment [7]. As per the document, the recommended reporting interval for ships at anchor or moored and not moving faster than 3 knots is 3 minutes. For ships at anchor or moored and moving faster than 3 knots, the recommended interval is 10 seconds. Additionally, the document specifies reporting

intervals for other dynamic ship conditions.
If the time data in AIS reports deviates from the protocols of Rec. ITU-R M.1371-5, it indicates that the AIS station is not compliant with the international standards endorsed by the International Telecommunication Union (ITU) and IMO. This discrepancy may lead to unreliable information being transmitted or received by other AIS stations, potentially impacting the safety and efficiency of navigation.
In our analysis of various tugs, we observed discrepancies between the actual ping frequencies (real delta time) and the intervals reported in protocols (theoretical delta time). Here are the findings for specific tugs: Eliseo Vazquez, exhibited a 26% conformity in time between AIS data and the Rec. ITU-R M.1371- 5. In contrast, Willy T demonstrated only a 0.2% conformity in time, see Figure 3. The conformity of time between AIS data and Rec. ITU-R M.1371-5 in Montbrio, Azabra, Cala Verd, Cala Sequer and Cala Gullo were 0.3%, 2.5%, 2.5%, 2.7% and 24.1%, respectively. These percentages reflect the alignment of time data between AIS records and the ITU-R M.1371-5 recommendation.
There could be various reasons why AIS data sometimes are not reliable. Here we bring the most common reasons: the AIS device may have hardware or software defects that affect its ability to generate or propagate accurate and exact time data. Maybe AIS operators record incorrect or outdated time data manually, or fail to synchronize the device with the UTC time source.

Table 2. AIS data of tugs in the port of Barcelona in March 2023.

Ship name	Speed(knot) (Max)(μ ± std)	Navigational Status (NS)	Ping Frequency (s) (Mode)
Azabra	12.1(3.9 ± 3.4)	5 (moored)	10.0
Cala Gullo	13.3(1.5 ± 2.5)	15 (undefined)	10.0
Cala Sequer	13.1(4.2 ± 3.1)	5 (moored)	10.0
Cala Verd	13.1(4.2 ± 3.1)	5 (moored)	10.0
Eliseo Vazquez	12.1(1.0 ± 2.3)	0 (underway using engine)	10.0
Montbrio	13.1(1.1 ± 2.5)	0 (underway using engine)	10.0
Willy T	11.9(1.1 ± 2.5)	15 (undefined)	10.0

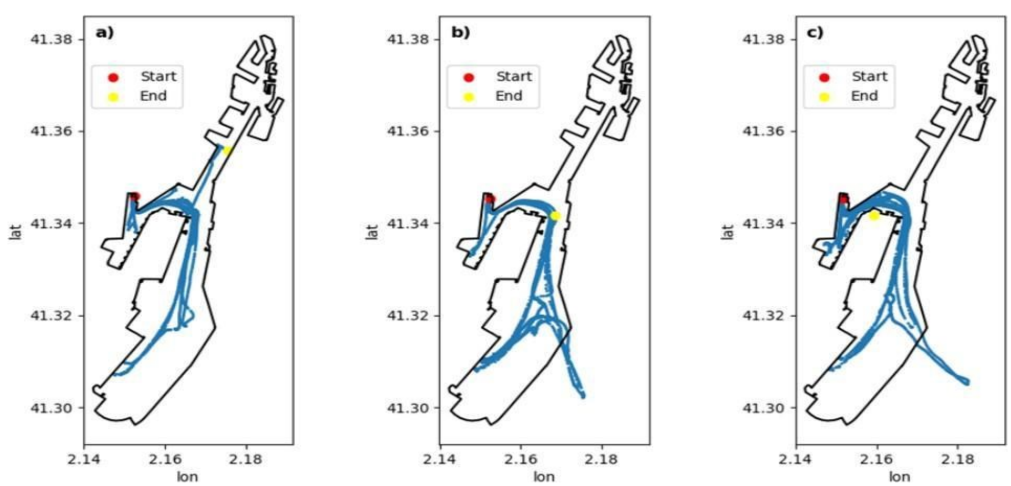

Figure 2.AIS Trajectories of vessels with NS=5 (moored status) in the Port of Barcelona in March 2023. Red dot indicates the beginning of the maneuvers whereas the yellow dot indicates the end of the maneuvers. a) Azabra ; b) Cala Sequer; c) Cala Verd.

Sometimes the AIS signal distorted or blocked by natural or artificial factors, such as weather, can directly affect the signal quality or propagation. The AIS data may be intentionally changed or manipulated by the sender or a third party, for various reasons such as hiding identity, location or activity. These causes may affect the integrity, accessibility, and authenticity of the AIS data, and thus compromise the safety and efficiency of maritime navigations. "Going dark" refers to intentionally deactivating the AIS transmission for potentially dubious purposes. Thus, detecting and classifying abnormal behaviors is a key task of maritime situational awareness, for several reasons such as the extraction of relevant contextual information and the proper monitoring of both self-reporting systems (such as AIS) and non-cooperative systems (such as satellite imagery or coastal radar). The operator must receive information of sufficient quality to make informed decisions and also comprehend the underlying significance of the data, guided by evaluation criteria. These criteria encompass several factors, with the primary ones being uncertainty, imprecision, and trueness. Uncertainty represents the level of confidence attributed to a specific value (when its truth is known), which can arise from either lack of knowledge or the inherent variability of the process. Imprecision refers to the source's inability to provide a single precise value or distinguish between multiple values.

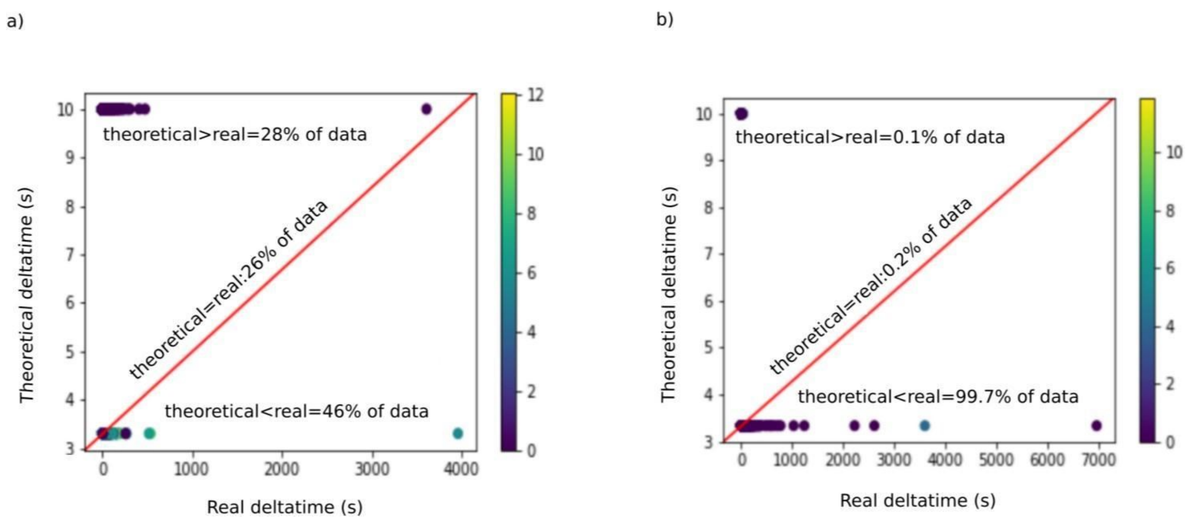

Figure 3.Theoretical delta time, as per Rec. ITU-R M.1371-5, is compared with Real delta time based on recorded AIS data. The color map represents SOG (knot). a) Eliseo Vazquez b) Willy T

Trueness, on the other hand, connects a piece of information to the truth (or a reference), often described as the agreement between the expected value and the actual measurement [8].
Taking all these factors into account and identifying anomalies is crucial. Additionally, there are several aspects that warrant consideration in future research. For instance, investigating the optimization of in- port tugboat emissions, the allocation of tugs for each operation, and the engine power of tugs. Generally, the number of tugs tends to increase with the size of large vessels. Besides, docking operations may require more tugs compared with undocking operations, because docking operations could involve more risks such as quay collisions. Furthermore the engine power of tugs could affect the number of assigned tugs, so the relationship between them should be studied more.

5 CONCLUSIONS

The AIS data collected from seven tugs operating in the Port of Barcelona, Spain, during March 2023, has provided valuable insights for enhancing tug services and optimizing fleet operations. The key findings include:

- The average SOG of the tugs ranged from 1 to 4 knot. Notably, Cala Sequer achieved the highest maximum speed of 13.8 knots, while Willy T had the lowest maximum speed at 11.9 knots.
- The NS values exhibited a scattered and incoherent values since they were not changed during the maneuvers and were set constant to values 0, 5 and 15. This is a key to obtain higher frequency data because the NS sets the ping frequency rate.
- Missing data were encountered in both ROT and HDG information.
- Initial observations suggest that ping frequency and data gaps vary based on different variables (e.g., ROT, HDG, or SOG). We uncovered significant discrepancies between the actual ping frequencies (real delta time) and the intervals reported in protocols (theoretical delta time). Eliseo Vazquez exhibited a 26% conformity in time alignment between AIS data and Rec. ITU-R M.1371-5 and Willy T demon- strated a mere 0.2% conformity of time.
- In conclusion, this research contributes to better planning, timing, and assessment of tug services for vessel. By addressing data gaps and understanding navigational patterns, we can optimize tug fleet op-erations and improve overall efficiency in port activities. Furthermore investigation is required to arrive at more effective findings.

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