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Application of AIS data for qualitative and quantitative analysis of ship traffic flows

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The article presents the idea of method of processing AIS data into information useful for qualitative and quantitative analysis of ship traffic flows. In the introduction the manner of exchanging and storing data in AIS was generally characterised. An original programme for creating maps of ship traffic intensity and tabular ship profiles was de-scribed in the main part. The last part presents analysis of ship traffic flows in the Gdańsk Bay in the year 2017, conducted with the use of the original software.

Słowa kluczowe: Automatic Identification System, qualitative and quantitative analysis & processing AIS data.

Introduction

Safety in the sea is determined by the state of environmental conditions, objects in motion and organisation and realisation of human activity, which does not cause danger to the traffic of water drafts, human life and environment.

Safety conditions in a particular reservoir can be evaluated on the basis of depiction of ship traffic. Information regarding the traffic, depending on situation of the reservoir, can be obtained by applying different methods of observation, including AIS.

The static and dynamic AIS data describing depiction of ship traffic, after adequate processing can be very useful for executing qualitative and quantitative analysis.

AIS – Automatic Identification System is a system operating in the VHF sequence, working automatically and providing information in interfaces: ship-to-ship, ship-to-airborne SAR unit and ship-to-coast station, also including coastal base station.

According to the SOLAS Convention, AIS should automatically provide adequately equipped coastal stations, other ships and planes with information concerning identity of ships, type, position, course, speed, navigational status and other information that increases safety. It should also automatically receive such information from ships similarly equipped with this system, monitor, keep track of ships and exchange data with apparatus of coastal stations.

Information conveyed through AIS contain data regarding number of ships in a particular area, including their identity, type, length, width, immersion, cargo type, position, course and speed in relation to sea bed.

AIS also allows for displaying of ship traffic on an electronic map and a radar, supplying information to VTS centres, monitoring of obligatory and recommended routes, calculating of required surface of water lane and a ship's width, and plenty of other information which can be collected, archived and aimed for statistic purposes. Analysing AIS data one can:

- obtain information about number and size of different types of ships employing various shipping routes;
- improve safety of shopping through broadening of knowledge on the subject of requirements for navigational support systems and ship traffic;
- improve effectiveness and efficiency of planning, managing and maintaining of shipping routes, including support for navigation and ship traffic control;
- provide data for risk analysis;
- provide data for long-term planning;
- provide data for investigation of maritime accidents.

AIS data can also be collected from local, regional, state and international network systems of base stations and can be applied for further improvement in quality of services provided in maritime transportation

1.Gathering and processing of AIS data

For the purpose of conducting research we used the AIS data set from the area of the Gdańsk Bay stored in the year 2017 in a state data base of the Polish system AIS-PL (which was made available by Maritime Office in Gdynia for research purposes) [5]. This set is composed of daily files with „raw" AIS announcements with collective volume of approx. 8,6 GB [2][3]. On its basis we prepared:

- a quantitative profile – based on the layout of traffic intensity. A GRID-type file with mesh resolution 2" was used for its development,
- qualitative profiles – based on tabular files, utilised in the programme Microsoft Excel for building statistics with breakdown by type, immersion and ship length.

These profiles constituted a result source of information prepared for execution of qualitative and quantitative analysis.

GRID-type files have a form of regular grid of squares. Each of the squares was matched with a value referring to a number of ships „dwelling" in it in a given time period, determined as a result of analyses of relative positions of subsequent segments along which the water drafts cruise and segments limiting particular meshes in the GRID network (Figure no. 1).

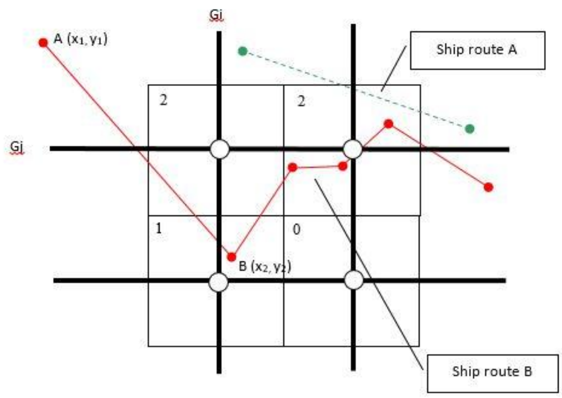

Fig. 1. Geometrical interpretation of the method of establishing value for a mesh in the GRID network

Figure no. 1 shows a fragment of the GRID (four reference system squares) and two trajectories of ship movement, drafted on the basis of the coordinates of ships observed within AIS. Each reference system square contains a GRID point mapped to a value established as a result of the reciprocal analysis of the location of consecutive segments, on which ships are moving, against the segments within particular GRID squares. The value of the point increases by one, if the segment on which the ship is moving crosses one of the segments that makes up the sides of the square within the GRID square of the point. A vessel which caused an increase in the value of the GRID point can lead to its further increase by one, if its next trajectory segment crosses one of the segments that belong to the sides of the square within another GRID square. Thanks to this one can avoid repeated influence of the same vessel on the same GRID point. This is especially significant in the case of messages from the position coordinates (no 1-3, 18), which can be transmitted from ships with high frequency (even every 2 seconds) – depending on the navigation status, speed and manner of manoeuvring [2]. Demonstrated below are simple mathematical relationships for calculating the X ordinate and the Y abscissa of the points of intersection of lines passing through points A(x_1,y_1) and B(x_2,y_2) which form the next segment of ship trajectory and lines passing through the sides of the GRID square for each GRID point:

$$Y = \frac{y_2 - y_1}{x_2 - x_1}(Gi - x_1) + y_1 \qquad (1)$$

$$X = \frac{x_2 - x_1}{y_2 - y_1}(Gj - y_1) + x_1 \qquad (2)$$

Calculated coordinates of the point should be located on the analysed line of the side of the square, which means that the water draft has entered the mesh zone and that the knot value should be increased by one.

Below we present the format of the GRID result network saved in an output file [4].

ncols 10
nrows 10
xllcorner 18.00000000
yllcorner 54.00000000
cellsize 0.00027778
NODATA_value 0
0 0 0 0 2 0 0 0 0 0
0 0 0 0 0 1 0 0 0 0
0 0 0 0 1 0 0 1 0 0
0 0 0 0 0 0 0 2 0 0
0 0 0 0 0 3 0 0 0 0
0 0 0 2 0 0 1 0 0 0
0 0 0 2 0 0 1 0 0 0
0 0 2 0 0 0 1 0 0 0
0 0 2 0 0 0 0 1 0 0
2 2 0 0 0 0 0 1 0 0
0 0 0 0 0 0 0 0 1 0

This file can be imported by applications of GIS type (Geographic Information Systems), such as: MapInfo, ArcGIS and subsequently used in those programmes for creating maps with layouts of ship traffic intensity with cartographical basis (e.g. in cartographic modelling of Merkator).

In turn, output tabular files can be imported by applications with functionality of a spreadsheet e.g. Microsoft Excel and subsequently utilised for creating statistics of qualitative ship movements.

This file is produced as a result of appropriate processing of announcements with static information about a ship, i.e. no. 5 and 24 to a text format [2]. It contains a numerical tally of ships with breakdown by type compliant with ITU-R M.1371-5 (Tab. No. 1), immersion, length and class of used AIS transponder and class of used AIS transponder.

Tab. 1. Breakdown of ships by type applied in AIS [2, p. 114].

Identifiers to be used by ships to report their type

Identifier No.	Special craft
50	Pilot vessel
51	Search and rescue vessels
52	Tugs
53	Port tenders
54	Vessels with anti-pollution facilities or equipment
55	Law enforcement vessels
56	Spare – for assignments to local vessels
57	Spare – for assignments to local vessels
58	Medical transports (as defined in the 1949 Geneva Conventions and Additional Protocols)
59	Ships and aircraft of States not parties to an armed conflict

Other ships

First digit (1)	Second digit (1)	First digit (1)	Second digit (1)
1 – Reserved for future use	0 – All ships of this type	–	0 – Fishing
2 – WIG	1 – Carrying DG, HS, or MP, IMO hazard or pollutant category X(2)	–	1 – Towing
3 – See right column	2 – Carrying DG, HS, or MP, IMO hazard or pollutant category Y(2)	3 – Vessel	2 – Towing and length of the tow exceeds 200 m or breadth exceeds 25 m
4 – HSC	3 – Carrying DG, HS, or MP, IMO hazard or pollutant category Z(2)	–	3 – Engaged in dredging or underwater operations
5 – See above	4 – Carrying DG, HS, or MP, IMO hazard or pollutant category OS(2)	–	4 – Engaged in diving operations
	5 – Reserved for future use	–	5 – Engaged in military operations
6 – Passenger ships	6 – Reserved for future use	–	6 – Sailing
7 – Cargo ships	7 – Reserved for future use	–	7 – Pleasure craft
8 – Tanker(s)	8 – Reserved for future use	–	8 – Reserved for future use
9 – Other types of ship	9 – No additional information	–	9 – Reserved for future use

DG: dangerous goods
HS: harmful substances
MP: marine pollutants
(1) The identifier should be constructed by selecting the appropriate first and second digits.
(2) NOTE 1 – The digits 1, 2, 3 and 4 reflecting categories X, Y, Z and OS formerly were categories A, B, C and D.

Figure no. 2 presents the main window of the original programme application for creating of the described GRID type files and tabular files.

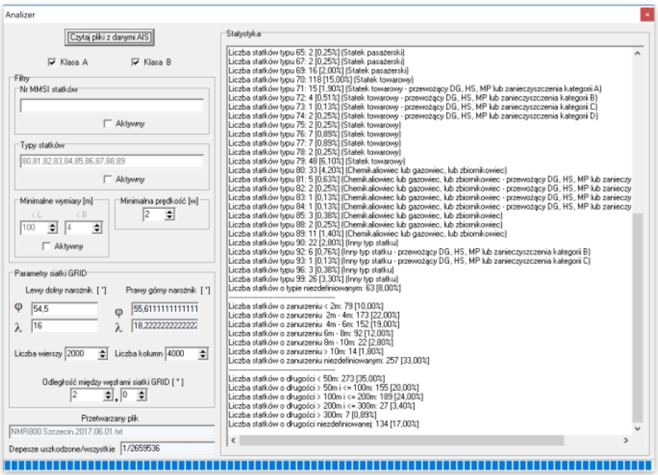

Fig. 2. Main window of the original programme application for processing of AIS data

This application was prepared in the integrated environment of application development C++Builder 10.2.3. It is compatible with the operating system Windows 10 [1].

2. Obtained results

a) Quantitative profile

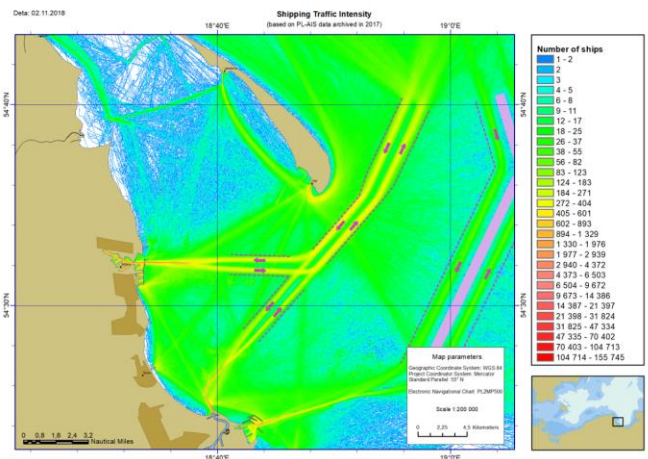

Fig. 3. Layout of ship traffic intensity in the Gdańsk Bay in the year 2017

b) Qualitative profile

Overall, 3168 ships were registered, of which 2660 (84.0%) had AIS transponders of class A and 508 (16.0%) transponders of class B.

Tab. 2. Numerical tally of ships with breakdown by type

Ship type	Number of ships	Percentage	Number of ships / Number of ships in total
Vessel - fishing [30]	176	5.6%	176/3168
Vessel - towing [31]	7	0.2%	7/3168
Vessel - towing and length of the tow exceeds 200 m or breadth exceeds 25 m [32]	19	0.6%	19/3168
Vessel - engaged in dredging or underwater operations [33]	25	0.8%	25/3168
Vessel - engaged in diving operations [34]	9	0.3%	9/3168
Vessel - engaged in military operations [35]	56	1.8%	56/3168
Vessel - sailing [36]	105	3.3%	105/3168
Vessel - pleasure craft [37]	35	1.1%	35/3168
Vessel - reserved for future use [38]	2	0.1%	2/3168
Vessel - reserved for future use [39]	2	0.1%	2/3168
High-speed craft (HSC) [40]	10	0.3%	10/3168
High-speed craft (HSC) - carrying DG, HS, or MP, IMO hazard or pollutant category X [41]	3	0.1%	3/3168
High-speed craft (HSC) - carrying DG, HS, or MP, IMO hazard or pollutant category OS [44]	16	0.5%	16/3168
High-speed craft (HSC) - reserved for future use [45]	8	0.3%	8/3168
High-speed craft (HSC) - reserved for future use [48]	17	0.5%	17/3168
High-speed craft (HSC) - no additional information [49]	5	0.2%	5/3168
Pilot vessel [50]	3	0.1%	3/3168
Search and rescue vessels [51]	8	0.3%	8/3168
Tugs [52]	100	3.2%	100/3168
Port tenders [53]	4	0.1%	4/3168
Vessels with anti-pollution facilities or equipment [54]	3	0.1%	3/3168
Law enforcement vessels [55]	7	0.2%	7/3168
Spare – for assignments to local vessels [56]	5	0.2%	5/3168
Spare – for assignments to local vessels [57]	1	0.0%	1/3168
Passenger ships - all ships of this type [60]	45	1.4%	45/3168
Passenger ships - carrying DG, HS, or MP, IMO hazard or pollutant category X [61]	7	0.2%	7/3168
Passenger ships - carrying DG, HS, or MP, IMO hazard or pollutant category Y [62]	1	0.0%	1/3168
Passenger ships - carrying DG, HS, or MP, IMO hazard or pollutant category Z [63]	1	0.0%	1/3168
Passenger ships - carrying DG, HS, or MP, IMO hazard or pollutant category OS [64]	16	0.5%	16/3168
Passenger ships - reserved for future use [65]	4	0.1%	4/3168
Passenger ships - no additional information [69]	39	1.2%	39/3168
Cargo ships - all ships of this type [70]	1233	38.9%	1233/3168
Cargo ships - carrying DG, HS, or MP, IMO hazard or pollutant category X [71]	106	3.3%	106/3168
Cargo ships - carrying DG, HS, or MP, IMO hazard or pollutant category Y [72]	14	0.4%	14/3168
Cargo ships - carrying DG, HS, or MP, IMO hazard or pollutant category Z [73]	9	0.3%	9/3168
Cargo ships - carrying DG, HS, or MP, IMO hazard or pollutant category OS [74]	13	0.4%	13/3168
Cargo ships - reserved for future use [75]	5	0.2%	5/3168
Cargo ships - reserved for future use [76]	14	0.4%	14/3168
Cargo ships - reserved for future use [77]	15	0.5%	15/3168
Cargo ships - reserved for future use [78]	12	0.4%	12/3168
Cargo ships - no additional information [79]	260	8.2%	260/3168
Tanker(s) - all ships of this type [80]	213	6.7%	213/3168
Tanker(s) - carrying DG, HS, or MP, IMO hazard or pollutant category X [81]	40	1.3%	40/3168

Tanker(s) - carrying DG, HS, or MP, IMO hazard or pollutant category Y [82]	33	1.0%	33/3168
Tanker(s) - carrying DG, HS, or MP, IMO hazard or pollutant category Z [83]	17	0.5%	17/3168
Tanker(s) - carrying DG, HS, or MP, IMO hazard or pollutant category OS [84]	11	0.3%	11/3168
Tanker(s) - reserved for future use [85]	4	0.1%	4/3168
Tanker(s) - reserved for future use [88]	5	0.2%	5/3168
Tanker(s) - all ships of this type [89]	124	3.9%	124/3168
Other types of ship [90]	49	1.5%	49/3168
Other types of ship - carrying DG, HS, or MP, IMO hazard or pollutant category Y [92]	14	0.4%	14/3168
Other types of ship - carrying DG, HS, or MP, IMO hazard or pollutant category Z [93]	2	0.1%	2/3168
Other types of ship - reserved for future use [96]	4	0.1%	4/3168
Other types of ship - reserved for future use [97]	2	0.1%	2/3168
Other types of ship - no additional information [99]	25	0.8%	25/3168
Undefined [0]	156	4.9%	156/3168

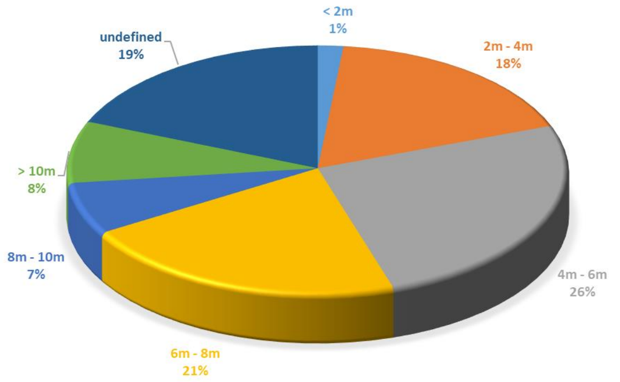

Fig. 4. Percentage breakdown of ships by immersion

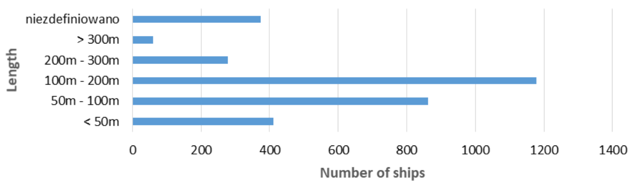

Fig. 5. Numerical breakdown of ships by length

Conclusions

The presented method of processing AIS data could automatise the process of examining the state of environmental conditions, objects in motion, organisation and realisation of human activity in the sea.

Obtained results in the form of:

- map of layout of ship traffic intensity allow for determining of the number of ships cruising through the area in shape of an ellipsoidal trapezium with a given side length (in the research the length of 2" was adopted) in a particular period of time (in the research the period of 1 year was adopted),
- numerical tallies of ships with breakdown by type of transponder and a ship, immersion and length,

constitute useful information about quantitative and qualitative profiles of ship traffic. On their basis one can evaluate the safety conditions of shipping in a maritime reservoir. However, it should be remembered that this evaluation should be executed in connection with analysis of many other coefficients describing e.g.: reservoir, water drafts, positioning systems, hydro-meteorological conditions, navigational infrastructure, systems of control and traffic surveillance, which could also cause danger for water drafts, human life and natural environment.

Bibliografia:

1. Emarcadero, ttps://www.embarcadero.com/products/cbuilder/features/windows (10.01.2019).
2. IEC, future publication. 61162-3: Maritime navigation and radiocommunication equipment and systems – Digital interfaces – Part 3: Multiple Talker and multiple listeners. High speed network bus, 2014.
3. ITU, M.1371-5, Technical characteristics for an automatic identification system using time division multiple access in the VHF maritime mobile frequency band, 2014.
4. K. NAUS, A. MAKAR, J. APANOWICZ, "Usage AIS data for analyzing ship's motion intensity, Annual of Navigation", No. 13, Gdynia, 2008.
5. MARITIME OFFICE IN GDYNIA, http://www.umgdy.gov.pl/ (10.01.2019).

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