

# Automatic Identification System (AIS)

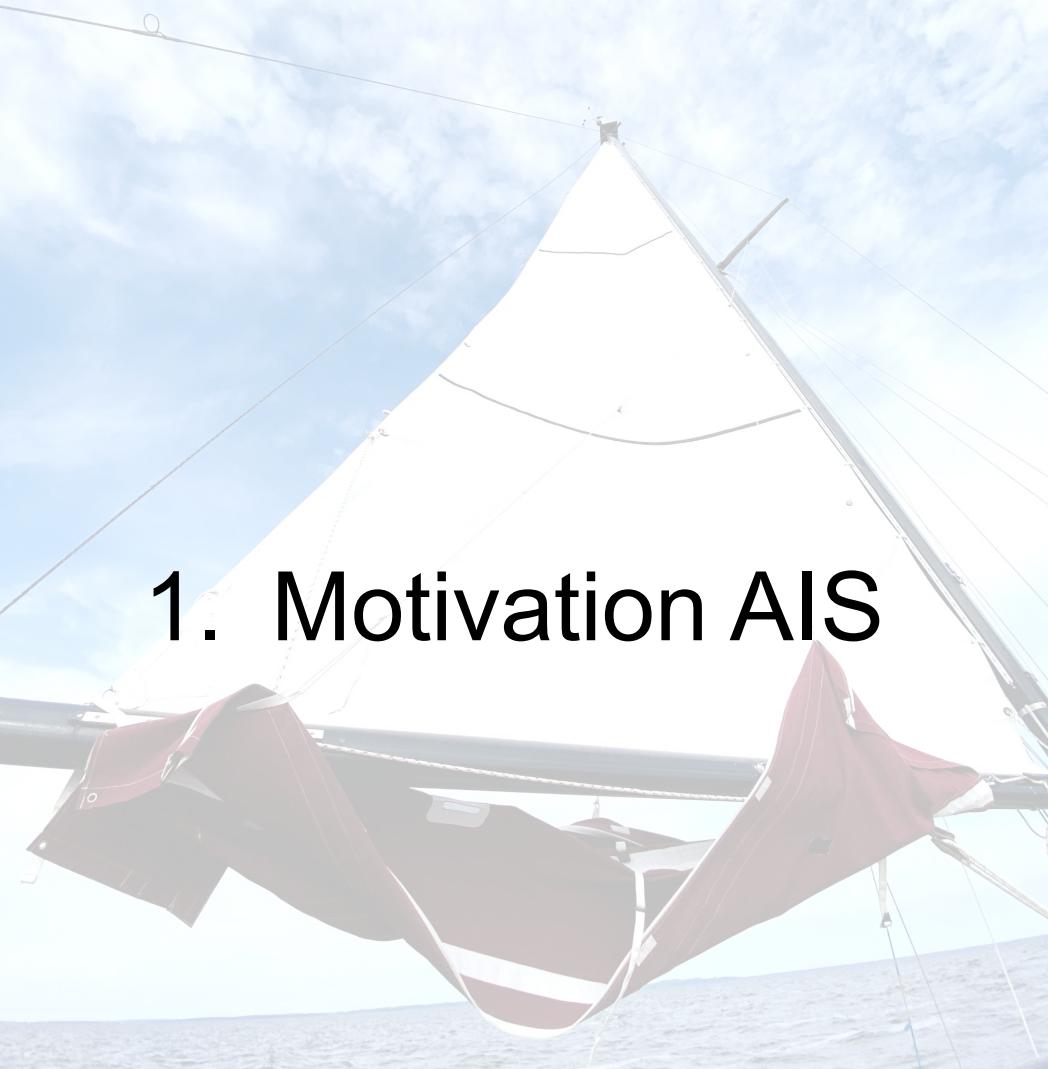
Trends in Betriebssystemen & Middleware  
SoSe 2022

Helena Lendowski

# Agenda

1. Motivation AIS
2. Functionality of AIS
3. AIS tooling
4. Collision detection: demo, implementation & relevant data
5. Future work

# 1. Motivation AIS



# Why AIS?

ensure safety at sea

vessel identification system

collision avoidance

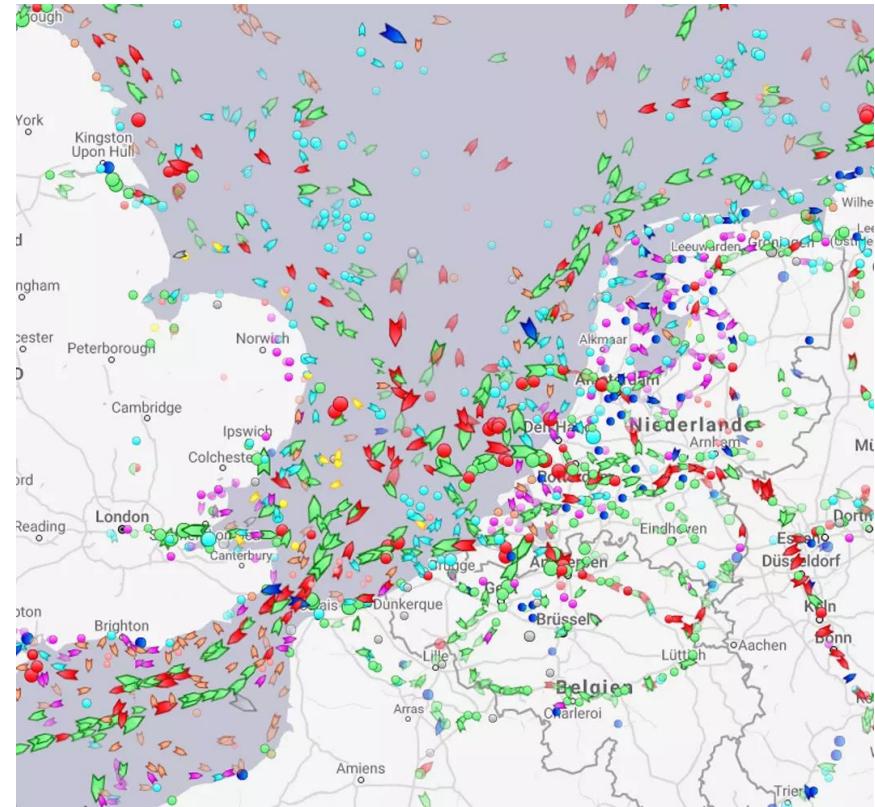
sea traffic control: monitoring of vessels

visibility in real time (MarineTraffic & Vesseltracker)

search & rescue (SAR)

AIS vs. radar

 view behind solid objects



# Research

... with AIS-data

- cargo weight, estimated based on draft and vessel size (Jia, Prakash, & Smith, 2018)
- global oil trade forecast using AIS data by aggregating the volume of ships at sea (Adland, Jia, & Strandenes, 2017)
- port performance (Chen et al., 2016)
- environmental impacts of shipping (Gerritsen, Minto, & Lordan, 2013) assessed at the ship level

# AIS types

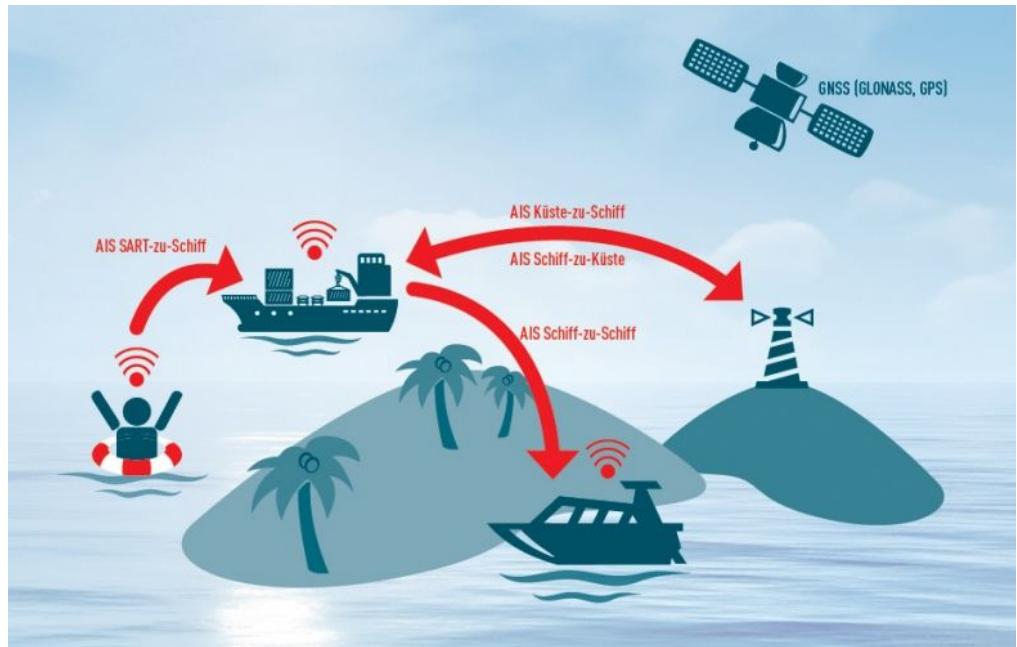
vessel-based AIS transceivers

terrestrial-based AIS (T-AIS)

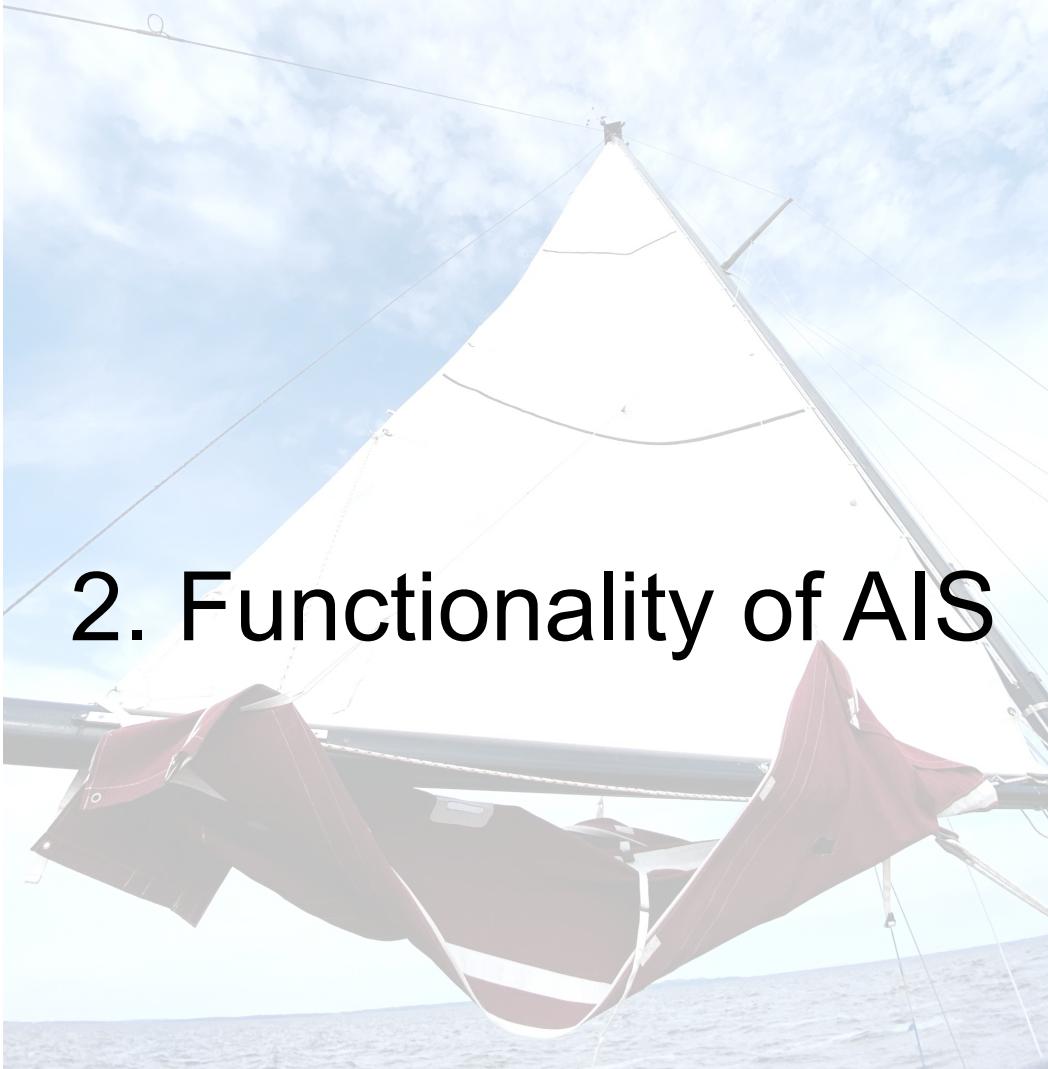
satellite-based AIS (S-AIS)

aids to navigation (AtoN)

search and rescue transmitter  
(SART) / man overboard  
(MOB)



## 2. Functionality of AIS



# How does AIS work?

very high frequency (VHF) transmitter & VHF receiver

GPS

alternating on 2 channels: VHF channel 87B & 88B

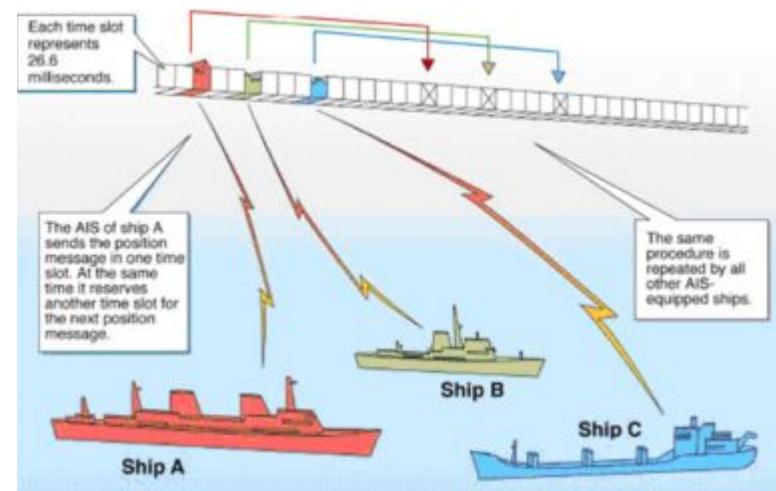
- AIS channel A: 161.975 MHz
- AIS channel B: 162.025 MHz

data protocol: High-Level Data Link Control (HDLC)

AIVDM/AIVDO sentences

access of vessel-based AIS transceivers

- class A                      Self Organising Time Division Multiple Access (SOTDMA)
- class B                      Carrier Sense Time Division Multiple Access (CSTDMA)



# AIS-data

Type of Information	Information	Broadcasting Rate
Dynamic Information	Maritime Mobile Service	At anchor or moored (<3 kts): 3 min
	Identity number (MMSI)	At anchor or moored (>3 kts): 10 s
	Ship position	Ship 0–14 kts: 10 s
	Speed over ground	Ship 0–14 kts and changing course: 3.3 s
	Course over ground	Ship 14–23 kts: 6 s
	Navigational status	Ship 14–23 kts and changing course: 2 s
	Time Etc.	Ship >23 kts: 2 s
Static and Voyage-related Information	MMSI number	Every 6 min and on request
	Ship type	
	Length and beam	
	Estimated time of arrival	
	Destination Etc.	

# Range

The higher the antenna and the higher the transmitting power, the greater the range.

AIS has much longer vertical than horizontal transmission.

1 Nm = 1.852 km

Transponders	W	Range in Nm
Class A	12.5	20-25
Class B+	5	10-12
Class B	2	7-8
MOB/SARTs	1	3-4
T-AIS		up to 54 (50–100 km)
S-AIS		up to 215,983 (400 km)

# AIVDM/AIVDO sentences

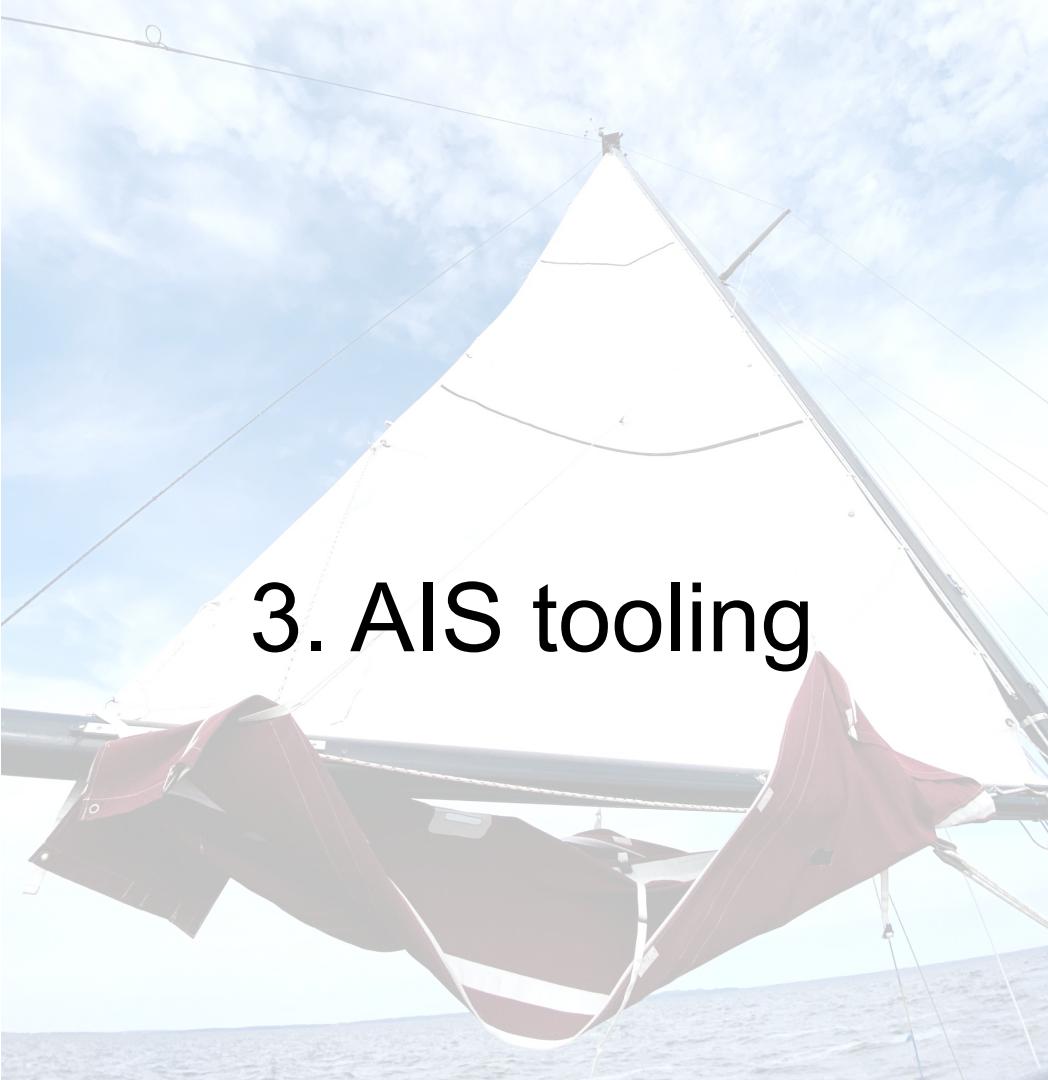
6-bit binary coding

using the NMEA 0183 or NMEA 2000 data formats

sample message:



### 3. AIS tooling



# Hardware

software-defined radio (SDR): de-/modulation of radio signals

VHF range: 30 MHz to 300 MHz

VHF antenna



RTL-SDR

GPS



Universal Software Radio Peripheral (USRP)



# SDR

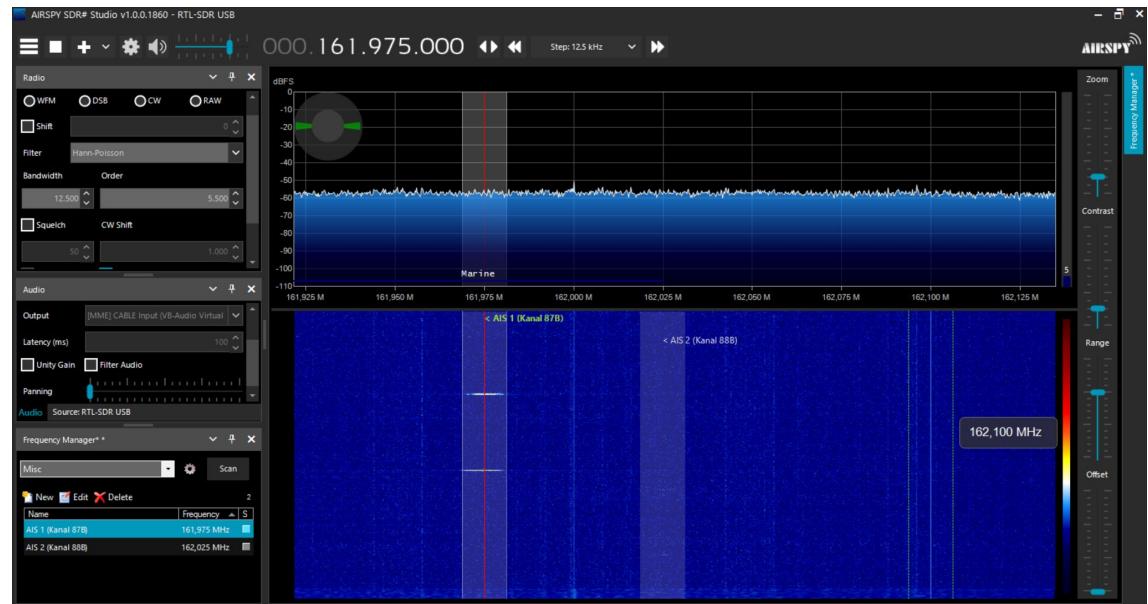
SDR package

AIRSPY: <https://airspy.com/download/>

- **SDRSharp**
- Airspy drivers
- HackRF driver
- **USRP driver**
- **RTL-SDR driver**

USRP Hardware Driver (UHD)

Zadig driver for RTL-SDR on Windows



# Problems

**issues with libraries** *librtlsdr*, *libusb1.0* and installing the appropriate *udev rules* (Windows & Linux)

solution with [OsmoSDR](#) and [UHD and USRP Manual](#) “Binary Builds” instructions on  
<https://osmocom.org/projects/rtl-sdr/wiki/Rtl-sdr> and [https://files.ettus.com/manual/page\\_build\\_guide.html](https://files.ettus.com/manual/page_build_guide.html) (*last accessed: 14.08.2022*)

**getting started with SDR:** often no proper explanation of the value settings (e.g., filter, sample rate, gain, ...)

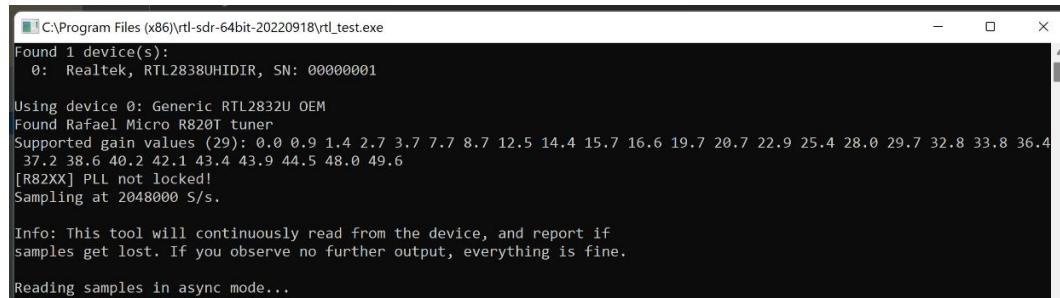
**gain** (= frequency correction (ppm)) and **sample rate** depend on device!

center frequency:

162 MHz (161.975 MHz / 162.025 MHz)

RTL-SDR values:

- gain: 1.4 ppm
- sample rate: 2.048 MHz



The screenshot shows a Windows application window titled "C:\Program Files (x86)\rtl-sdr-64bit-20220918\rtl\_test.exe". The window displays the following text:

```
Found 1 device(s):
  0: Realtek, RTL2838UHIDIR, SN: 00000001

Using device 0: Generic RTL2832U OEM
Found Rafael Micro R820T tuner
Supported gain values (29): 0.0 0.9 1.4 2.7 3.7 7.7 8.7 12.5 14.4 15.7 16.6 19.7 20.7 22.9 25.4 28.0 29.7 32.8 33.8 36.4
  37.2 38.6 40.2 42.1 43.4 43.9 44.5 48.0 49.6
[R82XX] PLL not locked!
Sampling at 2048000 S/s.

Info: This tool will continuously read from the device, and report if
samples get lost. If you observe no further output, everything is fine.

Reading samples in async mode...
```

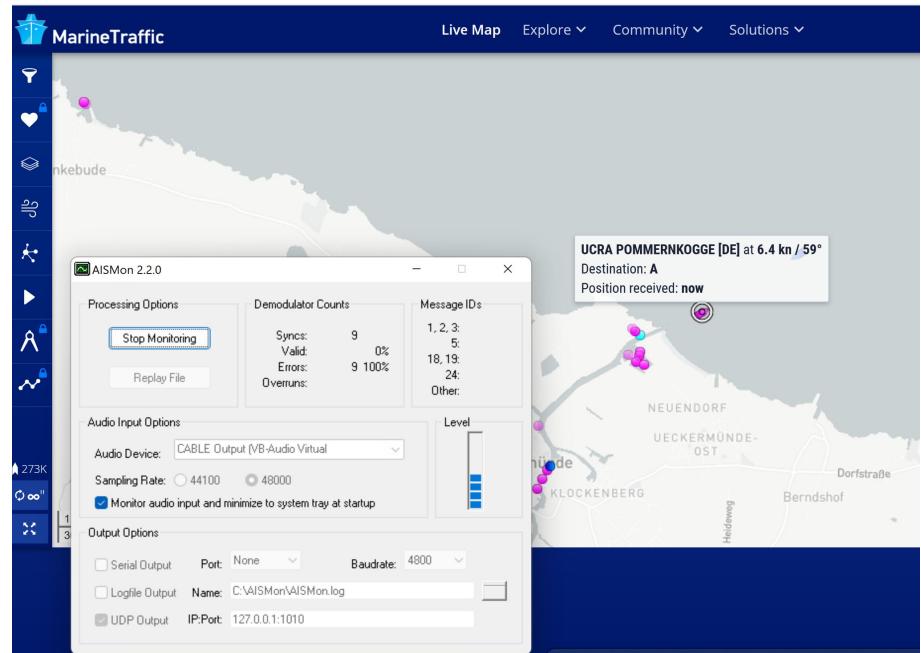
# Software for signal processing to NMEA

**AISMon:** demodulator/decoder which outputs AIS-data in NMEA format

SDR: narrow-band frequency modulation (NFM)

send signal via virtual audio cable to AISMon

100% errors while being in the marina



# Software for signal processing to NMEA

**GNURadio:** provides signal processing blocks to implement software radios

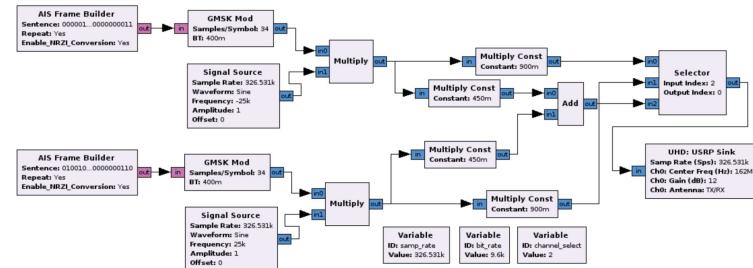


Figure 3: AISTX architecture on GnuRadio.

**AIS Frame Builder block / AIS transmitter (AISTX)** (available on <https://github.com/trendmicro/ais>) for GNURadio is not compatible with GNURadio v 3.9+

- Balduzzi, M., Pasta, A., & Wilhoit, K. (2014, December). A security evaluation of AIS automated identification system. In *Proceedings of the 30th annual computer security applications conference* (pp. 436-445).
- Cruz, F. R. G., Gania, R. C. M., Garcia, B. W. C., & Nob, J. C. R. (2018). Implementing Automatic Identification System Transmitter on Software Defined Radio.

## BitsToAIS-NMEA block

- Fun With Electronics (2012). Automatic Identification System (AIS) using GNU Radio. Available on <https://www.funwithelectronics.com/?id=9> (last accessed 10.09.2022)

# Software SDRangel

[Video](#)

# Software AIVDM/AIVDO decoder

AIS decoder expects NMEA format

many projects

The screenshot shows a GitHub search interface with the query "ais decoder". The results page displays 94 repository results. On the left, there are navigation sections for "Repositories" (94), "Code" (235K), "Commits" (12K), "Issues" (218), "Discussions" (4), "Packages" (2), "Marketplace" (0), "Topics" (0), "Wikis" (23), and "Users" (0). Below that is a "Languages" section showing counts for Python (17), C++ (11), Java (9), and others. The main area shows the search results:

- bistromath/gr-ais**: Automatic Information System **decoder** for shipborne position reporting for the Gnuradio project. Stars: 122, Language: C++, Updated: 21 Jun 2021.
- tbsalling/aismessages**: AISMessages is a Java-based light-weight, zero-dependency, and ultra-efficient message **decoder** for maritime navigation... Stars: 134, Language: Java, Updated: 11 days ago.
- M0r13n/pyais**: AIS message **decoding** and **encoding** in Python (AIVDM/AIVDO). Tags: python, decoding, nmea, ais, nmea-sentences, nmea-protocol. Stars: 86, Language: Python, License: MIT license, Updated: 12 days ago. This repository is highlighted with a blue border.
- schwehr/noadata**: Pure python AIS **decode** and **encode**. Stars: 43, Language: Python, Updated: 5 Oct 2017.

At the top right of the results area, there is a "Sort: Best match" dropdown. The GitHub header includes the GitHub logo, the search bar with "ais decoder", and navigation links for Pull requests, Issues, Marketplace, and Explore. There are also notification and user profile icons on the far right.

## 4. Collision detection



# AIS collision detection related work on GitHub

AIS catcher (C++):

<https://github.com/jvde-github/AIS-catcher>

collision risk assessment for vessels (Python):

<https://github.com/ByronAH/Collision-Risk-Assessment-for-Vessels>

safety device for fishing vessels based on AIS (Python):

<https://github.com/vjg28/Device-for-ship-detection>

1 repository result

helenalendowska/ais\_cd Private

AIS collision detection

Python Updated 3 days ago

Repositories 1

Code 101K

Commits 2K

Issues 37

Discussions 1

Packages 0

Marketplace 0

Topics 0

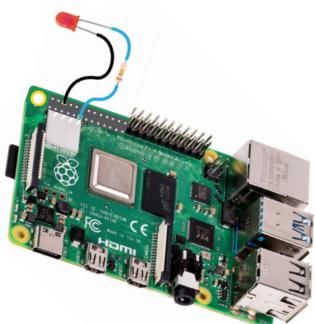
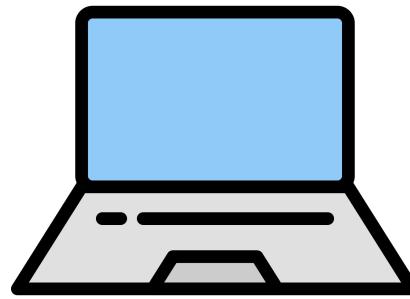
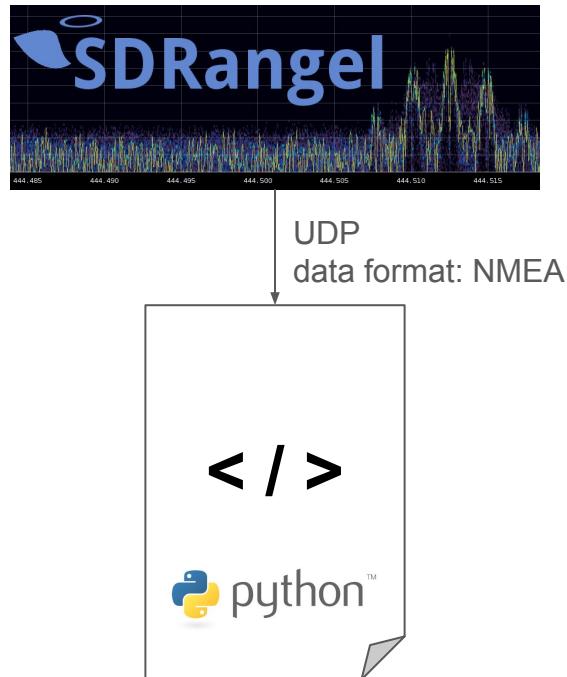
Wikis 38

Users 0

[Repositorium](#)



# AIS collision detection implementation



# Collision detection demo

[Video](#)

# AIS message types

01 Position Report Class A	<input checked="" type="checkbox"/>	15 Interrogation
02 Position Report Class A (Assigned schedule)		16 Assignment Mode Command
03 Position Report Class A (Response to interrogation)	<input checked="" type="checkbox"/>	17 DGNSS Binary Broadcast Message
04 Base Station Report	<input checked="" type="checkbox"/>	18 Standard Class B CS Position Report
05 Static and Voyage Related Data	<input checked="" type="checkbox"/>	19 Extended Class B Equipment Position Report
06 Binary Addressed Message		20 Data Link Management
07 Binary Acknowledge		21 Aid-to-Navigation Report
08 Binary Broadcast Message		22 Channel Management
09 Standard SAR Aircraft Position Report		23 Group Assignment Command
10 UTC and Date Inquiry		24 Static Data Report
11 UTC and Date Response		25 Single Slot Binary Message
12 Addressed Safety Related Message		26 Multiple Slot Binary Message With Communications State
13 Safety Related Acknowledgement		27 Position Report For Long-Range Applications
14 Safety Related Broadcast Message		

# GPS

**\$GNRMC:** Time, date, position, course, speed data (kn)

position format serial GPS:

**latitude** in 'DDMM.MMMMMM' format      **lat\_dir** 'N' or 'S'

**longitude** in 'DDDMM.MMMMMM' format      **lon\_dir** 'E' or 'W'

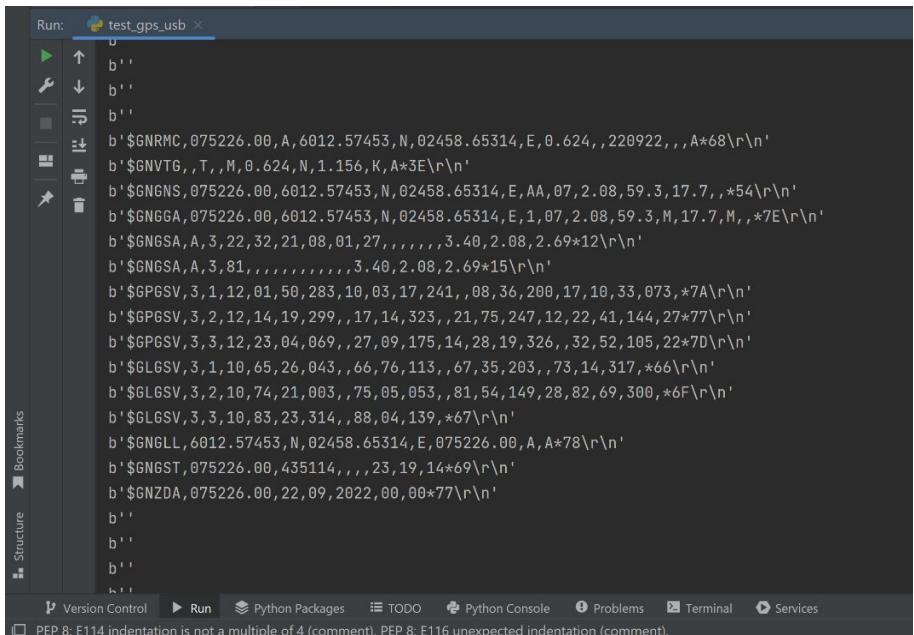
different position formats:

**sexagesimal degree:**  $40^{\circ} 26' 46''$  N  $79^{\circ} 58' 56''$  W

**degrees and decimal minutes:**  $40^{\circ} 26.767'$  N  $79^{\circ} 58.933'$  W

**decimal degrees:** +40.446 -79.982

← AIS data format



The screenshot shows a code editor interface with a dark theme. The top bar displays the file name "test\_gps\_usb.py". The code area contains several lines of raw binary data represented as strings of characters. These strings represent various GPS NMEA messages. Some of the visible message types include \$GNRMC, \$GNVTG, \$GNGNS, \$GNGGA, \$GNGSA, \$GPGSV, \$GPGSV, \$GLGSV, \$GLGSV, \$GNGLL, \$GNGST, and \$GNZDA. The code editor includes standard navigation tools like backspace, forward, and search, along with tabs for Version Control, Run, Python Packages, TODO, Python Console, Problems, Terminal, and Services.

# Nautical terminology

**true north:** fixed point on a map and it will never change (North Pole)

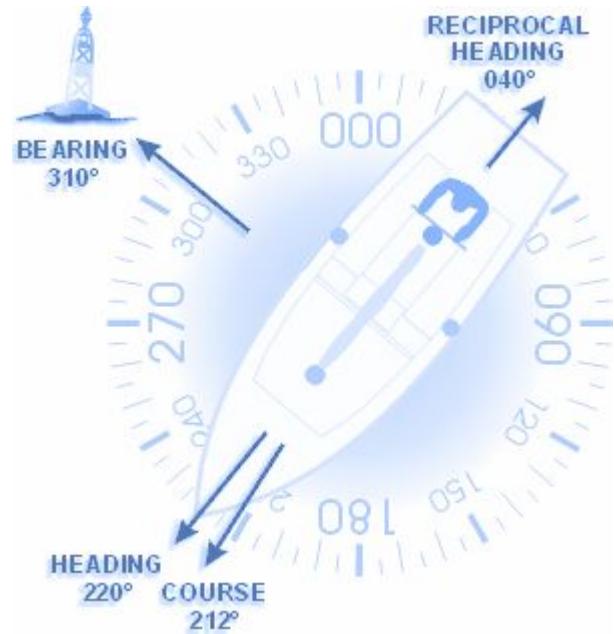
**magnetic north:** north of a compass needle based on the earth's magnetic field; shifts over time thanks to magnetic variation

**course:** intended/planned direction to reach a destination

**heading:** direction the vessel is pointed at a given moment

**bearing:** angle between north and the direction of another object/your destination

**relative bearing:** angle between the heading of the vessel and the object/ destination (heading and course are aligned → relative bearing =  $0^\circ$ )



# CPA & TCPA of a target

closest point of approach (cpa): computing the minimal distance between two ships

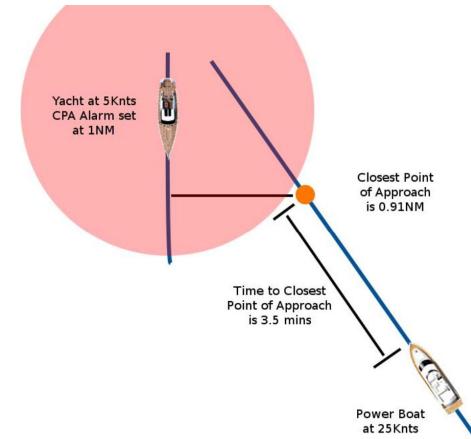
time to closest point of approach (tcpa)

AIS received data relative to true north

haversine formula: for the great-circle distance

automatic radar plotting aids (ARPA)

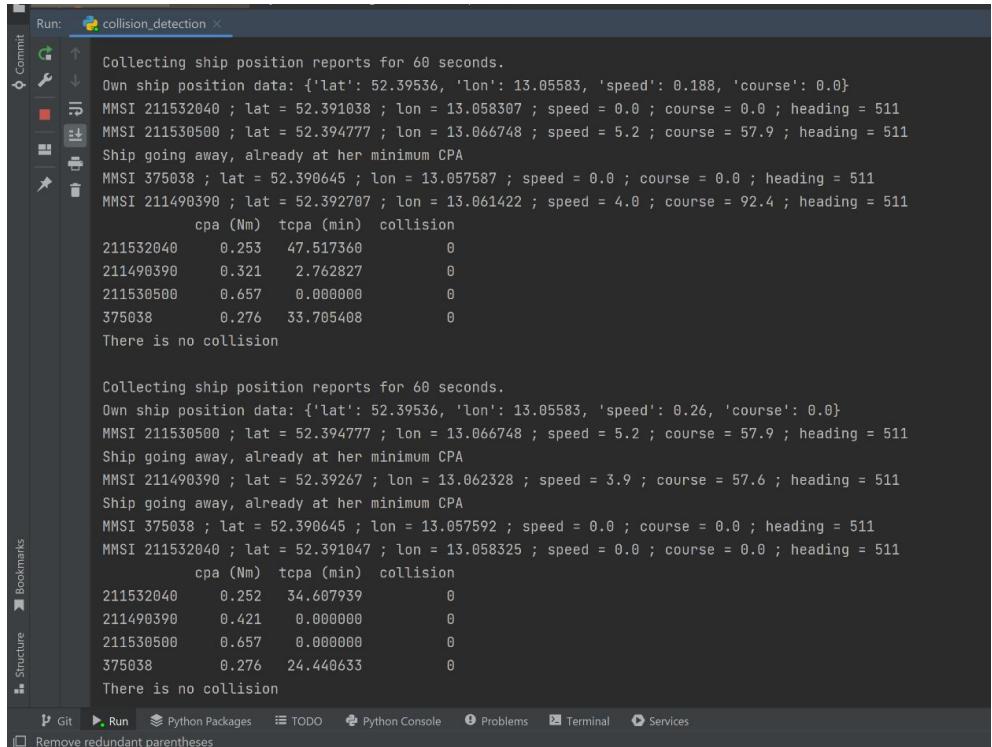
ARPAoCALC library: <https://github.com/nawre/arpaocalc>



# AIS data insight

dynamic data: heading = 511

AIS heading most of the time not available!



```
Run: collision_detection.x

Commit
Collecting ship position reports for 60 seconds.
Own ship position data: {'lat': 52.39536, 'lon': 13.05583, 'speed': 0.188, 'course': 0.0}
MMSI 211532040 ; lat = 52.391038 ; lon = 13.058307 ; speed = 0.0 ; course = 0.0 ; heading = 511
MMSI 211530500 ; lat = 52.394777 ; lon = 13.066748 ; speed = 5.2 ; course = 57.9 ; heading = 511
Ship going away, already at her minimum CPA
MMSI 375038 ; lat = 52.390645 ; lon = 13.057587 ; speed = 0.0 ; course = 0.0 ; heading = 511
MMSI 211498390 ; lat = 52.392707 ; lon = 13.061422 ; speed = 4.0 ; course = 92.4 ; heading = 511
      cpa (Nm)  tcpa (min)  collision
211532040    0.253   47.517360     0
211498390    0.321   2.762827     0
211530500    0.657   0.000000     0
375038       0.276   33.705408     0
There is no collision

Collecting ship position reports for 60 seconds.
Own ship position data: {'lat': 52.39536, 'lon': 13.05583, 'speed': 0.26, 'course': 0.0}
MMSI 211530500 ; lat = 52.394777 ; lon = 13.066748 ; speed = 5.2 ; course = 57.9 ; heading = 511
Ship going away, already at her minimum CPA
MMSI 211498390 ; lat = 52.39267 ; lon = 13.062328 ; speed = 3.9 ; course = 57.6 ; heading = 511
Ship going away, already at her minimum CPA
MMSI 375038 ; lat = 52.390645 ; lon = 13.057592 ; speed = 0.0 ; course = 0.0 ; heading = 511
MMSI 211532040 ; lat = 52.391047 ; lon = 13.058325 ; speed = 0.0 ; course = 0.0 ; heading = 511
      cpa (Nm)  tcpa (min)  collision
211532040    0.252   34.607939     0
211498390    0.421   0.000000     0
211530500    0.657   0.000000     0
375038       0.276   24.440633     0
There is no collision
```

Git Run Python Packages TODO Python Console Problems Terminal Services Remove redundant parentheses

# AIS data insight

static data often not available!

relies on user input

# AIS data insight related work

**“AIS still lacks availability for both static and dynamic data and that the reporting intervals are not as reliable as specified within the technical AIS standard.”**

Last, P., Bahlke, C., Hering-Bertram, M., & Linsen, L. (2014). Comprehensive analysis of automatic identification system (AIS) data in regard to vessel movement prediction. *The Journal of Navigation*, 67(5), 791-809.

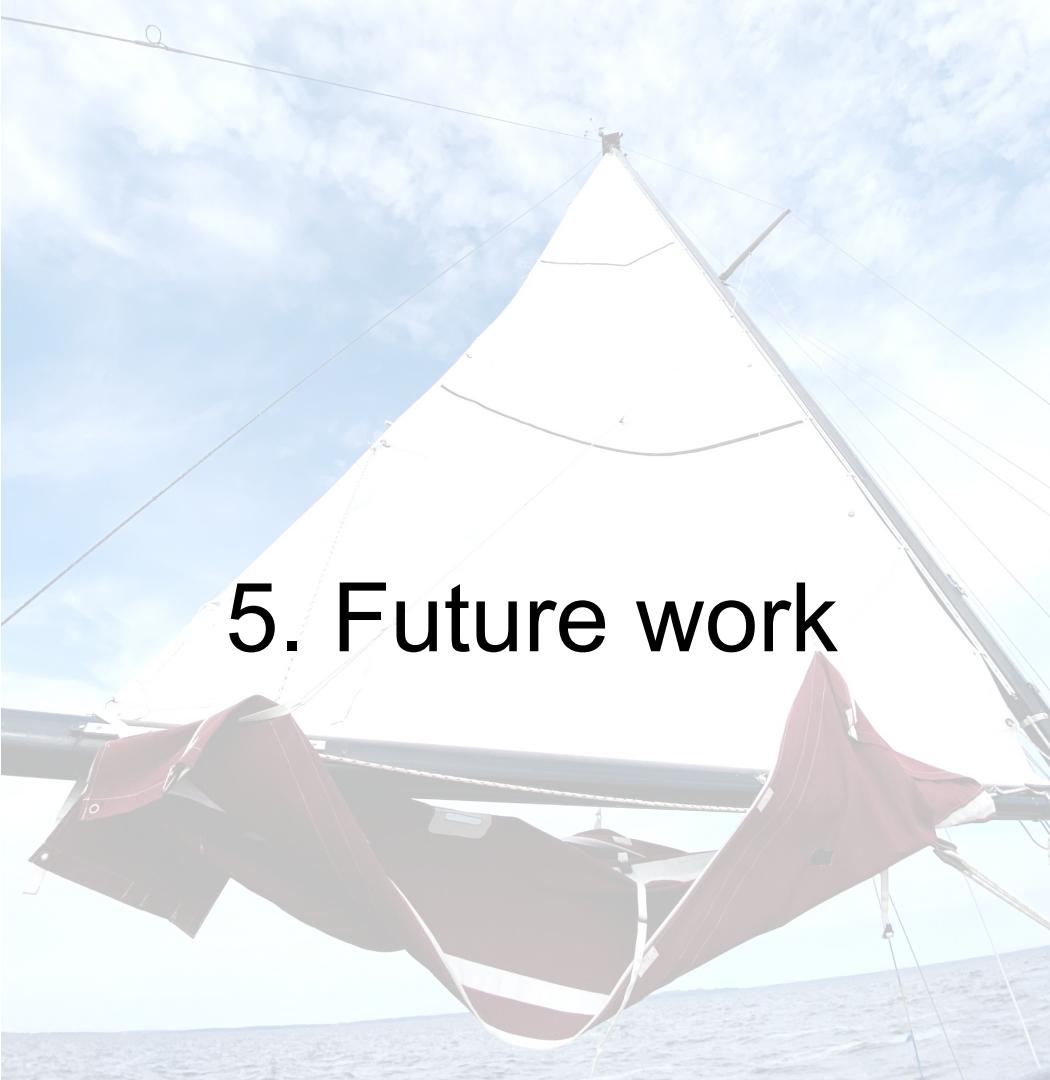
**“The most significant findings were that the amount of positional noise was 5.6% for sailing vessels and 0.31% for moored vessels within their specific intervals, and that missing values can reach up to 86% for static and up to 48% for voyage related AIS data.”**

Emmens, T., Amrit, C., Abdi, A., & Ghosh, M. (2021). The promises and perils of Automatic Identification System data. *Expert Systems with Applications*, 178, 114975.

Harati-Mokhtari, A., Wall, A., Brooks, P., & Wang, J. (2007). Automatic Identification System (AIS): data reliability and human error implications. *The Journal of Navigation*, 60(3), 373-389.

Felski, A., Jaskólski, K., & Banyś, P. (2015). Comprehensive assessment of automatic identification system (AIS) data application to anti-collision manoeuvring. *The Journal of Navigation*, 68(4), 697-717.

## 5. Future work



# Future work

- real time testing on the open sea
- include “position accuracy” of AIS message into collision warning system
- include AIS SART
- fix: GPS speed is greater 0 without moving
- depending on speed more frequently collision check
- send collision data to OpenCPN to display on map
- performance optimization
- signal processing in Python to remove socket (e.g., with pyrtlsdr: <https://pypi.org/project/pyrtlsdr/>)
  
- support SDRangle <https://github.com/f4exb/sdrangel/issues>
- make AIS Frame Builder projekt (<https://github.com/trendmicro/ais>) compatible with newer GNURadio versions (use Pybind11 instead of Swig)



You cannot only rely on AIS!



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[https://en.wikipedia.org/wiki/Geographic\\_coordinate\\_conversion#Conversion\\_from\\_Decimal\\_Degree\\_to\\_DMS](https://en.wikipedia.org/wiki/Geographic_coordinate_conversion#Conversion_from_Decimal_Degree_to_DMS) (last accessed: 20.10.2022)

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[http://www.coastalnavigation.com/samples/sec\\_3/3\\_qrfx/heading\\_dia.gif](http://www.coastalnavigation.com/samples/sec_3/3_qrfx/heading_dia.gif) (last accessed: 21.10.2022)

[https://de.wikipedia.org/wiki/Containerschiff#Entwicklung\\_der\\_Schiffsgr%C3%B6%C3%9Fe](https://de.wikipedia.org/wiki/Containerschiff#Entwicklung_der_Schiffsgr%C3%B6%C3%9Fe) (last accessed: 21.10.2022)

[https://files.ettus.com/manual/page\\_install.html](https://files.ettus.com/manual/page_install.html) (last accessed: 15.09.2022)

Baldazzi, M., Pasta, A., & Wilhoit, K. (2014, December). A security evaluation of AIS automated identification system. In *Proceedings of the 30th annual computer security applications conference* (pp. 436-445).

Cruz, F. R. G., Gania, R. C. M., Garcia, B. W. C., & Nob, J. C. R. (2018). Implementing Automatic Identification System Transmitter on Software Defined Radio. 2018 IEEE 10th International Conference on Humanoid, Nanotechnology, Information Technology,Communication and Control, Environment and Management (HNICEM). doi:10.1109/hnicem.2018.8666288

<https://pypi.org/project/pyais/> , resp. <https://github.com/M0r13n/pyais> (last accessed: 20.10.2022)

Felski, A., Jaskólski, K., & Banyś, P. (2015). Comprehensive assessment of automatic identification system (AIS) data application to anti-collision manoeuvring. *The Journal of Navigation*, 68(4), 697-717.

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<https://images.app.goo.gl/usCtVMWjg4up2QUP6> (last accessed: 20.10.2022)

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# Sources

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<https://www.svb.de/de/ratgeber/alles-was-sie-ueber-ais-wissen-sollten.html> (last accessed: 17.06.2022)

[https://en.wikipedia.org/wiki/Automatic\\_identification\\_system](https://en.wikipedia.org/wiki/Automatic_identification_system) (last accessed: 20.09.2022)

[https://digitalyacht.de/wpAdmiGermdy1118/wp-content/uploads/guides/Was\\_ist\\_AIS\\_Digital\\_Yacht.pdf](https://digitalyacht.de/wpAdmiGermdy1118/wp-content/uploads/guides/Was_ist_AIS_Digital_Yacht.pdf) (last accessed: 17.06.2022)

[https://usa.oceana.org/wp-content/uploads/sites/4/4046/oceana\\_ais\\_fin\\_all\\_hr-07\\_0.pdf](https://usa.oceana.org/wp-content/uploads/sites/4/4046/oceana_ais_fin_all_hr-07_0.pdf) (last accessed: 14.06.2022)

<https://images.app.goo.gl/mGpdXv2w1dQlmka08> (last accessed: 17.06.2022)

<https://images.app.goo.gl/11VtcBCVwDk7svKD7> (last accessed: 17.06.2022)

<https://images.app.goo.gl/uqWmJJ5yvotfYrNK9> (last accessed: 19.06.2022)

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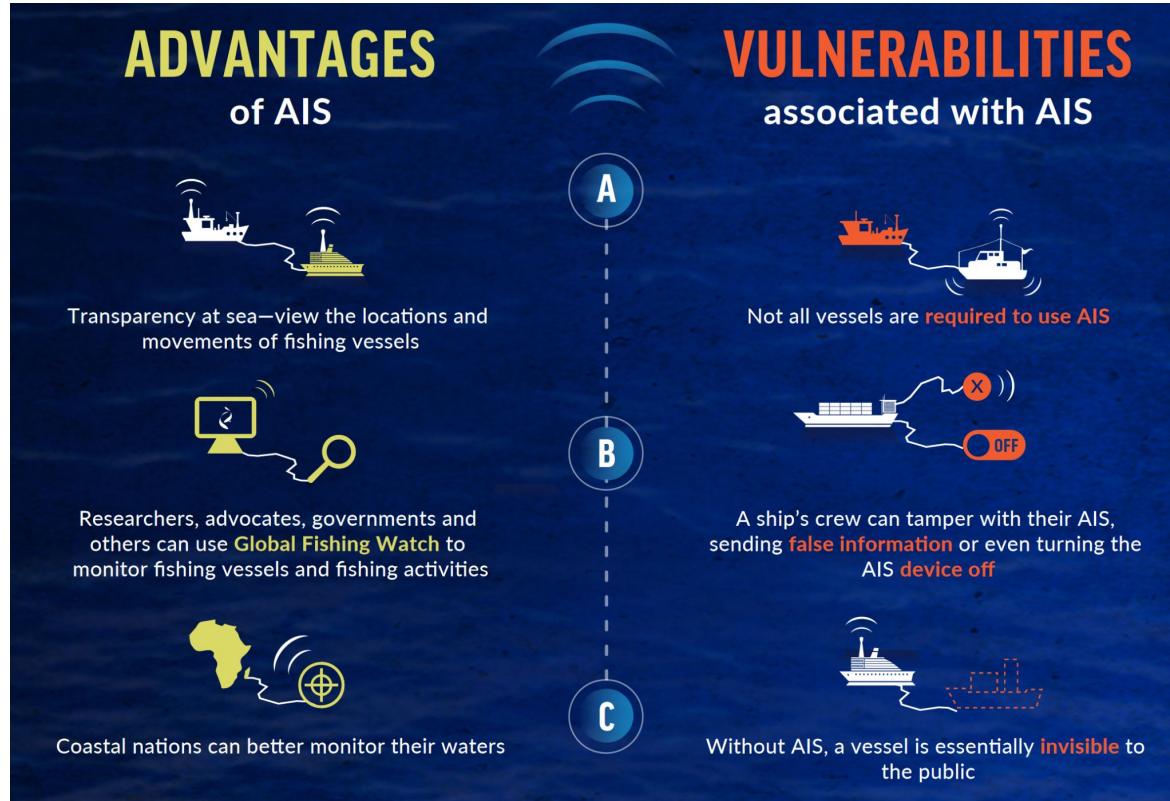
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# Collision detection set up

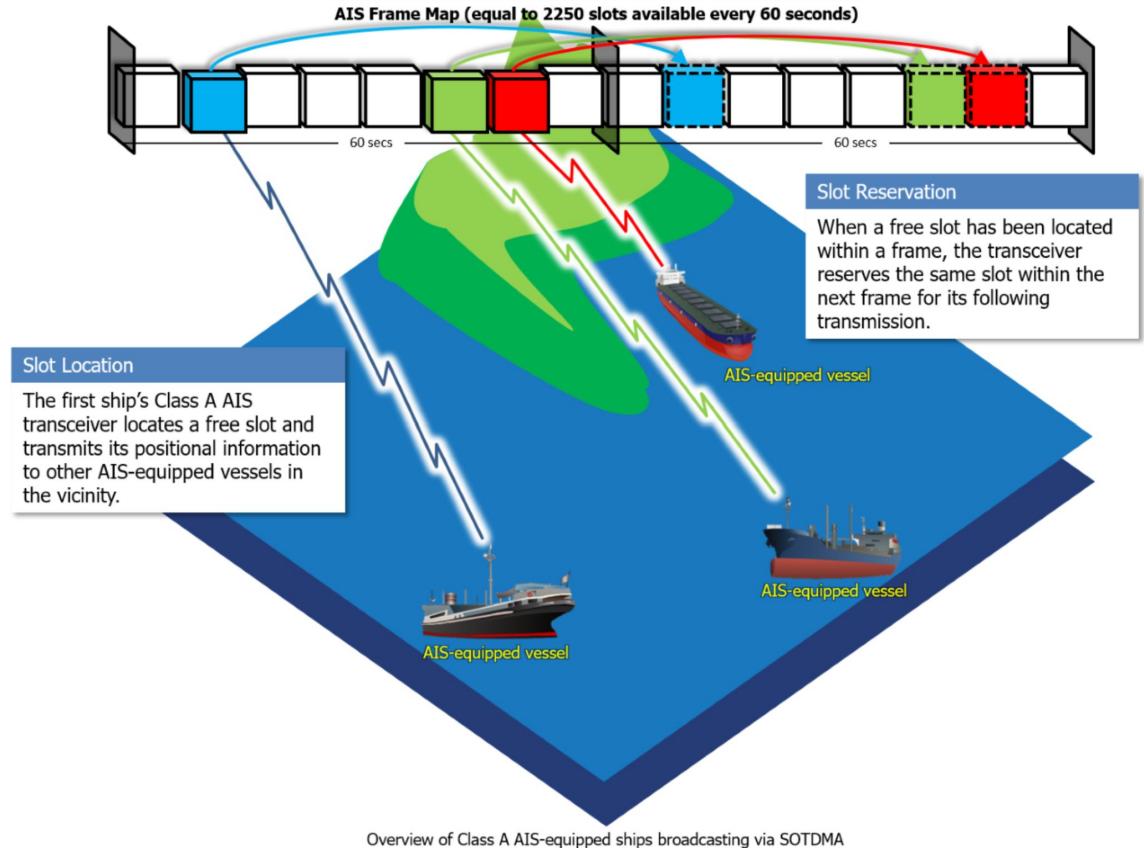


# AIS pros & cons



# Self Organising Time Division Multiple Access (SOTDMA)

- divides a channel into frames, which furthermore are subdivided into a vast number of time slots
- Class A AIS device will scan for available and “un-reserved” slots in the AIS slot frame map (one frame is equal to 2250 slots available in one minute intervals)
- reserve slot within the following frame for the next transmission as long as the ships using the same frame map



<https://marinfo.gc.ca/e-nav/docs/sotdma-cstdma-en.php> (last accessed: 20.06.2022)