Visual Encoding of Automatic Identification System (AIS) Data for Radar Systems

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ABSTRACT

The Automatic Identification System (AIS) is a maritime system mostly used for automatically exchanging tracking and other relevant information between vessels. It supports decision making of nautical personnel such as master mariners. AIS data are multivariate including many aspects for identification and localization of ships and for navigation. However, during navigation not all AIS data are made visually available to the nautical personnel. In this paper, we propose a glyph-based visualization consistent with currently used encodings for intuitively and effectively encoding further so far missing AIS data attributes on radar screens. Proposed extensions aim at increasing maritime safety by helping mariners to assess traffic situations. We applied our visualization methods to real-world data recorded at the German North Sea coast and evaluated them with the help of an expert group.

Keywords

Information visualization, Visualization techniques and methodologies, Application

1. INTRODUCTION

The Automatic Identification System (AIS) allows for transmitting data between AIS systems, which can be installed on vessels, base stations like harbor authorities, landmarks like buoys, or on search and rescue airplanes. The AIS data which are exchanged is divided in three different types [ITU13]:

- Static data (e.g., vessel name and the dimensions of the vessel)
- Dynamic data (e.g., vessel position, course over ground, and heading)
- Voyage-related data (e.g., current draught, description of cargo, and destination)

Thus AIS is a useful complement to systems like Radio Detection and Ranging (radar) by providing additional information which would otherwise not be available. Both static and dynamic AIS data provide useful information for course corrections and collision avoidance, respectively.

Radar systems which are installed on vessels make use of received AIS data by adding additional information extracted from the AIS data stream to the radar screens. So far the most common way of displaying AIS information is a visual encoding of basic information such as the geographical position and the current heading of the vessel. However, AIS data provide much more information and therefore the potential of AIS data for navigational purposes is not yet fully exploited.

We extend the existing AIS glyphs through identifying and encoding additional relevant AIS data attributes while considering general glyph design principles. Our main contributions are:

- Summarizing the current state of the art of representing AIS data on radar screens.
- Developing a visual encoding of additional identified attributes with the help of maritime experts which builds on and extends existing glyphs to ensure a high acceptance by users.
- Evaluating our proposed results by collecting feedback from an expert group.

AIS data are also used within Electronic Chart Display and Information Systems (ECDIS). Even though there is a strong link between both radar and ECDIS our focus lies on displaying AIS data on radar screens, i.e., on devices with limited resolution and with low rendering performance.

2. RELATED WORK

Currently, within the visualization area AIS data are used to predict and visualize vessel movements. Within this context important work has been released by Scheepens et al. who created interactive density maps or contour based visualizations of vessels and vessel trajectory data by using AIS data [Sch11a-c] [Sch14]. However, the AIS data representation as glyphs used by mariners on board has not advanced in the past years. A glyph is a small visual object which represents attributes of a data record. A variety of design guidelines and design criteria exist to develop glyphs [Che12] [Mag12][Pet10][Rop11].

Within this context important work related to AIS data has been released by Motz et al. [Mot08] who performed an experimental investigation for the German Federal Ministry of Transport, Building, and Housing to evaluate the presentation of AIS target information on Electronic Chart Display and Information Systems. They state that "[…] there is a compelling need for a suitable graphical presentation of AIS information in order to improve target identification, to reduce the mariner's workload by presenting information in a readily assimilated format, to enhance 'Situation Awareness', and thereby to reduce the risk of collision and to improve the safety of navigation, particularly in congested waters." [Mot08]. Further work has been performed by Motz and Widdel by evaluating the graphical presentation of AIS information on ships [Mot01]. Two experiments were conducted with simulated traffic scenarios on ECDIS and radar systems to identify symbols including symbol properties and visual channels such as size and color which are most suitable to display AIS information. Their results show that oriented triangles with additional attributes are the most suitable glyphs to represent vessels even though a diamond shaped symbol caused a faster detection rate of moving vessels [Mot01]. Based to the work of Motz and Widdel, guidelines for the presentation of navigation-related symbols have been released by the International Maritime Organization in 2004 [IMO04] which are shown in Fig. 1.

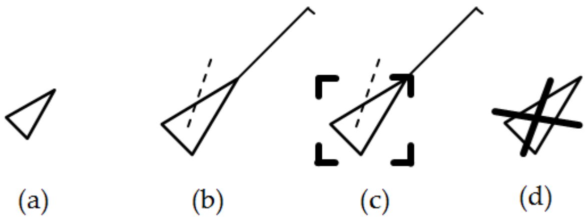

Figure 1. AIS symbols representing different AIS targets as recommended in [IMO04].

Fig. 1 (a) shows a non-moving AIS target symbol indicating the current position and heading of a vessel, (b) shows the recommended symbol for an active AIS target showing a rate of turn indication (ROT) as a small flag connected to a line which emphasizes the heading (HDG). The dashed line is a vector consisting of speed over ground (SOG) and course over ground (COG) and represents the actual movement and time based course prediction of the vessel which may differ from the HDG information. Glyph (c) represents a selected target and (d) a lost target which means that no AIS message has been received from this entity for a specific amount of time. Dangerous targets should be drawn bold and colored red. In addition they should be flashing until they are acknowledged. In 2008 an amendment to these guidelines had been released [IMO08]. AIS Search and Rescue Transmitters (AIS-SART) can be identified by their unique Maritime Mobile Service Identity (MMSI) number, therefore the latest update [IMO08] contains an additional glyph indicating AIS-SART targets, see Fig. 2.

Figure 2. Recommended symbol for AIS-SART as shown in [IMO08].

Further general design considerations with respect to maritime data can be adopted from the guidelines released by the International Hydrographical Organization (IHO) [IHO10]. Since the IHO intends to ensure a clear and unambiguous display of ECDIS screens, the proposed specifications [IHO10] are considered within our glyph design. In conclusion the current glyphs used for the representation of AIS targets shown in Fig. 1 and Fig. 2 give an indication to the mariner whether an AIS information is available or not. This includes:

- Geographical position consisting of latitude and longitude,
- HDG,
- COG,
- SOG, and
- ROT not equal to zero.

Therefore mostly visual channels of geometric and topological/relational type are used to encode AIS data visually. E.g., the guidelines for the presentation of navigation-related symbols almost do not make use of further visual channels such as color or transparency even though current radar systems provide color support. Furthermore, not every AIS system transmits all of the mentioned data fields as shown in [Las14]. E.g., it is possible that a vessel does not transmit HDG and COG, i.e., it is difficult to draw the triangle symbol correctly rotated. In contrast even more information might be available for a specific vessel but is not yet visually encoded in the glyphs in Fig. 1 and 2. This includes the ship type or the draught of a vessel. This leads to a lack of AIS indicators and missing glyphs in specific situations.

3. LIMITATIONS OF CURRENT AIS REPRESENTATION

The current graphical representation of the information provided by AIS covers a wide range of aspects relevant for navigational purposes. However, while evaluating recorded AIS data, we identified that the current visual encoding of AIS data is in some traffic situations not sufficient to display all relevant information. We address this problem by giving examples for such situations as well as by making proposals to extend existing symbols as well as by adding new symbols for currently not covered aspects.

Vessel type encoding

As shown in Fig. 2 AIS-SART systems can be easily identified on a radar screen since they are displayed with a separate symbol. However, AIS systems are installed on many more vessel types. Examples taken from [ITU13] are *Pleasure Craft, High Speed Craft, pilot vessels, law enforcement vessels,* or *Cargo*. This information is not encoded within the current AIS symbol set. However, encoding the vessel type allows a mariner identifying vessels which are relevant for the current situations at sea. The vessel type gives information about a vessel's maneuverability and may additionally include a cargo classification. Encoding additional vessel types allows the mariner to distinguish faster between radar and AIS echoes in situations with heavy traffic. Therefore it allows them to get in contact with, e.g., a Search And Rescue (SAR) vessel. Indicating the vessel type also allows a manual prediction of possible vessel movements, since a high speed craft has a bigger operational radius than a tanker and can also quickly change its movement direction. We propose to extend glyph (b) in Fig. 1 by adding a transparent filling if the vessel has transmitted its vessel type. In addition, we propose to use different colors to encode specific groups of vessels.

Navigational status encoding

In total, 16 different navigational statuses exist, of which seven are reserved for future use [ITU13]. The navigational status also belongs to the static information. The statuses *At anchor, Moored,* and *Aground* are currently concluded as non-moving AIS targets with the appropriate glyph shown in Fig. 1. All remaining statuses are considered as moving AIS targets. Related to the navigational status, our dataset shows that within crowded situations, e.g., in harbors, non-moving AIS targets may clutter the screen. However, filtering non-moving targets is not always possible since one may be interested in data of such a vessel.

Dimensions encoding

The AIS system provides the possibility to transmit the dimensions of a vessel. The dimensions are static, since they are entered manually when the AIS system is initially configured. The approach of displaying these dimensional values is described as AIS Target – True Scale Outline in [IMO04]. It is written that "A true scale outline may be added to the triangle symbol. […] Located relative to reported position and according to reported position offsets, beam, and length. Oriented along target's heading." [IMO04]. Even though these guidelines are almost 10 years old only few radar systems provide the possibility to show the vessel's dimension as an additional overlay. However, the vessel dimensions provide important information for collision avoiding and navigational purposes. The AIS target glyph of Fig. 1 (b) does not provide any information about actual vessel dimensions. Depending on the radar scale, the actual vessel size and also shape may be smaller or even bigger than the AIS target glyph. The radar echo itself may provide further information, however an echo is not always available and depending on the weather or other passing objects not reliable since shadowing may occur.

(SAR) aircraft encoding

Even though AIS is intended for usage by SAR aircrafts, our data set evaluation shows that it is not uncommon to install AIS systems on further aircrafts such as planes or helicopters which are, e.g., used to transfer workers to oil rigs. So far current systems do not display these aircrafts or they use the same symbol which is used for displaying vessels. This may lead to confusion since aircrafts have a different behavior since they are much faster than vessels and may not always provide a radar echo. So far no glyph representing aircrafts exists leading to irritations when aircrafts are being displayed with the vessel symbol shown in Fig. 1. Since SAR transmitter are represented by an own AIS glyph, we propose using a separate glyph for aircrafts as well.

Draught encoding

So far the vessel draught which is measured in meters is not visually encoded. Encoding the draught allows the mariner to estimate possible vessel movements since a container vessel with full cargo has a bigger draught than an empty one. This information cannot be obtained from the radar echo. In addition to this the draught value gives – if available – information about possible vessel movements and restrictions. E.g., if a vessel has a large draught, it may only drive in specific fairways. Furthermore encoding the draught roughly indicates a vessel's size to the user since a container ship has usually a higher draught than, e.g., a sailing yacht.

4. CONSTRAINTS FOR DISPLAY

Current radar systems which are used on board of professional operating vessels consist of a radar antenna to generate radar echoes, a radar processor unit (RPU), a radar screen to display radar echoes and further information calculated by the RPU and a trackball as an input device allowing the user to interact with the system. The RPU is usually an embedded system which queries and processes current sensor states and has therefore a restricted performance. Within the professional operating field a common size for radar screens is 19" with a resolution of 1280x1024 (SGXA). Beside the trackball further buttons exist which are connected to

 ISBN 978-80-86943-66-4

specific functionalities which must be accessed quickly. Those buttons are also related to the AIS data visualization, e.g., switching the AIS visualization on or off. Fig. 3 shows a radar screen excerpt displaying a situation with and without AIS overlay activated.

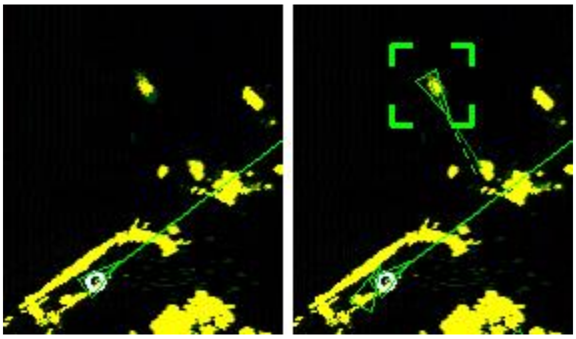

Figure 3. Radar screen excerpt. The white point indicates the own vessel position.

Visual encoding techniques are often used to encode rich data sets which consist of recorded data. Appropriate hardware and tools are available for data processing. However, Fig.3 shows that a radar system is a real time application with a restricted user interface and it is obvious that a graphical representation has to be very basic. Glyphs are represented by a limited number of pixels due to the low resolution and smoothly shaded objects cannot be rendered due to low-level graphics hardware. Extending the existing AIS encoding must not distract the user from his/her tasks. The visual encoding of AIS data must cause minimal occlusion of radar information while providing an additional benefit for the mariner. Large and complex glyphs are not an option and official guidelines such as [IHO10] must necessarily be considered. These guidelines "[…] ensure a base […] and appropriate compatibility with paper chart symbols as standardized in the Chart Specifications of the IHO" [IHO10]. Furthermore it is necessary to ensure that "[…] the display is clear and unambiguous" and "[…] that there is no uncertainty over the meaning of colors and symbols on the display […]". [IHO10] also includes technical limitations. Furthermore extensive studies have been performed to identify the most suitable glyphs shown in Fig. 1 and Fig. 2 to represent AIS data attributes. For that reason the concept of familiarity as described in [McD99] should be considered and therefore AIS extensions should be based on the existing encoding which has been proven and tested for years to achieve high acceptance by users. In addition to this, while developing AIS glyphs one has to consider that AIS data is sometimes partially missing or simply wrong [Har07][Las14].

5. GLYPH-BASED VISUAL ENCODING

Within this section we are presenting our novel glyph-based visual encoding approach. The existing visual AIS encodings are extended to overcome the problems mentioned in Section 3 while considering the constraints of Section 4. The evaluation is done by performing a qualitative user study with domain experts. The group of domain experts consisted of five experts aged between 35 and 65. All experts studied at a maritime academy, are (master) mariners, and have been working continuously in the maritime area. The range of professional experiences varies between 10 and 45 years. These experts are referred below as Expert 1, Expert 2, … , Expert 5.

Vessel type encoding

While experimenting with different colors and questioning users of our ship handling simulator we evaluated that, even though in total 100 codes exist to describe different vessel types, only a few of them are of interest for navigational purposes. We introduced two additional colors to indicate if a vessel belongs to a specific group. Perceptual studies have shown that the number of colors to be used shall be restricted [Hea96], here we suggest not using more than four different colors in total due to the limited resolution.

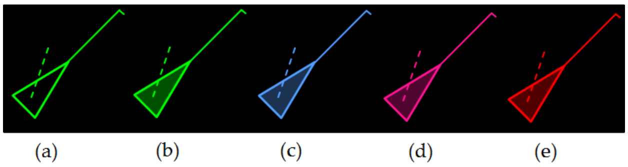

Figure 4. Encoding the vessel type information by using transparent fillings and two additional colours (blue and magenta).

Fig. 4 shows our proposed results using color and transparency as visual channels. Symbol (a) is equal to the AIS symbol for active targets shown in Fig. 1 (b) which is represented in a bright green RGB(0,255,0) by almost all current radar systems. We propose to use this glyph if no information about the vessel type is available (yet). Symbol (b) indicates that the ship type information is available and has been received. However, the ship type is not relevant for navigational purposes and therefore not separately color-coded. Examples for symbol (b) are the following ship types taken from the official AIS standard: *Local Vessel*, *Reserved*, *Pleasure Craft*, *Sailing*, or *Other Type*. If desired by the user the detailed ship type can be obtained from the radar menu. Symbol (c) uses a desaturated blue such as RGB(84,159,255) to represent assistance vessels like pilots and tugs, since blue as a foreground color is currently not used for AIS representations [IHO10]. Symbol (d) indicates that the AIS target represents an

 ISBN 978-80-86943-66-4

official vessel such as SAR vessels and Law Enforcement vessels using desaturated magenta color such as RGB(255,20,147), since magenta "[…] is used to highlight critically important features[…]" [IHO10]. Desaturated colors are used since the usage of saturated colors resulted in undesired pop-up effects. This pop-up effect should be reserved for dangerous targets which are being displayed red. Used filling colors are equal to the border colors, however the main body of the triangles is filled using transparency whereas the triangle borders are solid lines. Evaluations showed that a transparency value of around 68% allows the user to identify the color as well as to display radar echoes which are lying underneath the drawn AIS glyph. It is possible to use only colors for indicating the vessel type since each mariner has to pass a fitness test for sea service within regular intervals, starting with the beginning of the nautical education. Therefore mariners are tested for color blindness and similar diseases which represent a criterion for exclusion.

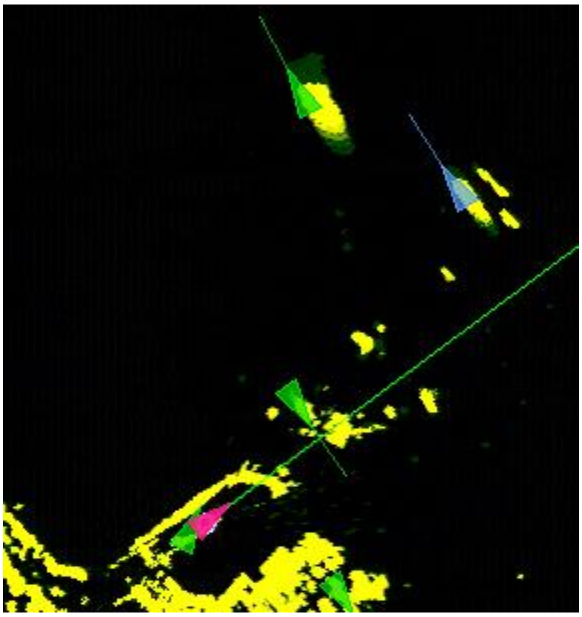

Figure. 5. Extended AIS glyphs using additional colors indicating the vessel type while using real data.

Discussion. While developing the glyphs we tried to group further vessel types such as *Tanker*, *Cargo*, and *Passenger* to a common group cargo or to display the vessel type *High Speed Craft* with an additional color. However, while experimenting with grouping and displaying further vessel types we realized that only few suitable colors with high contrast to the background, to radar echoes, and to AIS targets exist. Furthermore users of our ship handling simulator reported that coloring further vessel types beside (c) and (d) does not provide an actual benefit while navigating. We identified the same for the encoding of *Hazardous categories A-D* which can be added to the vessel type. E.g., it is possible to declare a vessel type as *Cargo - Hazardous category C* while using AIS. One approach was to encode an eventually available hazardous category by using the color red RGB(255,0,0) for the solid triangle border while still using the proposed main body colors in Fig. 4. This caused a pop-up effect as described by Chung et al. [Chu13]. Even though this implementation provides a good visual interpretability, users of the ship handling simulator reported that the benefit of encoding hazardous categories is not significant for navigating.

Results. Fig. 5 shows our proposed encoding using recorded AIS and radar data. We can observe that all visible vessels transmitted their vessel type. The appropriate radar echoes are still visible since transparency is used. Furthermore it is visible that the blue target is an assistance vessel whereas the magenta target is a SAR vessel, more precisely, the SAR vessel which had been used to record the shown radar and AIS data. Since we suggest assigning a higher priority to SAR and Law Enforcement vessels as shown in Fig. 4 (d) these vessel types should always be drawn on top. This approach allows identifying and selecting such AIS targets even in cluttered situations.

Evaluation. The evaluation feedback from the expert group is positive. Expert 3 states that the usage of colors to represent vessel types "[…] is definitely a huge advantage". Expert 3 also agrees that the amount of color groups which were developed within our work represent the maximum. Expert 2 agrees that our color encoding is helpful. Furthermore Expert 2 states that a further differentiation of vessel types with additional colors would be confusing. Only Expert 4 stated that he would not color any of the different vessel types at all, since, despite the usage of transparency, radar echoes might be covered if too many vessels are located close to each other. Concerning the vessel types only pilots are of interest for Expert 4. In summary, the expert group agrees that the vessel type encoding provides a benefit. The opinions only differ related to the vessel types which should actually be encoded. Examples are Expert 5 who is interested in a separate encoding for high speed crafts and Expert 4 who is only interested in pilot vessels.

Navigational status encoding

We used real-world data to analyze different situations with non-moving and moving targets. Since the current glyph for non-moving targets is still similar to the glyph for moving or active targets, evaluations showed that it can be difficult to distinguish the two glyphs, especially in areas with a high vessel density. Thus, we suggest a more

 ISBN 978-80-86943-66-4

meaningful glyph for non-moving targets as shown in Fig. 6.

Figure 6. Indicating non-moving vessels by drawing a circle inside of the triangle.

Results. Fig. 7 shows a scenario with the proposed glyph visually encoding non-moving vessels. Furthermore the proposed vessel type encoding is visible. The radar range is 1.5 nautical miles and the images are using a reduced scale. All non-moving targets can be distinguished from active targets even though the images show a cluttered scene representing real data.

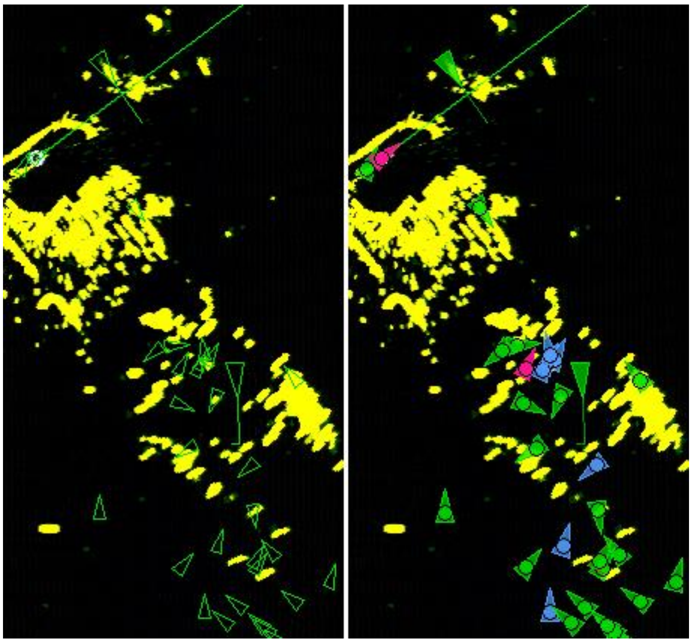

Figure. 7. Comparison of currently used AIS glyphs (left) and proposed glyphs (right) concerning vessel types and navigational status.

Evaluation. Only Expert 4 stated that the currently used encoding is sufficient to display non-moving targets. All other experts agreed that our proposed encoding allows for a faster assessment of the scene and to distinguish non-moving and active targets. E.g., Expert 2 stated that our encoding is "[…] reasonable and allows for a faster situation assessment".

Dimensions encoding

Since only 3.4% of all vessels fail to transmit their dimensions [Las14], current ECDIS and radar system should support their visual encoding. The guidelines for the presentation of navigation-related symbols recommend drawing a true scale outline [IMO04]. However, during our evaluations we observed that (depending on further visual channels such as color) a vessel's outline is hard to spot even on low radar ranges. Our evaluations showed that drawing the dimensional values is best recognizable when being drawn as a filled polygon with a slightly differing border color. We recommend a cyan filling color of RGB(0,255,255) and a blue outline color of RGB(0,0,255). The polygon itself should be drawn on top of the appropriate AIS target symbol, since it provides more detailed information and is easier to spot as shown in Fig. 8. One target to the left has not transmitted its dimension values indicating that these values might not be available or simply have not been received so far.

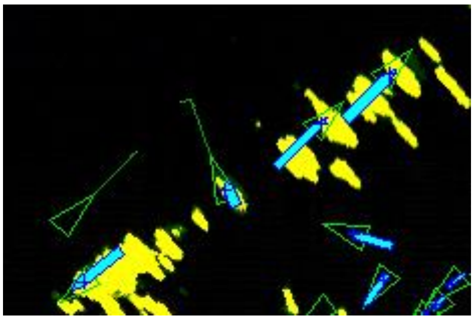

Figure 8. Dimensions are drawn as additional overlay for AIS targets. Radar range is 1.5 nautical miles.

Results and Discussion. As exemplarily shown in Fig. 8, the AIS glyph size is barely ever similar to the actual dimensions of the visible vessels. Only using the triangle glyph may cause a wrong impression to the mariner. As shown in Fig. 8, several driving and moored vessels are actually located mostly outside of the AIS target glyph since only the antenna position which is in these cases close to the bow is used to draw the AIS target glyph. The antenna positions are displayed by a blue cross for test purposes. We also evaluated that the vessel's dimensions should be displayed independently of the radar range. Even though vessels with small dimensions are more difficult to spot if the radar range exceeds 1.5 nautical miles, larger vessels are still good to spot. Therefore displaying vessel dimensions should not be related to a specific radar range but able to be (de-)activated by using an additional button to avoid cluttered scenes. While working with the provided vessel dimensions, each mariner should be aware that the dimensional data are error-prone, since they were entered manually. Therefore, uncertainty of these data has to be considered, especially when vessels are close to each other. Nevertheless these data should be used since it provides useful information for mariners.

Evaluation. The expert group agrees that our proposed overlay provides a huge benefit. Nevertheless Expert 2 states that "[…] it is important not to clutter the radar screen.". Expert 3 states that "[…] the amount of features being displayed should not distract from the actual situation". Therefore all experts agreed to our decision that it should be possible for the mariner to (de-)activate this kind of overlay as and when required.

(SAR) aircraft encoding

As mentioned beforehand AIS systems can also be installed on aircrafts. While evaluating recorded data we identified fast moving AIS aircraft targets. Currently SAR Aircrafts and vessels share the same glyph for active AIS targets as they are both AIS targets. While analyzing AIS data we identified scenarios with SAR aircrafts and vessels in which using the same glyph may result in confusion, since the user expects that the active AIS glyph represents a vessel and not a SAR aircraft. We propose to use a glyph which has been initially developed for vessels by [Mot01] but has been replaced by the glyph shown in Fig. 1 (b) to avoid confusion in situations where SAR aircrafts are additionally displayed. Even though a COG attribute is included in the appropriate AIS message we suggest using the glyph shown in Fig. 9 to represent SAR aircrafts since our evaluations show that the COG attribute might also not be available.

Figure 9. Proposed (SAR) aircraft glyph which can be distinguished from the active target glyph shown in Fig. 1(b) since no rotation is used. COG might be indicated by a solid line, if available.

Evaluation. The feedback we got was mixed. Expert 1 agrees that a separate symbol should be used. However, Expert 1 states that the symbol of Fig. 9 "is too similar to the current active target symbol". Expert 2 agrees with Expert 1 that a general representation is desired but the symbol of Fig. 9 might not be suitable. All further experts state that civil aircrafts should be in general not displayed since they are not of interest. However, since it is not possible to distinguish between civil and SAR aircrafts because of the used AIS message type, a usage of a separate glyph is meaningful.

Draught encoding

Visually encoding the dimensions allows for predicting a vessel's route and possible maneuvers which can be performed by the vessel. The same applies for a vessel's draught, which has not been visually encoded so far. We propose to distinguish the three classes *small draught* of 0m to 2m, *middle draught* of 2m to 10m, and *large draught* of more than 10m and visually encode this information with 1, 2, or 3 filled circles at the beginning of the heading line, see Fig. 10. Missing circles indicate that there is no draught information available. If a vessel is a non-moving target, both heading line and draught information are not displayed since only moving targets whose courses are related to the own vessel's course are of interest to a mariner in terms of navigation. Therefore draught information for non-moving targets does not provide any benefit.

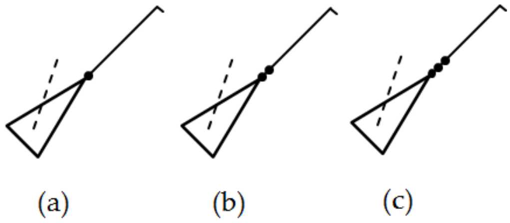

Figure 10. Encoding draught values using the classes of draughts represented by filled circles attached to the heading line.

Results and Discussion. Fig. 11 shows exemplarily the proposed encoding applied to real world data. The left image of Fig. 11 shows two vessels with a middle draught and a few non-moving targets. The right image of Fig. 11 shows a vessel with a large draught. In the present case, the radar echo already indicates that this vessel has a huge size and therefore a higher draught. However, the radar echo may not always be available. E.g., the vessel with a middle draught in the right image is almost completely shadowed by the bigger vessel and has therefore almost no radar echo. Encoding both dimensional and draught values as shown above allows mariners to assess traffic situations and to predict possible vessel movements.

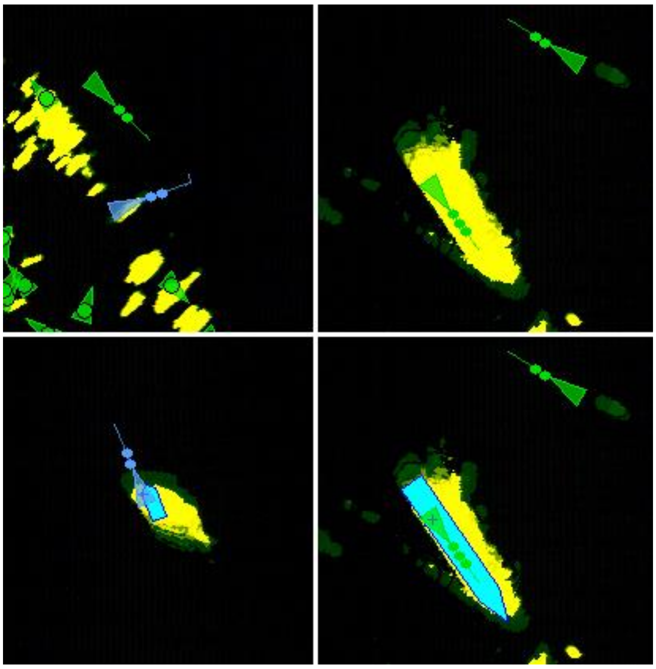

Figure 11. Encoding AIS draught values.
Top left: Two vessels with middle draught (2m-10m) can be spotted. Top right: One vessel has middle draught; one vessel has large draught with more than 10m. The bottom images show the dimensions additionally (if received).

 ISBN 978-80-86943-66-4

Evaluation. Expert 3 and Expert 4 would slightly modify our proposed values. These experts would only distinguish between heavy draught bigger than 10m and no draught. However, Expert 5 prefers the proposed values. In general, all experts agreed that our proposed draught encoding is a huge benefit for the mariner. E.g., Expert 2 stated that "[…] a faster assessment of possible vessel movements and movement restrictions is possible" when using our encoding. Expert 5 states that our encoding is "[…] absolutely meaningful, especially in narrow waters".

6. CONCLUSION & FUTURE WORK

Within this paper we identified several AIS aspects which provide a benefit for users of radar systems and which are currently not visually encoded. We proposed several extensions for using glyphs to encode this information visually on radar screens. While identifying and encoding missing AIS attributes such as draught, each extension represents a trade-off between encoding data as detailed as possible and not overloading the radar screen. While implementing and evaluating different approaches we considered the concept of familiarity as an important factor. Therefore, our work is based on current AIS glyphs. Experiments were conducted with recorded traffic scenarios on radar systems to collect expert feedback. In conclusion, all experts agree that AIS features need to be activated as and when required. If detailed information is desired an additional inspection needs to be performed by the user to avoid cluttered scenes. Furthermore our work shows that different experts assign different features a higher or lower priority. Therefore future work should include a detailed user study as well as controlled experiments to evaluate, e.g., reaction times.

7. ACKNOWLEDGMENTS

The authors are grateful for the assistance by Deutsche Gesellschaft zur Rettung Schiffbrüchiger (DGzRS) (German Maritime Search and Rescue Service). This study has been funded by the Federal Ministry of Education and Research (BMBF) (Grant no. 03FH001PX2).

8. REFERENCES

[Che12] M. Chen and L. Floridi, "An Analysis Of Information Visualisation," Synthese, vol. 190, pp. 5,6, 2012.

[Chu13] D. H. Chung, P. A. Legg, M. L. Parry, R. Bown, I. W. Griffiths, R. S. Laramee and M. Chen, "Glyph Sorting: Interactive Visualization For Multi-Dimensional Data," Information Visualization, pp. 4, 2013.

[Har07] A. Harati-Mokhtari, A. Wall, P. Brooks and J. Wang, "Automatic Identification System (AIS): Data Reliability and Human Error Implications," Journal of Navigation, vol. 60, pp. 373-389, 2007.

[Hea96] G. Healey, C., 1996. Choosing Effective Colours for Data Visualization, IEEE, ed. In: Visualization '96. Proceedings., Oct. 27-Nov. 1 1996, pp. 263-270.

[IHO10] IHO. S-52 - specifications for chart content and display aspects of ECDIS. 2014(05/05), pp. 13,14,17,38,39,40,45. 2010. Available: http://www.iho.int/iho_pubs/standard/S-52/S-52_e6.0_EN.pdf

[IMO04] IMO. Guidelines for the presentation of navigation-related symbols, terms and abbreviations. 2014(05/05), pp. 4,9. 2004. Available: http://www.iho.int/mtg_docs/International_Organizations/IMO/ECDIS-ENCDocuments/English/SN_Circ243.pdf

[IMO08] IMO. Amendment to guidelines for the presentation of navigtion-related symbols, terms and abbreviations. 2014(05/05), pp. 1,2. 2008. Available: http://www.iho.int/mtg_docs/International_Organizations/IMO/ECDIS-ENCDocuments/English/SN_Circ243-Add.1.pdf

[ITU13] ITU. Technical characteristics for an automatic identification system using time-division multiple access in the VHF maritime mobile band. 2013(05/12), pp. 3-109. 2010.

[Las14] P. Last, C. Bahlke, M. Hering-Bertram and L. Linsen, "Comprehensive Analysis of Automatic Identification System (AIS) Data in Regard to Vessel Movement Prediction," Journal of Navigation, vol. 67, pp. 1-19, 2014.

[Mag12] E. Maguire, P. Rocca-Serra, S. Sansone, J. Davies and M. Chen, "Taxonomy-Based Glyph Design—With A Case Study On Visualizing Workflows Of Biological Experiments," IEEE Trans. Visual. Comput. Graphics, vol. 18, pp. 6, 2012.

[McD99] S. J. P. McDougall, M. B. Curry and O. de Bruin, "Measuring symbol and icon characteristics: Norms for concreteness, complexity, meaningfulness, familiarity, and semantic distance for 239 symbols," Behavior Research Methods, Instruments. & Computers, vol. 31, pp. 4,5, 1999.

[Mot01] F. Motz and H. Widdel, "Graphical Presentation of AIS Information on Ships," Proceedings of the Human Factors and Ergonomics Society Annual Meeting, vol. 45, pp. 1-6, 2001.

[Mot08] F. Motz, H. Widdel, S. MacKinnon, A. Patterson and L. Alexander, "Experimental investigation for presentation of AIS symbols on ECDIS in a motion-based ship bridge simulator," in Ergonomie Und Mensch-Maschine-Systeme, Springer Berlin Heidelberg, Ed. 2008, pp. 147-159.

[Pet10] R. Pettersson, "Information Design—Principles and Guidelines." Journal of Visual Literacy, vol. 29, pp. 6,9, 2010.

[Rop11] T. Ropinski, S. Oeltze and B. Preim, "Survey Of Glyph-Based Visualization Techniques For Spatial Multivariate Medical Data," Comput. Graph., vol. 35, pp. 2, 2011.

[Sch11a] Scheepens, R., Willems, N., van de Wetering, H., Andrienko, G., Andrienko, N. and van Wijk, J.J., Composite Density Maps for Multivariate Trajectories. IEEE Transactions on Visualization and Computer Graphics, 17(12), pp. 2518-2527, 2011.

[Sch11b] Scheepens, R., Willems, N., van de Wetering, H. and van Wijk, J.J., Interactive Density Maps for Moving Objects. Computer Graphics and Applications, IEEE, 32(1), pp. 56-66, 2011.

[Sch11c] Scheepens, R., Willems, N., van de Wetering, H. and van Wijk, J.J., Interactive Visualization of Multivariate Trajectory Data with Density Maps. Pacific Visualization Symposium (PacificVis), 2011 IEEE, pp. 147-154, 2011.

[Sch14] Scheepens, R., van de Wetering, H. and van Wijk, J.J., Contour based visualization of vessel movement predictions. International Journal of Geographical Information Science, 28(5), pp. 891-909, 2014.

 ISBN 978-80-86943-66-4