Measuring Field of Vision Using Digital Human Modelling Techniques

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ABSTRACT

This paper will provide the methodology used to evaluate the field of vision for an entire target population whilst only working in a digital environment using digital human modelling techniques. The context is an evaluation of a small, powered craft at sea, operating at different running trims. The maritime regulations stipulate that the pilot of the boat must be able to see the surface of the water at one boat length. The standard BS EN ISO 11591:2019 'Small craft – Field of Vision from the steering position' provides the practitioner with the target conditions in the horizontal and vertical fields but very little information on the evaluation of the different boats that exist. This paper will take the reader through the entire process for measuring the Field of Vision for any small craft (i.e. less than 24 metres in length), at a range of running trims, using digital human modelling and computer aided drawing techniques.

KEYWORDS

Field of Vision, Digital Human Modelling, Computer Aided Drawing, Naval Architects, Proof of Concept

Introduction

Over the course of the Covid-19 pandemic more and more projects are being conducted remotely because of travel restrictions and local lockdown rules. Digital human modelling is suited for remote working, it is possible to analyse a digital design concept with representatives of the target population. The accuracy of the technique is determined by the skill and experience of the practitioner.

This paper shares some techniques that will enable practitioners to measure the field of vision for pilots of small craft at sea. This paper is important because it will provide naval architects with the methodology to evaluate their designs against the standards, to identify shortfalls and improve the field of vision for all.

The paper is organised in the following manner:

- Step 1 – Gather source evidence
- Step 2 – Build virtual testing environment
- Step 3 – Build digital human models
- Step 4 – Experimental design
- Step 5 – Findings and Conclusion

This paper will provide an overview of each step and explore key decisions that influenced the overall approach and selection of measurement techniques and tools used for the field of vision assessment. A substitute boat, a Norwegian fishing trawler has been used to showcase the methods that were used for a client in order to maintain their anonymity. The results of the study have not been published as per the confidentiality agreement with the client.

1. Gather Source Evidence

This step is essential for ensuring that the field of vision study can be verified against recognised bodies of work and that the findings can be defended when scrutinised by a client led multi-disciplined review panel.

Current body of knowledge and general pilot requirements

The following maritime legislation and human factors guidance were reviewed at the start of the project.

- MGN 313 (F) ‘Keeping a Safe Navigational Watch on Fishing Vessels’
- MGN 314 (F) ‘Wheelhouse visibility onboard fishing vessels’
- ABCD-TR-15-001: Supplement ‘High Speed Craft Human Factors Engineering Design Guide’ 2016
- ABCD-TR-08-01 V1.0 ‘High Speed Craft Human Factors Engineering Design Guide’, Section B Sight
- COLREGs – Preventing Collisions at Sea, 1972
- MSN 1781 (M + F) Amendment 2 ‘Navigation Safety: The Merchant Shipping (Distress Signals and Prevention of Collisions) Regulations 1996 – COLREG
- 2002 No.1473 Merchant Shipping Safety, ‘The Merchant Shipping (Safety of Navigation) Regulations 2002
- BS EN ISO 11591:2019 ‘Small craft – Field of Vision from the steering position’

The initial review helps to identify some of the initial criteria for the Field of Vision study, the following high level pilot requirements were identified.

- To see the bow of the craft
- To view the sea surface at a distance of one craft length or less from the hull over an arc from dead ahead to the beam on each side (i.e. view straight ahead, view port, view starboard)

The standard BS EN ISO 11591:2019 ‘Small craft – Field of Vision from the steering position’ provides prescriptive advice for assessing a standing operator and seated operator but before the approach can be formulated, it is essential to understand your client requirements and their own body of knowledge.

Client Requirements and body of knowledge

The client requested the study based on a series of other studies that had been conducted during sea trials of the boat in question. A sea trial was eliminated because of the restrictions imposed by the Covid-19 pandemic, the request for the digital model review was a primary requirement.

A number of documents were provided that covered the following:

- Ethnographic study of life onboard the boat
- Anthropometric data captured for the pilot target population
- Video footage of the boat from inside the wheelhouse
- Crew feedback associated with the operation of the boat
- CAD model and technical data for the boat (e.g. running trim at different speeds, boat length)

Following the review of the client literature, it was possible to determine that the study needed to focus on the eye view of a seated pilot, whilst performing a set of tasks with the boat at a range of running trims.

The Standard BS EN ISO 11591:2019 ‘Small craft – Field of Vision from the steering position’ provides a pictorial guide for identifying obstructions in the vertical field for a seated pilot, see Figure 1 below.

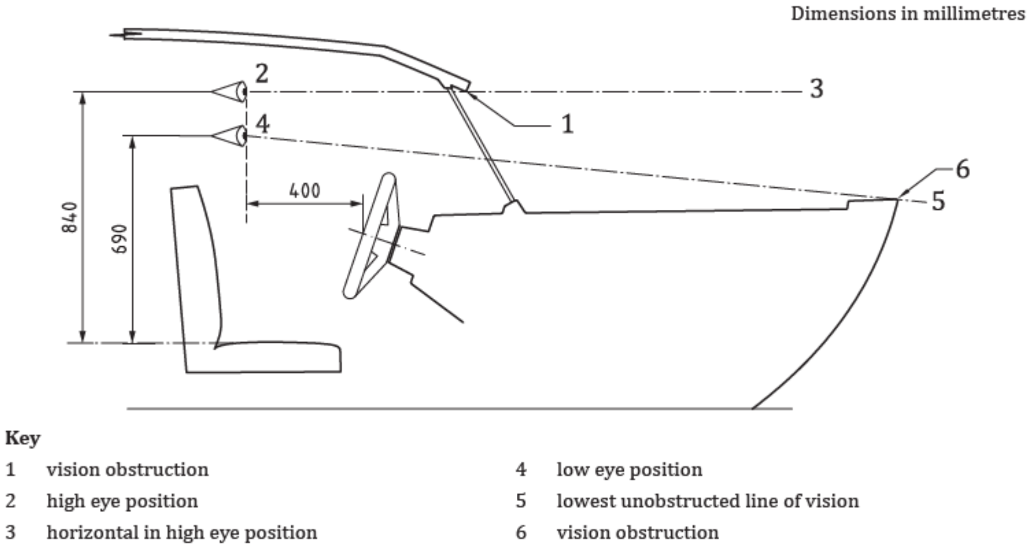

Figure 1: Eye positions and vertical Field of Vision – operator in seated position

Standards always require interpretation, in the case of the client’s boat, there is no steering wheel but instead an armrest mounted tiller was used and a throttle on the other armrest. The high eye position and low eye position criteria have been adjusted to reflect the anthropometric data set agreed by the client.

The Standard BS EN ISO 11591:2019 ‘Small craft – Field of Vision from the steering position’ provides an illustration of the field of vision in the horizontal plane, this is useful for setting out the boundaries of the study and determing measurement criteria, see Figure 2 below.

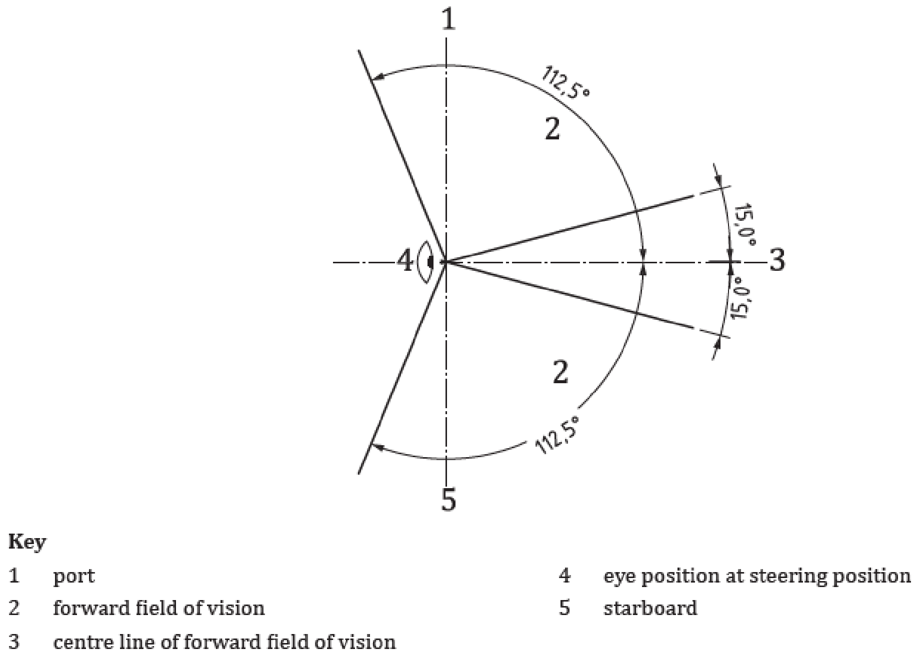

Figure 2: Field of vision, forward, horizontal

2. Build Virtual Testing Environment

This is a critical point in the methodology, the accuracy of the virtual testing environment directly influences the shape of the study and the validation of any outcomes drawn.

Computer Aided Design Model Import

The Client's naval architect team provided a Computer Aided Model (CAD) of the boat at the centre of the study. In order to use a CAD model in the Digital Human Modelling software, it is necessary to translate the CAD file from its native format into a JT format. During the translation process it is possible for the CAD model to become corrupted and for the geometry of the model to alter.

To counteract this potential risk, the geometry of key reference points on the model are double checked with the original model. Following the geometric checks, the translated model was sufficiently validated for use in the virtual test environment.

Creating multiple test environments

As previously mentioned, the client had specific requirements regarding the trim of the boat, they wanted to see how the boat speed and corresponding boat trim influenced the field of vision.

Table 1: Boat speed and running trims used for the study

Boat speed (knots)	Angle of running trim (°)
0	0
8	3
18	7
25	5

A minimum of four test environments were required, one for each running trim.

Adjusting running trim

A dialogue was set up with the naval architects, in order to establish if the boat's attitude in the virtual test environment was an accurate portrayal of the calculated running trim of the boat at the different boat speeds and to identify the point of rotation relative to the waterline.

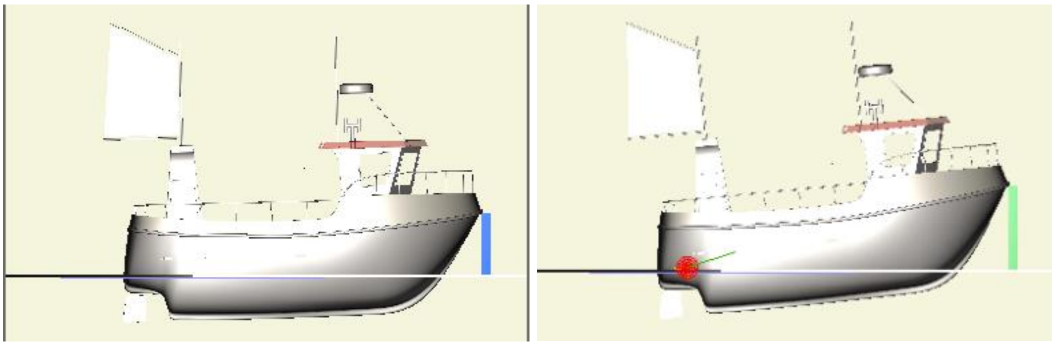

Figure 3: Boat at 0^0 running trim (left hand image), point of rotation and running trim at 3^0

Once the point of rotation was agreed with all stakeholders, it was possible to then orientate the boat relative to the waterline. To ensure that the boat was accurately positioned, a landmark on the bow was identified, and then a measuring rule was added to the waterline element of the model, the measuring rule interfaced with the underside of the landmark.

Creating a referenceable sea surface

When revisiting the pilot's original task goal to see the water's surface. In Figure 4 below, the green band is one boat length and the threshold with the yellow band is the visual target zone.

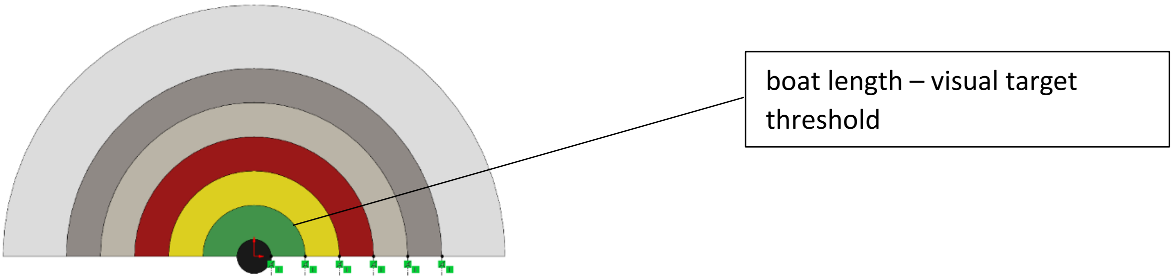

Figure 4: Sea surface boat length reference tool

3. Build Digital Human Models

It is important that the digital human models used accurately represent the range of the target population. For this study, 6 virtual participants were used with sitting eye heights that ranged from 678 mm to 882 mm.

Anthropometric datasets

It is possible to select the key anthropometric dimensions for building the digital human models once you understand how the pilot interacts with the boat (i.e. seated or standing postures). Seven data points were selected for building the digital human models. The datasets were primarily sourced from the peoplesize2020 database and cross referenced with the client's own anthropometric database to ensure that the data used was representative of the entire client target population.

Build and calibrate Digital Human Model

The anthropometric data was entered into the advanced anthropometric body scaling tool in the digital human modelling software, a segmented model was then converted into a smooth rendered model using the copy function for transferring anthropometric data. See Figure 5 for an example of the software function being executed.

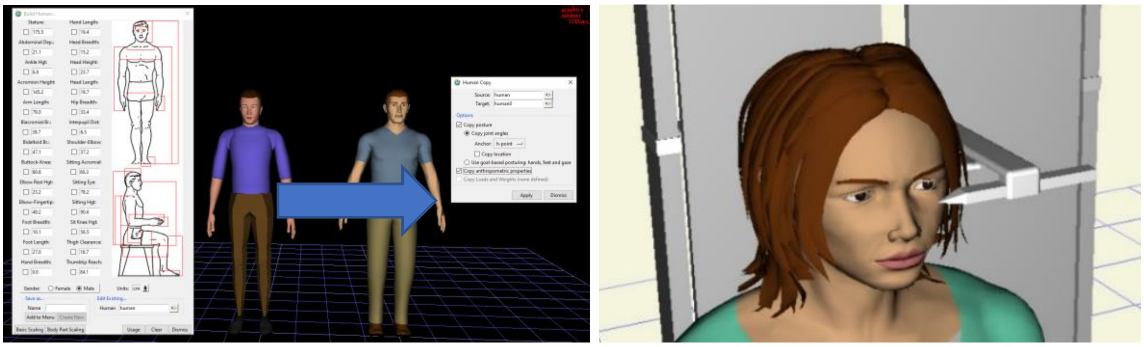

Figure 5: Build Digital Human (L-H), Measurement of sitting eye height (R-H)

Once the models are built, a virtual anthropology laboratory is used to take real world measurements of the human models to confirm that the sitting height and sitting eye height aligned with the anthropometric data tables, see Figure 5 above. Using this approach, it was possible to calculate compression corrections for the fine adjustment of the model's seated posture.

4. Experimental design

Most of the components for running the field of vision study have been added to the virtual test environment. Four different virtual environments have been created, one for each running trim, the sea surface has been added in all four environments, the next step is to revisit the study criteria.

Study criteria

The following study requirements were identified following the literature review.

- Identify vision obstructions to the field of vision in horizontal and vertical planes
- To view the sea surface at one boat length
- Assess the impact of running trim on the obscuration zones, by measuring the clear and blind sectors of the field of vision

In order to identify the vision obstructions, it is necessary to take a closer look at the inside of the small craft's wheelhouse. It is also necessary to establish a repeatable measurement technique of the field of vision using the digital human models.

Reference points inside the wheelhouse

The internal furniture of the wheelhouse is labelled up and given initials so that the features can be used as points of reference when describing the field of vision. See Figure 6 below for a description of the wheelhouse reference points.

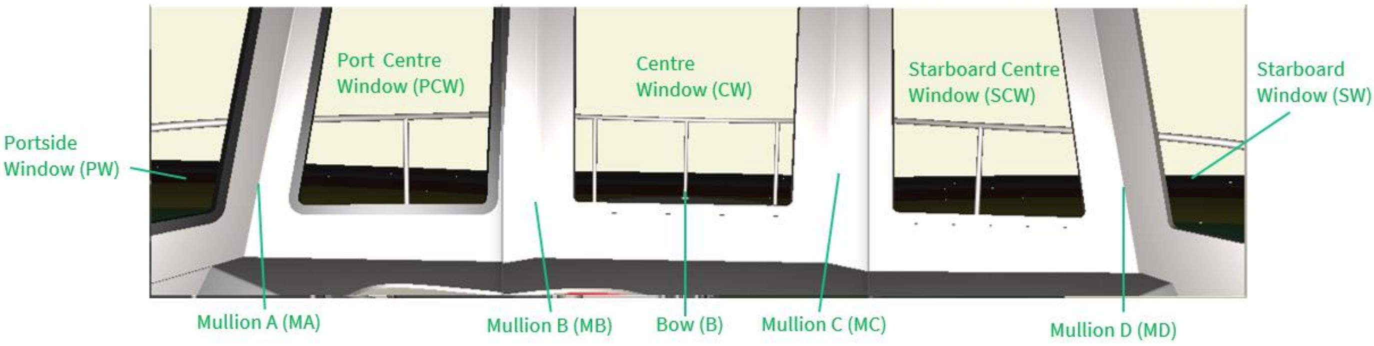

Figure 6: Wheelhouse reference points for data interpretation

The Digital Human Model set up

The digital human models eye view function is used to measure the field of vision, it is important that the measures used are reliable and repeatable. The range of the target population are all in the same seated posture, same posture used to record sitting height and sitting eye height, seated straight. For an element of realism, the digital human models are gripping a steering wheel, the full control console has not been recreated for this study, See Figure 7 below to see the seated postures used for the digital human models used for this study, and their location within the wheelhouse, and the three different head postures used to represent a reasonable movement of the head to scan the horizon.

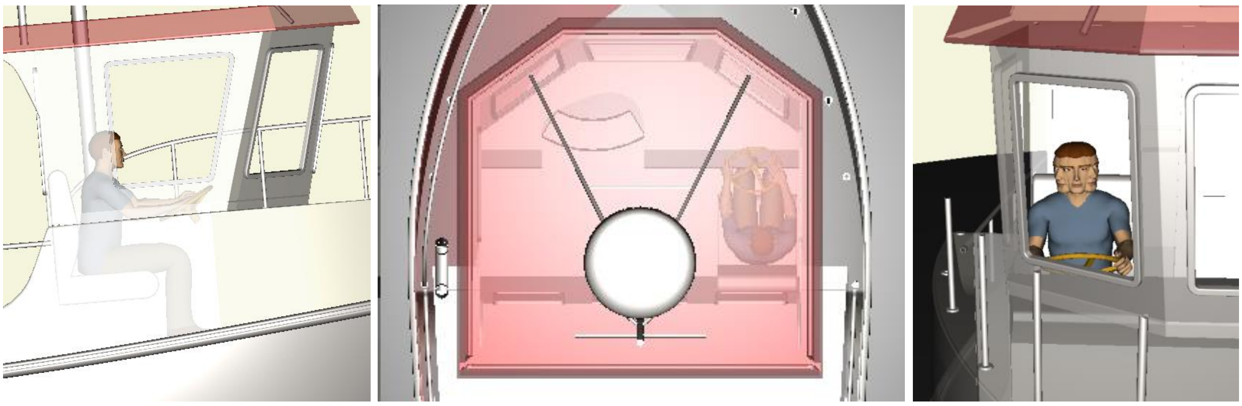

Figure 7: Seated postures (L-H), location within wheelhouse (C), head postures used (R-H)

The seats used by the client are non-adjustable in height, and for the purpose of the study the seat base remained at the same height throughout the study. There is movement of the seat at sea but to model up all of the different combinations of seat height when travelling over waves would detract away from the original scope which was to determine if running trim influenced the field of vision.

Three replicas of the model were positioned on top of each other, then the atlanto_occipital joint was rotated to -43^{o} and + 43^{o} on two of the models in order to simulate a full Field of Vision achievable by the target population using reasonable postures. In order to simplify the study, only the movement of the head was considered to be representative of the body postures used when scanning the horizon. The different head postures eye view windows are numbered for identification.

Digital human model eye view function

The digital human modelling software has an eye view function designed to replicate a human field of view. As with all models, it is important to understand the limitations of the model and with this aim, the viewing cones are calibrated using a sphere in the Field of Vision. The estimated viewing cone is 48^{0}. The combination of the three different head postures (head views 6, 4, and 5), enables the assessor to build up a panoramic field of vision, see Figure 8 below.

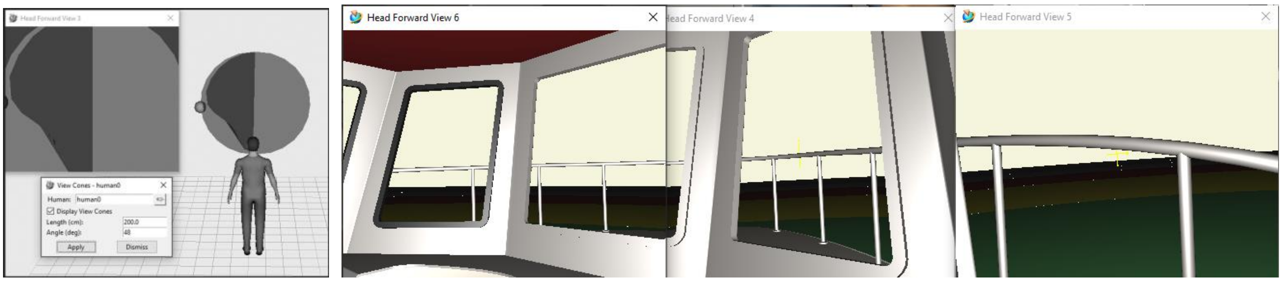

Figure 8: Digital human model eye view check (L-H), panoramic eye view (R-H)

Field of vision control condition

In order to understand the limitations of the study, the Field of Vision was measured without the wheelhouse. The full unobstructed vision for the pilot using the study protocols for the whole-body postures used and the eye view set up was 136^{o}, and this was recorded as the FoVc, Field of Vision control. The Field of Vision that included the wheelhouse was recorded as the FoVa, actual field of vision.

5. Findings and Conclusion

The findings are limited to the design of the experiment and dependent on the manipulation of the digital human models within the wheelhouse, the accuracy of the CAD model and the accurate location of the point of rotation and boats angle at the different running trims. It is recognised that this study assumes that the boat is travelling on a flat sea (i.e., calm day), and that the results would vary if different sea conditions were modelled up.

Example of findings interpretation of results

A series of small boats were positioned around the field of vision arc, to gauge the size of the clear and blind sectors. Either end of the field of vision was marked using small boat passengers, one green and one red.

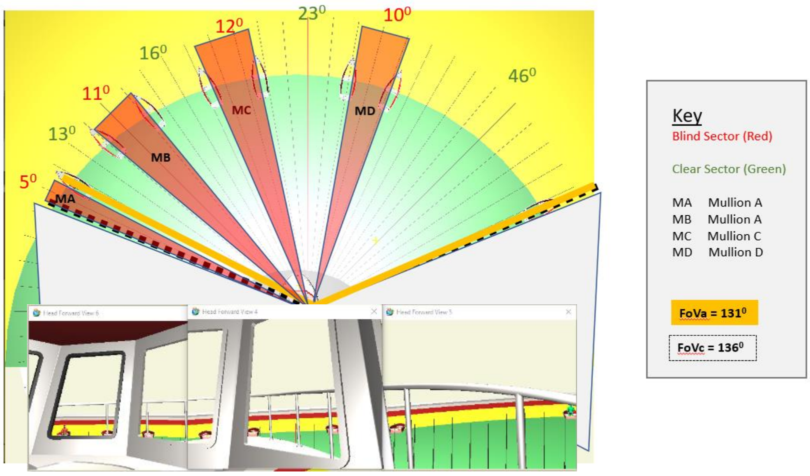

Figure 9: example data capture and analysis

The pilots panoramic view was then captured, a plan view was then used to measure the sectors using the Field of vision tool, each sector is 5^0 and it is possible to quickly calculate the size of the clear and blind sectors, see Figure 9 above.

Conclusion

This method identified a number of factors that influence the pilot's field of vision, such as running trim, sitting eye height, location of pilot's seat within the wheelhouse, the wheelhouse layout, the design of the wheelhouse windows, and the overall shape of the boat's hull. The method was quick to deploy (< 3 weeks) and is repeatable providing the experimental design is followed.

The findings confirmed that running trim did influence the field of vision, and it identified the factors that influence field of trim. The next steps require the validation of the results with real world testing at sea, using instrumentation such as eye tracking, combined with video observation. The recommendations were to optimise the wheelhouse design to improve field of vision. For existing boats, to explore the use of camera systems that will cover the blind spots, and to also consider the use of LiDAR technology to detect / measure the distance to objects in the water.

References

BS EN ISO 11591:2019 'Small craft – Field of Vision from the steering position'

ABCD-TR-08-01 V1.0 'High Speed Craft Human Factors Engineering Design Guide', Section B