Modelling Maritime SAR Sweep Widths for Helicopters in VDM

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Abstract. Maritime Search and Rescue (SAR) is to look for and help people at sea who are in danger. SAR teams are generally charities with limited search effort, and SAR missions are time critical. Search managers need to objectively decide which search resource (e.g., helicopter vs fixed-wing aircraft) would be better to use. A key metric in the SAR community is Sweep Width (W), which provides a single measure for a search resource's search effective width. This paper investigates whether a VDM model can recreate W results from the sweep widths for helicopters table from the IAMSAR Manual and also consider some basic human factors. VDM was used to reproduce sweep widths for helicopters based on the IAMSAR Manual and considers the different factors for each search object, i.e., altitude and visibility. The VDM model computes W and considers some basic human factors relating to sometimes detection happens. The results for the VDM model vs the IAMSAR Manual expected values looked quite different, and this may be because the VDM model does not currently distinguish between various search objects modelling its depth when detection happens.

1 Introduction

Search and Rescue (SAR) covers the search for persons in distress or danger, and the provision of aid to them. While there are several specialised fields, primarily based on the terrain in which the search is conducted, the general problem of search is similar across these. In essence, a *search manager* is responsible for a search has a number of *search assets*; the search manager must select how best to use these assets to find the missing persons (*mispers*) or objects, based on last known location, search area, local knowledge etc. There are a range of search assets that can be used, e.g. humans, dogs, drones, each with some form of *sensor*, e.g. eyes, noses, cameras. Each of these assets has different characteristics in terms of their ability to search an area within a given period and a given level of accuracy.

Search managers must be able to make quick decisions on how to deploy their available assets during a search; this depends on being able to quickly quantify and compare available assets. Sweep Width (abbreviated to *W*) is a concept that helps in these decisions by providing a single metric for each assets ability to search in a given set of conditions. This metric allows diverse search assets to be compared easily in order to support fast and high-quality decisions at critical times. Search manuals, such as the International Aeronautical and Maritime SAR (IAMSAR) Manual (see Section 2) provide tables of W for different types of assets and conditions. The IAMSAR Manual, for example, provides tables for W for helicopters at a given height and visibility, with modifiers for known information, such as whether the misper is wearing a high-visibility life jacket.

Accurate W tables are vitally important to effective SAR, but since they are produced primarily from empirical studies in the field, they can be extremely expensive to run. SAR teams in the UK are primarily operated by small charities (annual income of less than £1m) and staffed by volunteers, and cannot regularly run field trials to generate new information. This paper presents some early results in work to explore the possibility of computer modelling to run "virtual field trials" to help SAR teams to better understand new search assets such as drones, with reduced need to run expensive field trials. As a first investigation, the paper presents a model that attempts to recreate results for a helicopter searching an open ocean. The results show that the model needs to be refined to better reflect the reality of the search.

In the remainder of this paper, Section 2 provides background information on SAR concepts. Section 3 describes the modelling a lateral range experiment. Section 4 covers the results and evaluation. Section 5 provides some closing remarks.

2 Background

This section introduces the key concept in SAR called Sweep Width, abbreviated to W, and the aircraft and maritime SAR manual that provides data against which the results of this paper are compared.

2.1 Sweep Width

Effective search width [5,6], effective sweep width [5,6], and sweep width [3] are used synonymously in the literature. All terms are generally abbreviated to *W*. W is about quantifying how effectively a specific sensor detects a specific object in specific environmental conditions [3] by specifying a single measurement for each sensor by which sensors can be compared. W is a key concept in "search theory", which was developed in World War II for naval warfare by Koopman [5,6].

One of the methods to derive W is to calculate the area under the Lateral Range Curve (LRC) [5,6,2,1,4,8,7]. An LRC will be explained using a lateral range experiment [8].

The lateral range experiment is represented in figure 1. The idea of the lateral range experiment is that a sensor follows a straight path. Along the sensor's path, there are detection opportunities represented as D_1 to D_6 for detecting objects O_1 to O_6. The solid arrow represents a detection, and the dashed arrow represents a missed detection. When an object is detected, it is detected at x lateral range. At each x lateral range, there is detection data for how many objects were detected compared to how many were there, and this is how the LRC is derived.

Figure 2 represents an example of a sensor's performance profile in reference to its detection capability after a lateral range experiment like figure 1. E.g., at lateral range 0, 100% of objects were detected. At lateral range 1 or -1, 90% of objects were detected. At lateral range 2 or -2, 80% of objects were detected, and so on. There are many

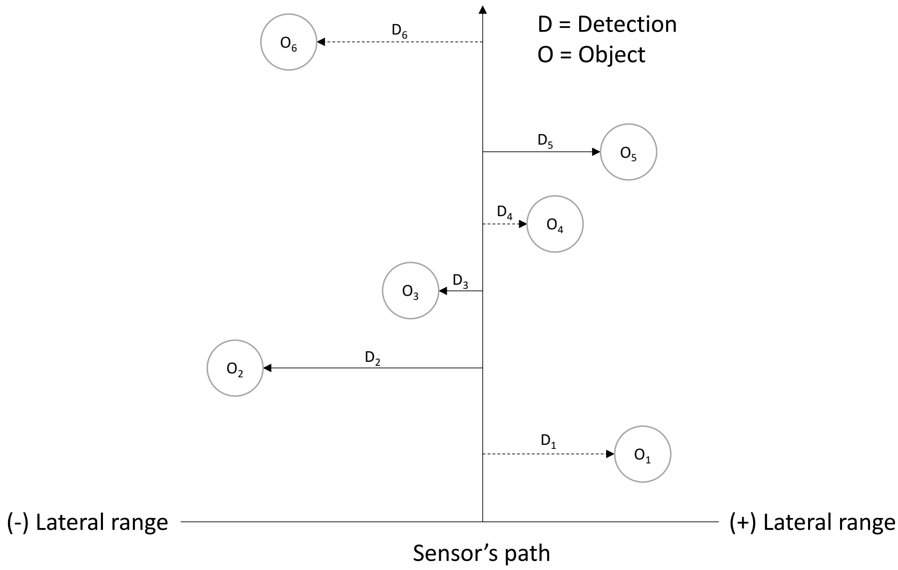

Fig. 1: Sensor lateral range experiment

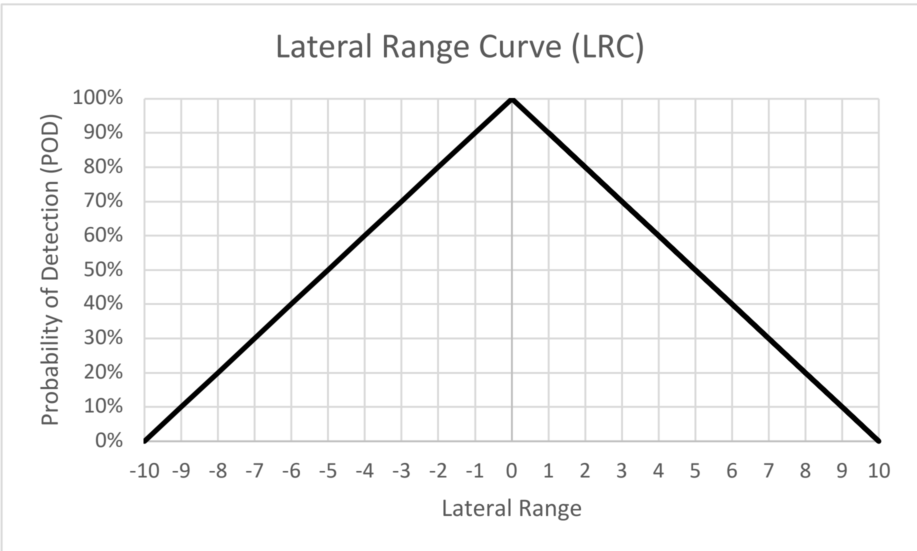

Fig. 2: Lateral Range Curve (LRC) example

different LRCs [2], e.g., the Definite Range Model of Detection, the M-Beta Detection Model, the Inverse Cube Model, etc.

2.2 The IAMSAR Manual

The International Aeronautical and Maritime SAR (IAMSAR) Manual produces guidelines for aircraft and maritime SAR activities. The IAMSAR manual is split into three volumes. Volume I is about the overall SAR system. Volume II is for SAR managers. Volume III is for when on a SAR mission.

The IAMSAR Manual Volume II [3] provides a way of measuring the effectiveness of a sensor detecting a search object in given environmental conditions. E.g., sensor (human eyes in a helicopter), search object (Ship) and environmental conditions (ideal). The measurement is in the form of sweep width tables.

3 Model

This section has been modelled from the IAMSAR Manual Volume II [3] sweep widths for helicopters N-5 table. This section has been broken down into modelling the sensor, search objects, environmental conditions, lateral range experiment, and sweep width.

3.1 Sensor

```
ALTITUDES : seq of nat1 = [150,300,600]
```

Listing 1.1: Helicopter's altitudes constant

Listing 1.1 shows the altitudes constant for the helicopter. The helicopter can fly at three altitudes, 150 metres, 300 metres and 600 metres.

```
distanceToHorizon :  nat1 -> real
distanceToHorizon(alt) == 3.83 * MATH`sqrt(alt);
```

Listing 1.2: Searcher's distance to horizon function

Listing 1.2 shows the searcher's distance to horizon function, which is taken from the IAMSAR Manual Volume II [3]. The distance to horizon function takes altitude in metres as an input like from listing 1.1, and outputs a distance in kilometres.

```
setDetection: () ==> ()
setDetection() == if MATH`rand(4) in set {1,2,3}
then detection := true else detection := false;
```

Listing 1.3: Set detection operation

Listing 1.3 shows the searcher has a 75% chance of 100% detection.

3.2 Search objects

```
SEARCH_OBJECTS : map seq of char to nat1 = {
    -- Same as raft 1-person
    -- "Person 1" |-> 1,
    "Raft 1-person" |-> 1,
    "Raft 4-person" |-> 4,
    "Raft 6-person" |-> 6,
    "Raft 8-person" |-> 8,
    "Raft 10-person" |-> 10,
    "Raft 15-person" |-> 15,
    "Raft 20-person" |-> 20,
    "Raft 25-person" |-> 25,
    "Power boat 2" |-> 2,
    -- Same as raft 6-person
    -- "Power boat 6" |-> 6,
    -- Same as raft 10-person
    -- "Power boat 10" |-> 10,
    "Power boat 16" |-> 16,
    "Power boat 24" |-> 24,
    "Sail boat 5" |-> 5,
    -- Same as raft 8-person
    -- "Sail boat 8" |-> 8,
    "Sail boat 12" |-> 12,
    -- Same as raft 15-person
    -- "Sail boat 15" |-> 15,
    "Sail boat 21" |-> 21,
    -- Same as raft 25-person
    -- "Sail boat 25" |-> 25,
    "Ship 37" |-> 37,
    "Ship 69" |-> 69,
    "Ship 92" |-> 92
};
```

Listing 1.4: Search objects constant

Listing 1.4 shows the search objects represented as a constant. The search object consists of mapping the name of the search object to its area in square metres. E.g., “raft 1-person” is 1 metre squared.“Person 1” has been commented out as in this model, it is treated the same as “raft 1-person” and so on with the other search objects.

3.3 Environmental conditions

```
VISIBILITIES : seq of real = [1.9,5.6,9.3,18.5,27.8,37];
```

Listing 1.5: Visibilities constant

Listing 1.5 shows the searcher's visibilities constant that the searcher has to operate in when detecting. The last visibility, 37 kilometres, stands for 37 kilometres and greater.

3.4 Lateral range experiment

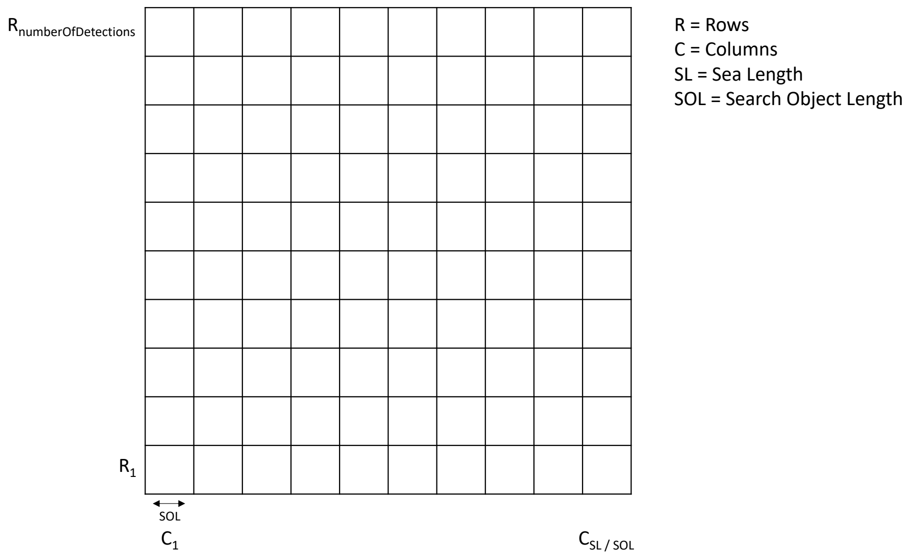

Fig. 3: Lateral range experiment grid setup

Figure 3 shows the lateral range experiment grid setup. The setup consists of a grid of rows and columns. Rows' length is the number of detections. The columns' length is the sea length defined as 54200 metres divided by the search object length in metres. Each column is the search object length.

Figure 4 represents the next step in the lateral range experiment. The next step is to place one search object in a random location in each row.

Figure 5 represents the last step of the lateral range experiment. The sensor (human eyes in a helicopter) goes along each row, detects laterally depending on the maximum lateral range (MLR) and other factors shown in listing 1.6.

```
lateralRangeDetection: nat * Searcher ==> bool
lateralRangeDetection(searchObjectStartXPosition,
    searcher) == (
    dcl maximumLateralRangeMetres : real := searcher.
        getMaximumLateralRangeMetres();
    dcl visibilityMetres : real := searcher.getVisibility
        () * 1000;
```

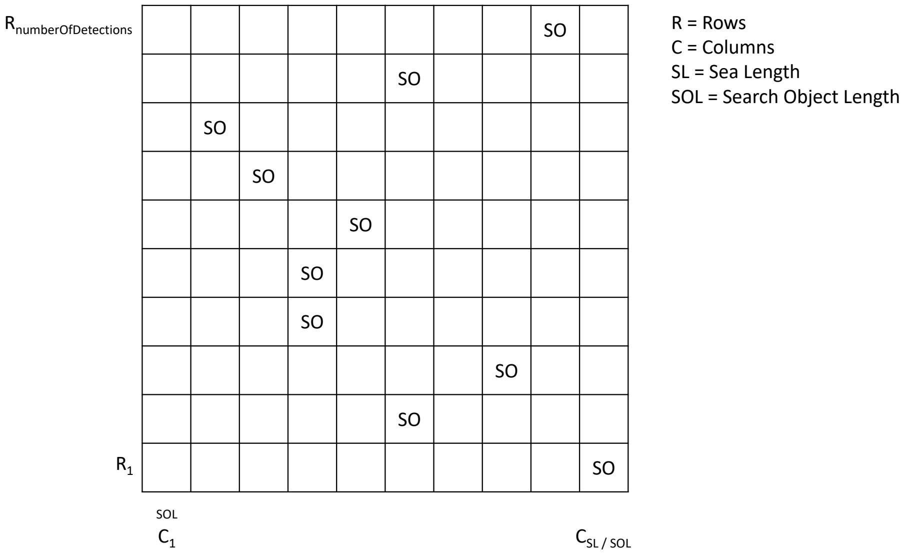

Fig. 4: Lateral range experiment place search objects

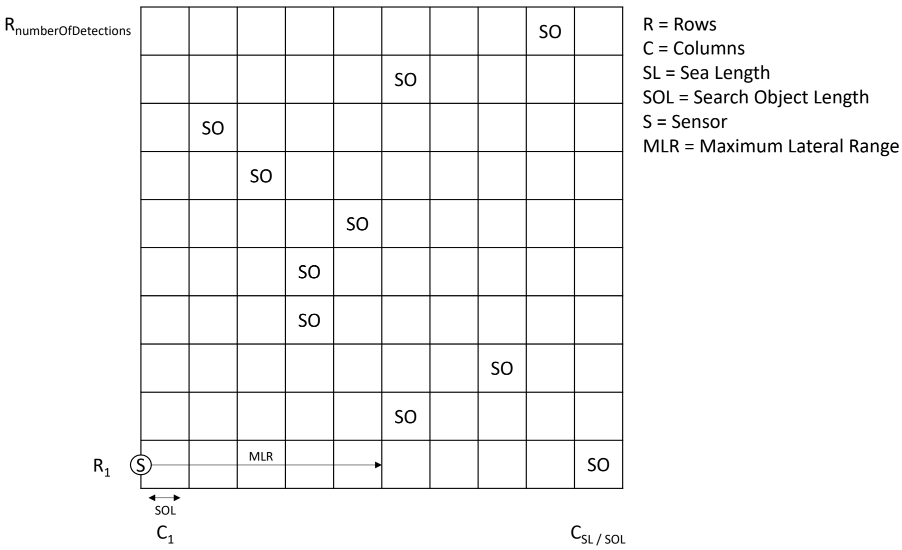

Fig. 5: Lateral range experiment detection

```
    searcher.setDetection();
    if searcher.getDetection() then (
        if visibilityMetres >= searchObjectStartXPosition
            then (
            if maximumLateralRangeMetres >=
                searchObjectStartXPosition then (
                    return true
            )
        )
    );
    return false
);
```

Listing 1.6: Lateral range detection operation

The lateral range detection operation is shown in listing 1.6. The way detection is setup is that first, if it is true that the searcher will detect shown in listing 1.3, then move on to if searchObjectStartXPostion is within the visibility shown in listing 1.1, then if searchObjectStartXPostion is within the maximumLateralRangeMetres calculated in listing 1.2 then detection happens.

```
searchObjectsStartXPositionDetectionData : map nat to (
    nat * nat * real)
```

Listing 1.7: Search object detection data

Listing 1.7 represents that each search object has detection data based on its X start position mapped to a tuple consisting of how many times the search object has been detected, how many there are, and the percentage of the number of detections vs how many there are.

3.5 Sweep width

```
main : () ==> ()
main () == (
    -- For each search object
    for all searchObject in set dom searchObjects.
        getSearchObjects() do (
        -- For each altitude
        for altitude in helicopter.getAltitudes() do (
            helicopter.getSearcher().
                setMaximumLateralRange(altitude);
            -- For each visibility
            for visibility in visibilities.
                getVisibilities() do (
                dcl searchObjectLength : nat1 :=
                    searchObjects.getSearchObjects()(
                    searchObject);
```

```
                helicopter.getSearcher().setVisibility(
                    visibility);
                lateralRangeExperiment.setNumberOfColumns
                    (searchObjectLength);
                lateralRangeExperiment.
                    lateralRangeExperiment(
                    searchObjectLength, helicopter.
                    getSearcher());
                calculateSweepWidth(searchObjectLength)
                )
        )
    )
);
```

Listing 1.8: Main sweep width operation

Listing 1.8 represents the main sweep width operation containing three for loops. The outer loop is the search objects in listing 1.4, the middle loop is the helicopters' altitudes in listing 1.1, and the inner loop is visibilities in listing 1.5. In the inner loop, the lateral range experiment is executed, which produces search object detection data. Lastly, the search object detection data is used to calculate the sweep width.

```
calculateSweepWidth: nat1 ==> ()
calculateSweepWidth(searchObjectLength) == (
    dcl sweepWidthMetres : real := 0;
    dcl searchObjectsDetectionData : map nat to (nat *
        nat * real) := lateralRangeExperiment.
        getSearchObjectsDetectionData();
    for all searchObject in set dom
        searchObjectsDetectionData do (
         dcl searchObjectPrecentageDetected : real :=
             searchObjectsDetectionData(searchObject).#3;
         sweepWidthMetres := sweepWidthMetres +
             searchObjectPrecentageDetected;
    );
    sweepWidthMetres := sweepWidthMetres *
        searchObjectLength;
    sweepWidth := sweepWidthMetres / 1000;
)
```

Listing 1.9: Calculate sweep width operation

Listing 1.9 represents how sweep width is calculated. The sweep width is calculated by adding all the search object start X position percentage of the number of detections vs how many there are data, then multiplying it by the specific search object length, and afterwards converting it into kilometres.

4 Results

This section will discuss the actual simulation model results and how it compares with the expected results. The problem with the simulation model and how this affects the results. Next steps for fixing the problem.

4.1 Actual

Figure 6 shows the simulation model results for sweep width estimates for helicopters detecting different search objects at different altitudes and visibilities. E.g., a helicopter's sweep width for detecting a "Raft 8-person" search object at 300 metres altitude with 9.3 kilometres visibility is 0.8 kilometres. Figure 6 shows the same sweep width estimates for search objects "Person 1" and "Raft 1-person", "Power boat 6" and "Raft 6-person", "Power boat 10" and "Raft 10-person", "Sail boat 8" and "Raft 8-person", "Sail boat 15" and "Raft 15-person", "Sail boat 25" and "Raft 25-person" as this is how the search objects have been modelled. Figure 6 shows the search objects named "ship 37" instead of "ship 27-46", "ship 69" instead of "ship 46-91", and "ship 92" instead of "ship > 91" from the IAMSAR Manual Volume II [3].

4.2 Expected

Figure 7 shows the absolute difference between the sweep widths for helicopters table from the IAMSAR manual [3] and the simulation results in figure 6. E.g. the sweep width for a helicopter detecting a 'ship 92' at 600 metres altitude greater than 37 kilometres visibility absolute difference is 32.8 kilometres.

4.3 Problems

There are two main problems with the simulation model affecting the results. The first problem is that the current model cannot distinguish between search objects solely based on the distance to horizon function in listing 1.2 for calculating the searcher's (human eyes in a helicopter) maximum lateral range for detection. E.g. a maximum lateral range of 50 kilometres for a searcher may not be able to detect a 1 metre squared person at 50 kilometres, but the current model does. The second problem is that the search objects when placed on a row don't have the same set of outcomes. E.g. a 1 metre squared person in a row sea length of 55 kilometres has $55,000$ outcomes or columns to be placed in, but a 100 metre squared ship has 550 outcomes.

4.4 Next steps

To implement a searcher's maximum lateral range that takes into consideration three-dimensional search object properties, i.e., depth. Implementing the searcher's maximum lateral range that considers the search object's depth also deals with the problem of search objects not having the same outcomes when placed on a row. This is because the search objects will be treated as cuboids with different depths, as all the search objects

	Altitude 150 metres						Altitude 300 metres						Altitude 600 metres					
	Visibility (kilometres)						Visibility (kilometres)						Visibility (kilometres)					
Search object (metres)	**1.9**	**5.6**	**9.3**	**18.5**	**27.8**	**> 37.0**	**1.9**	**5.6**	**9.3**	**18.5**	**27.8**	**> 37.0**	**1.9**	**5.6**	**9.3**	**18.5**	**27.8**	**> 37.0**
Person in water	0	0.1	0.1	0.2	0.4	0.5	0	0.1	0.1	0.2	0.4	0.5	0	0.1	0.1	0.3	0.4	0.5
Raft 1-person	0	0.1	0.1	0.2	0.4	0.5	0	0.1	0.1	0.2	0.4	0.5	0	0.1	0.1	0.3	0.4	0.5
Raft 4-person	0.1	0.3	0.5	1	1.4	1.9	0.1	0.3	0.5	1	1.4	1.9	0.1	0.3	0.5	0.9	1.5	1.9
Raft 6-person	0.2	0.4	0.7	1.5	2.2	3	0.2	0.4	0.8	1.4	2.2	3	0.1	0.4	0.7	1.5	2.1	3
Raft 8-person	0.1	0.6	1	1.9	2.8	3.6	0.2	0.5	0.8	2	2.9	3.8	0.2	0.6	0.9	1.7	3	3.6
Raft 10-person	0.3	0.7	1.1	2.4	3.3	4.5	0.2	0.5	1.2	2.4	3.5	4.7	0.2	0.8	1.3	2.4	3.4	4.6
Raft 15-person	0.4	1	1.5	3.4	5	6.5	0.4	1.1	1.8	3.1	4.9	6.4	0.4	1	1.8	3.3	4.9	6.5
Raft 20-person	0.4	1.3	2.1	4.5	6.3	8	0.5	1.5	2.4	4.6	6.4	8	0.6	1.5	2.1	4.5	6.5	8.3
Raft 25-person	0.6	1.6	2.5	4.8	7.5	9.6	0.6	1.8	2.6	5.4	7.8	10	0.5	1.5	2.6	5	7.9	9.8
Power boat 2	0	0.1	0.3	0.5	0.7	1	0.1	0.1	0.2	0.5	0.8	1	0	0.1	0.3	0.5	0.8	0.9
Power boat 6	0.2	0.4	0.7	1.5	2.2	3	0.2	0.4	0.8	1.4	2.2	3	0.1	0.4	0.7	1.5	2.1	3
Power boat 10	0.3	0.7	1.1	2.4	3.3	4.5	0.2	0.5	1.2	2.4	3.5	4.7	0.2	0.8	1.3	2.4	3.4	4.6
Power boat 16	0.4	1	1.7	3.4	5.3	7.1	0.4	0.9	1.8	3.5	5.3	6.9	0.3	1.1	1.9	3.9	5.5	7
Power boat 24	0.5	1.5	2.5	5.1	7.1	9.7	0.4	1.7	2.2	4.9	7.7	9.5	0.6	1.2	2.5	4.7	7.6	9.8
Sail boat 5	0.2	0.3	0.6	1.2	1.8	2.4	0.2	0.4	0.5	1.2	1.8	2.3	0.1	0.3	0.6	1.1	1.8	2.4
Sail boat 8	0.1	0.6	1	1.9	2.8	3.6	0.2	0.5	0.8	2	2.9	3.8	0.2	0.6	0.9	1.7	3	3.6
Sail boat 12	0.3	0.9	1.4	2.7	3.9	5.6	0.2	0.8	1.2	2.9	4.3	5.1	0.2	0.8	1.4	2.4	4.1	5.5
Sail boat 15	0.4	1	1.5	3.4	5	6.5	0.4	1.1	1.8	3.1	4.9	6.4	0.4	1	1.8	3.3	4.9	6.5
Sail boat 21	0.4	1.3	2.2	4.6	6.7	8.6	0.4	1.3	2.2	4.5	6.6	8.9	0.5	1.1	2.3	4.4	5.9	9.1
Sail boat 25	0.6	1.6	2.5	4.8	7.5	9.6	0.6	1.8	2.6	5.4	7.8	10	0.5	1.5	2.6	5	7.9	9.8
Ship 37	0.7	2.2	3.5	6.9	11.4	14	0.8	1.9	3.7	6.3	10.4	13	0.8	2.1	3.8	7.3	11.1	14.3
Ship 69	1.1	2.4	4.9	9.2	13.6	18.9	1	3	4.7	9.9	15	19.4	1.1	2.9	5.1	9.8	14	20.3
Ship 92	1.5	3.6	5.7	10.4	17.1	22.4	1	3.1	5.8	11	16.4	23.1	1.2	3.6	5.5	11.6	16.9	22.4

Fig. 6: Sweep widths for helicopters simulation model results (kilometres)

	Altitude 150 metres						Altitude 300 metres						Altitude 600 metres					
	Visibility (kilometres)						Visibility (kilometres)						Visibility (kilometres)					
Search object (metres)	**1.9**	**5.6**	**9.3**	**18.5**	**27.8**	**> 37.0**	**1.9**	**5.6**	**9.3**	**18.5**	**27.8**	**> 37.0**	**1.9**	**5.6**	**9.3**	**18.5**	**27.8**	**> 37.0**
Person in water	0	0.1	0.1	0	0.2	0.3	0	0.1	0.1	0	0.2	0.3	0	0.1	0.1	0.3	0.4	0.3
Raft 1-person	0.7	1.6	2.1	2.8	2.9	2.8	0.7	1.6	2.1	2.8	2.9	2.8	0.4	1.4	2.1	2.7	2.9	2.8
Raft 4-person	0.8	1.9	2.5	3.1	3.4	3.3	0.8	1.9	2.6	3.3	3.4	3.5	0.5	1.9	2.6	3.4	3.5	3.7
Raft 6-person	0.7	2.2	2.8	3.5	3.7	3.5	0.7	2.2	2.9	3.8	3.7	3.5	0.5	2.2	3	3.7	4	3.7
Raft 8-person	1	2.2	2.7	3.3	3.3	3.3	0.7	2.3	3.1	3.4	3.4	3.2	0.4	2.2	3	3.9	3.7	3.6
Raft 10-person	0.8	2.3	3	3.3	3.4	2.9	0.7	2.5	2.9	3.5	3.4	2.9	0.4	2.2	3	3.7	3.8	3.2
Raft 15-person	0.7	2.1	2.8	2.7	2.4	1.6	0.7	2	2.6	3.4	2.7	1.9	0.2	2.1	2.8	3.4	3.1	2.2
Raft 20-person	0.7	2	2.7	2.5	2.2	1.4	0.6	1.8	2.6	2.6	2.3	1.6	0.1	1.8	2.9	2.9	2.6	1.7
Raft 25-person	0.5	1.9	2.5	2.8	1.8	0.8	0.5	1.7	2.6	2.4	1.6	0.6	0.2	2	2.8	3	1.9	1.1
Power boat 2	0.9	2.1	2.5	3	3.4	3.3	0.8	2.1	2.8	3.4	3.5	3.6	0.6	2.3	2.8	3.8	4	4.1
Power boat 6	1.1	3.3	4.7	6.5	7.4	7.7	1.1	3.5	4.8	6.7	7.6	7.9	0.6	3.5	4.9	6.8	8.1	8.3
Power boat 10	1.2	3.9	6.1	9.1	11.1	12.2	1.1	4.3	6	9.3	11.1	12.2	0.7	4	6.1	9.5	11.4	12.6
Power boat 16	1.1	4.7	7.7	13.6	17.5	20.1	0.9	4.8	7.8	13.5	17.5	20.5	0.6	4.5	7.7	13.3	17.5	20.6
Power boat 24	1	4.6	8.1	14.9	20.7	24.4	1.1	4.4	8.4	15.3	20.1	24.8	0.3	4.7	8.1	15.5	20.4	24.5
Sail boat 5	1.1	3.2	4.4	6	6.9	7.2	0.9	3.1	4.7	6.2	7.1	7.7	0.6	3.2	4.6	6.7	7.5	8
Sail boat 8	1.4	3.8	5.9	8.7	10.3	11.6	1.1	4.1	6.1	8.7	10.6	11.6	0.7	4	6.1	9.4	10.9	12.3
Sail boat 12	1.2	4.7	7.7	12.7	17	19.4	1.1	4.8	7.9	13	16.8	19.9	0.7	4.8	7.7	13.7	17	19.7
Sail boat 15	1.1	4.7	8.1	14.2	18.5	21.8	0.9	4.6	8	14.5	18.8	22.1	0.5	4.7	8	14.5	19	22.2
Sail boat 21	1.1	4.6	8	14.7	19.4	23.4	1.1	4.6	8.2	14.8	19.7	23.1	0.4	4.8	8.1	15	20.6	23.1
Sail boat 25	0.9	4.5	8.1	15.6	20.7	25	0.9	4.3	8	15	20.5	24.8	0.4	4.4	8	15.6	20.6	25.2
Ship 37	0.8	4.1	7.6	15.7	20.8	26.6	0.7	4.4	7.4	16.3	21.8	27.6	0.1	4	7.3	15.3	21.3	26.4
Ship 69	0.4	3.9	6.8	16	24.2	30.4	0.5	3.3	7	15.3	22.8	29.9	0.2	3.4	6.6	15.4	23.8	29
Ship 92	0	2.9	6.2	16.1	23.8	32.8	0.5	3.4	6.1	15.5	24.7	32.1	0.1	2.7	6.4	14.9	24.2	32.8

Fig. 7: Sweep widths for helicopters simulation model results actual vs expected absolute difference (kilometres)

will have the same height and width. If every search object has the same height and width, e.g. when placed randomly in a row sea length of 55 kilometres. The column dimensions in the row are the same height and width as all the search objects. Each search object will have the same set of outcomes of 55000 columns.

To add graphs showing the relationships with variables, i.e., number of detections, sweep width, altitude, visibility and search object depth. The graphs have not been added yet as the authors think the problems above should be fixed first before reasoning deeply with the results data.

5 Conclusions and Future Work

In this paper, a simulation model using VDM was created to reproduce the sweep widths table for helicopters from the IAMSAR Manual Volume II whilst considering some basic human factors. The simulation model successfully considers the different factors for each search object, i.e., altitude, visibility, and considered some basic human factors, i.e., detection only sometimes happens. The simulation model computed sweep width. The results for the actual simulation model vs expected from the IAMSAR Manual looked quite different. A suggestion for why the results look quite different is that the simulation model does not currently distinguish between search objects modelling depth. Future work is to implement lateral range detection that correctly considers the search object dimensions, i.e., depth, assuming a searcher (human) using a sensor (eyes) from a helicopter at a given altitude and visibility in the model section 3. Also, to add graphs in the results section 4 showing the relationships between different variables, i.e., number of detections, sweep width, altitude, visibility and search object depth. The graphs will be added once the simulation model lateral range detection considers search object depth, as this will provide more meaningful results data to analyse. The future work should take around three weeks.

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