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PROBABILITY OF CONTAINMENT AND SEARCH EFFORT FACTOR IN THE DYNAMIC SEARCH AREA

ABSTRACT

In the paper, there is presented a problem of search object drift during SAR operation. Presented method of conducting search takes into account probability of containment (POC) of searched object inside search area. Its also consider available endurance of SAR unit. Described method allows for achieving as good as possible average POC.

INTRODUCTION

During SAR operation first step is determining search area. For the purpose of determine search area we have to take into account many factors. Most important of them are: search object drift speed and direction, time needed to achieve search area by SAR units, available search effort and, what is connected with that, on-scene endurance of SAR units. On-scene endurance is the amount of time a SAR facility may spend at the scene (in the determined search area) engaged in search and rescue activities [IAMSAR Manual, 2007]. Real search endurance is usually taken to be 85% of the on-scene endurance. Endurance is especially important factor when we use dynamic search area (Budny, 2006). If we have limited number of SAR units with limited search effort we should concentrate our search inside the area with the highest probability of containment (POC) of searched object. When we determine dynamic search area we take into account probable movement of searched object during search. The movement is caused by wind and water surface current (Burciu, 2003). In spite of that, area with the highest POC is also moving. In the paper we describe that problem which occurs during SAR operations.

DECREASING OF POC

In the paper we determine stationary search area on the basis of method developed at Gdynia Maritime University for the South Baltic (Burciu, 2003). The South Baltic area is a polish Search and Rescue Region (SRR). We assume that hydro-meteorological conditions are known and constant during search. According to that method search area has a rectangular shape. Size of the rectangle depends on a few factors, but one of the most is time period between the accident and determination of search area. Size area is getting larger as time grows. It is caused by growing errors (which are time dependent) of probable position of searched object. Highest POC occurs in the center of determined search area. Important factor is time needed to search out whole determined area. It can take few hours. During that search searched object is in constant move. We can compare position and size of search area determined at the beginning of search with areas which would be determined later. Such comparison is shown in fig. 1. Values of POC cells in the grid are calculated from two-dimensional normal distribution.
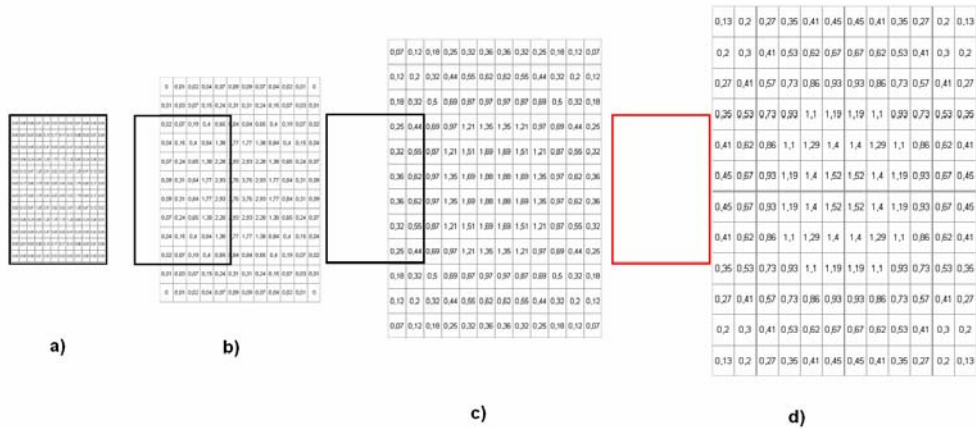

Fig. 1. Determined search area and the POC grid: a) at the beginning of search,
b), c), d) one, two and three hours after the beginning of search, respectively

As we can see at fig. 1, despite significant growth of POC grid, common part of search area and moved grid is decreasing. In this example three hours after beginning of search they are separated. In fig. 2, there are three transferred POC grids and diagrams of their three normal distributions. From the upper diagram we conclude that common parts of determined area and moved areas (grids) have very

low POC. It is caused by the fact that the highest POC region is located in the center of the grid. If we conduct SAR operation and search inside the area determined at the moment of reaching it by SAR unit, we stay in the region of very low (later close or equal to zero) POC.

Fig. 2. Three transferred POC grids and three POC normal distributions

In fig. 3, there is a diagram showing an example POC percentage decreasing. As a comparison there is also shown decreasing of common parts of determined and moved areas. Calculations have been done for the wind speed 35 knots. Search object was a 10-person life raft with drogue. From above example we can conclude that conducting search inside the area determining at the beginning of SAR operation can be not effective. Such situation occurs particularly when search object drift is fast and simultaneously search effort in time unit is small. Those two above factors occur when hydro-meteorological conditions are bad i.e. strong wind, high

waves and rainfalls. When we plan SAR operation in such conditions we should take into consideration direction of drift and speed of search object during searching. We can determine dynamic (or non-stationary) search area which increase effectiveness of the operation.
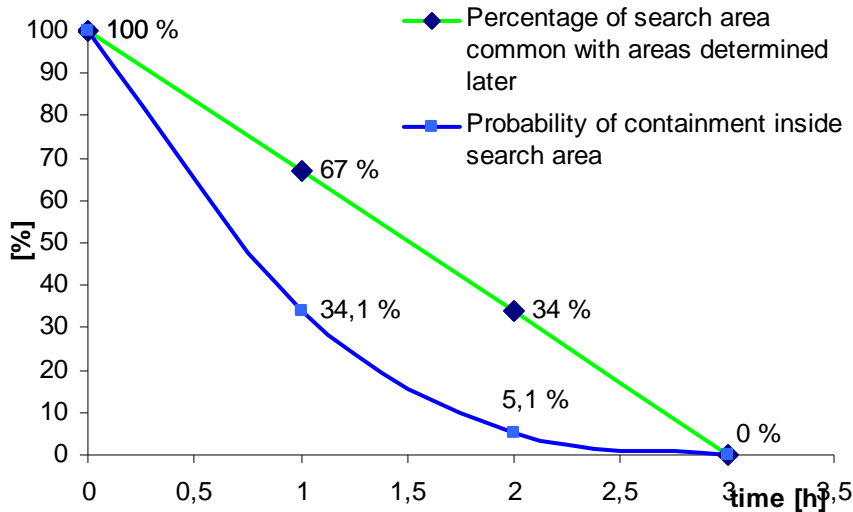

Fig. 3. Decreasing of POC and common parts of the grids

SHAPE OF DYNAMIC SEARCH AREA

Dynamic search area is built as a combine of few consecutive stationary areas. Stationary search areas are determined in one-hour time intervals. If we take into account fact that growth of search area is continuous we obtain shape of dynamic search area shown on fig. 4. Search area has a shape of trapezium and rectangular stick together. Last stationary area is determined at the end moment of search. Search is limited by the fact that SAR unit's endurance is limited and it has to be taken into account.

Knowing all needed data, i.e. search object drift speed and dimensions of determined stationary search areas we can calculate the size of dynamic area using formula:

$$P = [2l_{1_{OST}} \cdot (l_{2l_{OST}} + l_{2p_{OST}})] + [0,5 \cdot (l_{2l_{OST}} + l_{2p_{OST}} + l_{2l_p} + l_{2p_p}) \cdot (V_{TR} \cdot t_{DR} + l_{1_P} - l_{1_{OST}})], \quad (1)$$

where: $l_{1_{OST}}$ — last determined area's semi-axis parallel to the search object drift direction;

$l_{2l_{OST}}, l_{2_{POST}}$ — last determined area's semi-axis, left and right respectively, perpendicular to the search object drift direction;

l_{1_P} — first determined area's semi-axis parallel to the search object drift direction;

$l_{2l_P}, l_{2_{PP}}$ — first determined area's semi-axis, left and right respectively, perpendicular to the search object drift direction;

V_{TR} — search object drift Speer;

t_{DR} — SAR unit on-scene endurance (or search object drift time during searching).

drift direction

1 Mm

Probable incident location

0 1 2 3 4 5 6 **time since incident [h]**
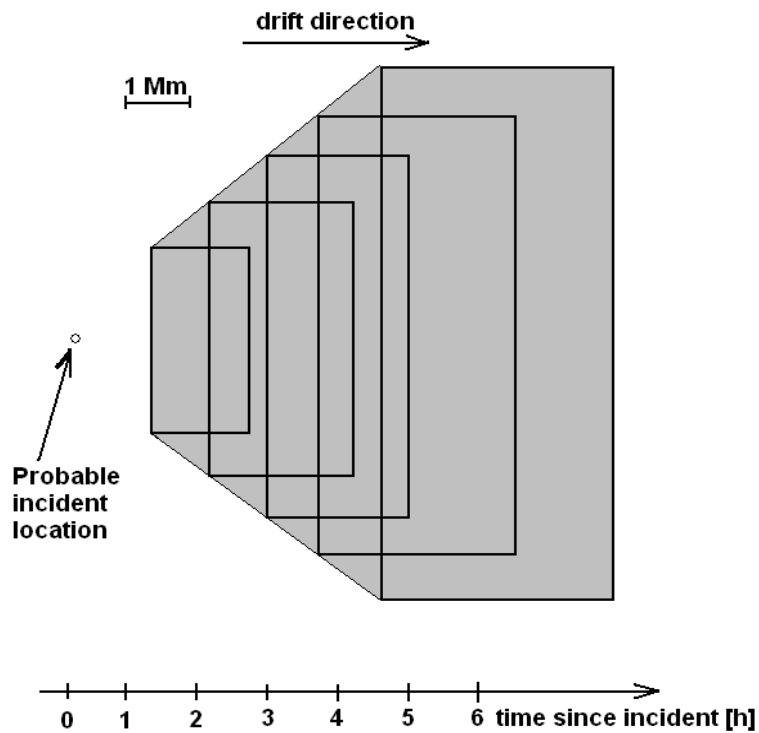
Fig. 4. Example of dynamic search area.
Endurance — 4 h, from 2nd, until 6th hour since incident

In most cases dynamic search area P is larger than available search effort during endurance time. If we have fixed our search effort per time unit we can determine highest POC areas that can be searched out in one hour. We assume that search effort is constant in time. That situation is shown in fig. 5. Each of four green rectangles in the fig. 5 can be searched out completely in one hour time. Moreover each of them is located in the center of respective POC grid. Because of growth of consecutive POC grids, areas that can be searched out have decreasing POC. POC decreasing rate however is significantly lower than simple 'search effort to whole POC grid area ratio' decreasing rate. The reason for that is concentration of the POC in the center of the grid. POC area that can be searched out in one hour is shown as a function of time in fig. 6. Because of above presented facts we should propose appropriate search pattern for dynamic search area.
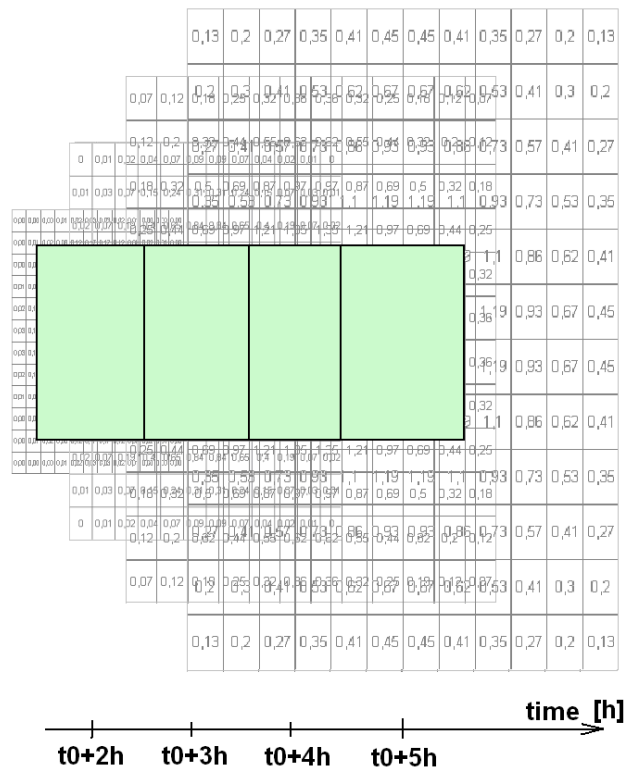

Fig. 5. Four consecutive POC grids and areas possible to search out in one hour time
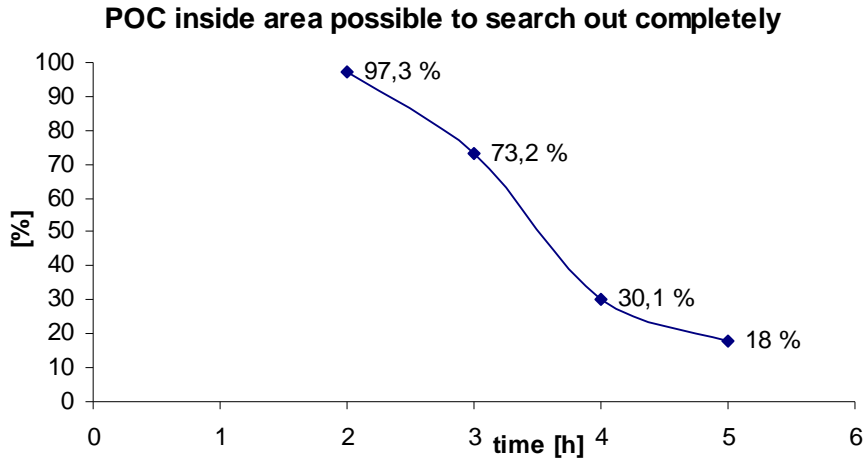
POC inside area possible to search out completely

Fig. 6. Decreasing of POC with time

SEARCH PATTERN PROPOSAL

International Maritime Organization recommends few search patterns [IAMSAR Manual, 2007]. The most appropriate for dynamic search area is creeping line search pattern (CLS, fig. 2). According to [SAR, 2000] CLS is used when the probable location of the search object has been determined to be more likely at one end of the search area than at the other end. Exactly that situation occurs in the case of dynamic search area.
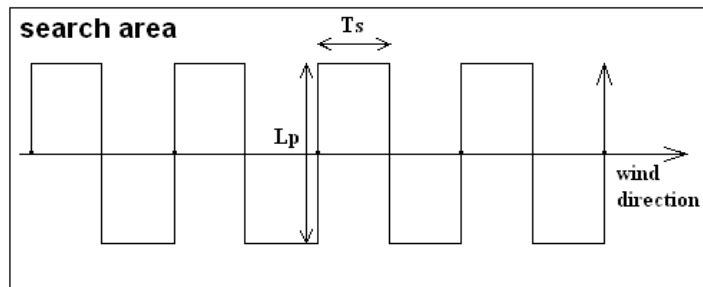

Fig. 7. Creeping line search pattern [SAR, 2000]

Commence search point (CSP) should be located at a point half of the distance selected as the sweep width inside the corner of the search area. Sweep width is a distance measured on both sides of a SAR unit and is determined by search object type and size, hydro-meteorological conditions and used sensors (visual,

infrared devices, radar) [IAMSAR Manual, 2007]. It is necessary to calculate exact length of legs which SAR unit has to proceed along with. In that calculation SAR unit available speed and search object total drift has to be taken into consideration. We also assume that searching has to finish at the other side of determined area at particular moment of time, because of limited endurance. Parameters of search pattern should assure displacement of SAR unit according to probable move (drift) of searched object. Knowing sweep width, available speed of SAR unit and its endurance and dimensions of determined search area we can calculate exact track spacing, TS, between adjacent tracks (legs). Track spacing, TS, is given by equation

$$\overline{T}_S = \frac{(V_{TR} \cdot t_{DR} + l_{1_p} + l_{1_{OST}} - S_W)}{N} , \qquad (2)$$

where: S_W — sweep width;

   N   — closest integer number to result of division $\dfrac{(V_{TR} \cdot t_{DR} + l_{1_p} + l_{1_{OST}} - S_W)}{S_W}$.

Thanks to above assumptions we also can calculate length of parallel legs using equation

$$\overline{L}_P = \frac{t_{DR} \cdot V_{SAR} - \overline{T}_S \cdot N}{N + 1} , \qquad (3)$$

where V_{SAR} — available speed of SAR unit.

EXAMPLE OF SAR OPERATION

Let's assume that wind speed during SAR operation equals 35 knots. Visibility is 5 kilometers. We assuming that time needed to achieve search area is 2 hours. We have only one SAR unit which available speed is 8 knots and its search endurance equals 4 hours. Search object is standard 10-person life-raft with drogue. In assumed conditions life-raft drift speed is 1,4 knots (Burciu, 2003).Sweep width, according to [National, 2004] equals 0,6 Nm, so that total search effort is 19,2 square Nm (Budny, 2006). Search area determined according to earlier presented method has an area of 127 square Nm. Using above data, we obtain TS from equation (2) and LP from equation (3)

$$\overline{T}_S = 0,6\,Nm , \overline{L}_P = 1,3\,Nm .$$

Complete track of SAR unit and area searched out is shown in fig. 8.
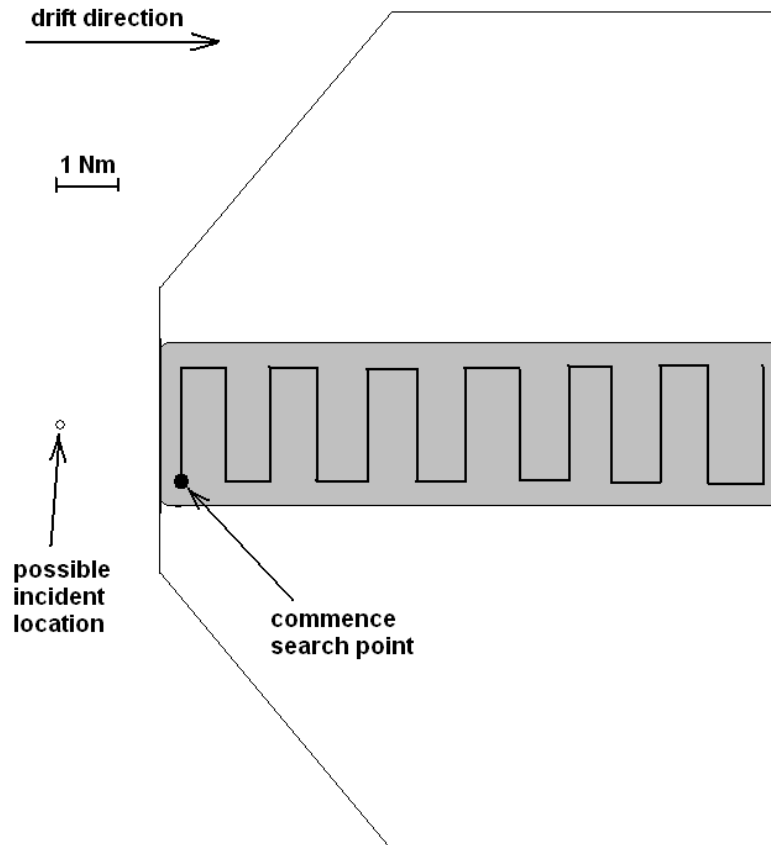
Fig. 8. Determined search area and SAR unit track

Despite the fact that only a relatively thin center strip of determined dynamic area is searched out average POC during 4 hours of operation is as high as 47%. This average was achieved thanks to conduct of searching inside the area with the highest POC all the time during SAR operation.

CONCLUSIONS

In described situations SAR unit search effort is use in most effective way. But in real situation we should assure enough SAR units to search out whole determined search area. To increase coverage factor and search out greater part of search area we have to use more surface units or helicopters. Air units have limitations (wind speed and cloud basement), but in most cases they can be used in SAR operation.

When we have only limited number of surface rescue units presented method of searching is the most effective, because allow us to continue searching in the area with the highest probability of containment of searched object.

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