The Critical Distance method: estimating the Probability of Detection for Grid Searching by a Land SAR Field Team

Dave Perkins, The Centre for Search Research, Ashington, Northumberland, UK

February 2008

Abstract

There has been much discussion in recent years over the role of search theory in land SAR. This author welcomes it for the consistent, objective approach that it can provide for estimating probability of detection (POD) for a land SAR field team.

This paper takes some of the ideas discussed in an earlier paper[1] and develops them to describe a procedure for estimating grid search POD. The procedure is called the critical distance method. It is entirely self-contained: it all takes place at the time of the search, it uses data provided by the field team and it does not depend on results from prior field trials.

The linear lateral range curve

The linear lateral range curve (LLRC) forms the basis for the critical distance method. Figure 1 shows an example of a LLRC. It shows how the probability that a searcher will detect an object as they pass it by depends on the distance between the searcher and the object.

When the object is at zero distance from the searcher, the searcher is bound to see it. As the distance increases, the probability decreases at a uniform rate. Eventually, when the object is at a certain distance from the searcher, the probability that the searcher will see it becomes zero and remains at zero for all distances beyond that. In other words, there is a point at and beyond which the searcher cannot see the object. The distance between this point and the searcher is very significant, and we will refer to it as the critical distance.

Any lateral range curve, including the LLRC, relates to a particular sensor and a particular search object in a particular environment. If any of those factors change then the lateral range curve will change. To put that into a land SAR context for the LLRC, we would say that the critical distance depends on the searcher, what they are searching for, and the conditions (the terrain, vegetation and visibility) in the location where they are searching for it.

Effective sweep width

A sensor's effective sweep width is the area under its lateral range curve. It can be shown[2] that the area under the LLRC in fig.1, and therefore the effective sweep width of the human searcher it represents, is equal to the critical distance. This is an important property of the LLRC.

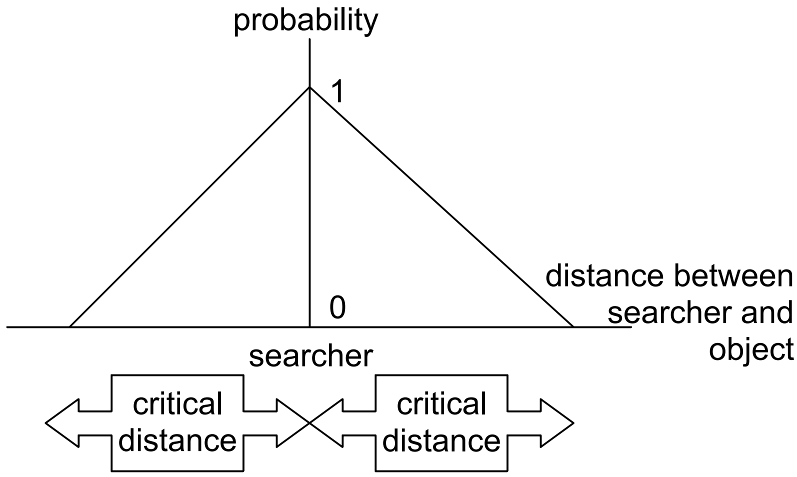

Figure 1: the linear lateral range curve (LLRC)

The LLRC in figure 1 is for one searcher. That searcher could find their critical distance (and therefore their sweep width) by the careful application of a simple field technique that would amount to little more than placing an object on the ground, walking away from it until they can no longer see it and measuring how far from it they have walked.

If each of the searchers in a field team used a similar method to find their own critical distance, the effective sweep width for the field team would be the average of these.

This is a simple description of the field technique that would enable a field team to find their effective sweep width for the missing person that they are searching for in the sector that they are assigned to search:

a. they choose a location that is typical of the sector in terms of its terrain and vegetation
b. they place an object, if possible similar in appearance to the missing person, on the ground in that location
c. they gather round the object and then walk away from it in different directions until it is no longer visible
d. they determine how far each of them has travelled
e. the effective sweep width for the field team is the average of these distances

That was a simple, outline description of the field technique. There is a more detailed description later in the paper; it is essential that anyone wishing to use the technique should read it carefully, together with the worked example and the comments that follow it.

Calculating coverage

The concept of coverage is well documented. It is sufficient here to give two ways of calculating it for a field team. If W is the effective sweep width then:

a. after the field team has searched a sector, and their average track length has been calculated, their coverage of the sector that they have just searched is given by

$$\text{coverage} = \frac{\text{average track length x W x manpower}}{\text{area of the sector}}$$

where 'manpower' means the number of searchers in the field team

b. if the field team is searching with a constant spacing of nW, where W is the effective sweep width and n > 0 is a constant, then the above formula is equivalent to

$$\text{coverage} = \frac{\text{sweep width}}{\text{spacing}} = \frac{1}{n}$$

The critical distance POD curve

The LLRC in fig. 1 shows how likely a single searcher is to detect a single object at a particular distance as they pass by it. In practice we are usually interested in how likely a group of searchers is to detect an object that lies anywhere within their overall path; this is their POD for the object in question in the environment in which they are searching.

Figure 2 shows a graph of POD versus coverage based on the LLRC; the way in which it was derived is described elsewhere.[3] The graph is referred to as the critical distance POD curve.

Grid searching

The derivation of the critical distance POD curve depends on the fact that the members of the field team are moving along parallel paths and maintaining a constant spacing between adjacent searchers. This is grid searching, or line searching, and the procedure described below should therefore only be used for that type of searching.

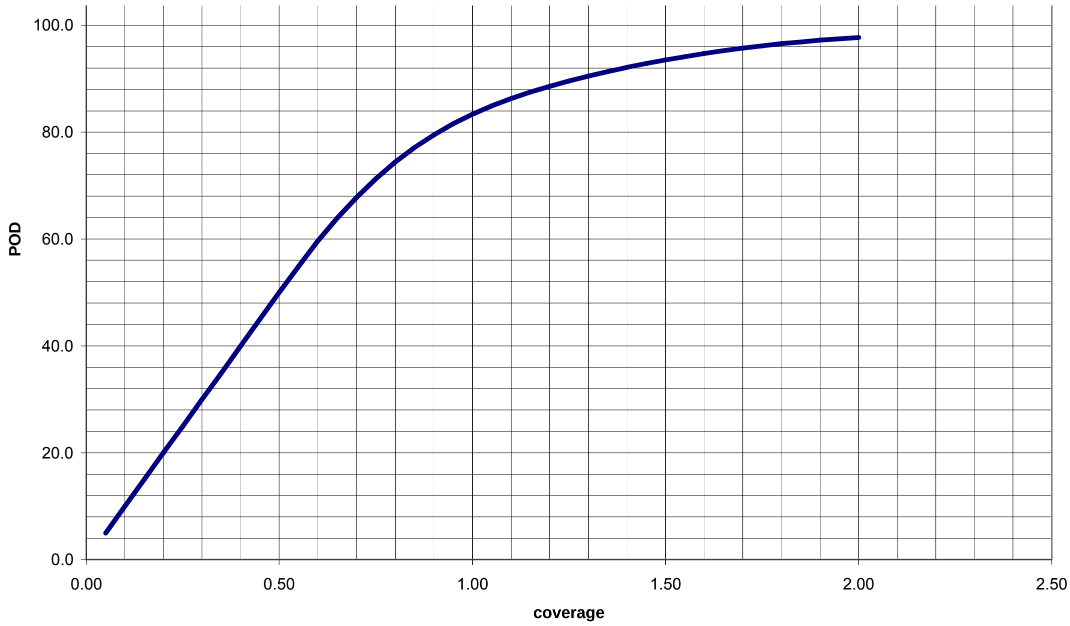

Figure 2: the critical distance POD curve

The critical distance method: a complete description of the procedure

1. Each field team should have at least one GPS; ideally, each member of the field team should carry one.
2. When they arrive at their sector, the field team needs to find a location that they consider to be representative of the sector as a whole. They should take great care to make sure that, as far as possible, its terrain and vegetation are typical of the entire sector. This is where they will determine the effective sweep width.
3. They put an object on the ground in the middle of their chosen location. They may give it an appropriately coloured covering so that it resembles the colour of the clothing worn by the missing person. A backpack is a good body substitute for an adult; if they are searching for a specific size or type of clue, or a child, then they use something that is closer in size and appearance to that search object.
4. The members of the field team gather round the object, and then walk away from it, each heading in a different direction. They look back at the object at regular intervals. Each of them is trying to find the point at which they can no longer see it as they move away from it. The exact point at which this happens for each searcher will need to be checked carefully by moving towards and then away from the object a few times. It would be useful if each searcher marked this point by putting a marker (for example a walking pole or hiking pole) on the ground.

5. The distance between a searcher's marker and the object the field team placed on the ground in step 3 is that searcher's critical distance.
6. Each searcher needs to measure their critical distance. It is sufficient to do this by pacing, provided that they can do it reliably and accurately, and can convert their paces to distances. If not, they should use some sort of measuring device. The marker that they put down should simplify this task; it also allows a second searcher to check the measurement, if necessary.
7. They inform the planner of the critical distance for each searcher; the average of these is the effective sweep width for that object in that environment for that field team. The planner records this for use in step 10.
8. Each member of the field team with a GPS sets the track length to zero, and they begin their search as instructed in their briefing.
9. When they finish, each member of the field team with a GPS reads the track length; they send all these readings to the planner.
10. The planner works out the average track length, and calculates the field team's coverage:

    $$\text{coverage} = \frac{\text{average track length x effective sweep width x manpower}}{\text{area of sector}}$$

    where 'manpower' means the number of searchers in the field team.

11. The planner then reads the POD corresponding to that coverage from the critical distance POD curve.

If the terrain, vegetation or conditions change during the search by an amount that the field team considers would affect their critical distance, they take the following action:

- they inform the command post
- they provide the command post with sufficient information to identify the portion of the sector that they have searched so far, for example the map coordinates of their current location and a description of where they have been
- they read the track lengths from each GPS they have with them and send those to the command post
- they return to step 2 and proceed as though they were about to start searching a new sector
- the planner determines the area of the portion of the sector that the field team has searched so far, calculates their coverage for it and uses the critical distance POD curve to give the POD

In most situations, the procedure just described is the preferred option. There are two alternatives:

a. In situations where the spacing between adjacent searchers can be determined easily and accurately, the following replaces steps 8 to 10 in the original procedure:

8. The searchers space themselves as instructed in their briefing.
9. They determine the spacing between adjacent searchers by some suitable method; they send this information back to the command post and commence their search.
10. The planner calculates their coverage as effective sweep width divided by spacing.

b. In situations where the field team's briefing was to search with a particular spacing, for example 'grid search at twice the sweep width', the following replaces steps 8 to 10 in the original procedure:

8. The planner calculates the spacing that is required, and informs the field team.
9. The field team space themselves at that distance using some suitable method, and commence their search.
10. The planner calculates their coverage as effective sweep width divided by spacing.

Worked example

The following example refers to distances in metres. Readers who prefer to work in non-metric units should read the word 'metres' as 'yards' whenever it occurs between here and the end of the paper. Wherever kilometres are mentioned, a distance in miles that is approximately the same is given as well.

As part of the search for a missing adult male, a six-person field team is detailed to search a sector that is roughly rectangular, nearly two and a half km long and about 400 metres wide (almost a mile and a half long by a quarter of a mile wide). Their brief is to spread themselves across the sector and search it with a constant spacing.

The missing person was wearing a red jacket when last seen, and their briefing suggests that he is likely to be still wearing it. Their brief is to search for an adult male in a red jacket, who is on the ground and non-responsive.

When they reach the sector, they cover a backpack with a red jacket that they have with them, and lay it on the ground to find their critical distances. These are the six values (in metres) from the six members of the field team: 43, 41, 42, 44, 40 and 42. They radio these back to the command post, and the planner calculates that the average is 42 metres. Therefore, for that field team, in that sector and under those current conditions, the effective sweep width is 42 metres when looking for an adult on the ground wearing a red jacket.

They then space themselves across the sector, with the two outer searchers half a spacing from the sector boundaries[4]. Four members of the team have a GPS with them, and they each reset the track length to zero. The team then starts searching. When they reach the end of the sector and finish searching, those same four searchers read the track length from their GPS, and radio them back to the command post. The four track lengths are 2.33 km, 2.35 km, 2.32 km and 2.36 km; the planner works out the average as 2.34 km. (Note that 1 km is 1000 metres, and so the track lengths for the four searchers are 2330, 2350, 2320 and 2360 metres respectively, and the average is 2340 metres).

The planner has already established that the area of the sector is 0.85 sq. km (850,000 sq. metres) and can now calculate the field team's coverage:

$$\text{coverage} = \frac{\text{average track length x effective sweep width x manpower}}{\text{area of sector}}$$

$$= \frac{\text{2340 metres x 42 metres x 6 searchers}}{\text{850, 000 sq. metres}}$$

$$= 0.69$$

From the critical distance POD curve, the planner reads that coverage of 0.69 corresponds to a POD of 67%. The field team's POD was therefore 67% for that sector.

Comments on the worked example

1. The three measurements in the coverage formula (average track length, effective sweep width and the area of the sector) all need to be expressed in the same kind of unit (metres and square metres in the example).
2. The members of the field team perform two important tasks; the first is selecting a location that is representative of the whole sector, and the second is estimating their critical distances in that location. There are training implications here.

Summary

1. the critical distance method is based on a straightforward field technique
2. both the field technique and the critical distance POD graph are based on the same model of searcher performance
3. the critical distance method enables grid search teams to find their POD at the time of the search; it therefore reflects the current conditions
4. the field technique can be adapted to conform to the appearance of the missing person
5. as with any other new procedure, there are training implications

The critical distance POD curve

A full page version of the graph in figure 2 is available on the websites for The Centre for Search Research and The International SAR Alliance (see reference 1 for the web addresses). It will be easier to use than the graph on page 4. The numerical values that make up the graph are on page 2 of the pdf for those who either want to construct their own graph or prefer to use a table of numbers instead of a graph.

References

1 Perkins, D. and Lovelock, D., 2008, Lateral Range Curves, Search Probabilities and Grid Searching, available at www.isaralliance.com and www.searchresearch.co.uk

2 ibid, page 3

3 ibid, pages 7 to 14

4 ibid, page 10; although this is common practice, the positioning of the end searcher at half a spacing from a sector boundary will not always ensure that the POD for the line of searchers extends all the way to that boundary; this issue will be dealt with in a later paper

Acknowledgement

The author acknowledges the advice, assistance and encouragement provided by David Lovelock, Department of Mathematics, University of Arizona, Tucson, throughout the time spent in the production of this paper.