POC ≠ POA

David Lovelock
Department of Mathematics, The University of Arizona, Tucson, Arizona,USA

February 28, 2008

Abstract

The terms Probability of Containment and Probability of Area have been used in search operations for many years. Recently some people have been using the terms interchangeably, even though they are different quantities, and measure different things. This has caused some confusion. Here we clarify these terms, and suggest a simple way to decide which one to use.

Initial Consensus

When starting a large-scale search involving n segments, the probabilities that the subject is in each of those segments are estimated by the initial consensus. Let us denote these initial probabilities by $P(1)$, $P(2)$, ..., $P(n)$, that is, $P(i), i = 1 \ldots n$, where $P(1) + P(2) + \ldots + P(n) = 1$. As each of these segments is searched, the probability that the subject is in a particular segment changes.

The Probability of Containment (POC)

Let $POC(seg, op)$ be the probability of containment for segment seg, $(1 \leq seg \leq n)$ at the end of operational period op where $op = 0$ at the start of the search. Thus, $POC(seg, 0) = P(seg)$. Now imagine that during operational period 1, segment s is searched without success with a probability of detection $POD(s)$. Then the probability of containment for segment s at the end of operational period 1 is given by the formula[1]

$$POC(s, 1) = POC(s, 0)(1 - POD(s)),$$

while all the other segments values remain unchanged, that is,

$$POC(i, 1) = POC(i, 0), \text{ for } i \neq s.$$

The Probability of Containment for a segment is the probability that the subject is in that segment, IGNORING ALL OTHER SEARCHES THAT HAVE TAKEN PLACE OUTSIDE THAT SEGMENT.

If a segment is searched unsuccessfully then only the POC for that segment is changed: it decreases. The POCs for all other segment are unchanged.

Notice that

$$\begin{aligned} &POC(1,1) + POC(2,1) + \cdots + POC(s,1) + \cdots + POC(n,1) \\ &\quad = POC(1,0) + POC(2,0) + \cdots + POC(s,0)(1 - POD(s)) + \cdots + POC(n,1) \\ &\quad = P(1) + P(2) + \cdots + P(s)(1 - POD(s)) + \cdots + P(n) \\ &\quad = 1 - P(s)POD(s), \end{aligned}$$

which is always less than one. The sum of the POCs after a search is always less than the sum before.

[1] See, for example, *International Aeronautical and Maritime Search and Rescue Manual*, Version 1.00, 1991, Volume 2, Section 4.6.16, page 4–20.

The Probability of Area (POA)

Let $POA(seg, op)$ be the probability of area for segment seg ($1 \leq seg \leq n$) at the end of operational period op where $op = 0$ at the start of the search. Thus, $POA(seg, 0) = P(seg)$. Now imagine that during operational period 1, segment s is searched without success with a probability of detection $POD(s)$. Then the probability of area for segment s at the end of operational period 1 is given by the formula[2]

$$POA(s, 1) = \frac{POA(s, 0)(1 - POD(s))}{1 - POD(s)POA(s, 0)},$$

while all the other segments are calculated from

$$POA(i, 1) = \frac{POA(i, 0)}{1 - POD(s)POA(s, 0)}, \text{ for } i \neq s.$$

The Probability of Area for a segment is the probability that the subject is in that segment, TAKING INTO ACCOUNT ALL SEARCHES THAT HAVE TAKEN PLACE INSIDE THE SEARCH AREA.

If a segment is searched unsuccessfully then the POAs for all segments change. The POA for the searched segment falls, while the POAs for the other segments rise.

Notice that

$$\begin{aligned} &POA(1, 1) + POA(2, 1) + \cdots + POA(s, 1) + \cdots + POA(n, 1) \\ &\quad = \frac{POA(1, 0) + POA(2, 0) + \cdots + POA(s, 0)(1 - POD(s)) + \cdots + POA(n, 0)}{1 - POD(s)POA(s, 0)} \\ &\quad = 1. \end{aligned}$$

The sum of the POAs is always 1.

Which One Should You Use?

That is easy to decide, using your intuition. Imagine you have two search segments, Segment 1 and Segment 2. Assume there is a 50% chance that the subject is in Segment 1, and a 50% chance that the subject is in Segment 2. You put all your resources into Segment 1, and do not find the subject. As a result of this unsuccessful search, do you think that the chance that the subject is in Segment 2 has

1. Increased?
2. Remained the same?
3. Decreased?

If you answer "Increased", then you should use POAs. If you answer "Remained the same", then you should use POCs. If you answer "Decreased", then you should keep your day job.

If you are undecided, there is another way to decide. The ROW[3] is the probability of the subject being outside the search area taking into account all searches that have taken place inside the search area. So ROW is a POA and not a POC. Thus, if you want to use ROW, then you should use POAs. ROW and POCs are incompatible.

Summary

When the consensus is taken the initial POCs and POAs are the same. Thus, at the start of a search $POA = POC$, but they will no longer be the same once a POD is used to update them, because the updating equations differ.

Caution

Some authors[4] use the term POA when they should be using POC. An easy way to see which method is being used is to sum the probabilities for all the segments (including the ROW, if one is used) after a search has been accounted for. If the sum is less than 1, then they are using POCs.

[2] See, for example, *Managing The Search Function*, Third Edition, 1987, page 23–9. For a derivation of these equations, see Appendix D of *Win C.A.S.I.E. III: A Manual For Experienced Inland Search Personnel*, available from www.wcasie.com.

[3] The ROW is mathematically the same as any other search segment, except we do not plan to search it, so its POD is always zero, and its POA always increases, unless we expand the search area.

[4] For example, *The TEXTBOOK for Managing Land Search Operations*, ERI Publications & Training, First Edition, 2006, page 369.