Calculating the benchmark spatial-temporal accuracy of scan statistics

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OBJECTIVE

This paper puts forward for discussion two novel measures for the spatio-temporal accuracy of spatial scan statistics when applied to benchmark data: *comprehensiveness* and *succinctness*. They should be applicable to any event based scan statistic with any shaped scan window, for either areal or point data.

BACKGROUND

The statistical power of spatial scan statistics has been widely studied (e.g. [1]). Spatial and spatio-temporal accuracy much less so, and it appears that no universally applicable method of measuring it yet exists. Assessing the spatial-temporal accuracy of scan statistics for syndromic surveillance is useful, as correctly rejecting a 'no outbreak' hypothesis may be of limited use if the alternative (outbreak) hypothesis specifies (a) a wrong/incomplete location or (b) an area/time-period much larger than the outbreak itself.

METHOD

Simulated outbreaks are generated by increasing the normal (non-outbreak) disease rate λ at certain points (or areas) s within study space R: an abstract solid with 2 space dimensions and 1 of time. The proportional increase in rate at s is the outbreak relative risk, $rr(s)$. Simulations may contain trivial variations in rr, so the outbreak zone H (also a space-time solid) is that part of R where $rr(s)>\varepsilon$, an arbitrarily negligible amount. The remainder of R is the non-outbreak area H_c. A spatial scan statistic returns zero or more statistically significant space-time solids, the union of which I call Z. This delimits, for a given significance threshold, where/when it thinks the outbreak(s) are. Fig. 1 illustrates these concepts. Spatial-temporal accuracy is defined here with two parameters: *comprehensiveness* and *succinctness*, addressing (a) and (b) above, respectively. Comprehensiveness is the proportion of increased disease rate attributable to the outbreak (H) contained within Z. It is 0 (worst) when Z and H do not intersect, and 1 (best) when Z wholly contains H. Succinctness reflects the intersection of H_c and Z (hereafter $Z \cap H_c$), relative to R, in terms of λ. This is modified by β to be sensitive to $Z \cap H_c$ that are small compared to R yet large in proportion to H. It is lowest when Z wholly includes H_c (i.e. Z covers all R outside H), and 1 (best) when Z does not intersect H_c at all. It is 0.5 when the normal disease rate inside $Z \cap H_c$ equals that inside H. The optimum dual score occurs when $Z=H$. Formulae are given below. Integral signs denote numerical integration across the specified zone in space/time dimensions.

$$Comprehensiveness = \frac{\int_{s\in Z}(rr(s)-1)\lambda(s)\,ds}{\int_{s\in H}(rr(s)-1)\lambda(s)\,ds}$$

$$Succintness = 1 - \left[\int_{s\in Z\cap H_c}\lambda(s)\,ds \Big/ \int_{s\in R}\lambda(s)\,ds\right]^{\beta}$$

$$\beta = \log(0.5) \Big/ \log\left[\int_{s\in H}\lambda(s)ds \Big/ \int_{s\in R}\lambda(s)\,ds\right]$$

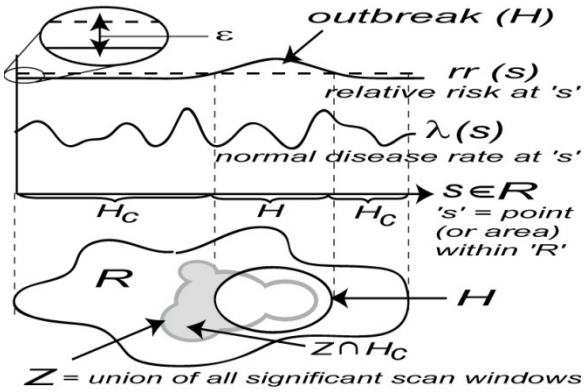

Fig. 1 – 2D (space-only) cross-section of study region R.

RESULTS

Fig. 2a/b show histograms of these measures as applied to output from SaTScan (www.satscan.org) when detecting two simulated 3 day old outbreaks in Williamsburg NYC and 4 neighboring ZIP codes (using circular prospective scan; default settings). Each simulation has 1000 datasets, freely available on the SaTScan site and described in [1]. Both have a uniform rr within the outbreak area/period: 4.47 & 3.06. Z is the union of all scan circles with p ≤0.05.

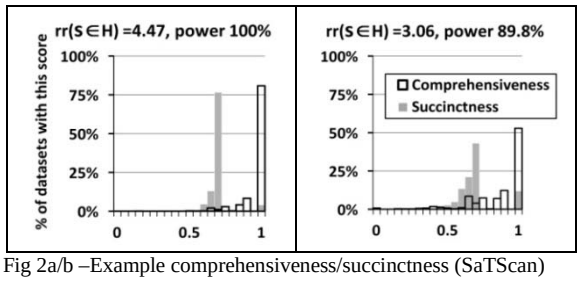

Fig 2a/b –Example comprehensiveness/succinctness (SaTScan)

CONCLUSIONS

Spatio-temporal accuracy appears to increase with rr, as does power. SaTScan performs well, with comprehensiveness 1 (or nearly 1) in most datasets. Succinctness is consistent, although lower; probably as the scan window is circular but the outbreak area is not. I intend to test other datasets and scan windows.

REFERENCES

[1] Kulldorff, M., Zhang, Z., Hartman, J., Heffernan, R., Huang, L. & Mostashari, F. (2004). "Benchmark data and power calculations for evaluating disease outbreak detection methods". MMWR September 24th, 2004. Issue 53 (Suppl), p144-153.