REFEREE REPORT ON "SOURCE DETECTION IN ASTRONOMICAL IMAGES BY BAYESIAN MODEL COMPARISON"

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Abstract. The paper presents a new Bayesian method to detect extended objects in noisy images. Although I am not convinced that the source prior chosen in this work is really a canonical or good description of the statistical properties of astronomical sources, the work is interesting, informative about how the method performs, and therefore deserves publication. Only if this possibility is explored, we can know how well it works and the paper is helpful in this respect.

The adopted prior, however, requires more explanation. On the one hand, the authors should try to express what is roughly means in "colloquial" language. On the other hand, the mathematical description is hard to follow, mostly due to inefficiencies in the notation. This has to be fixed. For a paper with the word Bayes in the title, the reader expects an explicit expression stating the prior.

Finally, I have a number of questions, which are the basis of my skepticism on the chosen prior. Given the space constraints, I can understand if the authors do not address them fully. However, in case the authors do have good answers to some of them, they might put them into the manuscript, thereby advancing the discussion on this approach.

Incomprehensible prior specification:

I had a hard time to guess what the prior means and can not say that I succeeded to decode it from the text and formula. There is only a procedural description of its construction, but not an abstract one (which principles are behind it, what source properties are expressed). Furthermore, the procedural description is unnecessarily complicated and incomplete.

Unnecessary are ...

- the introduction of $C_k^{x,y}$ and $\hat{C}_k^{x,y}$; it would be much simpler if the expressions they encode are directly put into the equations.
- the repeated definition of the Kronecker-delta; everyone knows this.
- the sentence explaining how the indicator variable $C_k^{x,y}$ is composed. It took me some time to realize that this is not new information, but just a restatement of $C_k^{x,y} = \delta_{b_{x,y}k}$.
- the detailed formula in Eq. 1-3 of a non-centered Gaussian with full covariance structure. It would suffice to state that W_{xy}^{θ} describes such a Gaussian. Actually, the letter f in Eq. 1 has confused me, it should be W_{xy}^{θ}, right?

Missing are ...

- a proper definition of the symbol used for the not binned sky brightness. I guess this is $i_{x,y}$, right?
- the exact specification of the multinomial distribution to be integrated out. This is the key to understand what the chosen prior might mean, but it is missing in the text. Of course the reader could guess what the authors could have done here, and analyze this. But no one will actually do so, partly for the risk to work with something that is different from what the authors used, partly because the reader wants to be told this and not have to work it out.

Questions about the prior (only if space permits):

- Why is the distribution of binned flux values a good generic signature of objects? There are bright objects and faint ones. They have very different brightnesses. Nothing about the particular brightness values they have is special.
- I have the feeling that the noise level plays a special role in this approach, in the sense that for different noise levels the source prior would be different. If this is the case, it would not be a proper prior, since a prior only should expresses properties of the sources and not of the measurement process. My suspicion is fed by the statement "sources are brighter than background", which is mostly wrong in astronomy, as most sources are fainter than the background of most observations (we have typically decreasing power law luminosity functions and the many faint objects escape our measurement, and actually form partly the background)
- Is the discussion of distribution of binning schemes in the introduction really relevant and used? I could not spot it in the formula.

- The sentence about the regions in the image with "unusual" distribution should be more elaborated, as it hints to what the prior is selecting. In which sense (or by which metric) are unusual distributions identified by the method?
- How much does the prior request a Gaussian shape of the sources?

Other remarks:

- When Bayesian source detection methods are cited, please also refer to the paper of Marco Selig and me ('D³PO - Denoising, Deconvolving, and Decomposing Photon Observations' Marco Selig, Torsten A. Enßlin, submitted, arXiv:1311.1888 and also these proceedings). The method described in this paper can deal with a large number of point sources.
- I like Fig. 2 a lot, as it nicely visualizes the method. It also shows a problem: If the half width is above a certain value, the algorithm does not find its way to the peaks but escapes into the upper region.
- When the mock data test with three object is performed, the single-source detection algorithm is run exactly three times. This way, the result can have only three sources. An interesting way of telling the method what to find but not being a completely proper blind test, or?.