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Faint compact object detection in wide field interferometric radio images using a hybrid method based on local thresholding and wavelet decomposition.

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Abstract. Automated detection of compact objects in wide field images has classically been produced using thresholding techniques based on local noise estimation. More recently Multiscale Vision Models that use wavelet decomposition have been proposed for the same aim. We propose a hybrid method where both techniques are used at different stages: In a first step bright sources are detected using classical local thresholding and a residual image that does not contain them is produced. In a second step wavelet decomposition is applied to the residual image in order to detect faint compact objects. We show the obtained results using a wide field radio map of the Cygnus OB2 region obtained at 49 cm with the GMRT interferometer and compare them with the published catalogue produced from this image.

1. Introduction

The amount of large astronomical deep field surveys that have appeared in recent years and the need of creating reliable catalogues from them, has brought up the necessity of having fast and robust tools for automated source detection and classification. This is specially noteworthy in the case of wide field mosaicked maps produced from Radio interferometric Aperture Synthesis techniques. These images typically contain, on top of some very bright sources, a large amount of faint objects and diffuse emission with intensities near to detection levels. The high dynamic range of these kind of images makes it difficult to visualize the full range of intensities of the global map (see for example Taylor et al. 2003 and Stil et al. 2006). On top of that, they typically present a diffuse interferometric pattern and deconvolution artifacts produced by strong sources. In this context, wavelet image decomposition can be thought as a tool to detect and separate objects that can be represented at different spatial frequencies (Bijaoui & Rué 1995). In the next sections we show the performance of wavelet decomposition on these kind of images when bright sources are previously removed. In partic-

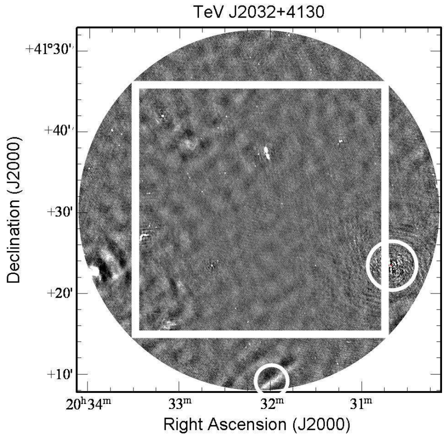

Figure 1. Wide field radio map of the Cygnus OB2 region based on multi-epoch GMRT observations at 49 cm (from Paredes et al. 2007). For a better visualization of the details this image and all its subproducts shown in this paper have been contrast stretched. To avoid filtering border effects we use the sub-image contained in the white square shown in the figure. Martí et al. 2007 do not include in the catalogue the area contained in the circles. We also exclude these zones for comparison purposes.

ular we apply the method to the detection of faint compact and semi-compact objects and we compare our results with a previously existing catalogue.

2. Test image and original catalogue

To illustrate our method we use the deep radio image obtained by Paredes et al. 2007 with the Giant Metrewave Radio Telescope (GMRT) covering the TeV J2032+4130 field (Figure 1). We compare our results with the catalogue produced from this image by Martí et al. 2007.

This image is a paradigmatic test bench for automated detection methods because: 1) It shows a significant amount of detail due to its high spatial dynamic range (over 500), 2) it has a remarkable population of compact sources and shows extended diffuse emission and 3) it shows unwanted interferometric pattern mainly caused by deconvolution artifacts and grating rings from strong sources, and possibly some correlator calibration problems.

3. Wavelet decomposition of our image using the "à trous" algorithm

Multiscale Vision Models (Bijaoui & Rué 1995) decompose an image in J scales or wavelet planes and segment independently each of the images representing a scale. Low index scales emphasize high spatial frequencies (which translates to compact objects and semi-compact in case of true signal). High index scales emphasize low spatial frequencies (in this case diffuse emission and interferometric pattern). We have decomposed our image in 6 scales plus the smoothed array using the "à trous" algorithm with a B_3 filtering function (see for example Starck & Murtagh 1994 and references therein).

The main problem encountered with this approach is the presence at each scale of polluting negative artifacts around strong sources. This is due to the decomposition constraint where the wavelet coefficient mean at each level has to be kept at zero.

3.1. Our algorithm

We propose to create an image where bright sources are substituted by local noise. Wavelet decomposition will then be applied to this new image in order to detect fainter compact objects. The algorithm we follow is the next one:

1. We calculate local noise in the original image and derive a local threshold to extract bright sources.
2. Two images are created: a "residual image" where bright sources have been substituted by local noise, and a binarized image with the bright sources.
3. We apply a 6-scale Wavelet decomposition using the "á trous" algorithm and a B_3-spline filtering function to the "residual image".
4. Local thresholding and binarization is applied to the 3 first scales.
5. We create a binary image from the addition of the binarized 3 first scales and the bright sources.
6. From this last image connected zones and their centroids are calculated to produce the source positions catalogue.

4. Results and discussion

In figure 2 source positions found using our method are displayed on the original sub-image together with the positions found by Martí et al. 2007 using the automated extracting procedure SAD of the AIPS package (based on local thresholding and gaussian fitting).

Table 1 shows the symbol code used in the figure and the number of True Positive (TP) and False Positive (FP) detections found in each work (classification of TP and FP detections has been done by close visual inspection of the image by the authors of both works. FP are basically believed to be deconvolution artifacts near bright sources).

Table 1. Number of detections found in each method

Detections	True Positive	False Positive
Present work	○ 71(61c + 10e)	× 15(2c + 13e)
Martí et al. 2007 catalogue	□ 68(63c + 5e)	+ 33(17c + 16e)

(c)Isolated compact source, (e)Extended emission

The number of TP detections is very similar in both works. However, our method succeeds in reducing the number of FP to more than half with respect to SAD. Most of our FP detections are grouped in zones of extended emission artifacts, while half of the SAD FP detections could be identified as an isolated compact object.

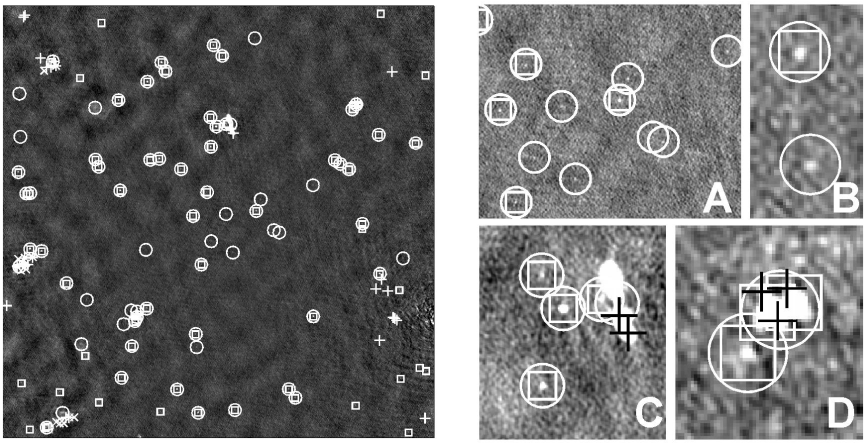

Figure 2. Left: Locations of detections found using the two methods (see symbol code in Table 1). Right: Detailed parts of left image commented in the text.

Although both works have almost the same number of TP some of these are not coincident in position: Firstly, 16 of the 68 SAD TP are not found by us. All of them are located at a large radius from the center (see Figure 2, left). Secondly, 21 of the present work 71 TP are not found by SAD. Many of them are located near the center (see zoomed parts A and B in Figure 2, right).

Some of the double bright sources marked with 2 or more detections by SAD are correctly identified as one source in our work (see zoomed parts C and D in Figure 2, right).

To conclude, we think the performance of our algorithm is very satisfactory, specially near the pointing center. To improve its performance at large radii we need to implement a better noise model according to the primary beam response. The implementation of the algorithm is simple and can be thought as a future automated detection method of faint objects. In the future a performance analysis using a wide range of parameters and images will be published.

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