Stellar Object Detection Using the Wavelet Transform

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Abstract

Several algorithms are used nowadays for detecting stellar objects in astronomical images, for example in the DAOPHOT program package and in SExtractor (Software for source extraction). Our team has become acquainted with the wavelet transform and its good localization properties. After studying the manual for DAOPHOT and SExtractor, and becoming familiar with the à trous algorithm used for calculating the wavelet transform, we set ourselves the task to implement an algorithm for star detection on the basis of the wavelet transform. We focused on detecting stellar objects in complex fields, such as globular clusters and galaxies. This paper describes a stellar object detection algorithm with the help of the wavelet transform, and presents our results.

Keywords: stellar object detection, wavelet transform.

1 Introduction

The DAOPHOT program [1,2] and SExtractor [3,4] calculate the estimated background value and perform thresholding of each pixel: if it is more than a specified threshold and meets certain conditions, we consider it to be a light source. Otherwise we assume that it is noise. Problems arise in the case of faint stars, whose brightness is close to the ambient background. For this reason, they may not be properly detected. Multiresolution methods of image analysis, e.g. the wavelet transform, have therefore gained ground. The main advantage of this transform is its ability to separate light sources contained in an image according to their size, enabling us to analyze both large, bright objects and the small, faint stars in their neighborhood.

2 Wavelet transform of a 2D image

To realize the wavelet transform of an image it is necessary to make an image convolution with a pre-selected wavelet, first by rows and then by columns. The result is an approximation of the original image and the presence of details in horizontal, vertical and diagonal direction. With increasing decomposition level we extract larger details from the image. In order not to change the scale of the low-pass or high-pass wavelet filters, the image has to be subsampled by a factor of 2. Therefore, when the wavelet transform is implemented by the Mallat algorithm [5] there is for each additional degree of decomposition an image with dimensions twice smaller than on the previous level. For detecting stellar objects, this is not a good property, because we need to have the same number of pixels on each scale in order to comply with the same coordinates. Therefore, the wavelet transform for astronomical purposes is realized by the à trous algorithm (“with holes”).

3 The à trous algorithm

Wavelet transform implementation by the à trous algorithm involves convoluting the input image with a 2D convolution kernel representing a two-dimensional scaling function, which imitates the stellar PSF [6]. To imitate the subsampling process, we have to change for each next decomposition level the filter length in such a way that $2^j - 1$ zeros are inserted between the coefficients, where $j$ is the decomposition level [6].

- During the first decomposition (we start from $j = 0$) we convolute the original image $S_0$ with an unmodified kernel $K_0$ and the result is the smoothed matrix $S_1$.
- Subtracting $S_1$ of $S_0$, we get wavelet coefficients for the first decomposition level corresponding to the smallest details $W_1 = S_0 - S_1$.
- $j = j + 1$.
- Expand the filter by $2^j - 1$ zeros.
- Calculate the smoothed matrix $S_2 = S_1 \star K_1$ and the wavelet coefficients for the second decomposition level: $W_2 = S_1 - S_2$, etc. If we stop this algorithm here, the original image is the sum of $S_2$, $W_1$ and $W_2$ (Figure 1).

4 Detecting stellar objects

Stellar objects are detected in wavelet coefficients $W_1$, $W_2$, etc., representing details contained in the original image. This means that stars with the nar-