OV_WAV: A New Software Package for Multiscale Analysis Applied to Astronomy

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Abstract. A big obstacle to the process of analysis of astronomical images lies in translating information obtained by a detector into information on a set of physical objects. Certainly, a very powerful method has been recently introduced in astronomy. Known as Multiscale Analysis (Starck, Murtagh, and Bijaoui [1]), it has in the wavelet transform a valuable tool. In this kind of analysis, an image is redefined in a position-scale space. At a given scale, only features with a characteristic size are found, without much interference from features of other sizes. We have developed a series of codes to apply the wavelet transform to the multiscale analysis of various astronomical problems. The codes were written under the Interactive Data Language (IDL) during the last three years. We have run a number of controlled tests, and developed a series of basic applications to verify our results. The final package, called OV_WAV, will soon be available to the scientific community.

OV_WAV includes three main modules: noise removal; automatic detection of both compact and extended objects, including the determination of a hierarchy, if one exists; and partial reconstruction of an image, including only one or a subset of objects found in the image. This last feature can be used to separate two nearby or overlapping objects through the definition of the multiscale volume associated to each individual object. The package also includes many auxiliary tasks to handle images in the multiscale space.

The fundamental data structure for all tasks is the representation of the image in wavelet space (a space that maps position and scale). Known as the wavelet structure, all tasks perform operations in this space. This 3-dimensional structure (two dimensions defined by the size of the original image + a number of selected wavelet scales) is obtained in our package by the application of a discrete "à trous" (with holes) wavelet transform to the original image. Another crucial structure is the multiresolution support. It defines the significance level associated with each pixel in the wavelet structure. Basically, it measures the significance of a pixel value against its local noise. A threshold is then established through a hard or soft method, or through a combined evidence method, which includes a cross-correlation with pixels at the subsequent wavelet scale.

A basic noise filtering can be applied by multiplying the wavelet structure by the multiresolution support. The package also includes more refined tasks, with iteractive filtering and convergence tests. The detection of objects is another application of much interest in astronomy. The definition of an object is based on the analysis of significant and connected pixels at a given wavelet scale (defining one region), and on positional relations among regions found at different scales. Therefore an object defines a volume in the multiscale space, whose properties can be easily converted back to the image space.

The most sophisticated application of the package is the one that deals with the partial reconstruction of an image. Given a selected object or a set of objects, it is possible to reconstruct its image from the multiscale volume information resulting from the object detection task. Other tasks solve the inverse problem of finding the image that produces that same multiscale volume and excludes all other objects. This is done by the adoption of a regularization criterion that minimizes the energy.

A series of controlled tests have been performed to check the results obtained with the OV_WAV package. Even though more thorough tests are still being developed, the results so far are very satisfactory. Some astrophysical applications are already in progress. They include the search for diffuse light around compact groups of galaxies, and the morphological study of substructures present in the Hubble Space Telescope images of planetary nebulae.

References

[1] J.-L. Starck, F. Murtagh, and F. Bijaoui, *Image Processing and data analysis: the multiscale approach*, Cambridge University Press (1998).