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Astronomical Image Compression Using the Pyramidal Median Transform

J.-L. Starck

CEA, DSM/DAPNIA, CEA-Saclay, F-91191 Gif-sur-Yvette Cedex, France

F. Murtagh[1]

ST-ECF, ESO, Karl-Schwarzschild-Str. 2, D-85748 Garching, Germany

M. Louys

LSIT, ENSP, 7 rue de l'Université, F-67084 Strasbourg Cedex, France

Abstract. We describe image compression based on the pyramidal median transform, introduced as an alternative to the use of a wavelet transform. The use of a multiresolution support allows "protection" of astronomical objects in the image. Non-support parts of the images are subjected to noise suppression. Experimental applications are presented.

1. Introduction

Image compression is required for preview functionality in large image databases (e.g., *HST* archive), for linking image and catalog information in interactive sky atlases (e.g., Aladin), and for image data transmission, where more global views are communicated to the user, followed by more detail if desired. We describe an approach to astronomical image compression through noise removal. Noise is determined on the basis of the image's assumed stochastic properties. This approach is quite similar to the wavelet transform-based `hcompress` approach. We begin by explaining why transforms other than the wavelet transform are important for astronomical image compression.

2. Wavelet Transform and Image Compression

Practical problems related to the use of the wavelet transform include:

Negative Values. By definition, the wavelet coefficient mean is null. Every time we have a positive structure at a scale, we have negative values surrounding it. These negative values often create artifacts during the restoration process, or complicate the analysis. For instance, if we threshold small values (noise, non-significant structures, etc.) in the wavelet transform,

[1]Affiliated to Astrophys. Div., Space Sci. Dept., ESA)

and then reconstruct the image at full resolution, the structure's flux will be modified.

Point Objects. We often have bright point objects in astronomical images (stars, cosmic ray hits, etc.), and the convolution of a Dirac function with the wavelet transform is equal to the wavelet transform. So at each scale, and at each point source, we will have the wavelet. Cosmic rays can pollute all the scales of the wavelet transform.

This leads us to develop other multiresolution tools which we now present.

3. Pyramidal Median Transform

3.1. Multiresolution Median Transform

The median transform is nonlinear, and offers advantages for robust smoothing (i.e., the effects of outlier pixel values are mitigated). The multiresolution median transform consists of a series of smoothings of the input image, with successively broader kernels. Each successive smoothing provides a new resolution scale.

The multiresolution coefficient values constructed by differencing images at successive resolution scales are not necessarily of zero mean, and so the potential artifact-creation difficulties related to this aspect of wavelet transforms do not arise. For integer input image values, this transform can be carried out in integer arithmetic only, which may lead to computational savings.

3.2. Pyramidal Median Transform

Computational requirements of the multiresolution median transform are high, and these can be reduced by decimation: one pixel out of two is retained at each scale. In the Pyramidal Median Transform (PMT), the kernel or mask used to obtain the succession of resolution scales remains the same at each level. The image itself, to which this kernel is applied, becomes smaller. While this algorithm aids computationally, the reconstruction formula for the input image is no longer immediate. Instead, an algorithm based on B-spline interpolation can be used for reconstruction.

An iterative scheme can be proposed for reconstructing an image, based on pyramidal multi-median transform coefficients. Alternatively, the PMT algorithm, itself, can be enhanced to allow for better estimates of coefficient values, yielding an Iterative Pyramidal Median Transform.

4. PMT and Image Compression

The principle of the method is to select the information we want to keep, by using the PMT, and to code this information without any loss. Thus the first phase searches for the minimum set of quantized multiresolution coefficients which produce an image of "high quality." The quality is evidently subjective, and we will define by this term an image for which (1) there is no visual artifact in the decompressed image, and (2) the residual (original image minus decompressed image) does not contain any structure. Lost information cannot be recovered, so if we do not accept any loss, we have to compress what we take as noise, too, and the compression ratio will be low (only 3 or 4).

The method employed involves the following sequence of operations:

1. Determination of the multiresolution support.
2. Determination of the quantized multiresolution coefficients which gives the filtered image.
3. Coding of each resolution level using the Huang-Bijaoui method (Huang & Bijaoui 1991). This consists of quadtree-coding each image, followed by Huffman-coding the quadtree representation. There is no information lost during this phase.
4. Compression of the noise, if this is desired.
5. Decompression consists of reconstituting the noise-filtered image (plus the compressed noise, if this was specified).

Note that we can reconstruct an image at a given resolution without having to decode the entire compressed file.

5. Example

A simulated *HST* WF/PC (pre-refurbishment) stellar field image described in Hanisch (1993) was used. The image dimensions were 256×256. Here we used the aberrated, noisy image. With default options for the approach described in this article (`pcomp/pdecomp`; i.e., 5 iterations, 3σ thresholding, 4 multiresolution scales, and no conservation of the noise) a compressed image with 6643 bytes was obtained from the original image of 268,800 bytes. This is a compressed image equal to 2.5% of the original. Even with I2 storage of the input image, we have compression to about 5%. The total intensity dropped from 412,998 to 412,980 in compressing and decompressing, i.e., a loss rate of 0.0044%.

Using the known coordinate positions of the 470 stars in this image, we obtained the intensities at these positions in the reconstructed image and compared magnitudes in the reconstructed image with magnitudes in the input image. There was reasonable fidelity over about 8 magnitudes. For fainter objects, the noise filtering causes greater difficulty, as one would expect.

6. Conclusion

The approach described here works well in practice. Further experiments are described in the full paper. Work comparing the approach described in this paper with other well-known astronomical image compression procedures is continuing.

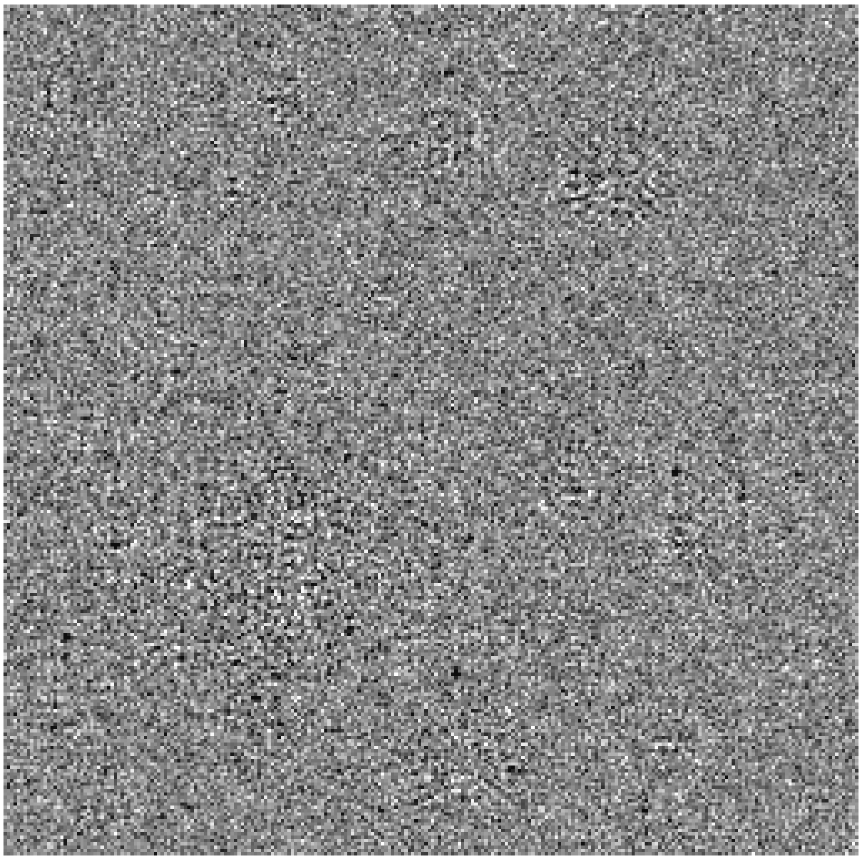

Figure 1. Difference between original and decompressed image, using a stellar field.

References

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