82

N91-18995

1990

NASA/JOVE PROGRAM

MARSHALL SPACE FLIGHT CENTER
THE UNIVERSITY OF ALABAMA

TEST IMAGES FOR THE MAXIMUM ENTROPY IMAGE RESTORATION METHOD

Prepared By:	James E. Mackey
Academic Rank:	Professor
University and Department:	Harding University Physical Science

NASA/MSFC:

Laboratory	Space Science
Division:	Solar Terrestrial Physics
Branch:	Solar
MSFC Colleague:	Dr. Jim Dowdy

Test Images for the Maximum Entropy Image Restoration Method

One of the major activities of any experimentalist, in addition to data collection, interpretation and subsequent communication of information, is data analysis/reduction. It is in this step that actual physical data as collected by a variety of instruments and techniques is transformed into information that can be effectively utilized in making interpretations of and drawing conclusions about the physical system being studied. In solar physics, remote observations are made of the sun in a variety of wavelengths and circumstances. In no case is the data collected free from the influence of the design and operation of the data gathering instrument as well as the ever present problem of noise. In analyzing the data, which is, in some fashion, always truncated and digitized fourier transform techniques have been extensively employed. The process can be simply represented as

$$d(x)=h(g(x)) + n(x)$$

where d(x) represents the collected data, g(x) the actual solar information, h(x) represents the given instrument and measurement procedure, and n(x) is the noise. In theory one merely inverts this relationship to obtain g(x) as an inverse operation of h(x), however, the presence of the noise and the fact that data d(x) is a limited representation of the true information g(x) makes this in practice impossible. To actually obtain the true information one characteristically makes assumptions about the data and extends the data into regions in which it is not actually known. The correlation function is normally evaluated at the points (called lags) where the sample data is actually known. One then takes the fourier transform of the correlation function to obtain the information desired. In the process of taking this transformation we find that there are a very large number of spectral functions that are consistent with the measurements we have. It is then common to extend the range of known correlation functions into the unknown region and typically assume that the extended values are all zero (conceivably one could make other assumptions about these values other than zero, but they remain **assumptions** and not true data). When this occurs the investigator has interjected an a priori statement and included an experimental bias. All of this is true apart from a consideration of noise. The present of significant noise (significant meaning too large to be neglected) invalidates the simple inversion procedure regardless of the range of known correlation functions.

The Maximum Entropy Method (MEM) attempts to perform this inversion by making minimal assumptions about the data. In simplistic terms the method chooses the correct restored data by requiring that the entropy (or information) of the process be maximized subject to constraints such as the total energy being constant or the sum of the probabilities being one, etc.

To provide a means of testing the MEM and characterizing its sensitivity to noise, choice of point spread function, type of data, etc., one would like to have test images of known characteristics that can represent the type of data being analyzed. Such images could provide an answer to objections that the apparently enhanced information obtained by MEM is nothing but a computer artifact of the restoration procedure and not real data.

In beginning to construct such images a choice was made to initially begin with images with a highly symmetric octagonal symmetry. This allows for easy construction of 512 by 512 pixel images from a 128 by 128 pixel square unit cell. A sample test image is shown as Figure 1. The area between the octagons models the network regions on the sun while the interior of the octagons models the cells. The distribution of area between the network and cells was chosen to reflect typical values for solar images. To allow for the influence of the instrument on the data, the test image is convolved with a point spread function appropriate to the particular instrument producing the data set, in this case the Harvard EUV Spectroheliometer flown on the 1973 Skylab missions. The point spread function or PSF is shown in Figure 2. The convolution of the test image and the PSF is shown in Figure 3, and the smoothing effects of the instrument PSF are clearly shown. Since the original data was 120 pixels by 60 pixels, it was subsequently expanded to form a square image by expanding each pixel by 5 horizontally and by 10 vertically (because of oversampling, the effective resolution on the surface of the sun was 2.5 arc seconds horizontally and 5 arc seconds vertically with one arc second corresponding to approximately 725 km on the solar surface). To approximate this data with our convolved test image we sampled the image for each 5th column and 10th row with every other row shifted by two pixels. The resulting sampled image is shown in Figure 4. Once the sampled image was constructed it was necessary to add noise appropriate to the instrument. Since the data was taken as instrument counts, the error can be taken as Poisson error. The modeled noise image is shown in Figure 5. A deviation of up to 10% from Poisson statistics was allowed. The resulting test image, shown in Figure 6, was constructed by adding the noise to the sampled image and shifting the byte threshold to make all the intensities positive.

The next step in test image construction, which is already in progress, is to add fine scale features to the original test image and repeat the above procedure to determine the size of fine scale features that can be seen in the images. These images will then be treated with the Maximum Entropy algorithm to see to what extent the fine scale detail can be recovered. Once the MEM has been verified to our satisfaction, it will then be applied to images of the quiet sun to attempt to recover small scale structure and determine the significance of the contribution from small scale magnetic loops in the solar network to the energy emitted from the networks. If the method can be adequately validated for such images, it can potentially be applied to a very wide range of other types of data that have been or will be collected by space instruments and probes.

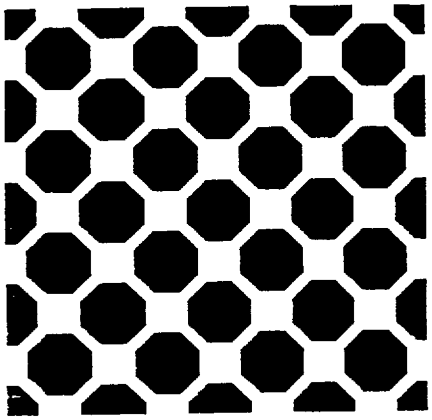

Fig.1

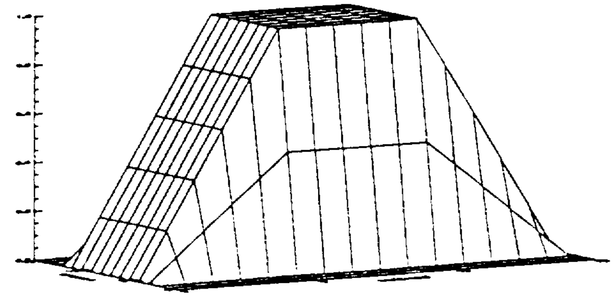

Fig.2

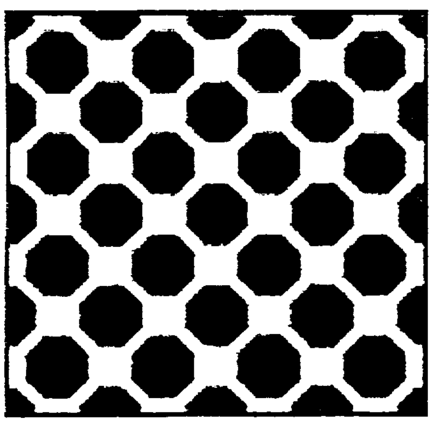

Fig.3

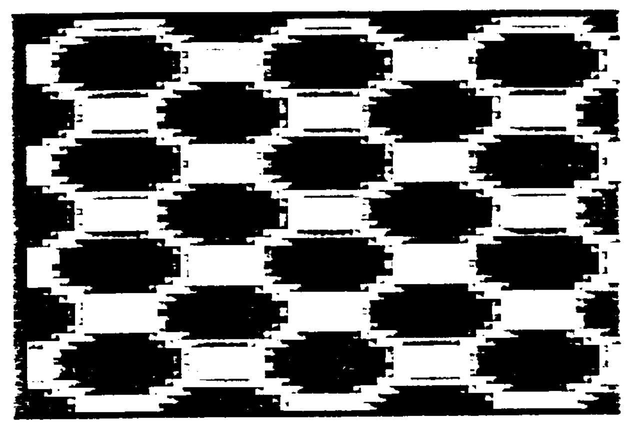

Fig.4

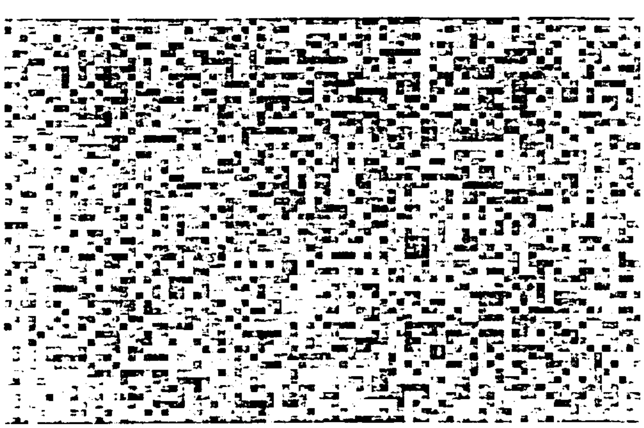

Fig.5

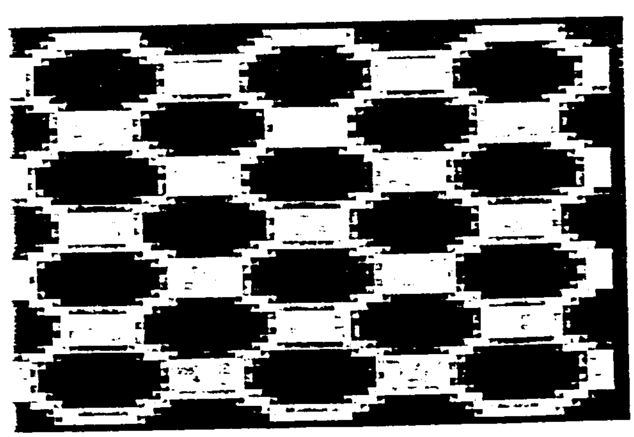

Fig.6