THE SIMULATION AND RESULTS OF A NEW SPECKLE IMAGE PROCESSING TECHNIQUE

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Abstract

A new technique called shift-and-add, which allows nearly diffraction-limited images to be formed of objects viewed through a randomly distorted, turbulent media, has been formulated. True images may be obtained through the earth's atmosphere when the method is used. It has been shown that this can be achieved even though the telescope may have severe aberration and when using a much wider bandwidth than that used at present in stellar Speckle Interferometry. Results are given for an object of greater extent than simple binary or groups of point sources.

1.0 INTRODUCTION

Shift-and-add, a remarkably simple approach to processing astronomical images, has been developed at the University of Canterbury over the past two years. This approach is a direct descendent of speckle masking [1] and combines the observations of Lynds, Worden and Harvey [2] with an adaption of the stocastic image restoration procedure of Bates [3].

2.0 SHIFT-AND-ADD ALGORITHM

The shift-and-add algorithm is simply described. We subscribe to the viewpoint that a speckle image consists of many distorted versions of the true image and contend that the brightest part of a speckle image is most probably a distorted version of the brightest part of the object. A simple method to reduce the distortion is to find, in each of a sequence of statistically independent speckle images, the brightest point and to superimpose it on the brightest point in each of the other images, thus aligning distorted versions of the true image. Providing the conditions of isoplanacity hold, and that there is enough light in each speckle image to form at least one speckle, a nearly diffraction-limited true image will result. An algorithm which performs this superposition of images is to shift the image, without rotation, so that the brightest point is in the center of image space, and add this to all similarly treated previous speckle images [4,5,6].

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3.0 RESULTS OF SHIFT-AND-ADD SIMULATIONS

The results of several different experiments with shift and add have been published previously. Bates and Cady [4] show that the normal bandwidth restriction of speckle interferometry can be relaxed to at least 100 nm. Cady and Bates [5] demonstrate that real images can be reconstructed even though the optical instrument suffers from severe defocus. Bates et al [6] show that aberrations such as coma can be corrected using the method.

4.0 IMAGING AN EXTENDED OBJECT

Lynds, Worden and Harvey [2] were the first to form an image of an extended object from a speckle image. To perform their method, a number of bright speckles must be identifiable in a single speckle image. The location of these speckles define a 'speckle mask'. The cross-correlation of the speckle mask with the speckle image averages the distortions in each individual speckle. In each of the cases where the method has been used, the object was only a few resolution elements in extent.

This requirement limiting the extent of the object is relaxed for shift-and-add processing. Providing the object has a bright point which on the average produces the brightest point in a speckle image, a processed image of an extended object many resolution elements in extent may be formed. Figure 1a shows an extended object when the seeing is perfect in narrow band radiation. The aperture creates an Airy disk three pixels in extent. The central bright point is roughly twice the intensity of the next brightest point in the object. Figure 1b shows the processed image after 128 iterations of shift-and-add. The contrast is low, but the general shape and intensity distribution can be seen.

5.0 CONCLUSION

Shift-and-add processing has been shown to work with wide band radiation and with severe instrument aberrations. It is effective for imaging groups of stars and extended objects. The extended object that was simulated has rather marked intensity variations over its extent. It also has a single bright point which is about two times brighter than any other point in the object. This object may belong to a limited class of objects for which the method will work.

Shift-and-add processing should provide a useful adjunct to other speckle processing methods. In conventional speckle interferometry, the accurate estimation of the intensities of stellar objects may be used to correct the shift-and-add image which has accurate positional (phase) information but a rather poorer intensity reconstruction. The phase in the processed shift-and-add image may be used with modulus information from speckle interferometry for the starting point in the Fienup algorithm [7].

Further work needs to be done to fully characterize shift-and-add processing. The full efficacy of the method in reconstructing extended objects has yet to be determined. The point spread function of the process, especially for complicated objects, must be investigated. We feel, however, it is now time to try the method with real astronomical data.

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DISCUSSION

KREIDL: I would like to comment that perhaps the geometric center defined by the mean of a number of bright points, say three, might lead to a better definition of the true image centroid.

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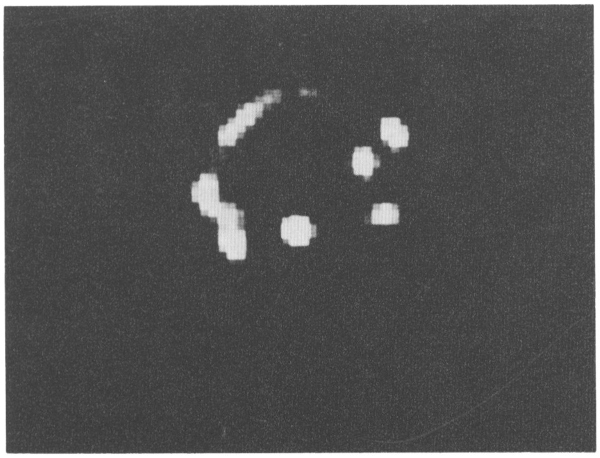

Fig. 1a. Extended object imaged with no turbulent atmosphere.

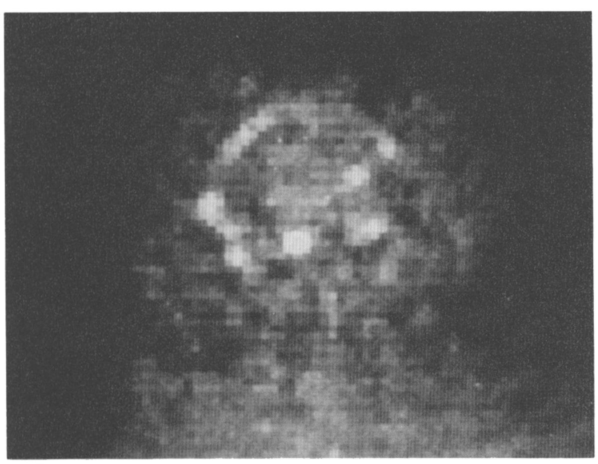

Fig. 1b. Reconstructed extended object image.

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