RESTORATION OVER FIELDS OF VIEW WIDER THAN THE ISOPLANATIC PATCH

G. THORPE and D. FRASER

Department of Electrical Engineering,
University of New South Wales, ADFA

ABSTRACT. This paper presents the results of a preliminary investigation into the problems in through-the-atmosphere image restoration which are more suited to data from a small telescope, i.e., one having a diameter of about 0.5 m, using techniques of image geometric transformation (and eventually, parallel image processing) in their solution. We have imaged bright objects, over fields of view which subtend angles greater than those in most "large" telescope experiments, i.e., between 40 and 100 arc sec, for example, where the isoplanatic assumptions are less valid.

1. Introduction

When objects are imaged through the atmosphere there is distortion due to the properties of the medium through which the incoming radiation passes. A major part of this degradation is caused by density variations in the earth's atmosphere caused by local variations in temperature which causes the shape of the incoming wavefront to be modified [1]. This causes wide area images, when viewed in real time, to have the appearance of continuous internal movement from moment to moment. The image changes shape as various parts move relative to each other. At a much smaller scale there is also speckle break-up of the image, but that is another problem.

1.1. METHOD ADOPTED

To overcome the distortion effect mentioned above we have adopted a technique whereby we take many short exposures where each image is captured after an integration time of 20 msec. The immediate effect of this operation is to freeze the motion but inevitably various regions are shifted and distorted relative to each other from frame to frame. Each short-exposure image in a set is divided into a number of "tiles" (see fig. 1), and the tile in image 1, row 1 and column 1 (1,1,1) is compared, shifted and added to image 2 row 1 column 1 (2,1,1) and so on to the N^{th} image (N,1,1). Mosaicking is then used to reform the original image using the enhanced segments. To determine the required shift between the segments, we carry out a cross-correlation between successive tiles (ie (1,1,1) is correlated with (1,1,2) which in turn is correlated with (1,1,3) and so on), while we use the same technique between overlapping regions, during mosaicking.

1.2. EXTENSION OF THE CURRENT METHOD

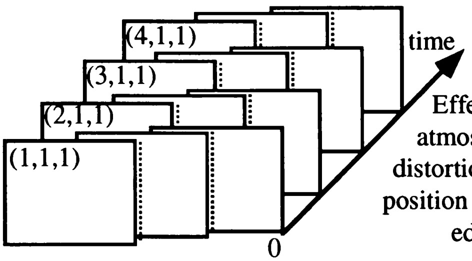
We are extending this concept to allow "continuous" geometric transformations across the whole field of view, which warp each of a large number of short-exposure images to a common datum, before summation to form a restored image. The geometric transformation removes the first-order position-dependent shift from the PSF, without the need to divide the image into tiles, while the summation improves signal-to-noise ratio. The result is also similar to a "shift-and-add" phase restoration, including the

J.G. Robertson and W.J. Tango (eds.), Very High Angular Resolution Imaging, 221–223.

position-dependence of the PSF which may overcome some of the speckle-related blurring.

2. Summation of Image Segments

Image segment summation is accomplished through the use of a cross-correlation procedure which gives the shift required to bring each new image into registration with the prototype image segment [2]. If there are N images then the noise in each segment after summation is reduced by $(1/\sqrt{N})$ when compared to the noise in any of the individual segment. This feature is important because as the exposure time is reduced the signal to noise ratio reduces. In effect the final result of each segment addition procedure is to produce an image that is very accurate geometrically and contains much greater high frequency detail than would be present in a time exposure of equivalent length (see fig. 2).



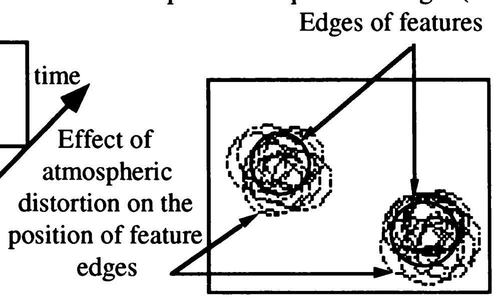


Fig. 1. Image segmentation

Fig. 2. Long term exposure effect

3. Rebuilding Large Images

3.1. CORRELATION BETWEEN ENHANCED SEGMENTS

After the corresponding segments have been enhanced through the summation procedure mentioned above it is necessary to rejoin the segments to recreate the original image. Since we have assumed that there is a relative shift between each of the segments introduced by the motion of the atmospheric cells it is necessary to determine how much each segment should be shifted by to rebuild an estimate of the original image. When the images are cut up there is around 50% overlap with the next segment. This means that after enhancemant of the segments through the shift and add procedure this overlap can be used to find the shift required to ensure that the overlap region matches as closely as possible wth the next image segment. The procedure adopted is to start at the top left position and proceed along to the right finding the shift required to rejoin the pieces. The segments in the next row are then compared with the segments immediately above to find the shift required (see fig. 3).

3.2.INACCURATE POSITIONING

Inaccuracies are introduced in the second and subsequent rows because only the image segment immediately above is used currently for the location procedure whereas there are a maximum of eight segments that each segment may overlap.

https://doi.org/10.1017/S0074180900107648 Published online by Cambridge University Press

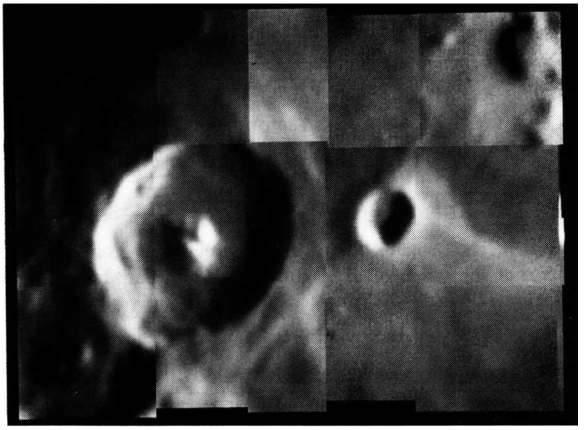


Fig. 3. Image after restoration showing vertical and horizontal segment shifts

4. Future Investigation

To enhance the accuracy of the final result we are planning to use accurate and fast methods of geometric transformation, using Fourier interpolation, to carry out the required shifts and summations in a spatially continuous manner. A multi-processor system, called PIPADS, which is being developed in the Department, in collaboration with CSIRO (Division of Information Technology), the University of Newcastle, and BHP, will allow very fast (i.e., real-time) image restoration, in the near future. Our eventual aim is to integrate a small telescope (less than 0.5m) with a CCD imager and capture system with this high speed multi-processor system.

5. References

[1] T. Stewart McKechnie, "Light propagation through the atmosphere and the properties of images formed by large ground-based telescopes", J. Opt. Soc. Am. A/vol. 8, No. 2 Febuary 1991.

[2] Michal Irani and Shmuel Peleg, "Improving Resolution by Image Registration", CVGIP Graphical Models and Image Processing vol 53, No. 3, May, pp 231-239, 1991.

https://doi.org/10.1017/S0074180900107648 Published online by Cambridge University Press