Interleaving tests

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1 Introduction

The purpose of this document is to show a simple demonstration of interleaving (also called interlacing) and to report on a few tests carried out using simulated WFCAM data.

Interleaving is used when data is undersampled. The technique involves reobserving a measurement after shifting the recording medium a fraction of the sample length. These are then combined to form a single measurement.

In the case of a CCD and 2x2 interleaving, 4 observations are taken, shifting the CCD by half a pixel in the appropriate directions *ie.* (0.0, 0.0), (0.5, 0.0), (0.0, 0.5) and (0.5, 0.5). The observations are then interleaved as if they were a single observation with twice the resolution.

This does not regain lost resolution, but it does restore the sampling if the PSF doesn't change. With accurate offsetting and interleaving you can recover lost frequency information due to the limited original sampling. The end result will be as if you had the extra resolution but it will be convolved with the original pixel size.

Here are some references to papers on interleaving *etc.* :

Hook, Pirzkal & Fruchter 1999 is a short review of available software for image reconstruction.

Lauer 1999a goes into the theory of interleaving and explains a Fourier reconstruction method.

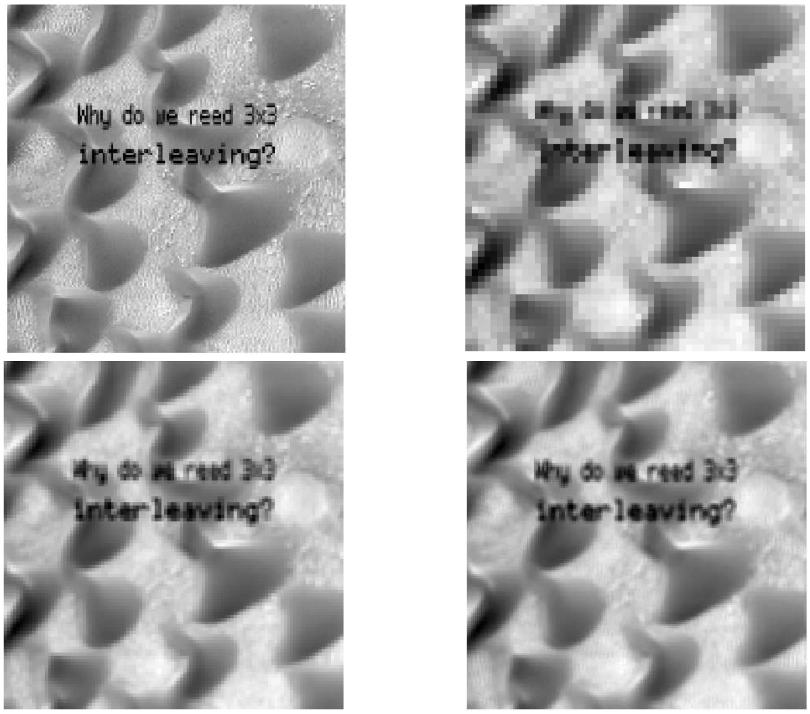
Lauer 1999b is mainly about calibrating intrapixel sensitivity with undersampled images.

Fruchter & Hook 2002 describes the Drizzle method for reconstructing undersampled images.

2 A simple demonstration of interleaving

In order to give a simple demonstration of interleaving an image was created with some recognizable detail in it. This was then rebinned such that the detail was just visible (Figure 1a). The source image was then further rebinned by a factor of 3 (Figure 1b) in order to provide the undersampled images. Figure 1a can be regarded as the control image.

Various undersampled images were created with appropriate offsets to create 2x2 (Figure 1c) and 3x3 (Figure 1d) interleaved images. As can be seen, more detail becomes apparent with interleaving, but you do not regain full resolution as in Figure 1a since the image is convolved with the original (Figure 1c) pixel size.



a b

c d

Figure 1: A simple demonstration of interleaving.

3 Simulations

The simulations carried out to test the effects of interleaving on the astrometric and photometric accuracies were done using the IRAF `artdata` procedures.[1] All the simulations were equivalent to J-band observations and followed the same parameterization as in the WFCAM simulations study (`http://www.ast.cam.ac.uk/~wfcam/docs/reports/simul/`), apart from for the seeing. Three different sets of simulations were carried out with different seeing conditions:

a. All four elements of the interleaved images were generated with the same seeing (0.6″).
b. Realistic seeing conditions – seeing is within 0.1″ of the median. Each of the four elements had a randomly determined seeing taken from a Gaussian distribution with a mean of 0.6″ and a sigma of 0.05″.
c. Bad seeing conditions – seeing suddenly increases by 0.5″. The seeing is determined as in b, but for the fourth element the seeing is increased by 0.5″.

Figure 2 shows example images from each of the sets of simulations. For images from Simulation c, "hedgehogging" of the image can be seen where the PSF becomes spiky. It is likely that this will cause problems to any PSF fitting algorithm used. Note that even in realistic seeing conditions (Simulation b) a small degree of 'hedgehogging" is seen.

In addition to these, a set of non-interleaved simulations were generated. In order to make the comparisons equivalent in terms of total observing time, these were generated with 4 times the exposure length.

Most of the simulations were 2x2 interleaved, but one set of 3x3 interleaved data was generated using the realistic seeing conditions *cf.* Simulation b.

[1]When carrying out these simulations it is important to use the command `artdata nxc=25 nyc=25` so that the PSFs are integrated with sufficient detail.

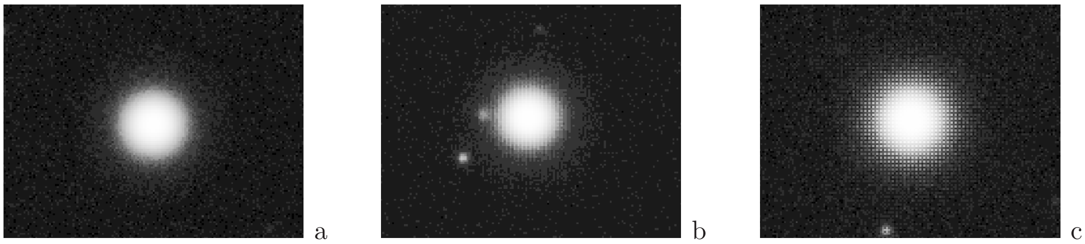


Figure 2: Example simulated images under different observing conditions (all 2x2 interleaved).

4 Comparisons

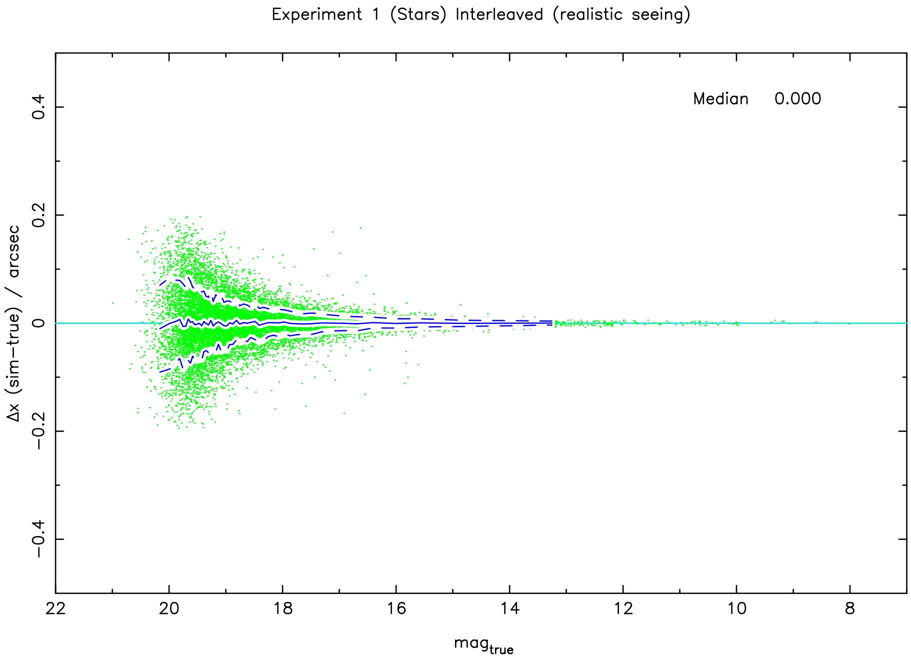


Figure 3: The residuals in x as a function of magnitude. The solid blue line shows the median of the distribution and the dashed blue line indicates the width (equivalent to a Gaussian sigma).

Each of the images generated were reduced using the programme `imcore_conf`, the standard source detection and parameterization programme used in CASU pipelines. Further information about how `imcore_conf` works can be found in Irwin 1996.

The x, y and flux values generated were then compared with the true values used to generate the `artdata` simulations. The widths of these distributions were then measured as a function of magnitude (see Figure 3). This gives a reasonable estimate for the errors in these parameters.

5 Conclusions

Analysis of the errors (Figures 4 and 5) show that there is not much difference between the 3 seeing cases for the interleaved reductions *ie.* interleaving seems to work reasonably well even in Simulation c.

For the non-interleaved astrometry (with same total exposure time) the bright end accuracy is two times worse. At the faint end there is no difference. This is due to the effect of undersampling, which is independent of magnitude, being swamped by Poisson noise effects.

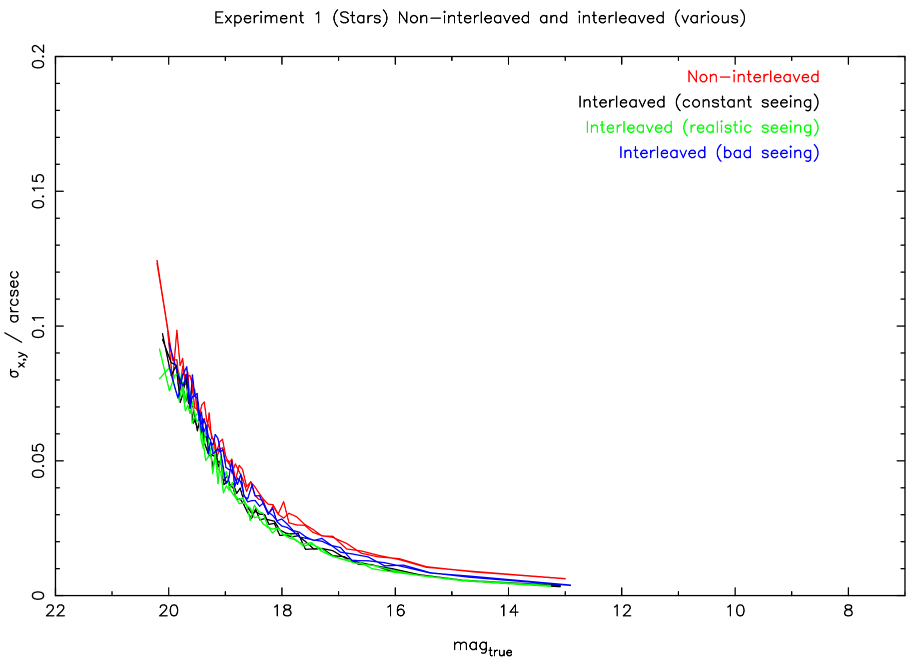


Figure 4: Astrometric errors as a function of magnitude. The results from the different simulations are in different colours. For each simulation a line is drawn for the errors in both x and y.

For photometry, there is no difference between the interleaved and non-interleaved simulations. This is basically due to the pixels effectively acting as photon buckets.

The difference between 2x2 and 3x3 interleaved data and non-interleaved data is shown in Figure 6. The 2x2 interleaved astrometry is about 2 times more accurate than the non-interleaved data at the bright end, while the 3x3 interleaved astrometry does not show much further improvement. This shows that the optimal sampling has already been achieved with the 2x2 interleaving.

At the faint end there is no significant difference in the astrometric accuracies.

The photometric errors show no differences between the interleaving configurations *cf.* Figure 5.

While these simulations show that the bright end astrometric errors are of order 5 mas or better for the 2x2 and 3x3 interleaved data, it is likely that in real life some additional errors will be present that have not been accounted for in these simulations *eg.* differential radial field distortions (see `http://www.ast.cam.ac.uk/~wfcam/docs/reports/astrom/`).

Also, these results will be indicative of relative astrometric and photometric errors. The absolute errors will depend on how well the standards can be applied.

References

Fruchter A.S., Hook R.N., 2002, PASP, 114, 144
'Drizzle: A Method for the Linear Reconstruction of Undersampled Images'

Hook R.N., Pirzkal N., Fruchter A.S., 1999, ADASS VIII ASP Conf., 172, 337
'Combining Undersampled Dithered Data – A Review of the Options'

Irwin M.J., 1996, Instrumentation for Large Telescopes, VII Canary Islands Winter School, eds. J.M.Rodríguez Espinosa, A.Herrero, F.Sánchez, p. 35.
'Detectors and Data Analysis Techniques for Wide Field Optical Imaging'

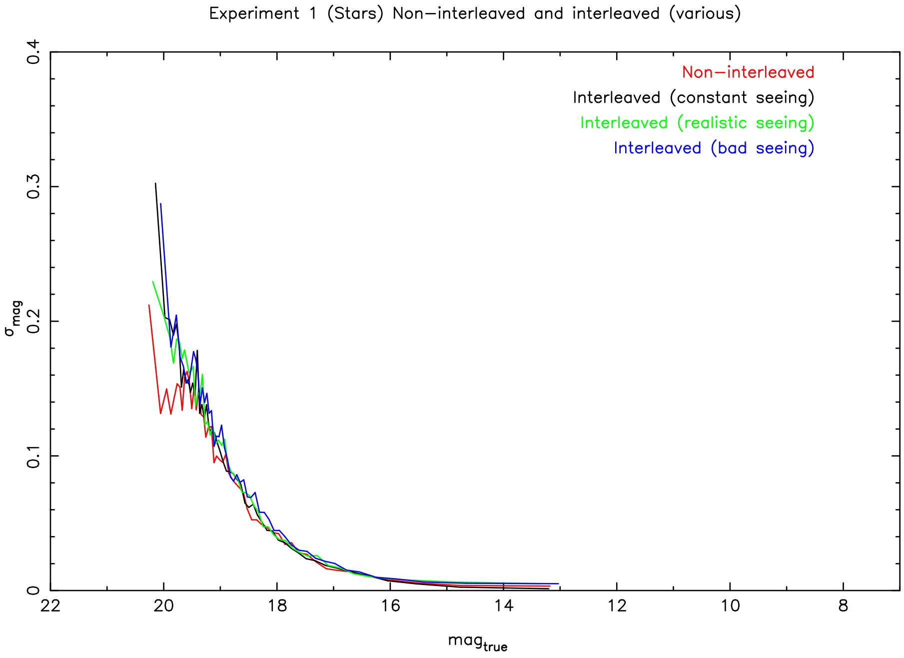


Figure 5: Photometric errors as a function of magnitude.

Lauer T.R., 1999, PASP, 111, 227
'Combining Undersampled Dithered Images'

Lauer T.R., 1999, PASP, 111, 1434
'The Photometry of Undersampled Point-Spread Functions'

A postscript version of this report can be found at
`http://www.ast.cam.ac.uk/~wfcam/docs/reports/interleaving/interleaving.ps`.

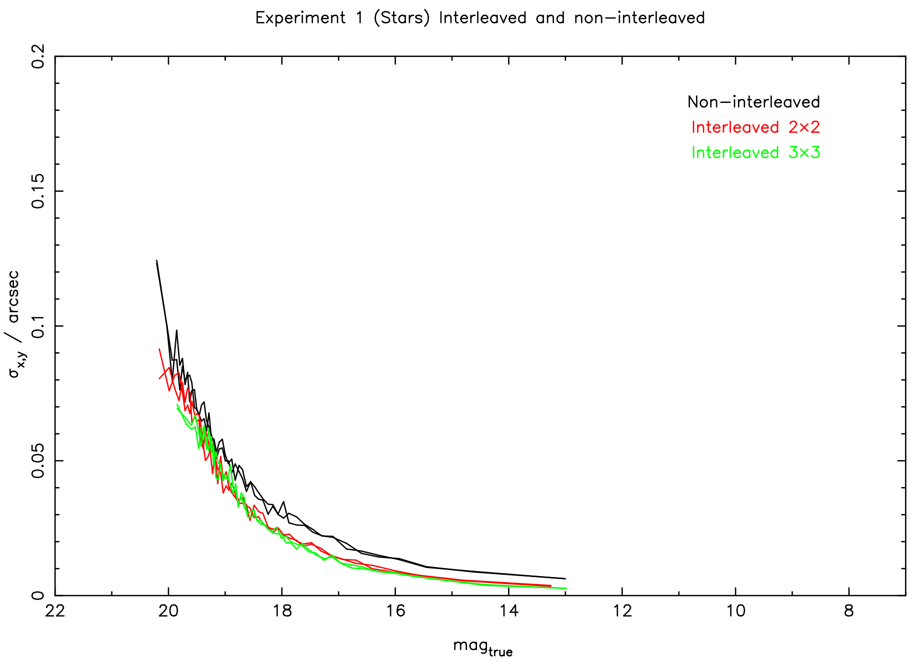


Figure 6: Astrometric errors as a function of magnitude for different interleaving configurations.