National Optical Astronomy Observatories

MEMORANDUM

TO: Distribution **DATE:** 1986/Revised 1992

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SUBJECT: FOCAS Sky Evaluation

I spent the past week looking into the sky evaluation performed by FOCAS. In particular I looked at the systematic dependence of the sky intensity on various parameters. This study led to researching new algorithms.

The algorithm for evaluting sky is as follows. First the mean density of all the points in the sky region and the the mean density of the object isophote are determined. If the sky region is badly contaminated by bright objects then its mean will exceed that of the isophote. The isophote is assumed to always be slightly above the sky background. The minimum of these two means is used as the center for a histogram of the densities of the sky pixels. The histogram bin width is 10% of the sky sigma recorded in the catalog header. The peak of this histogram is found and the mean of the histogram within two sky sigma of this peak is computed using intensities instead of density. This method is similar to a 2 sigma clipping algorithm except that instead of iterating the histogram is used.

There were two new sky evaluation stategies explored. Both of these measure the mode of the histogram. The first simply records the intensity value corresponding to the mode of the raw density histogram. This value is not a good estimate of an individual sky intensity. In the tables below we find that the standard deviation of this quantity is greater than the other measures of the sky.

The second method attempts to reduce the noise in the mode of the raw histogram by convolving the histogram by a gaussian. This smooths the raw histogram and uses all the data. The mode of the convolution is then determined. The mode is found by parabolic interpolation to a fraction of the histogram bin width. This method is discussed in greater detail in *International Workshop on Image Processing in Astronomy*, Trieste, 1979, by E. B. Newell page 100. This paper also discusses iterative k-sigma clipping to which I claim the mean about the mode method is similar. As an additional reference to the reader a new method is described by Ratnatunga and Newell in **AJ 89**, 1984, p. 176 called asymmetric clipping. This method was studied but seems too complex to program at this time.

Table 1 presents the statistics for the sky intensity from a number of tests. In all cases the data was the SA68 test field 1 provided by David Koo. The sky intensity was estimated for 338 objects. The three types of estimates are the two sigma width mean about the mode, the mode of the raw histogram, and the mode of a gaussian convolution of given sigma with the raw histogram. The "true" sigma of the sky is 5. The histogram bin width is approximately 2% of the sigma as opposed to 10% as used in the past.

Table 1: Sky Estimation Tests

Mean	Error	Minimum	Maximum	Type
174.691	0.113	169.76	179.57	Mean
174.434	0.118	169.03	178.98	Mean
174.324	0.137	167.20	180.80	Mode
174.406	0.137	167.20	180.84	Mode
174.718	0.112	169.76	179.56	Conv
174.600	0.112	169.68	179.08	Conv
174.524	0.113	169.64	178.96	Conv

174.449	0.116	169.44	178.96	Conv
174.467	0.116	169.48	179.00	Conv

Notes:

1. One density unit is about 0.04 intensity units. Thus a bin width of 0.24 is 6 density units and 0.08 is two density units.
2. The uncertainty estimate in the means is derived from the standard deviation by dividing by the square root of 338.

The points to note from table 1 are that the raw mode of the histogram yields the lowest sky estimates. They have, however, the greatest uncertainty. The estimate based on the mean about the mode decreases as the sigma used in determining the range about the mode is decreased. This indicates some small amount of skewness in the histogram. Finally, as the sigma of the convolution decreases from much greater than the actual sky sigma to less than the sky sigma the convolution mode estimates decrease systematically. This again indicates skewness in the histogram. Note the raw mode is identical to the convolution mode with a convolution sigma of 0.

My conclusions are that the while the convolution method is good for data containing significant skewness, for normal FOCAS data the clipped mean is just as good and 5 times faster computationally. I further suggest that the mean estimates be used with a statistically correction applied to reduce the mean of sky estimates to the mean of the raw mode estimates.

The following changes have been made to FOCAS.

1. The old **evaluate** task has been broken up into two tasks. The first task, called **sky**, evaluates the sky intensity only. The second task, also called **evaluate**, performs the remaining photometry, astrometry, and moment evaluations.
2. The **sky** evaluation task has been changed to correct the histogram binning error. Further, once the peak of the histogram is determined the mean is recomputed from the pixel data rather than from the histogram.
3. The **sky** task has several options. The default option is to compute the two sigma mean about the raw mode and also record the intensity of the raw mode. Another option is to also compute the convolution mode estimate. This option is considerably slower. The convolution mode is recorded as the sky estimate and the two sigma mean is recorded elsewhere in the object record. The last two options allow the addition of a user supplied constant to the sky estimates or the explicit setting of the sky intensity to a user supplied constant.
4. A script task, **skycorrect**, based on **sky** has been added. After running **sky** it computes the mean difference between the clipped mean about the mode and the mode over all objects. This difference, which should be negative for positively skewed sky histograms, is added to the clipped mean sky estimated for each object. This has the effect of applying a small correction for skewness due to unresolved background objects.
5. The evaluation task no longer applies the significance test based on the core to isophotal intensities. It also allows negative luminosities. If an object has a negative isophotal luminosity the DARK flag is set, the negative luminosity is recorded and the magnitude of the absolute value of this luminosity is recorded. Note that such an object will now have the EVALUATE flag set. The purpose of this change is to allow the noise contribution to the number counts to be determined since above and below sky detections will be treated exactly the same. The excess of above sky objects to below sky objects should be an unbiased estimate of the number of faint objects at that magnitude.

The suggested reduction procedure is now as follows.

1. Create the image files and catalogs as before with **rfits, rcam, rpds, fvpds**, and **setcat**.
2. Detect the objects with **detect**.
3. Evaluate the sky around the objects with **sky** using the default option; i.e. forget about the convolution mode.
4. Determine a correction to the sky from the difference between the mean of the 2 sigma mean about the mode estimates and the mean of the raw modes. Use **skycorrect** to compute and apply this correction to the objects in the catalog.
5. Run **evaluate**.
6. The remaining steps of template definition, resolution classification, and splitting are unchanged.