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GIRA - Two Channel Photometric Restoration

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Abstract. We report on the status of a two channel photometric restoration technique and its current implementation as an IRAF task called GIRA. This method is particularly suited to stellar photometric measurements in crowded fields or in images where an extended structured background is present. The current implementation allows the use of several analytical point-spread-functions, or the image of an empirical PSF. When an analytical PSF is used, the program can automatically adjust the positions of input objects to improve the fit to the observed data.

1. Introduction

One fundamental task in astronomy is that of making flux measurements of point sources in an observed field. A common problem limiting the accuracy of such flux measurement is the presence of nearby contaminating sources or the presence of an extended background in the field.

The transfer of positional information from one dataset to another allows one to devise new methods of using the new generation of large ground based telescopes in conjunction with high resolution space telescopes such as HST.

One such method is a two channel photometric restoration method known as GIRA first conceived by one of us (L. B. Lucy) and which is under development at the ST-ECF (Pirzkal et al. 1999). A few, often just one, high resolution space based images are used to improve our ability to measure the brightness of the same objects in a seeing-limited image or set of images. In seeing-limited images, not all of the sources might be visible or easily detectable using conventional means due to the spreading of the available photons by the seeing and because the sources are likely to be much more blended together and hence harder to even successfully detect.

2. Algorithm

We start by modeling the true sky Ψ as the sum of two different components, or channels. The first channel ψ^* is made up of all the stars in the field whose initial positions are known accurately (for example by using stellar positions obtained from higher resolution HST images). The second channel ψ is the remaining diffuse emission, or background emission in the field. Hence,

$$\Psi = \psi^* + \psi \tag{1}$$

If we denote an actual (noisy) observation of this field as $\bar{\Phi}$, then an estimate of this observed image Φ can also be written:

$$\Phi = \phi^* + \phi \tag{2}$$

where

$$\phi^* = \psi^* \otimes \eta \tag{3}$$

and

$$\phi = \psi \otimes (\eta \otimes G(\alpha)) \tag{4}$$

where $\otimes$ represents the convolution operator, η is an estimate of the PSF in $\bar{\Phi}$, and G is a two dimensional Gaussian whose full width at half maximum determines the additional level of smoothness α in ϕ. This extra level of smoothness is required in order to remove the degenerate solution of stellar objects represented by sharp peaks in the background channel ψ while simultaneously dropping the flux of the objects to zero in ψ^*. Consecutive estimates of ψ^* and ψ are computed using a scheme which maximizes the likelihood

$$H = \bar{\Phi} ln \Phi \tag{5}$$

using an iterative scheme developed by L. B. Lucy (Lucy 1974, Lucy 1991, Hook & Lucy 1991). This scheme ensures that the non-negativity of both ψ^* and ψ is enforced and that the total flux in Φ is conserved. Initially, each channel is assigned half of the total flux observed in $\bar{\Phi}$ and all the stars in ψ^* are assigned the same flux (half of the total flux divided by the number of stars).

Several aspects of this approach are noteworthy: First, this two channel restoration scheme does not produce ringing or other artifacts that are known to limit the accuracy of the photometry obtained with single channel restoration methods such as the classical Richardson-Lucy method. GIRA uses a general coordinate and brightness list to represent ψ^* and not simply a set of δ functions at fixed integer pixel coordinates and regularizes the background channel using a single parameter α instead of two free parameters as it is the case in the previous two channel restoration technique PLUCY. Second, nothing precludes an implementation of this algorithm which periodically adds automatic adjustments of the size of the chosen PSF η, or moves objects around their original positions in order to increase the value of H.

3. Examples

We wanted to assess GIRA's ability to measure stellar magnitudes of stars in NGC6712 and applied GIRA to a set of simulated 256x256 V and I images of this dense globular cluster. These images, with a PSF of 0.7" and a pixel scale of 0.09", closely matched the physical properties of real images of NGC6712 taken with the Test Camera during the Science Verification phase of UT1 VLT (ESO 1998). Each star was however assigned a set of known V and I stellar magnitudes drawn from a Tonry globular cluster model distribution (Tonry 1998). In Figure 2 we show that the magnitudes measured using GIRA suffer from no

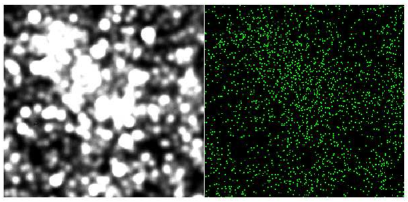

Figure 1. The V simulated globular cluster image. The image on the right shows the location of the 2157 stars in this image detected in an HST image of the same cluster.

apparent systematic effects and that the amount of error is within what would be expected when photometric noise and stellar crowding effects are accounted for.

The ability of GIRA to adjust and correct object positions in an image is also demonstrated in Figure 3. In this test, GIRA was used for 1000 iterations on an image containing three stars of magnitude -2.0,-2.0,and -3.0, with a FHWM of 7.2 pixels and separated by at most 4 pixels (Coordinates are [64,66],[64.9,63.4],and [66.9,63.4] respectively). Despite positional errors added to the input object positions of 0.038, 0.207,and 0.298 pixel respectively, all three final stellar positions were adjusted to within 0.05 pixel of the true stellar positions.

4. Conclusion

In its current IRAF implementation, GIRA is capable of precisely and accurately measuring the brightness of stars in cases of extreme stellar crowding. GIRA is also capable of performing object positional adjustments. We plan to generalize GIRA so that the positional and PSF adjustment features of the program can be used in conjunction with a 2D FITS image PSF.

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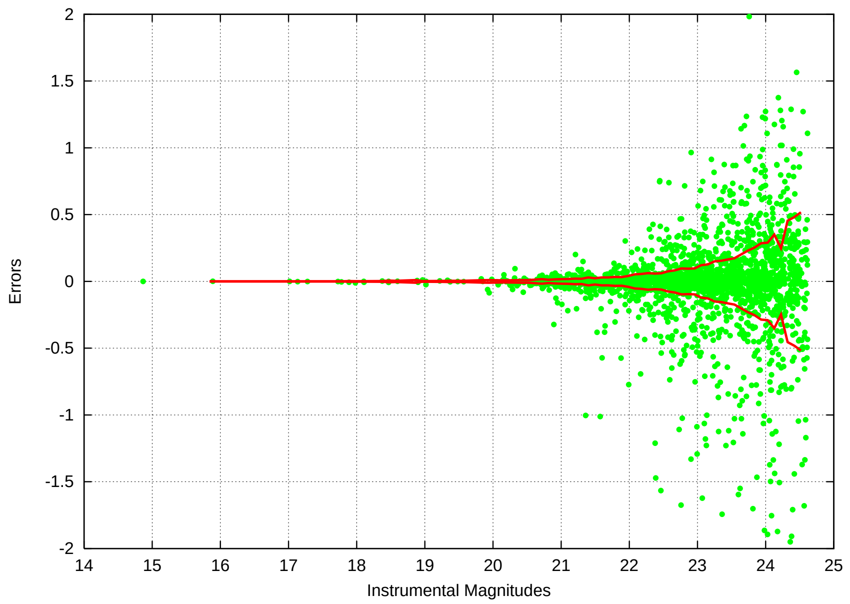

Figure 2. Errors in the GIRA measured magnitudes. The solid lines show the expected $\pm 1.0\sigma$ errors if one accounts for photon noise and stellar crowding effects.

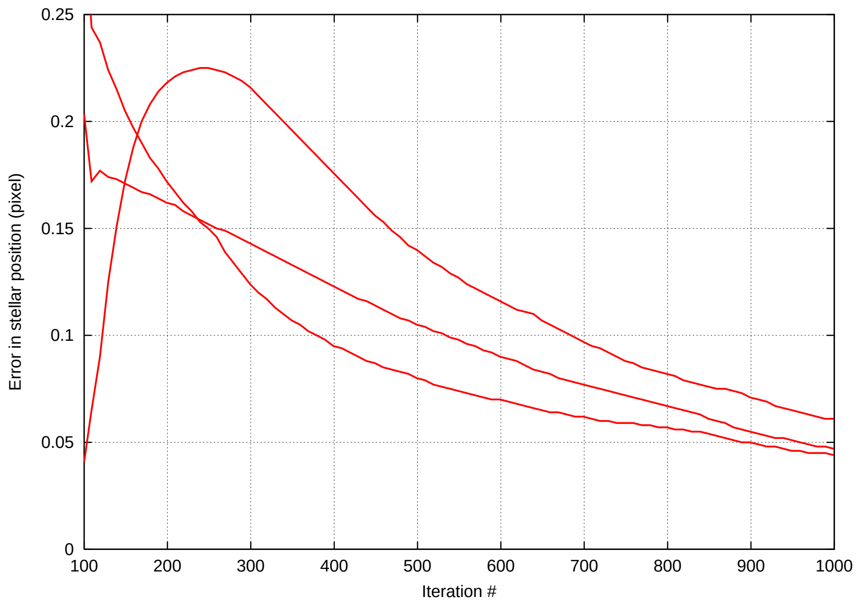

Figure 3. Error in object positions as a function of iteration when close-by objects are allowed to be moved by GIRA.