SImg Manual

Version 20060215 (Draft)
11th November 2006

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SImg is a collection of routines for scientific image processing, mainly intended for astronomy. It supports images of any size and number of colors. The internal processing is done with floating point numbers (of double precision by default), except of raw data processing.

The software consists in a library, which routines are used by small command line applications. These are mainly suitable for the usage in scripts, e.g. bash scripts. Also some graphical visualization tools are available.

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1.1 drdeconvo

Application

This is the Damping regularization deconvolution method, similar to the Wiener method (`wiener` (1.4) command), but with local damping.

Usage `simg drdeconvo [<options>] [@<parameter file>] <noise image> [<infile>] [<outfile>]`

Parameter

`<noise image>`	Noise image
`<infile>`	Source image (default: stdin)
`<outfile>`	Destination image (default: stdout)

Options:

`-s <nn.n>`	Radius of the Gauss-shaped PSF (default: 1.5)
`-psf <file>`	PSF (instead Gauss-shaped PSF)
`-snr <nn.n>`	Mean SNR (default: 10)
`-df <nn.n>`	Damping factor (default: 1)
`-it <nnn>`	Iterations (default: 3)
`-o <outfile>`	Destination image
`-h`	Help

Math A blurred image can be described as

$$i(x) = (s * o)(x) + n(x) \ ,$$

where i is the observed image, s is the PSF, o is the original, undegraded image, and n is the noise. The Damping regularization method is defined by the minimization problem

$$\|s * \hat{o} - i\|_2^2 + \lambda \left\| \hat{o} - \frac{i}{\sum_x s(x)} \right\|_2^2 + \lambda \left\| \tilde{\sigma}\big(\hat{o} - \frac{i}{\sum_x s(x)}\big) \right\|_2^2 = \min_{\hat{o}}!$$

with the regularization parameter λ and the normalized noise $\tilde{\sigma}$,

$$\tilde{\sigma} = \frac{r\sigma}{\sum_x \sigma(x)} \ ,$$

where σ is the given noise and r is the damping factor. The damping depends from $\tilde{\sigma}$. In matrix vector formulation the minimization problem reads as

$$(\boldsymbol{S}\hat{\boldsymbol{o}} - \boldsymbol{i})^2 + \lambda\Big(\hat{\boldsymbol{o}} - \frac{\boldsymbol{i}}{\sum_x s(x)}\Big)^2 + \lambda\Big(\operatorname{diag}(\tilde{\sigma})\big(\hat{\boldsymbol{o}} - \frac{\boldsymbol{i}}{\sum_x s(x)}\big)\Big)^2 = \min_{\hat{\boldsymbol{o}}}!$$

where $\cdot^2 = \cdot^T\cdot$. The minimization problem is solved by

$$\boldsymbol{S}^T\boldsymbol{S}\hat{\boldsymbol{o}} + \lambda\,\operatorname{diag}(1+\tilde{\sigma}^2)\hat{\boldsymbol{o}} = \boldsymbol{S}^T\boldsymbol{i} + \lambda\frac{\operatorname{diag}(1+\tilde{\sigma}^2)\boldsymbol{i}}{\sum_x s(x)} \ .$$

Unfortunately this formulation can't be expressed in the Fourier space. Therefore we solve the minimization problem using a fixed point iteration:

$$(\boldsymbol{S}^T\boldsymbol{S} + \lambda)\,\operatorname{diag}(1+\tilde{\sigma}^2)\hat{\boldsymbol{o}}^{(k+1)} = \boldsymbol{S}^T\boldsymbol{S}\,\operatorname{diag}(\tilde{\sigma}^2)\hat{\boldsymbol{o}}^{(k)} + \boldsymbol{S}^T\boldsymbol{i} + \lambda\frac{\operatorname{diag}(1+\tilde{\sigma}^2)\boldsymbol{i}}{\sum_x s(x)} \ .$$

The iterations can be solved in the Fourier space:

$$\mathfrak{F}\left\{(1+\sigma^2)\hat{o}^{(k+1)}\right\}(\omega)$$
$$= \frac{|S(\omega)|^2\mathfrak{F}\left\{\sigma^2\hat{o}^{(k)}\right\}(\omega) + S^*(\omega)I(\omega) + \frac{\lambda}{\sum_x s(x)}\mathfrak{F}\left\{(1+\sigma^2)i\right\}(\omega)}{|S(\omega)|^2+\lambda} \; .$$

This algorithm usually converges very quickly after 2 – 4 iterations. For the start value of $\hat{o}$ the fixed point iteration we choose

$$\hat{o}^{(0)} = \frac{i}{\sum_x s(x)} \; .$$

Description For the local damping the noise image σ must be given. For example it can be determined by `affineadd` (**??**) using the `-on` option. (`wiener` (1.4) can be used, if no noise σ is given). If the PSF is given it can be specified with the `-psf` option, else a Gauss-shaped PSF with the radius defined by `-s` is generated. The option `-snr` is used for the calculation of the regularization parameter λ by $\lambda = 1/\,\mathrm{SNR}^2$, see 1.4. With the damping factor `-df` the amount of damping can be influenced. The number of iterations can be small, usually between 2 and 4 for not too large damping factors.

1.2 starsplit **Application**

Separates stars from the background. This is the blind version, see starsplit2 (1.3) for the non-blind version.

Usage simg starsplit [<options>] [@<parameter file>] [<infile> [<outfile>]]

Parameter

<infile>	Source image (default: stdin)
<outfile>	Destination image (default: stdout)

Options:

-psf <outfile>	Output PSF
-stars <outfile>	Output stars
-sl <outfile>	List of stars in text format (¡x¿ ¡y¿ ¡brightness¿)
-si <outfile>	Output deconvolved stars
-le <nn.n>	Localization weight exponent (default: 0.5)
-i <nnn>	Iterations (default 20)
-n1 <nnn>	Number of stars in first iteration (default 20)
-n2 <nnn>	Number of stars in last iteration (default 100)
-ib <nnn>	Brightest pixels to be ignored for PSF estimation (default 0)
-h	Help
-o <outfile>	Output image

This is the blind version, i.e. the PSF is estimated from the input image.
In each iteration $n_1 + i(n_2 - n_1)/(m-1)$ stars are separated form the background, where i is the iteration number, m is the total amount of iterations defined by -i ($i = 0..m-1$) and $n_{1/2}$ are the numbers of separated stars in the first/last iterations defined by -n1 / -n2. With the parameter -le the ability of separating close stars can be adjusted (larger values → better separation). But large values decrease the accuracy of the estimated PSF and increase the amount of artifacts. The parameter -ib allows the specify that the brightest pixels should be ignored for PSF calculation. This is useful if the input image contains saturated parts.
The output image is the residuum, i.e. the input image minus the separated stars. The stars can be outputted as image using the -stars / -si options (undegraded / deconvolved) or as a list using the -sl option. With -psf a file for the output of the estimated PSF can be specified.
This algorithm is slower than starsplit2 (1.3) . Use starsplit2 (1.3) if the PSF is known (e.g. estimated using getpsf (**??**)) or the number of stars in the image is high.

1.3 starsplit2 — Application

Separates the stars from the background. This is the non-blind version, see `starsplit` (1.2) for the blind version.

Usage `simg starsplit2 [<options>] [@<parameter file>] <PSF> [<infile> [<outfile>]]`

Parameter

`<PSF>`	PSF image
`<infile>`	Source image (default: stdin)
`<outfile>`	Destination image (default: stdout)

Options:

`-stars <outfile>`	Output stars
`-sl <outfile>`	List of stars in text format (¡x¿ ¡y¿ ¡brightness¿)
`-si <outfile>`	Output deconvolved stars
`-le <nn.n>`	Localization weight exponent (default: 0.5)
`-i <nnn>`	Iterations (default 20)
`-n <nnn>`	Number of stars per iteration (default 70)
`-h`	Help
`-o <outfile>`	Output image

This is the non-blind version, i.e. a PSF needs to be given.
In each iteration n (defined by `-n`) stars are separated form the background, where the total amount of iterations is defined by `-i` With the parameter `-le` the ability of separating close stars can be adjusted (larger values → better separation). But large values increase the amount of artifacts.
The output image is the residuum, i.e. the input image minus the separated stars. The stars can be outputted as image using the `-stars` / `-si` options (undegraded / deconvolved) or as a list using the `-sl` option.
This algorithm is faster than `starsplit` (1.2) . Use this one if the PSF is known (e.g. estimated using `getpsf` (??)) or the number of stars in the image is high.

1.4 wiener

Application

Deconvolves an image using the Wiener method. This method is good for images with a low dynamic range, e.g. images of planets or terrestrial images.

Usage `simg wiener [<options>] [@<parameter file>] [<infile>] [<outfile>]`

Parameter

`<infile>`	Source image (default: stdin)
`<outfile>`	Destination image (default: stdout)

Options:

`-s <nn.n>`	Radius of the Gauss-shaped PSF (default: 1.5)
`-psf <file>`	PSF (instead Gauss-shaped PSF)
`-snr <nn.n>`	Mean SNR (default: 10)
`-o <outfile>`	Destination image
`-h`	Help

Math A blurred image can be described as

$$i(x) = (s * o)(x) + n(x) \ ,$$

where i is the observed image, s is the PSF, o is the original, undegraded image, and n is the noise. The inverse Wiener Y filter is defined in the Fourier space as

$$Y(\omega) = \frac{S^*(\omega)\Phi_o(\omega)}{|S(\omega)|^2\Phi_o(\omega) + \Phi_n(\omega)}$$

with the power spectra

$$\Phi_o(\omega) = \mathrm{E}[|O(\omega)|^2]$$

and

$$\Phi_n(\omega) = \mathrm{E}[|N(\omega)|^2] \ ,$$

where $E[\cdot]$ is the expectation. This filter is optimal in the meaning of

$$\mathrm{E}\left[\sum_x |y * i - o|^2\right] = \min! \ .$$

In practise the power spectra Φ_o and Φ_n are unknown and difficult to estimate. To obtain them we use an other approach, the Tikhonow regularization, which is defined by

$$\|s * \hat{o} - i\|_2^2 + \lambda\|\hat{o}\|_2^2 = \min_{\hat{o}}!$$

with the regularization parameter λ. In matrix vector formulation it reads as

$$(\boldsymbol{S}\hat{\boldsymbol{o}} - \boldsymbol{i})^2 + \lambda\hat{\boldsymbol{o}}^2 = \min_{\hat{\boldsymbol{o}}}!$$

where $\cdot^2 := \cdot^T \cdot$. The minimization problem is solved by

$$(\boldsymbol{S}^T \boldsymbol{S} + \lambda \boldsymbol{I})\hat{\boldsymbol{o}} = \boldsymbol{S}^T \boldsymbol{i} \ .$$

This formulation can be expressed in the Fourier space as

$$\hat{O}(\omega) = \frac{S^*(\omega)}{|S(\omega)|^2 + \lambda} I(\omega) \ .$$

which is Wiener filter method with the estimation

$$\frac{\Phi_n(\omega)}{\Phi_o(\omega)} = \lambda \ ,$$

i.e. λ can be interpreted as $1/\,\mathrm{SNR}^2$.

Description This method works good for images with a low dynamic range, e.g. images of planets or terrestrial images, even if no exact PSF is known. If the PSF is given it can be specified with the `-psf` option, else a Gauss-shaped PSF with the radius defined by `-s` is generated. The option `-snr` is used for the calculation of the regularization parameter λ.

This deconvolution method is fast and easy to use. If no exact PSF is known proper values for the options `-s` and `-snr` can determined as follows.

1. Start with a not too high SNR (e.g. 5 or 10) and a small PSF radius s (e.g. 0.8)
2. Increase s until artifacts are visible in the output image
3. Decrease s by approx. 10%
4. Increase the SNR parameter until the desired compromise of sharpness and noise is reached

A similar deconvolution method, but with local damping, is the Damping regularization method (`drdeconvo` (1.1) command).

Appendix A
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Version 1.1, March 2000

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