Image enhancement algorithms in FLOSS: sharpening

Anton Lytvynenko,
Kyiv, Ukraine

Getting supplementary data on LVEE

```
wget -m --limit-rate=100k
http://192.168.1.107/share/
```

Sources of image fuzziness

- Focusing error;
- Lenses low quality or softness;
- Flatbed scanners peculiarities;
- Camera shake due to hands trembling or other reasons of motion.

FLOSS projects to be considered

- GIMP (GPL3+);
- ImageMagick (Apache 2.0);
- G'MIC (CeCILL License) – *GIMP plugin and standalone program;*
- Krita (GPL2).

USM (unsharp mask)

- Algorithmically: mixing an image with the result of its gaussian blur;
- Present in any editor declaring image processing capabilities (GIMP, ImageMagick, G'MIC, Krita, *even optical printing from film negatives!*);
- Parameters of USM in different software differ.

USM (unsharp mask)

- *Pro:*
  - Present everywhere;
  - It is possible to apply threshold value to leave smooth area untouched (otherwise noise will be enhanced too);
- *Contra:*
  - Low selectivity, a morphology of the image is not taken into account;
  - USM relies on visual enhancement, no compensation of real blurring effects is applied;
  - Artifacts may be produced on severe sharpening levels.

Example: USM

Source

Result

Morphology-based algorithms

- Searching for contours and their enhancement.
  - Laplacian of gaussian (**ImageMagick**):

    convert 1.png -define convolve:scale='100,100%' -morphology Convolve 'Log:0x2' 1_sharpen.png
    http://www.imagemagick.org/Usage/convolve/#sharpen
  - *Erosion sharpening* (**GIMP** plugin)

    The image is mixed with results of „dilate“ and „erode“ operations with some weight coefficients.
- *Pro:* More selective in respect to USM.
- *Contra:* Threshold is usually not applicable, preliminary denoising should be applied.

Example: *erosion sharpening*

Source

Result

Wavelet sharpen

- Contours are selected using wavelets and enhanced (some components of the image wavelet decomposition are enhanced);
- Implemented as GIMP plugin;
- *Pro:*
  - One of the most effective methods of image sharpening;
  - May be combined with wavelet denoising.
- *Contra:*
  - No threshold usage is available, so preliminary denoising should be applied.

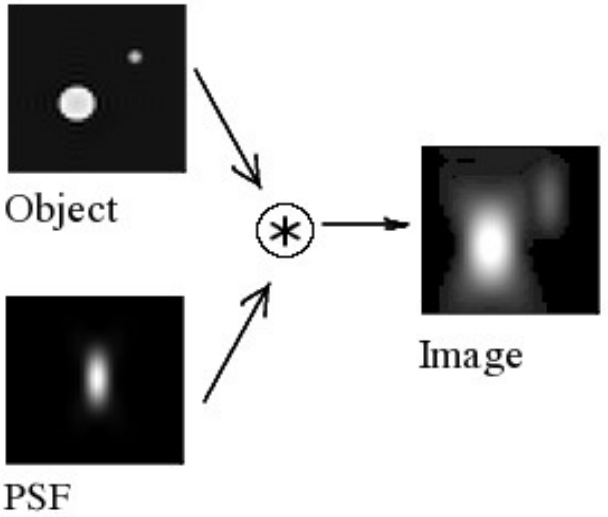
Example: *wavelet sharpen*

Source

Result

PSF-based algorithms

- Image blurring =
  = *stochastic* (*e.g.* noise, accidental defects)
  + *deterministic* (motion blur, focusing error);
- If *deterministic* blurring prevails and point spread function (PSF) is known, one can restore initial image exactly (but borders);



Problems:

- PSF usually unknown;
- Noise.

http://en.wikipedia.org/wiki/File:Convolution_Illustrated_eng.png

PSF estimation

- **G'MIC**: *deconvolution sharpening* (Richardson-Lucy algorithm: *JOSA, 62, 1, pp. 55-59 (1972); Astronomical Journal, 79, p. 745 (1974)*);
- *Refocus* plugin for **GIMP** (Wiener filter: *N. Wiener. Extrapolation, Interpolation, and Smoothing of Stationary Time Series. New York: Wiley, 1949*) – focusing errors *etc.*;
- *Refocus-it* plugin for **GIMP** (Hopfield neural network: *PNAS, 79, 8, pp. 2554—2558 (1982)*) – motion blur, focusing errors *etc.*

PSF-based algorithms

- *Pro:*
  - Try to compensate physical effects leading to fuzziness;
  - Can help to extract information from the image where other methods cannot (*e.g.* vehicle number blurred by motion and so on);
- *Contra:*
  - Require a lot of computational resources;
  - Often produce images with artifacts (ripple).

Example: *Refocus*

Source

Result

Conclusions

- FLOSS projects deliver a lot of powerful theoretically substantiated algorithms for image sharpening, based both on visual sharpness enhancement as well as on compensation of physical reasons leading to fuzziness;
- Image sharpening algorithms substantially differ in different programs (mostly as plugins or scripts). The most of them are implemented as **GIMP** plugin (especially taking into account **G'MIC**);

Basing on personal experience, author recommends wavelet algorithm usage in the majority of cases.

Yet another example :)

Source

Wavelet

Refocus

And yet another ;)

Source

Wavelet

Deconvolution sharpening