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Fast image processing methods for PC: 4. Iterative cleaning of the impulse noise.

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Abstract. An iterative cleaning procedure, suitable for removing cosmic events, is described. It uses convolution processing of the image, corresponding to smoothing with sliding regression surface of the 5th degree. The procedure reaches robust estimations of the pixels values. It recognizes the pixels containing impulse noise and replaces its values by the corresponding values of the regression surface.

Key words: photometry — method — noise reduction

1. Introduction

Three previous papers describe methods of median filtering, regression smoothing and iterative restoration for CCD frames (Georgiev, 1996a,b,c). They are part of the extension of the software PCVISTA (Treffers and Richmond, 1989) realized by Georgiev (1995).

The present paper is an improvement of the fast smoothing method, corresponding to sliding regression surface of the 5th degree (Georgiev, 1996b). It gives a possibility for iterative removing of the impulse noise from a frame (cosmic events, holes, hot and cool pixels), leaving the stellar images unchanged.

Let us compare the original noised image and the corresponding smoothed image, obtained by the smoothing method mentioned above. If the number of the pixels in the smoothing window is enough large, i.e. some tens, one single peak value (as appearance of the impulse noise) does not distort strongly the local regression surface. Each such peak may be recognized by its significant deviation from the regression surface and may be replaced by the corresponding surface value. The result of this procedure will be a cleaned frame. This is the first iteration.

Then the cleaned frame, where the highest deviations are already suppressed, may be smoothed and compared again with the original frame. The same highest deviations will be recognized again and numerous new ones will be added. All recognized peaks may be again replaced with the values of the new (better) smoothed frame. This is the second iteration which results in a better cleaned frame.

The procedure may be repeated again. The goal is achievement of a robust regression estimations (Draper and Smith, 1981) of the pixel values, containing the impulse noise.

To avoid changes of the central peaks of the stellar images, a suitable nonlinear transform of the pixel values must be made previously, i.e. logarithmic transform. Then the sliding regression surface follows well the brightness distribution of the frame, including the stellar images. In this case the procedure does not affect the shape of the stellar images, but recognizes and suppresses strong cosmic events in the stellar images.

The experience of the author with a computer program CLN, realizing the above mentioned cleaning procedure as an addition to the image processing software PCVISTA (Treffers and Richmond, 1989), shows that it removes successfully all significant single impulses. Only the bases of the very strong cosmic events, scattering over 3 or more pixels, remain in the frame and need manual actions.

The program computes the standard deviation S between the current cleaned and smoothed frames. The current threshold T for peak recognizing and changing is calculated as T=CS. The values of S and T decrease with increasing of the iteration number, up to a factor of two. The input (user defined) parameters of CLN are the size of the smoothing window W, usually W=7–9 pixels, and the above mentioned sigma-coefficient C=3–5. Usually three iterations are enough. Finally, about 0.5 per cent of the pixels in the frame occur changed by the procedure CLN.

Each call of the program CLN uses one input frame–file, F0, containing the raw image, and produces two output frame–files, F1, containing the cleaned image and F2, containing the residual image. The residual image is the difference between F0 and F1. It is very useful for visual control of the cleaning because it shows only the changed pixels. In the process of cleaning the files F1 and F2 store the smoothed and the raw frames respectively (in nonlinear scale).

The current version of the program CLN keeps and processes in the computer memory one frame with dimensions up to 600×400 pixels. Let us denote the reserved computer memory, storing one frame, as FM. The convolution smoothing procedure affect the whole frame, including its periphery. That is why the frame must be expanded artificially by adding H=W/2 upper and down rows and H left and right columns, taken from the corresponding opposite side of the frame. Consequently, if the image size is I x J pixels, the size of the matrix FM for one frame must be $(I + W - 1) \times (J + W - 1)$ pixels (Georgiev, 1996a).

Usually we use the "upper left part" of the area FM, with the size I×J pixels. Only for the smoothing procedure we move the frame to "down and right" in FM and add new rows and columns. Then, smoothing the frame we store the results again in the "upper left part" of FM, with back translation: the result for the first image pixel, (H,H) may be written in the place of FM pixel (0,0), the result for the second, (H,H+1), in (0,1), and so on.

The algorithm of the procedure CLN is described below, where RF, CF and SF mean respectively the raw, cleaned and smoothed frames (in nonlinear scale). Let N be the number of the desired iterations.

Step 0. INITIALIZATION

Computation of the smoothing convolution nucleus (Georgiev, 1996b).

Opening the file of the input frame F0 and the files F1, F2, for the smoothed and raw frames (in nonlinear scale).

Input the raw frame from F0 in FM.

Performing nonlinear transform of the raw frame in FM.

Output of the transformed raw frame RF from FM in F2.

Setting the iteration number n=0.
Note that here, at the beginning of the process, the frame memory FM contains the raw frame RF; RF is situated in the upper left part of the computer array FM.

Step 1. SMOOTHING

Moving of the CF to the inner part of FM.

Enlarging the periphery of CF.

Smoothing the CF, writing the result SM in the upper–left part of FM.

Output of the smoothed frame SF from FM in F1.

Step 2. CLEANING

Input the RF from F2 in FM.

Reading the SF from F1, comparing it with RF in FM using the deviations d(i,j)=RF(i,j)-SF(i,j) and removing the inpulse noise as follows:

if $| d(i, j) | \leq T$, then the values of RF(i,j) are assumed an an usual pixel value and remains unchanged;

if $| d(i, j) | > D$, then the values of RF(i,j) are recognized as unusual (noised) pixel value, and SF(i,j) changes it.

Increasing the iteration number n by 1 and checking it:
if $n \leq N$, go to Step 1, else go to Step 3.
Note that here, before the repeating of the step 1 (or before the end of the process) the frame memory FM contains the current cleaned frame CF; CF situated in the upper left part of the computer array FM.

Step 3. OUTPUT THE CLEANED FRAME

Restoration of the linear scale of CF in FM:
Output the result as final cleaned image in the file F1
Note that here FM contains the final cleaned frame in its original linear scale.

Step 4. OUTPUT THE RESIDUAL FRAME

Reading of the raw image from the file FO and change of FM(i,j) by the residual FO(i,j)-CM(i,j).
Output the result as a final residual frame in F2.

The procedure always needs a visual inspection of the residual frame. If the tops of bright stars are changed by the cleaning, a user must increase the sigma coefficient C and repeat the process. After cleaning the user may apply the smoothing procedure, described earlier (Georgiev, 1996b). In this case the corresponding smoothing window must be smaller than the cleaning window in the procedure CLN.

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References

Draper N.R., Smith H.: 1981, Applied Regression Analysis, John Wiley & sons, Part 6.14.

Georgiev T.B.: 1995, IAU Comission 9, WGWFI Newsletter **8**.

Georgiev T.B.: 1996a, Bull. Spec. Astrophys. Obs., **39**, 124.

Georgiev T.B.: 1996b, Bull. Spec. Astrophys. Obs., **39**, 131.

Georgiev T.B.: 1996c, Bull. Bull. Spec. Astrophys. Obs., **39**, 140.

Treffers R.R., Richmond M.W.: 1989, Publ. Astr. Soc. Pacific, **101**, 725.