An automatic pluviogram reducer
R. Leonardi, C. Rafanelli, T. Montefinale
CNR Instituto di Fisica dell'Atmosfera, 31 P. le Luigi Sturzo, 00144 Rome, Italy

Abstract
The meteorological data recording (rain, temperature, pressure and so on) using mechanical recorders occurs drawing the trend, trace, on a graduated paper by a pen-nib linked to instrument transducer. Manual techniques or hand-digitiser readings to reduce those traces are used. The vast amount of work to reduce a lot of pluviograms with high precision becomes prohibitive.
This paper shows a software, written in ‘C’ and running under Extended DOS, for fully automatic reading of scanner digitised pluviograms. So that it is possible to recover the large papery archives existing in many organisations and institutions.
The pluviogram digitised in a graphic file is submitted to a series of elaborations concerning image-enhancement, geometric transformation, scaling and filtering of the background, to clear the graduated scale and other spurious marks isolating the rain trace. Finally the rain amount versus time is recorded on file.

Key words : rain-gauge, pluviogram, image processing, software

1 Introduction
Nearly all countries make some effort to collect and publish the measurements of rainfall, collected with specified instruments named rain-gauges or pluviometer. Their number and the density varie greatly from country to country and even within the same country. The most dense networks have been established, as may be expected, in areas where there is great economic significance in local variation of rainfall and generally seem to be related to the density of population. In the more developed and densely populated countries as Italy, there have been fairly good networks for 70 to 100 years. Obviously after
a few years the manuscript records become voluminous and their management becomes a problem.

The goal of the work is to give a new digital method to read pluviographs for long historical series management.

In this paper only the tipping bucket rain-gauge paper recorder data are considered. This instrument write a mark on the chart a continuous trace in time stepped every 0.2 mm, height of the fallen rain volume, fig. 1,3,4. To know the intensity of rainfall or rate of precipitation, usually expressed in millimetre per hour, an operator reads the trace on these charts and makes up a report. This method adds random errors valued at about a 7% due to the training and tiredness of operators.

Also for a net of a few instruments this is a very long and tedious work so that considering the general purpose of data, the daily amount of rain only is generally reported. This for many scientific uses is a hard limitation that this digital method contributes to overcome, in fact the pluviographic charts are read by the software with a few minutes step and data recorded on a daily file. So that users can examine every time interval, multiple of unit interval.

The paper describes a software to produce rain data archives starting from digitised pluviogram image even if of short quality. To standardise and speed the process the image, obtained putting the hard-copy of a pluviographic chart in a scanner device, the values of brightness, contrast and resolution are always fixed.

Scanned image is recorded and is part of the archive for possible further analyses. The procedure treats the image full automatically and measures the rain intensity without adding significant errors besides those due to the pluviometre itself.

2 Software technique

This software elaborates a digital image to clear as much as possible the background signal to evidence the rain trace. The rain amount is measured versus time and the results are recorded in a file.

To produce the original digitised image, the pluviogram paper, approximately 7*20 cm, is obtained by a monochromatic scanner at 150 dpi, with 256 grey scale tones. The resolution and image greys depth are chosen as a trade off between the image quality and a relatively small file dimension. With this setting a typical pluviogram is represented by a 600*1800*1 byte image, producing a GIF file about 200-500 Kbyte.

The flow chart of the software here proposed has 7 mainly item:
1 - reading and showing image
2 - image enhancement and region selection
3 - image de-warping
4 - grid removing
5 - thresholding
6 - rain signal extraction
7 - final result and file recording

2.1 Reading and shoving image
At the beginning the pluviogram is shown on the screen, fig. 1. The resolution is settled at 800x600 pixels so that the image is shown in 1:1 pixel to pixel scale. At right hand there is a tote area showing parameters of the figure and other informations related to the elaboration progress. The operator can scroll the image and read the co-ordinates and value of each pixel pointing it by mouse.

2.2 Image enhancement and region selection
The overall quality of available original pictures to be scanned is often poor. In fact reproductions from microfilm or photo-copy are usually available instead of original pluviograms. So the pictures may be too light or too dark, much or less contrasted and also zoned because not uniformly illuminated. Moreover somebody may have wrote, by a pencil, fig. 1, fibre pen, fig. 4a, or stamp, fig. 3a, some notes or marks. Marks and not uniform areas affect the histogram of the frequencies of the grey tones. This is important feature because the analysis of this histogram makes possible to separate the pixels of the rain

Figure 1 : An example of screen hard copy. The tote area on the right shows the image parameters.
Figure 2: Two histograms of grey tones of scanned pluviograms. Picture a) is linked to fig. 3a. Histogram b) is linked to fig. 4a. The horizontal scales are 0 to 255 from left to right. In vertical axes the frequencies.

signal, in the dark region of histogram, from the background, on lighter values, Di Zenzo.

As an example the fig. 2 shows the histograms of the picture 3 and 4. The fig. 2a is linked to the light image of figure 3a with little of dark tones and many white values. On the contrary the fig. 2b shows grey tones shifted on the darker level.

As first step a routine scans the image to search for wide dark zones and remove those setting the values at a local mean of a larger area. Than the equalisation of the background level is obtained subtracting the local mode to each pixel and adding a fixed value of 180 that is the mode of a good and well scanned original, the effects are evident in figures 3b and 4b, respectively compared with 3a and 4a. The dimensions of area to computing the local mode is a compromise between processing stability and computing time.

A modified average filter, with $3 \times 3$ mask to reduce the noise without blurring contours, complete the operation of preliminary treatment, Cappellini.

The enhanced image is shown and the operator selects the region to be analyse choosing by the mouse the four extreme of a quadrangular shaped area, in witch fall the scales of rain and time. This is the first of the only two operator’s requested actions.

2.3 Image de-warping

The scanned image can be not correctly squared for the optical aberrations and the grid scale of pluviogram is represented in cylindrical co-ordinates. So that is convenient to square and re-scale into Cartesian co-ordinates the image (de-warping), Russ. Moreover to avoid some problems linked to the algorithm used for grid removing, discussed below, the image area is normalised in size multiple of power 2, for a typical 24 hours pluviogram to $512 \times 2048$ pixels. The
Figure 3: Example of pluviogram with light background. From top to bottom: a) original scanned pluviogram; b) after image enhancement; c) result of grid removing; d) effect of applying the optimum threshold; e) resulting rain trace.
Figure 4: Example of pluviogram with dark and not uniform background. From top to bottom: a) original scanned pluviogram; b) after image enhancement; c) result of grid removing; d) effect of applying the optimum threshold; e) resulting rain trace.
figures 3b and 4b show the pluviograms after enhancement of § 2.2 and de-warping algorithms application.

2.4 Grid removing

The background grid now consists of periodic vertical and horizontal lines and the rain trace is a non periodic signal. It is possible clear away the grid lines applying a bi-dimensional Fast Fourier Transform (FFT) technique, Press et al.\textsuperscript{2}. So that it is possible to build a filter to clear the only periodic marks. Moreover, in the same step, a 2\textsuperscript{nd} order Butterworth low pass filter, Russ\textsuperscript{3}, is applied to reduce noise and ringing effects, Melli\textsuperscript{1}. The fig. 3c and 4c show the results of filtering.

2.5 Thresholding

The operation of thresholding transforms a multi-grey level image in a dual colour map. The all grey pixels whit value lower than threshold are objects, the higher are background, Russ\textsuperscript{3}. The questions are how to define the optimum level of threshold and if there is a single threshold good all over the image.

From samples examined in this paper it is possible to note that also after the image pre-processing it is not possible clearly identify the levels of the objects, because the images are still noisy and the background level still diversified over the image itself.

The optimal threshold value can not be fixed for all images nor unique in the same image, Kittler et. al.\textsuperscript{6}. It is necessary to compute it from the image itself, considering the statistical properties of grey levels for various zones in each image. In this software, the thresholds of 4 areas in the image corners are chosen and a bi-linear interpolation solve the problem. In figures 3d and 4d are show the effects of the thresholding in the two sample pluviograms.

2.6 Rain signal extraction

At this point of analysis, the image is constituted by the rain signal and by spurious marks due to residuals of original grid, pencil and pen notes. It needs other filters to remove the isolated pixels, filling the little holes of traces and separate the true rain trace from other objects.

A process of skeleton, Russ\textsuperscript{3}, is used to reduce the objects to single pixel width traces. Following, the splitting of branching is made. Then techniques of pattern recognition are utilised to clear away the irregular shapes.

The true trace pursuing begin at one of extreme of image, finding the first pixel of a trace and following it until the last pixel. Here the nearest start points of other traces are searched applying a strategy that move forward or laterally, considering the relative distances, the previous and next directions and the reversing of motion at end-scale of the traces. All the objects that for own morphological characteristics are not possible to be considered rain trace are set background. Finally all remaining objects are jointed to produce the continuous rain trace, see fig. 3e and 4e.
2.7 Final result and file recording

The digital rain signal is showed on the screen, over-imposed on to the original image to evaluate the goodness of result. So the operator can choose to accept the pattern and an ASCII file is recorded with the name of station, the date and cumulative rain versus time every 5 minutes. This time interval is chosen because the amount of rain is indicated by the ordinate change, fig 1,3,4, between two consecutive pixels along time axis. Taking into consideration the digitalisation of image, five minutes correspond at about 7 pixels of abscissa. The size of ASCII file produced is typically of 3 Kbyte per day.

In this release, if the operator rejects the pattern the file will not be created. In the tests carried out this case has never occurred. However, in the future, it will be implemented a manual method to permit to locate correctly bad parts of trace.

3 Concluding remarks

It is to be noticed that today also other kinds of pluviometers are operated, those store observations directly on solid state memory or transmit them in real time. But the procedure of this paper is yet useful as for the tipping bucket nets as for management of the historical series existing, some of them is a merely storage of pluviographic charts because not completely read.

The software is tested with many pluviograms obtained as A4 size hard-copy from microfilms of Italian Air Forces archive, having good performances in precision and time. The actual release, running on a 486 DX2-66 PC under Extended DOS, allows a fully processing of a scanned 24 hour pluviogram in about 4 minutes.

The future evolution of the software aims at the improvement of the techniques of pattern recognition, at the enhancement of thresholding and at portability on other platforms.

The algorithms here implemented are written in ANSI “C” and with very little modifications, may be applied to other kind of recorders as thermometer or barometer and so on.

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Bibliography


