MEDIAN FILTERING AND IMAGE CORRELATION FOR AIR POLLUTION DETECTION

M. Kolínová * and A. Procházka *

* *Prague Institute of Chemical Technology*
Department of Computing and Control Engineering
Technická 1905, 166 28 Prague 6, Czech Republic
fax: +420-2-2435 5053
e-mail: {Magdalena.Kolinova, Ales.Prochazka}@vscht.cz

Abstract: Correlation of images allowing detection of their common features belongs to fundamental tools in their analysis and processing. This paper presents non-linear methods and algorithms for removal of specific image components at first. Median filtering is discussed in this connection as a commonly used method for removal of singularities. The main part of the paper is devoted to a general method for evaluation of the correlation function between two images using non-overlapping and overlapping matrix regions to allow the same resolution of the resulting correlation function and the original image. This method is verified for simulated images at first to study its ability to find hidden image objects. The resulting algorithm is then used for comparison of satellite images obtained from the NOAA observations of the same region for different frequencies. The goal of such a comparison is to detect dust particles and air pollution to enable comparison of processed satellite images with ground observations using their two-dimensional extrapolation. It is assumed that results of such a study will allow to use satellite observations for detection of the most important sources of pollution, prediction of situation in a specific region and control of pollution sources. All algorithms presented in the MATLAB environment are written in the general form to allow their application to other images as well.

Keywords: Image Processing, Median Filtering, Correlation Function, Satellite Observations, Noise Rejection

1. INTRODUCTION

Correlation methods form a fundamental part of various methods applied in the field of digital signal processing and image analysis and processing (Chellapa 1992, Watkins *et al.* 1993, Klette and Zamperoni 1994, Van der Heijden 1994). Their efficient use assumes proper signal preprocessing in many cases to remove specific signal components and substantial signal errors.

This paper is devoted to image preprocessing using median filtering and to the subsequent evaluation of correlation coefficients in overlapping matrices of the selected size. Mathematical methods are validated in the MATLAB/SIMULINK environment (Hicklin and Grace 1993) for simulated signals at first and then they are applied to satellite images as well.

2. IMAGE PROCESSING

Digital filtering techniques allow both linear and non-linear image processing. They can be used efficiently to remove various forms of noise from the processed data or some other specific parts of the data the presence of which is not desirable in further processing. In all these cases, the convolution kernel $\mathbf{H}_{K,J}$ of the filter applied moves along all rows and columns of the image data $\mathbf{A}_{M,N}$, modifying values of individual points of the image according to conditions specified by the two dimensional convolution

$$B(m+K/2, n+J/2) = \sum_{k=1}^{K} \sum_{j=1}^{J} h(k,j)\ A(m-k, n-j)$$

presented in Fig. 1. In the most simple case, the mean value of a certain subimage matrix moving through the whole image is computed for every point of the image using the same values of the convolution kernel evaluated as a reciprocal value of the number of kernel values.

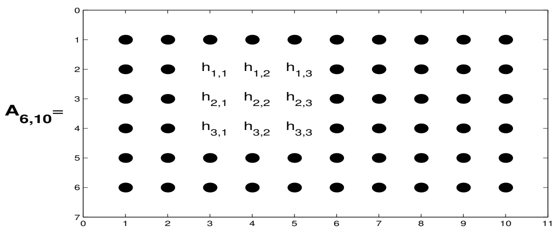

Figure 1. The application of the computational kernel for two-dimensional convolution

Median filtering (Chellapa and Sawchuk 1985, Tukey 1971) which is a non-linear method, allows very efficient removal of singularities in an observed sequence or image. This method is very often applied especially in such image processing which assumes application of overlapping matrices of size limited to 3 by 3 only, in many cases. The central element of this matrix moves along all rows and columns of the original image. The median value of the given subimage belonging to this window is then used instead of its reference element in every case.

This method has been applied to remove specific elements of satellite images described further, especially the border of the Czech Republic and meridians which form a part of the original data.

3. SATELLITE OBSERVATIONS

Real data processed in this paper represent pictures taken by a satellite operated by NOAA (The National Oceanic and Atmospheric Administration). As for satellites' orbits, all satellites fly on elliptical or circular orbits around the planet earth, the earth's centre being the focal or central point. This satellite belongs to the so-called polar orbiting satellites which ly in rather low altitudes, typically at 850 km height. Each full orbit around the earth takes 100 minutes, 14 orbits are achieved per day. These orbits are usually sun-synchronous, i.e. the satellite crosses a certain point always at the same time of the day. Polar orbiters provide meteorologists with excellent pictures of all parts of the earth including the polar regions. Due to their orbital characteristics they cannot monitor short-term variations. The main apparatus of NOAA satellites is a scanning radiometer marked as AVHRR (Advanced Very High Resolution Radiometer). This is a five-channel apparatus, and the five channels cover the following spectral ranges: Channel 1 covers 0.58-0.68μm which is the red region, channel 2 covers 0.725-1.1μm which is the close infrared radiation, and channels 3 to 5 cover 3.55-3.93μm, 10.3-11.3μm, and 11.5-12.5μm, respectively, and all of these regions represent heat radiation. The first two channels work with the reflected sun radiation only, the last two ones are fully heat radiation channels, and channel 3 is a mixed one.

Another type of satellites, represented by Meteosat satellites, should be mentioned as well. These satellites have a so called geostationary orbit, that means, that at a certain height above the equator the orbital period is exactly 24 hours and thus equals the orbital period of the earth itself, so that the satellite is always above the same point of the earth's surface. This orbit is found at 36000 km above the equator. Satellites in geostationary orbits always view the same portion of the globe (42% of the earth's surface are viewed by one satellite). They are especially suited to monitor quickly developing weather systems or diurnal variations in weather events. Due to their position above the equator geostationary satellites only give a very distorted view of the polar regions where they are of practically no use. With the exception of these high latitudes the existing system of geostationary meteorological satellites give a global view of our planet.

An observation of the Czech Republic in a selected time is presented in Fig. 2 and Fig. 3 for the first two channels of pictures taken by the NOAA satellite, representing images obtained for different frequency lengths. It is assumed that these images contain the same information about surface objects, and they differ in reflection of presence of dust particles in the air. Correlation between these two images can thus be used for detection of these dust particles, localization of sources of their immission and possible prediction of this type of air pollution.

4. IMAGE CORRELATION

Correlation of two images stored in two matrices assumes evaluation of the correlation coefficient for corresponding subimage regions in matrices $\mathbf{A}$ and $\mathbf{B}$ which can be obtained using the relation

$$r = \frac{\sum_m \sum_n (A(m,n) - \bar{A})(B(m,n) - \bar{B})}{\sqrt{(\sum_m \sum_n (A(m,n) - \bar{A})^2)(\sum_m \sum_n (B(m,n) - \bar{B})^2)}}$$

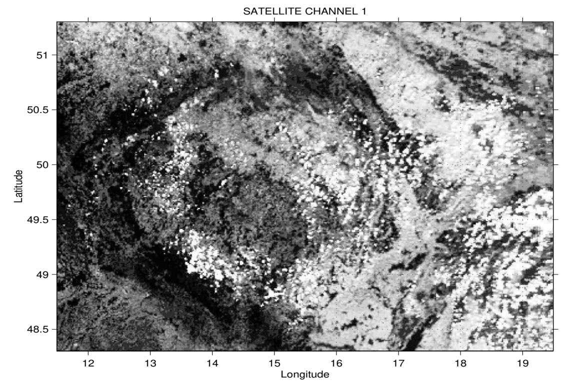

Figure 2. Channel 1 satellite image of the Czech Republic from the NOAA satellite observed on July 20th 1998 at 13:30

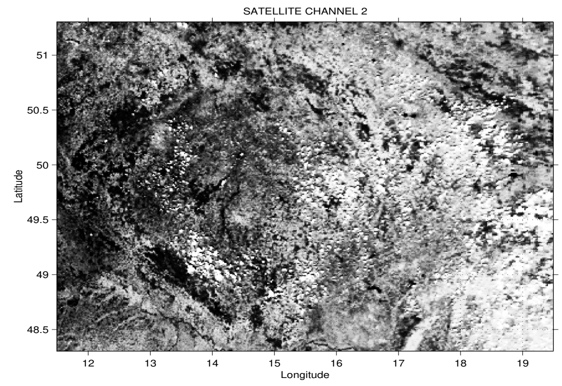

Figure 3. Channel 2 satellite image of the Czech Republic from the NOAA satellite observed on July 20th 1998 at 13:30

where $\bar{A}$ and $\bar{B}$ represent the mean values of the respective matrices **A** and **B**.

Results of this correlation for images covering area of 10 by 10 pixels corresponding to the region of 0.1 by 0.05 degrees in longitude and latitude respectively are presented in Fig. 4. As the low coefficient can be used as a measure for dust particles, Fig. 5 presents the distribution of this variable bellow a certain threshold level only.

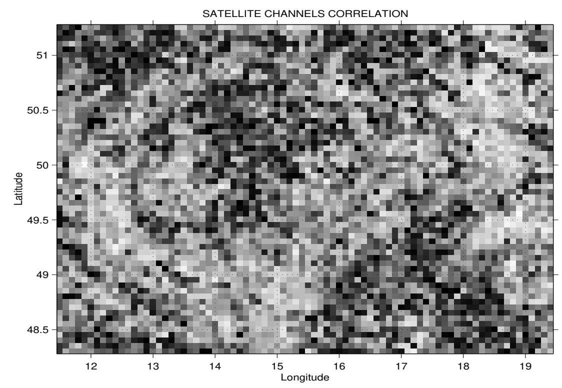

Figure 4. Correlation of channels 1 and 2 of satellite images of the Czech Republic from the NOAA satellite observed on July 20th 1998 at 13:30

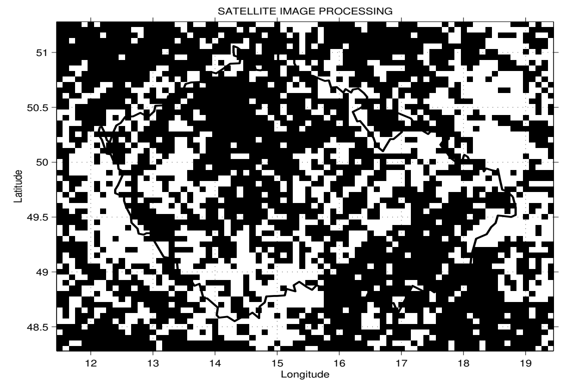

Figure 5. Thresholded correlation function of images of the Czech Republic from the NOAA satellite observed on July 20th 1998 at 13:30

5. SURFACE MEASUREMENT

In order to validate results of satellite image processing, it has been possible to compare resulting values with those obtained at 103 observation points precisely defined by their longitude and latitude at the same time. Fig. 6 presents these surface observations interpolated to the whole Czech Republic. In this case, the linear two dimensional interpolation has been used allowing for evaluation of a given variable at the given grid points. The result of this interpolation is also presented in Fig. 7 with values above a given thre-

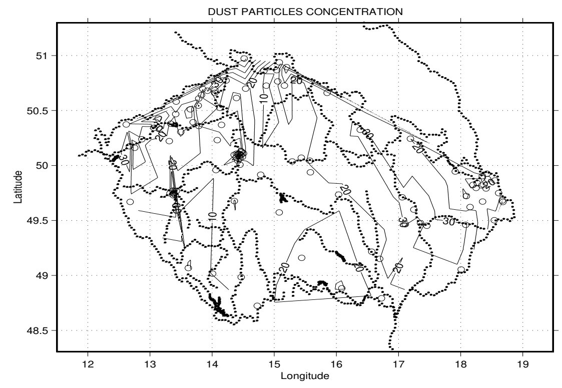

Figure 6. Surface observation of dust particles measured at 103 stations within the Czech Republic on July 20th 1998 at 13:30 and their linear two dimensional interpolation over the whole region

shold level allowing for comparison with values evaluated from satellite observation presented in Fig. 5.

As the result of this comparison strongly depends upon the method of image interpolation, it was possible to compare values at location of measuring stations obtained from surface measurements with those evaluated from satellite observations at these points. Results are presented in Fig. 8. Fig. 9 compares correlations evaluated for various

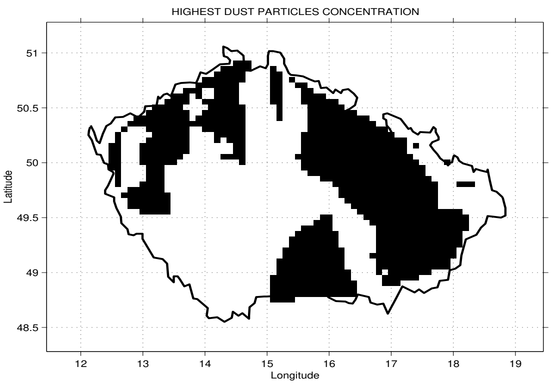

Figure 7. Surface observation of dust particles measured at 103 stations within the Czech Republic on July 20th 1998 at 13:30 and presentation of regions with the highest concentration

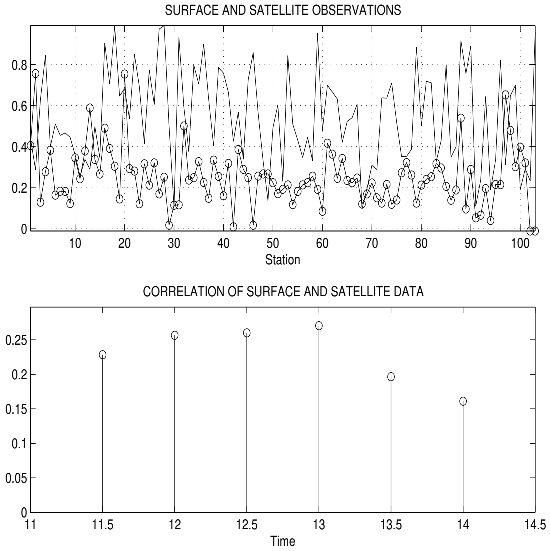

Figure 8. The comparison of normalized concentration obtained from surface measurements with those evaluated from satellite of dust particles at the top; higher values correspond with surface measurements and the lower ones with satellite data. The bottom part gives correlation of surface and satellite data for the date of July 20th, 1998, at 13:30

times of surface measurements close to satellite observations and for different sizes of correlated regions. The best correspondence has been found for the time 13:00 and region covering area of 4 by 4 pixels.

6. CONCLUSION

Results given in this paper are rather preliminary and will be used for further research of whether some valuable information on air pollution can or cannot be obtained from satellite observations. Correlation of the surface and satellite measurements gives very satisfactory results for some re-

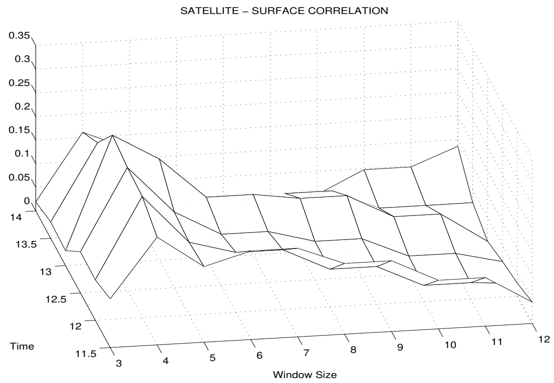

Figure 9. Correlation of satellite and surface data for all times on the day of July 20, 1998, for which the surface measurements are available

gions in which the concentration of dust particles in the air is measured, and it seems that we can state that the satellite images do indeed contain information on air pollution. More concrete statements on how this information can be used for evaluation of air pollution will be made after greater volumes of data are processed. Mathematical methods used for these studies will include further methods of image preprocessing, filtering, image enhancement, channels correlation and two dimensional interpolation using non-linear methods and wavelet functions.

7. ACKNOWLEDGEMENT

We would like to express our thanks for kind support of this project to Dr. K. Hlavatý, Dr. P. Hampl and Dr. J. Fiala from the Czech Hydrometeorological Institute who also kindly provided all signals and images used in this study.

8. REFERENCES

Hicklin, J. and A. Grace (1993). *SIMULINK*. The MathWorks, Inc.. Natick, Massachusetts 01760.

Chellapa, R. (1992). *Digital Image Processing.* IEEE Computer Society Press. Los Alamitos.

Chellapa, R. and A. A. Sawchuk (1985). *Digital Image Processing and Analysis: Volume 1: Digital Image Processing.* IEEE Computer Society Press. Silver Spring.

Klette, R. and P. Zamperoni (1994). *Handbook of Image Processing Operators.* John Wiley & Sons. New York.

Tukey, J. W. (1971). *Exploratory Data Analysis (preliminary ed.).* Addison-Wesley. Reading.

Van der Heijden, F. (1994). *Image Based Measurement Systems.* John Wiley & Sons. New York.

Watkins, Ch., A. Sadun and S. Marenka (1993). *Modern Image Processing: Warping, Morphing, and Classical Techniques.* Academic Press, Ltd.. London.