SIGNAL PROCESSING IN GEOGRAPHICAL INFORMATION SYSTEMS

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Abstract

Geographical information systems, related closely with satellite observations of the Earth surface, offer a wide range of applications. They allow to observe the Earth surface ecosystems, toxic contamination sources, air pollution concentrations together with other facts and variables all over the world, as well as to perform their precise localization. These observations using remote sensing methods are very important under stabilized conditions as well as during disasters like hurricanes, earthquakes etc., to detect abnormalities, to predict them and to provide notification of them using modern information technologies and the www service (see for example http://www.noaa.gov). The paper provides a summary of information sources related to dealing with the problems mentioned (see also http://www.mathworks.com/support/tech-notes/2100/2101.html) and the contribution of the Mapping Toolbox designed to evaluate, locate and visualize observations of the dust particles concentration over the Czech Republic territory. The main part of the contribution presents basic projection methods and their utilization in analysis of air pollution caused by dust particles concentration in various regions of the Czech Republic, separation of the desired information, and visualization of the results in the Matlab environment.

1 Introduction

The paper is devoted to selected problems of image analysis related to processing of satellite images [5, 2] allowing to observe air pollution caused by the dust particles concentration. Fig. 1 presents a result of data observation obtained by the NOAA (The National Oceanic and Atmospheric Administration) system. Other systems include MODIS (Moderate-Resolution Imaging Spectroradiometer) used for complex research [3] of the Earth forming a part of the so-called Earth Observing System (EOS) operated by National Aeronautics and Space Administration (NASA).

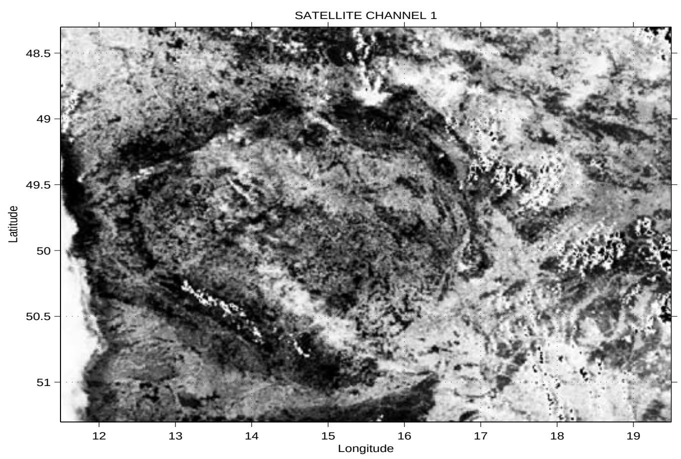

Figure 1: A satellite image of the Czech Republic from the NOAA Imaging Spectroradiometer

Results obtained by satellite observations can be verified by ground measuring stations located at about 100 places in the Czech Republic. The basic problem is to find precise coordinates of each image pixel of the satellite observation, in order to find the corresponding ground station defined by its longitude and latitude.

The basic problem of satellite image processing is to use the appropriate map projection, as all geospatial data must be flattened onto a display surface. Many map projections [1] have been developed during past centuries to transfer features from a sphere or spheroid to a plane. Projections including those to cylinders, cones, and planes form a basis of the MATLAB Mapping toolbox that can be efficiently used for this purpose.

2 Satellite Image Acquisition

The National Oceanic and Atmospheric Administration (NOAA) uses a set of satellite sensors for observation of the Earth surface. All these satellites fly on elliptical or circular orbits around the planet Earth, the Earth's centre being the focal or central point, and they belong to the so-called polar orbiting satellites which fly in rather low altitudes, typically at the 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 excellent pictures of all parts of the Earth including polar regions. Due to their orbital characteristics they cannot monitor short-term variations. The main apparatus of NOAA satellites is the scanning radiometer AVHRR (Advanced Very High Resolution Radiometer). This is a five-channel apparatus covering spectral ranges (1) 0.58-0.68μm, (2) 0.725-1.1μm, (3) 3.55-3.93μm, (4)10.3-11.3μm, (5) 11.5-12.5μm. More information concerning NOAA and other types of satellites is available in [4] and on the Internet.

A sample observation of the Czech Republic taken by the NOAA satellite at a selected time is presented in Fig. 1 for its first channel. Different channels observe the ground at different frequencies. It is assumed that images obtained contain the same information about surface objects, and they differ in reflection of presence of aerosol particles in the air. Correlation between these two images can thus be used for detection of aerosol particles, localization of sources of their immission and possible prediction of this type of air pollution.

Fig. 2 presents a basic program allowing to import binary NOAA data into the MATLAB environment. For the image obtained from the satellite observation, its upper left corner is defined by its longitude and latitude. In the simplified version it is possible to define distance between pixels for both coordinates as a constant. More accurate approach based upon the correct map projection is described for example in [1].

```
--------------------------------------------------------------------------------
      clear all
%%% Satellite Image Directory definition
      CH1='190799_1533UTC\ch1low.dat';
%%% Opening of the binary file
      [FID1,message]=fopen(CH1,'r','n');
%%% Input of the image matrix of the given size
      Rows=600; Cols=800;
      [A1,COUNT]=fread(FID1,[Cols, Rows],'int8');
%%% Transposition and normalization of image matrix
      A1=A1'; A1=(A1+128)/256;
%%% Projection definition
      I0=[48.305 11.5]; % Coordinates of the upper left corner
      StepLat=1/200; StepLon=1/100; % Steps between pixels
        Latitude=I0(1)+[0:Rows-1]*StepLat;
        Longitude=I0(2)+[0:Cols-1]*StepLon;
%%% Satellite image output
      imshow(histeq(A1),'XData',Longitude,'YData',Latitude)
        set(gca,'YDir','normal'); grid on;
        axis normal ij; set(gca,'visible','on')
        title('SATELLITE CHANNEL 1'); xlabel('Longitude'); ylabel('Latitude')
--------------------------------------------------------------------------------
```

Figure 2: Fundamental commands of the NOAA satellite image transfer to the MATLAB environment

The Moderate-Resolution Imaging Spectroradiometer (MODIS) represents another sensor that gathers information and properties of the land, the oceans and the atmosphere. At present two MODIS instruments [3] are on the Earth's orbit on board of two platforms, Terra and Aqua (officially known as EOS AM-1 and EOS PM-1, respectively). These two satellites are on a sun synchronous near-polar orbit with the period of 99 minutes, in the altitude of 705 km. The MODIS instrument is intended to measure reflected sun radiation using highly sensitive detectors in 36 spectral bands that range in wavelength from 0.4 μm to 14.4 μm with resolution from 250 m to 1 km. This provides possibilities of observation of terrestrial, atmospheric, and ocean phenomenology with a very high resolution.

3 Satellite Data Processing

Remote satellite images providing observations of the surface of the Earth transferred to ground observations must be further processed to

- reduce the additive noise present in images
- enhance images and to extract desired information

These problems imply the use of various mathematical methods of signal and image de-noising, statistical methods and methods of image filtering, segmentation and classification. Geographical information systems represent a very efficient tool to achieve these goals, as well.

Digital filtering techniques [7] 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.

To extract information concerning the difference between two channels providing two different images, correlation between these two images can be evaluated. Results of this correlation for images covering the 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. 3.

Application of more sophisticated FIR filters makes it possible to evaluate values of a convolution kernel in a more precise way to reject selected image spectral components. Image

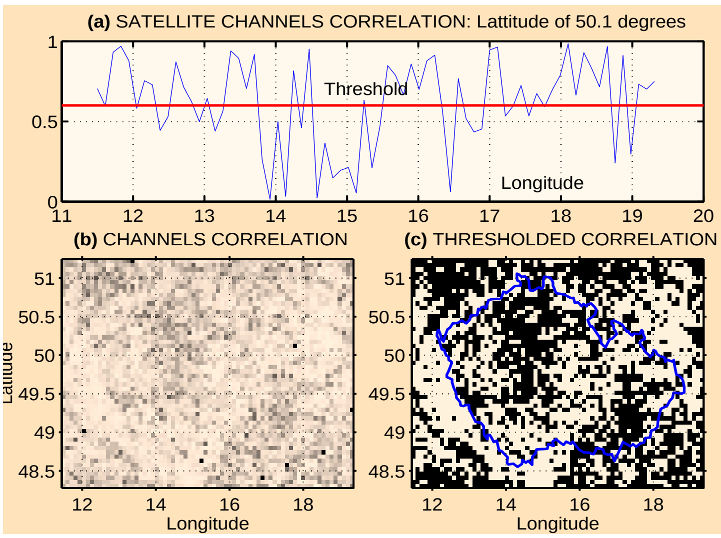

Figure 3: Thresholded correlation function of images of the Czech Republic from the NOAA satellite

de-noising has been studied also in connection with image decomposition and reconstruction by wavelet transforms [6]. This method provides a very efficient tool for image de-noising as well. Median filtering standing for a non-linear method stand for another very efficient tool for the removal of singularities in an observed sequence or image. This method has been applied to remove specific elements of satellite images.

Further research devoted to comparison of results obtained from satellite observations with those obtained from ground measuring stations proved correlation between these two kinds of air pollution estimations.

4 Conclusion

Remote satellite sensing forms a very special research area closely related to geographical information systems, allowing to obtain desired information through mathematical analysis of observed images transferred to the Earth. Results of such an analysis can be useful for detection both of environmental changes and for other general problems of satellite image processing.

Acknowledgments

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