A VISUALIZATION AND TRANSFORMATION TECHNIQUE FOR THE METEOSAT IMAGES

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Abstract: The need for a suitable visualization of infrared Meteosat images appeared during the period of constantly growing usage of remote sensing data in weather forecasting. In the main the problem is very simple, but when considering only the so-called SDUS (Secondary Data Users Station) data availability, a quite interesting image processing problem occurs. In this paper the method of image generation is described. At the beginning the geometry of Meteosat image is briefly presented. Then the removing of artifacts and the interpolation of gaps from the surrounding pixels are showed. The resulting image can be easily improved by adding afterwards the state and continent borders.

1. INTRODUCTION

Images of the geostationary satellite Meteosat have a lower geometrical resolution then those of the polar meteorogical satellites, such as NOAA (*National Oceanic and Atmospheric Administration*). The main advantage of geostationary satellites is their temporal resolution, which allows to create the space-time model of the whole atmosphere. As Meteosat 7 has a temporal resolution of half an hour, the image of the whole globe is acquired 48 times a day. On the other hand Meteosat has increasing geometrical distortion with higher latitudes. A quantitative comparison of these images with other data sources needs a geometrical transformation into cartographic projection. In remote sensing this process is usually realized by polynomial transformation. Such an approach is not suitable in our case, since the exact image geometry is well known and each pixel can be georeferenced without unnecessary errors. This problem is described in section 1. Section 2 is focused on image visualization it self. The Meteosat SDUS data have already been improved and the reference borders of states and continent have been placed as well. The present paper is first of all about this algorithm, but the knowledge of the geometry basics can also be useful by MSG (*Meteosat Second Generation*) image analyzes [Setvák, 2004]. The input data used for the work presented here are Meteosat 7 SDUS binary 8 bit images covering practically whole Europe. These images could be retrieved free of charge by WEFAX stations (*Wheather Fascimile*) as an analogue transmission by Eumetsat. Geometrical projections, corrections, cartographical projections are basic issues of remote sensing at all. It is the very basic prerequisit preceding any farther data analyses. Cartographical projection of geostationary satellites is well known and published even as part of public software packages: Matplotlib Basemap Toolkit [Whitaker, 2008], Proj4 project [Evenden1, 2003]. Self implementation for MSG images could be found for example here [Bruno

Combal, 2009]. However, it is not common to use image rectification algorithm with such precision, there is used ellipsoid as a reference, and such high performance, which allows building online system easily. There is no transformation by complicated mathematical algorithm, just reading and simple sampling of images and binary look-up-tables.

2. GEOMETRIC TRANSFORMATION

METEOSAT has a special solution for image formation. The principle is based on the so called mechanical scanner, including only one sensitized chip, the whole globe being scanned by satellite rotation and periodical movement of the mirror. The principle of georeferencing this image is based on assigning to each pixel the geographic coordinates ϕ and λ [EUMETSAT, 2000], [EUMETSAT, 2001]. These coordinates are then transformed into any suitable cartographic projection. The new image coordinates are then stored into a lookup table, where the new position in the new image of each pixel in the original image is available. The transformation itself does not need any resampling or function evaluation. In Fig. 1 the image geometry can be seen.

The METEOSAT satellite is placed on a geostationary orbit of 42164 km height. Its position corresponds precisely to the zero Greenwich meridian. The output is a multispectral image of 2500 by 2500 pixels covering the whole globe. The spin of 100 rotations per minute provides an acquisition of lines in the north-south vertical direction. A very high sampling frequency (83.3 KHz, 2500 pixels within 18°) allows pixel scanning in each line. An ellipsoid approximation of the Earth is used as solution. Thus the geographical latitude φ has to be recomputed into geocentric latitude ψ.

$$\tan \psi = \frac{(1-e)^2}{\tan \varphi} \qquad (1)$$

where e is the ellipsoid oblateness (1/298.275). By using geocentric latitude the

local radius can be easily computed:

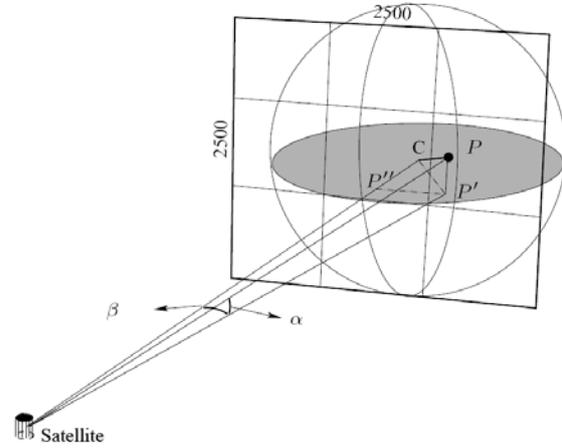$$R = \frac{a.b}{\sqrt{a^2 \cos^2 \psi + b^2 \sin^2 \psi}} \qquad (2)$$

Fig. 1: The geometry of METEOSAT image formation. For pixel georeferencing it is necessary to solve only triangles *Satellite, P, P′*, and *Satellite, P′, P″* containing angles α and β.

a, b states for semimajor and semiminor ellipsoid axes. From local radius and the values of ψ and λ the points position is determined in Cartesian coordinates, *x, y, z*. This position is then used for deriving three variables, which are directly used by image transformation. The first one is a value that indicates if the position on the surface is visible from satellite:

$$Vis = (H_{sat} - x) - y^2 - \frac{z^2 \cdot a^2}{b^2} \qquad (3)$$

H_{sat} is the satellite height from the Earth surface. Since METEOSAT is situated exactly above the zero Greenwich meridian, our angles of our interest can be expressed by:

$$\tan \alpha = \frac{y}{H_{sat} - x}$$

$$\tan \beta = \frac{z}{\sqrt{y^2 + (H_{sat} - x)^2}} \qquad (4)$$

These angular coordinates are then rescaled to pixel-line position in nominal

image by using the nominal one-pixel angular values. This operation is followed by the transformation of geographical coordinates into the cartographic projection. Lambert conform projection described by a set of equations was used [RSI Research Systems, 2004]:

$$a = \log(\cos\varphi_1) - \log(\cos\varphi_2)$$

$$b = \log\left[\tan\left(\frac{\pi}{4} - \frac{\varphi_2}{2}\right)\right] - \log\left[\tan\left(\frac{\pi}{4} - \frac{\varphi_1}{2}\right)\right]$$

$$n = \frac{a}{b}$$

$$c = \frac{\tan\left(\dfrac{\pi}{4} - \dfrac{\varphi}{2}\right)}{\tan\left(\dfrac{\pi}{4} - \dfrac{\varphi_1}{2}\right)} \qquad (5)$$

$$d = c^n$$

$$m = d \cdot R \cdot \left[\cos\left(\frac{\varphi_1}{n}\right)\right]$$

$$x = -m \cdot \cos(n \cdot \lambda) \qquad (6)$$
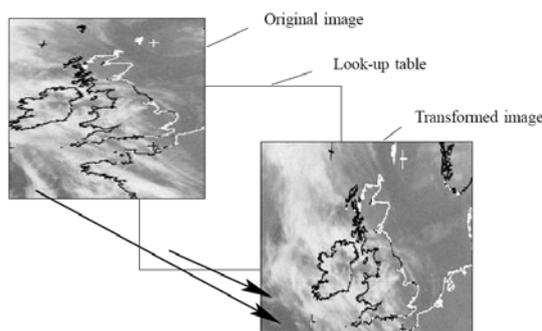$$y = m \cdot \sin(n \cdot \lambda) \qquad (7)$$

Fig. 2: The scheme of the data processing. Look-up table contains pixel-line coordinates for the transformation of each pixel in original image.

where φ_1, φ_2 are latitudes of the parallels of zero distortion, or the parallels of

intersection in the case of geometrically defined projection. φ, λ are the values of geographical latitude and longitude. With this algorithm the so called "look-up table" is obtained. It is the binary file containing the coordinates in pixels and lines for the new transformed image. The transformation is then realized by a very simple step (see fig. 2): data are read from the original image and "look-up table", and pixel by pixel are written into a new file.

3. IMAGE ENHANCEMENT AND VISUALIZATION

The SDUS METEOSAT data are not primary images, but already geometrically and radiometrically preprocessed images with continent borders added and small crosses suited for geographical network deriving. However, after the geometrical transformation these artifacts cause deterioration of the image information. In order to improve first of all the data visualization, the artifacts had to be removed. More conventional methods have been applied, but none suits for this purpose. Then a complex and special algorithm was developed. First the artifacts are masked out by a manually derived mask. The pixels have a quite random distribution of the values to automate this step. The mask is consequently used for replacing artifacts with interpolated values from the surrounding. As interpolation approach a variant of the inverse distance weighted algorithm was applied. The square of the sum of coordinates (not the mere distance) was used as weight. The good feature of this approach is a small propagation of the values to long distances causing the interpolated parts to have similar distribution and appearance as "original" data. In Fig. 3 the idea of

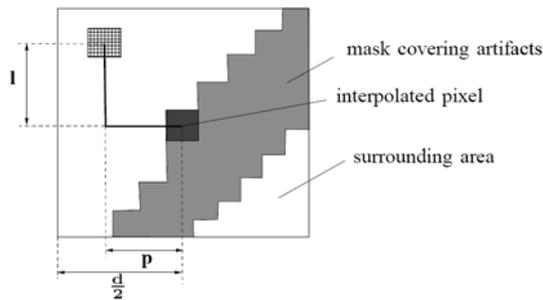this interpolation is outlined and described.

Fig. 3: The interpolation of pixel value from surroundings in specified square is used. The value is weighted average of surrounding area. Interpolation is applied only within the mask.

The computation of pixel value can be easily described by the following formulas: distance $D = l + p$ (not the real distance computed from triangle), which is then subtracted from the highest possible value $D' = 2 \cdot \dfrac{d}{2} - D$ and the weight $W = (D')^2$ is applied in weighted average:

$$V_p = \frac{\Sigma_{i=1}^{N} V_i \cdot W_i}{N} \qquad (8)$$

where V_p is the value of interpolated pixel, V_i, W_i are the values and weights of the surrounding area pixels beyond the mask, and N is the number of these pixels. In Fig. 4 the result of "removing artifacts" can be seen. This image can be then improved by pasting the new borders of continent and countries. Brightness and histogram enhancement can be applied as well.

As the result of this work can be considered the projected and enhanced METEOSAT image easily usable for presenting on internet, or even includable into some synthetic GIS analyzes. The small crop of the image can be seen in Fig. 4.
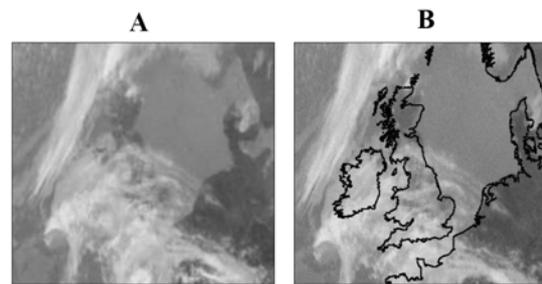

Fig. 4: Image enhancement by interpolation of artifacts - **A** and pasting of new borders - **B** is depicted. Northern part of the METEOSAT imaged area can be seen. Small discrepancies are caused by the already strong distortion in high latitude (imperfect matching of the image and borders, not ideal image interpolation). Nevertheless the image-derived information is easier understandable and interpretable then that from the original data.

High temporal resolution allows generation of the animation, where the dynamics of atmospheric events can be studied. The entire processing algorithm was implemented in C++ programming language and was running in operational mode with high performance. It is still applicable for new METEOSAT 7 coverige.

4. CONCLUSION

Deeper knowledge of the imaging geometry and the possibility of accurate transformation of Meteosat data into any cartographic projection helps not only in image visualization, but also offers the ability to include this data into complex geographical analyses. Nevertheless, a good visualization of the remote sensing information can provide valuable qualitative information for weather forecasting and is easily understandable by end users.

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