ERROR CORRECTION FOR NOAA AVHRR DATA USING REFERENCE DATA

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ABSTRACT: This paper describes a method that corrects the missing lines and the random noise pixels in NOAA images. NOAA images with the same orbit are received at various stations and overlap each other. To correct the errors in an original image, the other images, which overlap the original one, are referred. After specifying the overlapping area, missing lines are detected by checking time codes, and they are corrected by replacing with the corresponding lines from the reference data. Random noise pixels are recognized based on PN codes and the differences between their values and those of their neighbors. They are removed by assigning the new values from the reference data or their neighbors. This method was used to correct the NOAA images receiving at Tokyo by referring to the images from Bangkok and Ulaanbaatar. After correction, all errors were removed. The correcting time was less than 35 seconds per image.

1. INTRODUCTION

In recent years, AVHRR (Advanced Very High Resolution Radiometer) on the NOAA (National Oceanic and Atmospheric Administration) series of satellites has been an ideal observatory which has been providing very useful information about ecosystems, climate, weather, water, land cover monitoring at global and continental scales from all over the world (Mather, 2004a). In order to use NOAA data effectively, error correction method for NOAA image is necessary.

The missing lines and noise pixels in NOAA image are considered as errors. In the conventional correction method, missing lines are detected by checking time code – the time when the sensor starts to scan a line. A blank line is inserted into the image to correct a missing line (Mather, 2004a)(Yamauchi, 2000). For this reason, all missing data is lost. In this paper, a method to restore that missing data is proposed. Noise pixels are recognized by comparing their values with their neighbors' (Mather, 2004a)(Yamauchi, 2000). In the usual correction method, noise pixels are corrected based on the values of their neighbors (Mather, 2004a)(Yamauchi, 2000). Therefore, a noise pixel is probably assigned a wrong value. This paper also proposes a method that assigns the right values for the noise pixels.

This study uses the NOAA AVHRR data received at Tokyo (Japan), Bangkok (Thailand) and Ulaanbaatar (Mongolia).

2. HRPT FORMAT

NOAA data is received in HRPT (High Resolution Picture Transmission) format. This format includes PN code, time code and AVHRR data.

2.1 PN code

PN code is a pseudo-random sequence provided by a feedback shift register. There are three PN codes in HRPT format. When the register generates the polynomial $X^6+X^5+X^2+X+1$, the result is the first PN code. This PN code is used to specify the beginning data of a line. The second and the third PN codes are created when the register generates the polynomial $X^{10}+X^5+X^2+X+1$. The second PN code includes 1270 bits and the third one includes 1000 bits. Hence, the total length of the second and the third PN code is 2330 bits. These bits have pre-fixed values for each line of NOAA image. As a result, the second and the third PN codes can be used to detect the error lines. The error rate of each line is the ratio of PN code to 2330. A line will contain error when its error rate is greater than 0.

2.2 Time code

AVHRR sensor scans 6 lines per second. Time code is the time when the sensor starts to scan a line. It is recorded and it includes month, day, hour, minute, second and millisecond. The unit of time code is millisecond.

2.3 AVHRR data

The AVHRR data that sensor obtains from the Earth is stored in the lines of image. Data is coded in 10 bits. A line includes five data channels. These channels cover the following wavebands: channel 1 (green and red regions of the visible spectrum, 0.58-0.68µm), channel 2 (near-infrared, 0.725-1.1µm), channel 3 (thermal, 3.55-3.93µm), channel 4 (thermal, 10.3-11.3µm), and channel 5 (thermal, 11.5-12.5µm) (Mather, 2004b).

3. MISSING LINES AND NOISE PIXELS IN NOAA IMAGE

Errors in NOAA image can be due to the errors in the scanning or sampling equipment, in the transmission or recording of data, or in the reproduction of the media containing the data (Mather, 2004a). Missing lines and noise pixels appear at the beginning and ending parts of NOAA image. The cause is the NOAA data receiving system (Yamauchi, 2000).

3.1 Missing lines

Missing lines are normally seen as horizontal black or white lines in the image (Mather, 2004a). According to the conventional method, a missing line is detected by checking whether its time code is right or not. If the time code of a line is wrong, it is considered as a missing line (Yamauchi, 2000). Blank lines are used to replace the missing lines (Mather, 2004a)(Yamauchi, 2000). As a result, all missing data has gone.

3.2 Noise pixels

There are two kinds of noise in NOAA image: random noise and burst noise. Only random noise is considered in this study. The differences between the value of a random noise pixel and the values of its neighbors are approximately 32, 64, 128, 256 or 512 (Yamauchi, 2000). This characteristic is used to detect the random noise pixels in NOAA image. In order to correct a noise pixel, the conventional method replaces its value with a suitable value from its neighbors (Yamauchi, 2000). Thus, a noise pixel may be assigned a wrong value.

4. ERROR CORRECTION

4.1 Correction method

While sensor scans data, the time code for each line is recorded. When two NOAA images with the same orbit are compared, if the time code of a line in an image is equal to the time code of a line in another one, two images will overlap. In this case, the data in the overlapping area of one image can be used as reference data to correct the errors in the corresponding area of another one (Van, 2006). Based on this idea, an error correction method is proposed as is shown in Figure 1. With this method, the missing data of the missing lines can be restored. The noise pixels are also be assigned the right values from the reference data.

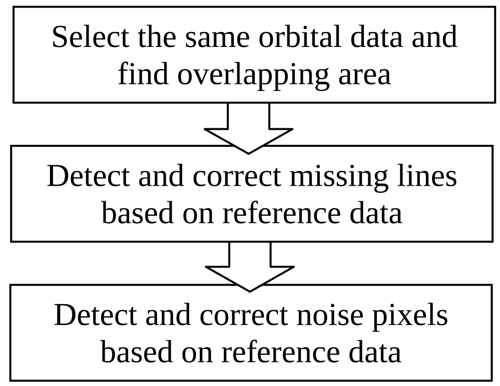

Figure 1. Error correction method

This study uses the same orbital data that is received at Tokyo, Bangkok and Ulaanbaatar.

4.2 Overlapping area

The time to scan the data for a whole NOAA image is about 14 minutes (NOAA KLM user guide, 1998). AVHRR data is then saved as a file whose name includes the time when the sensor started to scan the first line. For example, the NOAA image AH14012599191054 was scanned at the time 19:10:54 on January, 25th, 1999. Therefore, two images with the same orbital data will be overlapped if the difference in the time extracting from their names is less than 14 minutes.

To find out the overlapping area, the time codes of the lines in two images are compared. Two lines in two images will contain the same data if they have the same time code.

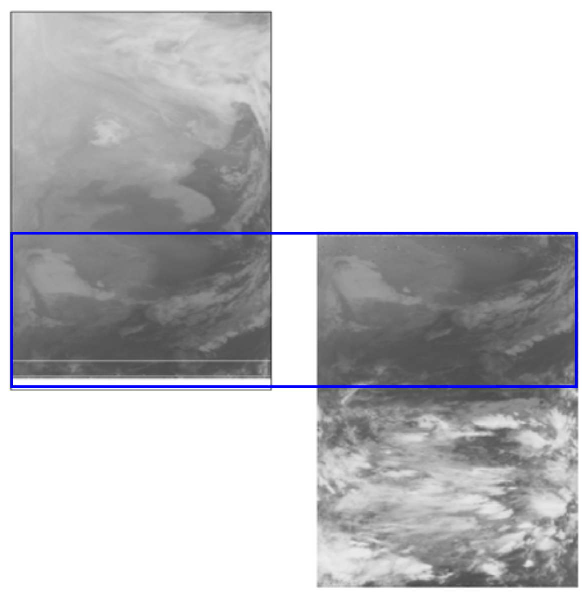

Figure 2. Overlapping area

Figure 2 shows an example of the overlapping area between image AH14012599191054 from Tokyo and image AH14012599191840 from Bangkok. The time difference between them is 7 minutes and 46 seconds. The total number of lines in the image from Tokyo is 4898 and in the one from Bangkok is 4753. The overlapping lines in the image from Tokyo are from 2770 to 4897 and in the image from Bangkok are from 0 to 2127. The total number of overlapping lines is 2128.

4.3 Missing lines correction

4.3.1 Missing lines detection

Missing lines are detected by checking time code. Because the errors appear at the beginning and ending parts of the image (Yamauchi, 2000), the time codes of the lines in the middle of NOAA image are correct. Moreover, sensor scans 6 lines per second; consequently, based on the time code of a line at the center of the image, the correct time codes for the other lines are inferred. If a time code of a line is wrong, this line will be considered as a missing line. Figure 3 shows an example of missing lines detection.

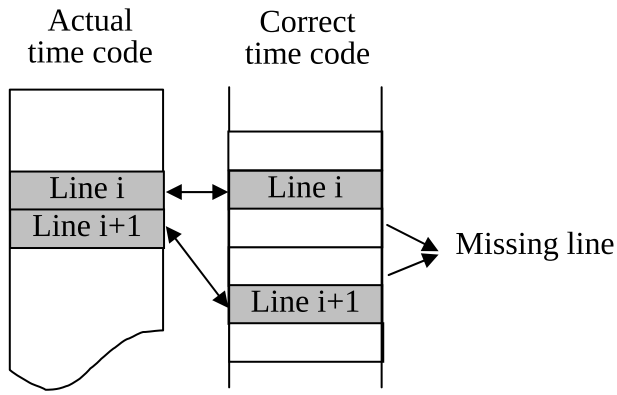

Figure 3. Missing lines detection

4.3.2 Missing lines correction

When a missing line is detected, it will be assigned a right time code. In order to restore the missing data, a reference line in the reference data that has the same time code with the one missing is used. If this reference line is not a missing line, the reference data will be inserted into the missing line. Otherwise, the missing line is replaced with a blank line.

4.3.3 Missing lines correction steps

Figure 4 is the flow chart of the missing lines correction method. When the reference line is not a missing line, the missing data will be restored. Therefore, the reference data will affect to the quality of the corrected image. In order to have good result, to select good reference data is important.

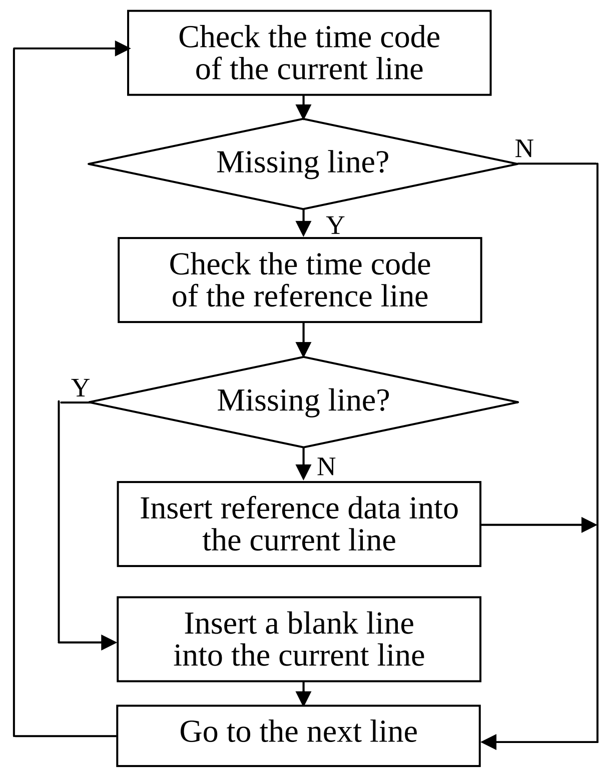

Figure 4. Missing lines correction

4.4 Noise pixels correction

4.4.1 Noise pixel detection

Noise pixels appear in the lines whose error rates are different from 0. A random noise pixel is detected by comparing its value with its neighbors'. (Yamauchi, 2000) has shown that the differences of a noise pixel and its 8 neighbors (or 5 neighbors if the noise pixel is in the boundary of the image) are about 32, 64, 128, 256 or 512. Thus, it is easy to detect the random noise pixels in NOAA image.

4.4.2 Noise pixel correction

When a noise pixel is detected, a reference pixel in the reference data is used to correct it. The reference pixel belongs to the reference line which has the same time code as the one contains the noise pixel. The positions of the noise pixel and its reference one in the corresponding lines are also the same. If the error rate of the reference line is 0, it will be used to replace the line containing the noise pixel in the original image. Otherwise, when the reference line contains error and the reference pixel is not a noise, its value will be used to correct the noise pixel. In the rest case, when the reference pixel is also a noise, the noise pixel will be assigned the value from one of its neighbors.

4.4.3 Noise pixel correction steps

Figure 5 shows the flow chart of the noise pixels correction method. With this method, when the reference pixel is not a noise, the noise pixel will be assigned the right value instead of its neighbors'. This replacement makes sure that the noise pixel will receive the right value.

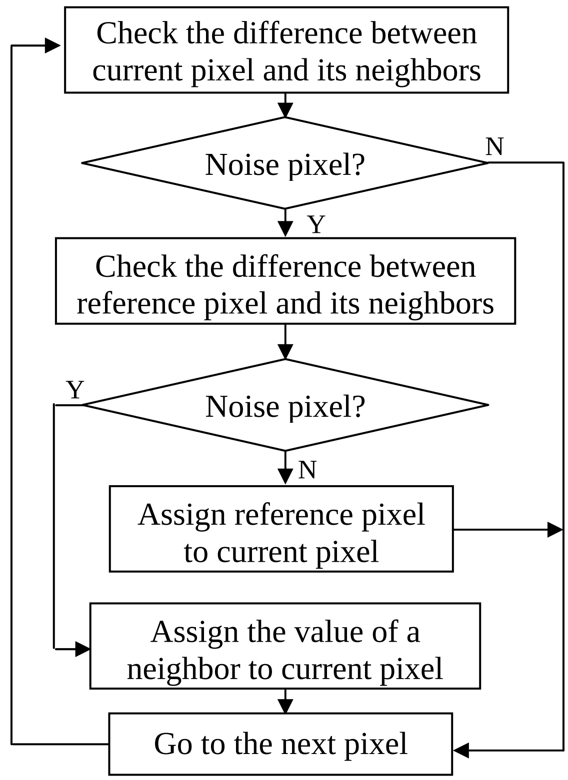

Figure 5. Noise pixels correction

5. RESULT

The result of the error correction is shown in Figure 6. This is the data of channel 5. In the Figure 6, the NOAA image from Tokyo (AH14082598064017) is corrected by using the reference data from Bangkok (AH14082598063414) and Ulaanbaatar (AH14082598064518). There are missing lines and noise pixels at the beginning and ending parts of the image from Tokyo. The beginning part of this image overlaps the image from Bangkok. Therefore, the errors at the beginning part of the image from Tokyo are corrected by using the reference data in the image from Bangkok. The ending part of the image from Tokyo also overlaps the image from Ulaanbaatar and the errors in this part are removed by using the reference data in the image from Ulaanbaatar. After correction, all missing lines and noise pixels disappeared. The processing time is 34 seconds.

On the Sun Ultra 45 Workstation with 1.6 GHz Sun UltraSPARC IIIi processor and 2GB RAM, the average processing time is approximately 35 seconds per image. This is an acceptable time for error correction.

6. CONCLUSION

A method to correct missing lines and random noise pixels in NOAA image is proposed. This method corrects the errors by using the reference data that overlaps the original data. Therefore, the missing data in the missing lines can be restored. The random noise pixels are also assigned the right values.

With this method, a random noise pixel will only be detected correctly when it is surrounded by the right pixels. Hence, it is necessary to study the noise pixels which are surrounded by some other noise pixels. In addition, other numbers of the neighbors considering in noise pixel detection should be verified because they may affect to the resulting image. It also requires studying burse noise besides random noise to get better result. And, because the quality of corrected images is affected by the reference images, a method to select the best reference images is essential as well.

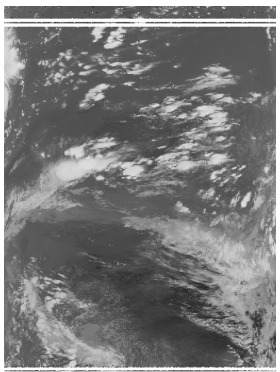

Image from Tokyo
(AH1408259806401

Image from Bangkok
(AH14082598063414

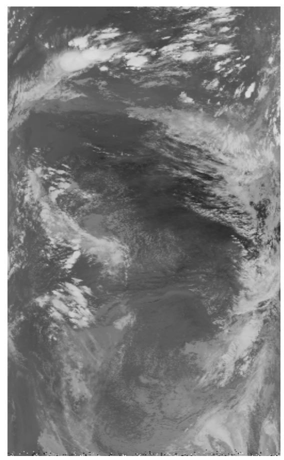

Image from Ulaanbaatar
(AH14082598064518)

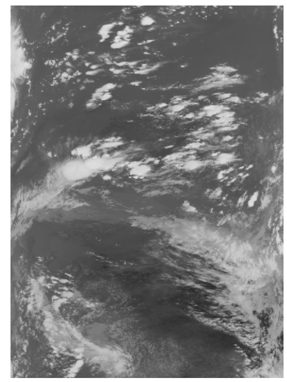

Image from Tokyo
after correction

Figure 6. Image from Tokyo is corrected by using reference image from Bangkok and Ulaanbaatar

7. REFERENCES

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