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Digital Image Processing - A Remote Sensing Perspective

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Abstract:
Digital image processing deals with manipulation of digital images through a digital computer. It is a subfield of signals and systems, but focuses particularly on images. DIP focuses on developing a computer system that is able to perform processing on an image. The input of that system is a digital image and the system processes that image using efficient algorithms, and gives an image as an output. This paper discusses the various image processing techniques and remote sensing applications.

Keywords*: digital, image, processing, remote sensing, algorithm and data.*

1. Introduction

Digital Image Processing (DIP) involves processing – or manipulation – of images – where images are represented by two-dimensional arrays – called digital values or digital numbers (DN values) – using a digital computer.
It is akin to photo processing or picture processing or satellite image processing. It is an interdisciplinary area where computer scientists work with domain experts in the areas of agriculture, forestry, geology, meteorology, medicine etc.

2. Digital Images

The reproduction of an image requires the knowledge of display devices, and color that it produces. The processing of an image comes into play between image capture and display.
The typical processing includes translating raw values into colorimetric values that can be used by anyone in the world, storing and transmitting data between devices so they can display the same image accurately. This is even despite different hardware and calibration of input and output devices. This will allow for the image data to be interpreted appropriately.
Images – may be binary in nature – where pixels – picture elements – which are two-dimensional array elements – are binary – either 0s or 1s – or representing gray values – whose range may vary from 128 (7-bit), 256 (8-bit),1024 (10-bit) to 2048 and beyond.
The image of Lena is used by many in industry and academia to test image coding methods. We can see many reproductions of Lena. The images vary tremendously because the original data was not captured accurately and there is no conversion to a standard display format. The following set of 8 pictures represent– in gray levels 256, 128, 64, 32, 16, 8, 4, and 2, respectively.

Figure 1

Depending on the dynamic range representing the gray values – images can be classified as gray scale images or color (multispectral) images. Depending on which part(s) of electro-magnetic spectrum they represent - spectral bands in the visible part of the spectrum (red, green or blue) – or in the IR, thermal or microwave parts of the spectrum. The following figure shows images taken in different parts of the electro-magnetic spectrum.

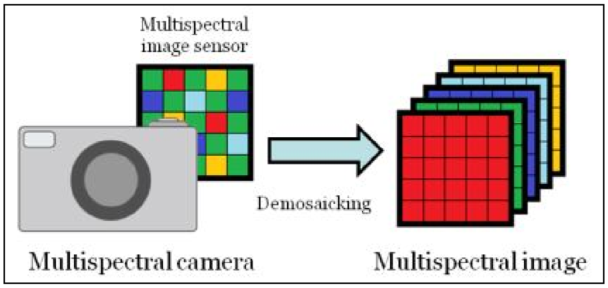

Figure 2

3. Digital Image Processing Techniques

Processing Techniques are broadly categorized into – spatial and frequency domain operations. In spatial operations a moving filter (or kernel) 3x3, 5x5 or 7x7 is moved across the width and height of the image to convolve with the original digital values. Image operations like average, medium, weighted mean etc come under this category. Frequency domain operations like Fast Fourier Transformation (FFT) where images are treated as signal in two-dimensions.

Many image processing and analysis techniques have been developed to aid the interpretation of remote sensing images and to extract as much information as possible from the images. The choice of specific techniques or algorithms to use depends on the goals of each individual project.

4. Pre-Processing of Satellite Imagery

Prior to data analysis, initial processing on the raw data is usually carried out to correct for any distortion (like geometry or radiometry) due to the characteristics of the imaging system and imaging conditions. Depending on the user's requirement, some standard correction procedures may be carried out by the ground station operators before the data is delivered to the end-user. These procedures include radiometric correction to correct for uneven sensor response over the whole image and geometric correction (also known as image re-alignment) to correct for geometric distortion due to Earth's rotation and other imaging conditions (such as oblique viewing). The image may also be transformed to conform to a specific map projection system. Furthermore, if accurate geographical location of an area on the image needs to be known, ground control points (GCP's) are used to register the image to a precise map (geo-referencing).

5. Image Enhancement

In order to aid visual interpretation, visual appearance of the objects in the image can be improved by image enhancement techniques such as grey level stretching to improve the contrast and spatial filtering for enhancing the edges. An example of an enhancement procedure is shown here.

Note that the minimum digital number for each band is not zero. Each histogram is shifted to the right by a certain amount. This shift is due to the atmospheric scattering component adding to the actual radiation reflected from the ground. The shift is particular large for the XS1 band compared to the other two bands due to the higher contribution from Rayleigh scattering for the shorter wavelength.

In the above unenhanced image, a bluish tint can be seen all-over the image, producing a hazy appearance. This hazy appearance is due to scattering of sunlight by atmosphere into the field of view of the sensor. This effect also degrades the contrast between different land covers.

It is useful to examine the image Histograms before performing any image enhancement. The x-axis of the histogram is the range of the available digital numbers, i.e. 0 to 255. The y-axis is the number of pixels in the image having a given digital number. The histograms of the three bands of this image are shown in the following figures.

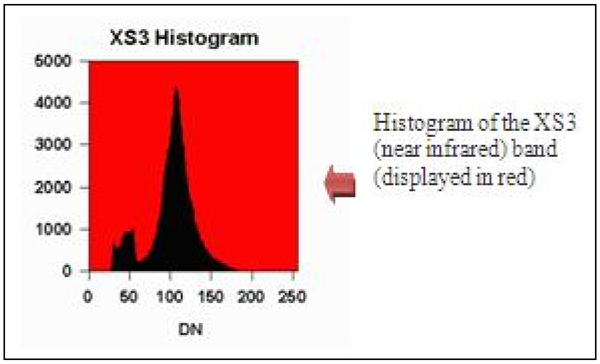

Figure 3

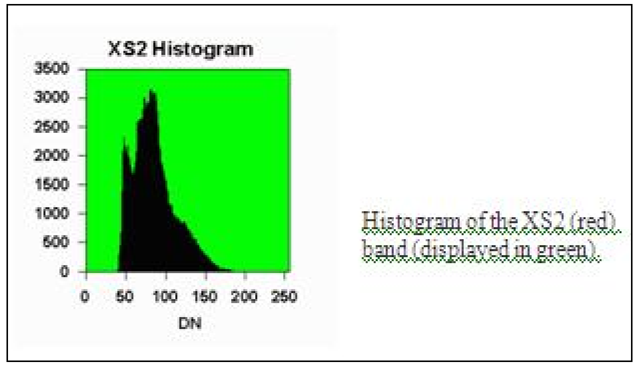

Figure 4

The figure gives the different steps involved in image processing

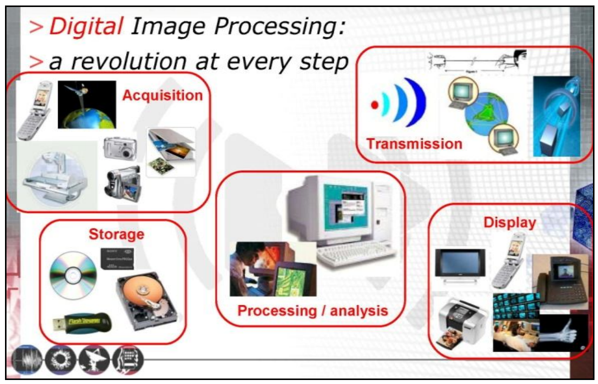

Figure 5

Image acquisition is the first process shown in Fig. and it could be as simple as being given an image that is already in digital form. Generally, the image acquisition stage involves reprocessing, such as scaling. Image enhancement is to bring out detail that is obscured, or simply to highlight certain features of interest in an image. By increasing the contrast, one can make the image look better .It is a very subjective area of image processing. Image restoration is an area that also deals with improving the appearance of an image, based on mathematical or probabilistic models of image degradation.
Representation and description almost always follow the output of a segmentation stage, which usually is raw pixel data, constituting either the boundary of a region (i.e., the set of pixels separating one image region from another) or all the points in the region itself. In either case, converting the data to a form suitable for computer processing is necessary.
The first decision that must be made is whether the data should be represented as a boundary or as a complete region. Description, also called feature selection, deals with extracting attributes that result in some quantitative information of interest or are basic for differentiating one class of objects from another. Recognition is the process that assigns a label (e.g., "vehicle") to an object based on its descriptors.
Remote sensing is a technology used for obtaining information about a target through the analysis of data acquired from the target at a distance. It is composed of three parts, the targets - objects or phenomena in an area; the data acquisition - through certain instruments; and the data analysis - again by some devices. This definition is so broad that the vision system of human eyes, sonar sounding of the sea floor, ultrasound and x-rays used in medical sciences, laser probing of atmospheric particles, are all included. The target can be as big as the earth, the moon and other planets, or as small as biological cells that can only be seen through microscopes.
Remote sensing data acquisition can be conducted on such platforms as aircraft, satellites, balloons, rockets, space shuttles, etc. Inside or on-board these platforms, we use sensors to collect data. Sensors include aerial photographic cameras and non-photographic instruments, such as radiometers, electro-optical scanners, radar systems, etc.

6. Use of Remote Sensing

A fundamental use of remote sensing is to extend our visual capability. In addition, remote sensing can enhance our memory because our brains tend not to remember every fine piece of details about what we see.
With remote sensing images, we can do a lot more than refreshing our memories, which is a primary goal of conventional photography.
We want to measure and map spatial dimensions of objects from remote sensing images. Furthermore, we use remotely sensed data to monitor the dynamics of the phenomena on the earth surface.

These include monitoring the vigor and stress of vegetation and environmental quality, measuring the temperature of various objects, detecting and identifying catastrophic sites caused by fire, flood, volcano, earthquakes etc.,

We can also estimate the mass of various components, such as biogeochemical constituents of a forest, volume of fish schools in water, crop production of agricultural systems, water storage and runoff of watersheds, population in rural and urbanized areas, and quantity and living conditions of wildlife species.

7. Remote Sensing Applications

Remote sensing has enabled mapping, studying, monitoring and management of various resources like agriculture, forestry, geology, water, ocean etc.

It has further enabled monitoring of environment and thereby helping in conservation. In the last four decades it has grown as a major tool for collecting information on almost every aspect on the earth.

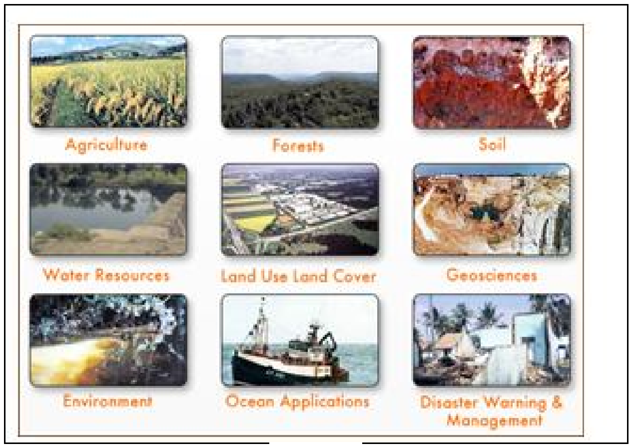

Figure 6

With the availability of very high spatial resolution satellites in the recent years, the applications have multiplied. In India remote sensing has been used for various applications during the last four decades and has contributed significantly towards development.

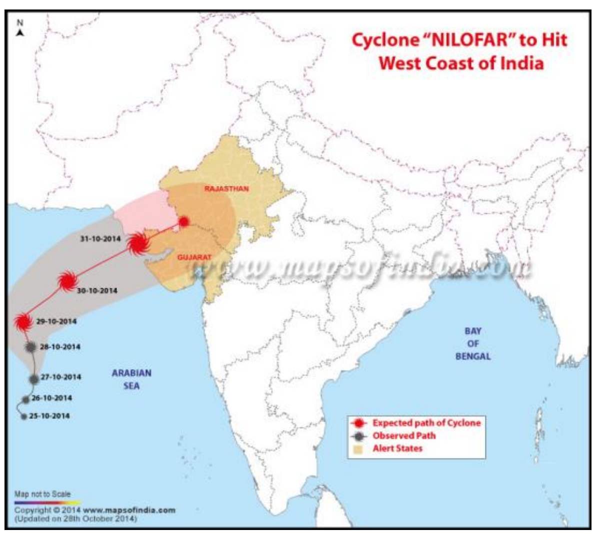

Figure 7: Forecast track and intensity of the system are given in the table below along with a map showing the path.

Date/ Date/ Time(IST)Time(IST)	Position (Lat. 0N/ long. 0E)	Maximum sustained surface wind speed (kmph)	Category of cyclonic disturbance
28-10-2014/0530	15.7/61.8	130-140 gusting to 155	Very Severe Cyclonic Storm
28-10-2014/1130	16.3/61.5	135-145 gusting to 160	Very Severe Cyclonic Storm
28-10-2014/1730	16.8/61.2	140-150 gusting to 165	Very Severe Cyclonic Storm
28-10-2014/2330	17.5/61.2	140-150 gusting to 165	Very Severe Cyclonic Storm
29-10-2014/0530	18.0/61.2	140-150 gusting to 165	Very Severe Cyclonic Storm
29-10-2014/1730	19.1/61.8	140-150 gusting to 165	Very Severe Cyclonic Storm
30-10-2014/0530	19.7/62.8	120-130 gusting to 145	Very Severe Cyclonic Storm
30-10-2014/1730	20.4/64.3	110-120 gusting to 135	Severe Cyclonic Storm
31-10-2014/0530	21.1/65.8	100-110 gusting to 120	Severe Cyclonic Storm
31-10-2014/1730	21.8/66.9	90-100 gusting to 110	Severe Cyclonic Storm
01-11-2014/0530	22.5/68.0	80-90 gusting to 100	Cyclonic Storm
01-11-2014/1730	23.2/69.1	50-60 gusting to 70	Deep Depression
02-11-2014/0530	23.7/70.2	35-45 gusting to 55	Depression

Table 1

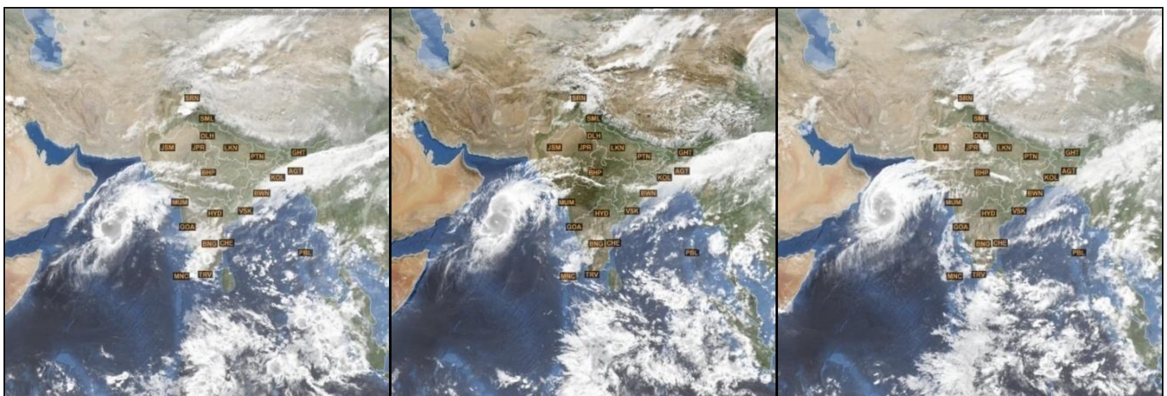

Figure 8: Meteosat images giving the eye-of-the storm (Nilofar) taken on 28th October, 2014

- **October 28, 14:30 (IST):** It is moving in north-northwestward direction and its position is 1,110 km southwest of Nalia at latitude 15.9 N and Longitude 61.6 E.

Figure 9

8. Conclusion

With the help of remote sensing and satellite communication, and warning system in place, we are able to avert the alarming situations and are prepared for the natural calamities thereby human loss is minimized.

Through the use of satellites, we now have a continuing program of data acquisition for the entire world with time frames ranging from a couple of weeks to a matter of hours. Very importantly, we also now have access to remotely sensed images in digital form.

Viewing from space also helps in understanding the intensity and scale of natural disasters like cyclones, floods, tsunami etc. It is difficult to resonate with the rhythm of our mother planet earth if one is not sensitive.

9. References

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