Image Processing in Remote Sensing

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1. Introduction

- Image Processing
  - Treat visuals as engineering

* Diagram *

Receive Information
100 times as fast as other sense

Casualty Insurance money is biggest

Application Field of Digital Image Processing

1. Document/Drawing Auto Recognition
2. Medical Field
   - X-ray film Interpretation, cell count/classify, CT
3. Industrial Field
   - Eye of industrial robot
   - Inspection of products
4. Remote Sensing
   - Land cover/Land use Classification
5. Automated Mapping
   - Building/Road/Signboard Recognition
6. Transportation
   - Vehicle count, Car license plate Recognition, speed measurement
Characteristics of Digital Image in R/S

1. Brightness in Numerical Data (Usually in integer)
   - Scaled from radiometer Instrument (W/m²/sr)
2. 3D Data
   - X-Y Spatially Distributed Geo-Coded Data
   - Z Multi-Channel
3. Big Volume
4. A lot of useful information
5. A lot of Distortions involved
   - Radiometric
   - Geo-location

USGS


Commercial Satellites/60cm

http://www.digitalglobe.com/

Free download Site
Preprocessing I

Visualization for better visual interpretation / understanding
- Contrast Enhancement
- Color Composite
- Edge Enhancement

Original Data is not suitable for visual interpretation. This is just data which represent radiance of earth surface

Preprocessing II

Geometric Correction: to know the exact position and overlay with maps.
Other correction: Radiometric Correction / Atmospheric Correction

Classification

- To divide images into several number of classes. –Landuse/Landcover

Map Publishing

Habitat type map of Phi Don Island.
Further Analysis
Calculating Physical Parameters using Models

- Water discharge
- Biomass, CO2
- SST (Sea Surface Temperature)
- Chlorophyll-a Concentration
- Suspended Sediment
- and etc.

Water Runoff Model
White: Saturated by Water

Chlorophyll-a distribution in Arabian Sea and Bay of Bengal using IRS-P4 OCM data
29 & 30 January 2000

Digital Image Data Pixel

Pixel (Picture Element), pixel has a value $f(x,y)$

- $x,y$: integer
- $f$: brightness in most case, integer

Pixel Value

Multi Channel Image

Color Image: 3 channel for R,G,B
Landsat TM 7 Channel

Band 1
Band 2
Band 3
Band 4
Bit and Binary System

The gray level of each pixel is recorded and stored as a finite number of bits.

If there are k bits/pixel, total of 2k gray levels over the range 0 to 2^k -1

Example of 3 bits image

<table>
<thead>
<tr>
<th>bit2</th>
<th>bit1</th>
<th>bit0</th>
<th>bitmap</th>
<th>graylevel</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>1</td>
</tr>
</tbody>
</table>

if k equals 8, the group of bits is called byte.

Binary System in Computer Memory

Pixel value is stored in limited space in a computer memory. 1 unit = 1 byte = 8 bits
8 bits has 2^8=2*2*2*2*2*2*2*2 = 256 combinations of on/off at bits. Thus k bits unsigned integer has 0 to 2^k-1 of data range.

• 8 bits ( 1 byte ) / pixel 0 -> 255
• 16 bits (2bytes)/pixel 0-> 65535
• 1024 bytes = 1KB
• 1024 KB = 1MB
• 1024 MB = 1GB

Image Size in Bytes

1024 width *1024 height *7 bands /
1 byte/pixel -> 7MB

How to store numerical value in limited number of Bits

Typical Computer Word Length
8 bits, 16bits, 32bits, 64bits

We usually use 8,16,32,64bits to store pixel values.

8bits unsigned integer 0-255 most common
16bits unsigned integer 0-65535 Optical, radar image
32bits unsigned integer 0-4,294,967,295
8 bits signed integer -128 to +127
16 bits signed integer -32768 to 32767

IEEE format floating point value
32bits float significant figures 7
64bits float complex
64bits double significant figures 15
128bits double complex

Byte Order

• If byte/ pixel is 2 or more,
• Byte order depends on the type of CPU (Central Processing Unit) There are 2 types in byte order

1. Motorola etc. ( Little endian CPUs, LSB First)
   • 680x0, PowerPC Macintosh
   • Sparc: SUN WorkStation

2. Intel ( Big endian CPUs, MSB First)
   • 80x86, Pentium IBM Compatible Personal Computer
Text Data

Text (Character) is being stored as an integer number following certain Character Code Set. Most of the case, ASCII (American Standard Code for Information Interchange). Or ISO 8859-1 is used. Sometime we just say ASCII file, or Text file, which means you can read it. Compare with image data which we call binary data, or binary file.

http://www.asciitable.com

Sampling & Quantization

Digitization of Gray Scale Images

- (Analog to Digital Image) Conversion of a continuous picture into a discrete form

1. **Sampling**: Selection of a discrete grid to represent an image (usually square grid)

2. **Quantization**: Mapping of the brightness into a numerical value (How many levels? usually 8 bits – 16 bits)

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**FOV and IFOV**

- **FOV**: Field of View
- **IFOV**: Instantaneous Field of View for 1 pixel

![Section 6.1.1 Concept of sampling](image)

![Section 6.2.1 FOV and IFOV](image)
Sampling Policy

Pixel Size or Sampling Rate

Shannon's sampling theorem

"There will be no loss of information if sampling is taken with a period of half of the reciprocal of the frequency involved in the original analog frequency wave"

Quantization

Figure 6.1.2 Concept of quantization

Figure 6.1.3 Quantization in the case of a signal containing a noise
Records and Files

- Image data is stored in secondary memory (Floppy, Hard Disks, many types of removable disks, Tape, etc.)
- Each line of image pixels is usually stored as a logical record, which is implemented on physical records on media. The total set of records which constructing an image is called file.
- In case of tape media, only sequential access can be done, and logical record is same as physical record.
- Gap separates physical record. TM (tape mark) separates files.

File Format

1. Band-Sequential (BSQ)
2. Band-interleaved by line (BIL)
3. Band-interleaved by pixel (BIP)

If the processing is pixel-by-pixel, the BIP format is convenient because the pixel gray levels in each band are stored contiguously within a data record.

If the processing is only on a single band from the multispectral image, the BSQ format is most attractive because it minimizes the amount of data that must be read to access a single band.

The BIL format represents a good compromise of efficiency and convenience for general application and is probably used more widely than either of the other formats.
Digital Image in Computer RAM

- If the quantities of image data are so large, it is impossible to store the whole image data on main memory of a computer (RAM). Image data are usually stored on the secondary memory (Hard disks, etc.).

- When specific data are necessary in the processing procedure, these data are transferred from disk to RAM line-by-line. Usually, the quantity of image data in one line is not so large.

Allocating RAM for image data

- If the images are not so huge, it is convenient to store whole image in the RAM. Because accessing RAM is fast, and it is easy to write image processing programs.

- In C language, the pointer is used to allocate memory for image data storage in the main memory.

```c
unsigned char **img; /* 2D array (single band image) */
int h,w;
int i,j;
img=malloc(sizeof( unsigned char * ) * h ); /* allocate pointer table for each line*/
for(i=0;i<h;i++) /* allocate memory for each line */
    img[i] = malloc( sizeof( unsigned char ) * w );
for(i=0;i<h;i++)
    for(j=0;j<w;j++) /* accessing to image data */
        img[i][j] = 0;
```

Pointer Structure for Allocating Memory

```
img -> img0
    img1
    img2
```

Neighbors of a Pixel

- 4-neighbors of p
- 8-neighbors of p
3. Visualization of Remote Sensing Data

1. Visualization is Important
   - Human’s extremely high capability on image recognition
   - Better Understanding by visual interpretation
     * Identify objects and their status, patterns, guess what is going on on the ground
   - Utilize Human’s capability to distinguish several thousands of colors

2. Image data is not always ready for visualization
   - Pixel has Digital Number (DN), which represents radiance from the ground.
   - Low contrast for visualization
   - Appropriate Enhancement and Color Composite is needed to visualize data on a computer display

3.1 Contrast Enhancement

Image Histogram

- The image histogram describes the statistical distribution of gray levels in an image in terms of the number of pixels (or percentage against the total number of pixels) at each gray level.
- An image histogram only specifies the total number of pixels at each gray level; it contains no information about the spatial distribution of gray levels through out the image.
There are 15,563 pixels which have value 76.
Histogram and Image Characteristics
Low Contrast Image

Histogram and Image Characteristics
High Contrast Image

Contrast Enhancement by A Linear Transformation Function

Deciding range of input level
Other Contrast Enhancement

1. Linear Piecewise
   - To give equal number of pixel to brightness
   - To convert histogram to Gaussian distribution
   - Natural Perception

\[ f(x) = \frac{1}{\sqrt{2\pi}\sigma} \exp\left( -\frac{(x - \mu)^2}{2\sigma^2} \right) \]

2. Piecewise Linear

Various Transformation

- Linear transformation
- Piecewise linear transformation
- Cyclic transformation
- Continuous function transformation
- Histogram Equalization
- Local contrast enhancement

Linear Transformation

- Equalization
  ➢ To give equal number of pixel to every brightness ranges

- Gaussian Histogram Conversion
  ➢ To convert histogram to Gaussian distribution

- Natural Perception
Non Linear Continuous Function Transformation

- If dynamic range of the original image is very big.

Thresholding

- It segments an image into two classes defined by a single gray level threshold
  1. Simple classification algorithm
  2. Divide the pixel into two using a value \( T \)
     - If \( x \) is less than \( T \) class 1 otherwise class 2
  3. Multiple thresholding
     - If \( x \) is in the range of \( T_1 \) to \( T_2 \), then class 1 otherwise class 2
  4. Change detection in a pair of multi-temporal images
Threshold is a simple classification

Look Up Table
No Math Operation -> Fast

Hardware or 1-dim Array in Progra