Active and Passive Collaborative monitoring

ChenFu, MaYong, Zhao Haoteng

2017/9/14
1、Active and passive remote sensing data

2、Active and passive collaborative monitoring and application
Active and passive remote sensing data
A remote sensing instrument collects *information about an object or phenomenon* within the instantaneous-field-of-view (IFOV) of the sensor system without being in direct physical contact with it. The sensor is located on a suborbital or satellite platform.
Sensors can be used to obtain specific information about an object (e.g., the diameter of a cottonwood tree crown) or the geographic extent of a phenomenon (e.g., the boundary of a cottonwood stand). The electromagnetic radiation (EMR) reflected, emitted, or back-scattered from an object or geographic area is used as a surrogate for the actual property under investigation. The electromagnetic energy measurements must be calibrated and turned into information using visual and/or digital image processing techniques.
Two types of remote sensing

• Passive

Sun’s energy which is reflected (visible) or absorbed and then re-emitted as thermal infrared wavelengths
ASTER, Landsat, AVHRR

• Active

Emit radiation
Radiation reflected is detected and measured
LIDAR, RADAR, and SONAR
Electromagnetic Energy

- Long wavelength radiation
- Reflection
- Short wavelength radiation
- Transmission at the speed of light, $c$
- Hydrogen fusion
- Sun
Passive – Solar Radiation

Electromagnetic Spectrum and the Photon Energy of Visible Light

- Wavelength in meters (m)
- Photon energy of visible light in electron volts (eV)
- Photon wavelength in nanometers (nm)

Sun

- Ultraviolet
- Visible
- Infrared
- Microwave and radio waves

Earth
Passive -- OLR
Passive -- Nightlight
Passive – Optical images

- Spatial resolution
- Temporal resolution
- Spectral resolution
- Radiometric resolution
Spatial Resolution

In this case, resolution refers to the pixel (cell) size (the area covered on the ground and represented by a single cell).

A higher spatial resolution implies that there are more pixels per unit area; therefore, the graphic on the left represents a higher spatial resolution than the graphic on the right.
Spatial Resolution

Imagery of Harbor Town in Hilton Head, SC, at Various Nominal Spatial Resolutions

a. 0.5 x 0.5 m.  
b. 1 x 1 m.  
c. 2.5 x 2.5 m.

d. 5 x 5 m.  
e. 10 x 10 m.  
f. 20 x 20 m.

g. 40 x 40 m.  
h. 80 x 80 m.

Nominal Spatial Resolution (enlarged view)
Temporal Resolution

Weather satellite images of Meteosat 7 every half an hour
Spectral resolution is defined through the number of spectral bands and their width. Their purpose is to capture the differences in the reflection characteristics of different surfaces.
Spectral Resolution

Many remote sensing systems record energy over several separate wavelength ranges at various spectral resolutions. These are referred to as multi-spectral, superspectral, and hyperspectral sensors.
Radiometric Resolution

Sensitivity of the detector to differences in EMR signal strength determines the smallest difference in brightness value that can be distinguished.
Radiometric Resolution

Bit Depth

- 6-bit (0 – 63)
  - LANDSAT – MSS (from LANDSAT 1-3)

- 8-bit (0 – 255)
  - LANDSAT – TM (from LANDSAT 6-7) & SPOT - HRV

- 11-bit (0 – 2047)
  - IKONOS & QuickBird

- 16-bit (0 – 65535)
  - LANDSAT – OLI (from LANDSAT 8)
Spectral and Radiometric Resolution

Spectral  (where we look)

Radiometric  (how finely can we measure the return)

0-63, 0-255, 0-1023
Active Remote Sensing

Active sensors emit energy pulse, measure backscatter, then record as a digital number.

Long wavelength – microwave

Penetrates clouds and vegetation

RADAR
**Radar** is the abbreviation for *Radio Detection and Ranging*, a method for the detection and ranging of earth surface features.

A radar system contains four parts:
--transmitter
--antenna
--receiver
--recorder
Bands

- P-band
- L-band
- S-band
- C-band
- X-band
- K-band

Two radar images of the same agricultural fields

© CCRS / CCT
Polarization

Polarization refers to the orientation of the electric field.

Most radars are designed to transmit and receive microwave radiation either horizontally polarized (H) or vertically polarized (V).

- HH - for horizontal transmit and horizontal receive,
- VV - for vertical transmit and vertical receive,
- HV - for horizontal transmit and vertical receive, and
- VH - for vertical transmit and horizontal receive.
The definition for the resolution of a radar system differs from that of an optical system.
Geometry of a Radar System

The platform travels forward in the **flight direction** (A) with the **nadir** (B) directly beneath the platform. The microwave beam is transmitted obliquely at right angles to the direction of flight illuminating a **swath** (C) which is offset from nadir. **Range** (D) refers to the across-track dimension perpendicular to the flight direction, while **azimuth** (E) refers to the along-track dimension parallel to the flight direction. This side-looking viewing geometry is typical of imaging radar systems (airborne or spaceborne).
Resolution of Radar

The resolution of radar imaging system tend to be higher than that of optical ones.

The resolution in range and azimuth derives from different physical processes, and in general need not be the same.
Range Resolution

The **range or across-track resolution** is the ability to distinguish between targets that are very close in range direction.

\[
R = \frac{CP}{2\cos\theta}
\]

Dependent on the length of the pulse (P) and the angle of incidence (\(\theta\)).
Azimuth Resolution

The **azimuth or along-track resolution** is the ability to distinguish between targets that are very close in azimuth direction.

This **beamwidth (A)** is a measure of the width of the illumination pattern.
SAR - Synthetic Aperture Radar
SAR - Synthetic Aperture Radar

Real beam width: $\beta = \frac{\lambda}{D}$
Real resolution: $\Delta L = \beta R = L_s$ (synthetic aperture length)
Synthetic beam width: $\beta_s = \frac{\lambda}{2L_s} = \frac{D}{2R}$
Synthetic resolution: $\Delta L_s = \beta_s R = \frac{D}{2}$

- $D$: real aperture
- $\beta$: real beam width
- $\beta_s$: synthetic beam width
- $h$: height
- $\Delta L_s$: azimuth resolution
- $\phi$: off nadir angle
Radar Image Distortions

side-looking viewing geometry

\[ G_R = \frac{S_R}{\sin \theta} \]

\[ S_R = G_R \times \sin \theta \]
Radar Image Distortions

Slant-range display

Ground-range display
Radar Image Distortions

Relief displacement

Cause foreshortening and layover in radar images.

When the radar beam reaches the base of a tall feature tilted towards the radar (e.g. a mountain) before it reaches the top **foreshortening** will occur.
Radar Image Distortions

**Layover** occurs when the radar beam reaches the top of a tall feature (B) before it reaches the base (A).
Both foreshortening and layover result in **radar shadow**. Radar shadow occurs when the radar beam is not able to illuminate the ground surface. Shadows occur in the down range dimension (i.e. towards the far range), behind vertical features or slopes with steep sides.
Radar Image Appearance

The brightness of features in a radar image is dependent on the portion of the transmitted energy that is returned back to the radar from targets on the surface.

4 types of scattering
• Surface scattering
• Double bounce (Corner reflection)
• Volume scattering
• Penetrating scattering
Radar Image Appearance

- **Surface scattering**
  - The rough surface can get a higher backscatter, and the flat surface often shows dark areas on the radar image (specular reflection).

- **Double bounce**
Radar Image Appearance

- Volume scattering
  - Generally occurs in low-frequency SAR systems (e.g., L, P-band)
  - Including multiple bounces and reflections from different components within the volume

Volume scattering of forest
(Upper - canopy layer, middle - trunk layer, lower - ground layer)
Radar Image Appearance

- **Penetrating scattering**
  - According to the polarization and wavelength, microwave can penetrate vegetation, bare soil (dry snow or sand)
  - In general situation, the longer the wavelength, the stronger the penetration ability.
  - Cross-polarization (VH / HV) is less permeable than copolarization (HH / VV).
Figure 4.7.1 (a) Widyan, Saudi Arabia and Iraq / SIR-A img.1) (courtesy of NASA/JPL)
Radar Image Appearance

- The backscatter is also related to moisture content and electrical properties of the target.
Radar Image Appearance

- Image speckle

Because SAR is a coherent system, speckle noise is its inherent characteristic.

In uniform area, the image shows a significant random change in brightness, which is not directly related to the resolution, polarization and incident angle, so the speckle noise is random noise.

Multi looks method and filter can suppress speckle noise
SAR Applied to many fields / industries

- City Mapping
- Land/Marine Target Detection
- Oil Spill Monitoring
- Sea Wave Height Estimation
- Snow/Glacier Mapping
- Landslide/Ground Monitoring
- Building Monitoring
- Land Cover Mapping
- Desertification Monitoring
- Flood/Wetland Monitoring
- Agricultural Monitoring
- Crop Yield Estimation
- Forest Mapping
- Desertification Monitoring
- Land Cover Mapping
- Building Monitoring
- Land/Marine Target Detection
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- Snow/Glacier Mapping
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- Land Cover Mapping
- Desertification Monitoring
- Flood/Wetland Monitoring
- Agricultural Monitoring
- Crop Yield Estimation
- Forest Mapping

SAR Applications
SAR Applications

SAR intensity data monitoring seaside vessels

Cosmo-SkyMed 1, 2
Incident angle: 38 °
polarization method: VV

Received date:
May 10, 2009 CSK1
May 26, 2009 CSK1
June 3, 2009 CSK2
SAR Applications

SAR intensity data monitoring seaside vessels

MAY 10, 2009
SAR Applications

SAR intensity data monitoring seaside vessels

MAY 26, 2009
SAR Applications

SAR intensity data monitoring seaside vessels

JUNE 3, 2009 (low tide)
SAR Applications

False Colored Synthesis Using Multi - temporal SAR Data

RED: 10/05/2009  GREEN:26/05/2009  BLUE:03/06/2009
SAR Applications

SAR intensity data for Vietnam flood mapping
SAR Applications

Burma Flood In 2008

False colored image superimposed on the reference data before the flood.

Blue-violet indicates the flood area.

Range 300 * 200 km
SAR Applications

Flood Monitoring

Original Data

Classification results

When flood occurs

Green – vegetation
Brown, gray – bare land
Blue - water

Three days later
SAR Applications

Estimation of crop area in small area

Original Cultivable area  The area may be cultivated at the beginning  Changes in crop growth process

Cultivated area
SAR Applications

Estimation of crop area in small area

At the beginning of cultivating
When the crop grows best
The phenological period of rice
Leaf area index (LAI)

Time period of monitoring

JUN  SEP

Bared soil
water
Tillering period
First heading time
Full heading time
Maturation period

<1
1–2
2–3
3–4
4–5
>5
SAR Applications

SAR for fine agriculture

June 2, 2011 SAR images

Csomo-SkyMed
North Germany

Backscatter coefficient

low high
SAR Applications

SAR for fine agriculture

- Estimate water content
- Estimate biomass
- Estimate crop production

Yield [t / ha]

Water content (%)

<table>
<thead>
<tr>
<th>Water Content</th>
<th>Yield [t / ha]</th>
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<tbody>
<tr>
<td>&lt; 1.5</td>
<td></td>
</tr>
<tr>
<td>1.5 - 3.0</td>
<td></td>
</tr>
<tr>
<td>3.0 - 5.0</td>
<td></td>
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<tr>
<td>5.0 - 7.0</td>
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<tr>
<td>7.0 - 9.0</td>
<td></td>
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<tr>
<td>&gt; 9.0</td>
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</table>
## Effects of Typhoon Haiyan on Rice (Isle of Wight, Philippines)

<table>
<thead>
<tr>
<th>CITY</th>
<th>Rice area</th>
<th>Flooded area</th>
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<tbody>
<tr>
<td>Alangalang</td>
<td>3,079</td>
<td>939</td>
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<tr>
<td>Albuera</td>
<td>58</td>
<td>2</td>
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<tr>
<td>Burauen</td>
<td>570</td>
<td>124</td>
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<td>Dagami</td>
<td>1,757</td>
<td>681</td>
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<tr>
<td>Dulag</td>
<td>1,055</td>
<td>370</td>
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<tr>
<td>Jaro</td>
<td>400</td>
<td>14</td>
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<tr>
<td>Julita</td>
<td>1,017</td>
<td>140</td>
</tr>
<tr>
<td>La Paz</td>
<td>209</td>
<td>17</td>
</tr>
<tr>
<td>Mayorga</td>
<td>395</td>
<td>199</td>
</tr>
<tr>
<td>Ormoc City</td>
<td>0</td>
<td>1</td>
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<tr>
<td>Palo</td>
<td>2,104</td>
<td>402</td>
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<tr>
<td>Pastrana</td>
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<td>71</td>
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<td>San Miguel</td>
<td>711</td>
<td>611</td>
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<tr>
<td>Santa Fe</td>
<td>1,715</td>
<td>781</td>
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<tr>
<td>Tabontabon</td>
<td>861</td>
<td>227</td>
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<tr>
<td>Tanauan</td>
<td>1,628</td>
<td>1,545</td>
</tr>
<tr>
<td>Tolosa</td>
<td>286</td>
<td>376</td>
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<tr>
<td><strong>Sum</strong></td>
<td><strong>17,272</strong></td>
<td><strong>6,501</strong></td>
</tr>
</tbody>
</table>

Flooded rice field area 3,000 ha
SAR Applications

Forest management -- Dynamic Monitoring of Deforestation

ALOS PALSAR-1, 15m

- before 2007
- 2007 - 2008
- 2008 - 2009
SAR Applications

Forest management -- Forest Fire Monitoring

With data before and after the forest fire, we can use dynamic monitoring technology to monitor damage the fire caused to the forest.
Active and passive collaborative monitoring and application
Active and Passive Collaborative monitoring

Active Remote sensing (SAR)

Advantages: no interference from cloud and rain, all day, the observation angle is relatively fixed, sensitive to abrupt changes
Disadvantages: greater noise, difficult to interpret

Passive Remote sensing (Visible to infrared)

Advantages: easy to interpret, rich band
Disadvantages: large interference by the atmosphere, cloud and rain, not sensitive to changes in certain features

GUILIN Xiangshan Park
SAR DATA: sentinel1A (GF-3)
Advantages:
- The viewing angle and pattern are fixed
- Repeat cycle fixed (6/12 days)
- Continuous dynamic monitoring, resolution up to 10m (Metal can be smaller)

Optical data: GF-1, GF-2, SPOT and other available high-resolution data,
- Interpret Change spot classification
Active and Passive Collaborative monitoring application

1. Construction survey
2. Forest destruction
3. Quarry monitoring
4. Water monitoring
5. Landslide
6. Comprehensive Application—Hulun Lake
7. Comprehensive Application—Jiuzhaigou earthquake
1. Construction survey
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Active and Passive Collaborative monitoring
----Construction survey

The screenshot of left map, A, B, C, D detailed explanation in next page

2015 ~ 2016 Beijing  SAR Change Detection Map
Active and Passive Collaborative monitoring
----Construction survey

Yuyuantan Park

enlarged SAR change detection map of A and B

Military Museum
Song Qingling International Art Center

2015-04-13

2016-05-03

enlarged SAR change detection map of C and D

Central Engineering Institute for Non-ferrous Metallurgical Industries
Active and Passive Collaborative monitoring

----Construction survey

2015 ~ 2016 Cambodia Phnom Penh SAR Change Detection Map
Active and Passive Collaborative monitoring
----Construction survey

2015 ~ 2016 Pakistan Islamabad SAR Change Detection Map
Active and Passive Collaborative monitoring

haven monitoring

2015 ~ 2016 Pakistan Gwadar SAR Change Detection Map
Active and Passive Collaborative monitoring
-----haven monitoring

Gwadar SAR Change Detection Map

2015-04-05

2016-05-11
Active and Passive Collaborative monitoring ---- Construction survey
(Meigu Nature Reserve, SiChuan Province)
1. Construction survey
2. Forest destruction
3. Quarry monitoring
4. Water monitoring
5. Landslide
6. Comprehensive Application—Hulun Lake
7. Comprehensive Application—Jiuzhaigou earthquake
1. Construction survey
2. Forest destruction
3. Quarry monitoring
4. Water monitoring
5. Landslide
6. Comprehensive Application—Hulun Lake
7. Comprehensive Application—Jiuzhaigou earthquake
Annual mean cloud cover based on ten years remote sensing data (China region)

From 2011-01-01 to 2017-02-01, Chengdu: rain 947 days, cloudy 1143 days, clear 64 days, snow 9 days.
Active and Passive Collaborative monitoring

Forest destruction

2015 ~2016 Chengdu SAR change detection map
Active and Passive Collaborative monitoring

----Forest destruction

2015 ~ 2016 Chengdu change detection screenshot map in region A
Active and Passive Collaborative monitoring
----Forest destruction

New building
Deforestation

2015 optical data
2016 optical data
Active and Passive Collaborative monitoring ---- Forest destruction

A-2

Forest destruction

2015 optical data

2016 optical data
Active and Passive Collaborative monitoring

----Forest destruction

Forest destruction seriously
1. Construction survey
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Active and Passive Collaborative monitoring

----Quarry monitoring (Guilin, Karst, world natural heritage)

January 2016 ~ December 2016 SAR change detection map
Quarry activity is weakening and measures are being taken to improve.

January 2016 ~ December 2016 SAR change detection image map
1. Construction survey
2. Forest destruction
3. Quarry monitoring
4. Water monitoring
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7. Comprehensive Application—Jiuzhaigou earthquake
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Active and Passive Collaborative monitoring
----Quarry monitoring (Guilin, Karst, world natural heritage)

Water is decreasing
Active and Passive Collaborative monitoring application

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Active and Passive Collaborative monitoring

Dynamic detection changes in nature reserves
(Meigu Nature Reserve, Sichuan Province)

Landslide point

SAR change detection Map

20150404 GF-1 2M

20161205 GF-1 2M
Active and Passive Collaborative monitoring application

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Active and Passive Collaborative monitoring application

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Comprehensive Application—**Hulun Lake**

[Map showing Russia, China, Mongolia, and Hulun Lake nature reserves]
Active and Passive Collaborative monitoring
---- Dynamic Detection changes in nature reserves

2016 ~ 2017 Hulun Lake Nature Reserve change detection (part)
Dynamic detection changes in nature reserves

A Construction change

2016 ~ 2017 SAR change detection image
Dynamic detection changes in nature reserves

B Small target change recognition

2016 ~ 2017 SAR change detection image

20160811 GF-1 2m

20170411 GF-1 2m
Dynamic detection changes in nature reserves

C New mine

2016 ~ 2017 SAR change detection image

20160811 GF-1 2m

20170401 GF-1 2m
Dynamic detection changes in nature reserves

D  Urban change

2016 ~ 2017 SAR change detection image
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Active and Passive Collaborative monitoring

Disaster monitoring
Active and Passive Collaborative monitoring

----Disaster monitoring

Change detection images before and after the earthquake in Jiuzhaigou Spark Sea Scenic Spot
Active and Passive Collaborative monitoring

--- Disaster monitoring

Change detection images before and after the earthquake in Jiuzhaigou Ruyi Area
Active and Passive Collaborative monitoring

---Disaster monitoring

Change detection images before and after the earthquake in Jiuzhaigou Ruyi Area
From March 2016 to March 2017, in each month a comparison is done with the previous month image to detect change region.
201611 ~ 12 Chengdu City SAR data change detection
From April to May, weeds grew on bare soil.

201604 ~ 05 SAR data change detection

201611 ~ 12 SAR data change detection

Nov. to Dec. site construction began

Active and Passive Collaborative monitoring
----Monthly monitoring
Active and Passive Collaborative monitoring can break the limitation of the prior optical remote sensing monitoring and gain a continuous and reliable results. It combine the advantages of radar data and optical data, and provide important information support and decision support for various monitoring applications.
谢谢！

中国科学院遥感与数字地球研究所
地址：北京市海淀区邓庄南路9号（100094）
电话：86-10-82178008 传真：86-10-82178009
邮箱：office@ceode.ac.cn
网址：www.radi.cas.cn