Lecture 3: Spatial Data Acquisition in GIS

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Learning Outcomes
• By the end of this lecture you should be able to:
  – Describe how paper maps are digitized
  – Know the basic ideas about remotely sensing
  – Know the basic image process methods
  – Explain what is and how to process LiDAR data into GIS
  – Know what is GPS and its integration with GIS

Data Input Stream in GIS

• Digitizer – the equipment for digitizing
• Operational procedure of digitization
• Coordinate transformation
• Error in digitization
• Editing operation in digitization
• Factors affecting digitization accuracy

Elements of a Digitizer
• Digitizing Table
• Mouse
• Paper map
1. Mount the map sheet on the digitizing table surface flat and secure.
2. Identify points with known coordinates.
   - Tic marks or control points
   - Minimum two points depending on the software
   - Points should be well distributed and covered the entire area to be digitized (usually, four corners of the map sheet)
3. Digitize control points and enter the true coordinates into the system
4. Software will compute coordinate transformation parameters and the residual
   - If residual is larger than the specified tolerance, you are required to redo the entire procedure.
5. Digitize Check Point
   - Check point is necessary to ensure that the map sheet mounted on the surface has not been changed or drafted.
6. Digitization
   - Two modes: point and stream (time or distance)
   Points digitized will be transformed from the digitizer local coordinates system to the known coordinates system using the computed transformation parameters

Map Digitization

Coordinate Transformation Models

- Similarity Transformation
  - Parallelity & azimuth of lines are maintained
  - 4 parameters
    \[ X' = a_1x + a_2y + a_3 \]
    \[ Y' = -a_2x + a_1y + a_4 \]
- Affine Transformation
  - Parallelity is still maintained, however the azimuth can be changed
  - 6 parameters
    \[ X' = a_1x + a_2y + a_3 \]
    \[ Y' = a_4x + a_5y + a_6 \]
- Projective Transformation
  - Parallelity and azimuth are not maintained
  - 8 parameters
    \[ X' = \frac{a_1x + a_2y + a_3}{a_5x + a_6y + 1} \]
    \[ Y' = \frac{a_4x + a_5y + a_6}{a_5x + a_6y + 1} \]

Errors in Manual Digitization

Possible Errors in Digital Map

- Geometric Errors
  - A node is missing or misplaced.
  - An edge is missing or misplaced.
  - An edge has a bad shape or too many (too few) points.
  - A node has more than one position.
- Topological Errors
  - Unconnected edges exist.
  - A polygon has a gap between two edges, that is it is not closed.
  - Duplicate arcs are present.
  - A polygon has more than one or no reference point associated with it (label point).
  - A polygon may be missing.
Factors Affect the Accuracy of Manual Digitization

1. Quality of original document
e.g. drafting method, drafting media, draftsman skill
2. Proper procedure of digitization and software
e.g. digitization of control points, accuracy of control points, digitization modes
3. Quality and resolution of the digitizer
e.g. resolution, repeatability, selectivity, consistency
4. Operator's skill and concentration

Field Survey

• Surveying
  Horizontal
  – Traverse
  – Triangulation
  – Trilateration
  Vertical
  – Leveling

Survey Instruments

- Level and Staff
- Electronic Theodolite
- Reflector
- Total Station

Remote Sensing

• The collection of data without being in contact with the object.
• There are usually two kinds of data we want to collect: thematic and positional.
• Thematic data tells us what the object is while positional data tells us where the object is located.

Energy Source & Spectral Bands

- Visible Bands
  – Blue (0.45-0.52 μm)
  – Green (0.52-0.60 μm)
  – Red (0.63-0.69 μm)
  – Panchromatic (0.50-0.90 μm)

Spatial Resolution

Ground sample distance (GSD) : The ground distance represented by the width of a pixel.
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Spatial Resolution of Typical Sensors

- Landsat TM (1982): 30 m
- SPOT-5 (2002): 5 m
- IKONOS (1999):
  - Panchromatic: 1 m
  - Multispectral: 4 m
- QuickBird (2001):
  - Panchromatic: 0.61 m
  - Multispectral: 2.4 m
- GeoEye (2008):
  - Panchromatic: 0.41 m
  - Multispectral: 1.65 m

China’s first survey satellite will be launched in 2011 with the resolution of 2.5 m and 4 m

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Spectral Resolution

The narrower the wavelength bands the sensor can detect, the higher the sensor’s spectral resolution

- Panchromatic sensors
  - To record the overall brightness of a scene
  - A camera with black and white film
- Multispectral sensors
  - Simultaneously record multiple wavelength bands
  - Landsat Thematic Mapper: seven multispectral bands
  - IKONOS and QuickBird: four multispectral bands
- Hyperspectral
  - Simultaneously record data in hundreds of contiguous, very narrow spectral bands in UV, visible, NIR, mid-IR bands
  - EO-1: 254 bands, 10 nm resolution

Panchromatic Image

Tampa Bay, FL

Multispectral Images

Multispectral Image Analysis

Hyperspectral Imagery
Remote Sensing Platform

- **Airborne**
  - Aerial photographs
  - SAR, InSAR
- **Satellite**
  - Landsat, SPOT, IKONOS, QuickBird
- **Ship/boat**
  - Sonar
  - Underwater Video

Airborne Remote Sensing

*The first form of remote sensing*

**Equipment**

- Cameras,
- Photographic films, and
- Camera filters.

Nevertheless recently high electronic system, the aerial photograph will continue to be primary form of remote sensing.

Airborne Remote Sensing

- Use Fixed-wing aircraft
- Flying over the area in the zigzag pattern
- Flight attitude: 3,000~4,000m
- Scale: 1:20,000~1:24,000
- Sidelap: 30%
- Overlap: 60%

All ground feature will appear on at least two photo.

Pushbroom CCD Camera

Stereo Image Processing & 3D Reconstruction

Aerial Photograph Geometry

- Interior Orientation
- Exterior Orientation
- Aerial Triangulation
- Collinearity Equations

\[
\begin{align*}
\Delta x &= \Delta x_0 + \Delta x_1 + \Delta x_2 + \Delta x_3 \\
\Delta y &= \Delta y_0 + \Delta y_1 + \Delta y_2 + \Delta y_3
\end{align*}
\]
Most satellite sensors detect electromagnetic radiation (EMR) electronically as a continuous stream of digital data. The data are transmitted to ground reception stations, processed to create defined data products, and made available for sale to users on a variety of digital data media.

**Satellite Remote Sensing**

- **Application of Satellite Images**
  - Deforestation in Bolivia
  - Mississippi Delta sediment deposition

**High-Resolution Satellite Imagery**

- **Rational Function Model**

**Deriving Information from Remote Sensing Images**

- **Image interpretation**
  - The detection, identification, and measurement of specific features
- **Digital image classification**
  - Classification of the total scene content into a limited number of major classes
- **Data transformations**
  - Mathematical operations on satellite image spectral data that enhance the interpretation or discrimination of selected terrain features
- **Change detection**
  - Detection of numerical differences in corresponding pixel values between dates

**Other Remote Sensing Technologies**

- LiDAR
- RADAR
- SAR
- SONAR

**Questions:**
Do you know about any of these technologies? What are these abbreviations stand for? Difference among them?
**Data Capture by Laser Scanning**
- **Airborne scanning**
- **Terrestrial scanning**

**LiDAR**
- **LiDAR** = Light Detection and Ranging
- Pulse of LASER light emitted
- Return time and intensity measured
- Converted into 3D coordinates

**LiDAR Data Format (LAS)**

**Cyber City Modelling from LiDAR Data**
- Scanned Urban Area
- 3D Cyber City Model

**Object Detection from LiDAR Data**
- 3D visualisation of the LiDAR points
- Photo taken from the site
**RADAR and SAR**

**RADAR = Radio Detection and Ranging**
A RADAR system has a transmitter that emits either microwaves or radio waves that are reflected by the target and detected by a receiver. Although the signal returned is usually very weak, the signal can be amplified. This enables RADAR to detect objects at ranges where other emissions, such as sound or visible light, would be too weak to detect.

**SAR = Synthetic Aperture Radar**
SAR is a form of radar in which the large, highly-directional rotating antenna used by conventional radar is replaced with many low-directivity small stationary antennas scattered over some area near or around the target area. The many echo waveforms received at the different antenna positions are post-processed to resolve the target.

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**SONAR**

**SONAR = Sound Navigation And Ranging**

• Sound waves travel in water at about 1,500 m/sec.

• Types
  – Side-scan sonar
  – Single-beam sonar
  – Multi-beam sonar

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**Global Positioning System (GPS)**

• **Global Positioning System (GPS)**
  – American version of satellite positioning system
  – Initiated in 1973
  – 24 satellites.

• **Global Navigation Satellite System (GLONASS)**
  – The Russian version of satellite positioning system
  – Initiated in 1982
  – 17 satellites

• **Galileo Positioning System**
  – Europe version of satellite positioning system
  – Initiated in 2005
  – Expect 30 satellites (1 on orbit now)

• **BeiDou Positioning System**
  – Chinese version of satellite positioning system
  – Initiated in 2000
  – Expect 35 satellites (4 on orbit now)

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**How GPS Works**

Mathematically, we need four satellite ranges to determine exact position.

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**Position Measurement**

1. The forth measurement from the forth satellite is necessary to determine the final position of the object.
2. But usually three ranges are enough because one of the two points is a ridiculous answer (either too far from Earth or moving at an impossible velocity) and can be rejected without a measurement.
Use GPS for Positioning

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- Digital Image Processing: http://www.cla.sc.edu/geog/rslab/rsccnew/

Further Readings

Review

• Summarization of the main ideas presented in this lecture:

• Questions?