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13.- Image Interpretation and Digital Image Processing

Digital Image Processing Concepts

LM-W13-V87

Digital Image Processing Concepts

An introductory overview of how digital remote sensing images are stored, enhanced, transformed, classified, and analyzed.

Focus: pixels, bands, correction, enhancement, filtering, classification, and change analysis

Designed for undergraduate students in remote sensing

Learning objectives and roadmap

Learning

Define digital image processing in the context of remote sensing.
Explain how pixels, digital numbers, and spectral bands represent information.
Describe major operations such as correction, enhancement, filtering, and classification.
Understand how temporal comparison supports change detection.
Recognize typical workflows in land, water, and environmental studies.

Roadmap

Image data → Preprocess → Enhance → Analyze → Output

Pixels & bands
The image is a grid of values recorded in one or more spectral bands.

Corrections
Errors caused by atmosphere, sensor geometry, or terrain are reduced.

Enhancement
Contrast stretch and filters make useful patterns easier to see.

Analysis
Classification and temporal comparison turn pixels into information.

Digital image processing converts raw image data into interpretable and decision-ready information.

What is digital image processing?

Sensor records energy → Digital image stored → Preprocessing → Enhancement / transformation → Interpretation / extraction

Input

Raw pixel values are collected from sensors on satellites, aircraft, or UAVs.

Operations

The image can be corrected, enhanced, transformed, or filtered.

Outcome

The goal is to improve visual quality or derive thematic information such as land cover, moisture, or change.

In simple terms, digital image processing means using computer-based methods to improve or analyze image data.

Pixels, digital numbers, and spectral bands

Pixel grid

12	18	24	35	42
15	22	30	48	56
18	27	41	60	72
25	39	54	68	80
31	44	58	76	92

Each pixel stores a digital number (DN). The DN represents the intensity measured in that location for a specific band.

Band stack

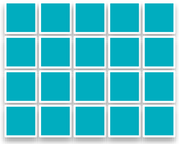
One band = one layer of measured energy. Multiple bands make spectral comparison possible. Combining bands allows false-color displays and indices such as NDVI.

A remote sensing image is both a spatial grid and a spectral record.

Resolution concepts in digital imagery

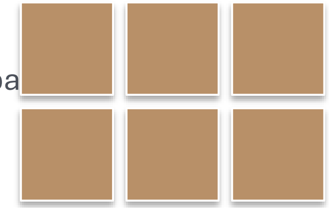
Spatial resolution

Pixel size on the ground. Smaller pixels show more detail.



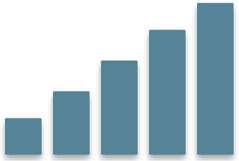
Spectral resolution

Number and width of bands. More ba capture finer spectral detail.



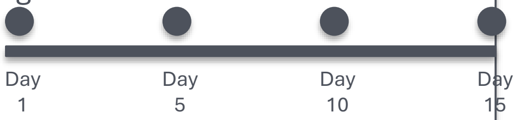
Radiometric resolution

Ability to distinguish small brightness differences, e.g., 8-bit vs 16-bit.



Temporal resolution

How often the same area is imaged.



Resolution strongly affects what can be detected and how accurately a scene can be analyzed.

Preprocessing: preparing raw data for analysis

Raw image

Sensor output may contain noise and distortions.

Radiometric correction

Reduce sensor and atmospheric effects.

Geometric correction

Align the image to real coordinates.

Resampling / registration

Match pixel grids across dates or sensors.

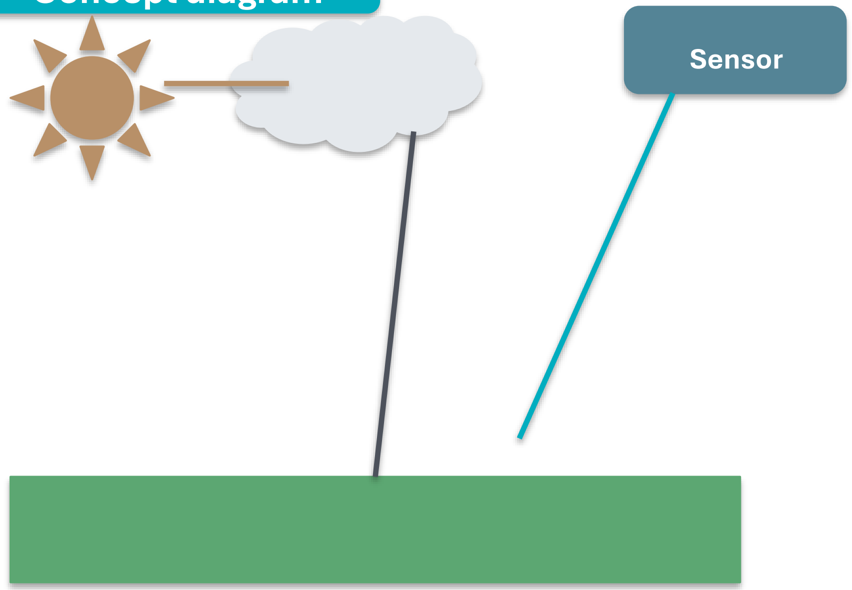
Ready for analysis

The image can now support enhancement or classification.

Preprocessing improves comparability, positional accuracy, and interpretability.

Radiometric correction and calibration

Concept diagram



Calibration and correction help ensure that the pixel values more closely represent surface reflectance rather than unwanted atmospheric or sensor effects.

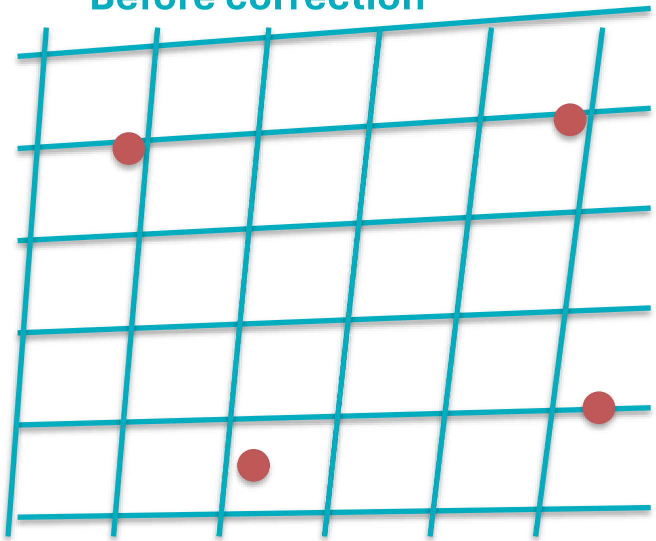
Why it matters

Reduces haze and atmospheric scattering.
Improves comparison between dates and sensors.
Supports reliable index calculations such as NDVI or NDWI.
Makes time-series analysis more consistent.
Converts raw digital numbers into radiance or reflectance values.

Radiometric correction improves the physical meaning of pixel values.

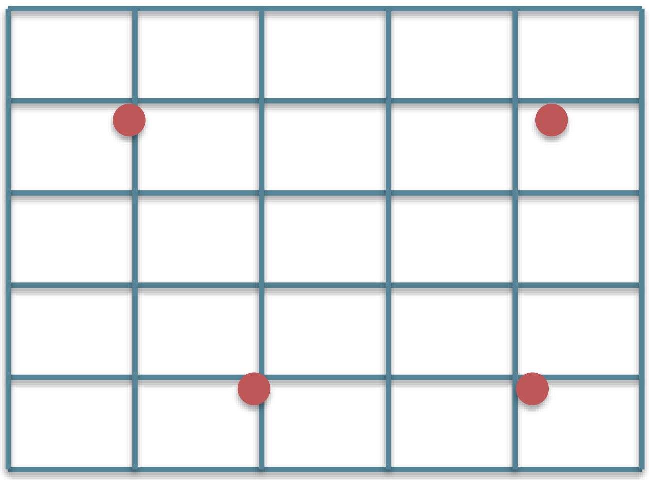
Geometric correction and image registration

Before correction



Use ground control points.
Select a projection.
Apply resampling.
Check alignment.

After correction



Geometric correction makes the image spatially accurate and suitable for mapping and overlay analysis.

Image enhancement concepts

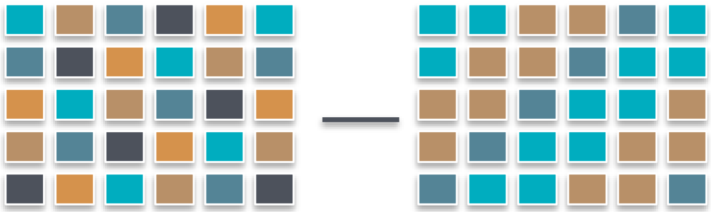
Contrast stretch

Original narrow range

Stretched range

Enhancement improves visibility without changing the scene itself.
Common methods include contrast stretching, density slicing, band composites, and edge enhancement.

Filtering example



Noisy image

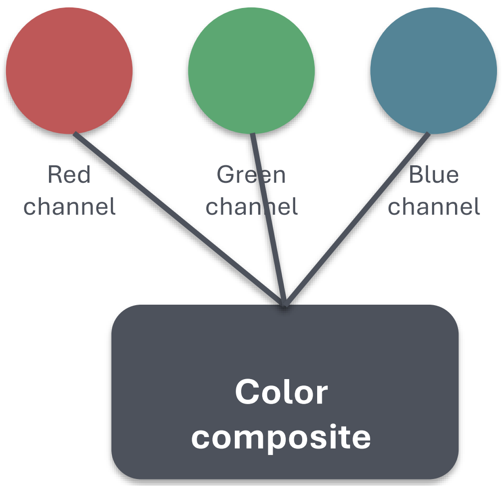
Smoothed image

Low-pass filters reduce random noise.
High-pass filters emphasize edges and fine detail.

Enhancement helps analysts see hidden structure and improve interpretability.

Band combinations and spectral transformations

Band combination



Common transformations

False color composite Highlights vegetation and water patterns.

Vegetation indices Combine bands to emphasize plant vigor.

Water indices Enhance open water or moisture features.

Principal components Reduce redundancy and highlight variance.

Band combinations and transformations highlight specific land surface properties.

Classification concepts

Supervised vs

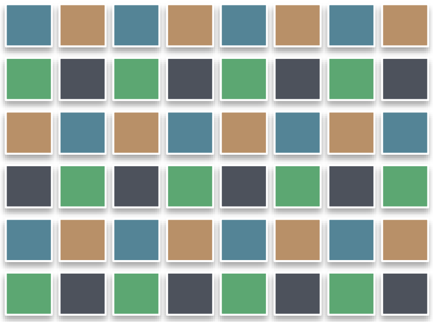
Training samples → **Known classes**

Automatic grouping → **Clusters → classes**

Classification assigns pixels or objects to land-cover categories such as water, vegetation, soil, or built-up area.

Simple example

- Water
- Vegetation
- Bare soil
- Built-up



Classified map output

Classification is one of the most common ways to convert imagery into thematic maps.

Neighborhood operations and filtering

Moving window

0	0	0	0	0
0	1	1	1	0
0	1	1	1	0
0	1	1	1	0
0	0	0	0	0

A filter uses neighboring pixels around a target pixel to smooth noise or emphasize edges.

Filter kernel

- Low-pass smoothing
- High-pass edge detection

Noise reduction

Common in preprocessing and feature extraction.

Edge emphasis

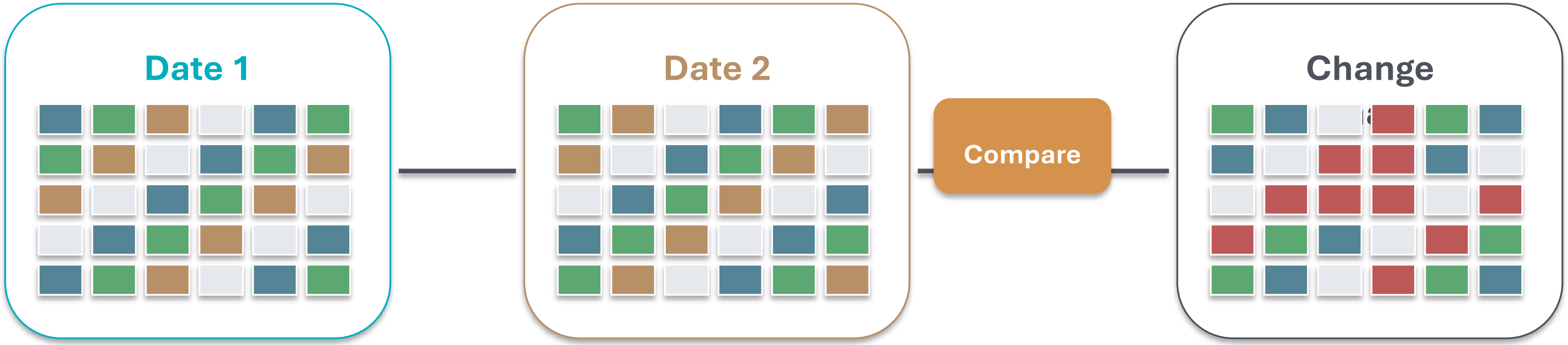
Common in preprocessing and feature extraction.

Texture measurement

Common in preprocessing and feature extraction.

Neighborhood operations examine local context rather than isolated pixels.

Temporal analysis and change detection



Change detection compares images from different dates to identify gains, losses, or transitions.
Typical applications: urban growth, flood extent, crop development, forest loss, shoreline change, and drought monitoring.

Reliable change analysis depends on consistent preprocessing and comparable image conditions.

Practical workflow and best practices

- 1. Define purpose
- 2. Select data
- 3. Preprocess
- 4. Enhance / transform
- 5. Analyze / classify
- 6. Validate results

Use suitable resolution

Match sensor resolution to your study objective.

Keep metadata

Record dates, projection, bands, and preprocessing steps.

Check quality

Look for clouds, haze, missing data, and misalignment.

Verify in the field

Ground truth improves interpretation and classification.

Compare carefully

Only compare images after consistent correction.

Explain uncertainty

Report errors and limitations clearly.

A structured workflow leads to more reliable and reproducible remote sensing results.

Campbell, J. B., & Wynne, R. H. (2011). Introduction to Remote Sensing (5th ed.). Guilford Press.
Jensen, J. R. (2015). Introductory Digital Image Processing: A Remote Sensing Perspective (4th ed.). Pearson.
Lillesand, T., Kiefer, R. W., & Chipman, J. (2015). Remote Sensing and Image Interpretation (7th ed.). Wiley.
NASA Earth Observatory. Earth observation image processing and interpretation resources.
USGS EROS Center. Remote Sensing Basics, Landsat tutorials, and data guidance.
ESA EO College. Introductory materials on image processing and remote sensing workflows.

Suggested activity: compare an original image with an enhanced image and explain which processing step made the features easier to detect.

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