INTRODUCTION TO DIGITAL IMAGE PROCESSING

GHAZANFAR A. KHATTAK

National Centre of Excellence in Geology
University of Peshawar

Digital Image Processing

is the manipulation of a digital image by computer and is performed either to prepare an image for display and interpretation, or to extract information from the image.

ADVANTAGES OF DIGITAL IMAGE PROCESSING

- Cost-effective for large geographic areas
- Cost-effective for repetitive interpretations
- Cost-effective for standard image formats
- Consistent results
- Simultaneous interpretations of several channels
- Complex interpretation algorithms possible
- Speed may be an advantage
- Compatible with other digital data

DISADVANTAGES OF DIGITAL IMAGE PROCESSING

- Expensive for small areas
- Expensive for one-time interpretations
- Start-up costs may be high
- Requires elaborate, single-purpose equipment
- Accuracy may be difficult to evaluate
- Requires standard image formats
- Data may be expensive, or not available
- Preprocessing may be required
- May require large support staff

MANUAL vs. DIGITAL ANALYSIS

- **MANUAL INTERPRETATION**
- Traditional: intuitive.
  Simple, inexpensive equipment.
  Uses brightness and Spatial content of the image.
  Usually single channel data or three channels at most.
  Subjective, concrete, qualitative.
- **DIGITAL INTERPRETATION**
- Recent: requires specialized training
  Complex, expensive equip.
  Relies chiefly upon brightness and spectral content, limited spatial.
  Frequent use of data from several channels.
  Objective, abstract, quantitative.

Broad Categories of Digital Image Processing (DIP)

(1) Preprocessing

(2) Image Enhancement

(3) Image Transformation

(4) Image Classification

Image Preprocessing:
Radiometric & Geometric Corrections

Image Preprocessing

- Operations are normally required prior to the main data analysis and extraction of information
- Generally grouped **as radiometric or geometric corrections**.

Image Preprocessing

- Geometric Correction
  - include correcting for geometric distortions due to sensor-Earth geometry variations, and conversion of the data to real world coordinates (e.g. latitude and longitude) on the Earth's surface.
- Radiometric Correction
  - include correcting the data for sensor irregularities and unwanted sensor or atmospheric noise, and converting the data so they accurately represent the reflected or emitted radiation measured by the sensor.

Image Enhancement

- Purpose is to improve the appearance of an image to assist in visual interpretation and analysis.
  - Examples include **contrast stretching** to increase the tonal distinction between various features in a scene, and **spatial filtering** to enhance (or suppress) specific spatial patterns in an image.

Image Enhancement

Image transformations

- Usually involve combined processing of data from multiple spectral bands.
  - Arithmetic operations (i.e. subtraction, addition, multiplication, division) are performed to combine and transform the original bands into "new" images which better display or highlight certain features in the scene.
  - Examples include **spectral or band** ratioing, and **principal components analysis** which is used to more efficiently represent the information in multichannel imagery.

Image Classification and Analysis

- Used to digitally identify and classify pixels in the data.
- Usually performed on multi-channel data sets and assigns each pixel in an image to a particular class or theme based on statistical characteristics of the pixel brightness values.

Image Classification

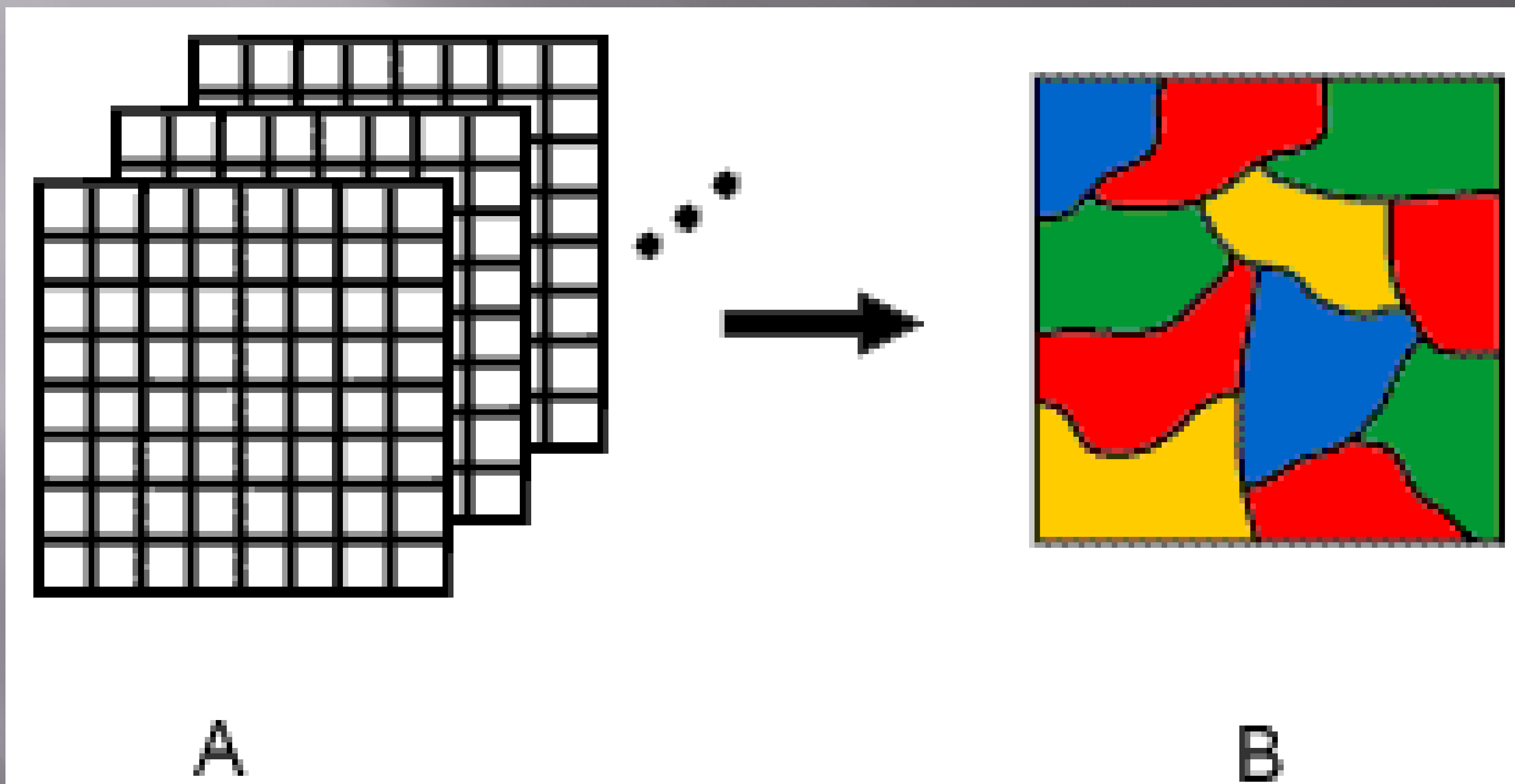


Image Preprocessing

- Sometimes referred to as **image restoration and rectification**
- Intended to correct for sensor- and platform-specific radiometric and geometric distortions of data.

Radiometric Corrections

- Radiometric corrections may be necessary due to variations in scene illumination and viewing geometry, atmospheric conditions, and sensor noise and response.
- Also, it may be desirable to convert and/or calibrate the data to known (absolute) radiation or reflectance units to facilitate comparison between data.

Radiometric Correction

- Various methods ranging from detailed modeling of the atmospheric conditions during data acquisition, to simple calculations based solely on the image data.
- An example of the latter method is dark object subtraction

Dark Object Subtraction

- Examine brightness values in an area of shadow or for a very dark object (such as a large clear lake) and determine the minimum value.
- The correction is applied by subtracting the minimum observed value, determined for each specific band, from all pixel values in each respective band.
- Since scattering is wavelength dependent the minimum values will vary from band to band.
- This method is based on the assumption that the reflectance from these features, if the atmosphere is clear, should be very small, if not zero.
- If we observe values much greater than zero, then they are considered to have resulted from atmospheric scattering.

Dark Object Subtraction

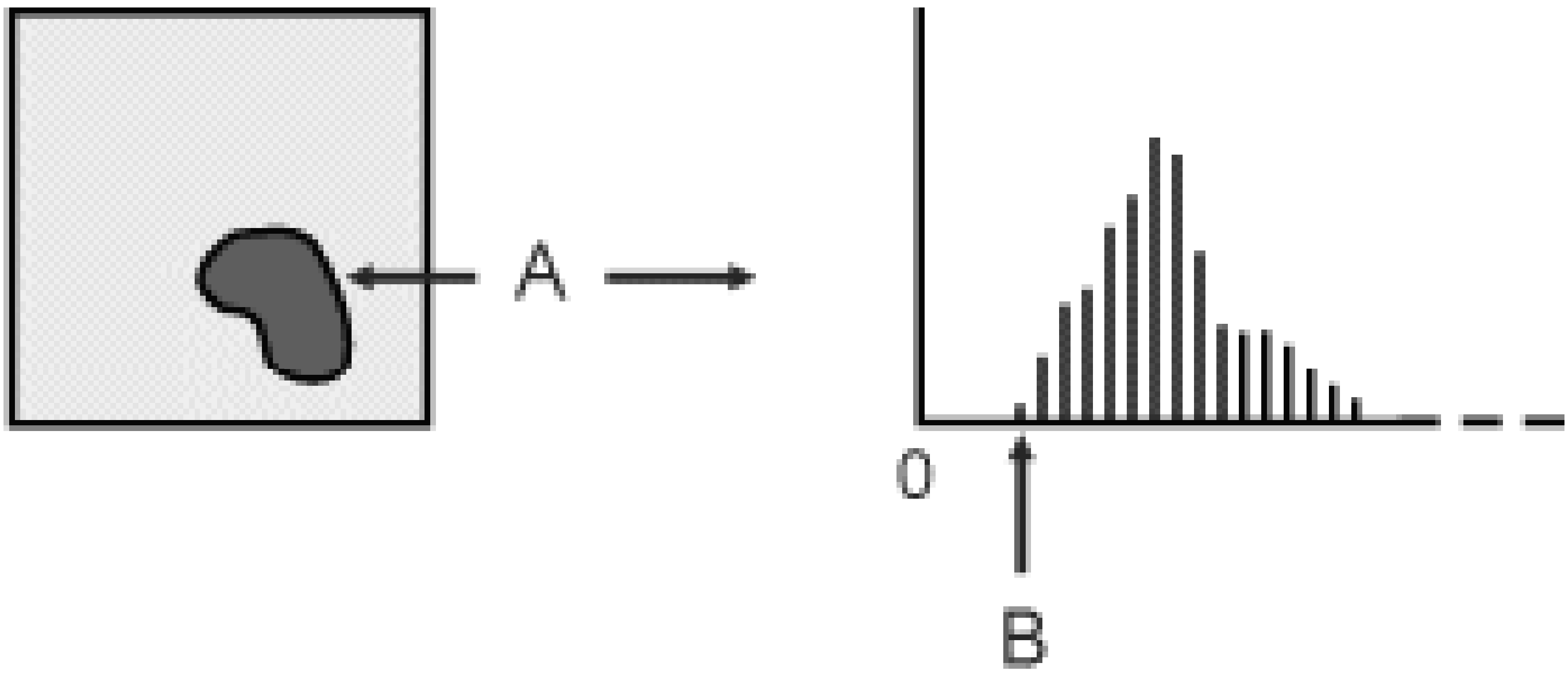


Image Noise Correction

- Noise in an image may be due to errors that occur in the sensor response and/or data recording and transmission.
- Common forms of noise include systematic striping or banding and dropped lines.

Image Striping

- Line striping often occurs due to non-identical detector response.
- Although the detectors for all satellite sensors are carefully calibrated and matched before the launch of the satellite, with time the response of some detectors may drift to higher or lower levels.
- As a result, every scan line recorded by that detector is brighter or darker than the other lines

Image Striping

- Striping was common in early Landsat MSS data
- Due to variations and drift in the response over time of the six MSS detectors.
- The 'drift' was different for each of the six detectors, causing the same brightness to be represented differently by each detector.
- The corrective process made a relative correction among the six sensors to bring their apparent values in line with each other.

Image Striping

Dropped Lines

- Occur when there are systems errors which result in missing or defective data along a scan line.
- Dropped lines are normally 'corrected' by replacing the line with the pixel values in the line above or below, or with the average of the two.

Dropped Lines

Calculating Reflectance

- Often it is necessary to convert the DNs to actual reflectance from the surface.
- Based on detailed knowledge of the sensor response and the way in which the analog signal (i.e. the reflected or emitted radiation) is converted to a digital number, (**analog-to-digital** (A-to-D) conversion).

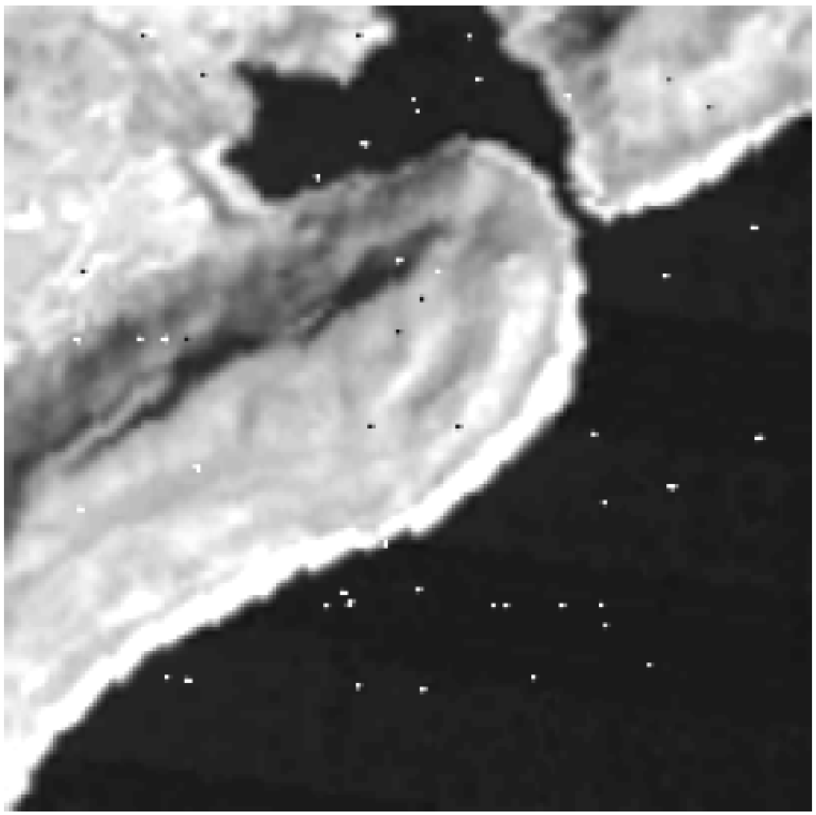
Random noise or spike noise

- The periodic line dropouts and striping are forms of non-random noise that may be recognized and restored by simple means.
- Random noise, on the other hand, requires a more sophisticated restoration method such as digital filtering.

Random noise or spike noise

- Random noise or spike noise may be due to errors during transmission of data or to a temporary disturbance.
- Individual pixels acquire DN-values that are much higher or lower than the surrounding pixels.
- In the image, these pixels produce bright and dark spots that interfere with information extraction procedures.

Random noise or spike noise



34	27	20	17	17	19	20	21	22	21	19	18	16	17	22
28	21	16	15	17	18	18	18	20	204	16	14	14	17	24
23	17	14	14	15	16	15	15	17	16	13	12	14	19	28
17	14	13	12	13	12	11	12	14	13	11	12	17	25	34
13	12	12	11	11	11	10	12	16	15	13	16	23	31	40
11	11	11	11	11	11	12	15	22	23	21	24	31	39	46
10	11	180	11	11	12	16	20	28	31	29	32	39	46	51
10	11	11	11	13	16	22	28	36	39	39	42	47	52	55
10	11	11	13	17	23	30	36	42	45	45	48	51	55	57
10	11	13	17	25	33	40	45	47	48	48	50	53	55	57
15	18	21	26	33	40	47	50	50	50	50	51	54	55	57
25	31	36	40	42	46	49	50	50	50	50	51	54	55	57
33	40	45	47	48	49	51	51	50	50	8	52	54	55	57
39	44	47	49	50	51	53	53	51	50	50	52	54	55	57
43	47	49	50	51	52	54	54	52	51	51	51	53	55	57
46	48	50	51	53	54	55	54	52	51	51	51	53	55	57
48	50	52	53	55	0	56	55	53	51	50	50	52	55	57
50	52	120	55	57	58	58	56	54	51	50	50	52	55	58
51	53	55	57	58	59	59	57	55	52	49	49	51	54	59
52	54	56	58	58	59	59	57	55	52	49	49	51	2	59
53	55	57	59	58	58	58	57	55	52	48	49	52	55	61

Geometric Distortions

- Can be due to several factors, including:
  - the perspective of the sensor optics;
  - the motion of the scanning system;
  - the motion of the platform;
  - the platform altitude, attitude, and velocity;
  - the terrain relief;
  - and, the curvature and rotation of the Earth.

Geometric Correction

Intended to compensate for these distortions so that the geometric representation of the imagery will be as close as possible to the real world.

Geometric Rectification

- Removing geometric errors in an image

Geometric Registration

- Assiging image coordinates to the real world either map, field, or other image.

Geometric Registration Process

- Involves identifying the image coordinates of several clearly discernible points, called **ground control points** (or **GCPs**), in the distorted image and matching them to their true positions in ground coordinates (e.g. latitude, longitude).

Ground Control Points

- The true ground coordinates are typically measured from a map.
- This is **image-to-map registration**.
- Geometric registration may also be performed by registering one (or more) images to another image, instead of to geographic coordinates. This is called **image-to-image registration**

Geometric Registration

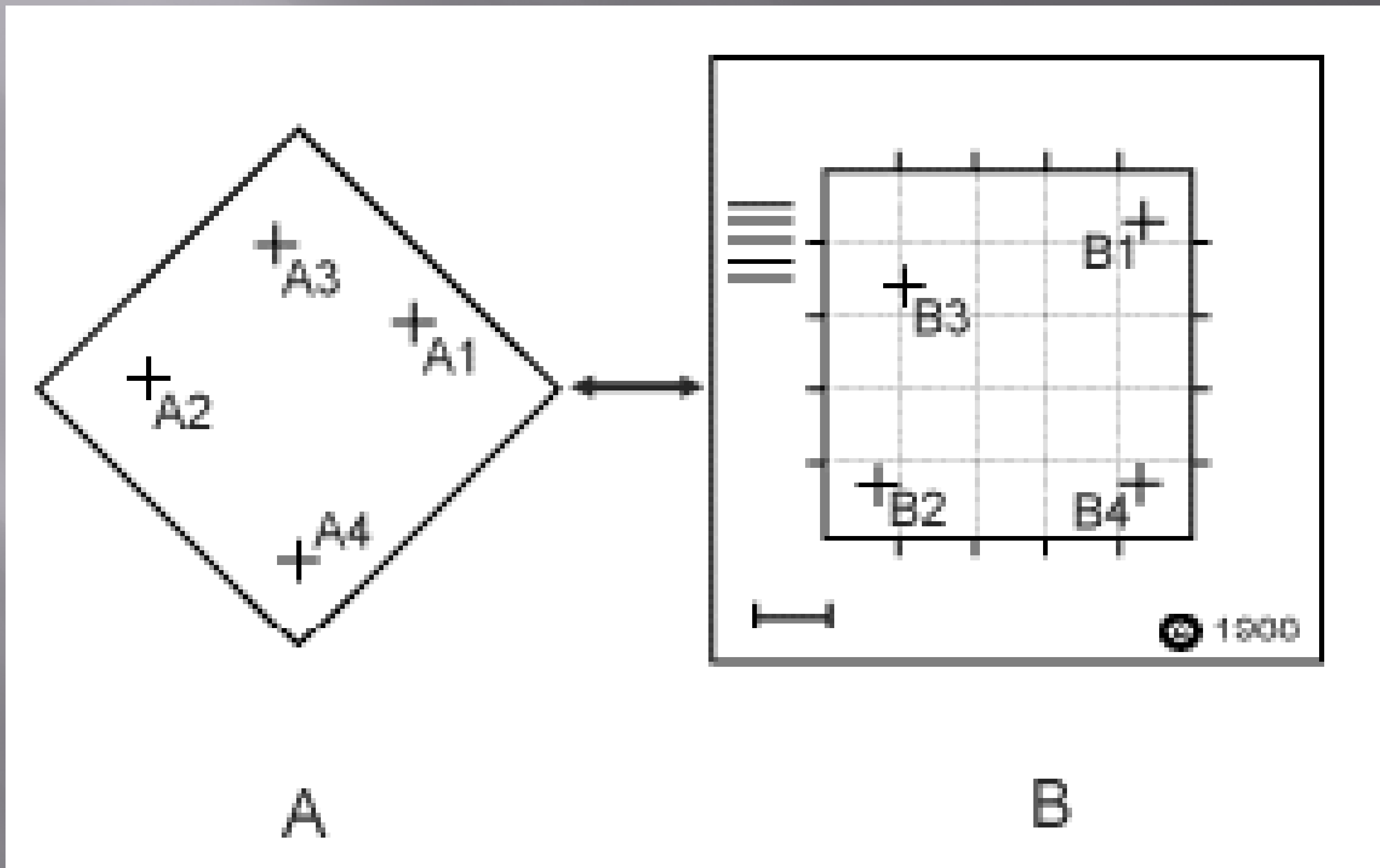


Image Resampling

- In order to actually geometrically correct the original distorted image, a procedure called **resampling** is used to determine the digital values to place in the new pixel locations of the corrected output image.

Image Resampling

- *3 common methods:*

  (1) nearest neighbor,

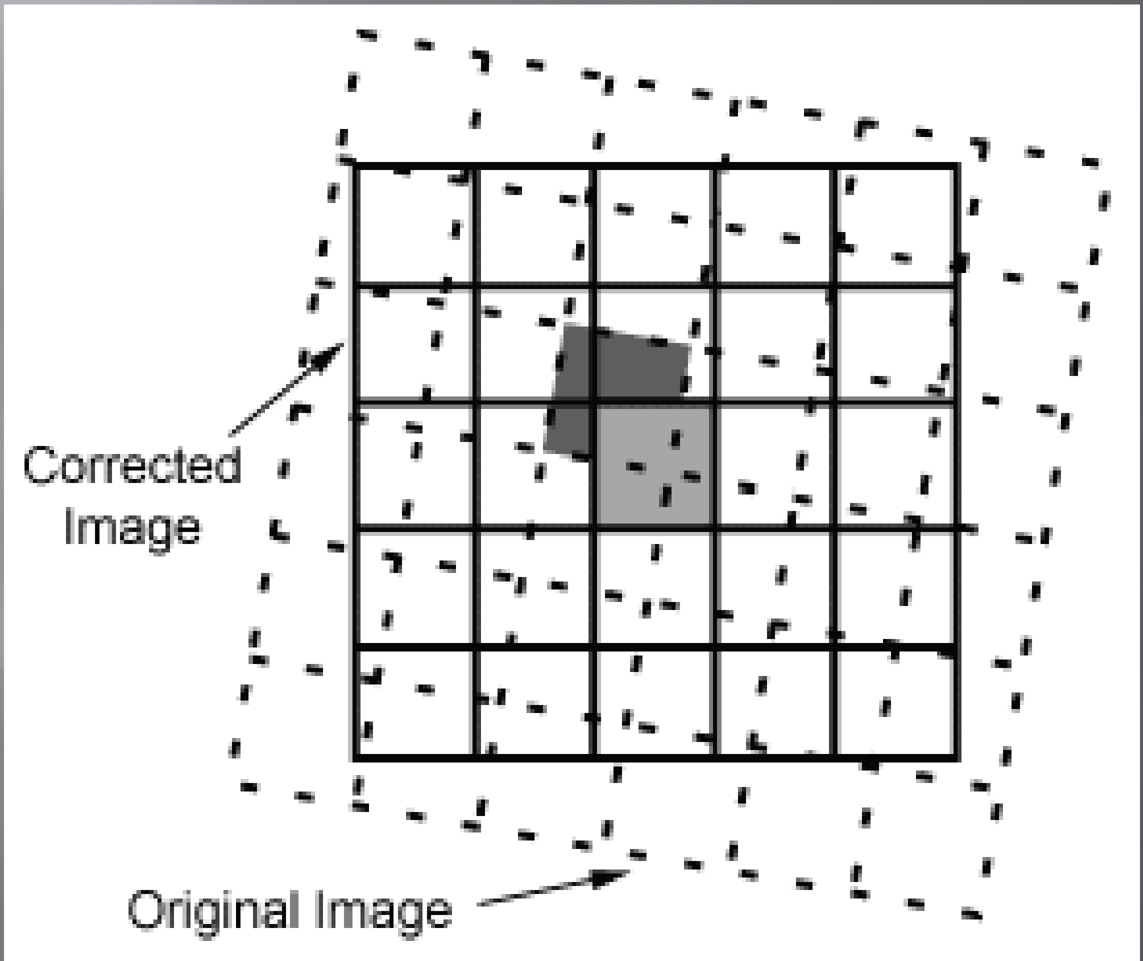
  (2) bilinear interpolation

  (3) cubic convolution

Nearest Neighbor

- Uses the digital value from the pixel in the original image which is nearest to the new pixel location in the corrected image.

Nearest Neighbor



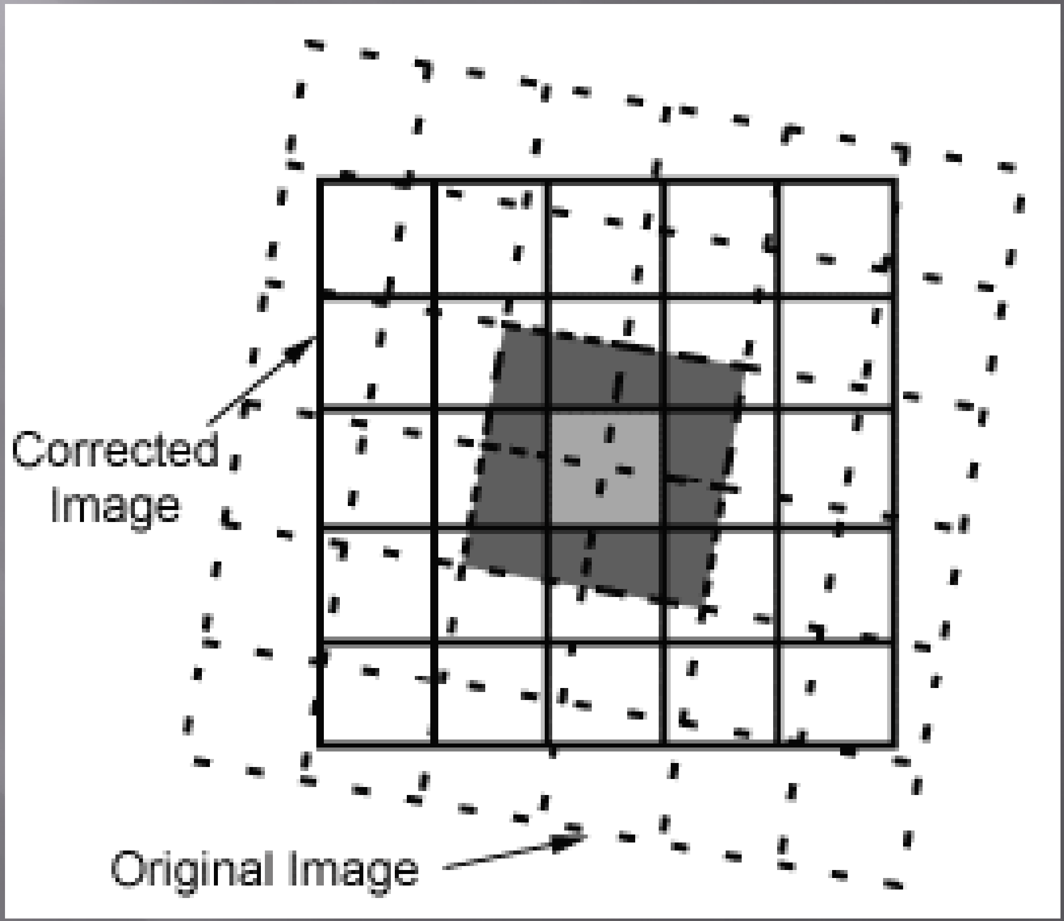
Nearest Neighbor

- Does not alter the original values,
  - May result in some pixel values being duplicated while others are lost.
- Tends to result in a disjointed or blocky image appearance.

Bilinear Interpolation

- Takes a weighted average of four pixels in the original image nearest to the new pixel location.

Bilinear Interpolation



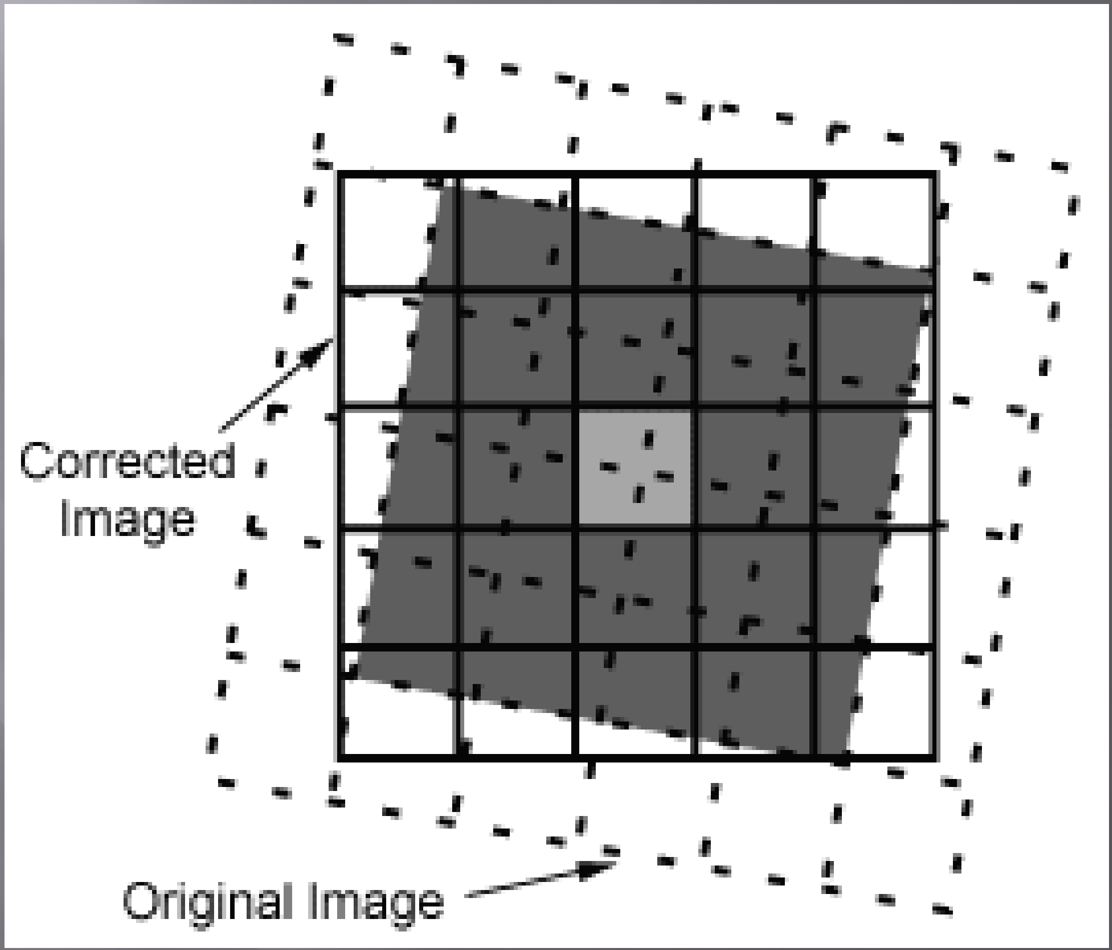
Bilinear Interpolation

- Alters the original pixel values and creates entirely new digital values in the output image.
  - This may be undesirable if further processing and analysis based on spectral response, such as classification, is to be done.
    - If this is the case, resampling may best be done after the classification process.

Cubic Convolution

- Calculates a distance weighted average of a block of sixteen pixels from the original image which surround the new output pixel location.

Cubic Convolution



Cubic Convolution

- Results in completely new pixel values.
- Bilinear Interpolation and Cubic Convolution both produce images which have a much sharper appearance and avoid the blocky appearance of the nearest neighbor method