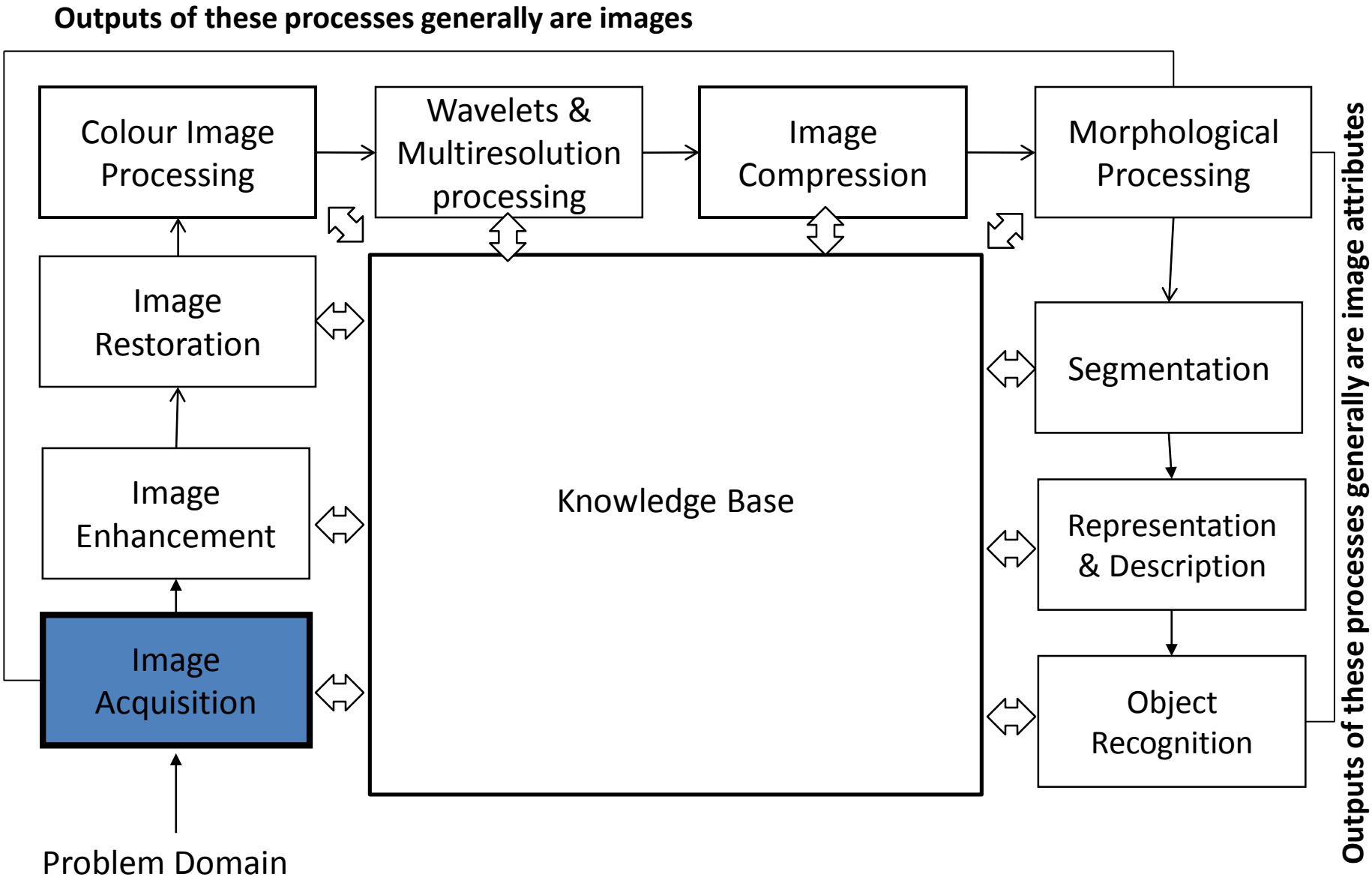
Fundamental Steps in Digital Image Processing:



Fundamental Steps in Digital Image Processing:

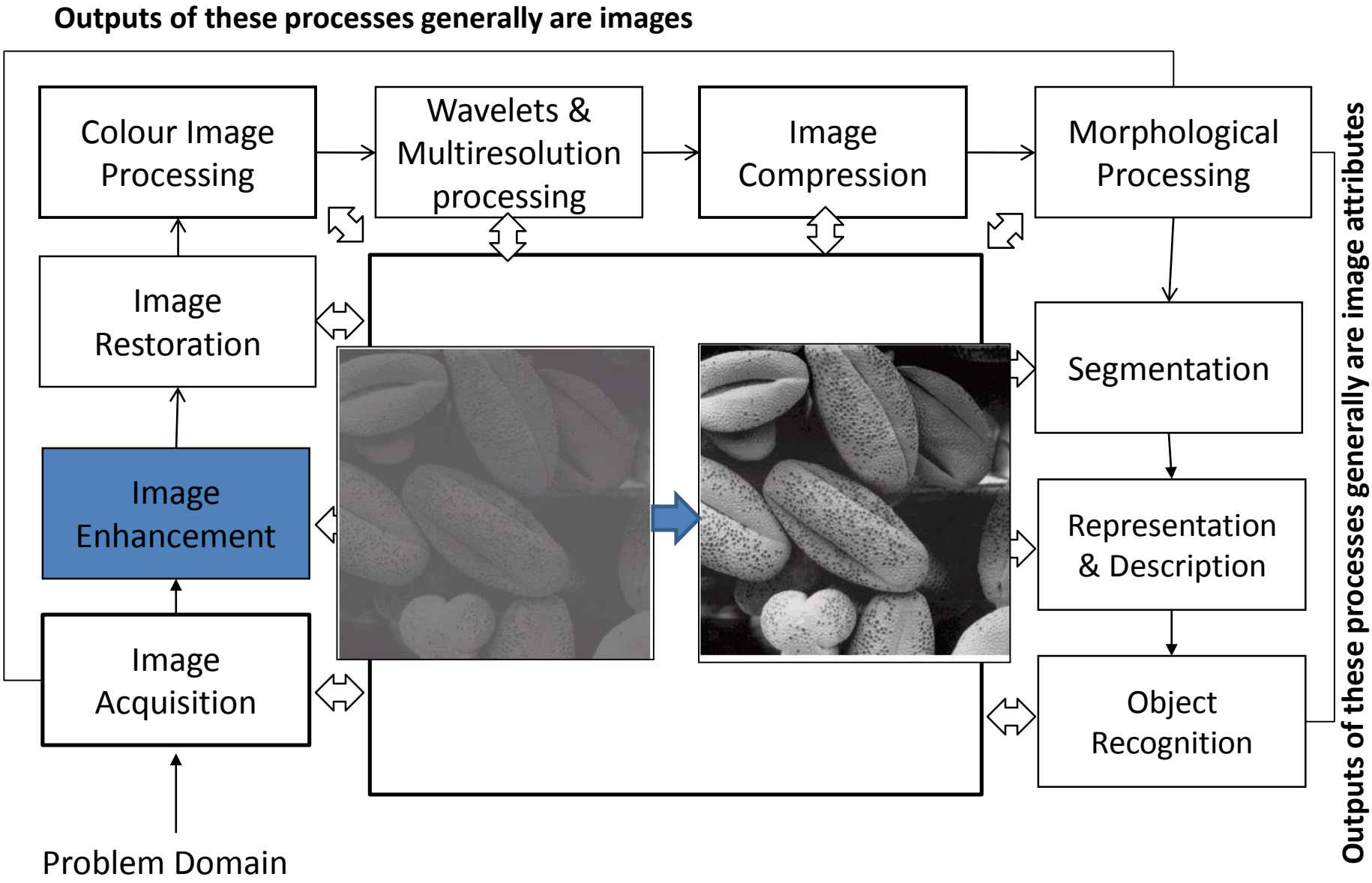


Image Enhancement

Images may suffer from the following degradations:

- **Poor contrast** due to poor illumination or finite sensitivity of the imaging device.
- **Electronic sensor noise** or **atmospheric disturbances** leading to broad band noise.
- **Aliasing** effects due to inadequate sampling.

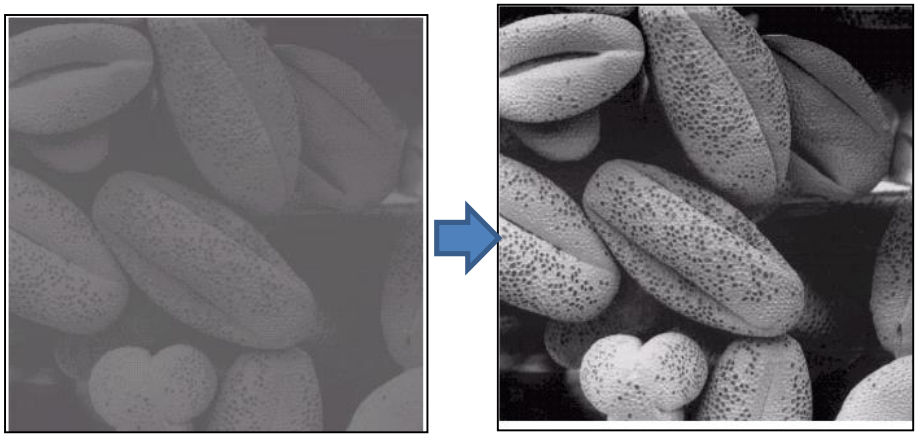


Image Enhancement: Reason

Image enhancement is the process of making images more useful.

- Highlights the **interesting details** in images.
- **Removes noise** from images.
- Makes images more **visually appealing**.
- **Improves the interpretability** or perception of information in images for human viewing.
- Provides **better input** for other automated image processing techniques.

Image Enhancement: Methods

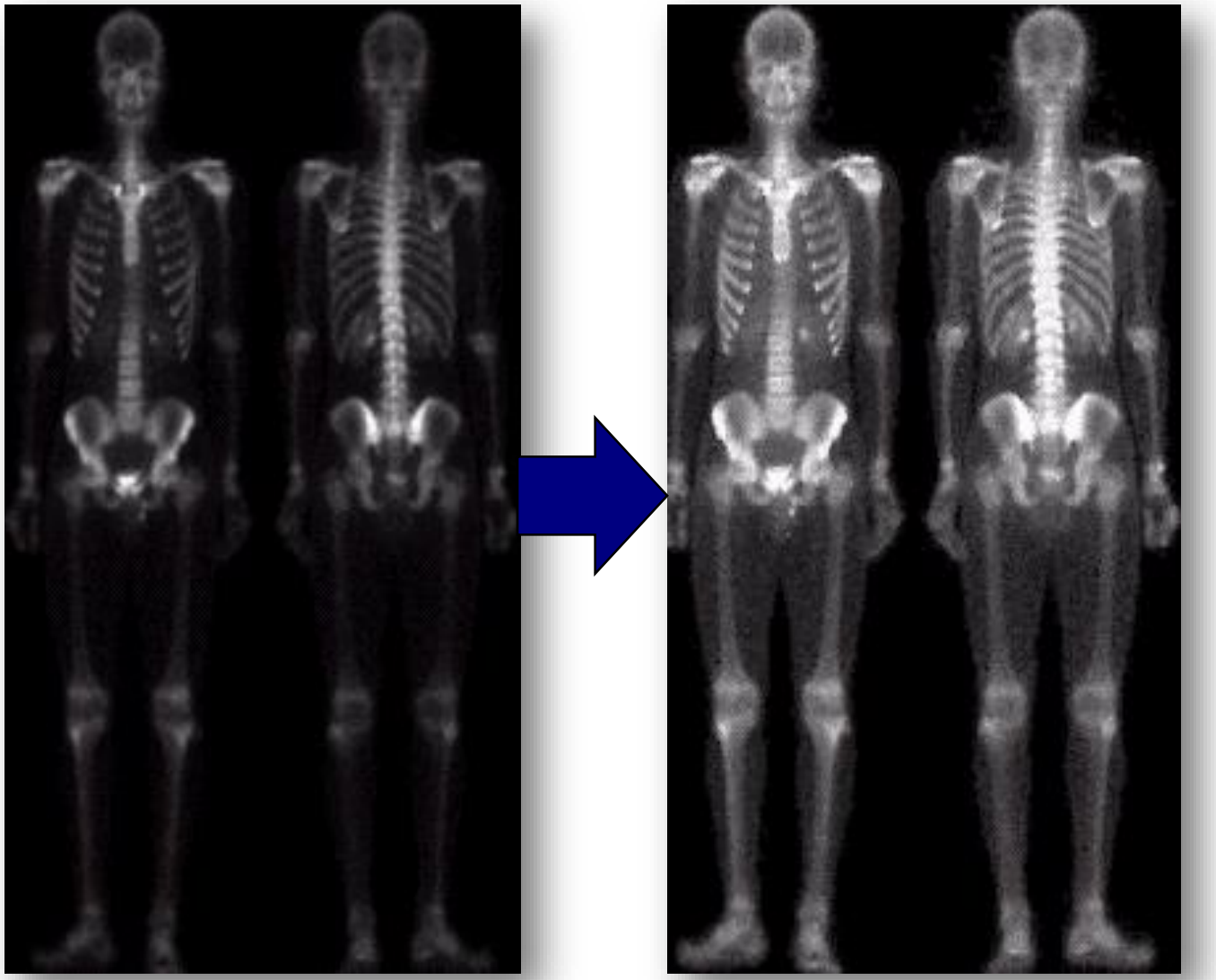
Spatial Based

- Basic point processing
- Power-Law Transformations
- Gamma Correction
- Contrast Stretching
- Histogram Equalization

Frequency Based

- Unsharp masking
- Homomorphic filtering

Image Enhancement: Examples



Fundamental Steps in Digital Image Processing:

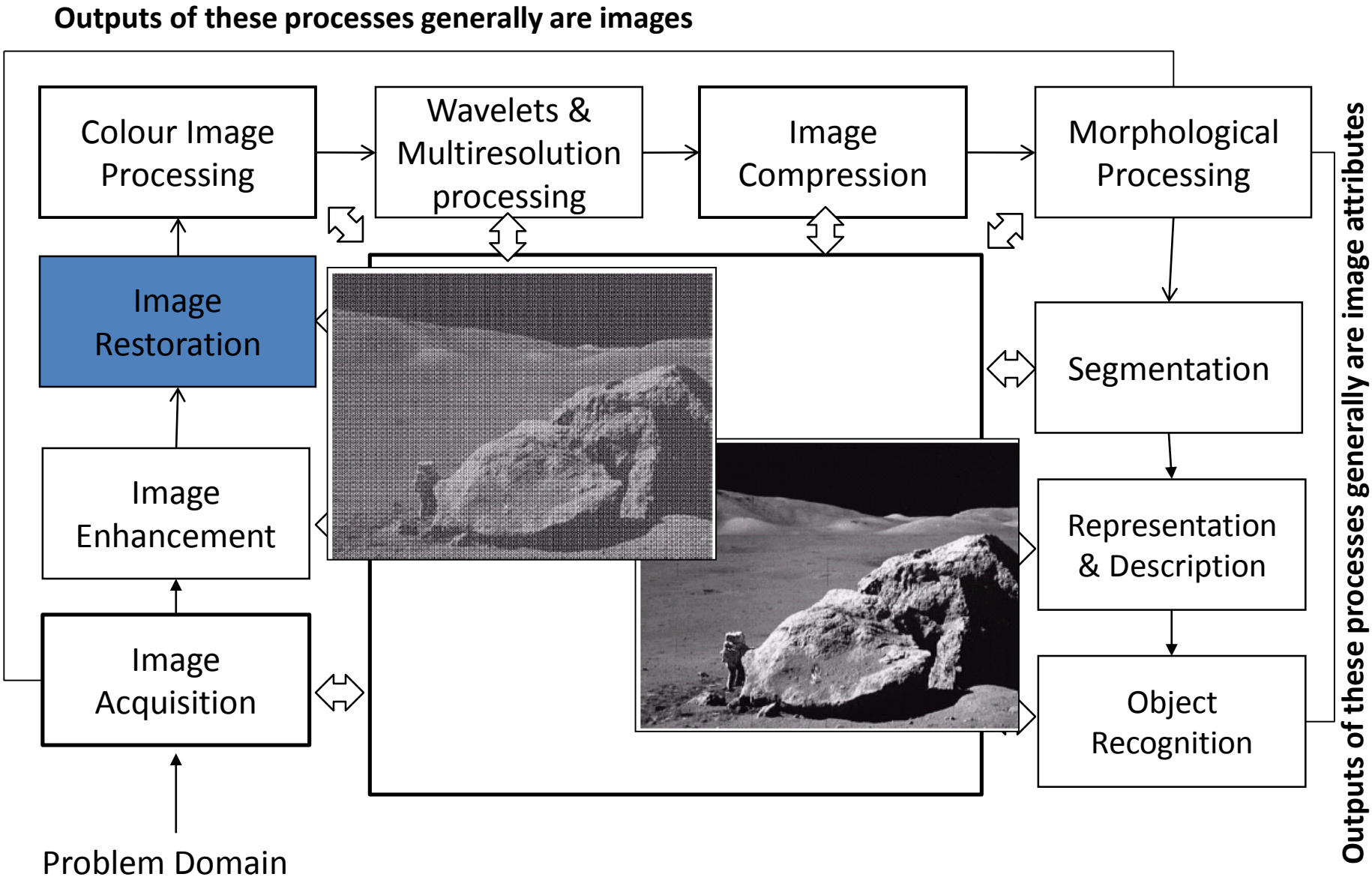


Image Restoration: Sources of noise

The sources of noise in digital images arise during image acquisition (digitization) and transmission

- **Imaging sensors** can be affected by ambient conditions.
- **Interference** can be added to an image during acquisition or transmission.

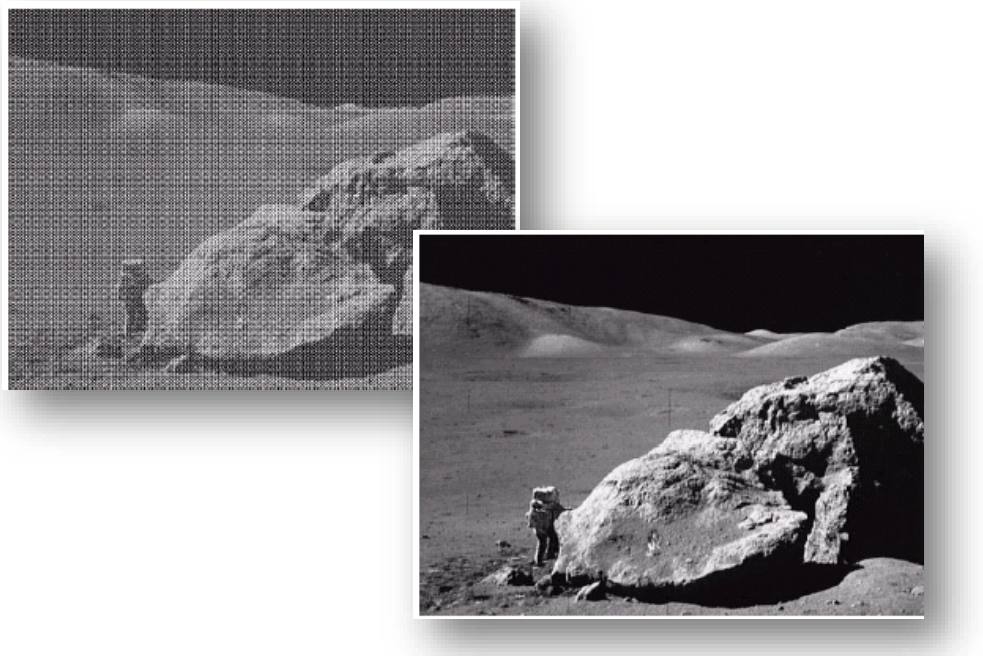


Image Restoration: Types of noise

- Impulse Noise (Salt and Pepper Noise)
- Gaussian Noise
- Addition Noise
- Image Blur
- Erlang (Gamma) noise
- Exponential noise
- Uniform noise
- Periodic noise

Image Restoration

Image restoration attempts to restore images that have been degraded

- Identify the degradation process and attempt to reverse it
- Similar to image enhancement, but more objective

$$g(x,y) = f(x,y) + \eta(x,y)$$

Image Restoration: Methods

Mean Filters

- Arithmetic Mean Filter
- Geometric Mean
- Harmonic Mean
- Contraharmonic Mean

Additional Features

- Band Reject Filters
- Adaptive Filters
- Adaptive Mean Filters

Spatial Filters

- Median filter
- Max and min filter
- Midpoint filter
- Alpha trimmed mean filter

Image Restoration Vs Image Enhancement

Enhancement:

- Priori knowledge about the degradation is not a must
- Procedures are heuristic and take advantage of the psychophysical aspects of human visual system

Restoration:

- Images are degraded
- Tries to recover the images by using the knowledge about the degradation

Image Restoration

Original

Optical

Motion

Spatial Quantization

Additive Intensity Noise

Fundamental Steps in Digital Image Processing:

Outputs of these processes generally are images

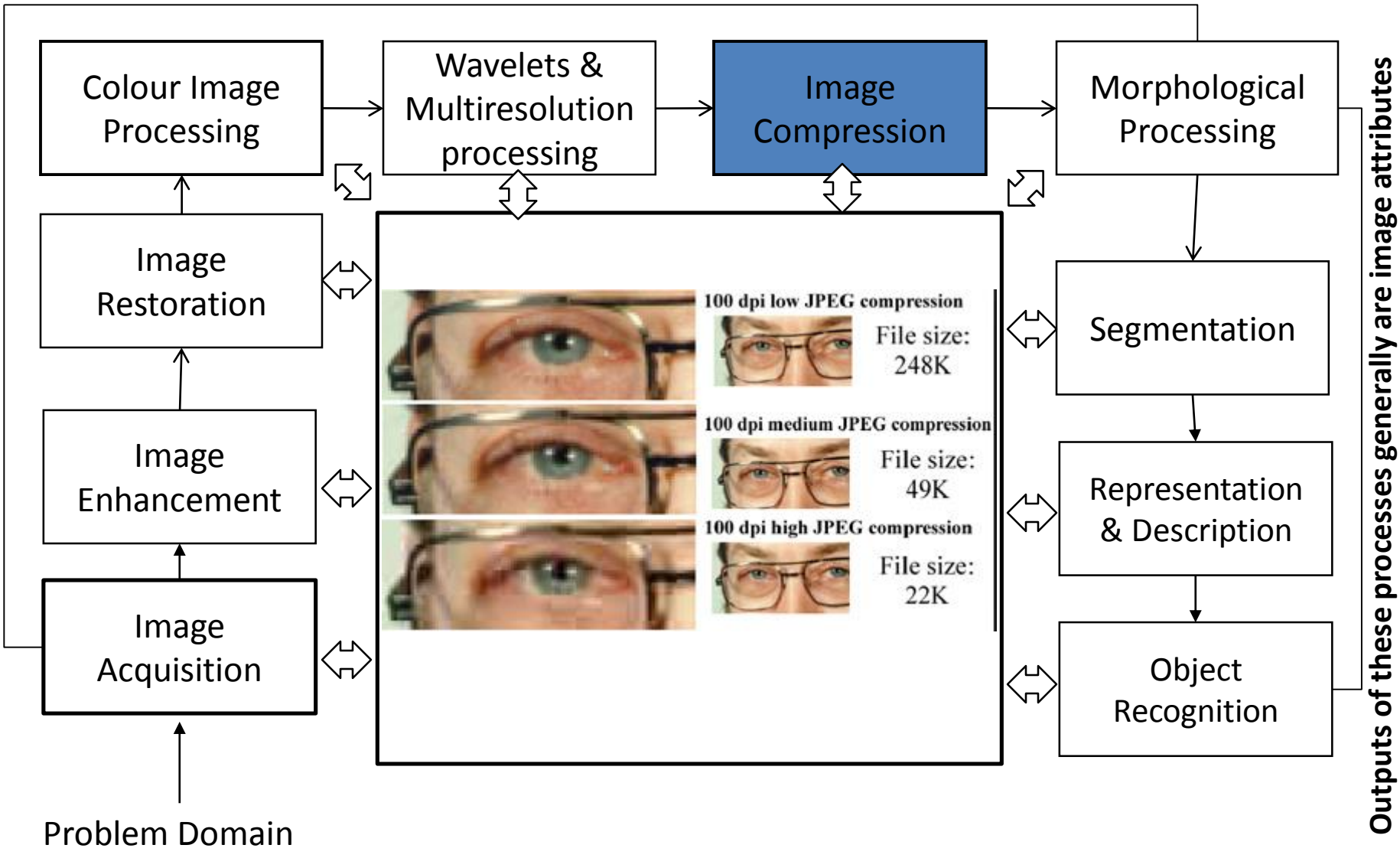


Image Compression

- The term data compression refers to the process of **reducing the amount of data** required to represent a given quantity of information
- Data might contain elements that provide **no relevant information**
- **Data redundancy** is a central issue in image compression. It is not an abstract concept but mathematically quantifiable entity

Image Compression

1. **Fundamentals**
   - Coding Redundancy
   - Interpixel Redundancy
   - Psychovisual Redundancy
   - Fidelity Criteria

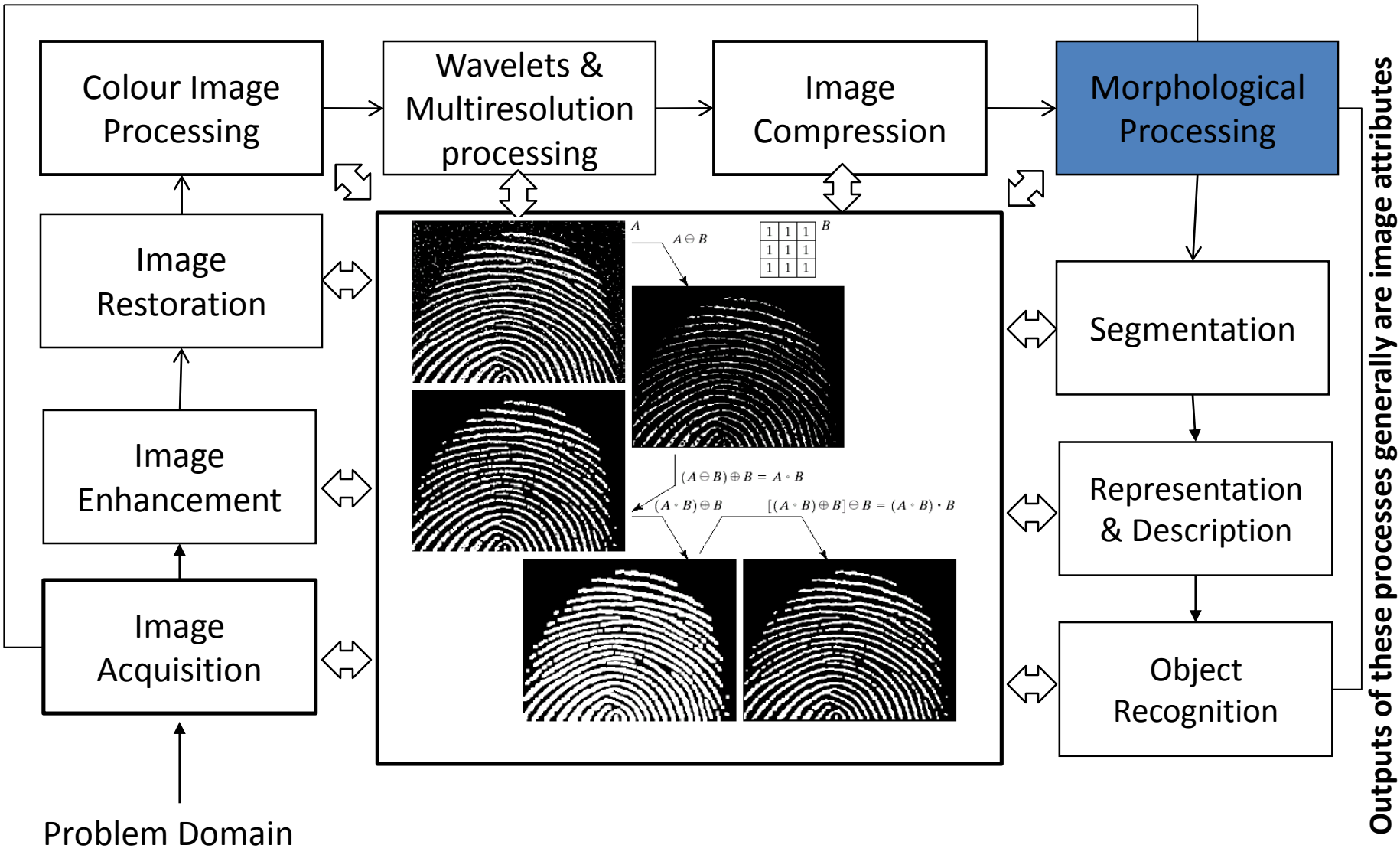
2. **Error-Free Compression**
   - Variable-length Coding
   - LZW Coding
   - Predictive Coding

3. **Lossy Compression**
   - Transform Coding
   - Wavelet Coding

4. **Image Compression Standards**

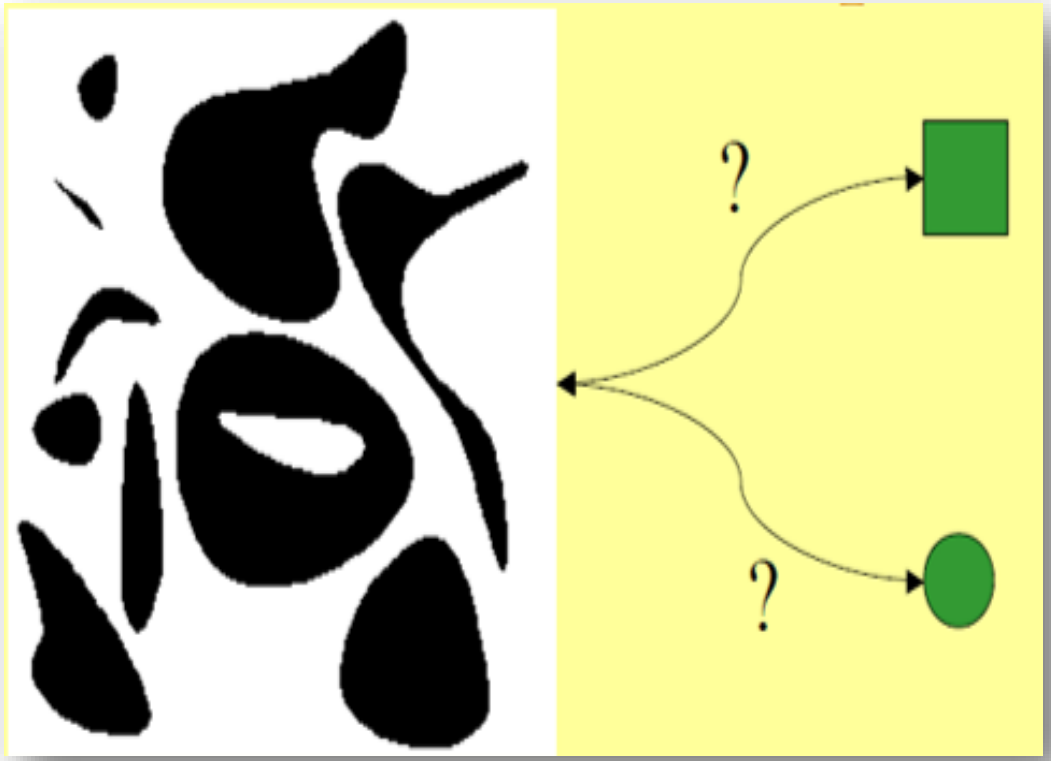
Fundamental Steps in Digital Image Processing:

Outputs of these processes generally are images



Morphological Processing

Once segmentation is complete, morphological operations can be used to remove **imperfections** in the segmented image and provide information on the form and structure of the image



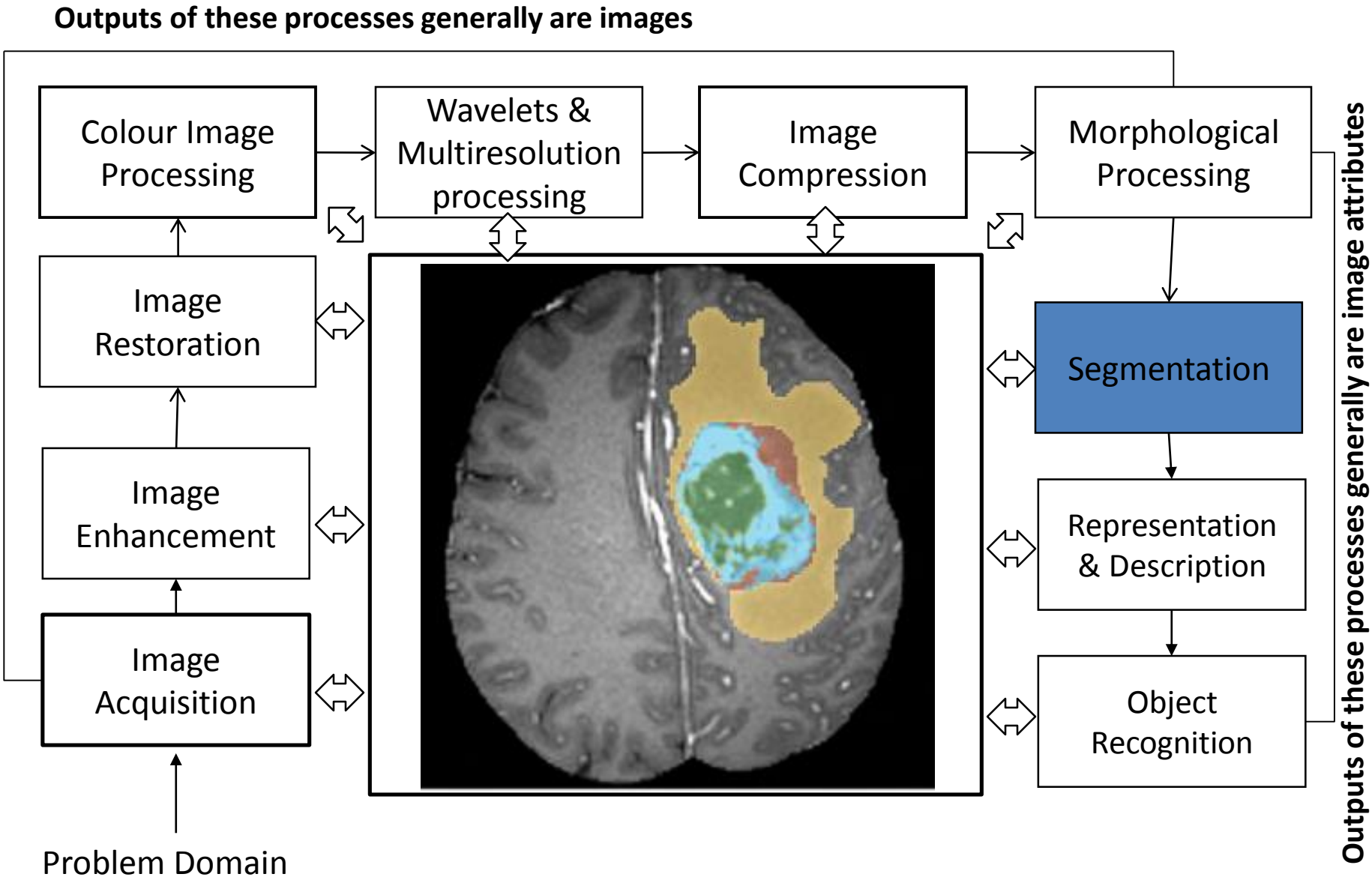
- Study of shape in an image
- Uses a Structural Element (SE) as a probe

Morphological Processing: Example

Image after segmentation

Image after segmentation and morphological processing

Fundamental Steps in Digital Image Processing:



Segmentation

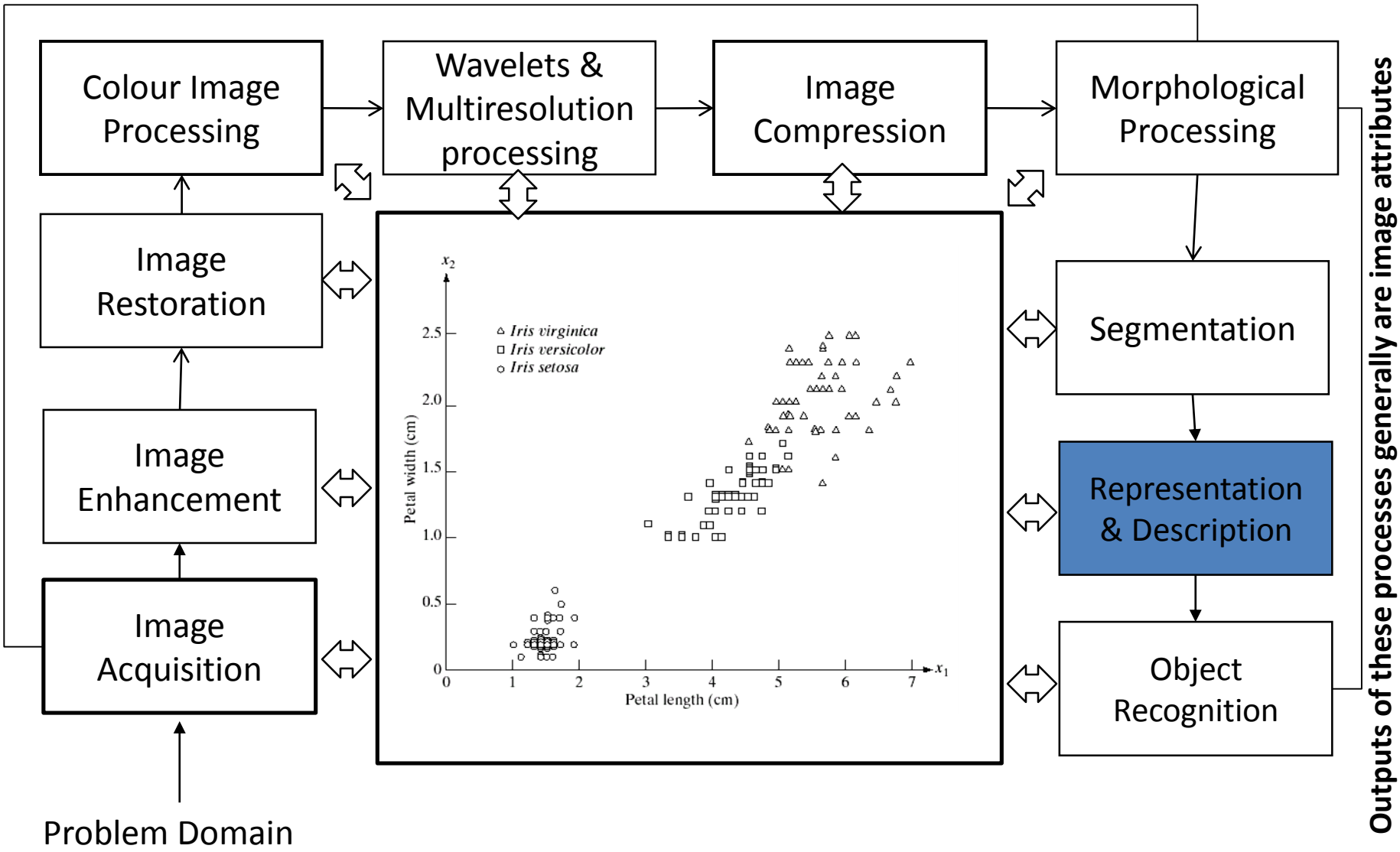
- The purpose of image segmentation is to **partition** an image into ***meaningful* regions** with respect to a particular application.
- Applications of image segmentation include
  - Identifying objects in a scene for **object-based measurements** such as **size and shape**.
  - Identifying objects in a moving scene for ***object-based video compression***
  - Identifying objects which are at different distances from a sensor using **depth measurements** from a laser range finder enabling path planning for a mobile robots.

Segmentation: Methods

- **Thresholding**
  - Basic Global Thresholding
  - Otsu's Method
  - Multiple Threshold
  - Variable Thresholding
- **Edge-based segmentation**
  - Basic Edge Detection
  - The Marr-Hildreth edge detector(LoG)
  - Short response Hilbert transform(SRHLT)
  - Watersheds
- **Region-based segmentation**
  - Region Growing
  - Data Clustering (Hierarchical clustering)
  - Partitional clustering
  - Cheng-Jin Kuo`s method

Fundamental Steps in Digital Image Processing:

Outputs of these processes generally are images



Representation & Description

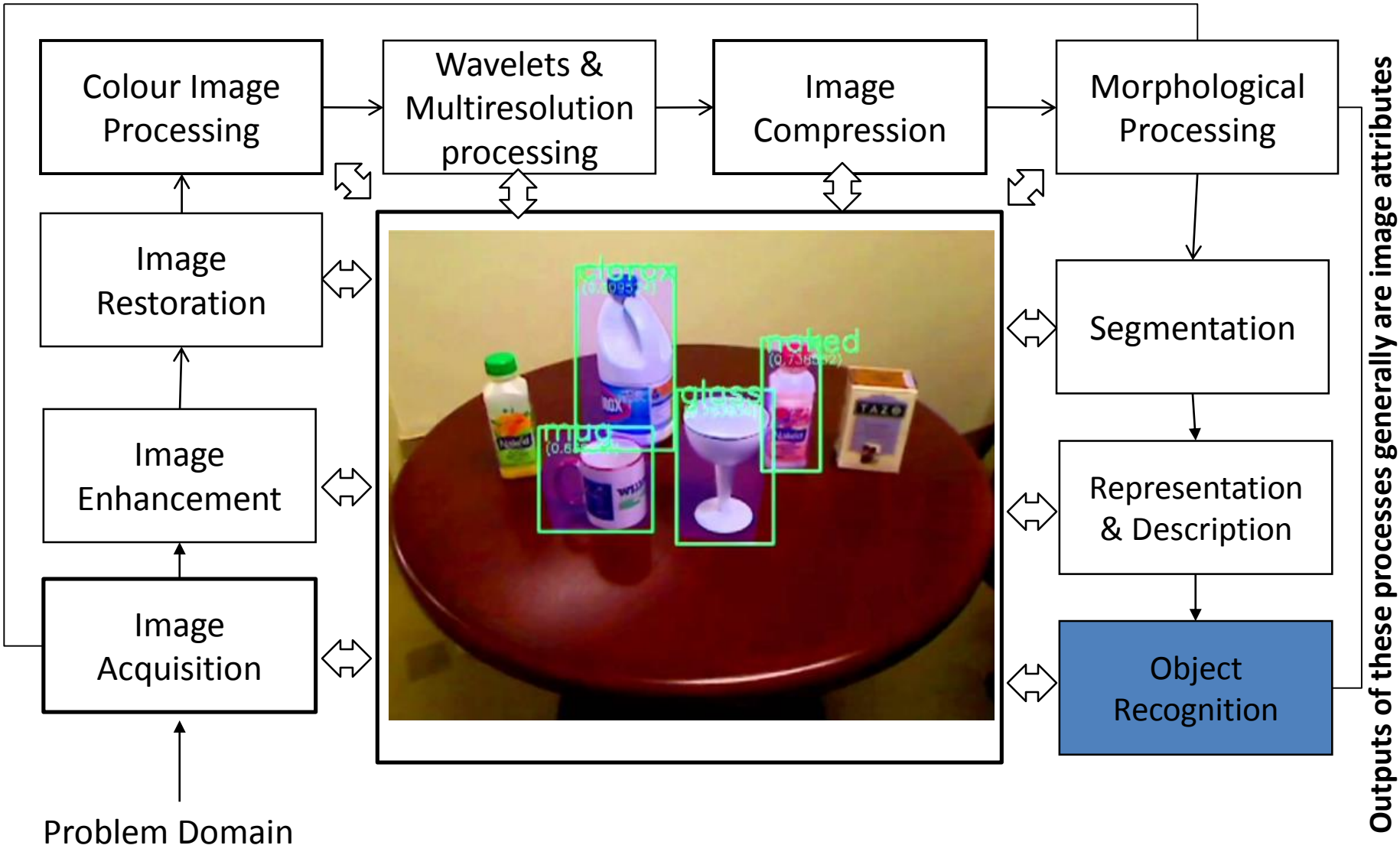
Representation: Make a decision whether the data should be represented as a boundary or as a complete region. It is almost always follows the output of a segmentation stage.

- **Boundary Representation:** Focus on external shape characteristics, such as corners and inflections
- **Region Representation:** Focus on internal properties, such as texture or skeleton shape

Description: also called, ***feature selection***, deals with extracting attributes that result in some information of interest.

Fundamental Steps in Digital Image Processing:

Outputs of these processes generally are images



Object Recognition

Given some knowledge of how certain objects may appear and an image of a scene possibly containing those objects, report **which** objects are present in the scene and **where.**

Recognition should be:

- invariant to view point changes and object transformations
- robust to noise and occlusions

Object Recognition: Challenges

View Point Variation

Michelangelo 1475-1564

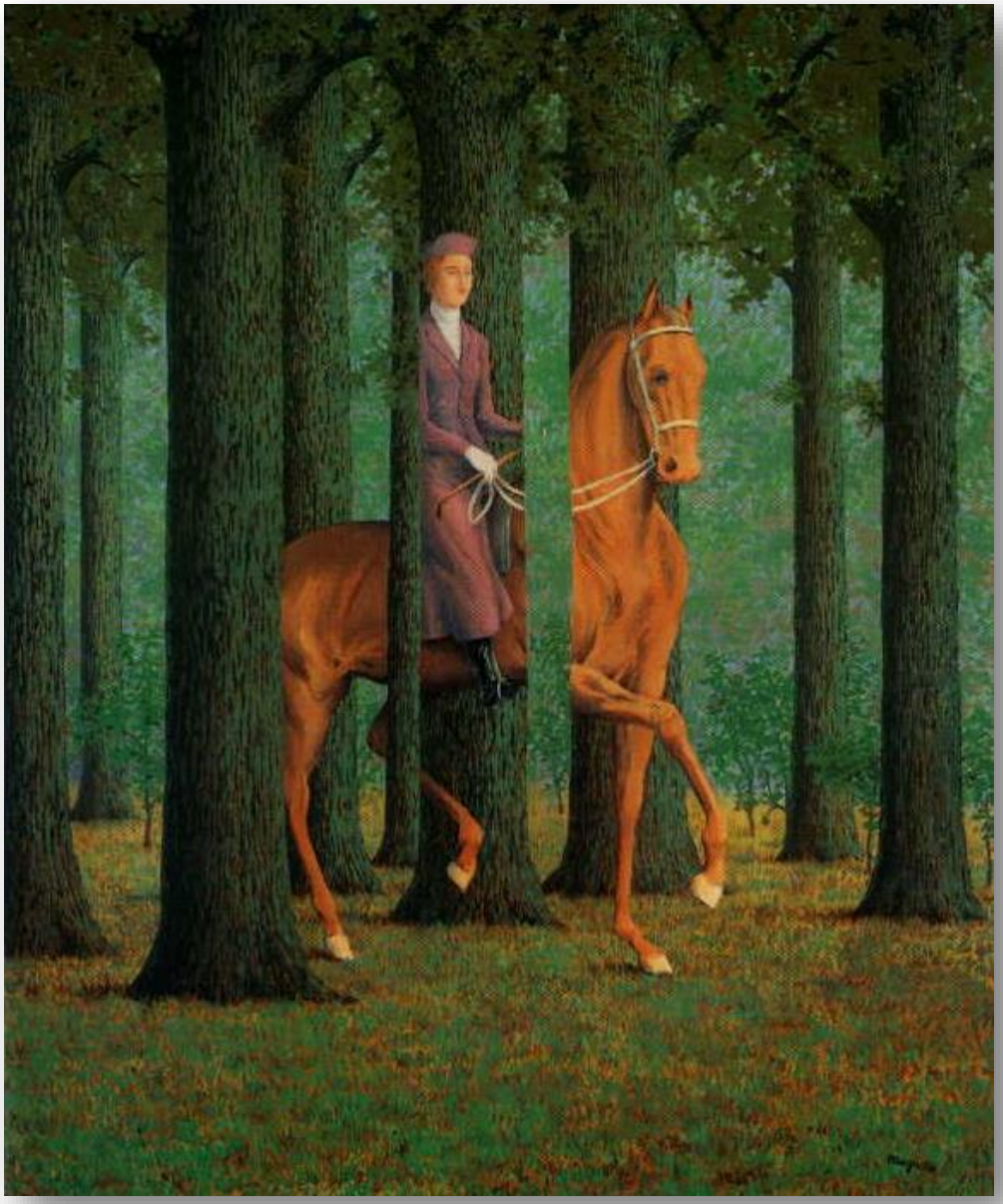
Object Recognition: Challenges

Illumination

slide credit: S. Ullman

Object Recognition: Challenges

Occlusion



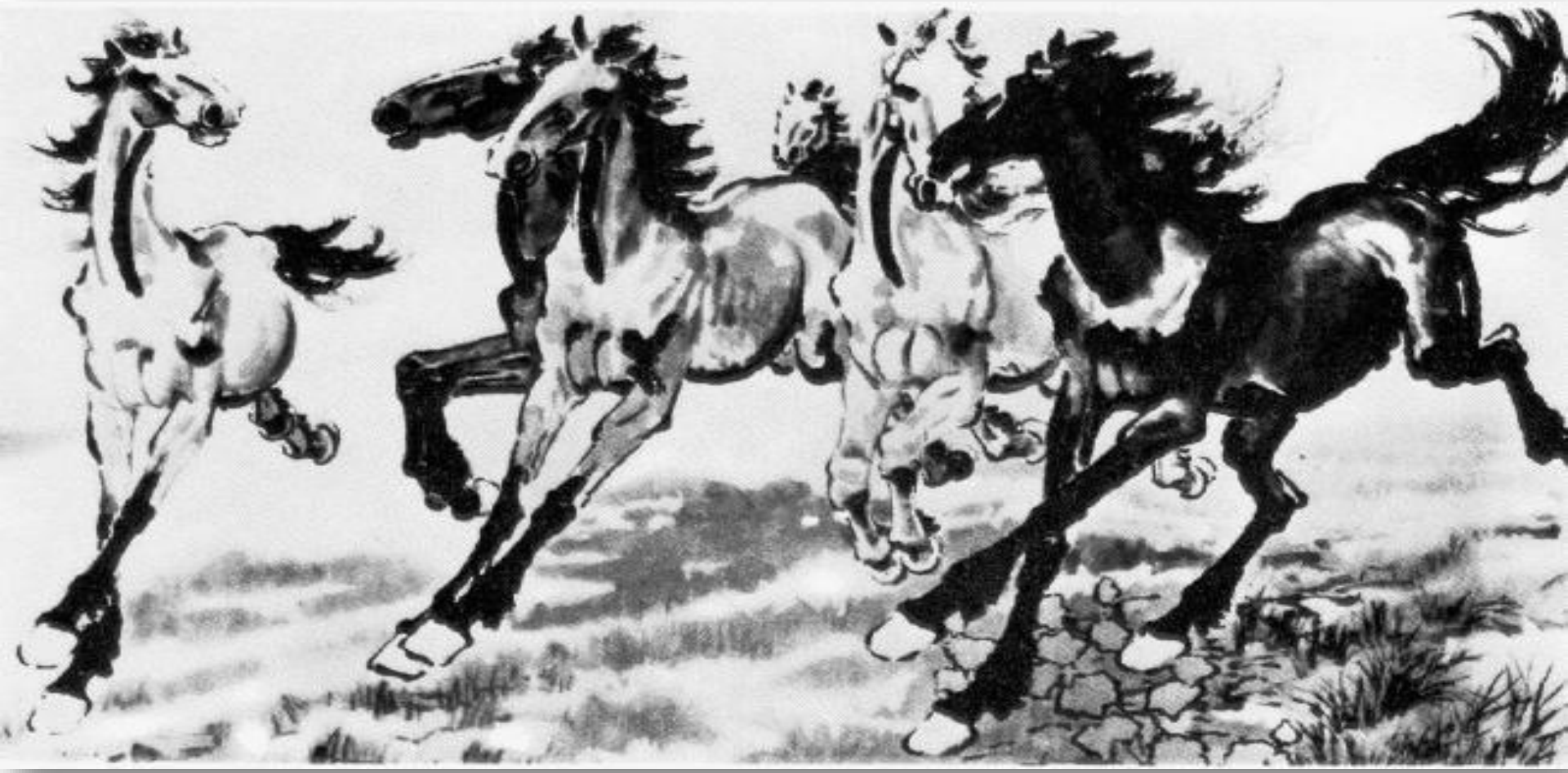
Magritte, 1957

Object Recognition: Challenges

Scaling

Object Recognition: Challenges

Deformation



Xu, Beihong 1943

Object Recognition: Challenges

Background Clutter

Klimt, 1913

Object Recognition: Approaches Differ

- **Knowledge they employ**
  - Model-based approach (i.e., based on explicit model of the object's shape or appearance)
  - Context-based approach (i.e., based on the context in which objects may be found)
  - Function-based approach (i.e., based on the function for which objects may serve)

- **Restrictions on the form of the objects**
  - 2D or 3D objects
  - Simple vs complex objects
  - Rigid vs deforming objects

- **Image formation model**
  - Perspective projection
  - Orthographic projection + scale

- **Representation schemes**
  - Object-centered
  - Viewer-centered

- **Matching scheme**
  - Geometry-based
  - Appearance-based

Object Recognition: Applications

- Quality control and assembly in industrial plants.
- Robot localization and navigation.
- Monitoring and surveillance.
- Automatic exploration of image databases.