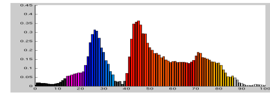
Dr. Qadri Hamarsheh



Digital Image Processing (750474)

Lecture 9

Intensity Transformation and Spatial Filtering

Outline of the Lecture

- **Introduction.**
- **Intensity Transformation Functions.**
- **Piecewise-Linear Transformation Functions.**

Introduction

Definition:

Image enhancement is the process that improves the quality of the image for a specific application.

Image enhancement methods:

1. **Spatial domain methods** (image plane)

Techniques are based on direct manipulation of pixels in the image.

2. **Frequency domain methods**

Techniques are based on modifying the Fourier transform of the image.

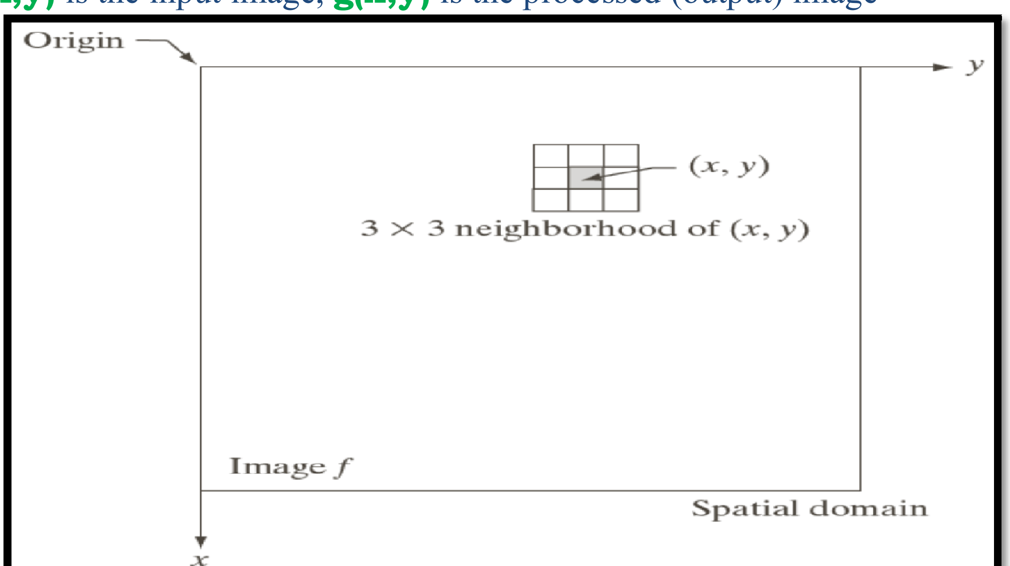
3. **Combinations methods:**

There are some enhancement techniques based on various combinations of methods from the two first categories.

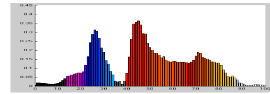
- **Procedures** that operate directly on pixels (spatial domain) can be denoted by the expression:

$$g(x,y) = T[f(x,y)].$$

Where: **f(x,y)** is the input image, **g(x,y)** is the processed (output) image



T-is an operator on **f(x,y)** defined over some neighbourhood of **(x,y)**



Mask/Filter: neighbourhood of a point **(x, y)** can be used, by using a square/ rectangular (common used) or circular sub image area centred at **(x, y).**
The **center** of the sub image is moved from pixel to pixel starting at the of the corner

Intensity Transformation Functions

Point processing:

- ***Neighborhood***: **1*1 pixel.**
- **g** depends on only the value of **f** at **(x,y).**
- And **T** becomes an **intensity transformation function** (***gray-level or mapping function***) of the form:

$$S = T(r)$$

Where: **r=** gray level of **f (x,y)**
S = gray level of **g(x,y)**

T- Is a function that maps r to S

Intensity transformation example:

1. **Contrast stretching:** (*Normalization*)

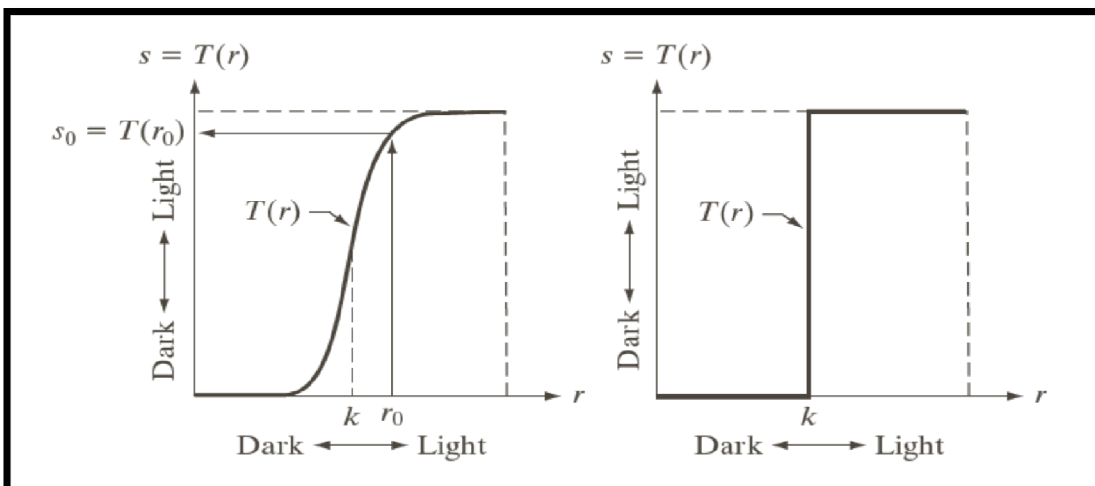
If **T(r)** has the form as shown in figure, the effect of applying the transformation to every pixel of **f** to generate the corresponding pixels in **g** would:

- Produce ***higher contrast*** than the original by:
- ***Darkening*** the levels below **k** in the original image.
- ***Brightening*** the levels above **k** in the original image.

Contrast stretching: simple image enhancement technique that improves the contrast in an image by '***stretching***' the range of intensity values it contains to span a desired range of values; typically, it uses a ***linear scaling function***

2. **Thresholding:**

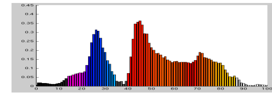
- Produce a ***two-level*** (binary) image, a mapping of this form called ***thresholding function***.

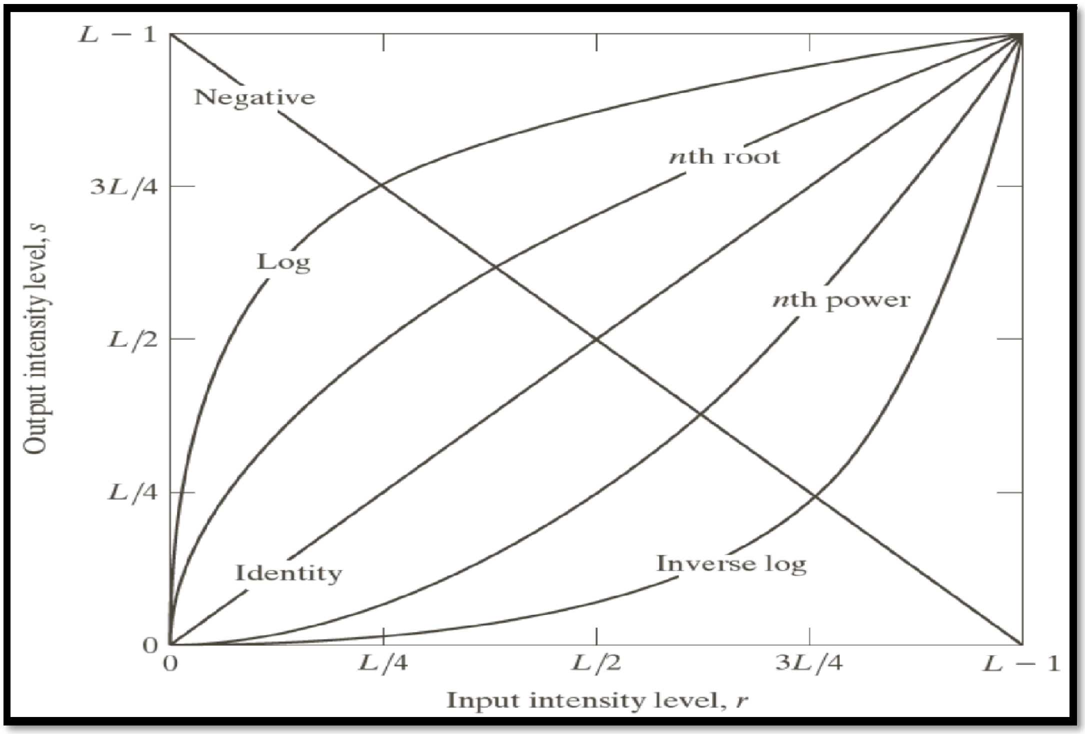


Some Basic Intensity Transformation Functions:

- Three basic types of functions used frequently for image enhancement:
  - ***Linear functions:*** ***negative*** and ***identity*** transformations.
  - ***Logarithmic:*** ***log*** and ***inverse*** log transformations.
  - ***Power-law functions*** (n_{th} ***power*** and n_{th} ***root*** transformations)

(As shown in figure):





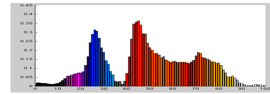
1. ***Identity*** function:
   - Output intensities to input intensities.
   - Is included in the graph only for completeness.
2. Image ***negatives***:
   - The negative of an image with gray level in the range **[0, L-1]**, where $L = 2^n$, **n=1,2,....** is obtained by using the negative transformation's expression:

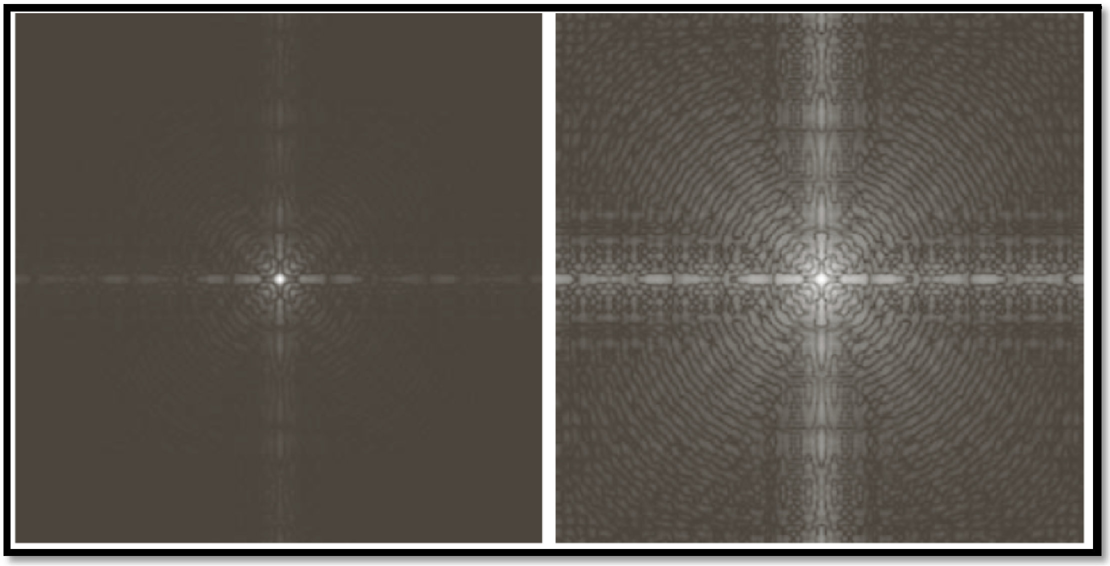
     $$S = L-1-r$$

     That reverses the intensity levels of an input image.
   - The negative transformation is suitable for enhancing white or gray detailed embedded in dark regions of an image, especially when the black area are dominant in size.
3. ***Log*** Transformation:
   - The general form of the log transformation:

     $$S = c. \log (1+r)$$

     C is a constant, and $r \geq 0$
   - ***log*** curve maps a ***narrow range*** of low gray-level values in the input image into a ***wider range*** of the output levels.
   - Used to ***expand*** the values of ***dark pixels*** in an image while ***compressing*** the ***higher-level*** values.
   - It ***compresses*** the dynamic range of images with large variations in pixel values.
   - Example of image with dynamic range: ***Fourier spectrum image***.
   - It can have intensity range from 0 to 10^6 or higher.
   - We can't see the significant degree of detail as it will be lost in the display.





Fourier spectrum image

4. **`Inverse logarithm`** Transformation:

- Do opposite to the log transformations.
- Used to ***expand*** the values of high pixels in an image while ***compressing*** the ***darker***-level values.

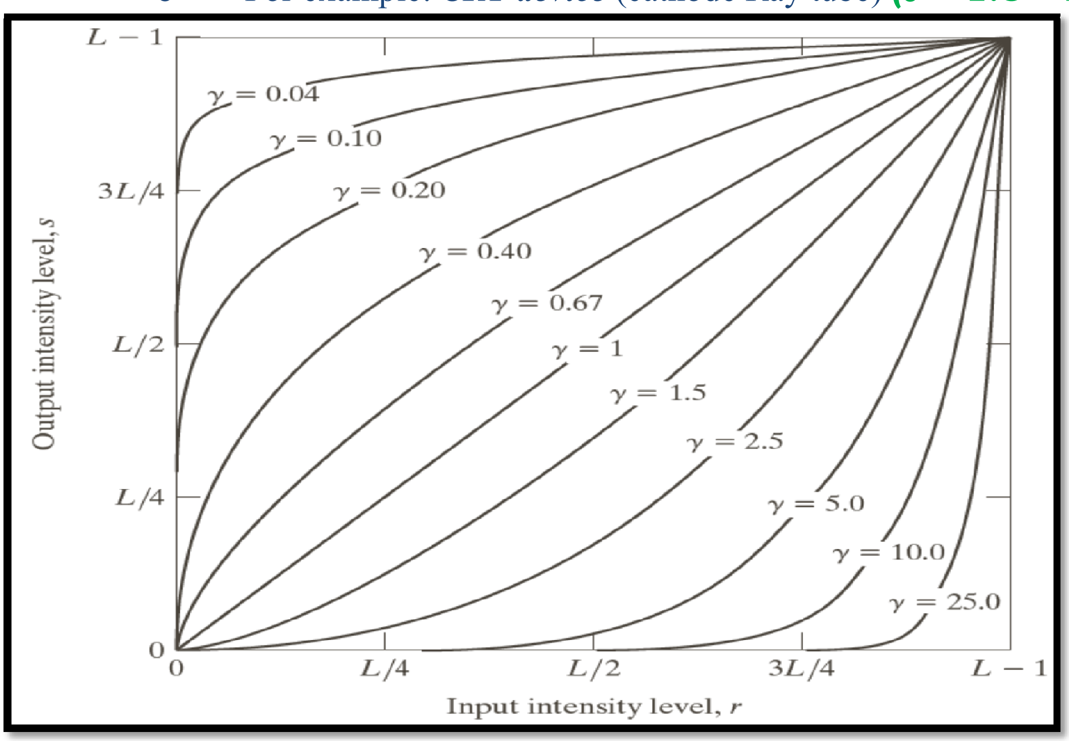
5. **`power-law (Gamma)`** Transformation:

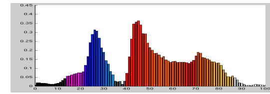
- The general form of the power-law transformation:

$$S = c.r^{\delta} ,$$

where c and $\delta \geq 0$

- Different transformations curves are obtained by varying δ (**`gamma`**).
- Many image capturing, printing and display devices use gamma correction, which enhances the given image by power-law response phenomena.
    - For example: ***CRT device*** (cathode Ray tube) (**δ = 1.8 – 2.5**)



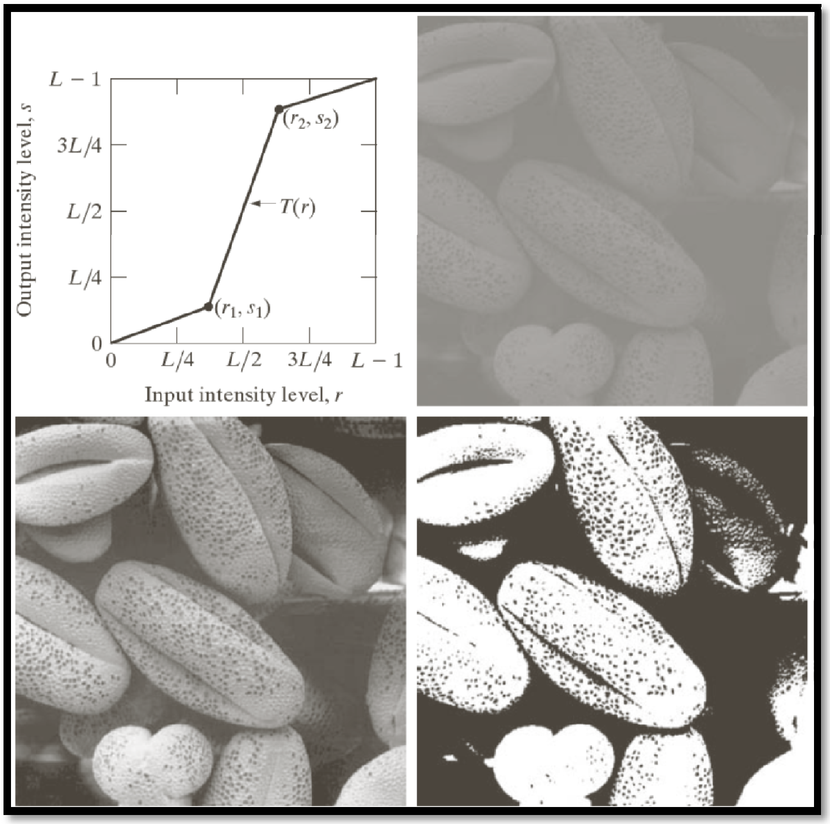


Piecewise-linear Transformation Functions

- **<u>Principal advantage</u>**: the form of piecewise function can be ***arbitrarily complex*** (more options to design), some important transformations can be formulated only as piecewise functions.
- **<u>Principal disadvantage</u>**: their specification requires more user input.

A. Contrast stretching:

- One of the most (simplest) piecewise functions is the ***contrast stretching***, which is used to enhance the low contrast images.



a b
c d

FIGURE 3.10 Contrast stretching. (a) Form of transformation function. (b) A low-contrast image. (c) Result of contrast stretching. (d) Result of thresholding. (Original image courtesy of Dr. Roger Heady, Research School of Biological Sciences, Australian National University, Canberra, Australia.)

a) **s1 = r1** and **s2 = r2** (***Identity transformation***) (**<u>no change</u>** in the image).
b) **r1= r2, s1= 0,** and **s2 = L-1** (***thresholding*** function – Image **<u>converted</u>** to black and white).
c) Intermediate values of **(r1, s1)** and **(r2, s2)** produces **<u>various degree of spread</u>** in the intensity level of the output image.

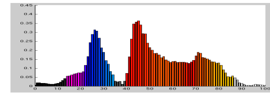
- In general, **r1 ≤r2** and **s1 ≤s2**, so the function is **<u>single</u>** valued and **<u>monotonically</u>** increasing.

Example:

- To enhance an 8-bit image with ***low contrast*** using ***contrast stretching***, and obtained by setting:

(r1, s1) = (rmin, 0) and **(r2, s2) = (rmax, L-1)**

where **rmin** and **rmax** denote the ***minimum*** and the ***maximum*** intensity level in the image. So the transformation function stretches the levels linearly from their original range to the full range **[0, L-1]**.

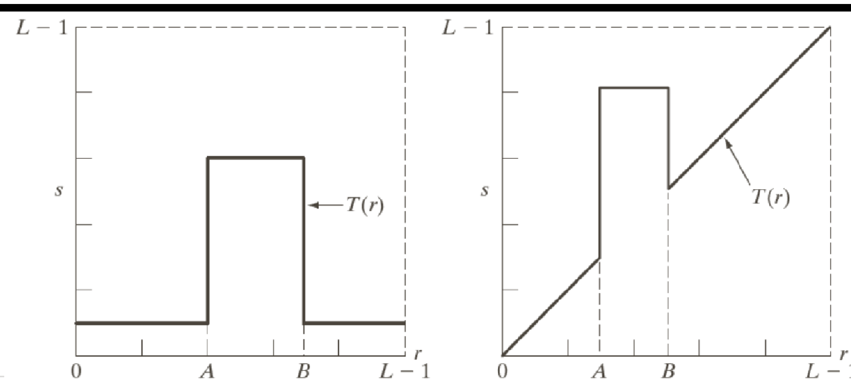


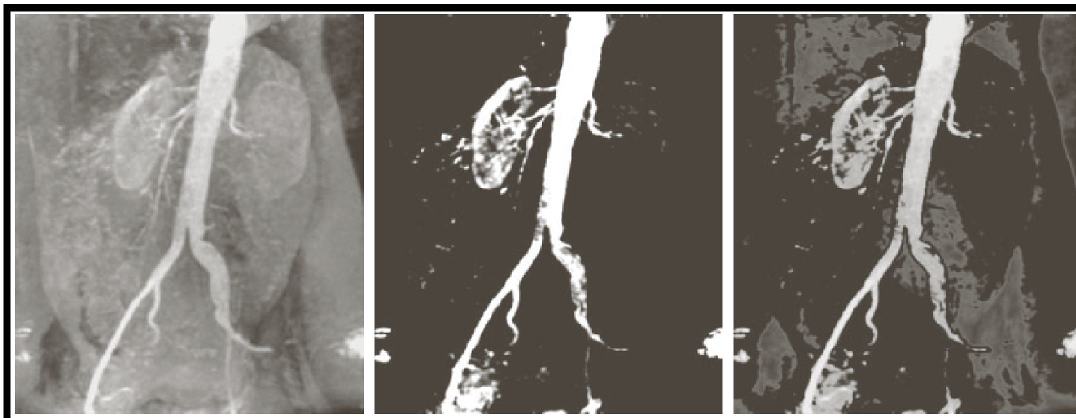
B. Gray-level slicing (Intensity-level slicing)

- This technique is used to ***highlight a specific range*** of gray levels in a given image, the process, often called ***intensity-level slicing***, and can be implemented in several ways.
    I. Display **<u>all values in the range of interest in one value</u>** (say, white), and **<u>other intensities in another value</u>** (say, black). As shown in figure, this transformation produces a **<u>binary image</u>**.
    II. The second approach **<u>Brightens (or darkens) the desired range of intensities but leaves all other intensities in the image unchanged</u>**, as shown in figure.

a b

FIGURE 3.11 (a) This transformation highlights intensity range [A, B] and reduces all other intensities to a lower level. (b) This transformation highlights range [A, B] and preserves all other intensity levels.





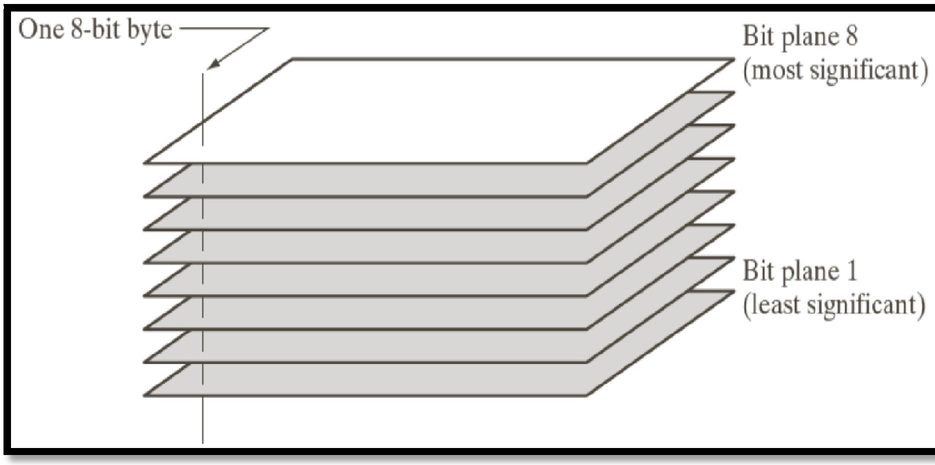
a b c

FIGURE 3.12 (a) Aortic angiogram. (b) Result of using a slicing transformation of the type illustrated in Fig. 3.11(a), with the range of intensities of interest selected in the upper end of the gray scale. (c) Result of using the transformation in Fig. 3.11(b), with the selected area set to black, so that grays in the area of the blood vessels and kidneys were preserved. (Original image courtesy of Dr. Thomas R. Gest, University of Michigan Medical School.)

C. Bit- plane slicing:

- Pixels are digital number composed of bits, instead of highlighting intensity-level range, we could **<u>highlight the contribution made by each bit</u>**, this method is useful and used in image compression.

Most significant bits contains the majority of the visually significant data



a b c
d e f
g h i

FIGURE 3.14 (a) An 8-bit gray-scale image of size 500 × 1192 pixels. (b) through (i) Bit planes 1 through 8, with bit plane 1 corresponding to the least significant bit. Each bit plane is a binary image.