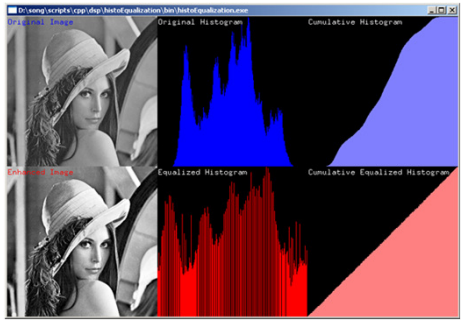
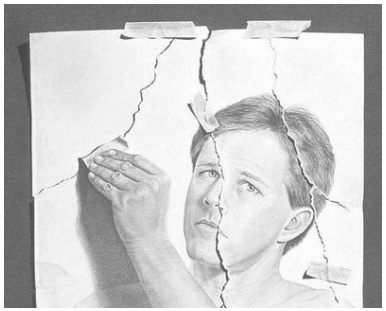
Point Operations



1

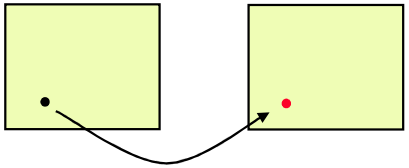
General Image Operations

- Three type of image operations
  1. Point operations
  2. Geometric operations
  3. Spatial operations



Point Operations

$$g(x,y) = M(f(x,y))$$



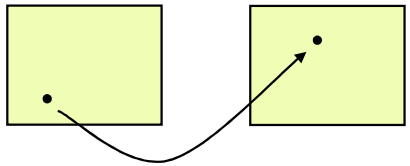
Point Operations

- Operation depends on Pixel's value.
- Context free (memory-less).
- Operation can be performed on the Histogram.
- Example:

$$g(x,y) = \alpha \cdot f(x,y) + \beta$$

Geometric Operations


$$g(x,y) = f(G(x,y))$$



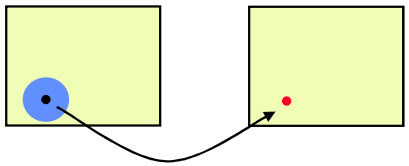
Geometric Operations

- Operation depend on pixel's coordinates.
- Context free.
- Independent of pixels value.
- Example:

$$g(x,y) = f(x+a, y+b)$$

Spatial Operations


$$g(x,y) = M(\{f(i,j) | (i,j) \in N(x,y)\})$$



Spatial Operations

- Operation depends on Pixel's value and coordinates.
- Context dependant.
- Spatial v.s. Frequency domain.
- Example:

$$g(x,y) = \sum_{i,j \in N(x,y)} f(i,j)/n$$

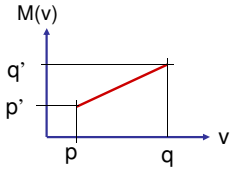
Point Operations

- A point operation can be defined as a mapping function:

$$v_{new} = M(v_{old})$$

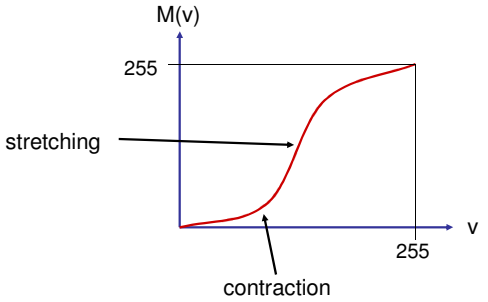
where v stands for gray values.

- M(v) takes any value v in the source image into v_{new} in the destination image.
- Simplest case - Linear Mapping: $M(v) = \alpha v + \beta$



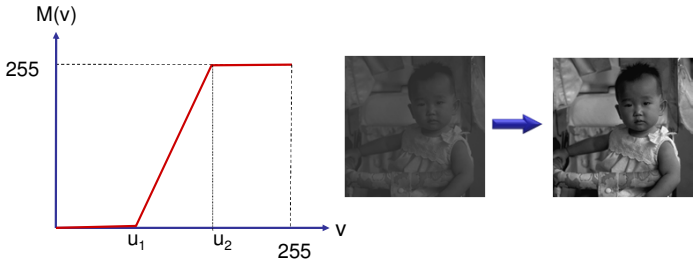
$$\alpha = \frac{q'-p'}{q-p} \quad ; \quad \beta = p'-\alpha p$$

- If it is required to map the full gray-level range (256 values) to its full range while keeping the gray-level order - a **non-decreasing monotonic mapping function** is needed:

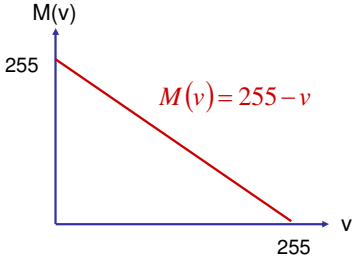


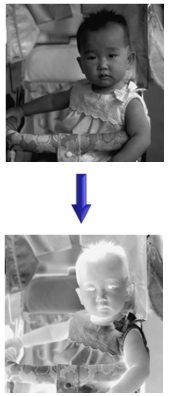
Contrast Enhancement

- If most of the gray-levels in the image are in $[u_1\ u_2]$, the following mapping increases the image contrast.
- The values u_1 and u_2 can be found by using the image's accumulated histogram.



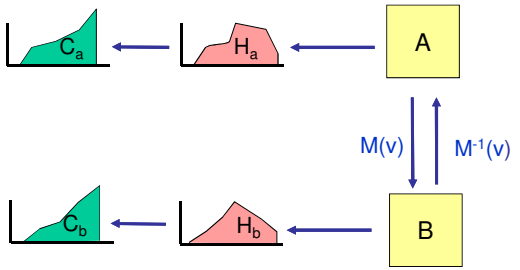
The Negative Mapping





Point Operations and the Histogram

Given a point operation: $v_b = M(v_a)$



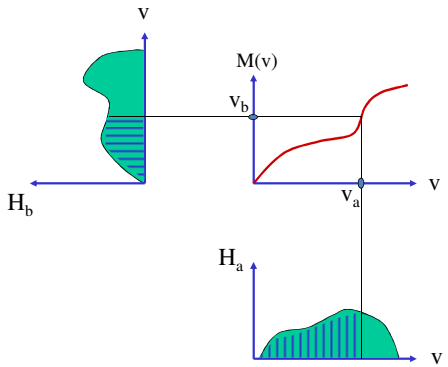
Point Operations and the Histogram

- Given a point operation:

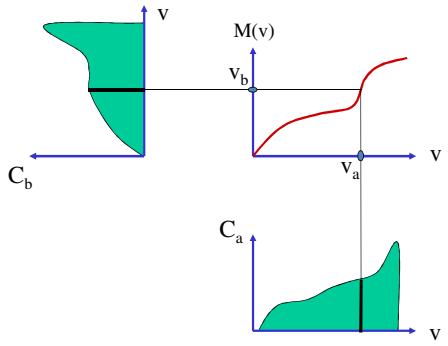
$$v_b = M(v_a)$$

- $M(v_a)$ takes any value v_a in image A and maps it into v_b in image B.
- **Requirement**: the mapping M is a monotonic increasing function (M^{-1} exists).
- In this case, the area under H_a between 0 and v_a is equal to the area under H_b between 0 and v_b

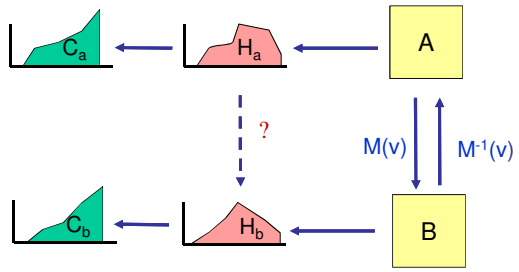
- The area under H_a between 0 and v_a is equal to the area under H_b between 0 and v_b=M(v_a)



- The value of C_a at v_a is equal to the value of C_b at v_b.

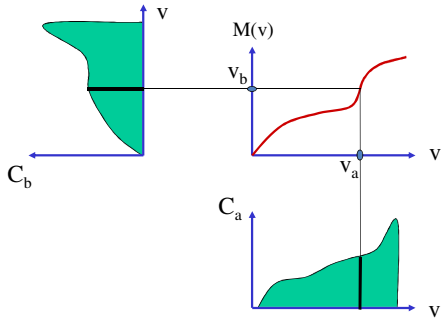


Q: Is it possible to obtain H_b directly from H_a and M(v)?



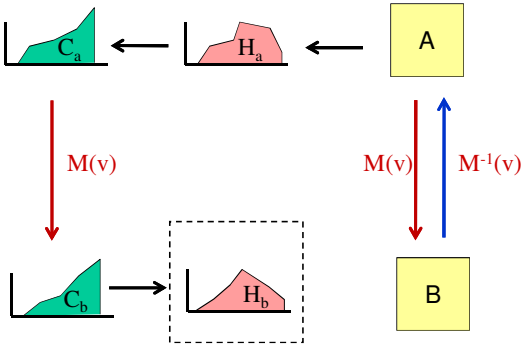
- **A**: Since M(v) is monotonic, $C_a(v_a)=C_b(v_b)$ therefore:

$$C_b(v_b)=C_a\left(M^{-1}(v_b)\right)$$

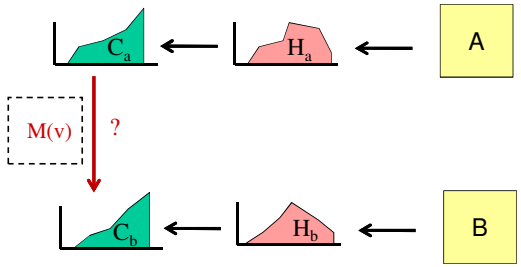


- The histogram of image B can be calculated:

$$H_b(v)=C_b(v)-C_b(v-1)$$



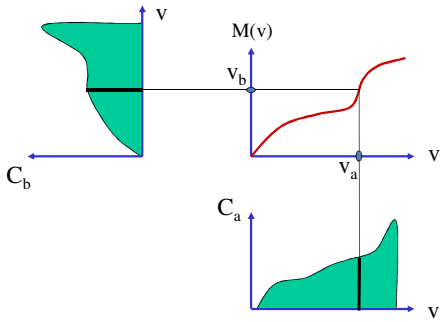
Q: Is it possible to obtain M(v) directly from H_a and H_b ?



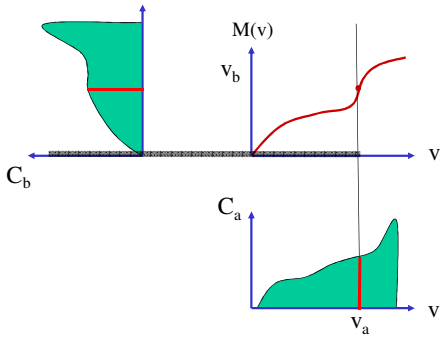
- **A**: Since C_b is monotonic and $C_b(v_b)=C_a(v_a)$

$$v_b = C_b^{-1} C_a(v_a) = M(v_a)$$

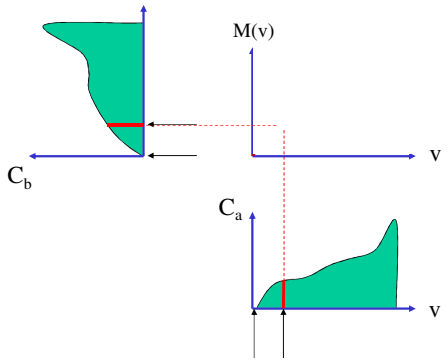
- Alternatively $M(v_a)=v_b$ if $C_a(v_a)=C_b(v_b)$



Calculating M(v) from C_a and C_b:



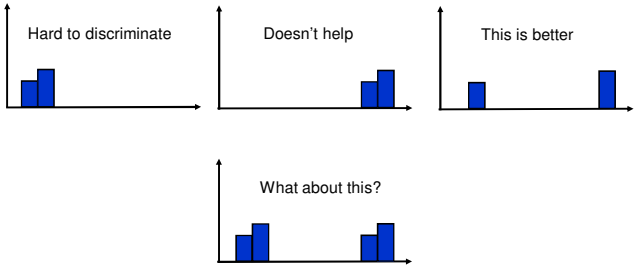
Calculating M(v) from C_a and C_b: 2-pointer Algorithm



Is this always possible?

Histogram Equalization

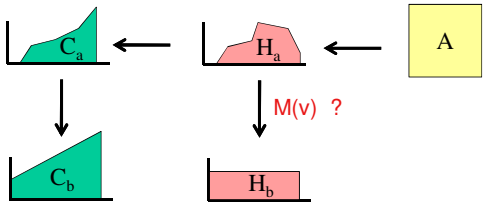
- Visual discrimination between objects depends on the their gray-level separation.
- How can we improve discrimination **after** image has been acquired?



Histogram Equalization

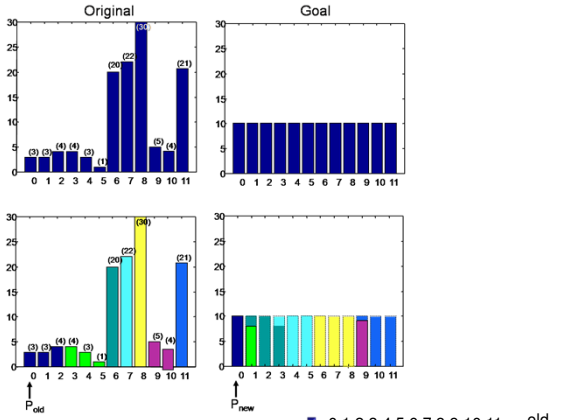
- For a better visual discrimination of an image we would like to re-assign gray-levels so that gray-level resource will be optimally assigned.
- **Our goal**: finding a gray-level transformation M(v) such that:
  - The histogram H_b is as flat as possible.
  - The order of gray-levels is maintained.
  - The histogram bars are not fragmented.

Histogram Equalization: Algorithm



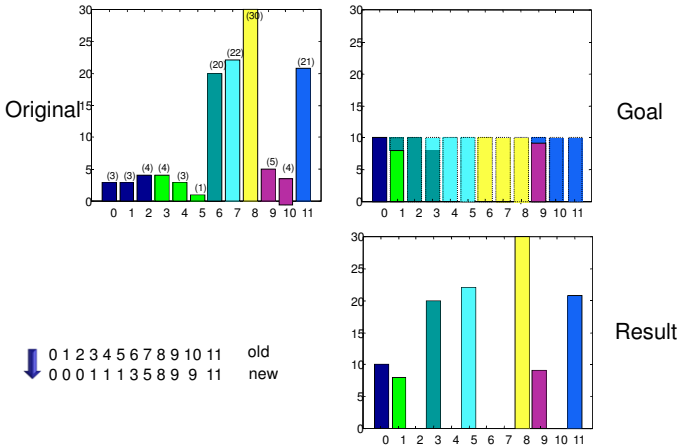
- Define: $C_b(v) = v * \frac{(\#\ pixels)}{\#\ grayValues}$
- Assign: $v_b = C_b^{-1}(C_a(v_a)) = M(v_a)$

Hist. Eq.: The two pointers algorithm



0 1 2 3 4 5 6 7 8 9 10 11 old
0 0 0 1 1 1 3 5 8 9 9 11 new

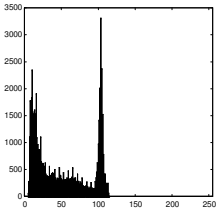
Hist. Eq.: The two pointers algorithm

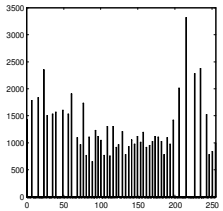


0 1 2 3 4 5 6 7 8 9 10 11 old
0 0 0 1 1 1 3 5 8 9 9 11 new

Hist. Eq.: Example 1



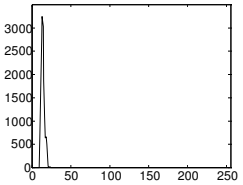


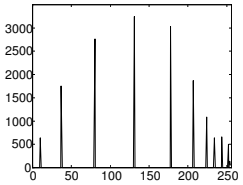


Original Equalized

Hist. Eq.: Example 2







Original Equalized

Hist. Eq.: Example 3


Adaptive Histogram Equalization

Original image | Global histogram equalization | Adaptive histogram equalization 8x8 tiles

From B. Girod, IP

Histogram matching

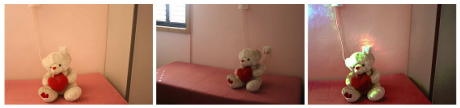
- Transforms an image A so that its histogram will match that of another image B.
- Usage: before comparing two images of the same scene (change detection) acquired under different lighting conditions or different camera parameters.

(a) (b) (c)

source target mapped source

- However, in cases where corresponding colors between images are not “consistent” this mapping may fail:

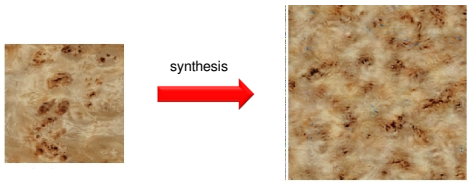
(a) (b) (c)



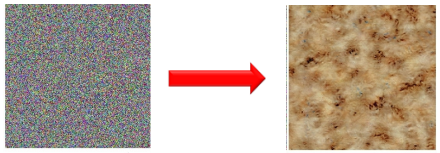
(a) (b) (c)

from: S. Kagarlitsky: M.Sc. thesis 2010.

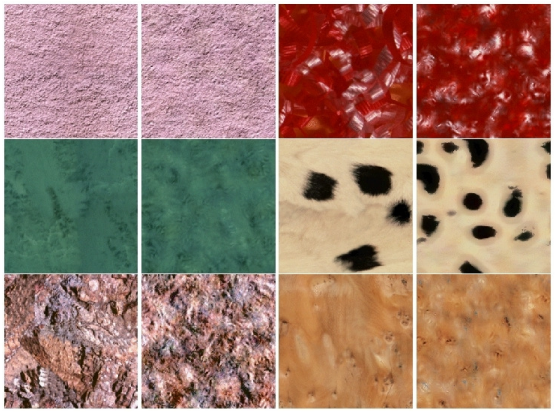
- Surprising usage: Texture Synthesis (Heeger & Bergen 1995).



– Start with a random image.
– Step1: multi-resolution decomposition
– Step2: histogram matching for each resolution
– Iterate



- More results: (Heeger & Bergen 1995):

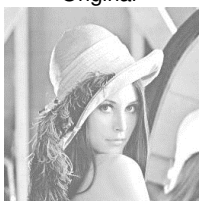


Discussion:

- Histogram matching produces the optimal **monotonic** mapping so that the resulting histogram will be as **close** as possible to the target histogram.
- This does not necessarily imply similar images.

Example:

Original



Destination

hist. match

Pattern Matching by Tone Mapping (MTM)

(ICCV 2011)

Find the BEST tone mapping between Pattern and Window

Pattern

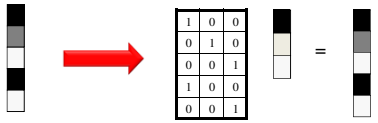
Window

Pattern Matching by Tone Mapping (MTM)

(ICCV 2011)

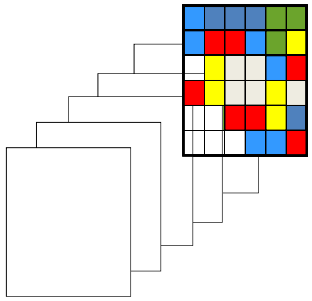
Use the Slice Transform (SLT) to represent image as a linear sum of "slice" signals:

Image x_A



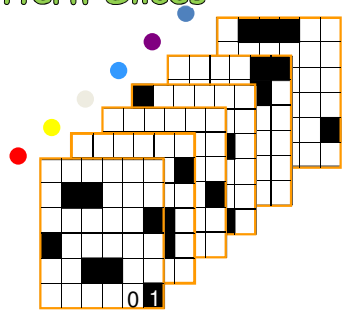
$$S_p(x_A)p = x_A$$

Pattern Slices



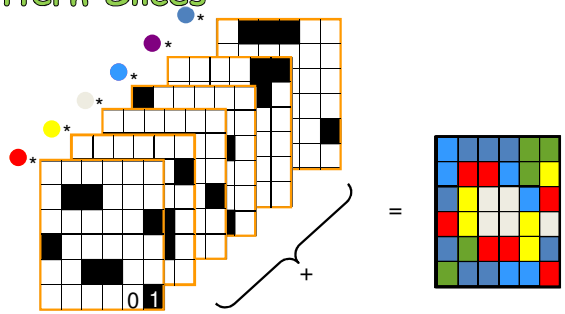
- We define a pattern slice $p^j(i) = \begin{cases} 1 & if \;\; B(p(i)) = j \\ 0 & otherwise \end{cases}$

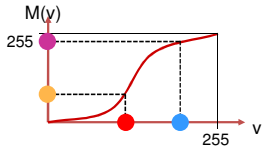
Pattern Slices



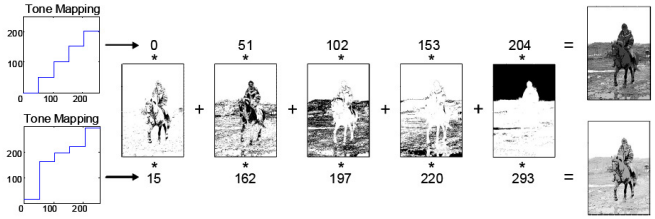
- We define a pattern slice $p^j(i) = \begin{cases} 1 & if \;\; B(p(i)) = j \\ 0 & otherwise \end{cases}$

Pattern Slices





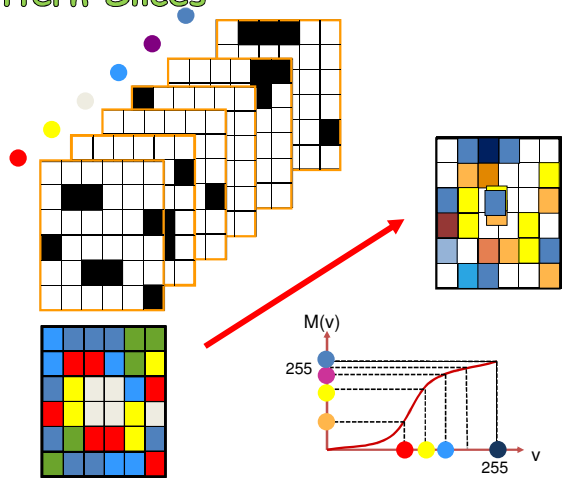
Linear Combination of Image Slices



5 bins were used **α** = [0, 51, 102, 153, 204, 256]

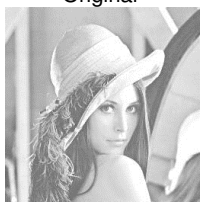
Slices are shown inverted (1 = white, 0 = black)

Pattern Slices



Example:

Original



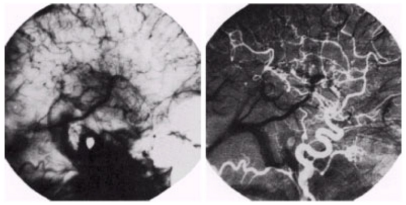
Destination

results

SLT

Hist. match

Point Operation on Two+ Images



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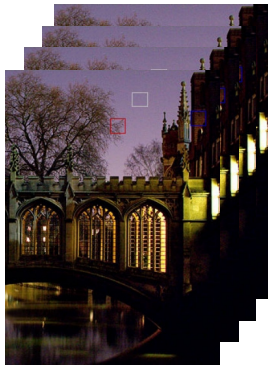
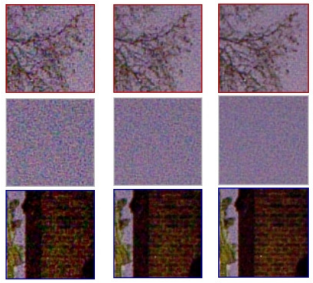
Noise reduction by Averaging



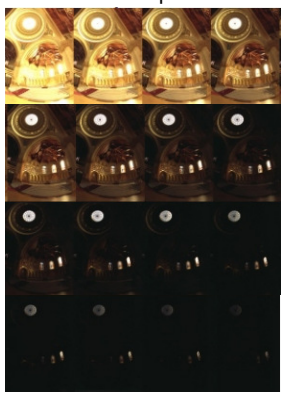
1 image 2 images 4 images



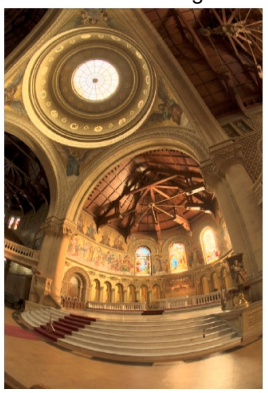
http://www.cambridgeincolour.com/tutorials

High Dynamic Range Images

Different Exposures



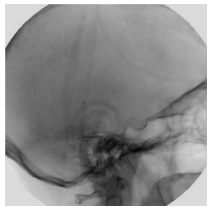
Combined Image

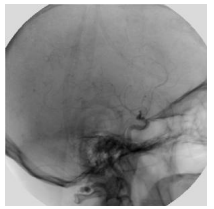


Malik 1997

Image Subtraction

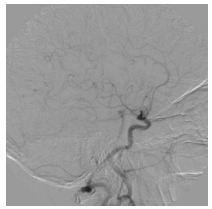
Mask Image





New Image

Difference Image

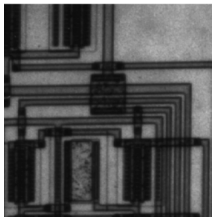


Contrast Enhanced Image

http://www.isi.uu.nl/Research/Gallery/DSA/

Image Subtraction

Image Proto



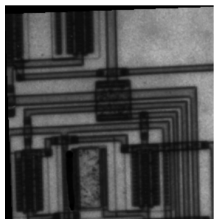
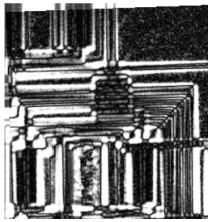
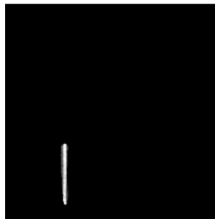


Image Defect

Difference Image No Alignment





Difference Image With Alignment

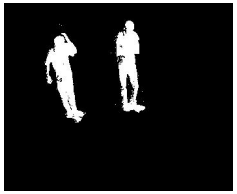
B. Girod

Image Subtraction – Foreground Detection

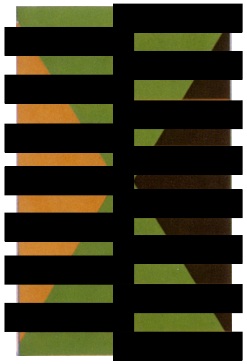
Frame 1

Frame 2

Difference Image



Real Difference Image



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