Fuzzy Techniques in Image Processing

Group 4

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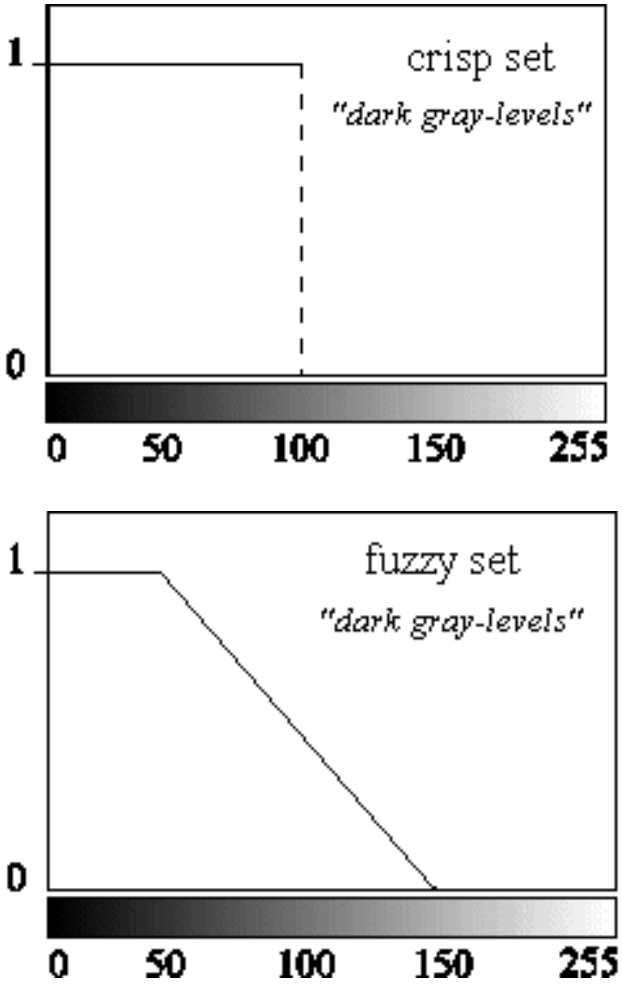
Presentation Flow

- Introduction to Fuzzy Logic
  - Fuzzy Sets
  - Fuzzy Inference Systems
- Fuzzy Image Processing Model
- Applications
  - Noise Detection and Removal
  - Contrast Enhancement

Fuzzy Sets

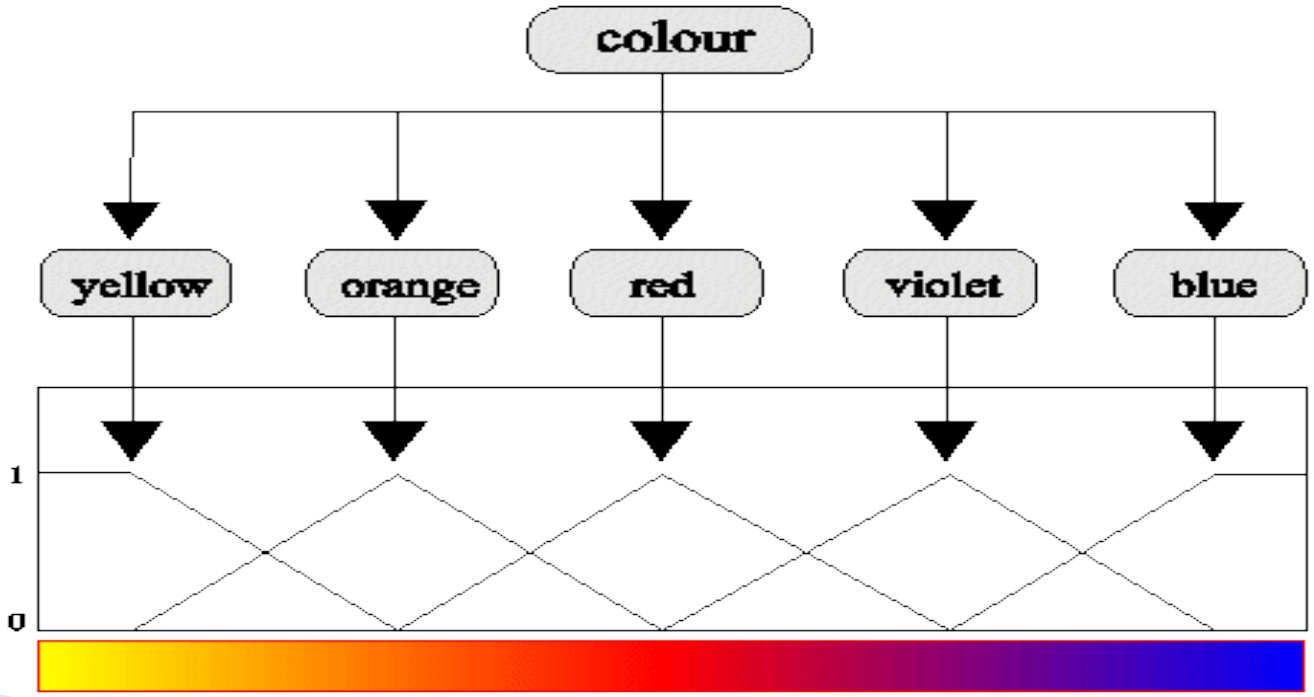
- Fuzzy set theory is the extension of conventional (crisp) set theory
- It handles the concept of partial truth using a membership function
- Instead of just black and white, the color belonging to a set has degree of whiteness & blackness



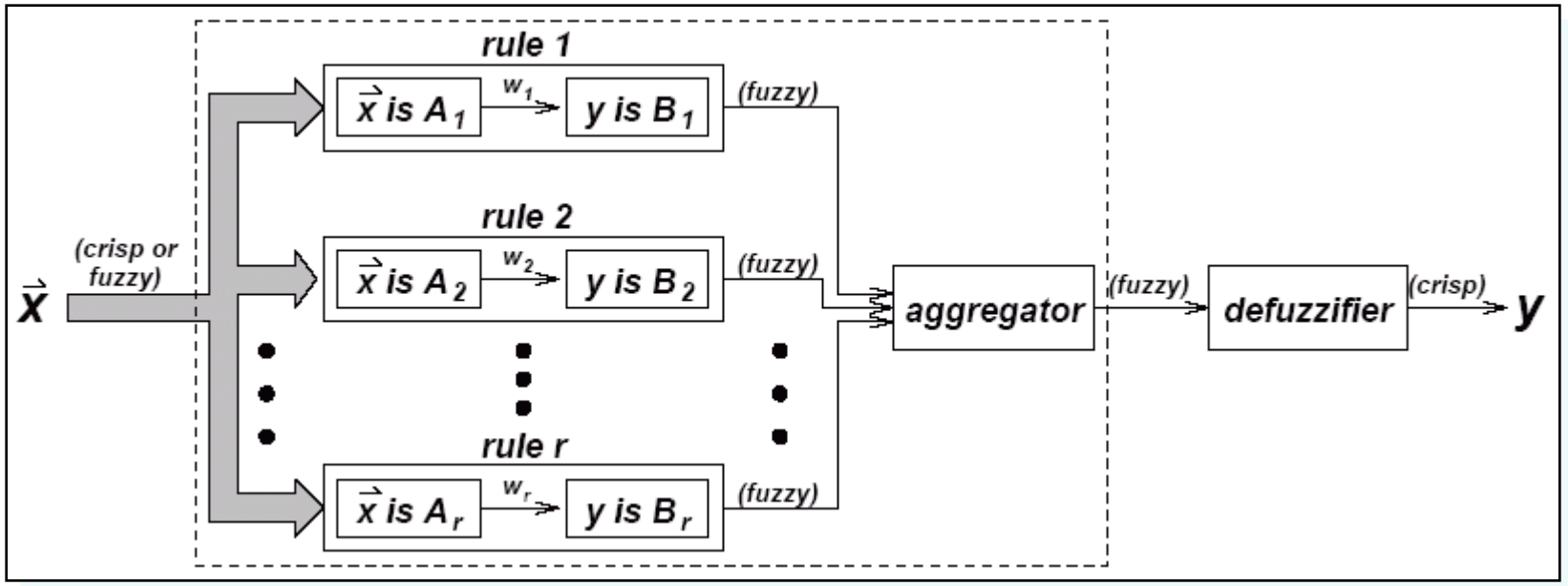
Contd..

- As an example, we can regard the variable color as a fuzzy set

color = {yellow, orange, red, violet, blue}

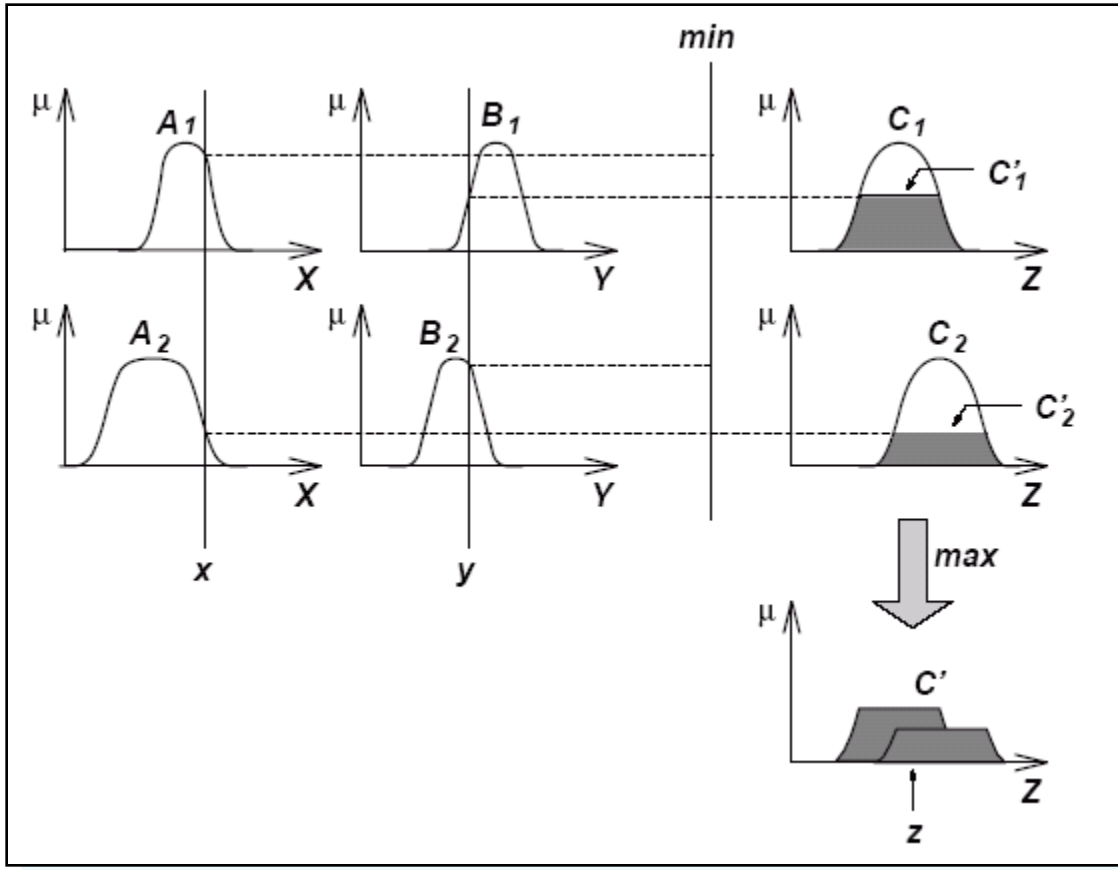


Fuzzy Inference System



The Reasoning Scheme

- Rules
  - If x is A1 and y is B1 then z is C1
  - If x is A2 and y is B2 then z is C2

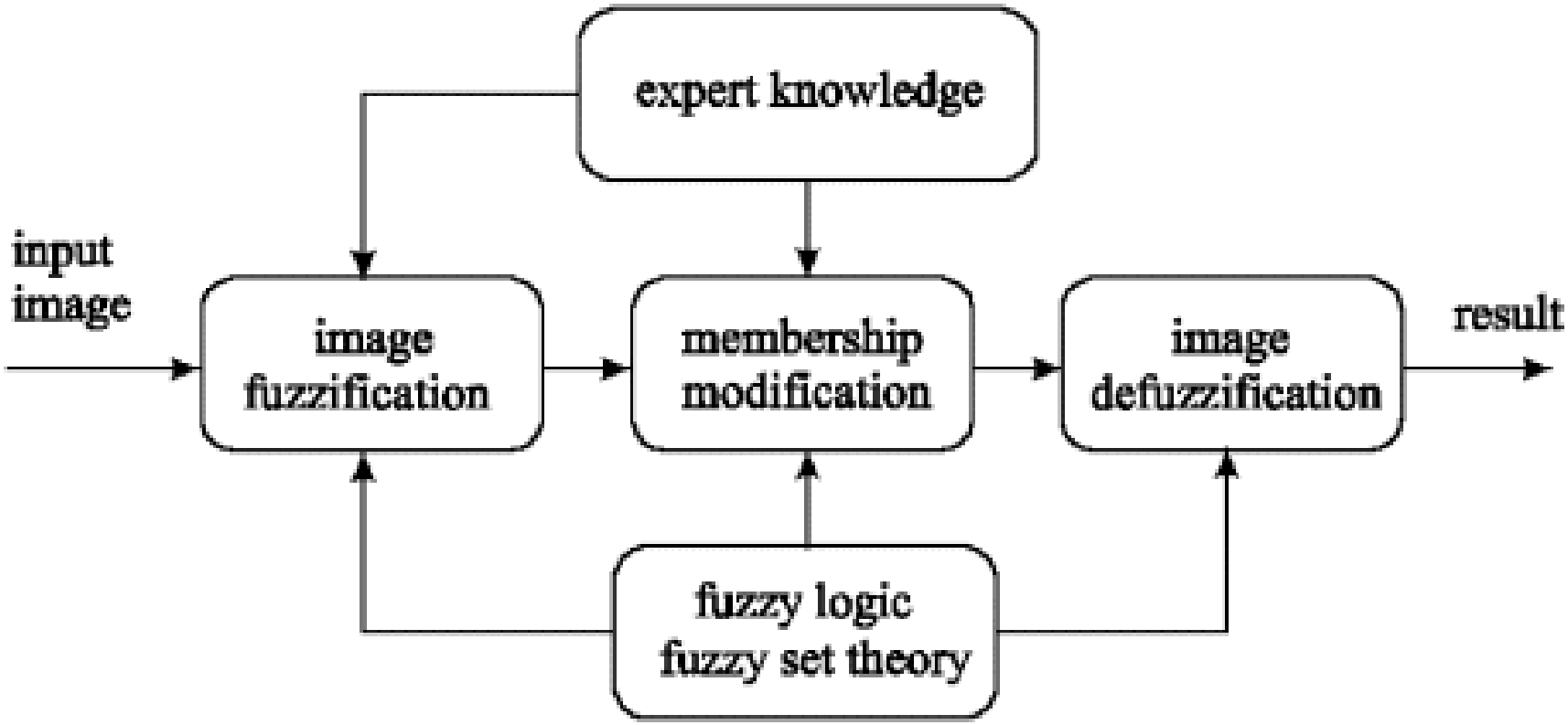


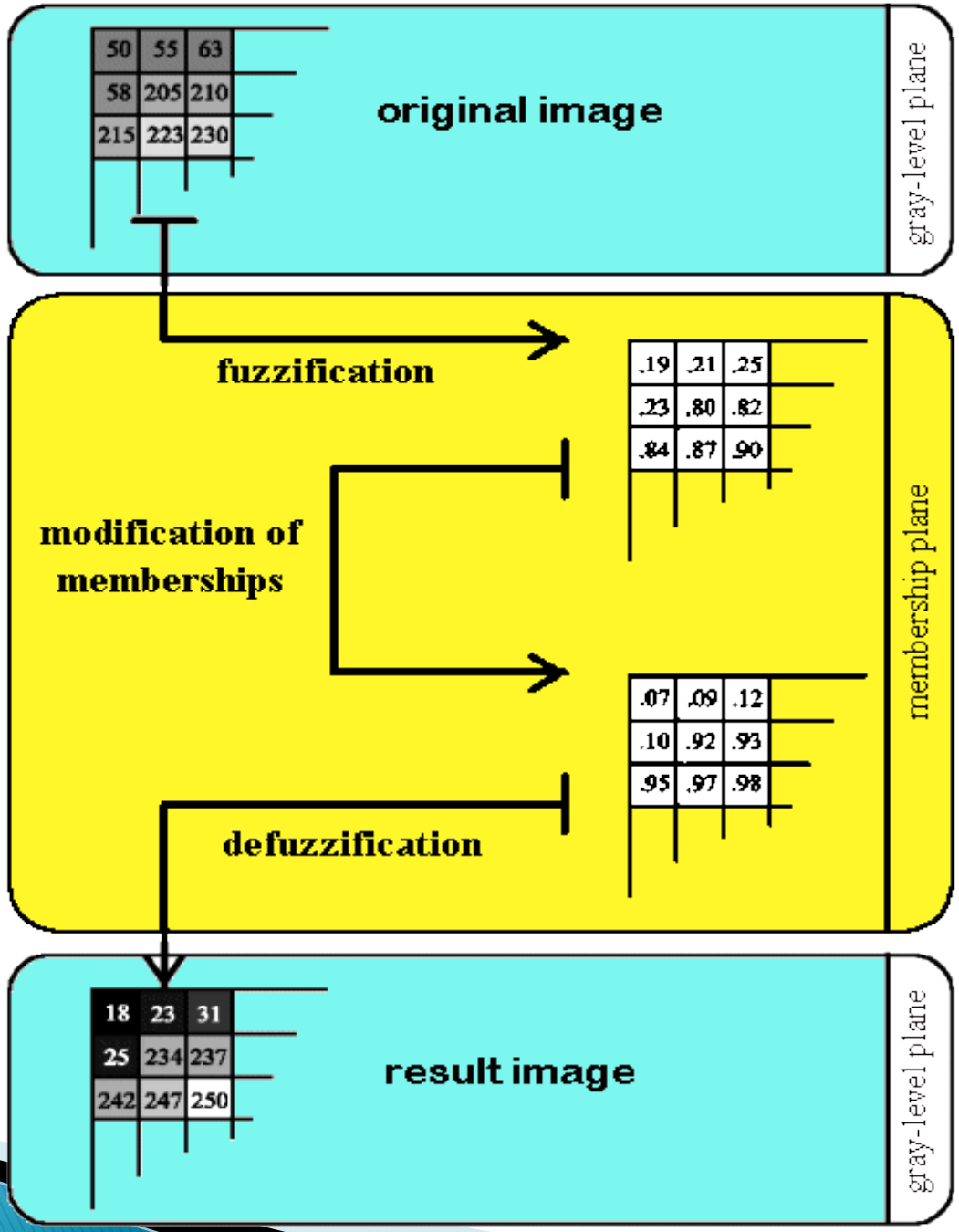
Fuzzy Image Processing

- Collection of all approaches that understand, represent and process the images, their segments and features as fuzzy sets.

- The representation and processing depend on the selected fuzzy technique and on the problem to be solved.

Fuzzy Image Processing Flow



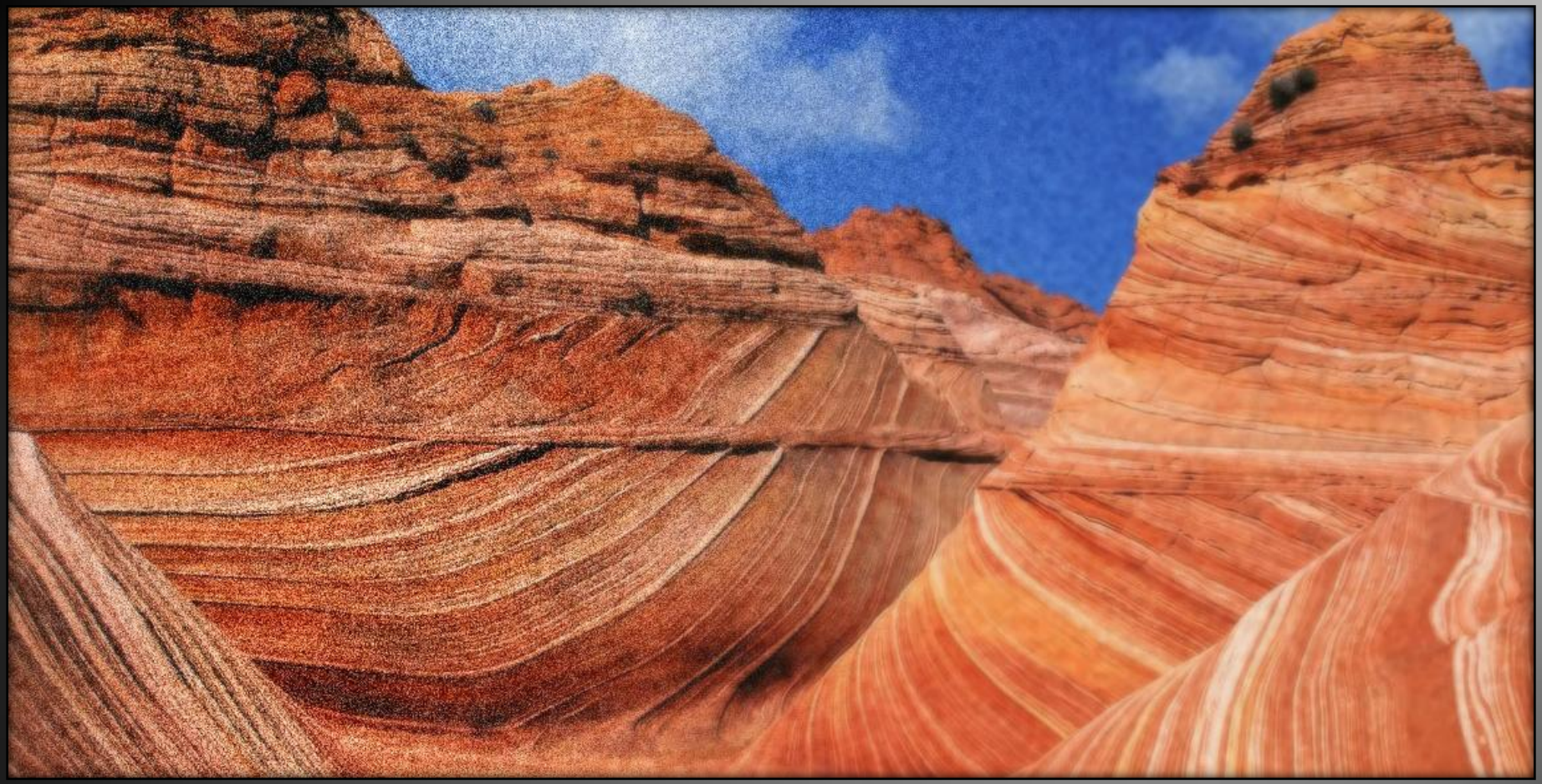

50 55 63
58 205 210
215 223 230
original image
gray-level plane
fuzzification
.19 .21 .25
.23 .80 .82
.84 .87 .90
modification of memberships
.07 .09 .12
.10 .92 .93
.95 .97 .98
membership plane
defuzzification
18 23 31
25 234 237
242 247 250
result image
gray-level plane

Why Fuzzy Image Processing?

- Fuzzy techniques can manage the vagueness and ambiguity efficiently (an image can be represented as a fuzzy set)
- Fuzzy Logic is a powerful tool to represent and process human knowledge in form of fuzzy if-then rules

History

1965 Zadeh	Introduction of Fuzzy Sets
1970 Prewitt	First Approach toward Fuzzy Image Understanding
1979 Rosenfeld	Fuzzy Geometry
1980-1986 Rosendfeld et al., Pal et al.	Extension of Fuzzy Geometry New methods for enhancement / segmentation
End of 80s-90s Russo/Krishnapuram Bloch et al. / Di Gesu /	Rule-based Filters, Fuzzy Morphology



Noise Reduction

Reference:

Noise Reduction by Fuzzy Image Filtering

Dimitri Van De Ville, Mike Nachtegael, Dietrich Van der Weken, Etienne E. Kerre,
Wilfried Philips and Ignace Lemahieu

Edges and Noise

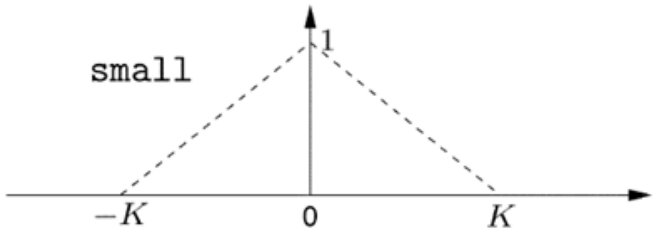
- Both represent a variation in intensity
- Usually edge has a large variation between adjacent pixels, compared to additive noise
- Use directional gradients to capture variations

NW	*N*	*NE*
W	*(x,y)*	*E*
SW	*S*	*SE*

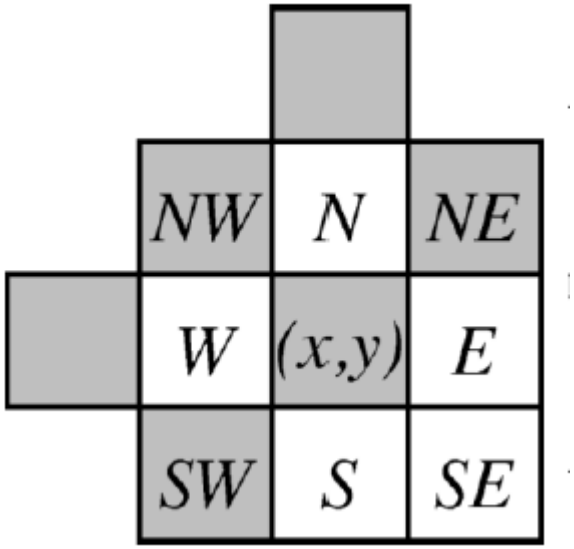
$$\nabla_N(x, y) = I(x, y-1) - I(x, y)$$

Separating Noise from Edges

- We fire 8 rules to differentiate noise from edges – one for each direction to find the fuzzy directional derivative



if $(\nabla_{NW}(x, y)$ is small and $\nabla_{NW}(x-1, y+1)$ is small) or
$(\nabla_{NW}(x, y)$ is small and $\nabla_{NW}(x+1, y-1)$ is small) or
$(\nabla_{NW}(x-1, y+1)$ is small and $\nabla_{NW}(x+1, y-1)$ is small)
then $\nabla^{F}_{NW}(x, y)$ is small.

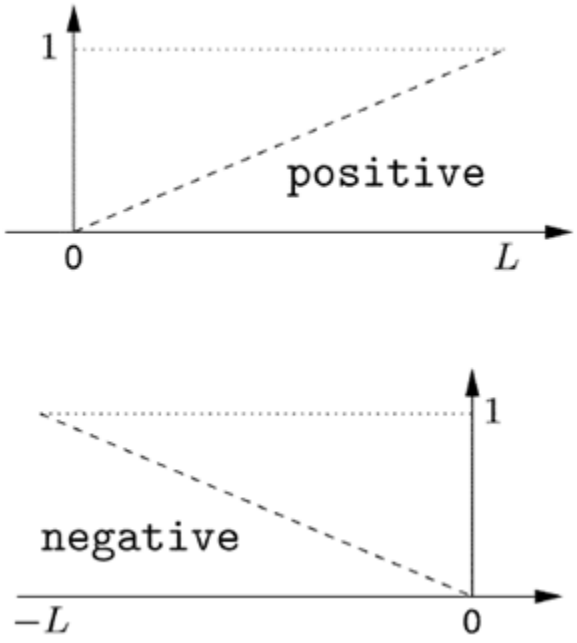


Filtering – Smoothing

- To compute the correction term, we fire additional rules

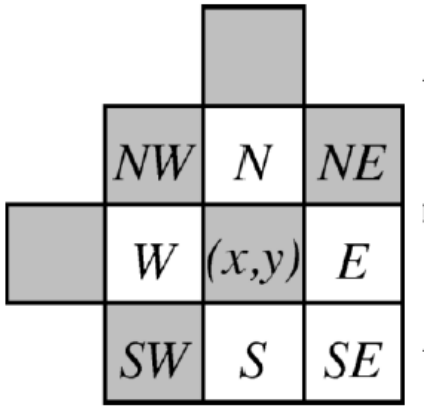
λ^{+}_{NW}: if $\nabla^{F}_{NW}(x, y)$ is `small` and $\nabla_{NW}(x, y)$ is `positive` then c is `positive`

λ^{-}_{NW}: if $\nabla^{F}_{NW}(x, y)$ is `small` and $\nabla_{NW}(x, y)$ is `negative` then c is `negative`.



- Using these, we calculate the correction term

$$\Delta = \frac{L}{8} \sum_{D \in dir} (\lambda^{+}_{D} - \lambda^{-}_{D})$$



Results

Contrast Enhancement

Contrast Improvement with INT- Operator

(Pal/King, 1981/1983)

Contrast Improvement based on Fuzzy If-Then Rules

(Tizhoosh, 1997)

INT-Operator

- Step 1: Define the membership function

$$\mu_{mn} = G(g_{mn}) = \left[1 + \frac{g_{max} - g_{mn}}{F_d}\right]^{-F_e}$$

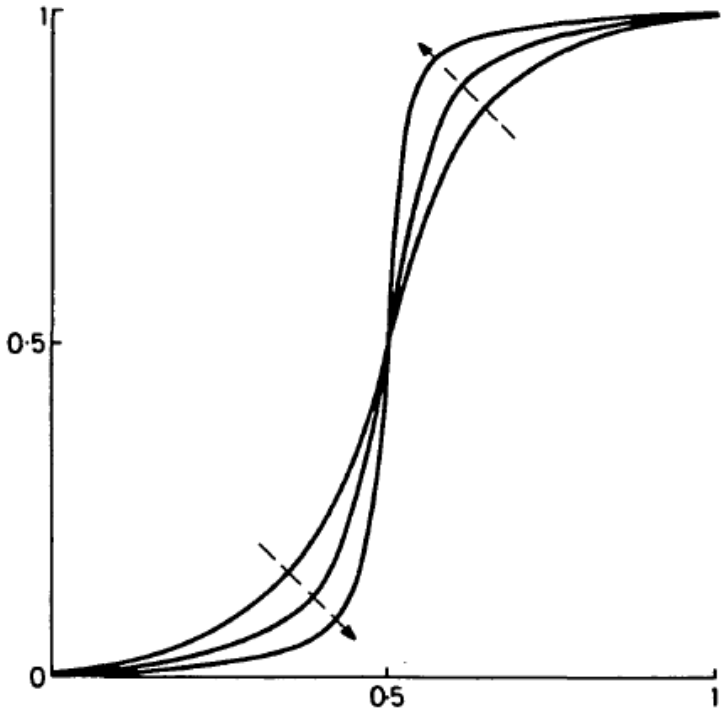
- Step 2: Modify the membership values

$$\mu'_{mn} = \begin{cases} 2 \cdot [\mu_{mn}]^2 & 0 \le \mu_{mn} \le 0.5 \\ 1 - 2 \cdot [1 - \mu_{mn}]^2 & 0.5 \le \mu_{mn} \le 1 \end{cases}$$

INT-Operator (Contd…)

- Step 3: Generate new gray-levels

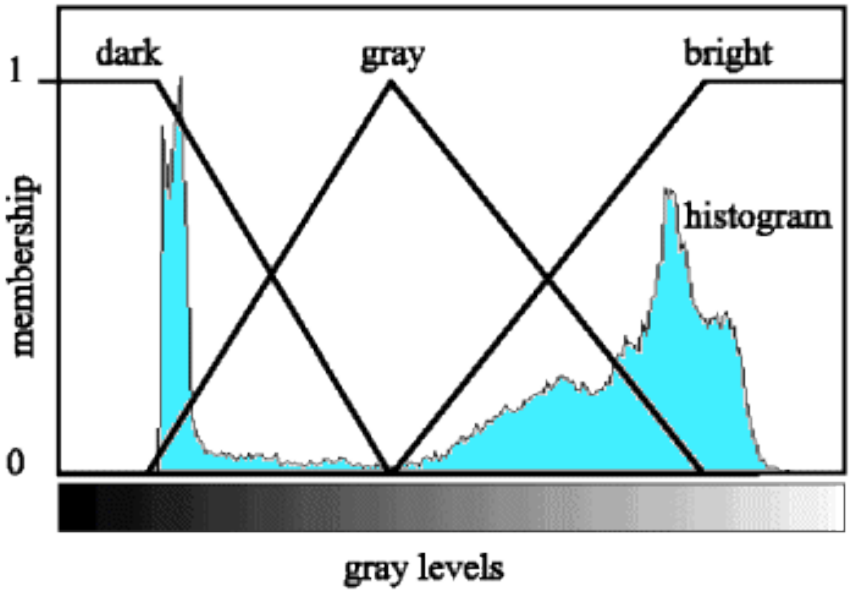
$$g'_{mn} = G^{-1}\left(\mu'_{mn}\right) = g_{max} - F_d\left(\left(\mu'_{mn}\right)^{\frac{-1}{F_e}} - 1\right)$$



Fuzzy Rule-Based

- Step 1:
  Setting the parameters of inference system (input features, membership functions,..)

- Step 2:
  Fuzzification of the actual pixel (memberships to the dark, gray and bright sets of pixels)



Fuzzy Rule-Based

- Step 3: Inference

e.g. if dark then darker, if gray then gray, if bright then brighter

- Step 4: Defuzzification of the inference result

Results

Thank You »

References

- www.wikipedia.org
- pami.uwaterloo.ca/tizhoosh/fip.htm
- Digital Image Processing

  Rafael C. Gonzalez
- Noise Reduction by Fuzzy Image Filtering

  Dimitri Van De Ville, Mike Nachtegael, Dietrich Van der Weken, Etienne E. Kerre, Wilfried Philips and Ignace Lemahieu
- Contrast Improvement with INT- Operator

  (Pal/King, 1981/1983)
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