Reconocimiento de Escritura

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Mar-2007

Outline

Lecture Organization: Update

Image Processing (continued)

Binary Images

Features of Connected Components

Morphological Image Processing

Compression of Textual Images

Outline

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Image Processing (continued)

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Update: Lectures

Times and Tentative Schedule:
by Daniel:

- Mar-27 — Introduction (1h)
- Mar-29 — Binary Image Processing & Compression (3h)
- Mar-30 — Isolated Character & Handwriting Recognition (4h)
- Apr-02 — Layout Analysis (2h)
- Apr-03 — OCR (1h)
- Apr-04 — Applications (3h)

by Alejandro (starting Apr-20):

- Off-Line Continuous Handwriting Recognition based on HMMs
- Use of Language Models
- On-Line Handwriting Recognition

Update: Web-Site

Web-Site:

- http://www.dsic.upv.es/docs/posgrado/20/RES/

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- Binary Images
- Features of Connected Components
- Morphological Image Processing
- Compression of Textual Images

Pixel Distance Metrics

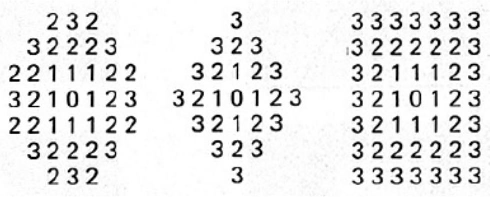
Metric $d(\cdot,\cdot)$:

- $d(x,y) = 0$ iff $x = y$
- $d(x,y) = d(y,x)$
- $d(x,y) + d(y,z) \geq d(x,z)$

Pixel Distance Metrics

L_p-norms:

- $d_p(x, y) = (\sum_d |x_d - y_d|^p)^{1/p}$
- $p = 2$ Euclidean
  $d_2(x, y) = \sqrt{\sum_d (x_d - y_d)^2}$
- $p = 1$ Manhattan / city-block (cp. N_4)
  $d_1(x, y) = \sum_d |x_d - y_d|$
- $p = \infty$ max-norm / chess-board (cp. N_8)
  $d_\infty(x, y) = max_d |x_d - y_d|$



Where is the error in this [Ballard&Brown]-Figure?

Other Image Representations

- run-length encoding*
- chain codes*
- trees, vectors, palettes

*: historically also used to compress size of symbols in memory

Run-length encoding (RLE)

A run is a sequence of pixels of the same color.

- encode runs of same color by their lengths
- often used for binary images
- more general approach also occurs in PNG and JPEG formats
- typical application: fax images $\rightarrow$ compression

Chain Codes

- only applied to binary images
- used for description of object or connected component borders

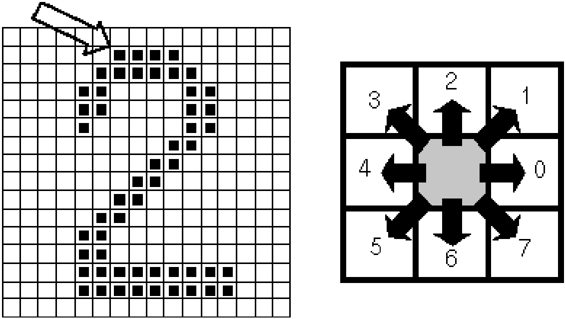
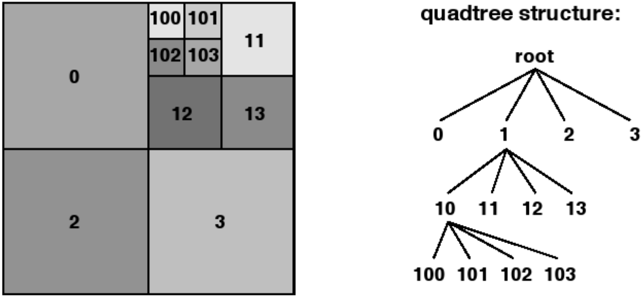


Figure 3.1 An example chain code; the reference pixel is marked by an arrow: 000077665555556600000006444444442221111112234445652211.

Other Representations

- pyramids (progressive transmission, wavelets: JPEG-2000)
- quad-trees (special case of pyramids, subdivide until only one color in node)



Other Representations

- vector-graphics (PostScript, SVG)
- palette / indexed (GIF, PNG)

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Common Image File Formats

- PGM: Portable Greymap Image
- TIFF or TIF: Tagged Image File Format
- JPEG or JPG: Joint Photographic Experts Group File Interchange Format
- GIF: Graphics Interchange Format
- PNG: Portable Network Graphic Format
- (E)PS: (Encapsulated) PostScript
- PDF: Portable Document Format
- SVG: Scalable Vector Graphics
- SWF: Shockwave Flash Binary vector format
- RAW: Raw image file, memory dump from digital camera
- Fax compression formats (e.g. G4, also used in TIFF)

For compressed formats, we distinguish lossy and lossless compression.

Signal Processing

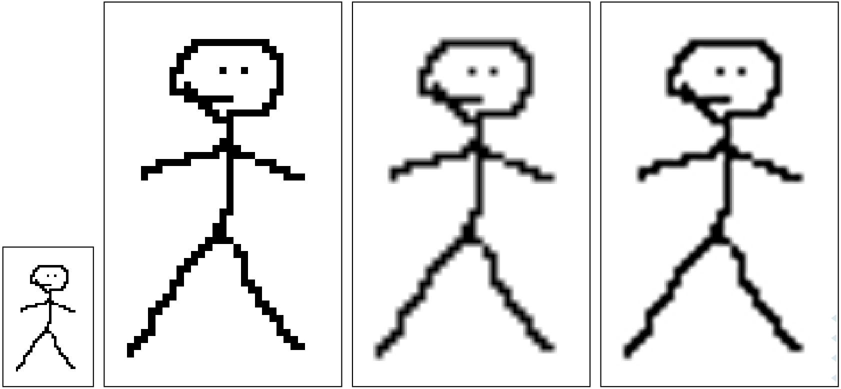
"For ease of reading, pictures of symbols tend to be produced with high contrast: most text and line are is essentially black-on-white. [...] Accordingly, linear signal-analysis techniques are less prevalent in DIA than in computer vision and in natural picture processing" (Nagy, 2000)

not much signal processing needed,
just a quick remark about scaling:

Problems in Image Processing: Upscaling

Scaling up an image (a) has the problem of undersampling.

- Nearest Neighbor interpolation (b) makes the image blocky
- Linear Interpolation (c) makes the image blurry.
- Spline Interpolation (d) is somewhere inbetween.



(a) (b) (c) (d)

Purpose of Preprocessing

"Preprocessing generally consists of a series of image-to-image transformations. It does not increase our knowledge of the contents of the document, but may help to extract it." (Nagy, 2000)

Outline

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Image Processing (continued)

Binary Images

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Binarization

Binary images are usually the result of a thresholding process.

- objects segmented from background
- textual images or document images

- much ‘information’ can be lost by binarization
- binary images are often simpler to process than grayscale images
- these arguments need to be traded off before choosing between binary and gray scale image processing approaches

Thresholding Revisited

possible principles for thresholding

- interactive / trial and error
- fix fraction for black and white and use histogram
- distribution-based (typically: two peaks in histogram)
  - find ‘valley’ between two ‘hills’
  - fit hill templates and compute boundary

thresholding

$$g(x,y) = \begin{cases} 1 & \text{if } f(x,y) > T(x,y,p(x,y)) \\ 0 & \text{otherwise} \end{cases}$$

- T constant $\rightarrow$ global
- T depends on local property $p(x,y)$ $\rightarrow$ local
- T depends on x, y $\rightarrow$ dynamic

Thresholding Revisited

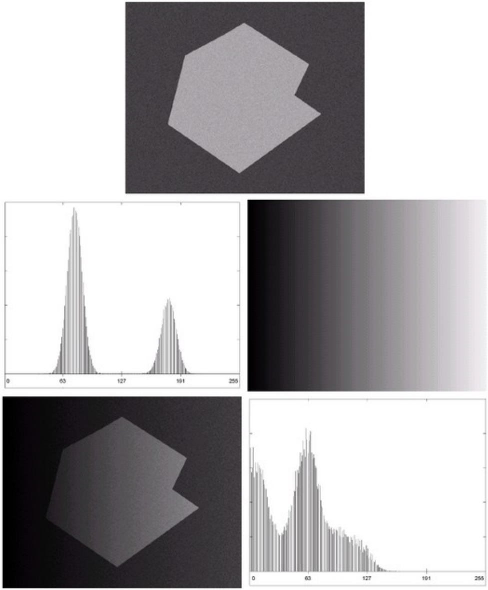
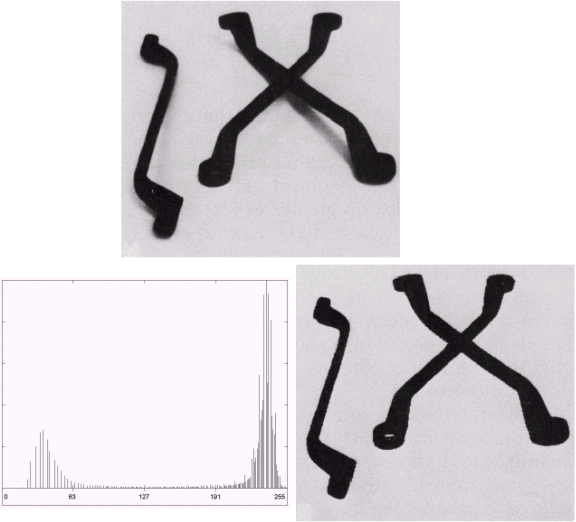


FIGURE 10.27 (a) Computer generated reflectance function. (b) Histogram of reflectance function. (c) Computer generated illumination function. (d) Product of (a) and (c). (e) Histogram of product image.

Basic Global Thresholding



a
b c

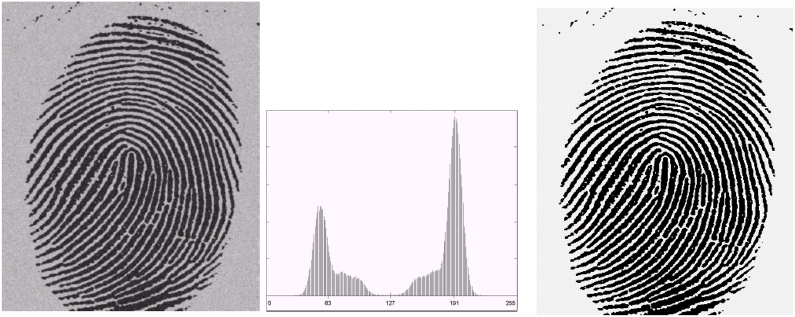
FIGURE 10.28 (a) Original image. (b) Image histogram. (c) Result of global thresholding with T midway between the maximum and minimum gray levels.

Basic Global Thresholding

heuristic for estimating a global T

1. select initial estimate T
   (between mean gray value and (min+max)/2,
   depending on the expected area of the objects)
2. compute average value μ_1 of pixels $> T$ and μ_2 of pixels $\leq T$
3. $T \leftarrow (\mu_1 + \mu_2)/2$
4. repeat from (2) until convergence

Basic Global Thresholding



Otsu Thresholding

maximize inter-class variance of gray values
minimize intra-class variance of gray values
(cp. linear discriminant analysis in pattern recognition)
let h be the normalized histogram of the given image

$$p_1 = \sum_{g=0}^{T} h_g, \quad p_2 = \sum_{g=T+1}^{L-1} h_g = 1 - p_1$$

$$\mu_1 = \frac{1}{p_1} \sum_{g=0}^{T} g\, h_g, \quad \mu_2 = \frac{1}{p_2} \sum_{g=T+1}^{L-1} g\, h_g$$

$$\mu = p_1 \mu_1 + p_2 \mu_2$$

$$\sigma^2 = \sum_{g=0}^{L-1} (g - \mu)^2 h_g = \sigma_b^2 + \sigma_w^2$$

$$\sigma_b^2 = p_1(\mu_1 - \mu)^2 + p_2(\mu_2 - \mu)^2 = p_1 p_2 (\mu_1 - \mu_2)^2$$

$$\hat{T} = \arg\max_T \sigma_b^2(T)$$

Otsu Thresholding

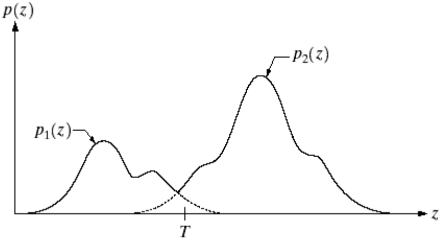
```
/* assume total sum of g * h[g] already computed */
sbmax = -1;
p1 = 0;
for (g = 0; g < 255; g++) {
  p1 += h[g];
  if (p1 == 0) { continue; }
  p2 = 1 - p1;
  if (p2 == 0) { break; }
  csum += g * h[g];
  m1 = csum / p1;
  m2 = (sum - csum) / p2;
  sb = p1 * p2 *(m1 - m2) * (m1 - m2);
  if (sb > sbmax) {
    sbmax = sb;
    T = g;
  }
}
```

Distribution-based Methods

Distribution-based thresholding methods use the tools you know from pattern recognition to estimate the distributions of gray values and to find the optimal class boundary.

In many document analysis cases, we know the expected target distribution including distribution of run-lengths and can optimize for that.

FIGURE 10.32 Gray-level probability density functions of two regions in an image.



(What is wrong here?)

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Example: Niblack's method

- at each pixel position determine:
- mean μ in a region of e.g. 15×15 pixels
- standard deviation σ in the same region
- set local threshold to $T = \mu - 0.2\sigma$

There exist a variety of other methods derived from this approach.

Local Methods

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Connected Components Revisited

We have seen an algorithm to determine the connected components of an image. In the following we will often only consider one such connected component (or region) at a time.

representations of digital regions:

- grid occupancy
  - labeling
  - run-length coding
  - quadtree coding
- boundary description
  - chain code
  - straight-line segments, polygons
  - higher order polynomials, splines

Features of Connected Components

shape features

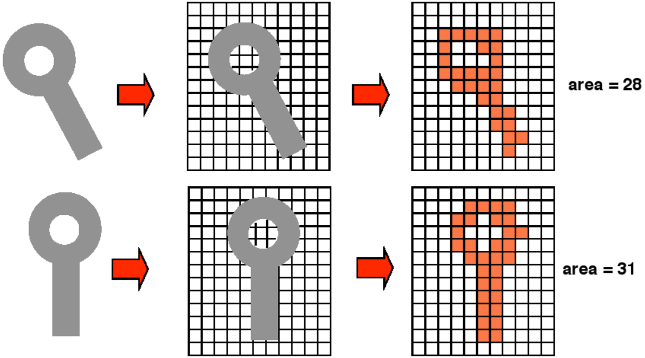
- area
- bounding box
- boundary length
- compactness
- second-order moments

features may or may not have invariance properties

- translation invariance
- rotation invariance
- scale invariance

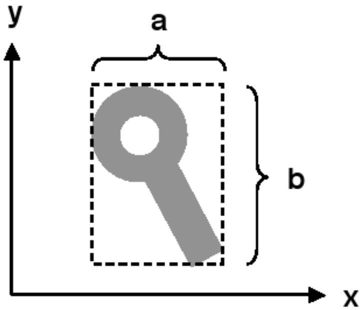
Area

- count number of pixels
- For an arbitrarily fine resolution, the area is translation and rotation invariant.
- Discretization effects may cause considerable variations.



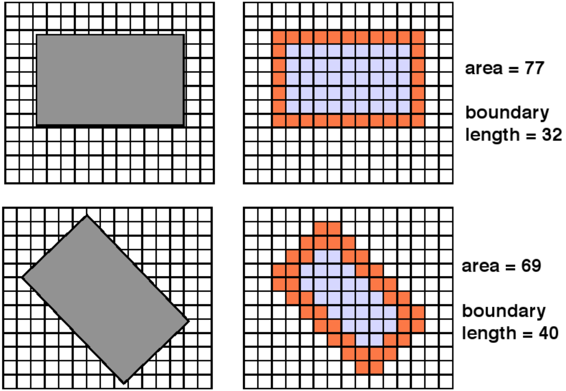
Bounding Box

- easy to compute
- invariance?



Boundary Length

The boundary length (perimeter) is defined as the number of pixels which constitute the boundary of a shape.



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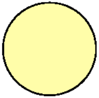
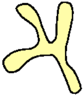
Compactness

$$\text{compactness} = \text{area} \;/\; \text{boundary length}^2$$



very compact



not very compact

Moments

moments of order $(p+q)$

$$m_{pq} = \sum_x \sum_y x^p y^q f(x,y)$$

$$\bar{x} = m_{10}/m_{00}, \quad \bar{y} = m_{01}/m_{00}$$

central moments

$$\mu_{pq} = \sum_x \sum_y (x-\bar{x})^p (y-\bar{y})^q f(x,y)$$

$$\mu_{00} = m_{00}, \quad \mu_{10} = \mu_{01} = 0$$

$\mu_{11} \rightarrow$ cp. correlation
$\mu_{20} \rightarrow$ cp. σ_x^2
$\mu_{02} \rightarrow$ cp. σ_y^2
if $f(x,y) \in \{0,1\}$ (binary), then the sums are simplified and only run over foreground pixels

Moments

orientation of axis of minimum inertia

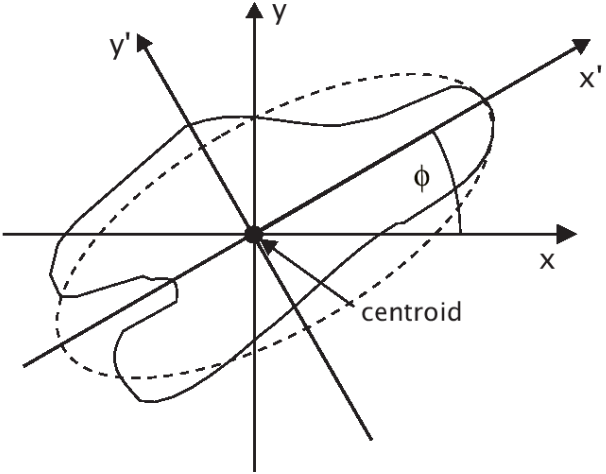
$$\Phi = \frac{1}{2} \arctan \frac{2\mu_{1,1}}{\mu_{2,0} - \mu_{0,2}}$$

normalized central moments

$$\eta_{pq} = \frac{\mu_{pq}}{\mu_{00}^{(p+q+2)/2}}$$

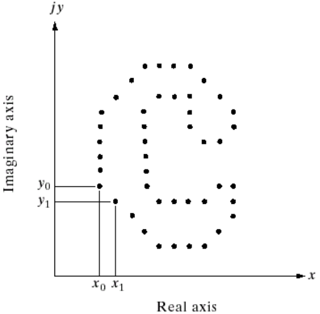
In 1962, Hu presented seven expressions involving the normalized moments that are invariant with respect to rotation, scale and translation (but can be susceptible to noise).

Principal Axes



Fourier Descriptors

view boundary as sequence of imaginary numbers



approximate boundary using only the first (low-frequency) coefficients of the discrete Fourier transform of the sequence

- invariance properties?
- quality of approximation?

Fourier Descriptors

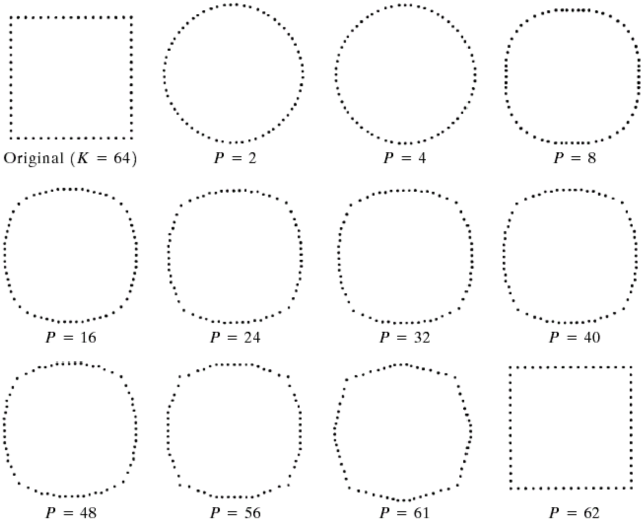
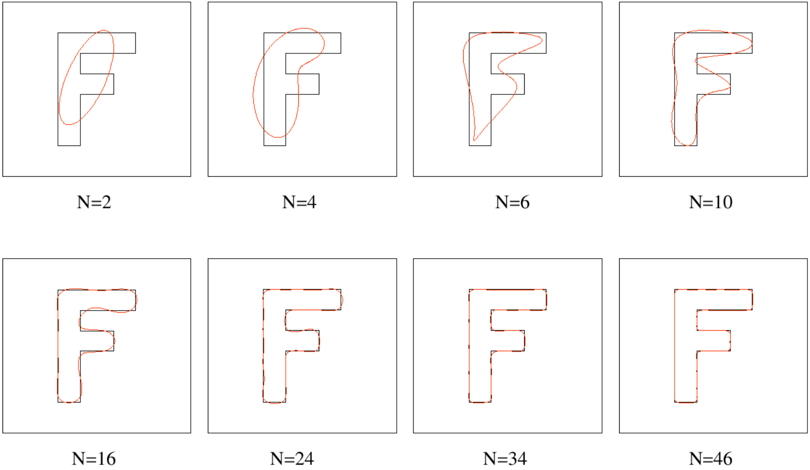


FIGURE 11.14 Examples of reconstruction from Fourier descriptors. P is the number of Fourier coefficients used in the reconstruction of the boundary.

Fourier Descriptors



Fourier Descriptors

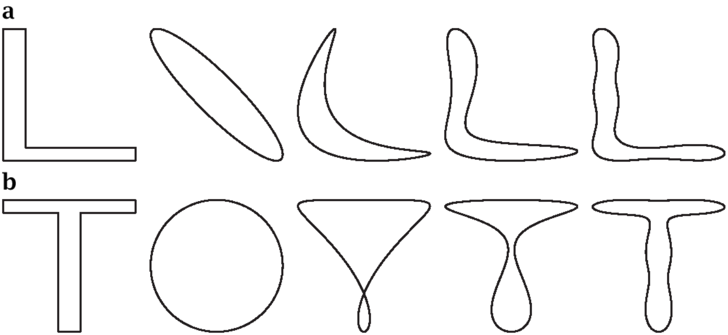


Figure 19.7: *Reconstruction of shape of **a** the letter "L" and **b** the letter "T" with 2, 3, 4, and 8 Fourier descriptor pairs.*

Fourier Descriptors

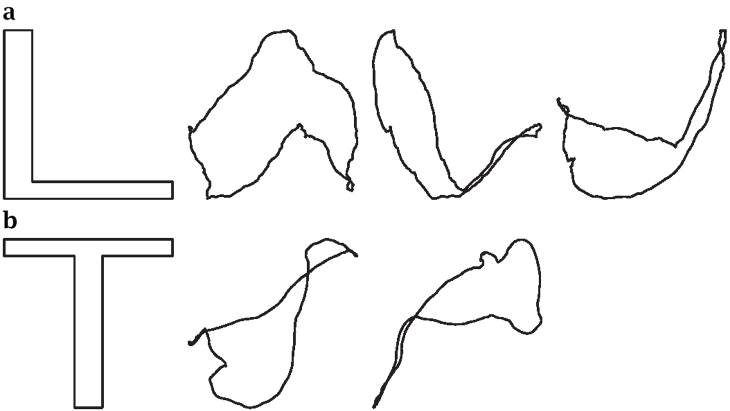


Figure 19.9: *Importance of the phase for the description of shape with Fourier descriptors. Besides the original letters, three random modifications of the phase are shown with unchanged magnitude of the Fourier descriptors.*

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view binary images as subsets of $\mathbb{Z}^2$

basic concepts you are familiar with:
element, empty set, subset, union, intersection,
disjoint sets, complement, difference

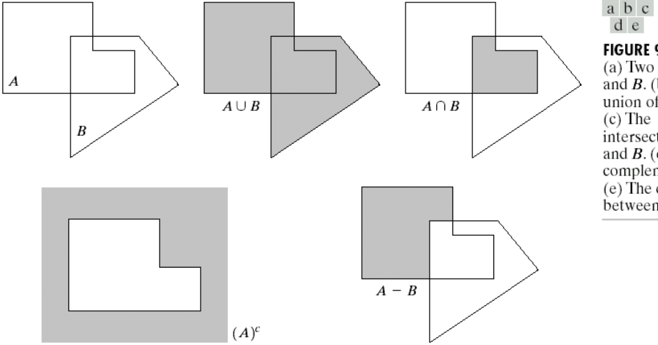


FIGURE 9.1 (a) Two sets A and B. (b) The union of A and B. (c) The intersection of A and B. (d) The complement of A. (e) The difference between A and B.

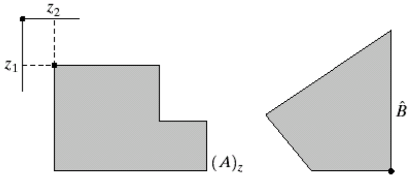
Additional Basic Concepts

reflection of B:

$$\hat{B} = \{w | w = -b, b \in B\}$$

translation of A by z:

$$(A)_z = \{c | c = a + z, a \in A\}$$



a b

FIGURE 9.2
(a) Translation of A by z.
(b) Reflection of B. The sets A and B are from Fig. 9.1.

Dilation

dilation of A by B:

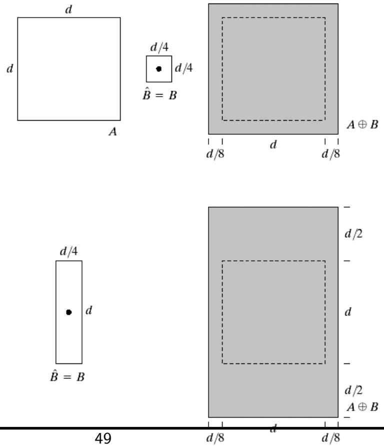
$$A \oplus B = \{z | (\hat{B})_z \cap A \neq \emptyset\} = \bigcup_{z \in A} (B)_z$$

B is called the structuring element

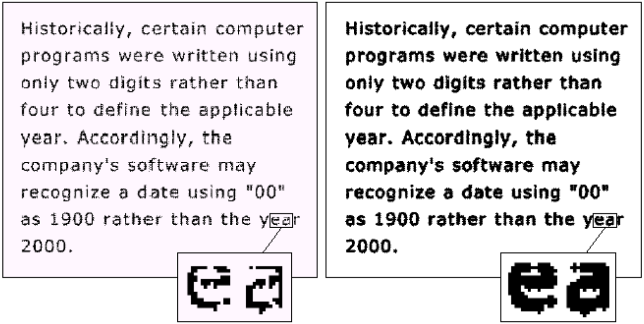
cp. convolution

a b c
d e

FIGURE 9.4
(a) Set A.
(b) Square structuring element (dot is the center).
(c) Dilation of A by B, shown shaded.
(d) Elongated structuring element.
(e) Dilation of A using this element.



Example use of Dilation



0	1	0
1	1	1
0	1	0

a c
b

FIGURE 9.5
(a) Sample text of poor resolution with broken characters (magnified view).
(b) Structuring element.
(c) Dilation of (a) by (b). Broken segments were joined.

Erosion

erosion of A by B:

$$A \ominus B = \{z | (B)_z \subset A\}$$

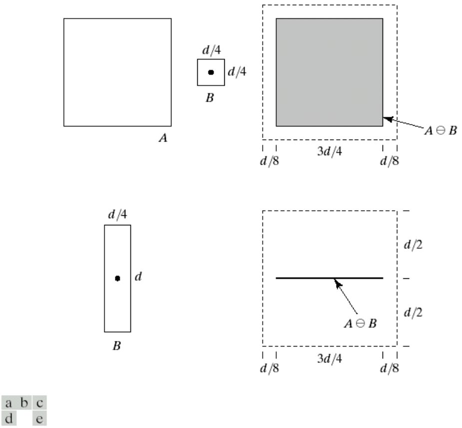
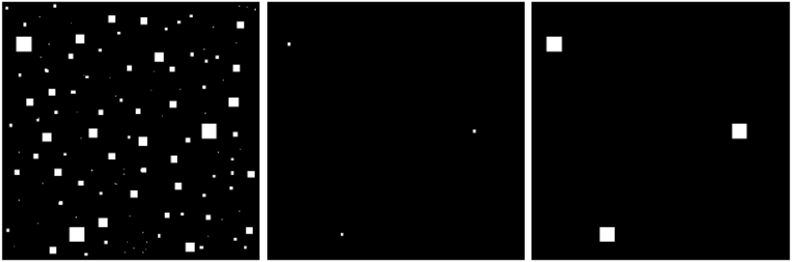


FIGURE 9.6 (a) Set A. (b) Square structuring element. (c) Erosion of A by B, shown shaded. (d) Elongated structuring element. (e) Erosion of A using this element.

Example use of Erosion



a b c

FIGURE 9.7 (a) Image of squares of size 1, 3, 5, 7, 9, and 15 pixels on the side. (b) Erosion of (a) with a square structuring element of 1's, 13 pixels on the side. (c) Dilation of (b) with the same structuring element.

Duality of Dilation and Erosion

$$(A \ominus B)^c = A^c \oplus \hat{B}$$

proof:

$$\begin{aligned}
(A \ominus B)^c &= \{z | (B)_z \subset A\}^c \\
&= \{z | (B)_z \cap A^c = \emptyset\}^c \\
&= \{z | (B)_z \cap A^c \neq \emptyset\} \\
&= \{z | (\hat{\hat{B}})_z \cap A^c \neq \emptyset\} \\
&= A^c \oplus \hat{B}
\end{aligned}$$

Opening and Closing

opening of A by B

$$A \circ B = (A \ominus B) \oplus B$$

- smoothes outlines
- breaks narrow bridges, removes protrusions

closing of A by B

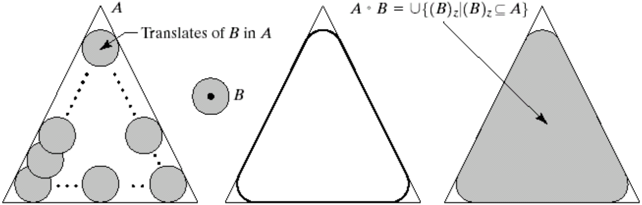
$$A \bullet B = (A \oplus B) \ominus B$$

- smoothes outlines
- fuses narrow breaks, eliminates holes, fills gaps in contour

$$A \circ B = \bigcup_{(B)_z \subset A} (B)_z$$

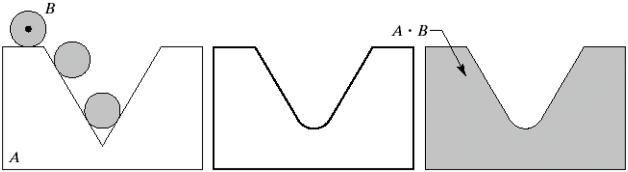
$$(A \bullet B)^c = (A^c \circ \hat{B})$$

Opening and Closing



a b c d

FIGURE 9.8 (a) Structuring element B "rolling" along the inner boundary of A (the dot indicates the origin of B). (c) The heavy line is the outer boundary of the opening. (d) Complete opening (shaded).



a b c

FIGURE 9.9 (a) Structuring element B "rolling" on the outer boundary of set A. (b) Heavy line is the outer boundary of the closing. (c) Complete closing (shaded).

Opening and Closing

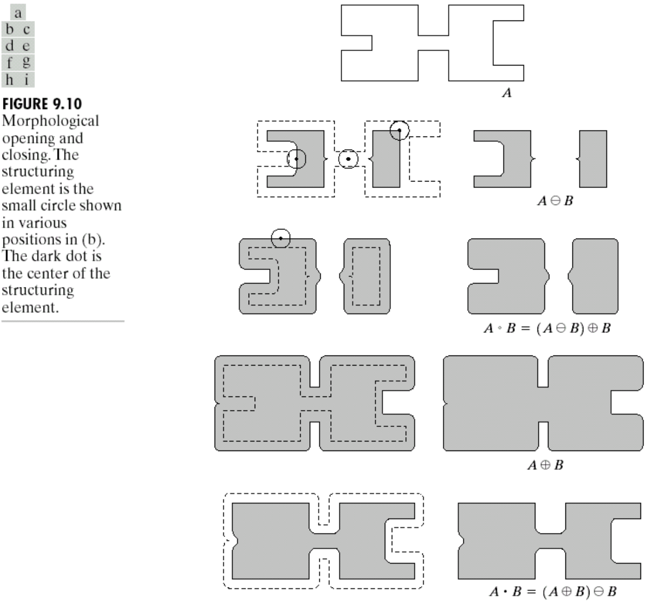


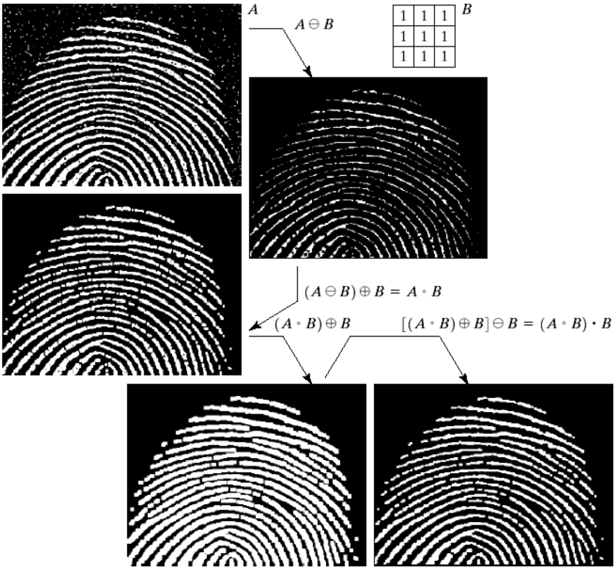
FIGURE 9.10 Morphological opening and closing. The structuring element is the small circle shown in various positions in (b). The dark dot is the center of the structuring element.

Further Properties of Opening and Closing

$$A \circ B \subset A$$
$$C \subset D \Rightarrow C \circ B \subset D \circ B$$
$$(A \circ B) \circ B = A \circ B$$

$$A \subset A \bullet B$$
$$C \subset D \Rightarrow C \bullet B \subset D \bullet B$$
$$(A \bullet B) \bullet B = A \bullet B$$

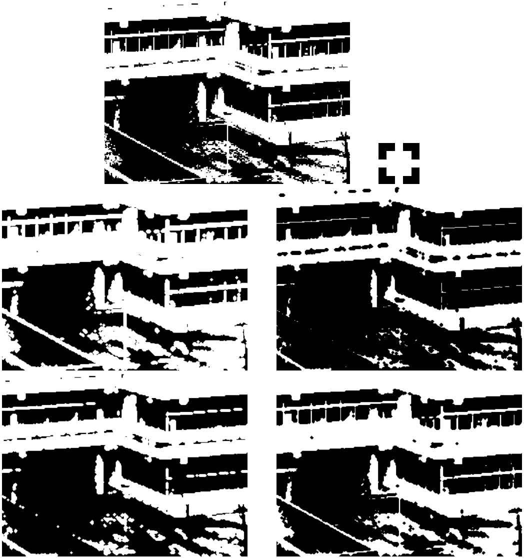
Example



a b
d c
e f

FIGURE 9.11
(a) Noisy image.
(c) Eroded image.
(d) Opening of A.
(d) Dilation of the opening.
(e) Closing of the opening. (Original image for this example courtesy of the National Institute of Standards and Technology.)

Example

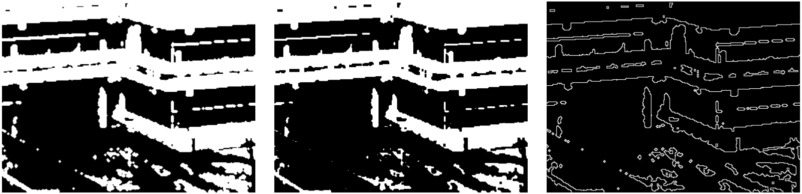


original, structure element, dilation, erosion, opening, closing

Boundary Extraction

boundary extraction using morphological operators

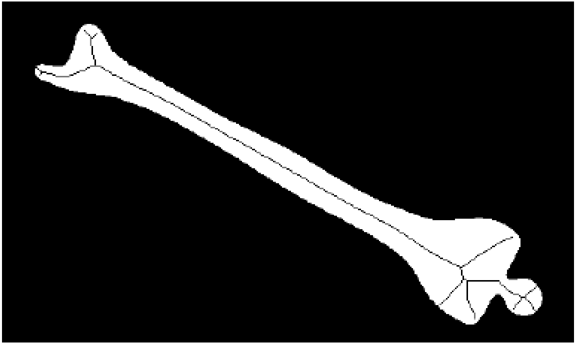
$$A - (A \ominus B)$$



Skeleton

The Medial Axis Transform is one way to define a skeleton: For a region it consists of all pixels which have more than one closest boundary point. ('closest' depends on digital metric)

problems with connectedness
$\rightarrow$ heuristic iterative rule-based algorithms



Skeleton

iteratively flag pixels for deletion when certain rules hold, then delete pixels and repeat until no more changes occur

examples for rules:

delete:

```
000   100   111   000
1 0   1 0   1 0   0 0
111   110   100   111
```

do not delete:

```
111   101   011   001
1 1   0 0   1 0   1 0
110   001   110   100
```

Outline

Lecture Organization: Update

Image Processing (continued)

Binary Images

Features of Connected Components

Morphological Image Processing

Compression of Textual Images

UNIVERSIDAD POLITECNICA DE VALENCIA

Document Image Properties

properties of document images (or textual images) relevant for compression:

- binary images / high contrast
- repetition of *symbols*
- regular distribution of symbols / symbol distances

Example Image

— Resolutie van de staten generael der Vereenighde Nederlanden, dienende tot antwoort op de memorie by de ambassadeurs van sijne majesteyt van Vranckrijck.
's Graven-hage, 1678. 4°. Fag. H. 2. 80. N°. 20.
Fag. H. 2. 85. N°. 17. Fag. H. 3. 42. N°. 4.

— Tractaet van vrede gemaeckt tot Nimwegen op den 10 Augusty, 1678, tusschen de ambassadeurs van [Louis XIV.] ende de ambassadeurs vande staten generael der Vereenighde Nederlanden.
Fag. H. 2. 85. N°. 21.

— Nederlantsche absolutie op de Fransche belydenis.
Amsterdam, 1684. 4°. Fag. H. 2. 50. N°. 22.

— Redenen dienende om aan te wijsen dat haar ho. mog. [niet] konnen verhindert werden een vredige afkomst te maken op de condition by memorien van den grave d' Avaux van de 5 en 7 Juny, 1684, aangeboden.
[*s. l.*] 1684. 4°. Fag. H. 2. 86. N°. 3.
Fag. H. 2. 96. N°. 8. Fag. H. 3. 44. N°. 52.

— Redenen om aan te wijsen dat de bewuste werving van 16000 man niet kan gesustineert werden te zullen hebben konnen strekken tot het bevorderen van een accommodement tusschen Vrankrijk en Spaigne.
[*s. l.*] 1684. 4°. Fag. H. 2. 86. N°. 4.
Fag. H. 2. 96. N°. 2.

— D' oude mode van den nieuwen staat van oorlogh.
[*s. l.* 1684]. 4°. Fag. H. 2. 86. N°. 12.
Fag. H. 2. 96. N°. 3.

— Aenmerkingen over de althans swevende verschillen onder de leden van den staat van ons vaderlant.
[*s. l.*] 1684. 4°. Fag. H. 2. 92. N°. 1.
Fag. H. 2. 98. N°. 16. Fag. H. 3. 1. N°. 18.

— Missive van de staten generael der Vereenighde Nederlanden, . . . 14 Maert, 1684.
's Graven-hage, 1684. 4°. Fag. H. 2. 92. N°. 10.

— Missive van de staaten generael der Vereenigde Nederlanden, . . . 11 July, 1684.
[*sin. tit.* 1684]. 4°. Fag. H. 2. 96. N°. 13.
Fag. H. 3. 44. N°. 69.

— Resolutie vande staten generael der Vereenighde Nederlanden, . . . 2 Maart, 1684.
's Gravenhage, 1684. 4°. Fag. H. 2. 92. N°. 11.
Fag. H. 3. 44. N°. 9.

— Extract uyt de resolutien van de staten generael, . . . 31 Maert, 1684.
[*s. l.*] 1684. 4°. Fag. H. 2. 92. N°. 13.
Fag. H. 2. 96. N°. 25. Fag. H. 3. 44. N°. 11.
Fag. H. 3. 44. N°. 15.

— Antwoort van de staten generael der Vereenighde Nederlanden op de propositie van wegen sijne churf. doorl. van Ceulen, Maert 23, 1684, gedaen.
's Gravenhage, 1684. 4°. Fag. H. 2. 92. N°. 12.

Compression Approaches

approaches for compression

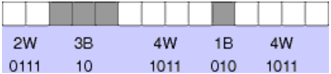
- standard-approaches like PNG/GIF (runs, repetitions)
- OCR and only save text and position
- fax compression (also used in TIFF, runs, similar lines)
- context-dependent arithmetic coding (JBIG)
- token-based compression and mixed raster format (DJVU)

JBIG=Joint Bi-level Image Experts Group
JPEG=Joint Photographic Experts Group

Fax Compression

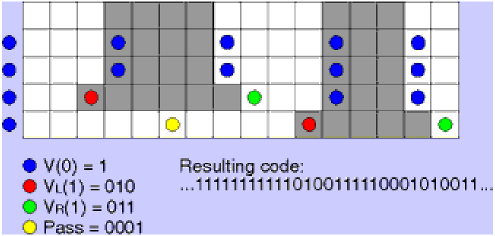
CCITT-G3

- current fax standard
- each line encoded separately (recover from errors)
- use Huffman coding for runs of pixels

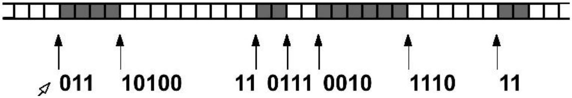


CCITT-G4

- used in TIFF-G4 compression
- lines can be encoded as in G3, or reference the previous line
- uses relative position of positions of color change

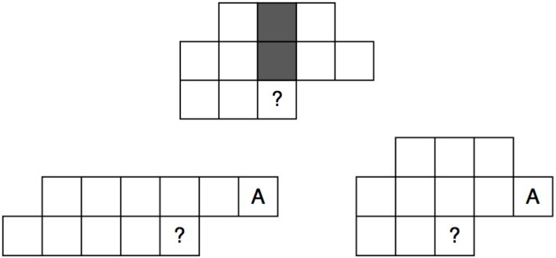


Fax Compression



Run Length	White Code Word	Black Code Word	Run Length	White Code Word	Black Code Word
0	00110101	0000110111	32	00011011	000001101010
1	000111	010	33	00010010	000001101011
2	0111	11	34	00010011	000011010010
3	1000	10	35	00010100	000011010011
4	1011	011	36	00010101	000011010100
5	1100	0011	37	00010110	000011010101
6	1110	0010	38	00010111	000011010110
7	1111	00011	39	00101000	000011010111
8	10011	000101	40	00101001	000001101100
9	10100	000100	41	00101010	000001101101
10	00111	0000100	42	00101011	000011011010
11	01000	0000101	43	00101100	000011011011
12	001000	0000111	44	00101101	000001010100
13	000011	00000100	45	00000100	000001010101
14	110100	00000111	46	00000101	000001010110
15	110101	000011000	47	00001010	000001010111

Context-Dependent Compression



- context allows a much better prediction of a pixel value
- context models have lower entropy and better compression

Example: JBIG (JBIG1)

Token-based Compression

- find all symbols (or tokens) $\rightarrow$ connected components
- construct a library of symbols (use repetition/similarity)
- compress library, sequence of symbols, and distances
- (lossless: compress difference image)

Example: JBIG2

Token-based Compression

Construction of the library:

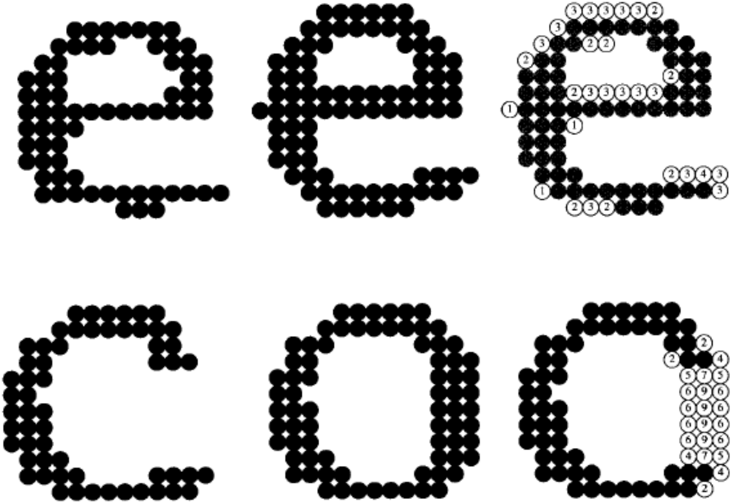
- for each token check if a *similar* token exists in the library, otherwise add it to the library
- needs a definition of similarity $\rightarrow$ character recognition

Example of (dis-)similarity:

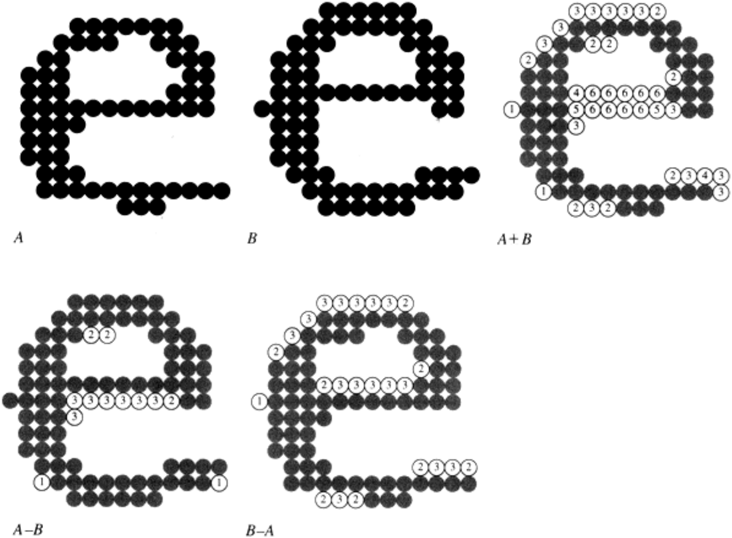
- perform rough pre-selection (e.g. by size)
- normalize tokens with respect to center of mass
- one of
  - weighted pixel-wise XOR
  - Fourier coefficients
  - flexible image matching
  - Hausdorff distance

Possible exercise: Compare different possibilities. (Use e.g. open source JBIG-encoder.)

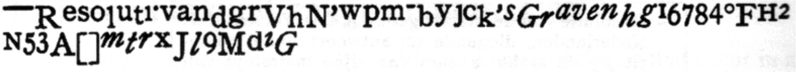
Dissimilarity of Tokens



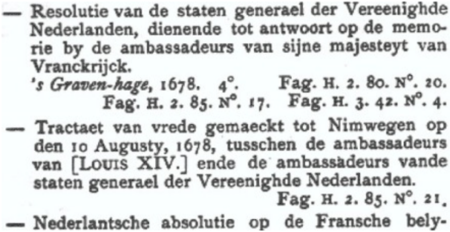
Dissimilarity of Tokens



Library and Symbol Sequence



Symbols and Distances			
Δx	Δy	No.	Symbol
19	62	1	—
24	7	2	R
2	-1	3	e
3	0	4	s
4	0	5	o
2	-1	6	l
3	0	7	u
3	0	8	t
3	0	9	ı
-8	-25	10	.
7	25	3	e
15	0	11	v

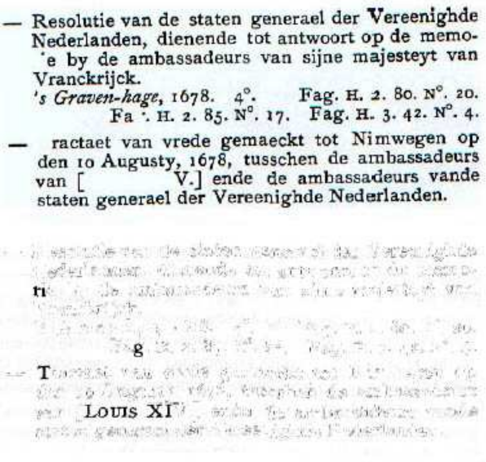


— Resolutie van de staten generael der Vereenighde Nederlanden, dienende tot antwoort op de memorie by de ambassadeurs van sijne majesteyt van Vranckrijck.
's Graven-hage, 1678. 4°. Fag. H. 2. 80. N°. 20.
Fag. H. 2. 85. N°. 17. Fag. H. 3. 42. N°. 4.

— Tractaet van vrede gemaeckt tot Nimwegen op den 10 Augusty, 1678, tusschen de ambassadeurs van [LOUIS XIV.] ende de ambassadeurs vande staten generael der Vereenighde Nederlanden.
Fag. H. 2. 85. N°. 21.

— Nederlantsche absolutie op de Fransche bely-

Difference to Reconstruction

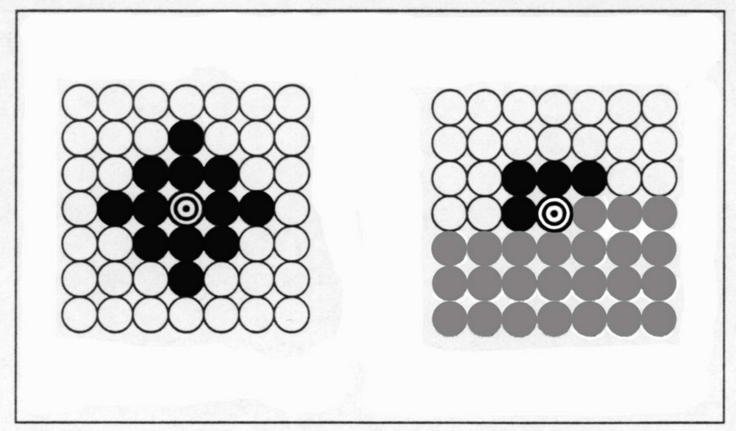


— Resolutie van de staten generael der Vereenighde Nederlanden, dienende tot antwoort op de memo-
'e by de ambassadeurs van sijne majesteyt van Vranckrijck.
's Graven-hage, 1678. 4°. Fag. H. 2. 80. N°. 20.
Fa '. H. 2. 85. N°. 17. Fag. H. 3. 42. N°. 4.

— ractaet van vrede gemaeckt tot Nimwegen op den 10 Augusty, 1678, tusschen de ambassadeurs van [V.] ende de ambassadeurs vande staten generael der Vereenighde Nederlanden.

- reconstruct image from library and positions
- code original image using the reconstructed image as context

Context Templates



When (de)coding the original image using the reconstructed image as context, we can use two contexts, one for the reconstructed (left) and another one for the already (de)coded part (right). This allows better compression.

Mixed Raster Format

example: DJVU (also: JBIG2)

split image into layers and encode separately with appropriate method

- text layer → token-based at about 300-400dpi
- text-color layer (usually black) → image at about 25dpi
- background, images, texture → image at about 100dpi

Mixed Raster Format