Technical University of Cluj - Napoca
Computer Science Department

Sisteme de viziune in robotica

An2, Master Robotica

Cuprins / contents

Prelucrari pe imagini binare / *Binary image processing*

1. Determinarea componentelor conexe / etichetare. *(Labeling connected components)*
2. Detectia si urmarirea conturului. *(Countour tracing)*
3. Calculul proprietatilor geometrice ale obiectelor binare *(Simple geometric features of binary objects)*
4. Operatii morfologice si aplicatii *(Morphological operations and applications)*

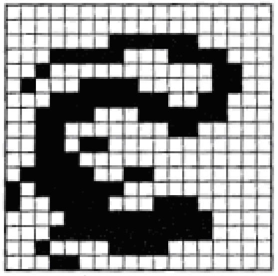
Imagine binara (binary image) ?

Images that contain only 2 colors / labels:

“0” – background pixels

“1” – object pixels

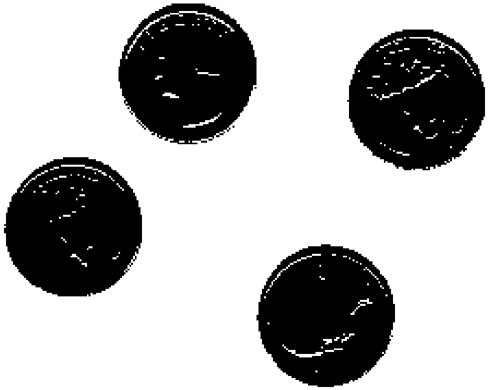
Obtained after a segmentation process !



Grayscale image

⇒

Segmentation



Binary image

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Etichetarea obiectelor

din imagini binare

Labeling connected components

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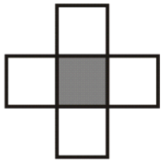
Definitions

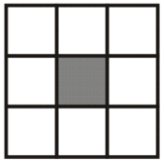
1. Vecini (Neighbors)

- 2 pixels are in a neighborhood relation N4 if they have a common frontier
- 2 pixels are in a neighborhood relation N8 if they have at least a common corner

N4



N8



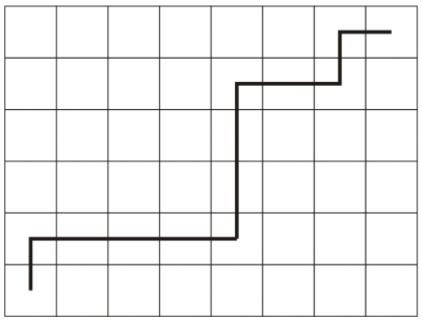
2. Cale (Path)

$$\text{Path}\ (p\ [i_0, j_0] \Rightarrow p\ [i_n,j_n]\ ) := \{\ [i_0,j_0], [i_1,j_1], \ldots, [i_n,j_n] \ \mid\ [i_k,j_k]\ N_{4/8}\ [i_{k+1},j_{k+1}]\ \forall\ k = 0\ ..\ n-1\ \}$$

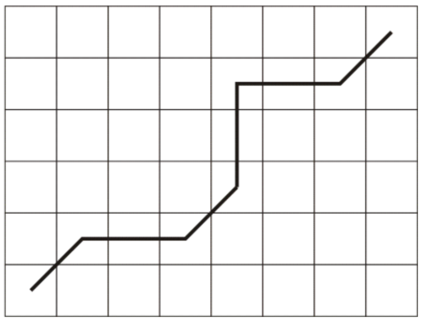
N4 $\Rightarrow$ 4-path

N8 $\Rightarrow$ 8-path

4-path



8-path



Definitions

3. Obiect (Foreground)

$S := \{ p[i,j] \mid p[i,j] = \text{"1"} \}$

4. Conectivitate (Connectivity)

$p_S \leftrightarrow q_S$ (connected) if $\exists$ Path $(p \Rightarrow q) \subset S$.

5. Componente conexe (Connected components)

$\{p_i \in S, i = 1 \dots n \mid p_k \leftrightarrow p_j, \forall (p_k, p_j) \in S, k,j = 1 \dots n\}$

6. Fundal (Background) := set of all connected components of C(S) which have points on the image margins. All other connected components from C(S) are *holes*.

7. Frontiera/Margine (Boundary)

Boundary (S): $= S' = \{ p \in S \mid \exists q \in N_{4/8}(p), q \in C(S) \}$

C(S) – complement of S

8. Interior

Interior (S) = S - S'

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Connected component (*object*)

Maximal set of connected components:

$\{p_i \in S\ ,\ i = 1 \dots n \mid p_k \leftrightarrow pj,\ \forall\ (p_k, p_j) \in S,\ \ k,j = 1 \dots n\}$

A modality to label objects from a binary image is to chose a start point b_{ij} =1 and assign a label to the point and to its neighbors. Further the neighbors of the neighbors are labeled …..

- When the recursive procedure is finished, a connected component is obtained and we can continue by choosing another start point (not labeled yet).
- To find this new start point, the image is scanned systematically and a new labeling procedure is initiated when an object point b_{ij} =1 is found.

$\Rightarrow$

Etichetare (Labeling)

Sequential labeling

Iterative algorithm (Haralick 1981)

- No need for extra memory (memory efficient).
- Processing time depends on the image size/complexity.

1. Initialization phase
2. Repeat

        propagate labels top-down & left-right

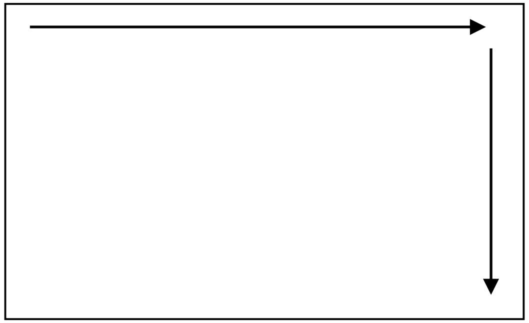
        propagate labels bottom-up & right-left

    until “no change”

```
procedure Iterate;
// Initialize each object pixel “1”with a unique label
for L:=1 to NLINES do
        for P:=1 to NCOLUMNS do
                if  I(L,P) =1
                then LABEL(L,P):=NEWLABEL()
                else LABEL(L,P):=0
        end for
end for;
```

Sequential labeling

“**procedure** Iterate – pag. 2”
“Successive: top-down & bottom-up iterations”



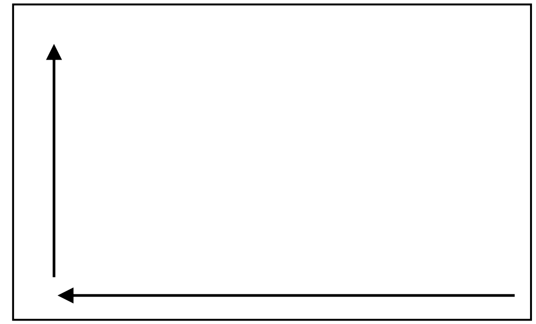
```
repeat

CHANGE:=false;

// top-down iteration
for L:=1 to NLINES do
        for P:=1 to NCOLUMNS do
                if  LABEL(L,P)<>0 then
                        begin
                                M:=MIN(LABELS(NEIGHBORS(L,P)U(L,P)));
                                if M <> LABEL(L,P)
                                then CHANGE:=true;
                                LABEL(L,P):=M
                        end
        end for
end for;
```

Sequential labeling

“**procedure** Iterate – pag. 3”



```
// bottom-up iteration
 for L:= NLINES to 1 by –1 do
          for P:= NCOLUMNS to 1 by –1 do
                    if  LABEL(L,P)<>0 then
                              begin
                                        M:=MIN(LABELS(NEIGHBORS(L,P)U(L,P)));
                                        if M<> LABEL(L,P)
                                        then CHANGE:=true;
                                        LABEL(L,P):=M
                              end
          end for
end for;

until CHANGE:=false

end Iterate
```

Sequential labeling

Example (N4)

	1	1		1	1	
	1	1		1	1	
	1	1	1	1	1	

1. Initial image

	1	2		3	4	
	5	6		7	8	
	9	10	11	12	13	

2. Initialization

	1	1		3	3	
	1	1		3	3	
	1	1	1	1	1	

3. Top-down & left-right label propagation

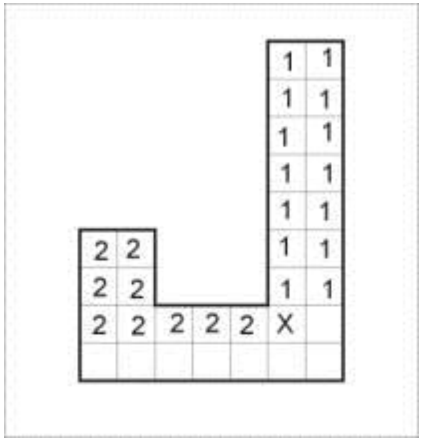
	1	1		1	1	
	1	1		1	1	
	1	1	1	1	1	

4. Bottom-up & right-left label propagation

Classic Algorithm (equivalence classes)

- Based on the classic algorithm that finds connected components in graphs
- Needs 2 iterations but a large table for the equivalences might be needed

1. 1-st step: labels propagation (similar with the previous algorithm)
   - When 2 different labels can be propagated to the same pixel, the smallest one is propagated and the found equivalence is stored in an equivalence table (ex. (1,2) $\rightarrow$ EqTable).
   - Every entry in the EqTable is an ordered pair containing the equivalent labels
   - After this step the equivalence classes are found
   - For every equivalence class a unique label is assigned (smallest or oldest value)



2. 2-nd step: the image is scanned and the corresponding label of the equivalence class is assigned to each pixel

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Classic Algorithm

Example (N4)

1					1	1
		1	1			1
		1				1
		1				1
1	1	1				1
	1	1		1		1
	1	1	1	1		1
				1	1	1

1. Initial image

1					2	2
		3	3			2
		3				2
		3				2
4	4	3				2
	4	3		5		2
	4	3	3	3		2
				3	3	2

2. Label image after top-down propagation

EQTABLE:
(4, 3), (3, 5), (3, 2) …

EQCLASSES:
1: {4, 3, 5, 2}
2: (6,8,9, …}
….
n: {….}

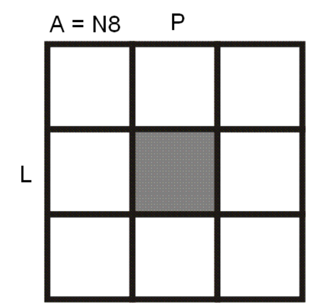
EQLABEL:

1: 2	1:1
2: 6 sau	2:2
…	…
n: x	n:n

SVR

Classic Algorithm

```
procedure Classical
"Initialize global equivalence table" and labels matrix
EQTABLE:=CREATE(); LABEL:=CREATE();

"Top-down pass 1"
for L:= 1 to NLINES do
        "Initialize all labels on line L to zero"
        for P:= 1 to NCOLUMNS do
                LABEL(L,P):=0
        end for
        "Process the line"
        for P:=1 to NCOLUMNS do
                if I(L,P):= 1 then
                        begin
                                A:= NEIGHBORS((L,P));
                                if ISEMPTY(A)
                                then M:=NEWLABEL()
                                else M:= MIN(LABELS(A));
                                LABEL(L,P):=M;
                                for X in LABELS(A) and X<>M
                                        ADD(X, M, EQTABLE)
                                end for;
                        end
        end for
end for;
```

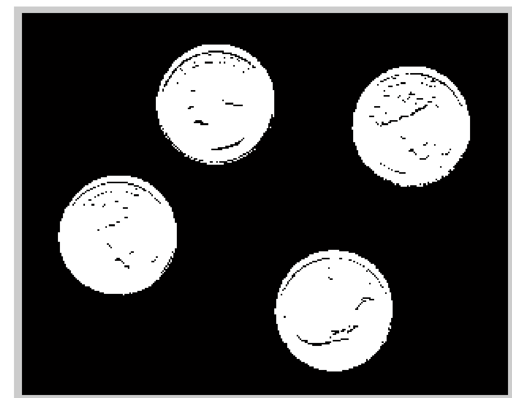


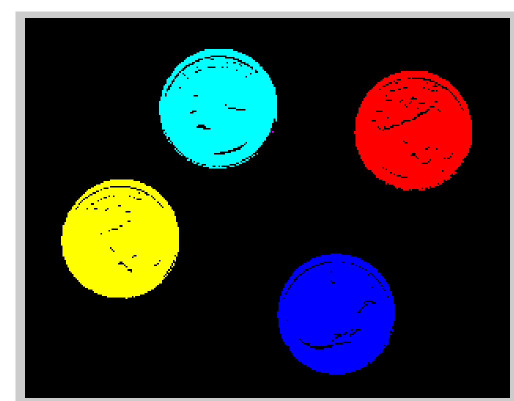
Classic Algorithm

```
"Find equivalence classes"
EQCLASSES:=Resolve(EQTABLE);

for E in EQCLASSES
        EQLABEL(E):= min(LABELS(E))
end for;

"Top-down pass 2"
for L:= 1 to NLINES do
        for P:= 1 to NCOLUMNS do
                if I(L,P) = 1
                then LABEL(L,P):=EQLABEL(CLASS(LABEL(L,P)))
        end for
end for
end Classical
```

- Resolve() - algorithm that finds the connected components of the graph defined by the equivalences set (EQTABLE) defined at step 1.
- Problem: for big images with many objects the table is large (large memory usage)

Example





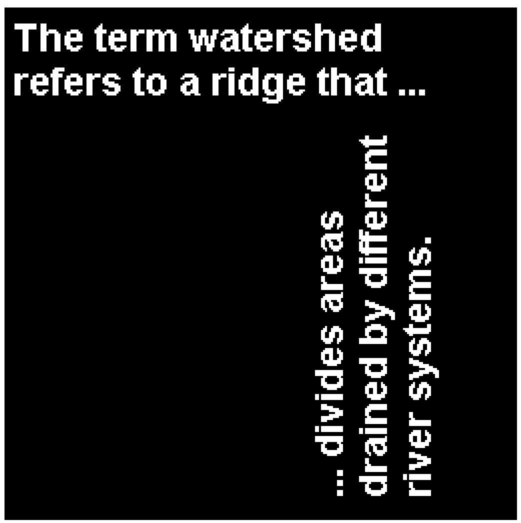
```
%read the grayscale image
I=imread('eight.bmp','BMP');
ColorDepth=256;
figure; imshow(I);
%Cimpute the threshold(see C2)
T=hist_threshold(I);
T_norm = T/ ColorDepth
%normalize the threshold: 0 ... 1
Ibw=im2bw(I, T_norm);
%Image negative:
%Background pixels: 0 (black)
%Object pixels: 1 (white)
Ibw=~Ibw;
figure; imshow(Ibw);
%Objects labeling
%Ilabel: matrix containing the labels
%0 - background, 1 - obiect1 label, 2 - obiect 2 label,
[Ilabel,num] = bwlabel(Ibw,8);
% Display the labels matrix in colors
Irgb= label2rgb(Ilabel, 'hsv', 'black', 'shuffle');
figure; imshow(Irgb);
```

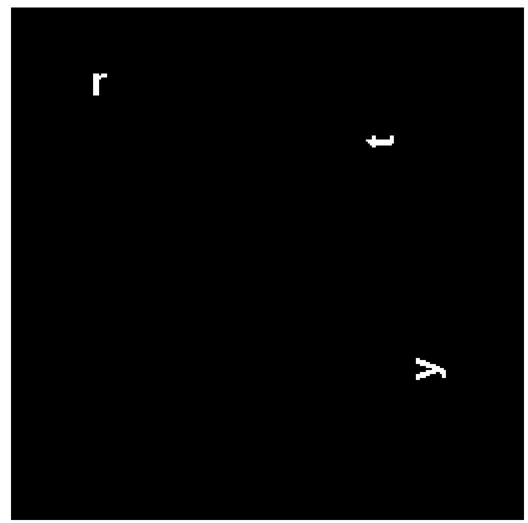
[L,NUM] = bwlabel(BW,N) - returns a matrix L, of the same size as BW, containing labels for the connected components in BW. N can have a value of either 4 or 8. 4 specifies N4 and 8 specifies N8.

Example

To select object from a binary image we can use the function *bwselect*, by specifying the coordinates of a pixel inside the object:

```
BW1 = imread('text.png');
c = [43 185 212];
r = [38 68 181];
BW2 = bwselect(BW1,c,r,4);
imshow(BW1), figure, imshow(BW2)
```





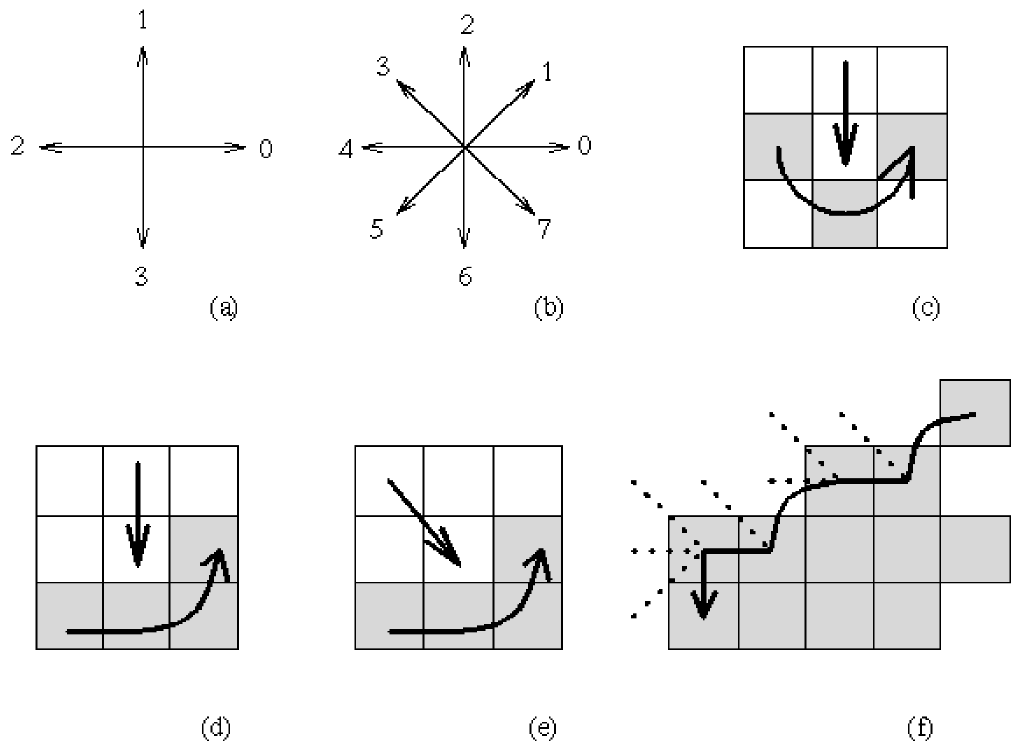
Contour Tracing (detectie contur)

Contour:

Contour(R) = { p ∈ R | ∃ q ∈ N4/8(p), q ∈ C(R) }

- *chain-code / direction codes*: *c*

(numerical operations applied on *c* are mod 4 or 8)



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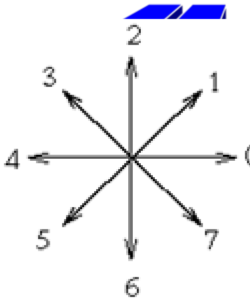
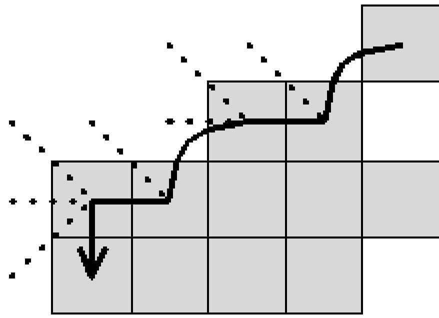
Contour Tracing (detectie contur)



Contour tracing algorithm:

1. Scan the image(top-down + left-right) until it finds a start pixel *P0. Define a* variable *dir* which stores the last movement direction along the contour (from the previous to the current point):
- *dir* = 0 for N4
- *dir* = 7 for N8



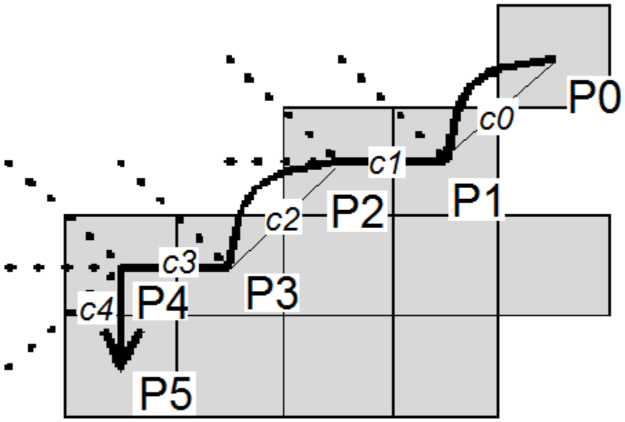
2. Search the next contour point in a neighborhood of 3x3 around the current pixel, by sequentially incrementing (dir++), In counterclockwise direction starting with direction:
- (*dir* + 3) *mod* 4 (N4)
- (*dir* + 7) *mod* 8 if *dir* is even (N8)
- (*dir* + 6) *mod* 8 if *dir* is odd (N8)

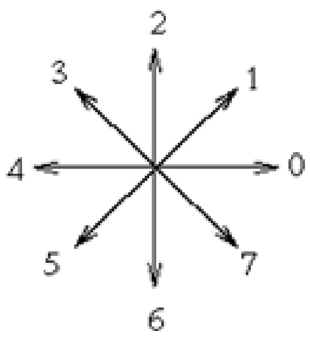
First pixel of "1" is the current contour pixel: *Pn*. In the same time it updateds *dir*.

3. If the current contour element *Pn* is identical with *P1* and if element *Pn-1* is identical with *P0*, STOP. Otherwise repeat step 2.

4. The detected contour is: *P0* … *Pn-2*.

Example – contour representation





$c_i \in \{0,1, \ldots ,7\}$ – direction codes

Var.1 – list of points:

$L = \{ P_0(x_0,y_0), P_1(x_1,y_1), \ldots , P_{n-2}(x_{n-2},y_{n-2}) \}$

Var .2 – chain codes:

$P_0(x_0,y_0) + \{c_0, c_1, \ldots , c_{n-2}\}$,

Var. 3 – *chain codes derivative* (invariant to rotation)

$P_0(x_0,y_0) + \{cd_0, cd_1, \ldots , cd_{n-2}\}$,

where: $cd_i = (c_i - c_{i-1})$ *mod* 8, $cd_0 = c_0$ *mod* 8

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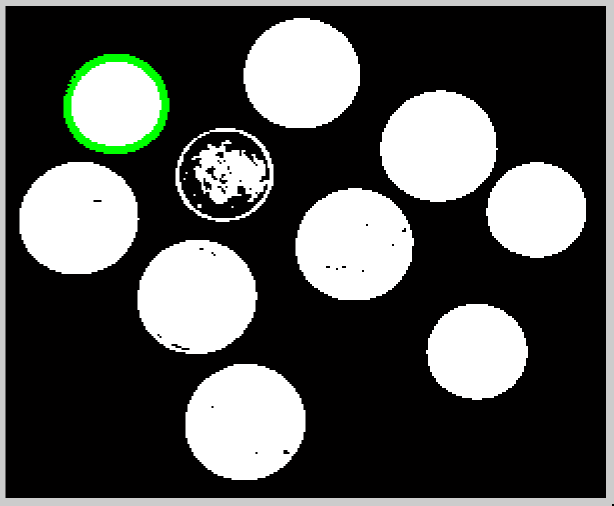
Example

```
I = imread('coins.png');
figure; imshow(I)
%thresholding / image segmentation
BW = im2bw(I);

%select a start point
dim = size(BW)
col = round(dim(2)/2)-90;
row = min(find(BW(:,col)))

boundary = bwtraceboundary(BW,[row, col],'N');

%displat the BW image and the contour
figure; imshow(BW)
hold on;
plot(boundary(:,2),boundary(:,1),'g','LineWidth',3);
```



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