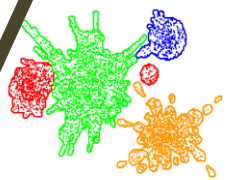
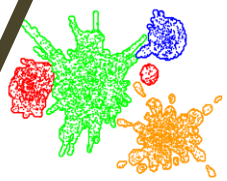
Interfatare vizuala om-masina
- modulul 2 -

Laura Florea



Extragere de trasaturi din imagini

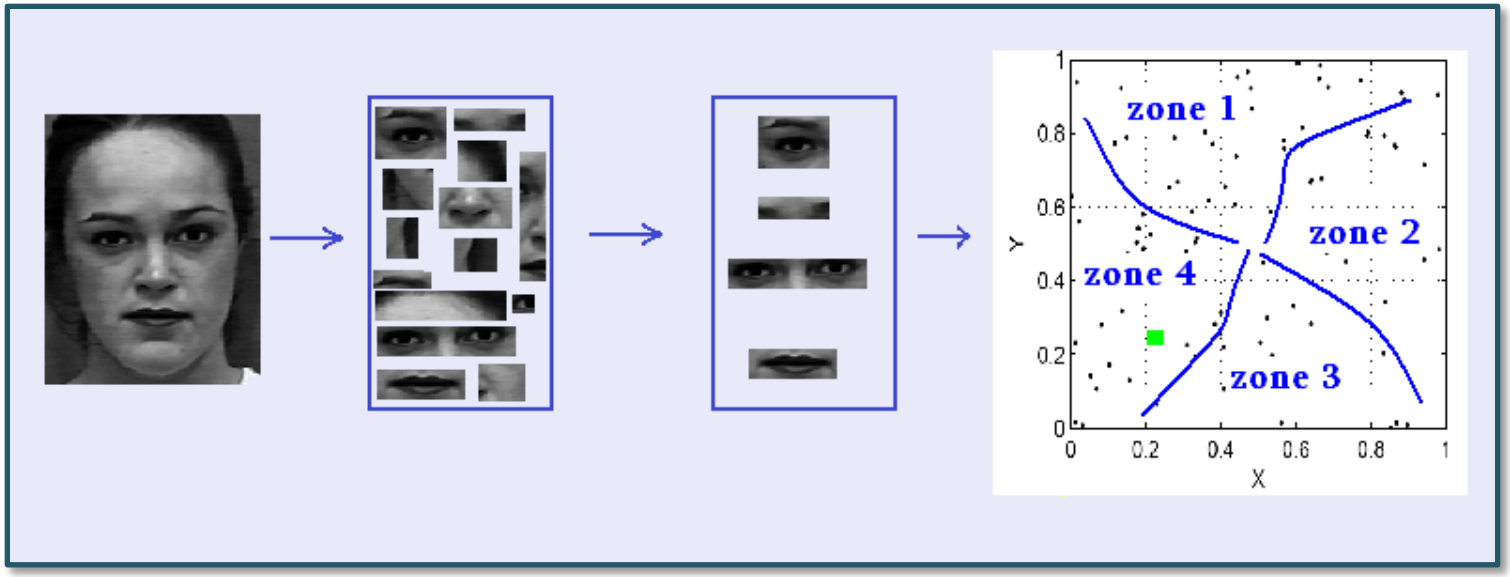
Interfatare vizuala om-masina



Problematica clasificarii

Etape:

- Extragere de trasaturi semnificative problemei
- Reducerea numarului de trasaturilor
- Clasificare:
  - Binara
  - Cu valori multiple

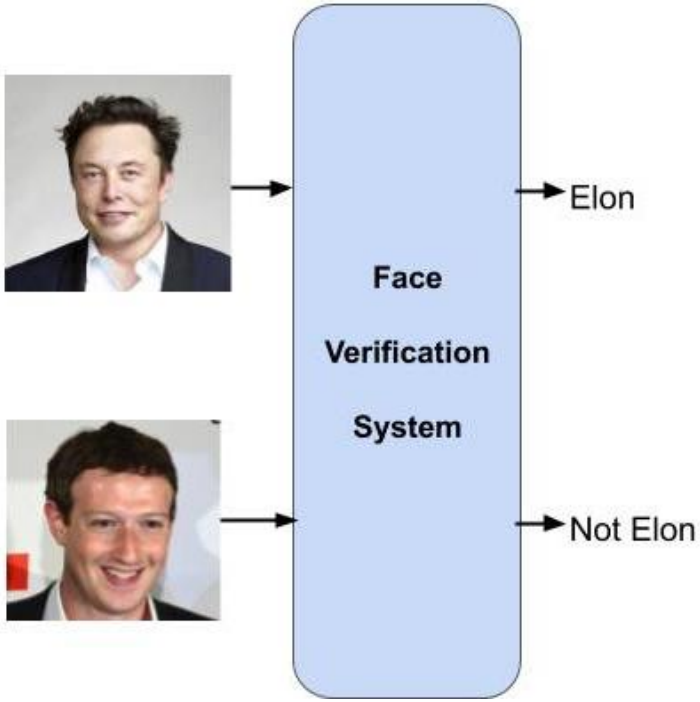


Clasificare binara

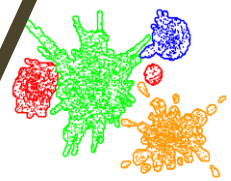


- Iesirea: 2 clase
- Exemple pentru analiza faciala:
  - Recunoastere de gen: barbat / femeie?
  - Sunt 2 persoane inrudite? Da/Nu



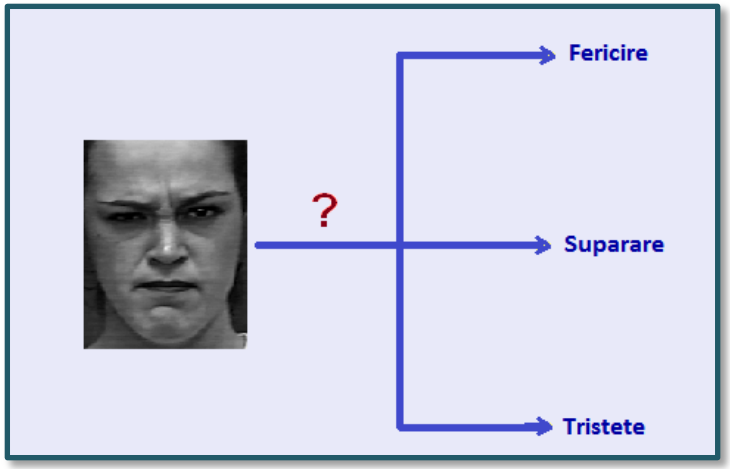


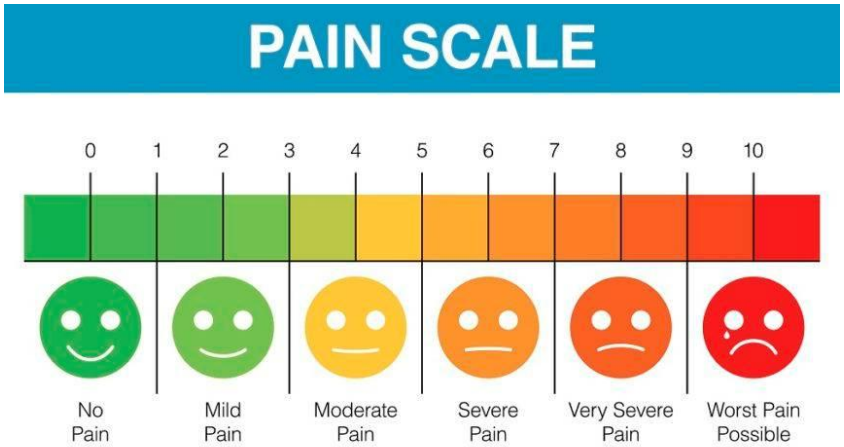
-Recunoastere de fete la momente de timp diferite (imbatranire): este aceeasi persoana? Da/Nu
- Recunoastere de fete (verificare de identitate): este acesta Elon? Da/Nu



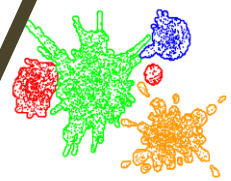
Clasificare cu mai multe clase

- Exemple pentru analiza faciala:
  - Recunoasterea de emotii: suparare, fericire, surpriza, dezgust, etc
  - Ce grad de rudenie au 2 persoane?





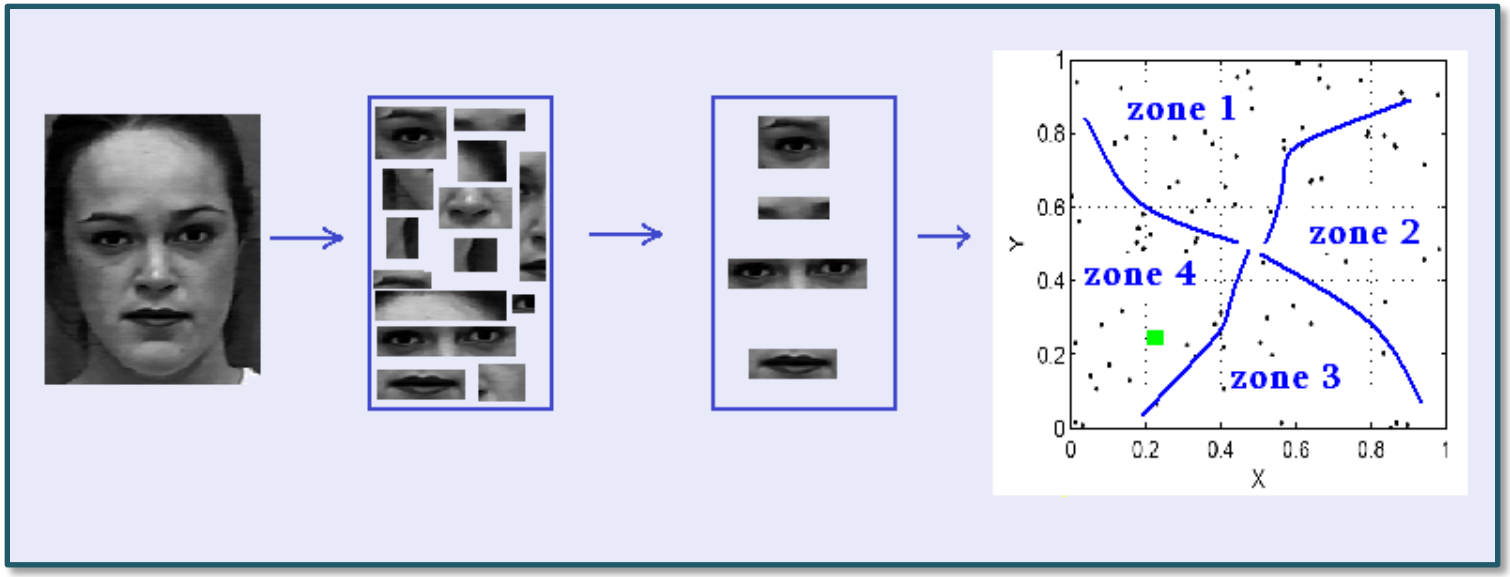
-Estimarea gradului intensitatii durerii: fara durere, durere mica, durere medie, durere puternica



Problematica clasificarii

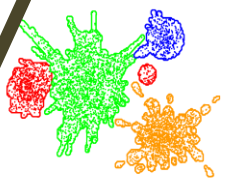
Etape:

- Extragere de trasaturi semnificative problemei
- Reducerea numarului de trasaturilor
- Clasificare:
  - Binara
  - Cu valori multiple



Parametri derivati din segmentare

- Poate cea mai uzuala metoda de clasificare
- Se segmenteaza zona de interes
  - De obicei se alege o zona mai mare
- Se filtreaza zona segmentata
  - Se filtreaza valorile extrase
  - Se filtreaza morfologic
- Se calculeaza diferite valori extrase din rezultat
- Pe o baza de antrenament se identifica valorile utile si se compune regula de decizie finala – divizarea in domenii

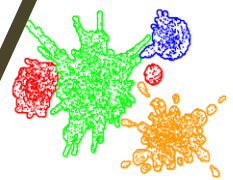


Parametri din segmentare: Exemplu

- Problema: Clasificare de gen
- Se segmenteaza pe culoare pielea
- Se construiesc parametri:
  - Raportul de compacticitate, ρ
    - Femeile au fata mai rotunda
  - Numarul de zone de piele in masca, N_H
    - Barbatii au par facial
  - Dimensiunea (aria) ochilor, A_E
    - Femeile au ochi mai mari





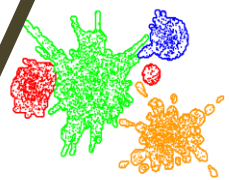


Parametri din segmentare: Exemplu

- Se construiesc parametri:
  - Fara suport fizic
    - Aria cercului circumscris / Aria dreptunghiului circumscris, R_A
    - Saturatia medie a fetei , S_{avg}
    - Varianta pe planul U, σ^2_U
- Pe baza unei baze de antrenament se construiesc **reguli de decizie**:
  - Decizia este luata pe baza unei reguli compuse







Parametri din segmentare: Exemplu

- Regula de decizie finala:

$R_F = (\rho < 0.5 \;||\; \rho > 0.5\,) \;\&\; (N_H > 24) \;\&\; (A_E < 15) \;\&$
$\&\; (R_A < 0.437) \;\&\; (S_{avg} > 23 \;||\; S_{avg} < 5) \;\&$
$\&\; (10 < \sigma^2{}_U < 34.1245)$



R_F < T - Barbat

R_F ≥ T - Femeie

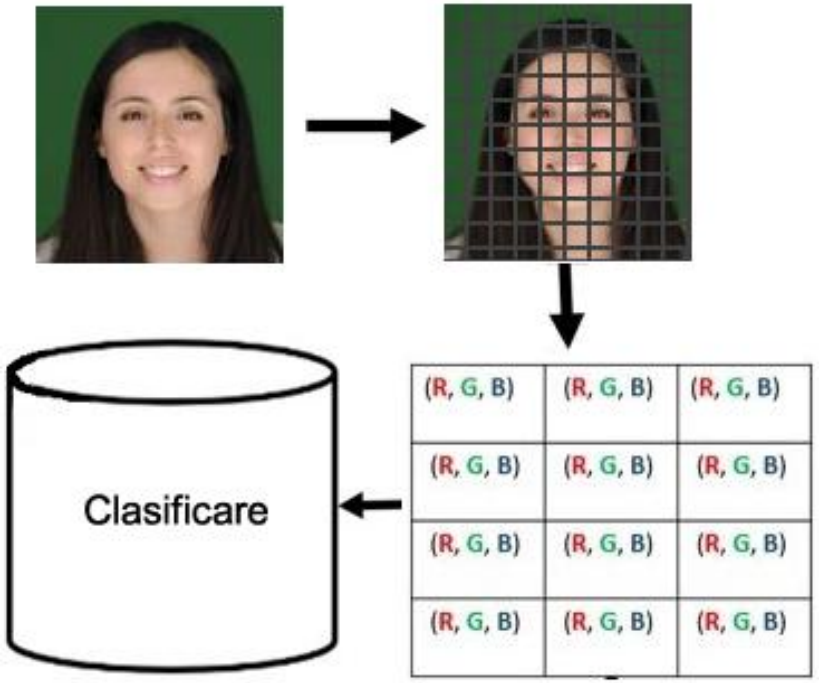
Se pot obtine rezultate foarte bune, dar cu:

- **Multa munca manuala**
- **Baza de date foarte bine aleasa**

Extragere automata de trasaturi

- Trasatura = scalar/vector care exprima o caracteristica locala a unei imagini/obiect

- Extragerea de trasaturi poate fi:
  - Spatiala
  - Spectrala
  - Mixta

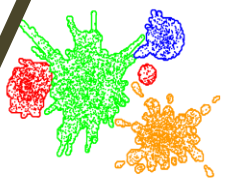


Extragere automata de trasaturi

Cand se aleg trasaturile trebuie avut in vedere:

- Suficienta - caracteristicile trebuie să aibă informaţii suficiente despre imagine şi nu trebuie să solicite cunoştinţe specifice domeniului pentru extragerea lor.
- Usor de calculat - abordarea să fie fezabilă pentru o colecţie de imagini de mari dimensiuni şi recuperare rapidă
  - Trasaturi “slabe” – usor de calculat, multe
  - Trasaturi “puternice” – putine, complexe.
- Compatibilitate cu SVU - trebuie să fie legate de caracteristici umane perceptuale.

http://facweb.cti.depaul.edu/research/vc/VC_Workshop/presentations/pdf/daniela_tutorial2.pdf



Domeniul de analiza

Domeniu spatial:

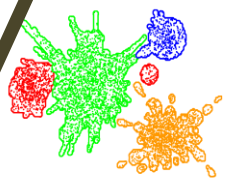
- Caut valori constante de o anumita intensitate
- Structuri cu o distributie fixa
  - Trasaturi de tip Haar; Local Binary Patterns

Domeniu spectral:

- Se obtine cu ajutorul transformatei Fourier/ DCT
- Caut variatii

Domeniu mixt

- Caut anumite valori combinate cu anumite variatii

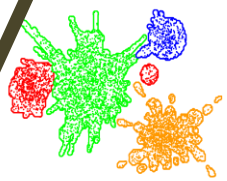


Imagine integrala

- Provine din Grafica – "Summed-area tables"
- Varianta 2D a conceputului ***prefix sums***
  - Fie un vector **f** =[f_1, f_2, f_3, …]
  - Se construieste suma cumulativa

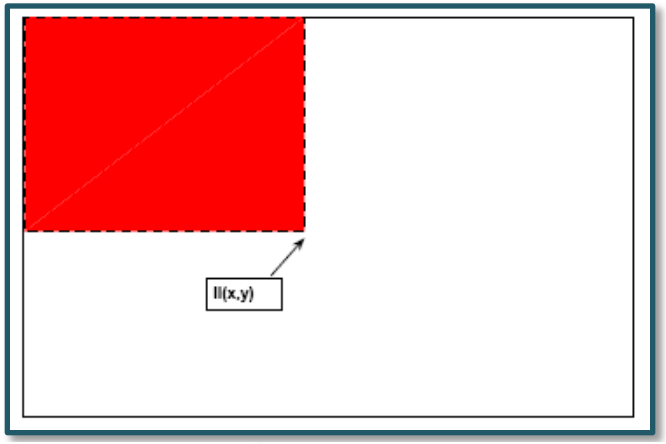
  F = [F_1=f_1, F_2=f_1+f_2, F_3 = f_1+f_2+f_3, …]
  - Suma elementelor consecutive din vectorul initial, dintre doi indici i_1 si i_2 este:

$$f_{i_1} + f_{i_1+1} + \ldots + f_{i_2} = F_{i_2} - F_{i_1-1}$$



Imaginea integrala

- Cum implementam acest principiu in 2D?



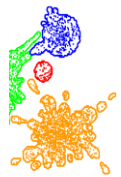
$$II(x,y) = \sum_{i=1}^{x}\sum_{j=1}^{y} I(i,j)$$

Image

5	2	5	2
3	6	3	6
5	2	5	2
3	6	3	6

Summed Area Table

5	7	12	14
8	16	24	32
13	23	36	46
16	32	48	64

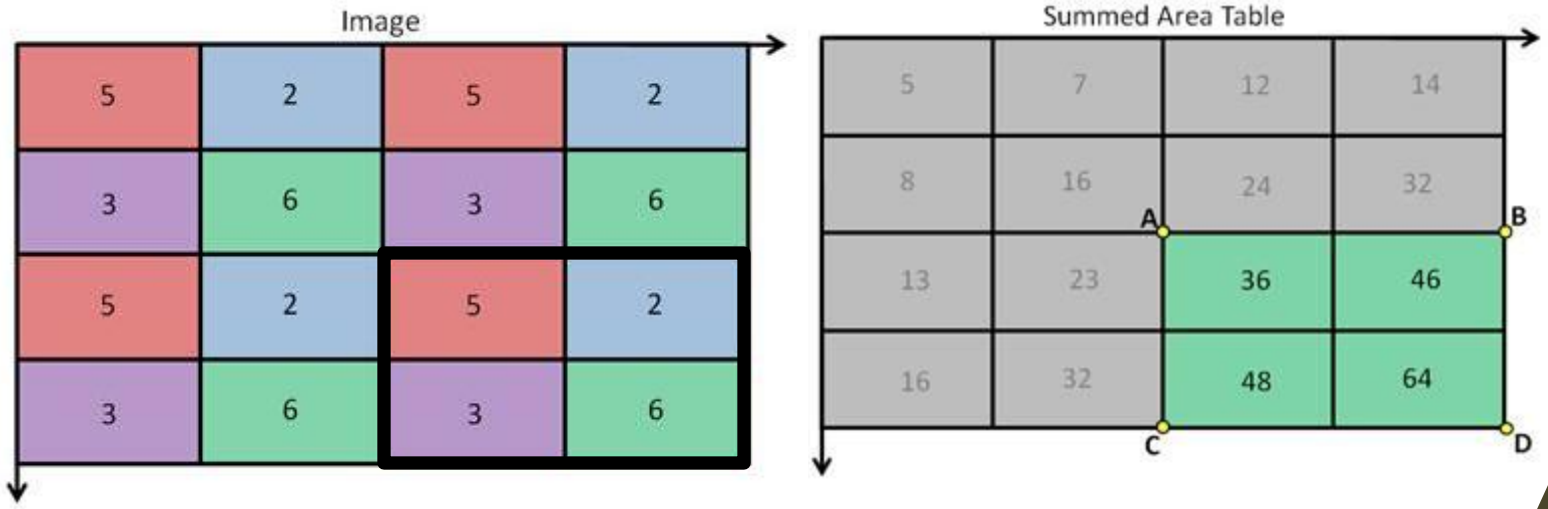


Imaginea integrala

$$\sum_{i=x_1}^{x_2}\sum_{j=y_1}^{y_2} I(i,\,j) = II(A) + II(D) - II(B) - II(C)$$

$$A = (x_1 - 1,\, y_1 - 1) \qquad B = (x_1 - 1,\, y_2)$$

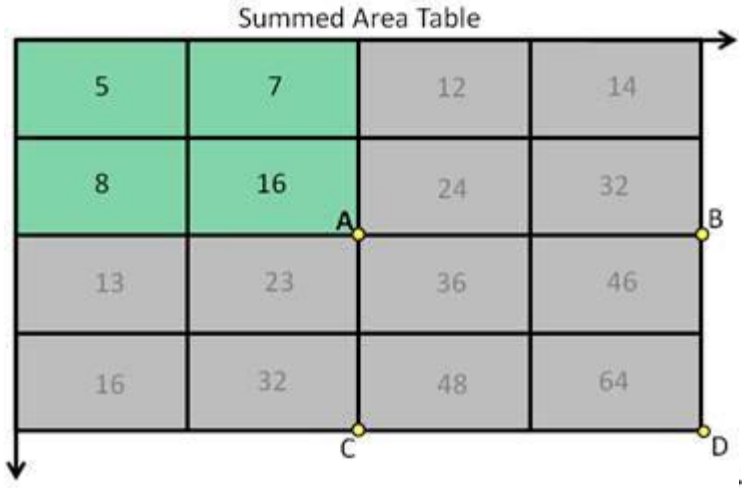
$$C = (x_2,\, y_1 - 1) \qquad D = (x_2,\, y_2)$$

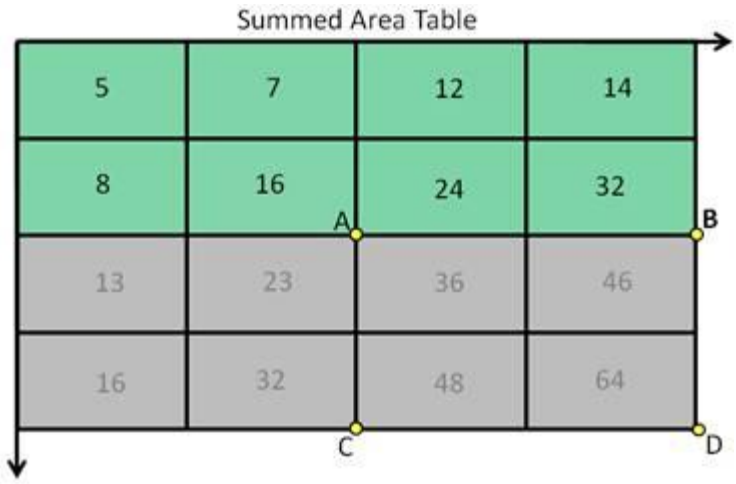


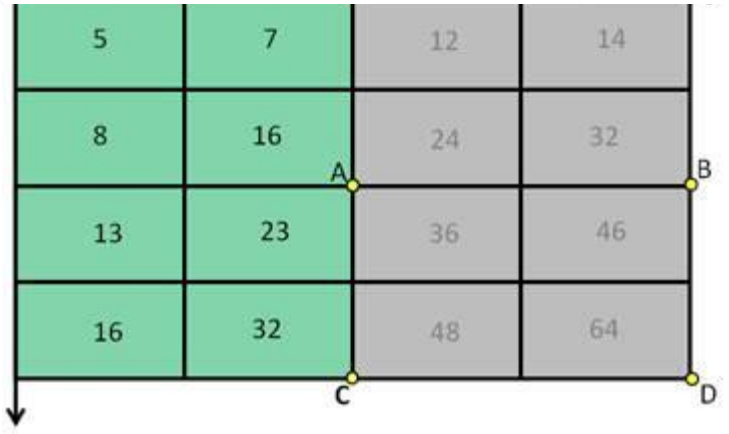
Evaluarea sumei valorilor dintr-o zona ajunge sa aiba complexitate O(1) [constanta] fata de O(n^2) [cuadratica].

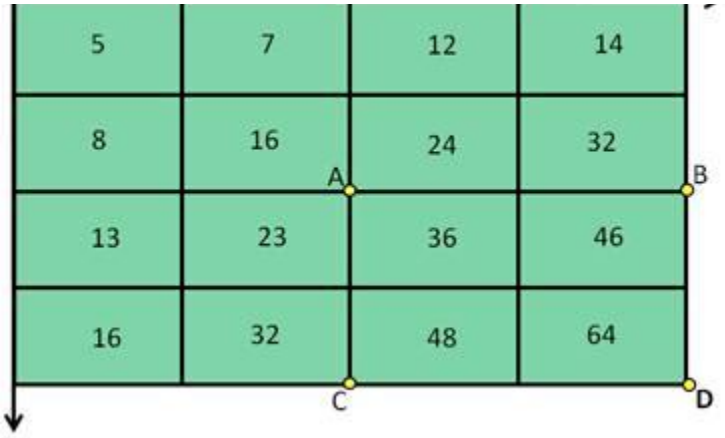
Imaginea integrala

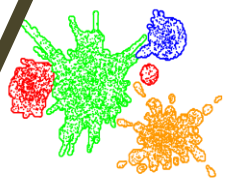
$$\sum_{i=x_1}^{x_2}\sum_{j=y_1}^{y_2} I(i,j) = II(A) + II(D) - II(B) - II(C) = 16$$





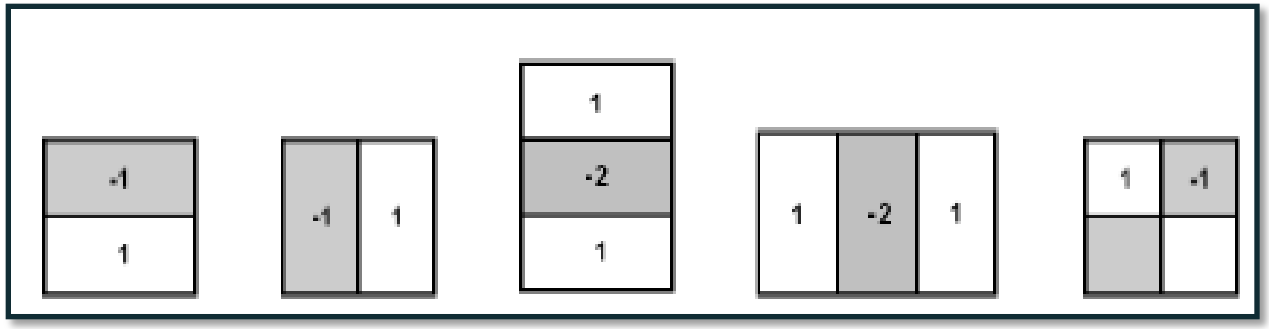


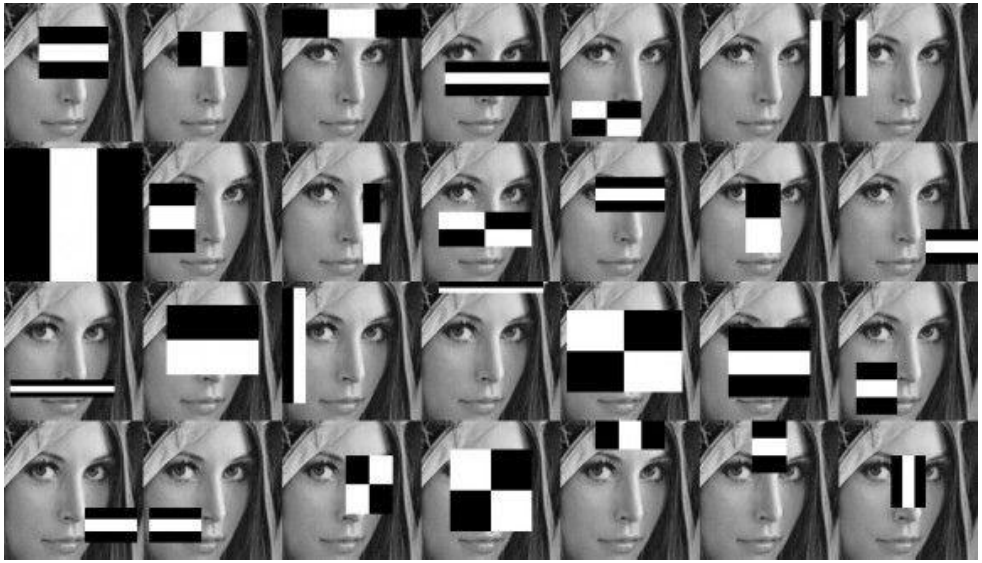




Trasaturi Haar

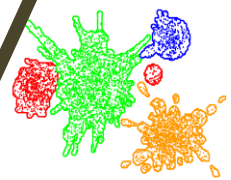
- Provin din transformata Wavelet de tip Haar





- Dupa Viola si Jones se numesc trasaturi Haar

- Se calculeaza eficient cu Imaginea Integrala



Trasaturi Haar extinse

Ex: Trasaturi Haar extinse

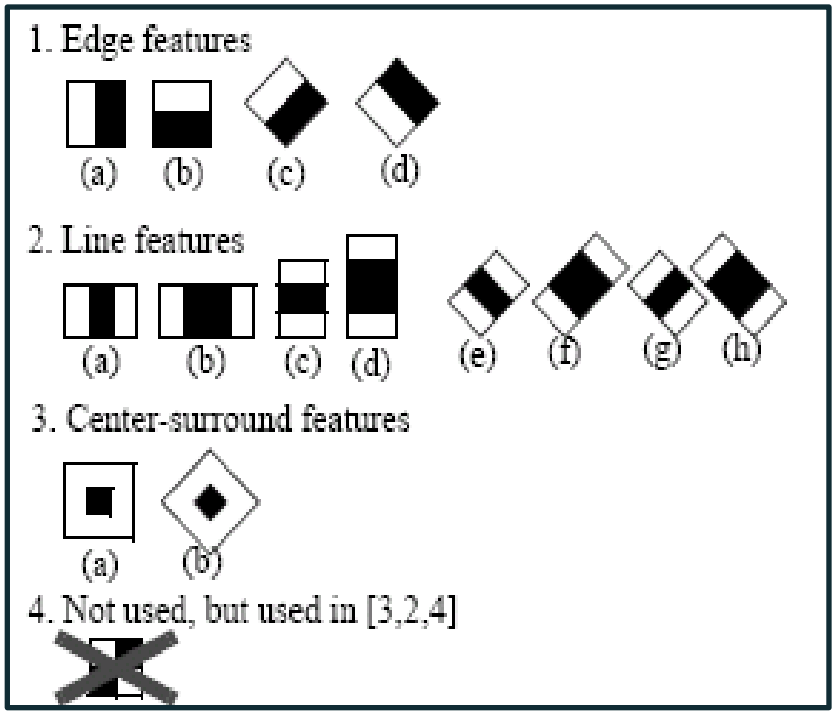
- Lienhart propune 45 trasaturi dreptunghiulare rotate
- O trasatura este reprezentata

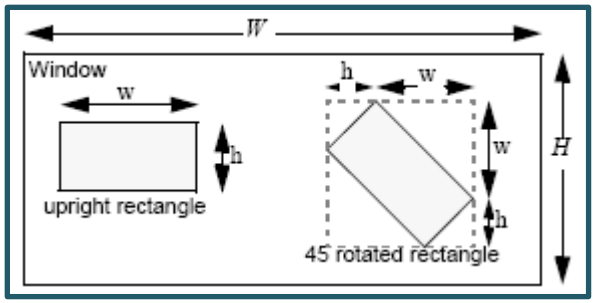
de:

  - Tipul trasaturii: 1(a), 2(b);
  - Locatia (x, y)
  - Dimensiunea trasaturii (w, h)

- Pentru o fereastra 24x24

exista 117,941 trasaturi diferite





Trasaturi Haar asimetrice

- **Ramirez** propune trasaturi asimetrice
- O trasatura este representata de:
  - Tipul trasaturii: 1,2,…6;
  - Locatia (x, y)
  - Parametri

- Pentru o fereastra 24x24 exista $2*10^8$ trasaturi diferite

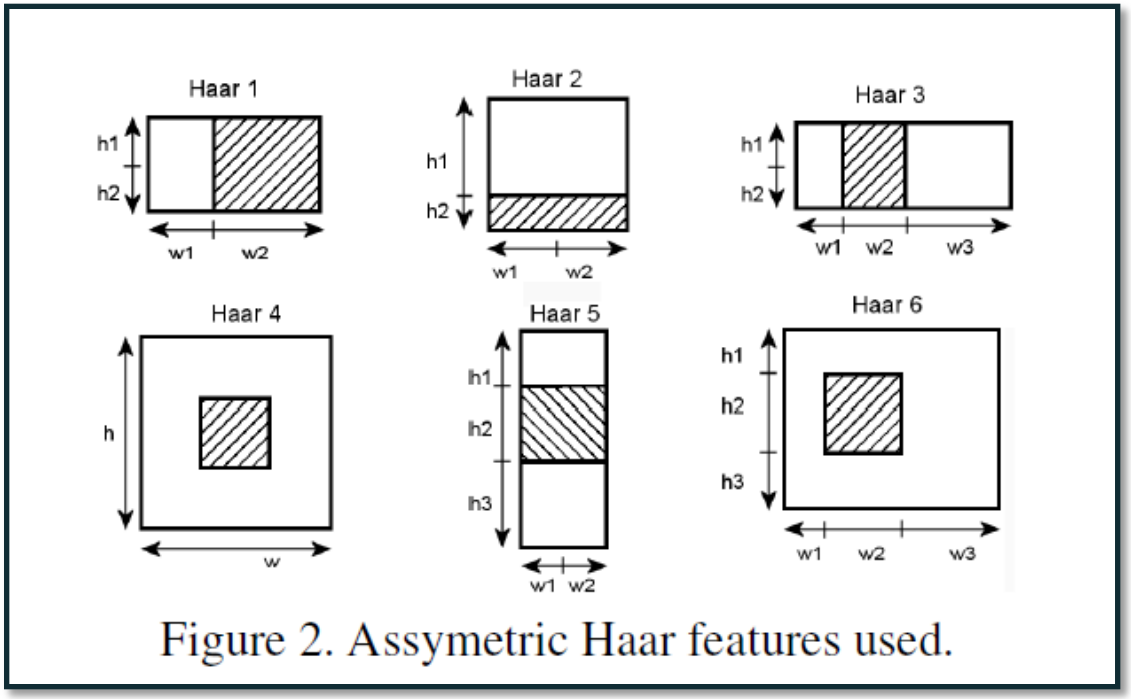


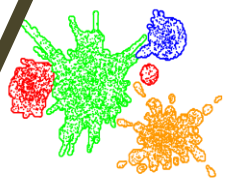
Figure 2. Assymetric Haar features used.

Trasaturi Census

- Introduse de Zabih si Woodfill (1994)

$$C(x) = \bigodot_{y \in \mathcal{N}} \zeta(I(x), I(y))$$

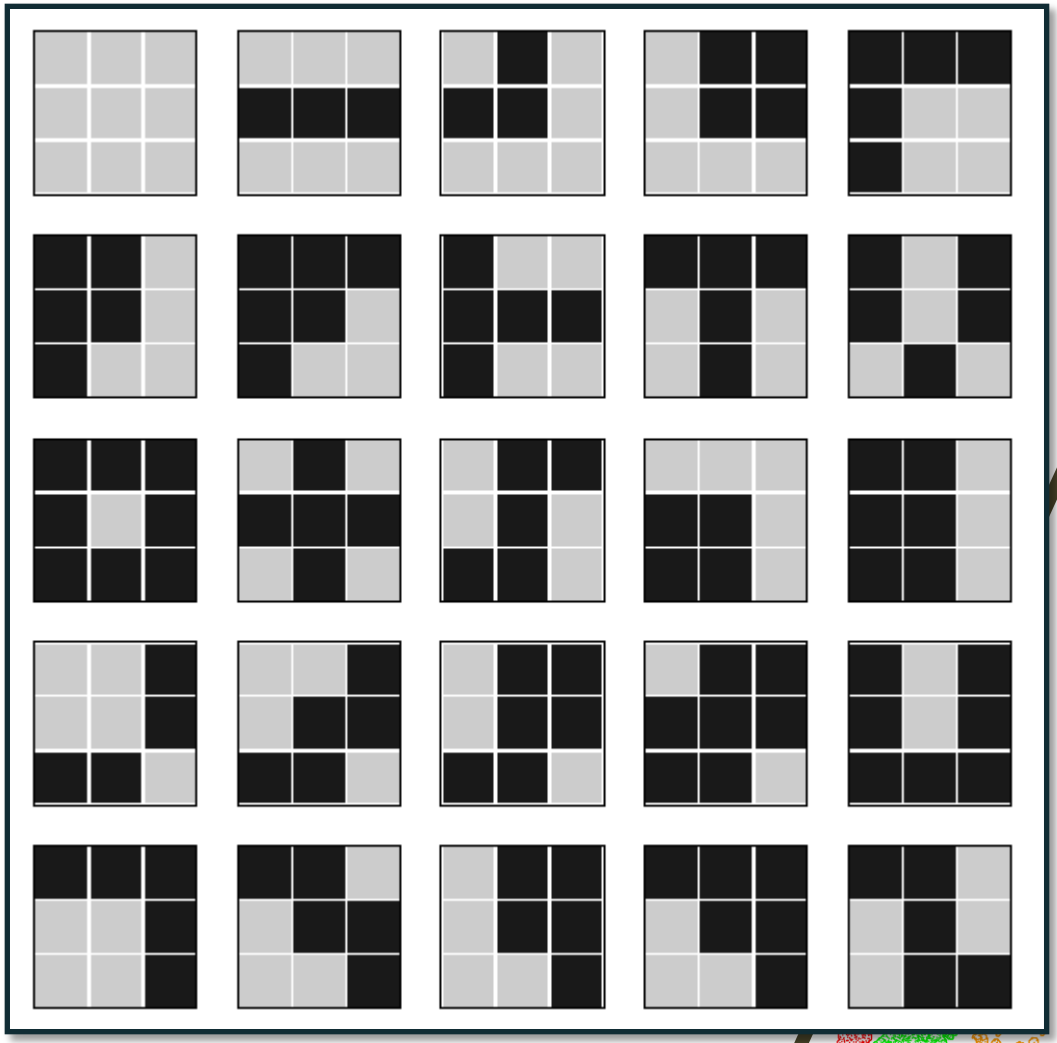
  - Se considera o vecinatate (ce exclude punctul curent)
  - ζ(A,B) functie de comparatie
    - Ia valoarea 1 daca A>B
    - Ia valoarea 0 daca A<B



Trasaturi Census

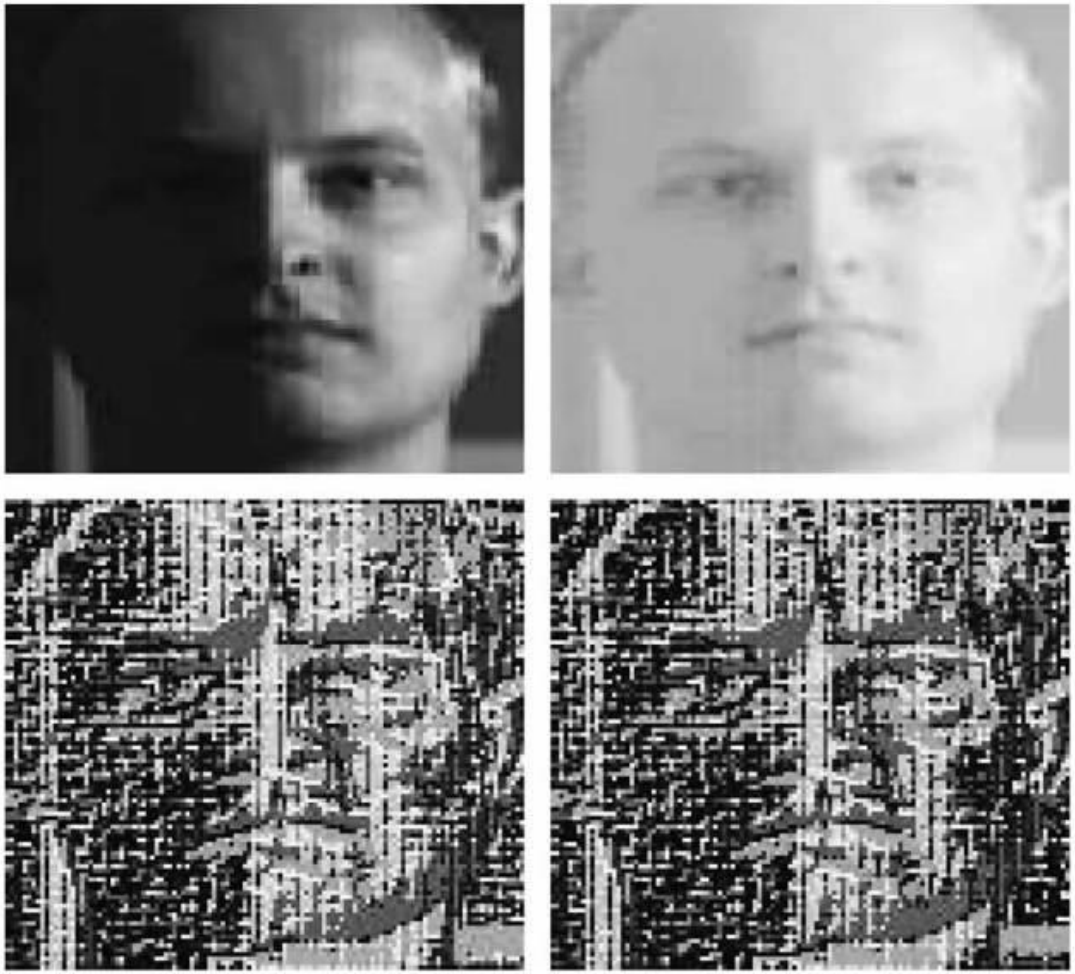
Kublbeck (2006) propune utilizare trasaturilor census in detectie de fete:

- Aproximeaza o succesiune de Haar
- Sensibile pentru textura
- Invariante la iluminare

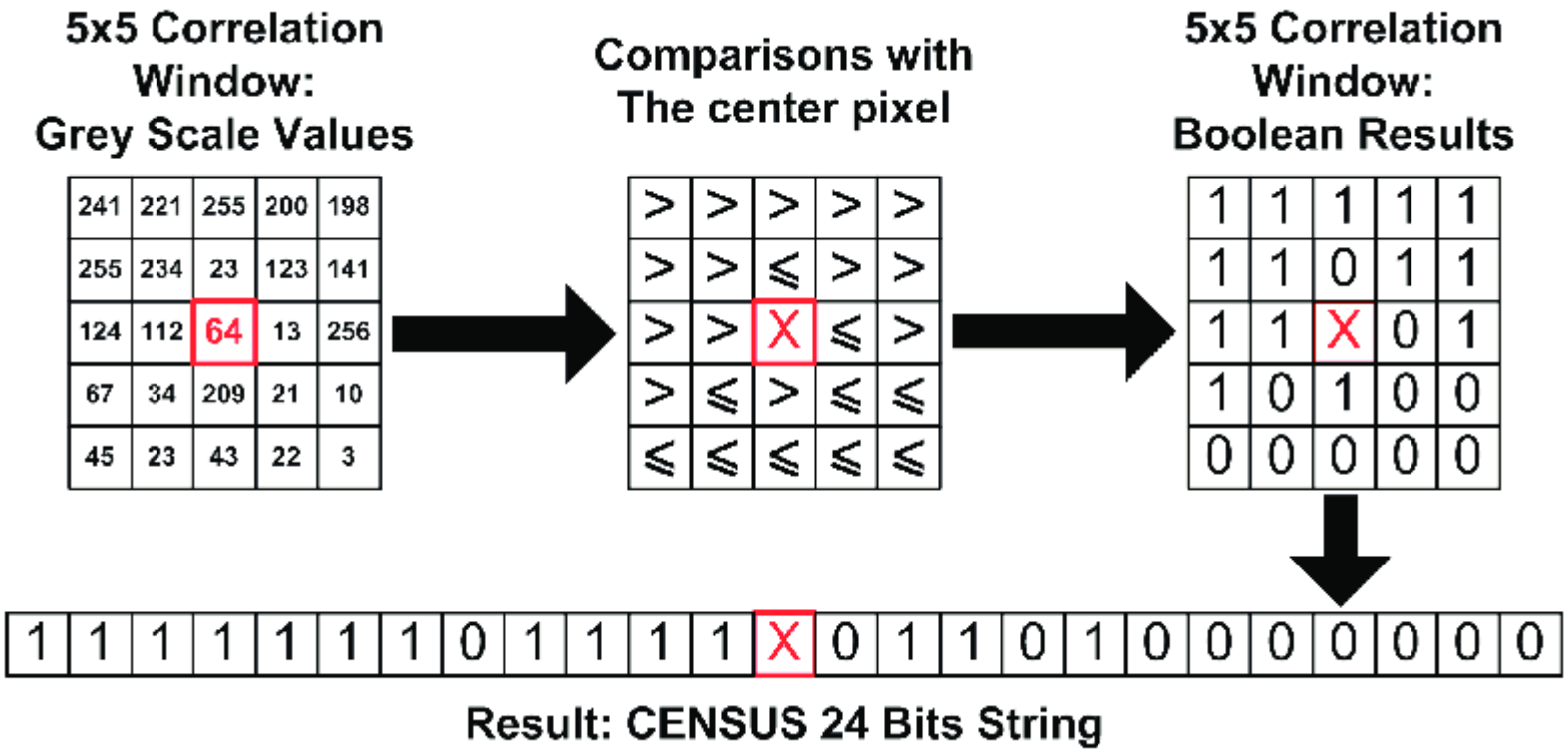


Vecinatati

Trasaturi Census



Trasaturi Census



Pelissier, Frantz & Berry, François. (2010). Design of a Real-Time Embedded Stereo Smart Camera. 344-356. 10.1007/978-3-642-17688-3_33.

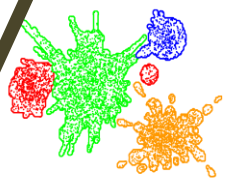
Texture Unit

- Introdus de He si Wang (1990)
- Descriptor primar de textura
- Se defineste pe o ferestra 3x3 in care
  - Valoarea curenta este V_0
  - Valorile din vecinatate sunt V_1,…, V_8

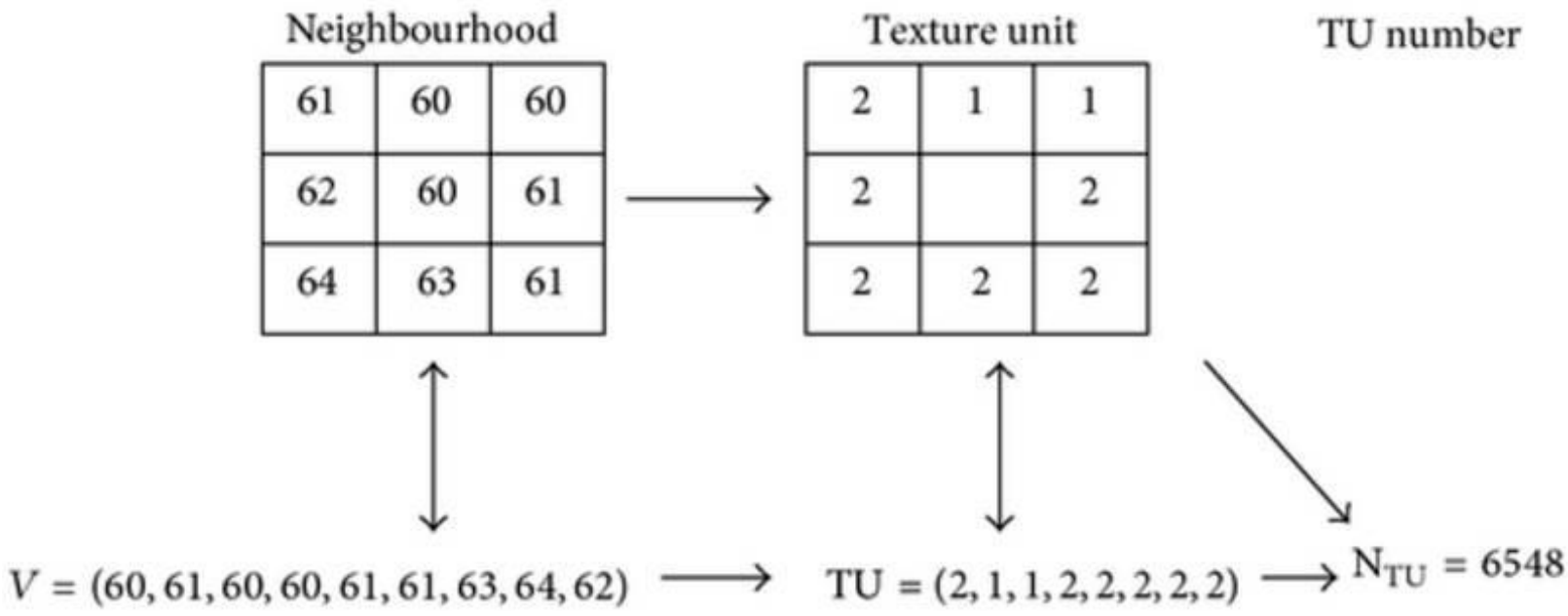
V_1	V_2	V_3
V_4	V_0	V_5
V_6	V_7	V_8

Texture Unit se defineste a fi o matrice 3x3 cu valorile E_1,…, E_8

$$E_k = \begin{cases} 0, V_k < V_0 \\ 1, V_k = V_0 \\ 2, V_k > V_0 \end{cases}$$



Texture Unit



Fuzzy Texture Unit

Exista variante:

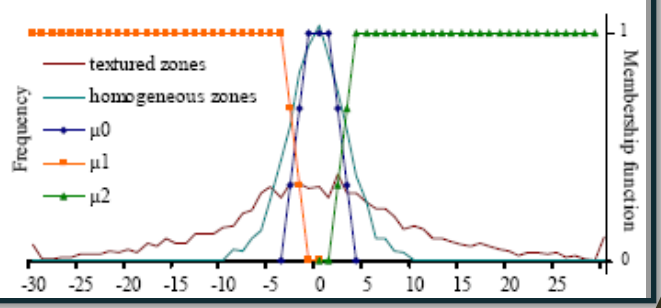
– Fuzzy Texture Unit definit pe baza functiilor de apartenenta, μ

$$E_k = \begin{cases} \mu_0(V_k - V_0) \\ \mu_1(V_k - V_0) \\ \mu_2(V_k - V_0) \end{cases}$$

$$\mu_0 = \begin{cases} 1 & if \quad x \le -4 \\ \frac{-(x+1)}{3} & if \quad -4 < x < -1 \\ 0 & if \quad x \ge -1 \end{cases}$$

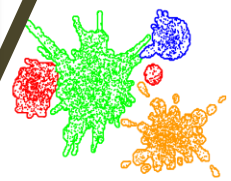
$$\mu_1 = \begin{cases} 0 & if \quad x \le 4 \\ \frac{x+4}{3} & if \quad -4 < x < -1 \\ 1 & if \quad -1 \le x \le 1 \\ \frac{4-x}{3} & if \quad 1 < x < 4 \\ 0 & if \quad x \ge 4 \end{cases}$$

$$\mu_2 = \begin{cases} 0 & if \quad x \le 1 \\ \frac{x-1}{3} & if \quad 1 < x < 4 \\ 1 & if \quad x \ge 4 \end{cases}$$



– Fuzzy Texture Unit simplificat

$$E_k = \begin{cases} -1, V_k - V_0 > T \\ 0, |V_k - V_0| \le T \\ 1, V_0 - V_k > T \end{cases}$$

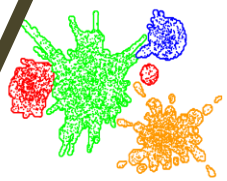


Texture Unit - exemplu

- Texture Unit simplificat
  - T=5
  - Fereastra 7x7

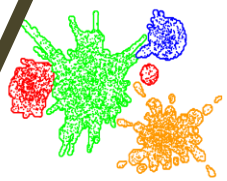
194	197	193	199	192	199	195
189	191	194	201	192	197	197
196	190	187	198	194	192	191
198	198	191	**195**	199	198	196
187	193	201	194	193	193	195
183	189	204	200	197	196	200
193	192	190	188	201	196	192

0	0	0	0	0	0	0
-1	0	0	1	0	0	0
0	0	-1	0	0	0	0
0	0	0	**0**	0	0	0
-1	0	1	0	0	0	0
-1	-1	1	0	0	0	0
0	0	0	-1	1	0	0



Texture Unit - Codare

- Reprezentarea Texture Unit:
  - Doi biti (trei valori) pentru fiecare punct al ferestrei
  - Fereastra *NxN*
  - Sunt necesari $2(N^2-1)$ biti
- Nu se poate mai simplu?
- Putem utiliza un singur bit pentru codare:
  - Local Binary Patterns



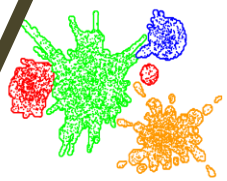
Local Binary Patterns (LBP)

- **Local Binary Patterns Histogram** (LBPH / LBP) este un descriptor de textura care codifica primitivele locale (muchii, curbe, pete, zone uniforme) intr-o histograma de trasaturi
- Se defineste pe o ferestra 3x3 in care
  - Valoarea curenta este g_0
  - Valorile din vecinatate sunt $g_1, \ldots, g_8$

g_1	g_2	g_3
g_4	g_0	g_5
g_6	g_7	g_8

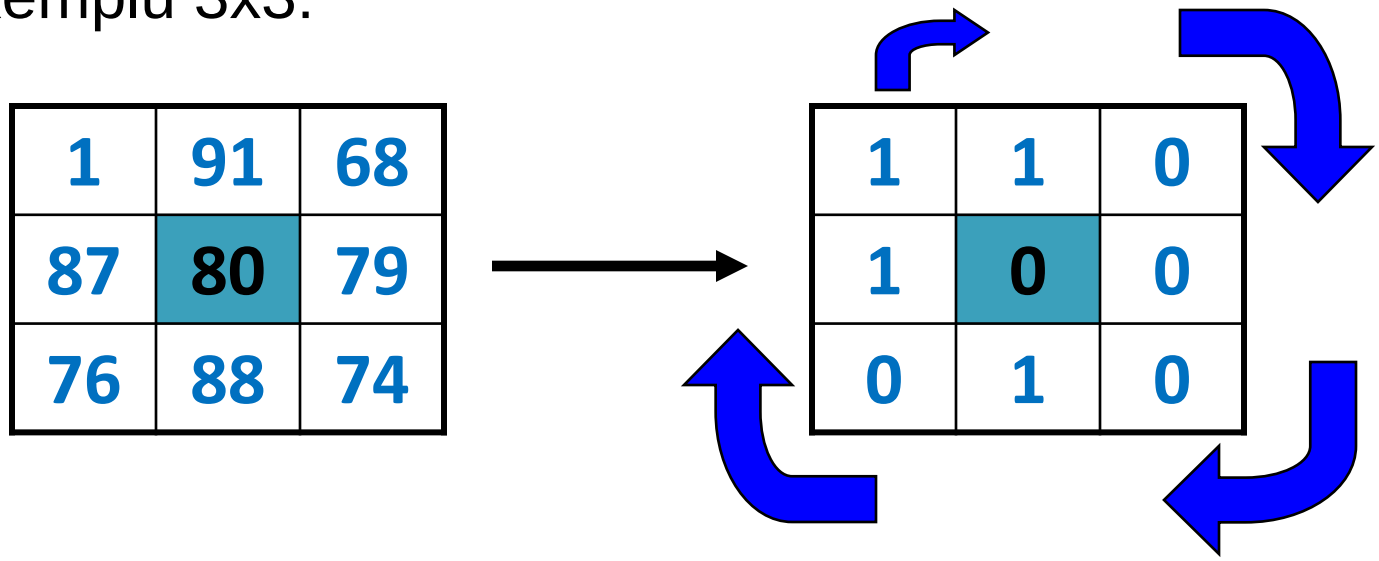
- Valoarea rezultanta este:

$$e_i = \begin{cases} 0, & g_i < g_0 \\ 1, & g_i \geq g_0 \end{cases}$$

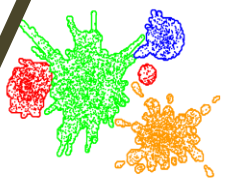


Local Binary Patterns (LBP)

- Exemplu 3x3:



- Cele 8 valori calculate formeaza cei 8 biti ai unui octet:
  - Se incepe din (0,0) si se parcurge circular
    - Se fixeaza directia
    - **11000101**



Local Binary Patterns (LBP)

- Numarul se reprezinta in baza 10:

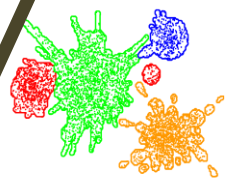
$128 \cdot 1+64 \cdot 1+32 \cdot 0+16 \cdot 0+8 \cdot 0+4 \cdot 1+2 \cdot 0+1 \cdot 1 = 201$

- Proprietati:
  - Invariant la orice schimbare monotona a nivelului de gri
  - Usor de calculat
- De multe ori este folosit in conjunctie cu contrastul *C*:

86	91	68
87	80	79
76	88	74

1	1	0
1	0	0
0	1	0

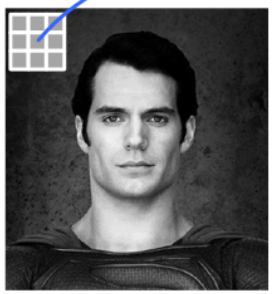
$C = (86+91+87+88)/4 - -(68+79+74+76)/4 = = -13.75$



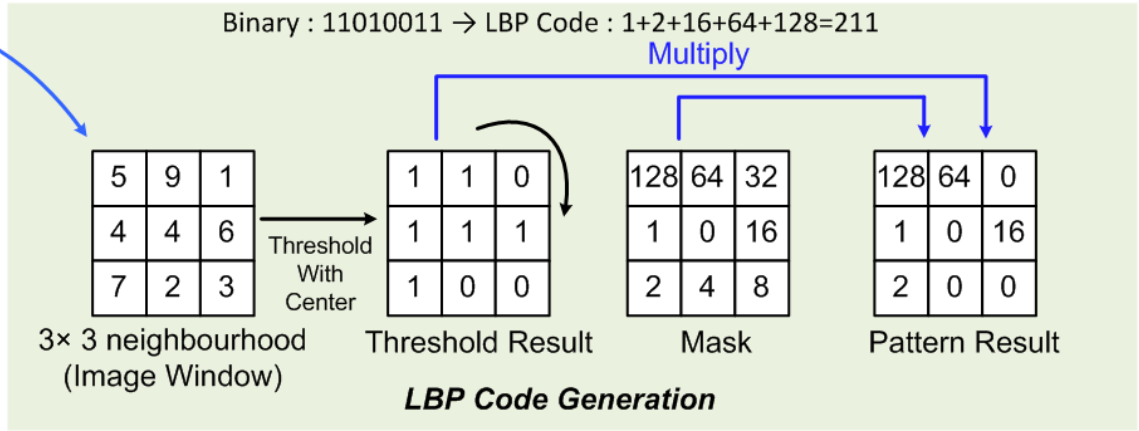
Local Binary Patterns (LBP)



Image assembled with Local Binary Patterns



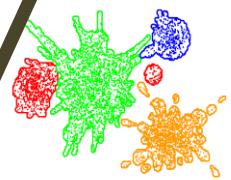
Image



https://medium.com/@ckyrkou/object-detection-using-local-binary-patterns-50b165658368

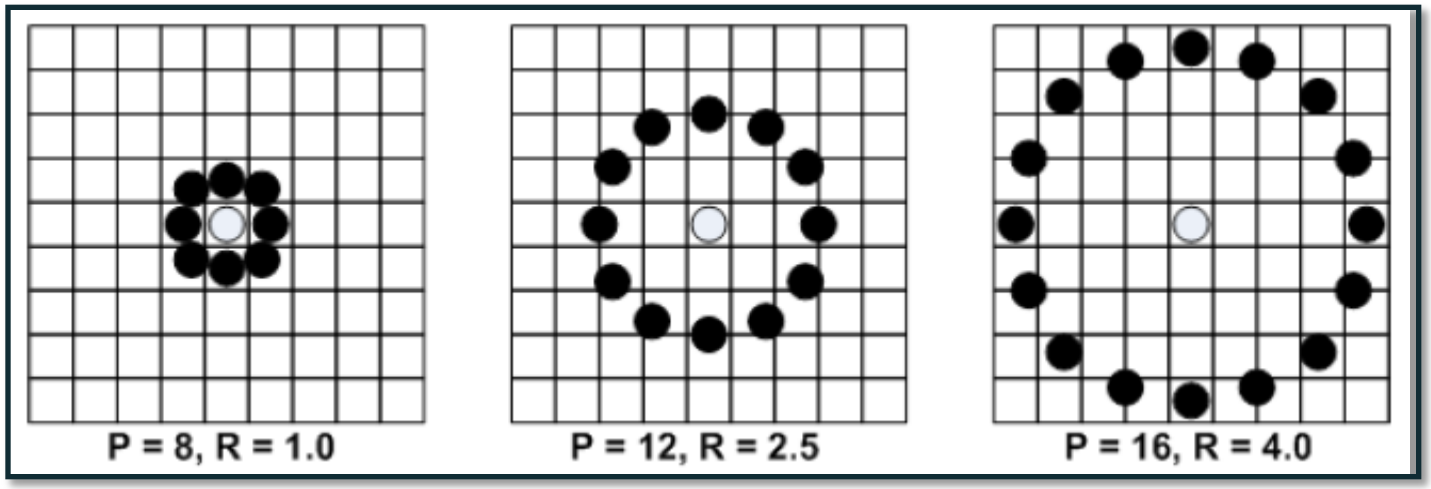


https://www.pyimagesearch.com/2015/12/07/local-binary-patterns-with-python-opencv/



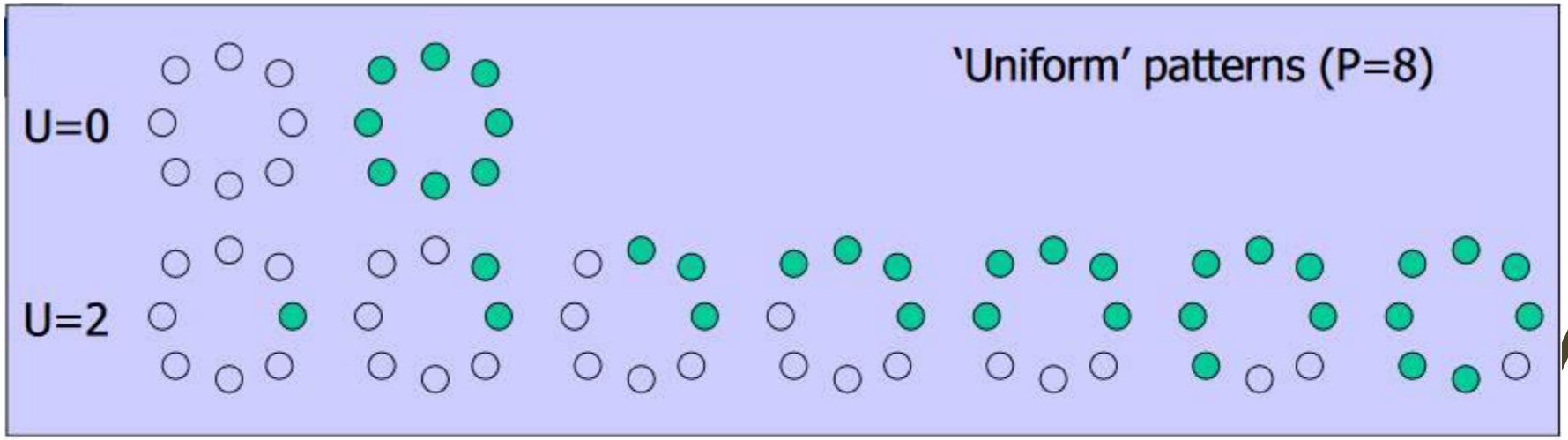
LBP- multirezolutie

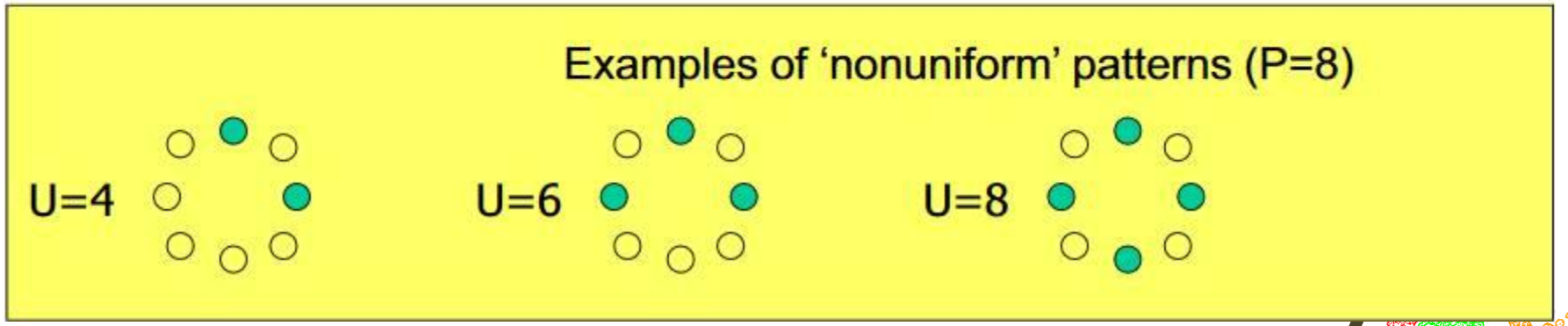
- Ferestrele de calcul sunt parametrice in functie de numarul de pixeli (biti), *P* si de raza, *R*
  - Daca nu se nimereste intr-un pixel, valoarea pt LBP se obtine prin interpolare (bi-lineara)
- Invariante la rotatie (in jurul punctului central)
- Invariante la variatia nivelului de gri



LBP – uniforme si neuniforme

- Se considera neuniforme daca au mai mult de 2 tranzitii 0 – 1
- de multe ori >90% sunt uniforme



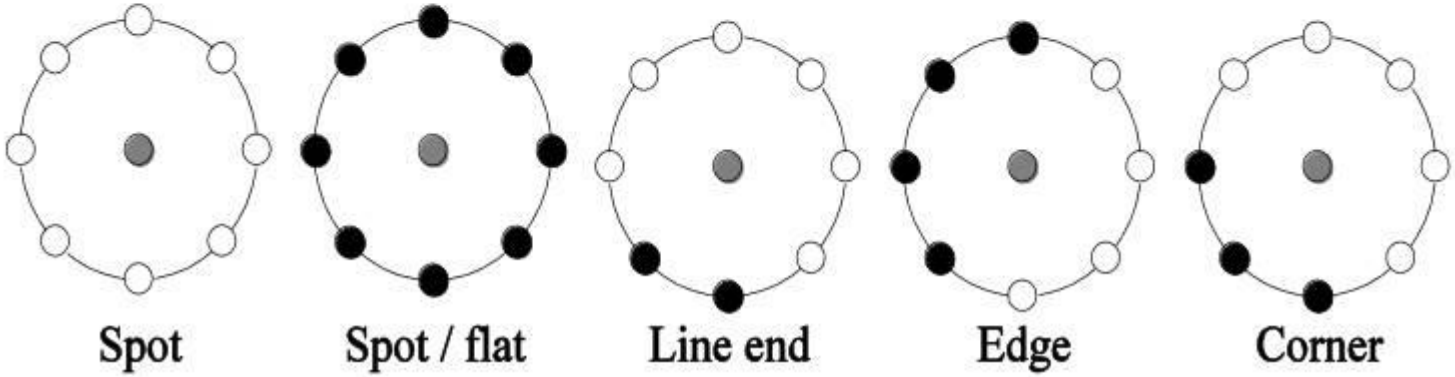


http://www.ee.oulu.fi/research/imag/mvg/files/pdf/CVPR-tutorial-final.pdf

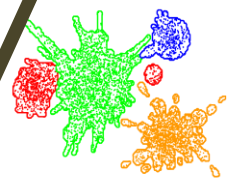
LBP – uniforme si neuniforme

Texture primitives ("micro-textons") detected by the uniform patterns of LBP

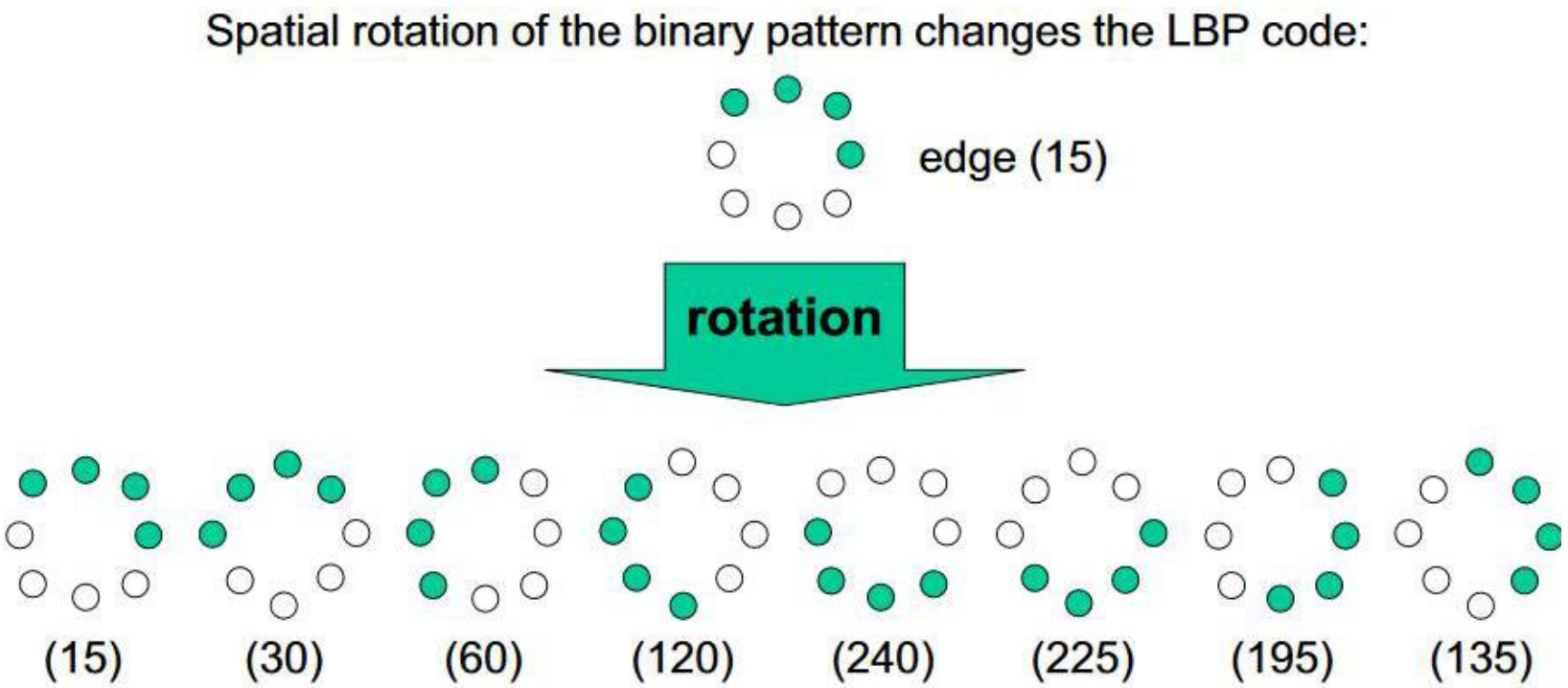
1 = black
0 = white



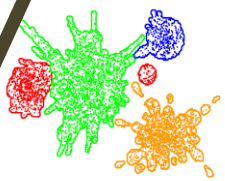
http://www.ee.oulu.fi/research/imag/mvg/files/pdf/CVPR-tutorial-final.pdf



LBP – invarianta la rotatie



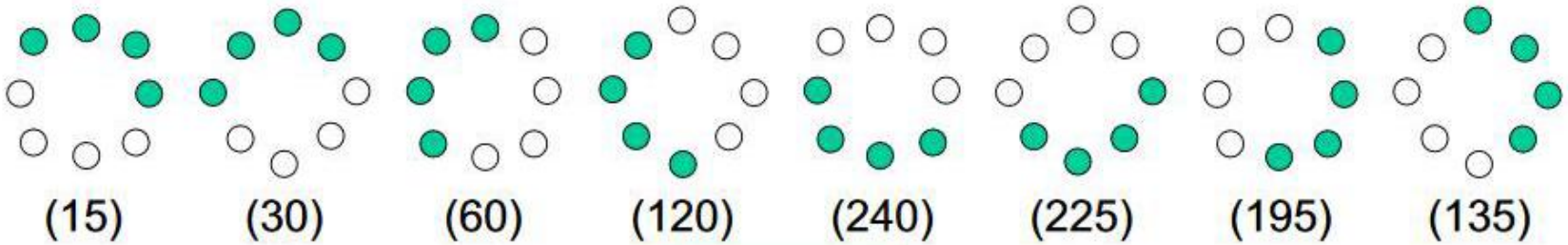
http://www.ee.oulu.fi/research/imag/mvg/files/pdf/CVPR-tutorial-final.pdf



LBP – invarianta la rotatie

Formally, rotation invariance can be achieved by defining:

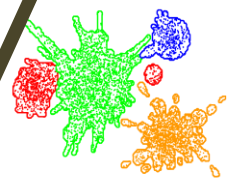
$$LBP_{P,R}^{ri} = \min\{ROR(LBP_{P,R}, i) \mid i=0, \ldots, P-1\}$$





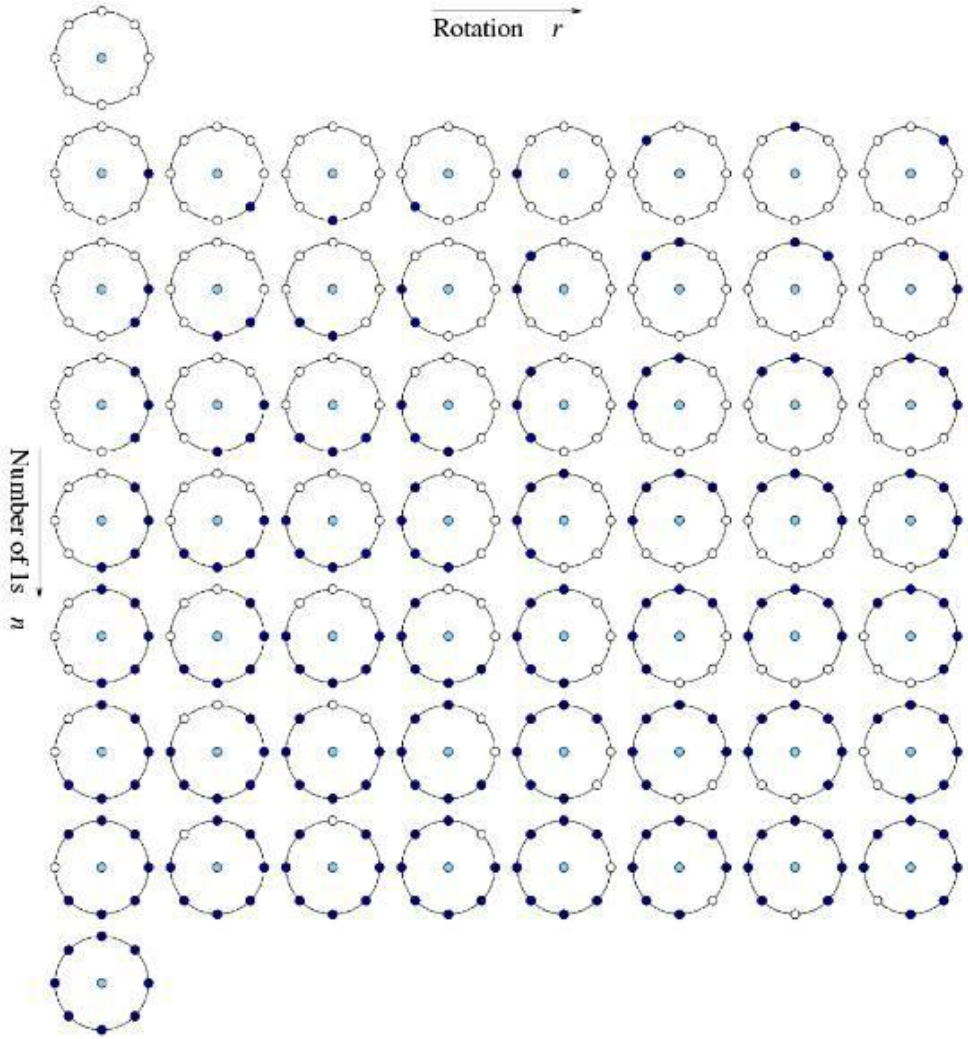
(15)

http://www.ee.oulu.fi/research/imag/mvg/files/pdf/CVPR-tutorial-final.pdf

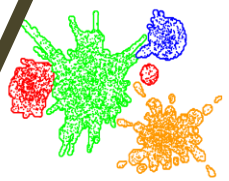


LBP – invarianta la rotatie

- Bit patterns with 0 or 2 transitions $0 \rightarrow 1$ or $1 \rightarrow 0$ when the pattern is considered circular
- All non-uniform patterns assigned to a single bin
- 58 uniform patterns in case of 8 sampling points



http://www.ee.oulu.fi/research/imag/mvg/files/pdf/CVPR-tutorial-final.pdf



LBP

- Varianta nivelelor de gri - masura de contrast

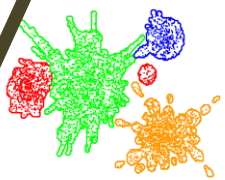
$$VAR_{P,R} = \frac{1}{P} \sum_{p=0}^{P-1} (g_p - m)^2$$

where

$$m = \frac{1}{P} \sum_{p=0}^{P-1} g_p$$

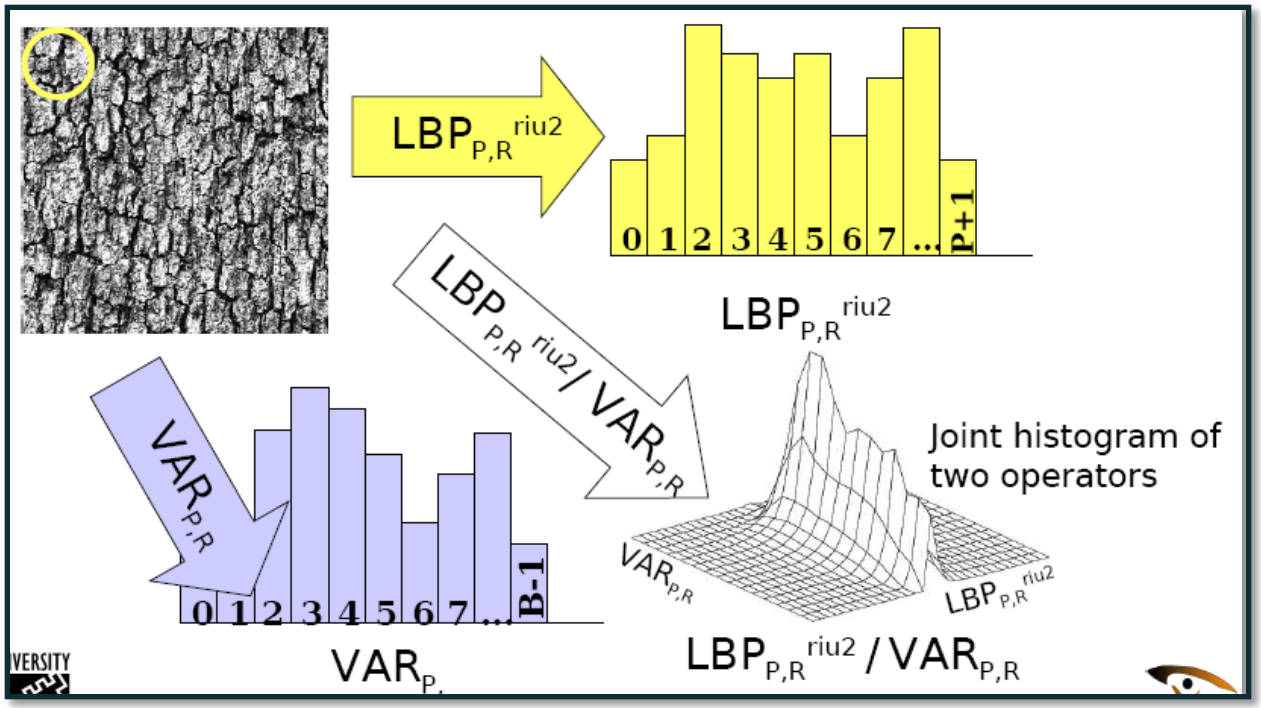
- Invarianta la translatia nivelurilor de gri
- Invarianta la rotatii in vecinatati circulare

http://www.ee.oulu.fi/research/imag/mvg/files/pdf/CVPR-tutorial-final.pdf



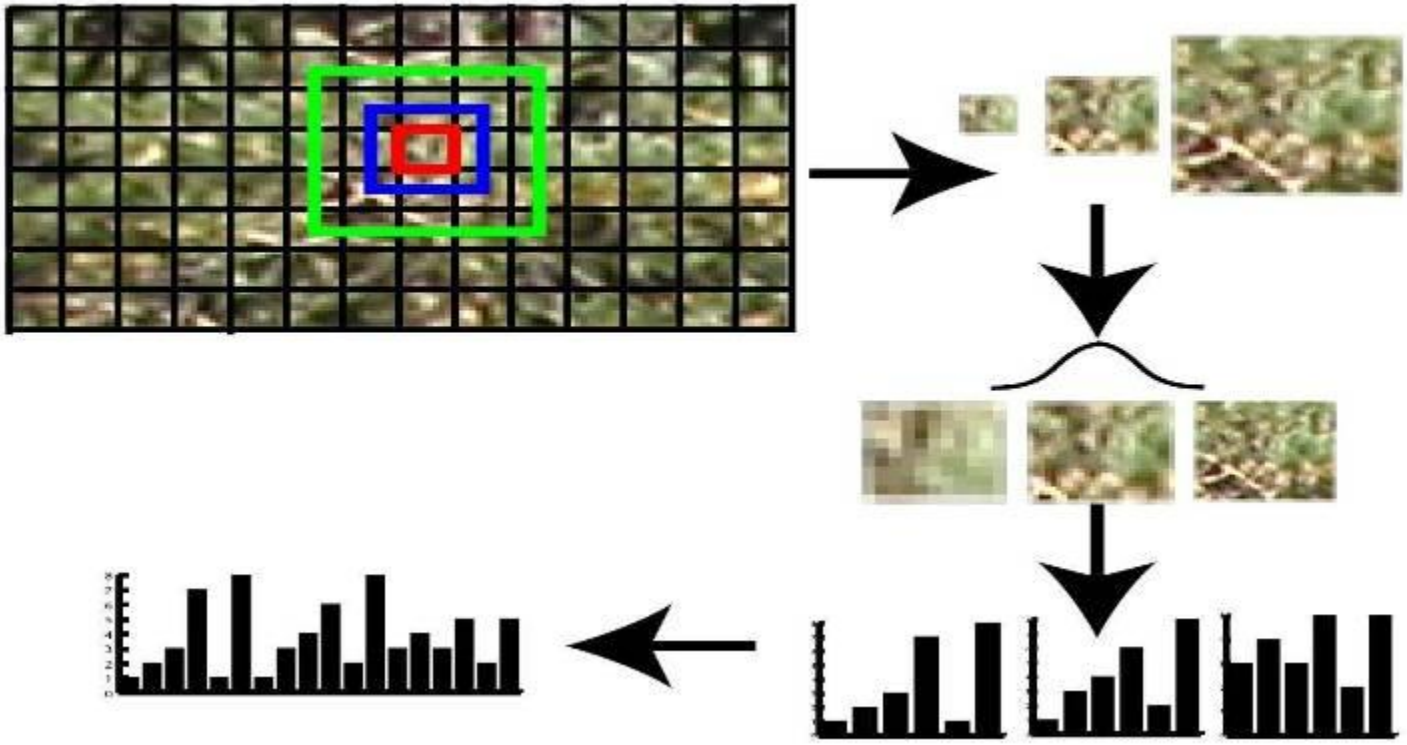
LBP- caracterizarea unei imagini

- Caracterizarea ↔ histograma trasaturilor (LBP si/sau Var)
- Pentru fiecare pixel se determina LBP-ul si se adauga in histograma

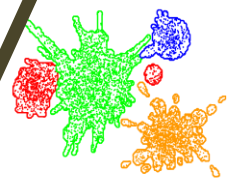


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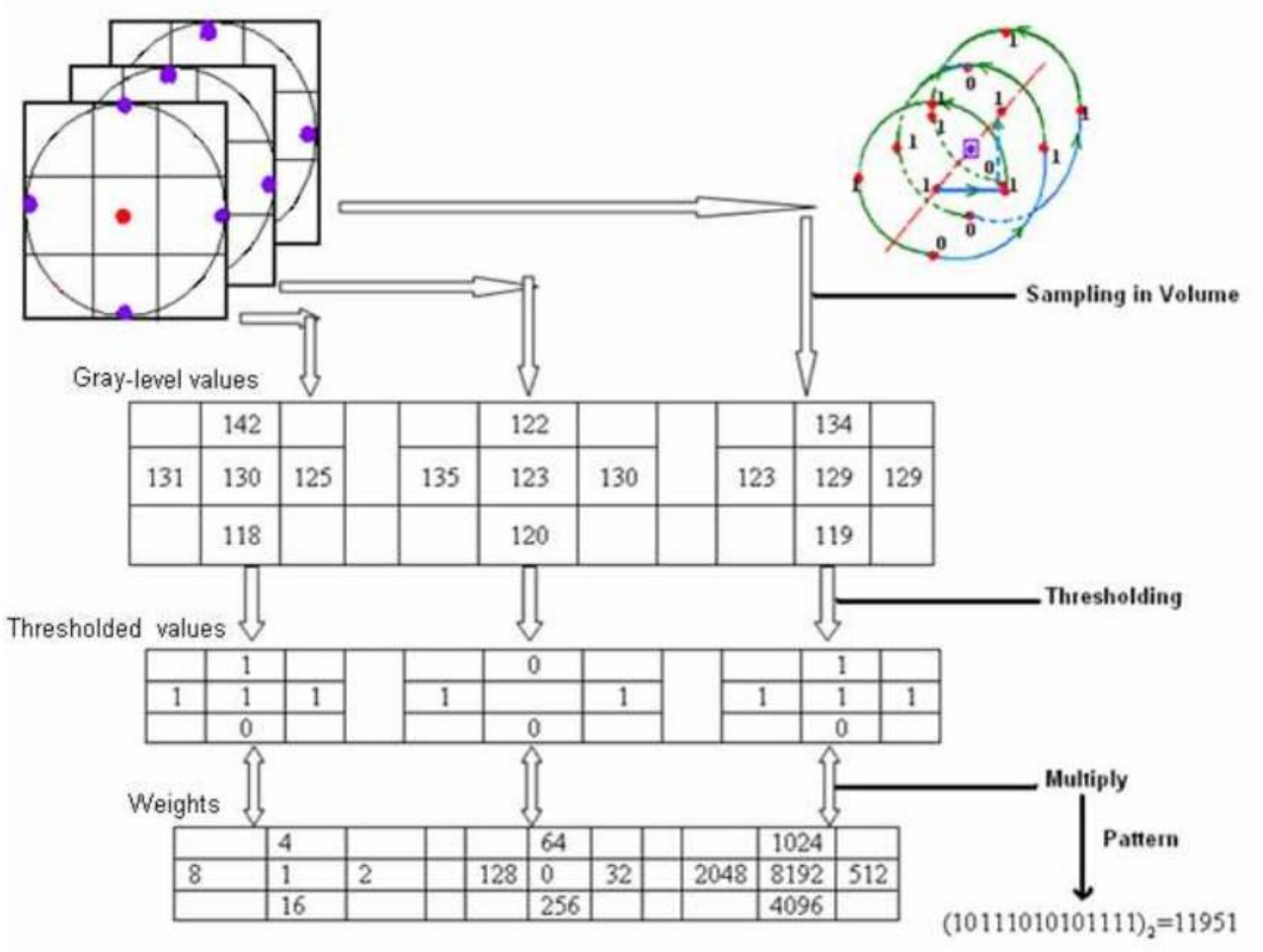
LBP - multiscala



http://www.ee.oulu.fi/research/imag/mvg/files/pdf/CVPR-tutorial-final.pdf

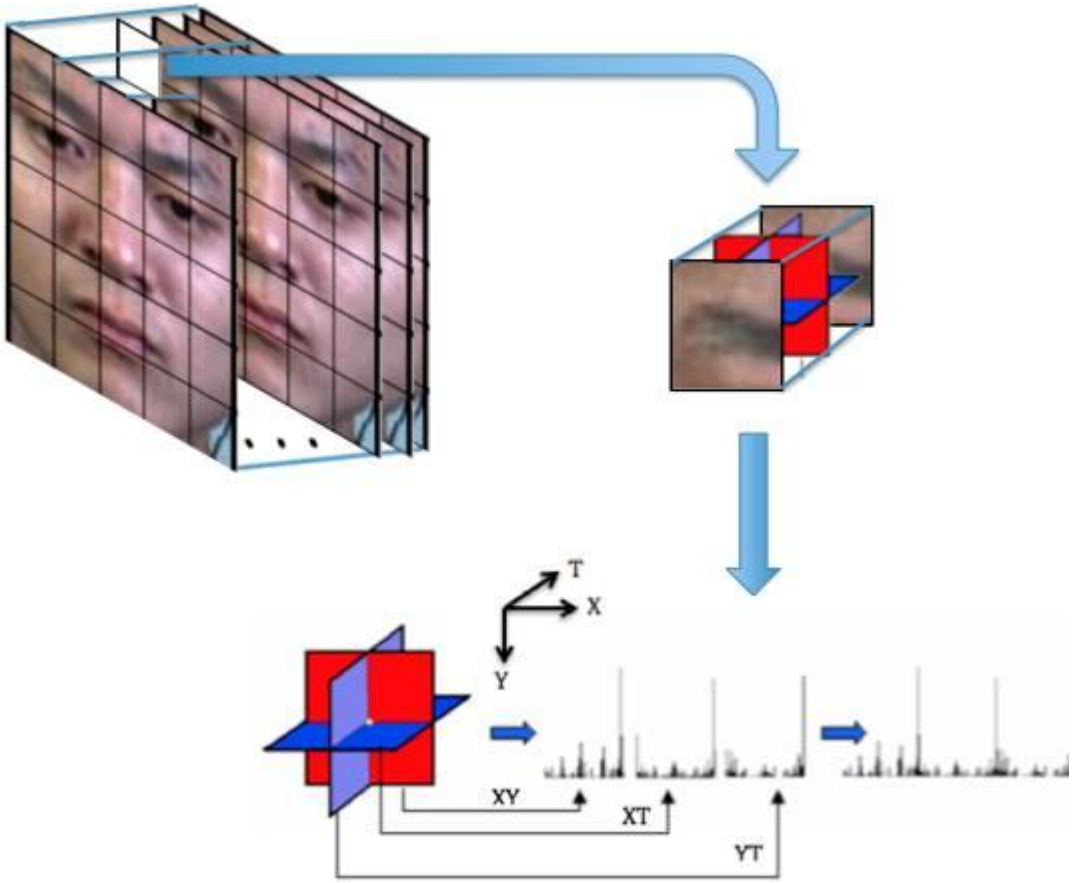


Volume LBP



G. Zhao and M. Pietikainen, “Dynamic Texture Recognition Using Local Binary Patterns with an Application to Facial Expressions,” IEEE Transactions on Pattern Analysis and Machine Intelligence, vol. 29, no. 6, pp. 915–928, 2007.

LBP - TOP



Huang, Xiaohua & Zhao, Guoying & Hong, Xiaopeng & Zheng, Wenming & Pietikäinen, Matti. (2015). Spontaneous Facial Micro-expression Analysis using Spatiotemporal Completed Local Quantized Patterns. Neurocomputing.

LBP - SIP

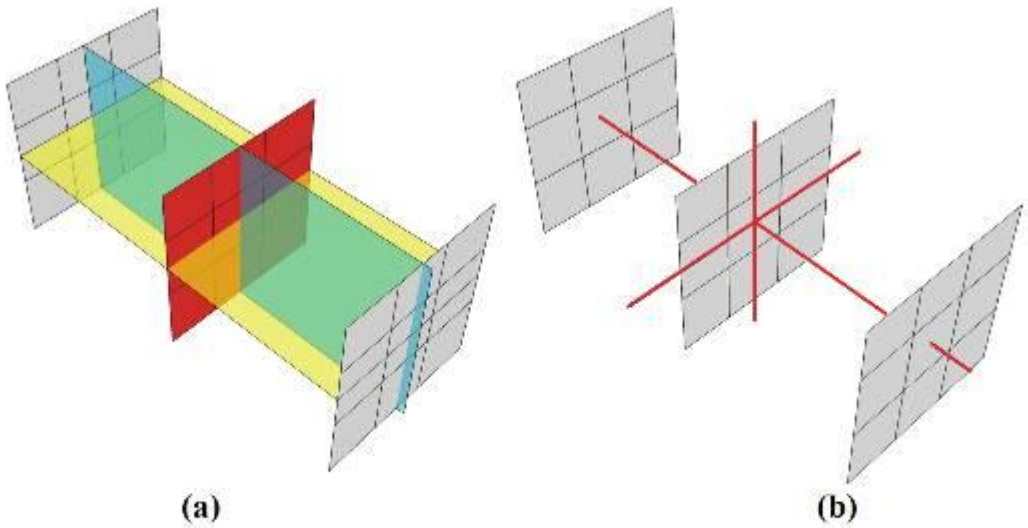
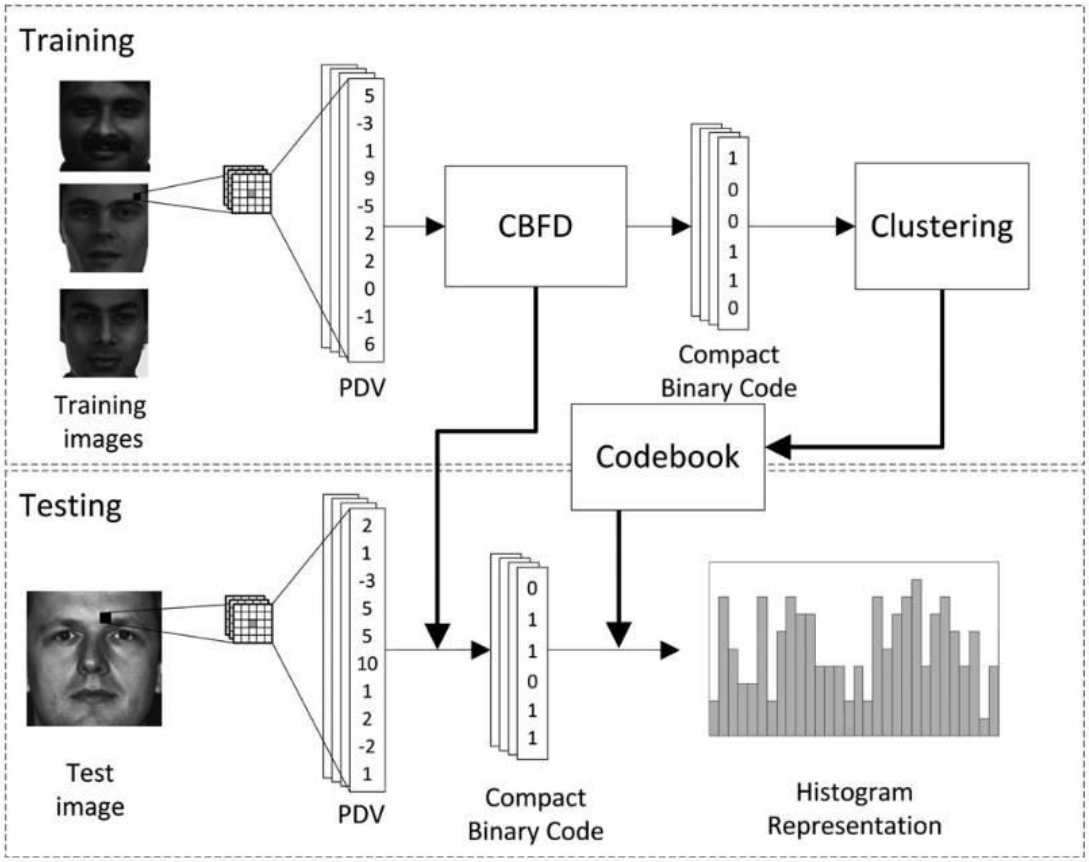
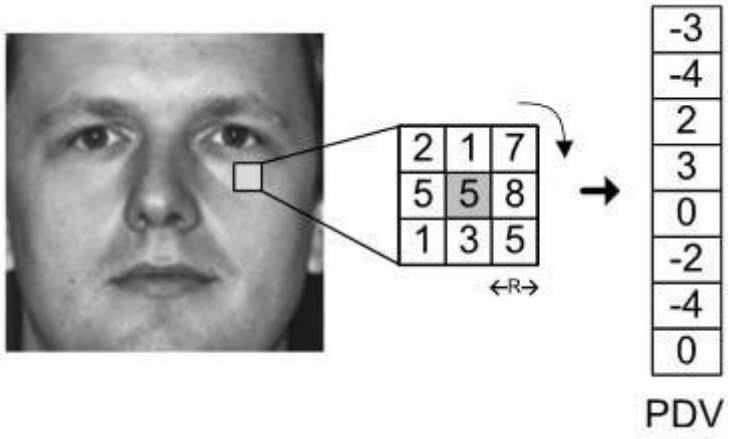


Fig. 1. (a) Three orthogonal planes in the LBP-TOP computation, and (b) Three intersecting lines crossing over the center pixel, formed by the three orthogonal planes, are considered to obtain the six distinct neighbour points surrounding the center point.

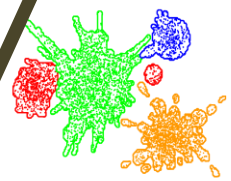
Y. Wang, J. See, R. C.-W. Phan, Y.-H. Oh, “LBP with Six Intersection Points: Reducing Redundant Information in LBP-TOP for Micro-expression Recognition,” in Asian Conference on computer Vision, pp. 525-537, 2015.

Pixel Difference Vectors (PDV)

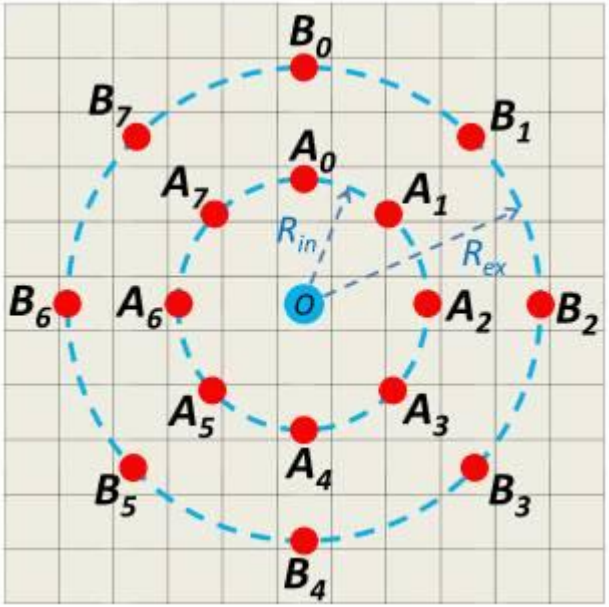




[Lu et al. 2015]



Dual Cross Pattern

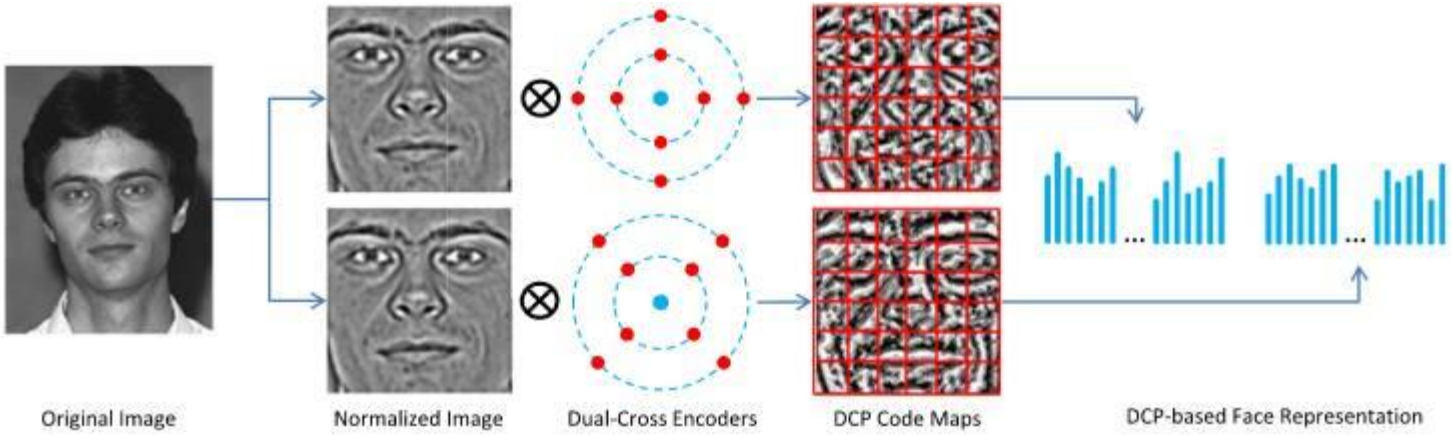


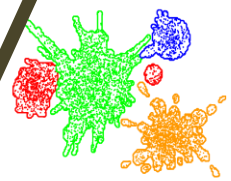
$$DCP_i = S(I_{A_i} - I_O) \times 2 + S(I_{B_i} - I_{A_i}), 0 \leq i \leq 7,$$

where

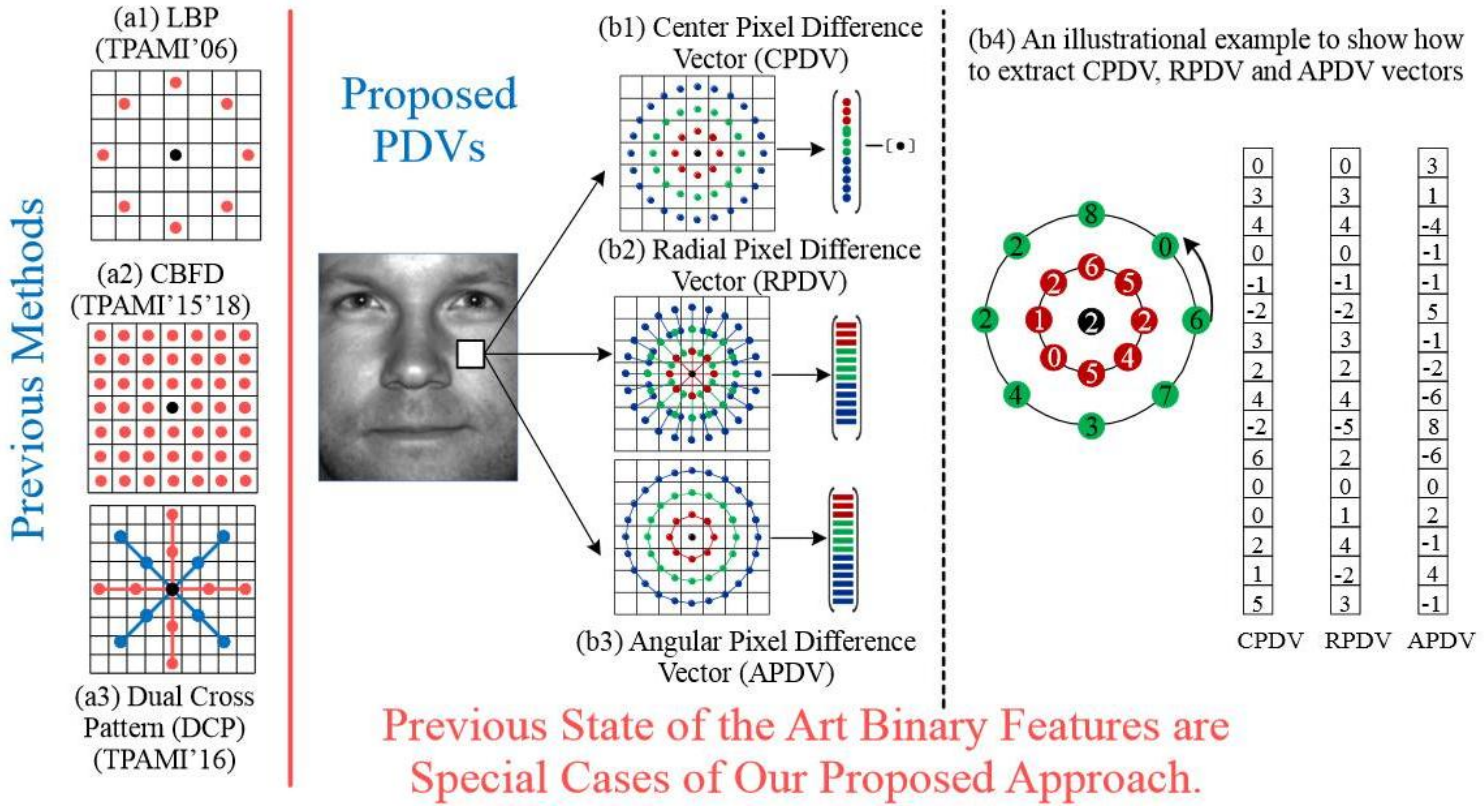
$$S(x) = \begin{cases} 1, x \geq 0 \\ 0, x < 0 \end{cases},$$

[Ding et al 2016]





BIRD: Binary and Illumination Robust Descriptor

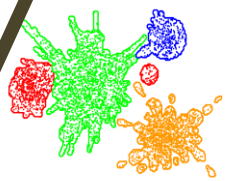


[Su et al 2019]

Histogram of Oriented Gradients (HOG)

- Trasatura localizata spatial, utila in special pentru texturi
- Introdusa de Dalal&Triggs in 2005
- **Ideea**: forma unui obiect poate fi descrisa cu ajutorul distributiei intensitatii gradientilor, respectiv a directiei muchiilor.
- Imaginea se imparte in celule. Fiecare celula are o histograma de orientari.

- **Descriptorul HOG** = **celule** x **histograme**

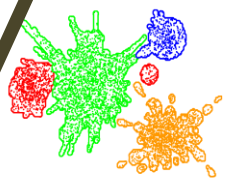


Histogram of Oriented Gradients (HOG)

Algoritm:

1. Calculul gradientului
2. Histograma de orientari
3. Blocul descriptiv
4. Normalizarea blocurilor
5. Constructia clasificatorului final

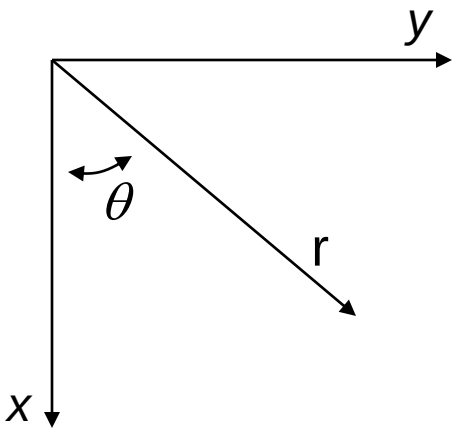
Antrenare



HOG: Calculul gradientului

Imaginea este modelata ca o functie continua 2D.

Derivata imaginii pe o directie oarecare *r* este:

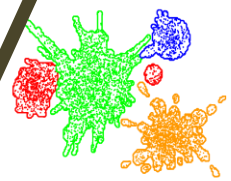


$$\frac{\partial f(x,y)}{\partial r} = \frac{\partial f(x,y)}{\partial x}\frac{\partial x}{\partial r} + \frac{\partial f(x,y)}{\partial y}\frac{\partial y}{\partial r}$$

$$\frac{\partial f(x,y)}{\partial r} = \frac{\partial f(x,y)}{\partial x}\cos\theta + \frac{\partial f(x,y)}{\partial y}\sin\theta$$

$$\frac{\partial f(x,y)}{\partial r} = f_x \cos\theta + f_y \sin\theta = F(\theta)$$

Derivata pe directie orizontala/verticala



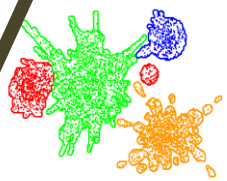
HOG: Calculul gradientului

- Pe ce directie *r* este cea mai mare variatie
  (pe ce directie e cel mai mare gradient)
- Derivata pe directia *r* este:

$$\frac{\partial f(x,y)}{\partial r} = f_x \cos\theta + f_y \sin\theta = F(\theta)$$

Vrem maximul acestei functii.
(Caut pentru ce θ derivata este 0). $\frac{\partial}{\partial\theta}\left(\frac{\partial f(x,y)}{\partial r}\right) = 0$

$$\frac{\partial}{\partial\theta}\left(\frac{\partial f(x,y)}{\partial r}\right) = f_x \frac{\partial}{\partial\theta}\cos\theta + f_y \frac{\partial}{\partial\theta}\sin\theta = -f_x \sin\theta + f_y \cos\theta$$



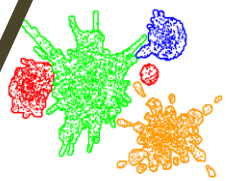
HOG: Calculul gradientului

$$\left.\begin{aligned} \frac{\partial}{\partial\theta}\left(\frac{\partial f(x,y)}{\partial r}\right) &= -f_x \sin\theta + f_y \cos\theta \\ \frac{\partial}{\partial\theta}\left(\frac{\partial f(x,y)}{\partial r}\right) &= 0 \end{aligned}\right\} \quad \theta_0 = \arctan\frac{f_y}{f_x}$$

Directia pe care variatia e maxima

Magnitudinea variatiei maxime:

$$\max\frac{\partial f(x,y)}{\partial r} = \frac{\partial f(x,y)}{\partial r}\Big|_{\theta=\theta_0} = f_x\cos\theta + f_y\sin\theta\Big|_{\theta=\theta_0} = \sqrt{f_x^2 + f_y^2}$$



HOG: Calculul gradientului

Cum calculez derivatele f_x si f_y

(derivata pe orizontala/verticala)

Convolutie cu:

- Nuclee necentrate

-1	1

-1
1

- Nuclee necentrate

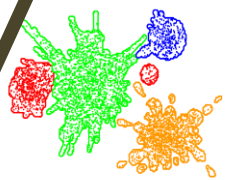
-1	**0**	1

-1
0
1

- Sobel

-1	0	1
-2	**0**	2
-1	0	1

-1	-2	-1
0	**0**	0
1	2	1

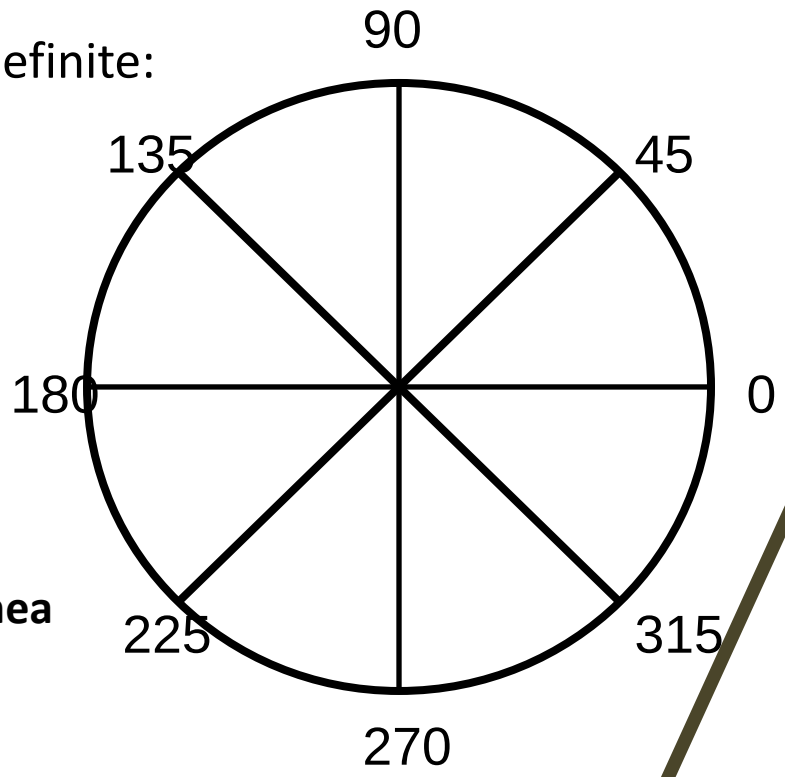


HOG: Histograma de orientari

Orientarea se calculeaza cu precizie continua

Se interpoleaza la un numar de pozitii predefinite:

- In domeniu fara semn [0,180]
- In domeniu cu semn [0,360]

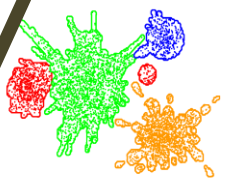


Un gradient voteaza la ambii vecini:

- In functie de **distanta** pana la ei
- Votul este proportional cu **magnitudinea**

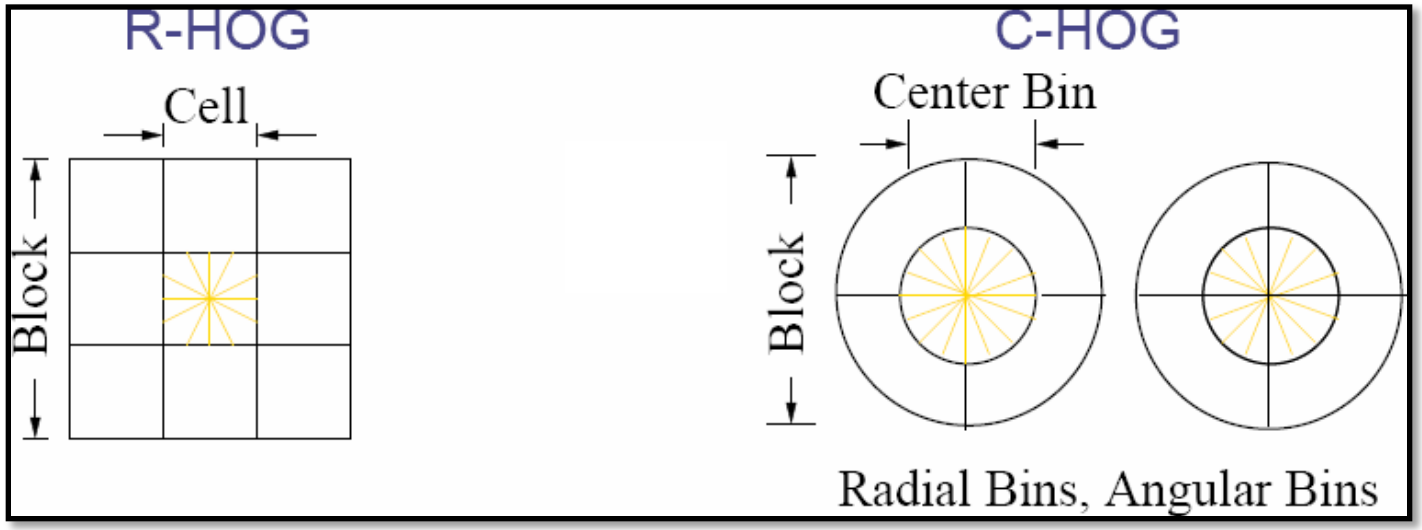
gradientului

- Se poate aplica o functie magnitudinii



HOG :Blocul descriptiv

- Imaginea se imparte in blocuri, partial suprapuse
- Fiecare bloc este alcatuit din celule
- Pe fiecare bloc se aplica **normalizarea contrastului**
- Celulele pot fi **rectangulare** sau radiale (log-polare)
- Histograma se calculeaza pe fiecare celula



HOG: Normalizarea blocurilor

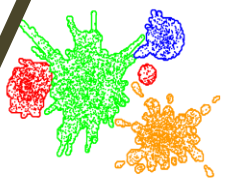
- Exista deja un descriptor pe fiecare bloc, v
- Pe fiecare bloc se aplica **normalizarea contrastului descriptorului:**
  - Norma L_2
  - Trunchere
  - Norma L_1

$$v = \frac{v}{\sqrt{\|v\|_2^2 + \varepsilon}}$$

Sa nu impartim la 0

Norma L_2

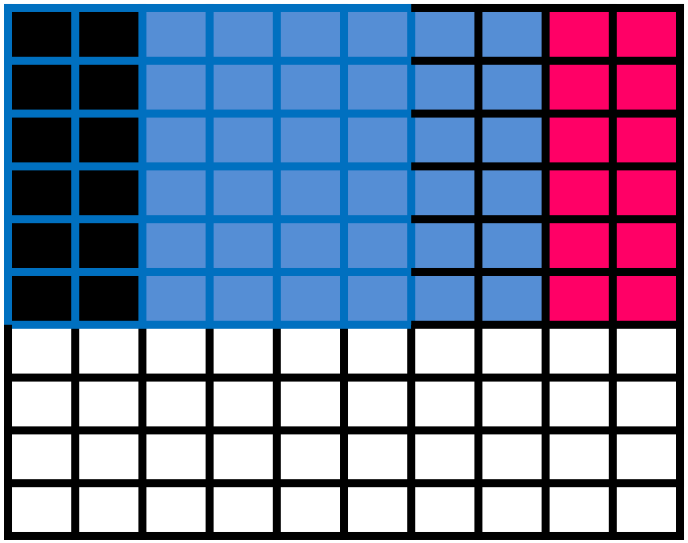
Descriptorul final este vectorul tutoror componentelor din toate celulele normalizate din toate blocurile din fereastra de interes

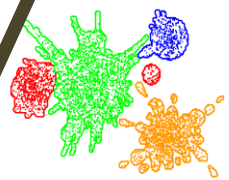


HOG :Exemplu

- Se utilizeaza nuclee centrate
- Celula
  - Imaginea este impartita in celule :

  fiecare pixel apartine unei celule si numai uneia
  - Ex: are 6 x 6 pixeli
- Blocul
  - Suparapuse sau distantate
  - Ex: are 3 x 3 celule
- 9 directii de orientare in [0 , 180]
- Norma L2 cu trunchere in [0, 0.2]





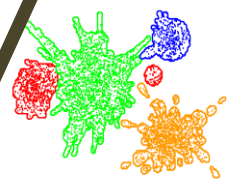
Recapitulare – transformata Fourier 2D

Transformata directa:

$$v(k,l) = \frac{1}{N} \sum_{m=0}^{N-1} \sum_{n=0}^{N-1} u(m,n) \exp\left(-\frac{2\pi j (kl + mn)}{N} \right)$$

Transformata inversa:

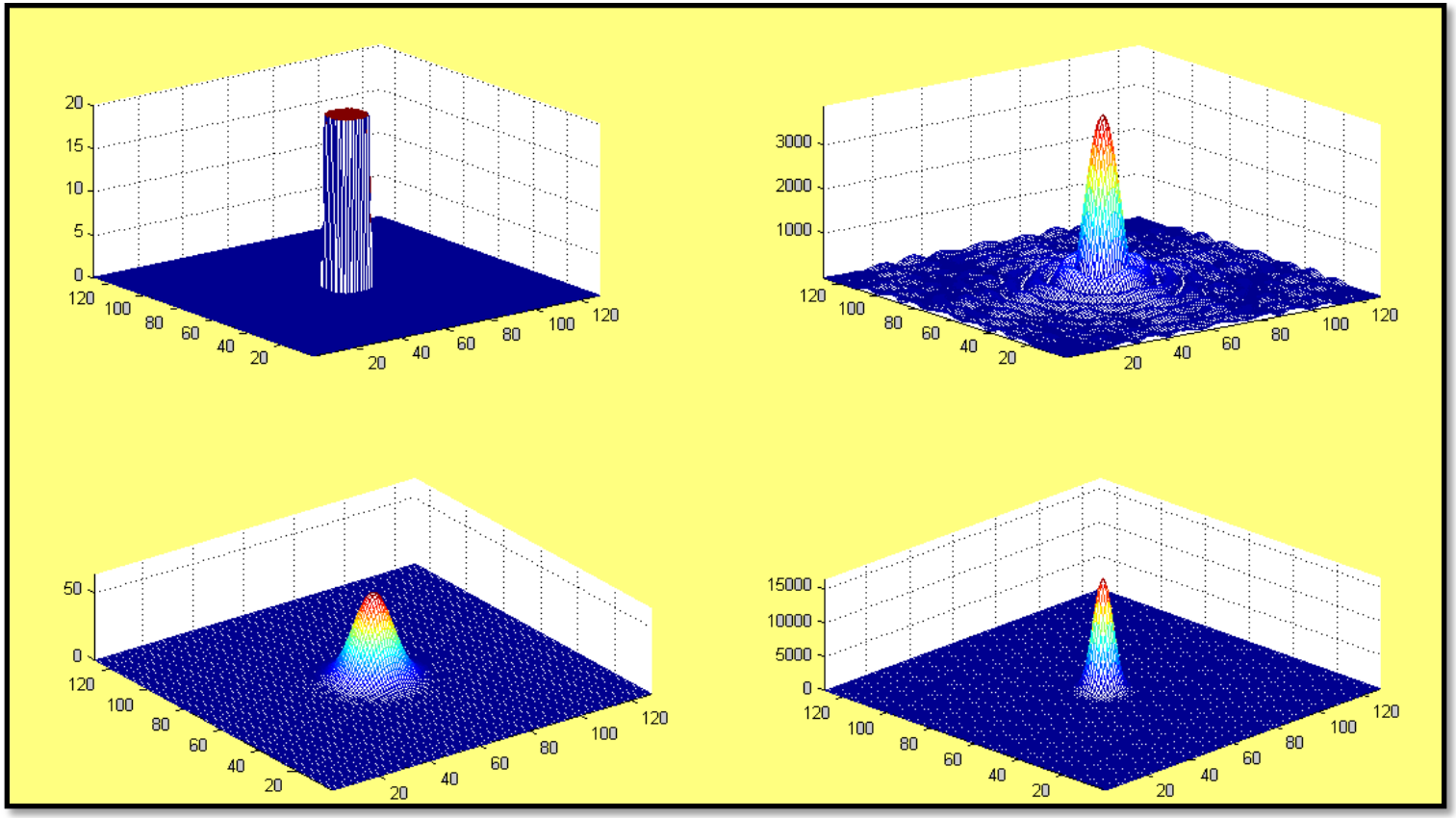
$$u(m,n) = \frac{1}{N} \sum_{k=0}^{N-1} \sum_{l=0}^{N-1} v(k,l) \exp\left(\frac{2\pi j (kl + mn)}{N} \right)$$



Exemple

Box (spatial) ↔ *Sinc* (spectral)

Clopot Gaussian (spatial) ↔ *Clopot Gaussian* (spectral)



Filtrul Gabor 1D

Filtru Gabor – produsul dintr-o infasuratoare gaussiana si o purtatoare sinusoidala complexa

$$g(t) = ke^{j\theta}w(at)s(t)$$

Unde:

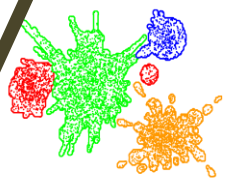
$$w(t) = e^{-\pi t^2}$$

$$s(t) = e^{j(2\pi f_0 t)}$$

$$e^{j\theta}s(t)e^{j(2\pi f_0 t)} = \sin(2\pi f_0 t + \theta) + j\cos(2\pi f_0 t + \theta)$$

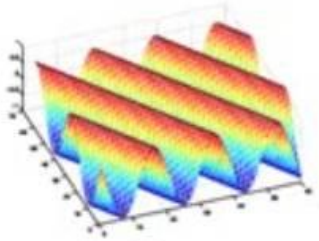
Aici k, θ, f_0 sunt parametrii filtrului.

Scalar de iesire – energia filtrului



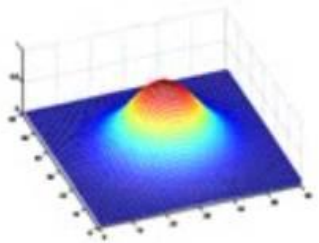
Filtrul Gabor 2D

Sinusoid oriented 30° with x-axis



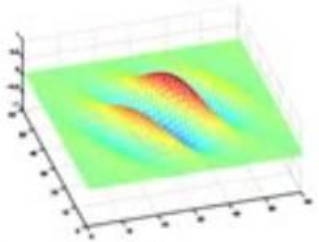
(a)

Gaussian



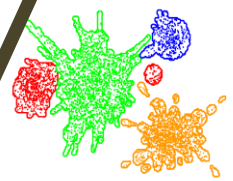
(b)

Gabor Filter

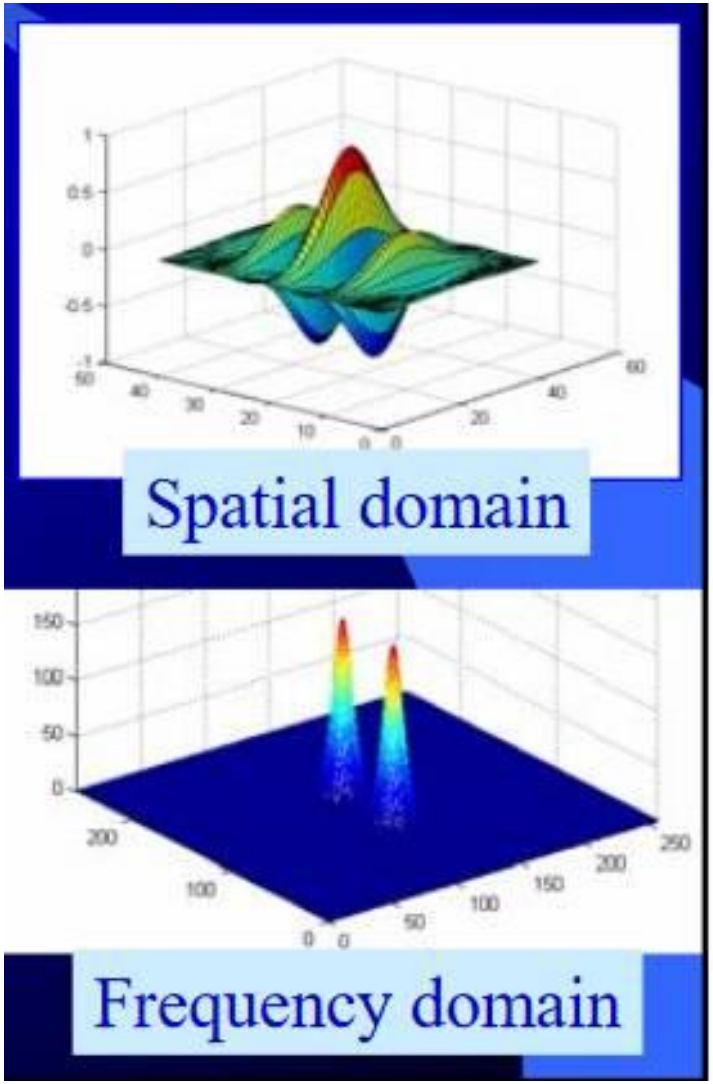


(c)

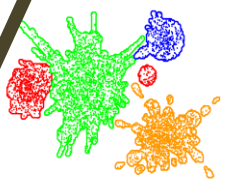
Source: Gabor Filter Visualization,
http://www.cs.umd.edu/class/spring2005/cmsc838s/assignment-projects/gabor-filter-visualization/report.pdf
Authors: V. Shiv Naga Prasad & Justin Domke



Filtrul Gabor 2D



http://www4.comp.polyu.edu.hk/~csjunxu/Teaching/comp4134_tut_5.pdf



Filtrul Gabor 2D

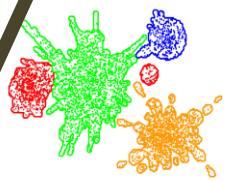
$$g(x, y) = s(x, y)\, w_r(x, y)$$

$$s(x, y) = exp\left(j\left(2\pi F_0 (x \cos \omega_0 + y \sin \omega_0) + P\right)\right)$$

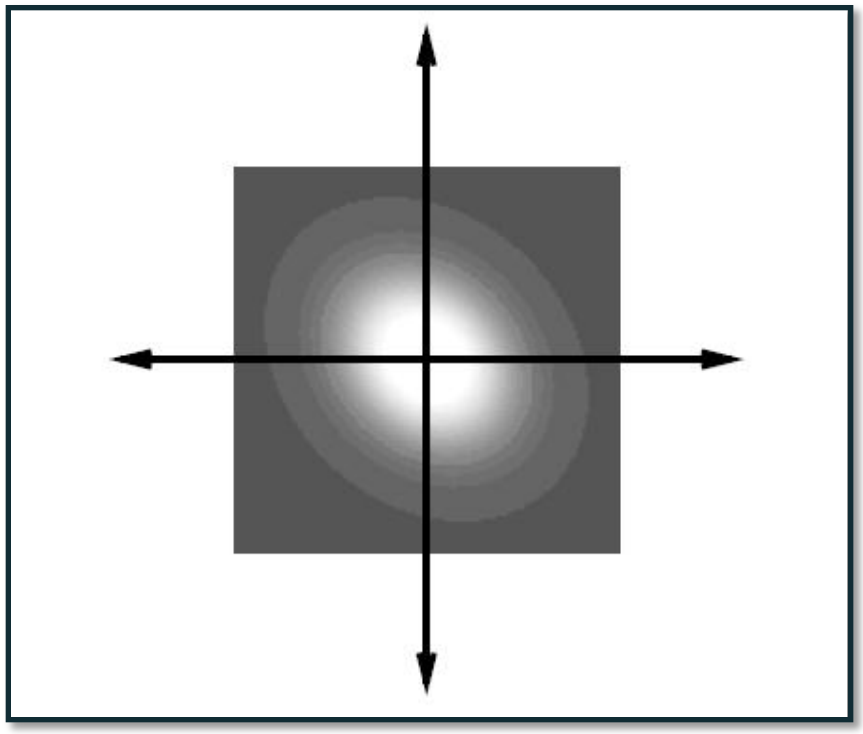
$$w_r(x, y) = K\, exp\left(-\pi\left(a^2 (x - x_0)_r^2 + b^2 (y - y_0)_r^2\right)\right)$$

Unde:

- K : Amplitudinea infasuratoarei Gaussiene
- (a, b) : Factorii de scala pe cele doua axe ale Gaussienei
- θ: Unghiul de inclinare al filtrului.
- (x_0, y_0) : Punctul central al filtrului
- F_0: amplitudinea infasuratoarei
- ω_0: frecventa (pulsatia infasuratoarei)
- P : Faza purtatoarei



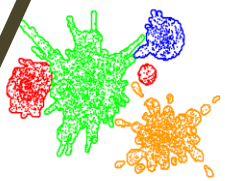
Filtrul Gabor 2D



[Movellan]

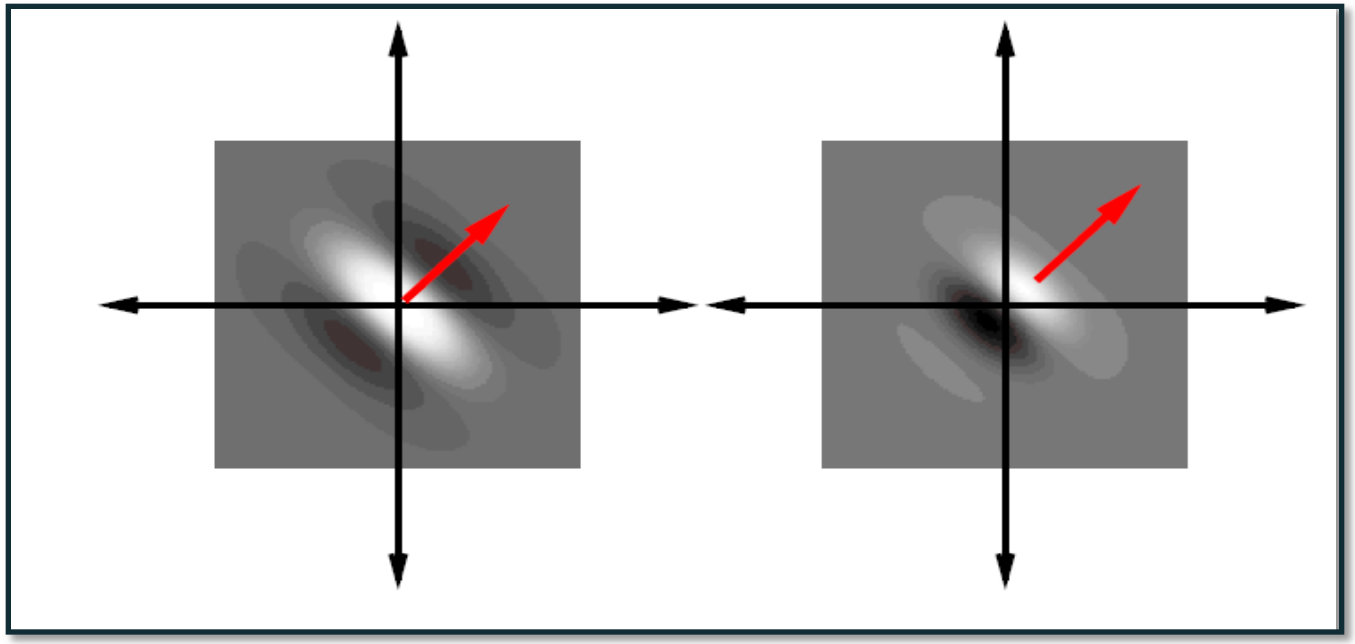
Infasuratoarea Gaussiana:

- $x_0 = y_0 = 0$
- $a = 1/50$ pixeli
- $b = 1/40$ pixeli
- $\theta = 45^o$



Filtrul Gabor 2D

Partea reala si imaginara a unui filtru Gabor in domeniul spatial:



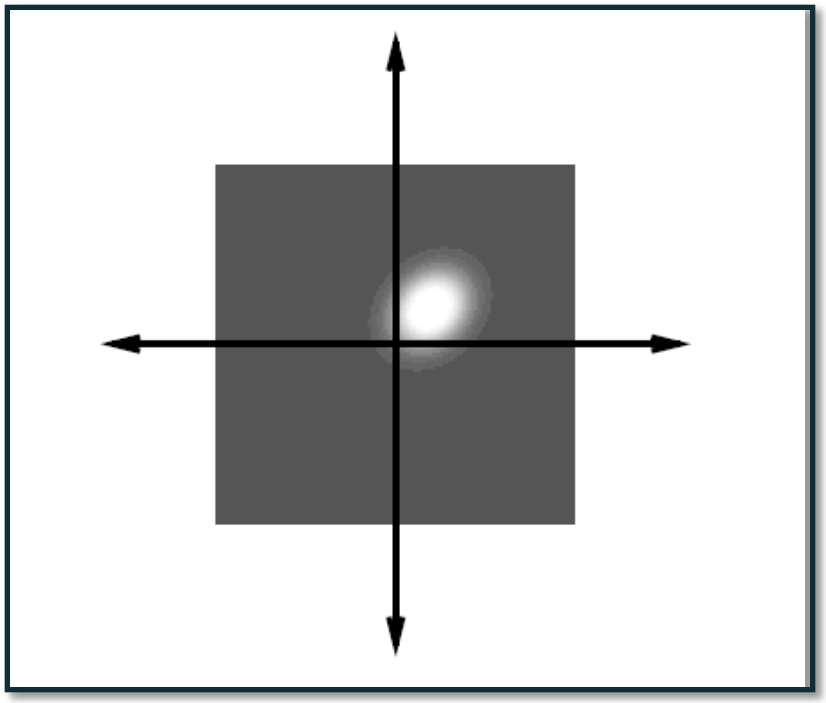
Imaginile sunt 128x128. Parametrii folositi sunt:

- $x_0 = y_0 = 0$
- $a = 1/50$ pixeli, $b = 1/40$ pixeli,
- $\theta = -45^o$, $F_0 = \sqrt{2}/80$ ciclii/pixel,
- $\omega_0 = 45\ ^o/s$, $P = 0^o$.

[Movellan]

Filtrul Gabor 2D

Transformata Fourier a filtrului Gabor



Imaginile sunt 128x128.

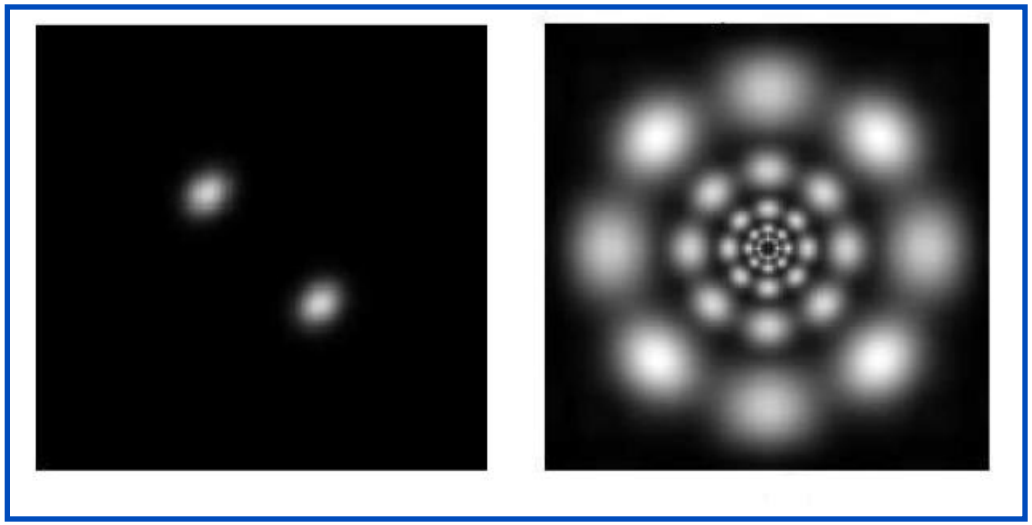
Parametrii folositi sunt:

- $x_0 = y_0 = 0$
- $a = 1/50$ pixeli, $b = 1/40$ pixeli,
- $\theta = -45^o$, $F_0 = \sqrt{2}/80$ ciclii/pixel,
- $\omega_0 = 45\ ^o/s$, $P = 0^o$.

[Movellan]

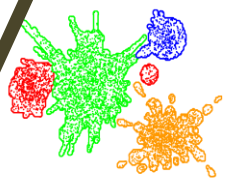
Bancuri de filtre Gabor

Pentru extragerea de trasaturi se folosesc bancuri de filtre Gabor



Amplitudinea functiei de transfer a unui filtru Gabor bi-dimensional cu orientare de 45º si frecvente centrale nenule;

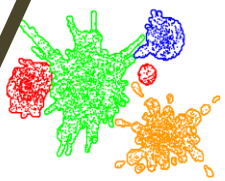
Amplitudinea unei functii de transfer a unui banc de filtre Gabor bi-dimensionale (4 orientarii si 5 scale);



MPEG-7

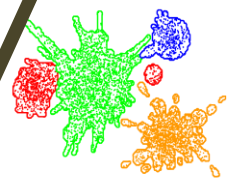
MPEG:

- Motion Picture Experts Group
- Elaborare de standarde pentru transmisie audio si transmisie si compresie video
- Include descriptori de textura:
  - Homogeneous Texture - ***3.2.3.1*** Banc de filtre Gabor
  - Edge Histogram
  - Texture Browsing

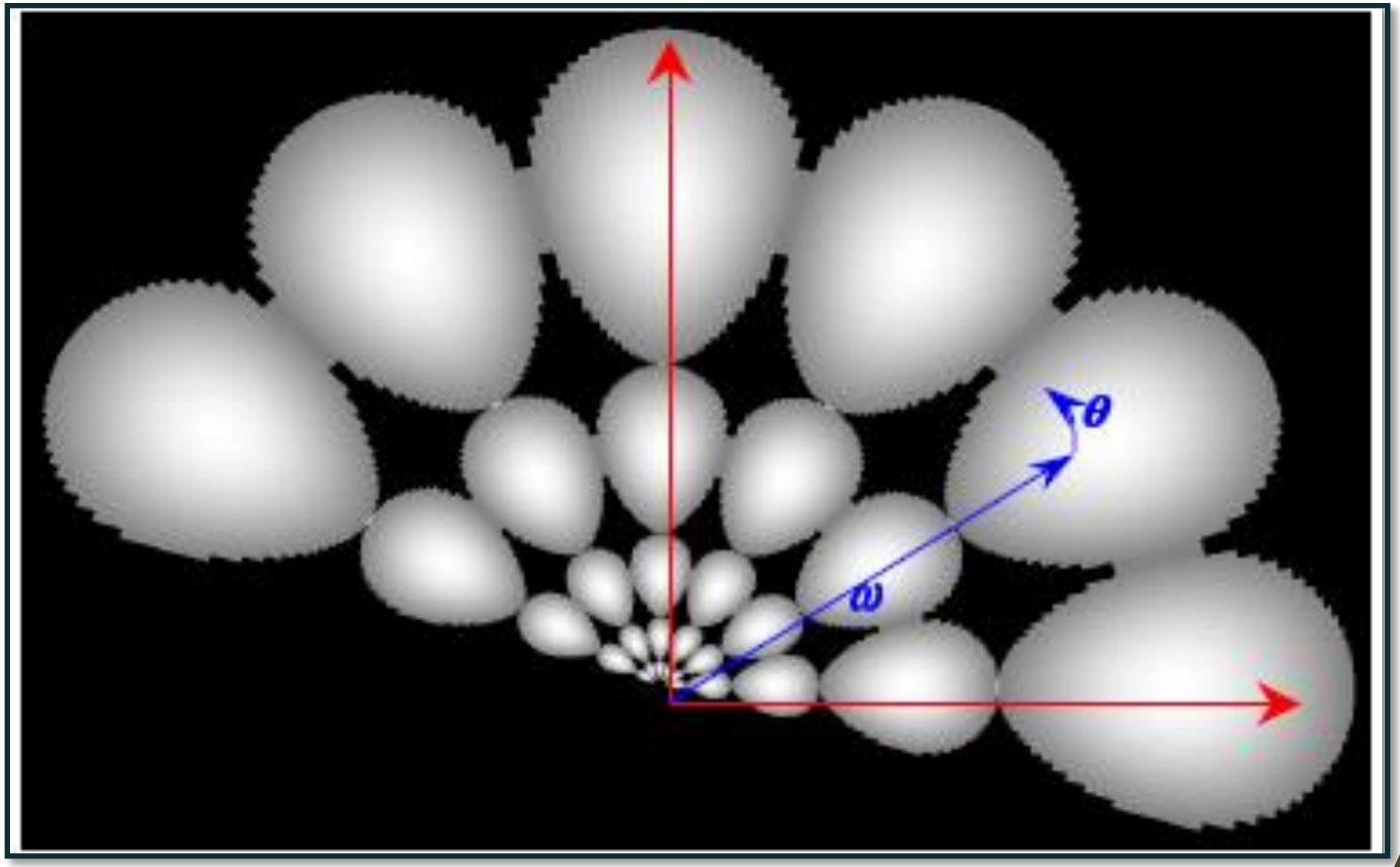


Filtre Gabor in MPEG-7

- Similaritate cu SVU – descompunere in benzi spectrale [ManRo]
  - Benzi simetrice fata de centru in coordonate polare
  - Benzi de latime constanta pe fiecare directie angulara
- Bancul de filtre Gabor este specificat:
  - Directii unghiulare spatiate cu 30 de grade – 6 directii
  - Frecventa centrala $\omega_s = \omega_0 2^{-s}$, $s=\{0,1,2,3,4\}$; $\omega_0 = 3/4$
  - Latimea de banda $B_s = B_0 2^{-s}$, $s=\{0,1,2,3,4\}$; $\omega_0 = 1/2$



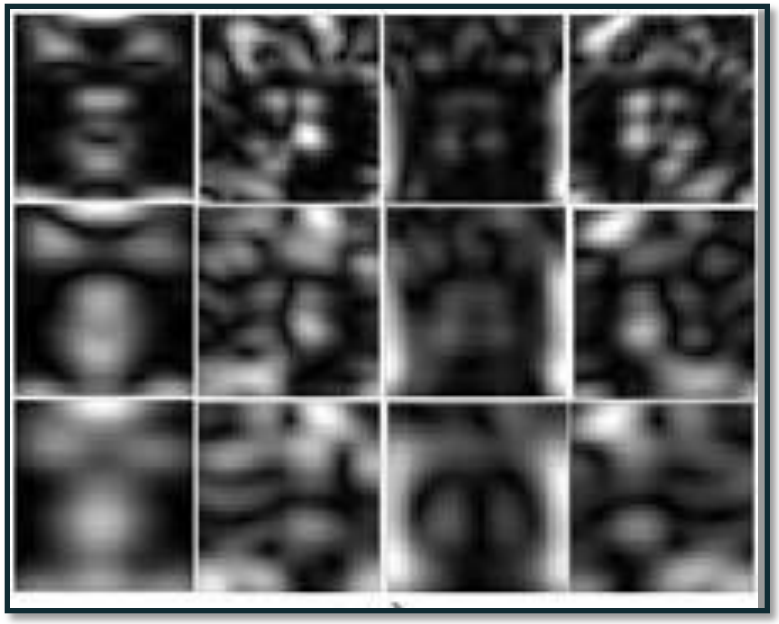
Filtre Gabor in MPEG-7



Bancul de filtre Gabor in coordonate polare;

[ManRo]

Exemplu – recunoasterea emotiilor

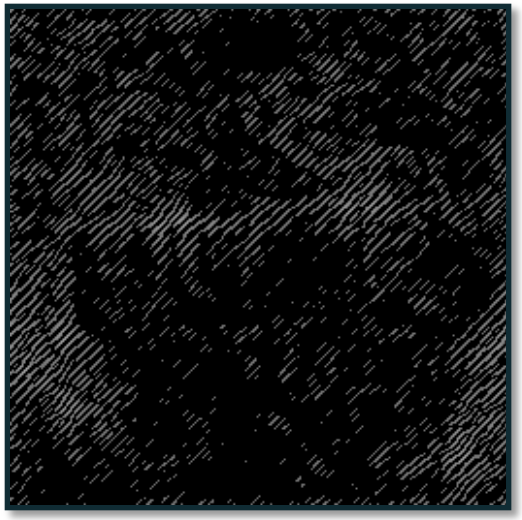
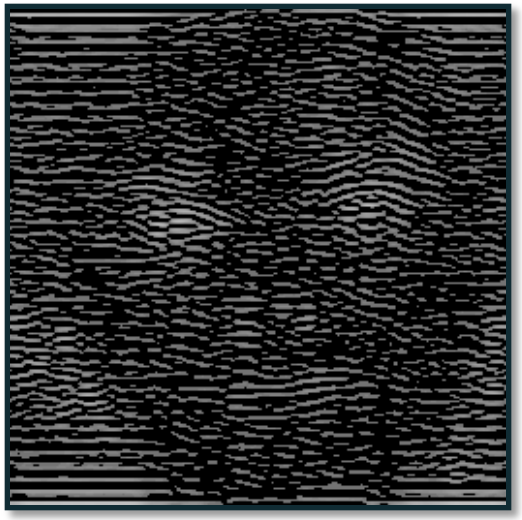
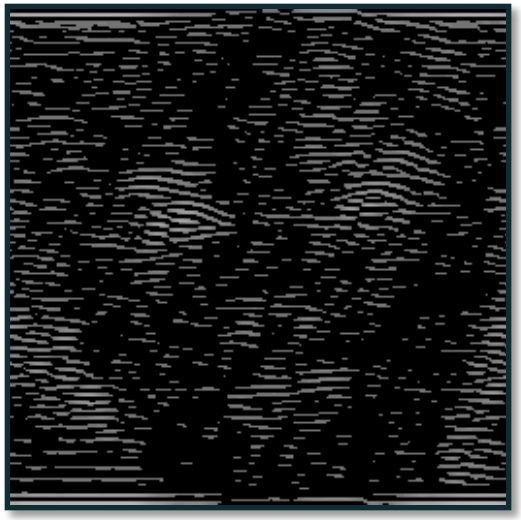
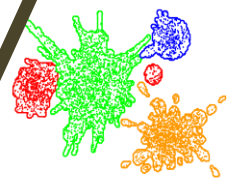


Magnitudinea imaginilor rezultate in urma unui filtrarii cu un banc de 12 filtre Gabor

[Buciu08]

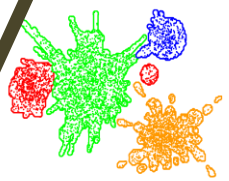
Exemplu: fata umana



SIFT

- **SIFT = Scale-invariant Feature Transform**
- **Brevetat pt aplicatii industriale**
- **Transforma imaginea in coordonate independente de scala**



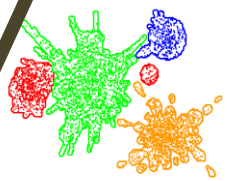
Referinţe bibliografice

Texture Unit:

- [He] He, D. and Wang, L., "*Texture unit, texture spectrum and texture analysis*," IEEE Trans. on Geoscience and Remote Sensing 28, pp.509-512 Iulie, 1990.

Local Binary Pattern:

- [Ojala1]T. Ojala et al, "*A comparative study of texture measures with classification based on feature distributions*", Pattern Recognition, vol. 29, pp. 51-59, 1996.
- [Ojala2] T. Ojala et al, "*Multiresolution gray-scale and rotation invariant texture classification with local binary patterns*", IEEE Transaction on Pattern Analysis and Machine Intelligence, vol. 24, pp. 971-981, 2002.
- [Ahonen] Timo Ahonen et al, "*Face Recognition with Local Binary Patterns*", ECCV 2004, LNCS 3021, pp. 469-481, 2004
- [Pietikäinen] Matti Pietikäinen, "*Face Analysis Using Local Binary Patterns*" http://www.ee.oulu.fi/mvg
- http://www.ee.oulu.fi/research/imag/mvg/files/pdf/CVPR-tutorial-final.pdf



Referinţe bibliografice

Pixel Difference Vectors

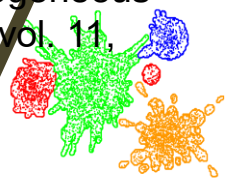
- J. Lu, V. E. Liong, X. Zhou and J. Zhou, "Learning Compact Binary Face Descriptor for Face Recognition," in *IEEE Transactions on Pattern Analysis and Machine Intelligence*, vol. 37, no. 10, pp. 2041-2056, 2015.
- C. Ding, J. Choi, D. Tao and L. S. Davis, "Multi-Directional Multi-Level Dual-Cross Patterns for Robust Face Recognition," in *IEEE Transactions on Pattern Analysis and Machine Intelligence*, vol. 38, no. 3, pp. 518-531, 2016.
- Zhuo Su, Pietikäinen Matti, Li Liu “BIRD: Learning Binary and IlluminationRobust Descriptor for Face Recognition”, BMVC 2019

Histogram of Oriented Gradient:

- [Dalal2005] Navneet Dalal, Bill Triggs, “Histograms of Oriented Gradients for Human Detection”, International Conference on Computer Vision and Pattern Recognition, Vol 2, pp. 886-893, 2005

Filtre Gabor:

- [Movellan] Javier R. Movellan “Tutorial on Gabor Filters”
- [Buciu08] Ioan Buciu, I. Nafornita, I. Pitas, “Facial Expression Recognition under Noisy Environment Using Gabor Filters”, Buletinul Ştiinţific al Universităţii "Politehnica" din Timişoara, Seria Electronica si Telecomunicatii, Tom 53(67), Fascicola 1-2, 28
- [ManRo] Y. Man Ro, M. Kim, H. K. Kang, B.S. Manjunath, and J. Kim “MPEG-7 Homogeneous Texture Descriptor” IEEE Transaction on Circuits and Systems for Video Technology, vol. 11, no. 6, June 2001



Multumesc pentru atentie!

In ceea ce priveste intrebarile… va ascult ?

