Ro.S.A. Robust Statistics Academy

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UNIVERSITÀ DI PARMA il mondo che ti aspetta DIPARTIMENTO DI SCIENZE ECONOMICHE E AZIENDALI

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UNIVERSITÀ DI PARMA DIPARTIMENTO DI Ingegneria dei Sistemi e delle Tecnologie Industriali DIPARTIMENTO DIDATTICA RICERCA TERZA MISS

UNIVERSITÀ DI PARMA il mondo che ti aspetta DIPARTIMENTO DI MEDICINA E CHIRURGIA

MATLAB in ambito aziendale, università e policy research

(V edizione)

VENERDI' 8 novembre 2024, ore 8.50-13.00

Un approccio efficiente basato sul machine learning per il rilevamento di micro-espressioni facciali

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Digital Information Processing Laboratory Lab

SAPIENZA UNIVERSITÀ DI ROMA

Problem

Automatic detection of the emotional state of a subject

Sentiment analysis

Real weight of communication

verbal: 7%

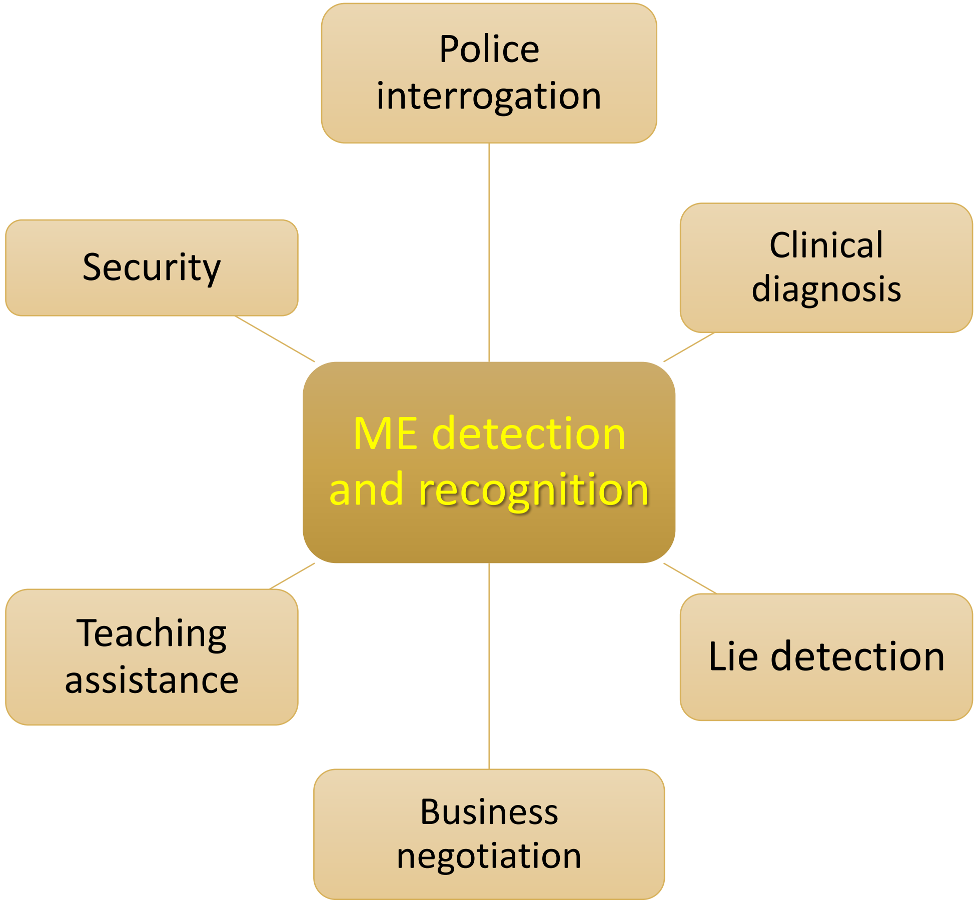
paraverbal: 38%

non verbal: 55%

Albert Mehrabian, Nonverbal Communication, Taylor & Francis Inc, 2007 ***(from 1972)***

Problem: some applications

Automatic detection of the emotional state of a subject in a *video sequence*



Problem: Investment 2020

By the way: **Automatic 'control' of customers emotional state:**

Some interested enterprises: ***GE Cisco IBM AutoDesk Qualcomm***

Investment in 2020 about 20 billions of dollars

Other examples: ***Apple*** acquired ***Emotient***

Nielsen acquired ***Innerscope***

Unilever P&G Mars Honda Kellogg Coca Cola

Problem

Facial micro expressions (MEs) play a key role in a *non verbal communication* as they reveal the actual internal emotional state and subject intentions

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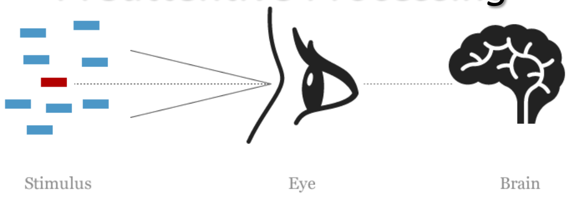
ME pros and cons

- *spontaneous* and very *informative*: minute muscle movements reflect the true emotions of a person
- *hard to detect*: due to the short duration and low intensity, they are very difficult to perceive and interpret correctly

Problem

Preattentive Processing



from 40 ms to 200 ms

200 ms

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State of the art

Detect and recognize ME

SPOTTING

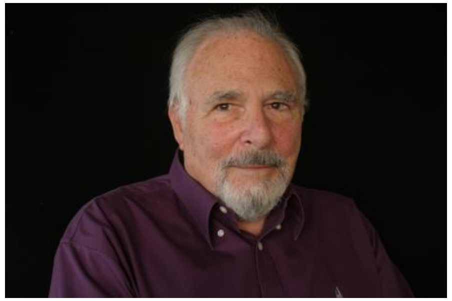
Temporal evolution

Accurate motion estimation

Neutral *Apex* *Neutral*

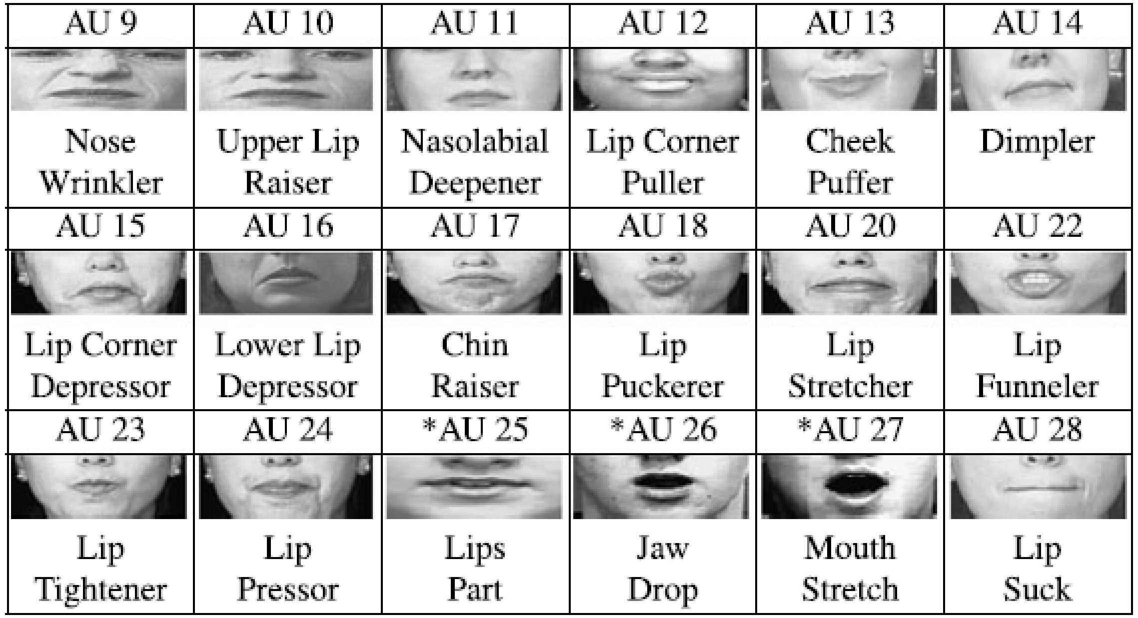
Onset *Offset*

State of the art



Paul Ekman

Detect and recognize ME



Partition into Action Units

⇩

Face segmentation

⇩

ME features

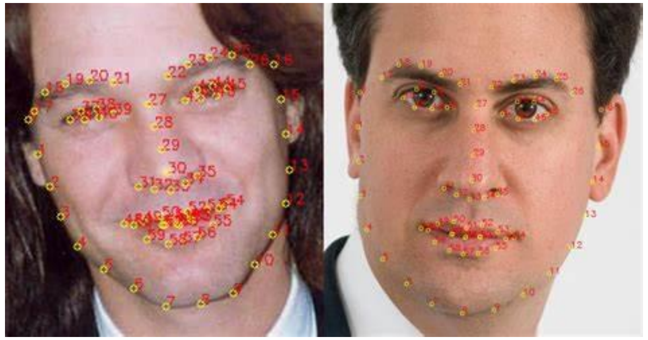
44 action units: each AU describes facial deformation due to each facial muscle movement

AUs involve contraction or relaxation of facial muscles and miscellaneous actions

State of the art

Detect and recognize ME

SPOTTING



Temporal evolution

⇓

Accurate motion estimation

Partition into Action units

⇓

Face segmentation

⇓

ME features

SPOTTING

RECOGNITION

Input video ⇒ Facial landmarks detection ⇒ Facial landmarks tracking ⇒ Salient face regions detection under noisy conditions ⇒ ME features description and recognition

A possible contribution

Preprocessing for spotting phase

Fast and effective method for selecting those frames where ME is present with high probability

Proposed method → Spotting → ME recognition

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Preprocessing for spotting phase

↓

Fast and effective method for selecting those frames where ME is present with high probability

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Aim: **to make faster the detection process**

ISHealth
bando Cyber 4.0

SICURI
Ambito 3: 'Aerospazio e Sicurezza'
Por FESR Regione Lazio

The proposed model

- MEs as temporal transients → Visual discontinuities
- ME as visual fingerprint → **P**erceptual **E**xpression **S**ignature (**PES**)

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First attempt

✓ simple IQA metric: ***SSIM*** (**S**tructural **SIM**ilarity index)

✓ global feature: temporal behaviour of the asymmetry of SSIM distribution

The proposed model

- simple IQA metric: SSIM

$$SSIM(I,J) = \underbrace{\frac{2\mu_I\mu_J + C_1}{\mu_I^2 + \mu_J^2 + C_1}}_{luminance\ adaptation} \underbrace{\frac{2\sigma_I\sigma_J + C_2}{\sigma_I^2 + \sigma_J^2 + C_2}}_{contrast\ masking} \underbrace{\frac{\sigma_{IJ} + C_3}{\sigma_I\sigma_J + C_3}}_{spatial\ correlation},$$

$-1 \leq$ *SSIM(I,J)* ≤ 1

The closer SSIM to 1, the higher the similarity between I and J

Remark: SSIM doesn't satisfy *triangle inequality* or *non-negativity*: ***not a distance***.
Under certain conditions, SSIM can be a normalized root MSE measure (distance), the square of such a function is not convex, but is *locally convex* and *quasiconvex*.

Wang, Zhou; Bovik, A.C.; Sheikh, H.R.; Simoncelli, E.P. (2004-04-01). "Image quality assessment: from error visibility to structural similarity". *IEEE Transactions on Image Processing*. **13** (4): 600–612

The proposed model

- simple IQA metric: SSIM

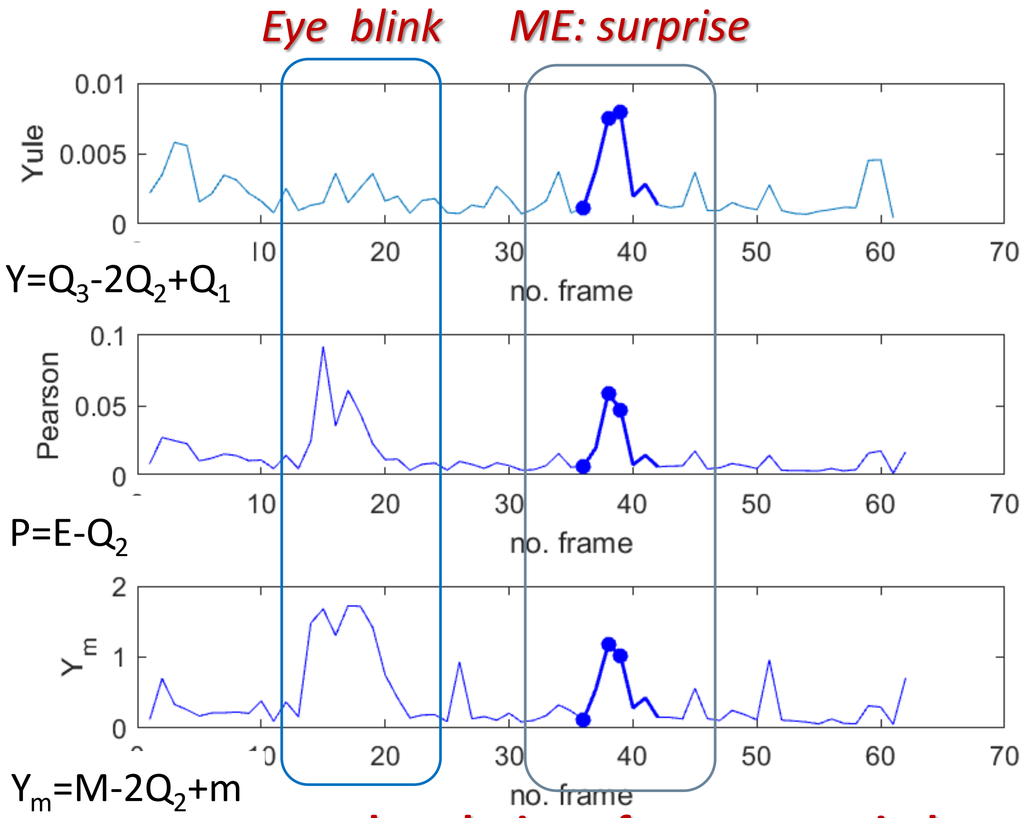
the larger S the higher the ***visual dissimilarity*** between ***two consecutive frames***

$$S(I,J) = 1 - SSIM(I,J) = 1 - \frac{2\mu_I\mu_J + C_1}{\mu_I^2 + \mu_J^2 + C_1}\,\frac{2\sigma_{IJ} + C_2}{\sigma_I^2 + \sigma_J^2 + C_2}$$

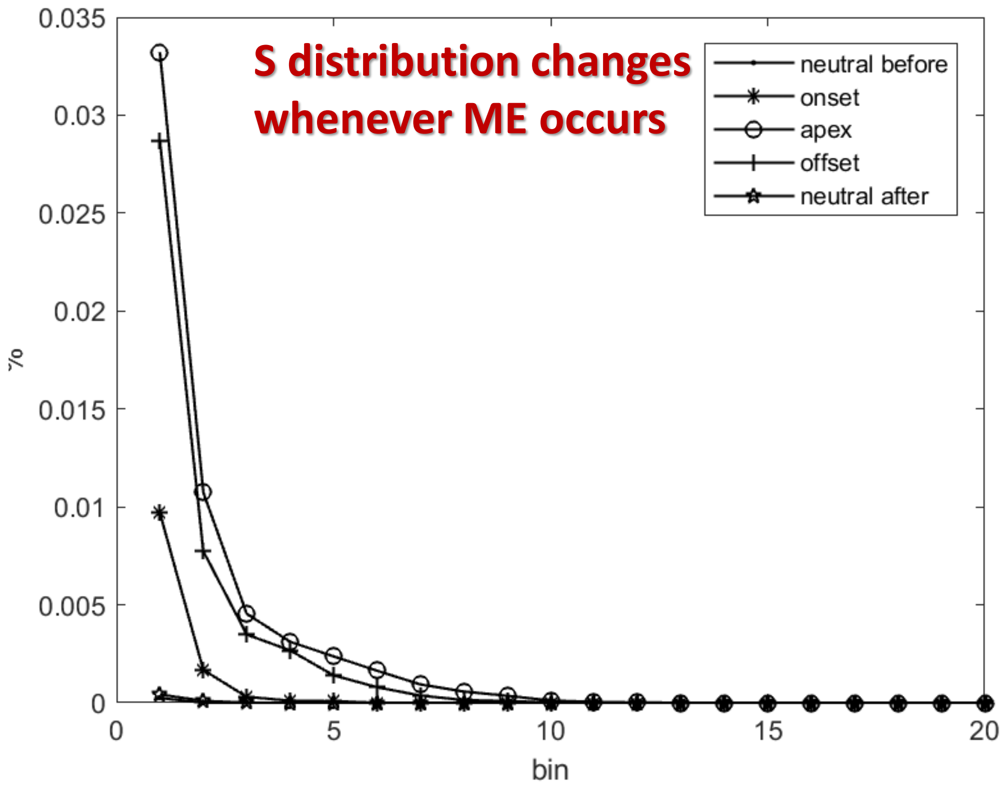
Neutral *Onset* *Apex* *Offset* *Neutral*

The proposed model

- Global feature: ***asymmetry*** of ***S=1-SSIM*** distribution in a global ROI (the face)



temporal evolution of asymmetry index

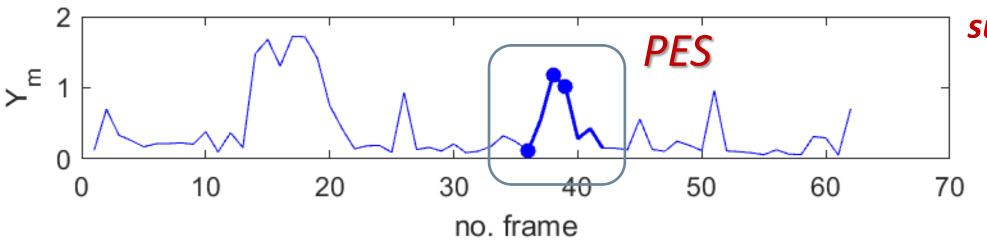


The proposed model

- PES: **1-SSIM** distribution asymmetry temporal profile *onset* → *apex*

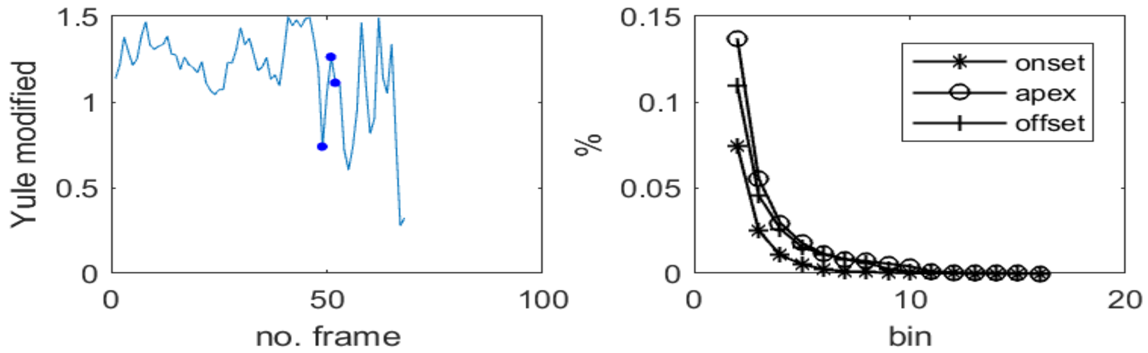
$Y=M-2Q_2+m$

surprise

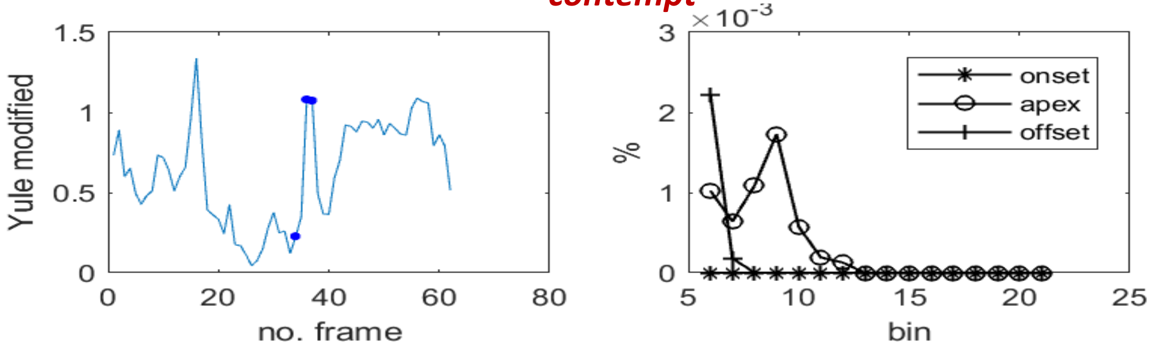


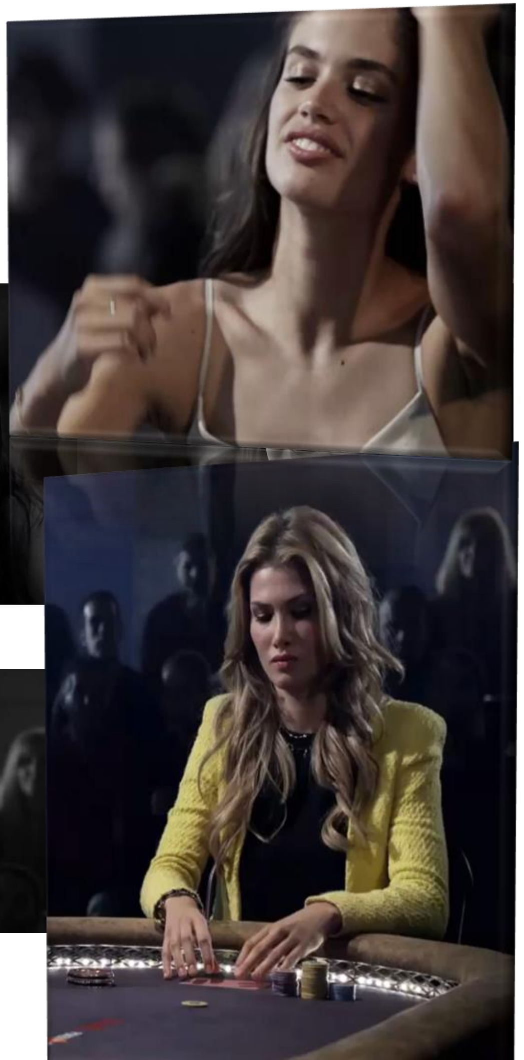
✓ *onset* and *apex* are common to all MEs

happy



contempt





Machine Learning: Support Vector Machine

SVM solves the binary classification problem as a ***supervised learning task***

Starting from a *training set*:

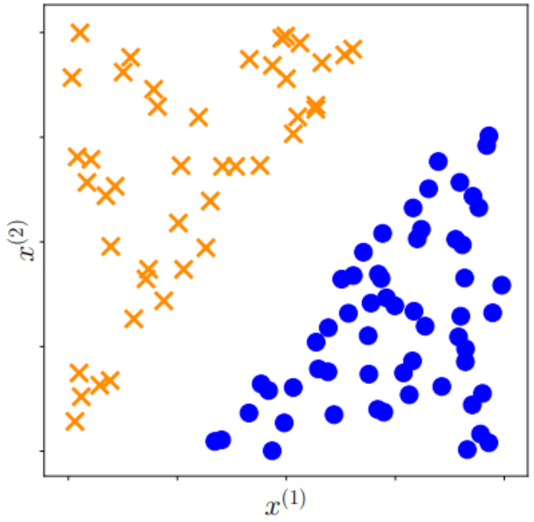
Gender ID	Degree	Latitude (in degrees)	Longitude (in degrees)	Age	Annual Salary (in thousands)
-1	2	51.5073	0.1290	36	89.563
-1	3	51.5074	0.1275	47	123.543
+1	1	51.5071	0.1278	26	23.989
-1	1	51.5075	0.1281	68	138.769
+1	2	51.5074	0.1278	33	113.888

where there is a set of examples $\boldsymbol{x}_n \in R^D$ with their corresponding (binary) labels $y_n \in \{+1, -1\}$

The parameters of the model, giving ***the smallest classification error***, must be estimated

Why SVM: it allows for a ***simple geometric way*** to think about supervised machine learning

Example on 2D data:



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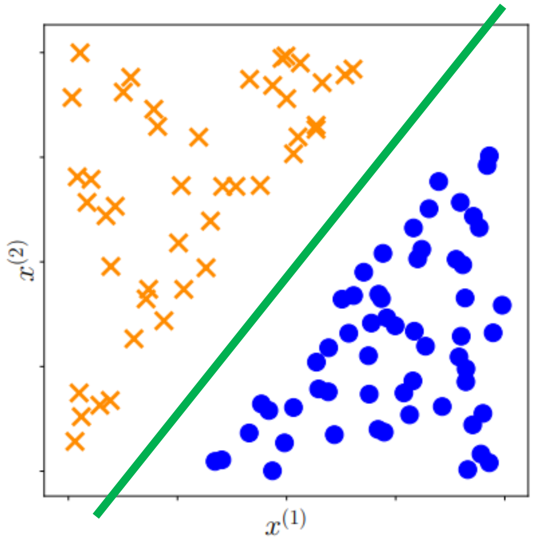
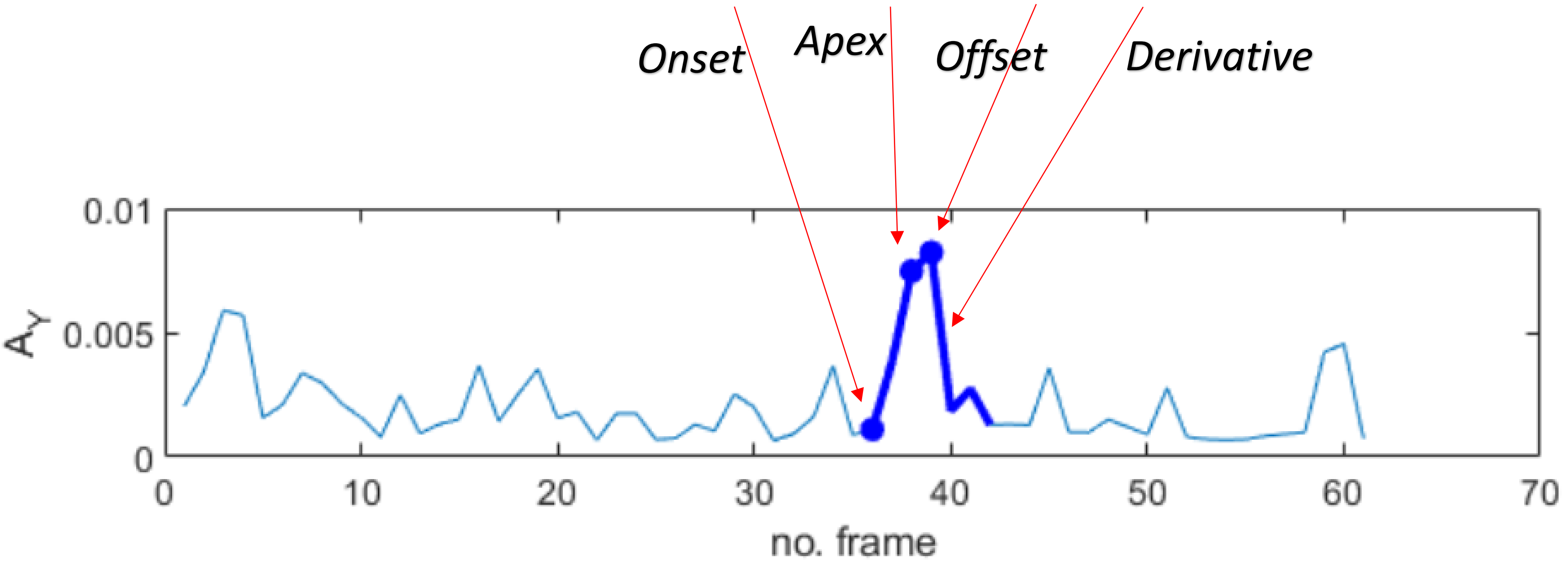


Machine Learning: Support Vector Machine

Perceptual Features: $V = [A(t_1)\ A(t_2)\ A(t_3)\ v_4],$



where: $v_4 \in \{-1, +1\}$

Data Augmentation

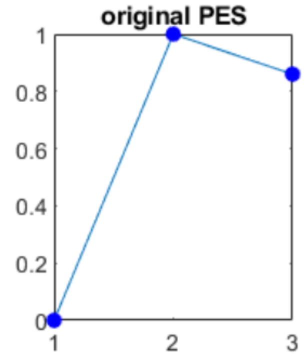
Problem: lack of data *(necessary for SVM)*

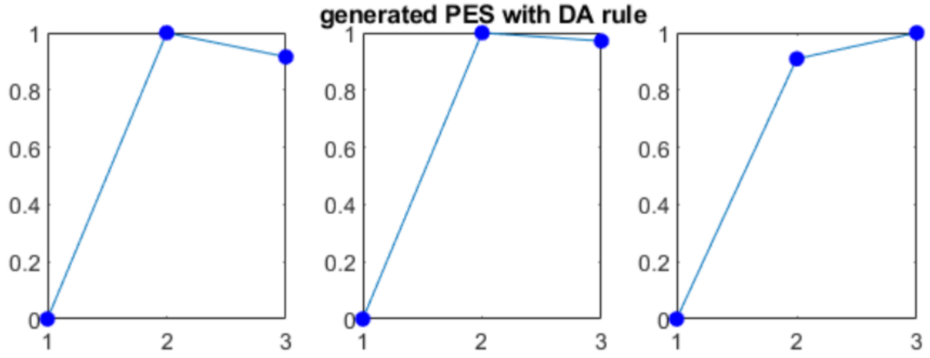
Solution: Data Augmentation *(adding a subtle visual noise)*

$$x_k = f(x_{k-1}) + \varepsilon \qquad \textit{where:} \qquad 0 \le \frac{\sigma_\epsilon^2}{\sigma^2_{f(x_{k-1})}} \le \rho$$

PES + just noticeable visibility threshold

Example:





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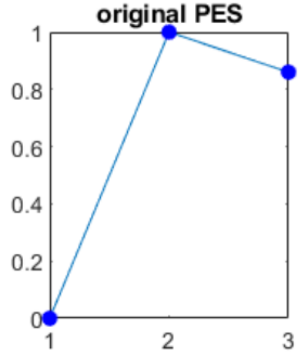
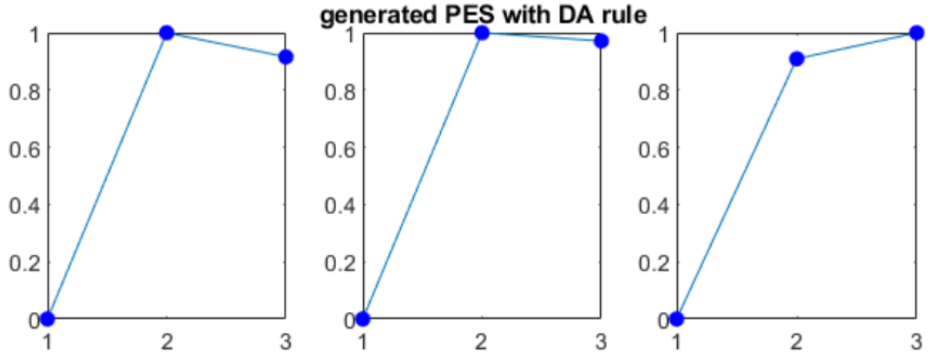
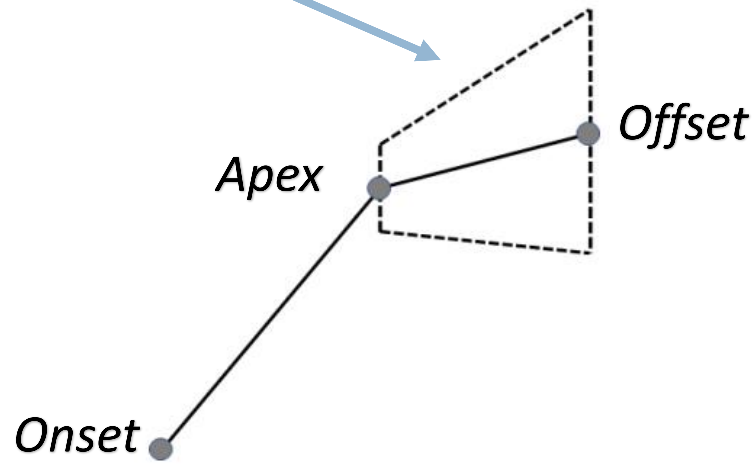


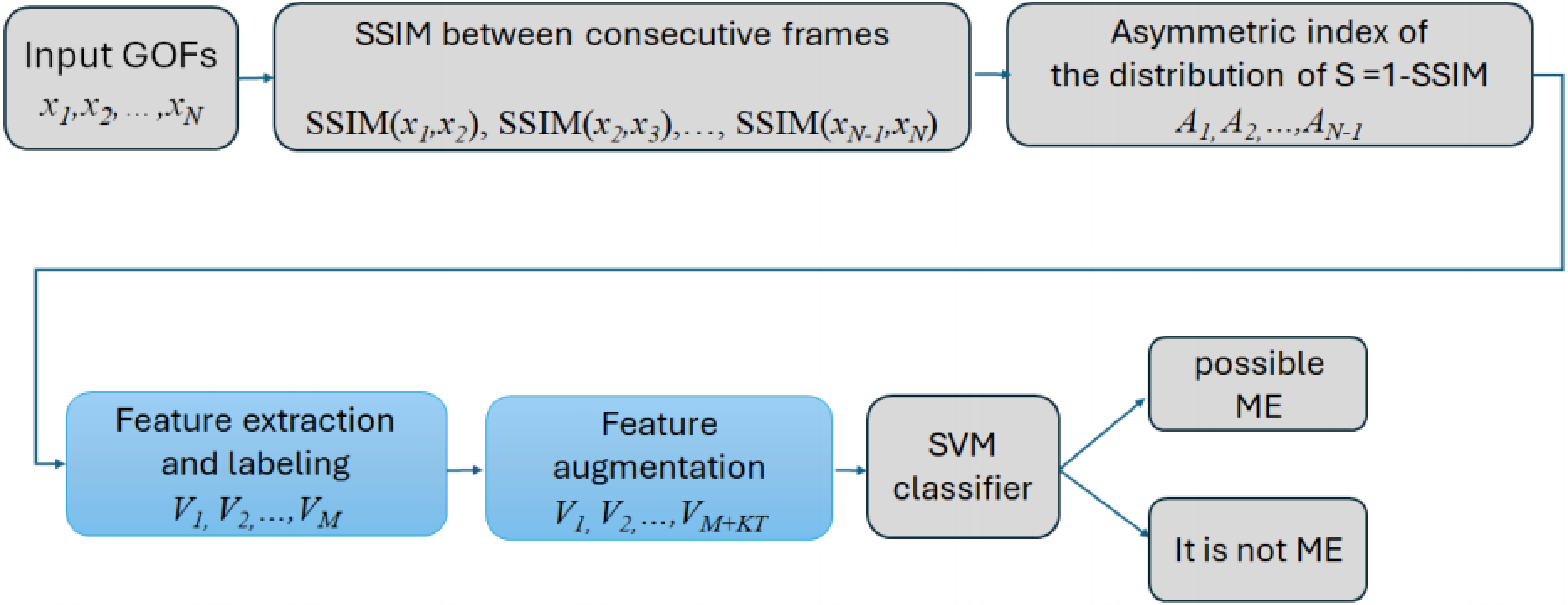




Block Scheme

***P**erceptual*
***E**motional*
***S**ignature of*
***M**icro-expressions via*
***S**sim and*
***S**vm*

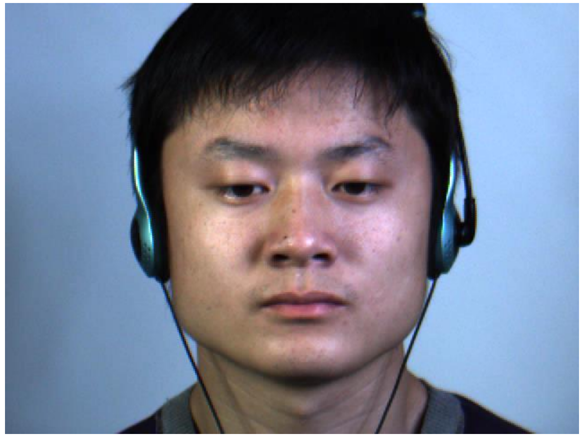
PESMESS

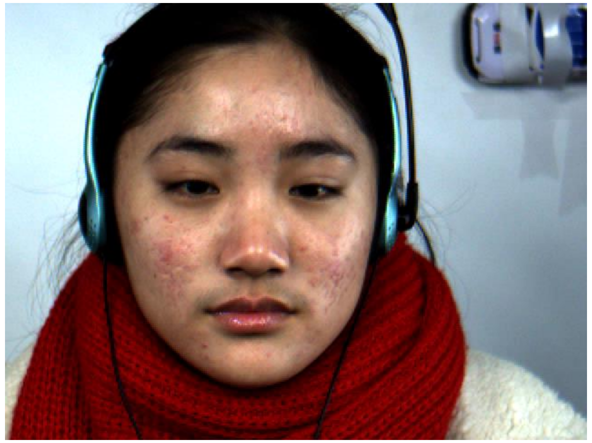


Does PESMESS work?

Adopted Databases: ***MEVIEW****: "in-the-wild" situations, with realistic poker game videos,31 videos, 3s*

CASME II: *(247 videos, 200 fps, MEs (less than .2 secs)*





Does PESMESS work?

Note: *few false alarms , 102 elements (positive and negative training examples),*
$\rho = 0.33\%$

		Sequence: 15.1			
PES no. 1	*Location*	3	*Description*	looks up
PES no. 2	*Location*	23	*Description*	open eyes
PES no. 3	*Location*	38	*Description*	ME (surprise)
		Sequence: 14.3			
PES no. 1	*Location*	5	*Description*	imperceptible smile
PES no. 2	*Location*	19	*Description*	ME (joy)
		Sequence: 1.1			
PES no. 1	*Location*	12	*Description*	zoom/stabilization
PES no. 2	*Location*	35	*Description*	zoom/stabilization
PES no. 3	*Location*	48	*Description*	ME begin
PES no. 4	*Location*	54	*Description*	ME reinforcement
PES no. 5	*Location*	64	*Description*	ME end
PES no. 6	*Location*	73	*Description*	mouth micro movement
		Sequence: 2.1			
PES no. 1	*Location*	29	*Description*	look down
PES no. 2	*Location*	81	*Description*	frozen eyes
PES no. 3	*Location*	99	*Description*	ME
		Sequence: 3.1			
PES no. 1	*Location*	27	*Description*	looks up
PES no. 2	*Location*	37	*Description*	frozen eyes
PES no. 3	*Location*	70	*Description*	mouth movement
PES no. 4	*Location*	78	*Description*	ME
		Sequence: 6.1			
PES no. 1	*Location*	3	*Description*	keep looking down
PES no. 2	*Location*	15	*Description*	ME
PES no. 3	*Location*	34	*Description*	eyes movement
PES no. 4	*Location*	47	*Description*	eyes and eyebrows

		Sequence: 7.9		
PES no. 1	*Location*	13	*Description*	mouth movement
PES no. 2	*Location*	27	*Description*	tongue movement
PES no. 3	*Location*	31	*Description*	tongue movement
PES no. 4	*Location*	46	*Description*	head movement
PES no. 5	*Location*	50	*Description*	head (FA)
PES no. 6	*Location*	60	*Description*	eyes movement
PES no. 7	*Location*	65	*Description*	tongue movement
PES no. 7	*Location*	65	*Description*	ME
		Sequence: 8.1		
PES no. 1	*Location*	13	*Description*	ME
PES no. 2	*Location*	22	*Description*	mouth (ME end)
PES no. 3	*Location*	32	*Description*	head movement
PES no. 4	*Location*	42	*Description*	eyes movement
PES no. 4	*Location*	46	*Description*	head movement
PES no. 5	*Location*	49	*Description*	head movement
PES no. 6	*Location*	56	*Description*	head movement
		Sequence: 8.2		
PES no. 1	*Location*	19	*Description*	ME
PES no. 2	*Location*	37	*Description*	head movement
PES no. 3	*Location*	43	*Description*	head and eyes movement

The role of MATLAB in PESMESS

SSIM

SVM

ObjectDetector

Web Service

The role of MATLAB in PESMESS: SSIM

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[Ssimval,Sssimmap] = ssim(A,ref)

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0.9930

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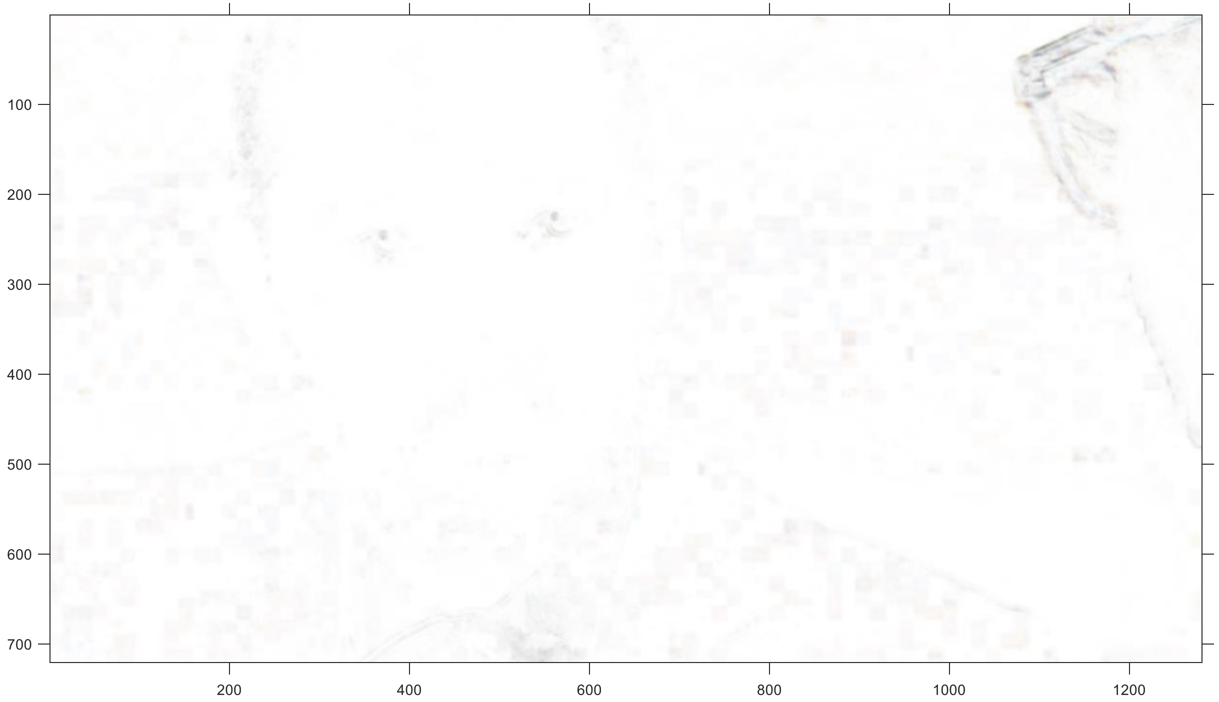

38

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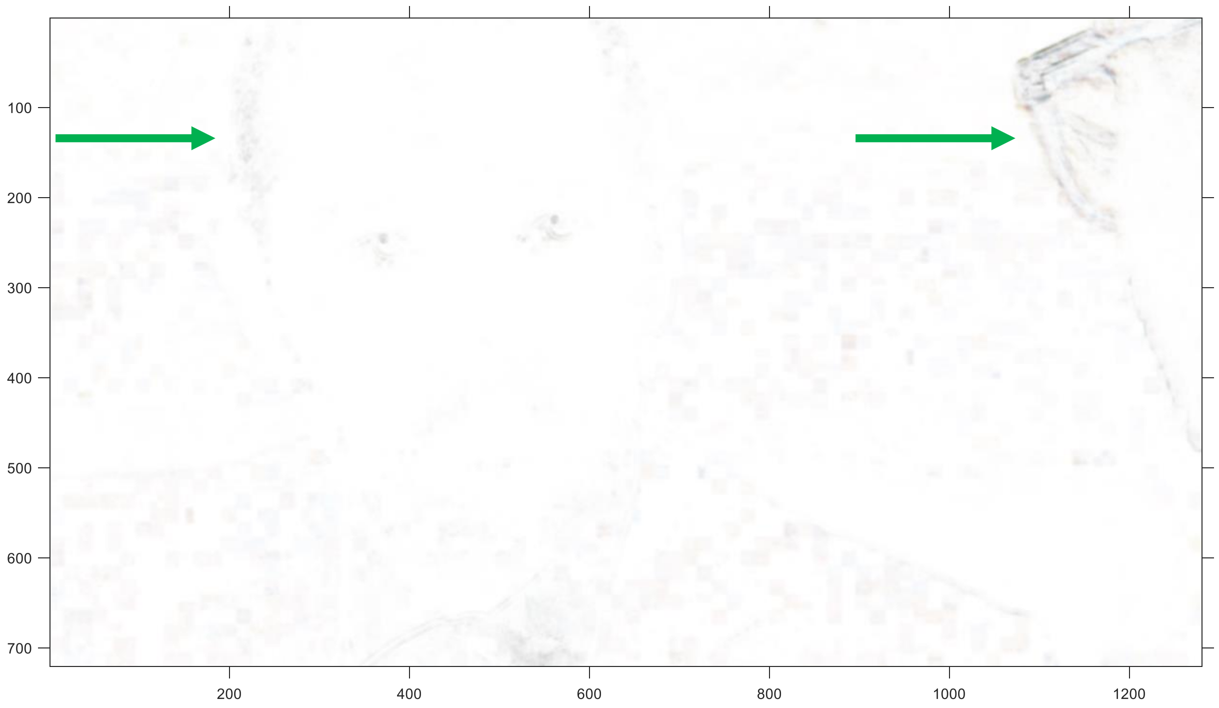

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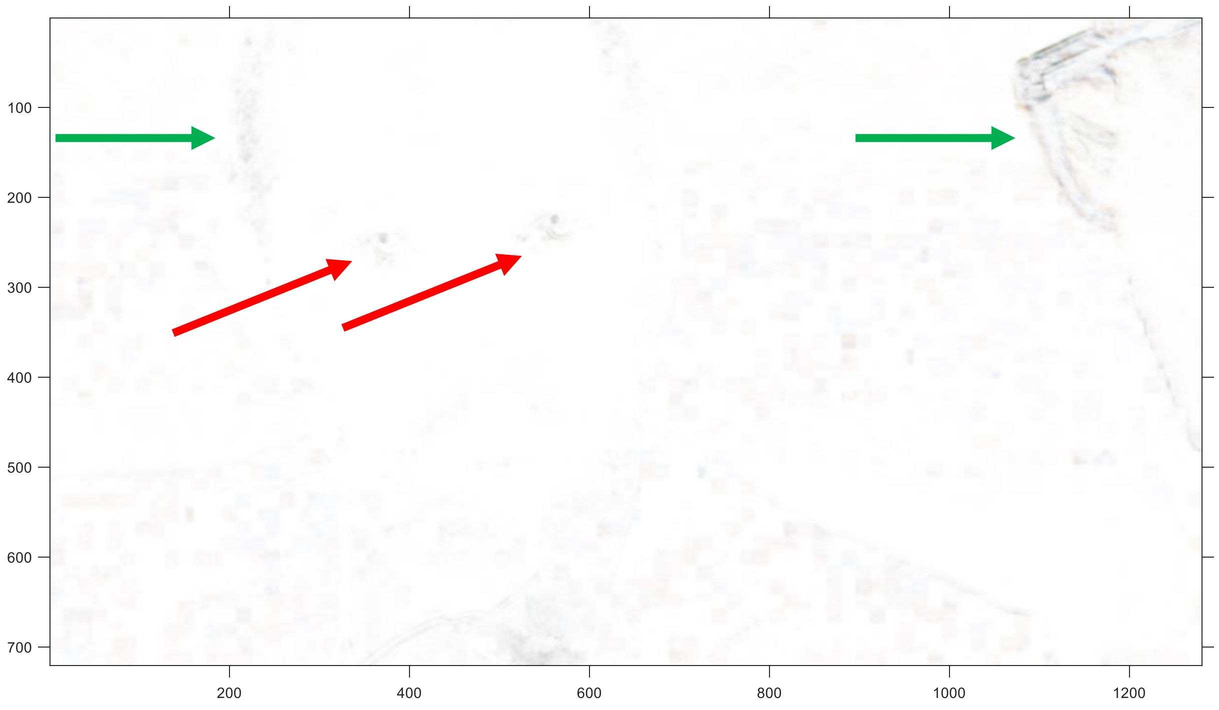

The role of MATLAB in PESMESS: SVM

Let's generate synthetic data (training set, noisy data around 2 centers of mass with coordinates (100,50) and (98,48):

```
% first class
X11 = 100 + rand(1,100); %first coord. 1st class
X12 =   50 + rand(1,100); %second coord. 1st class

X1 = [X11' X12'];

% second class
X21 = 98 + rand(1,100); %first coord. 2nd class
X22 = 48 + rand(1,100); %second coord. 2nd class

X2 = [X21' X22'];

X = [X1 ; X2]
```

```
X =

  100.0986   50.7519
  100.1420   50.2287
  100.1683   50.0642
  100.1962   50.7673
  100.3175   50.6712
         .
         .
   98.4116   48.2815
   98.6026   48.2304
   98.7505   48.7111
   98.5835   48.6246
   98.5518   48.5906
         .
         .
```

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X1 = [X11' X12'];

% second class
X21 = 98 + rand(1,100); %first coord. 2nd class
X22 = 48 + rand(1,100); %second coord. 2nd class

X2 = [X21' X22'];

X = [X1 ; X2]
```

```
X =

 100.0986   50.7519
 100.1420   50.2287
 100.1683   50.0642
 100.1962   50.7673
 100.3175   50.6712
          .
          .
  98.4116   48.2815
  98.6026   48.2304
  98.7505   48.7111
  98.5835   48.6246
  98.5518   48.5906
          .
```

```
Y = cell(200,1);

for i=1:100,   Y{i} = 'c', end
for i=101:200,  Y{i} = 'g', end
```

```
Y =
  200×1 cell array

   {'c'}
   {'c'}
   {'c'}
     .
     .
   {'g'}
   {'g'}
   {'g'}
     .
     .
```

The role of MATLAB in PESMESS: SVM

Let's generate synthetic data (training set, noisy data around 2 centers of mass with coordinates (100,50) and (98,48):

```
% first class
X11 = 100 + rand(1,100); %first coord. 1st class
X12 =   50 + rand(1,100); %second coord. 1st class

X1 = [X11' X12'];

% second class
X21 = 98 + rand(1,100); %first coord. 2nd class
X22 = 48 + rand(1,100); %second coord. 2nd class

X2 = [X21' X22'];

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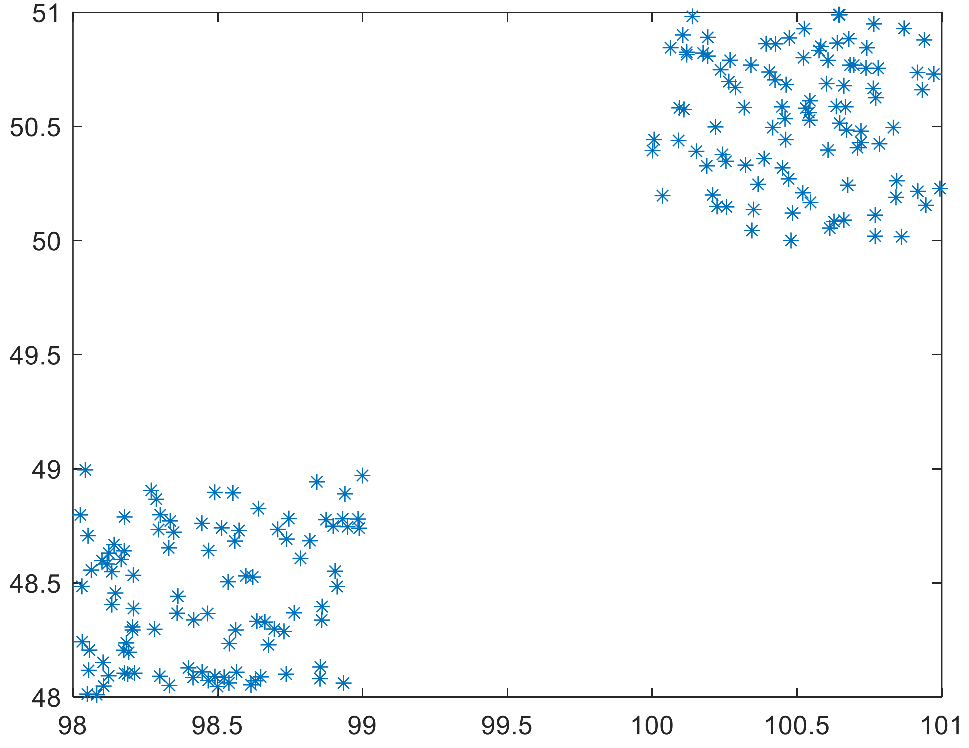
   98.6026   48.2304
   98.7505   48.7111
   98.5835   48.6246
   98.5518   48.5906
          .
          .
```

```
Y =
  200×1 cell array

    {'c'}
    {'c'}
    {'c'}
      .
      .
    {'g'}
    {'g'}
    {'g'}
      .
      .
```

The role of MATLAB in PESMESS: SVM

Let's generate synthetic data (training set, noisy data around 2 centers of mass with coordinates (100,50) and (98,48):



The role of MATLAB in PESMESS: SVM

Learning model:

```
SVMModel = fitcsvm(X,Y,'KernelFunction','rbf',...     % per classificazione binaria
'Standardize',true,'ClassNames',{'c','g’});

SVMModel =

  ClassificationSVM
           ResponseName: 'Y'
   CategoricalPredictors: []
             ClassNames: {'c'  'g'}
          ScoreTransform: 'none'
         NumObservations: 200
                  Alpha: [8×1 double]
                   Bias: -0.0074
        KernelParameters: [1×1 struct]
                     Mu: [99.5048 49.4672]
                  Sigma: [1.0565 1.0218]
          BoxConstraints: [200×1 double]
         ConvergenceInfo: [1×1 struct]
         IsSupportVector: [200×1 logical]
                 Solver: 'SMO'
```

The role of MATLAB in PESMESS: SVM

Learning model:

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SVMModel = fitcsvm(X,Y,'KernelFunction','rbf',...     % per classificazione binaria
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         BoxConstraints: [200×1 double]
        ConvergenceInfo: [1×1 struct]
        IsSupportVector: [200×1 logical]
                 Solver: 'SMO'
```

The role of MATLAB in PESMESS: SVM

Prediction data (test set) generation :

```
% P R E D I C T
%new samples
Xn11 = 100 + rand(1,10); %first coord. 1st class
Xn12 = 50 + rand(1,10); %first coord. 1st class

Xn1 = [Xn11' Xn12'];

%second class
Xn21 = 98 + rand(1,10); %first coord. 2nd class
Xn22 = 48 + rand(1,10); %first coord. 2nd class

Xn2 = [Xn21' Xn22'];

% a l l   i n   o n e

Xn = [Xn1 ; Xn2];
```

The role of MATLAB in PESMESS: SVM

Prediction phase:

```
d = 0.02;
[x1Grid,x2Grid] = meshgrid(min(Xn(:,1)):d:max(Xn(:,1)),min(Xn(:,2)):d:max(Xn(:,2)));
xGrid = [x1Grid(:),x2Grid(:)];
[~,scores] = predict(SVMModel,xGrid);

%[label,score] = predict(SVMModel,Xn); % altro predict sui dati test
```

Prediction phase:

label =

20×1 cell array

{'c'}
{'c'}
{'c'}
{'c'}
{'c'}
.
.

score =

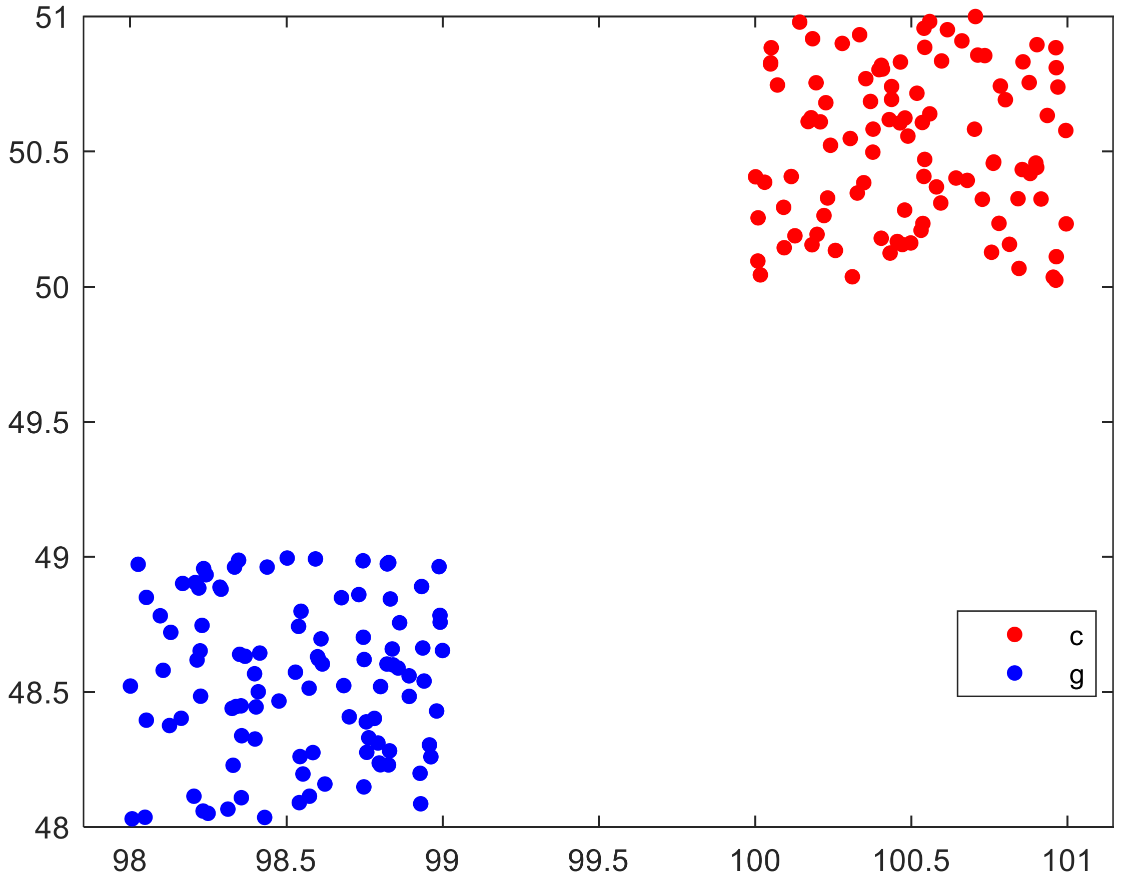
% likelihood that a label comes from a particular class

1.1398	*-1.1398*
1.1737	*-1.1737*
1.0761	*-1.0761*
1.0906	*-1.0906*
1.0687	*-1.0687*
.	
.	

The role of MATLAB in PESMESS: SVM

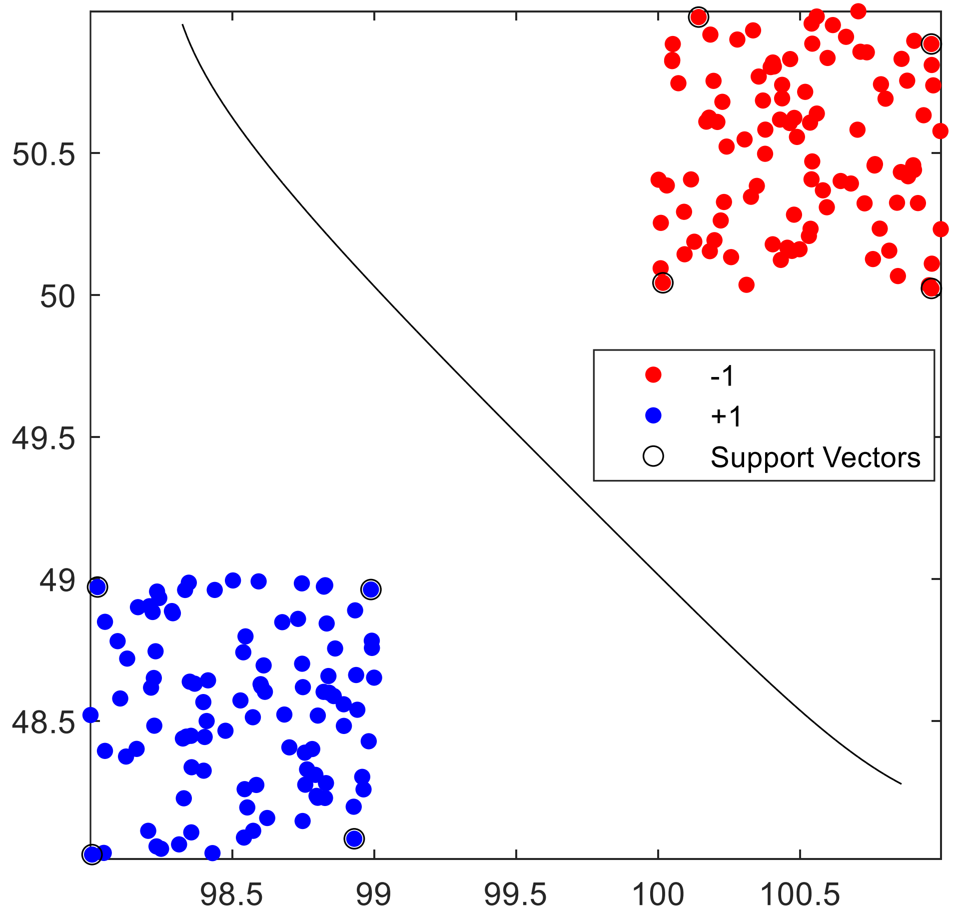
Prediction phase:

Initial data



The role of MATLAB in PESMESS: SVM

Prediction phase: ***with hyperplane and support vectors***



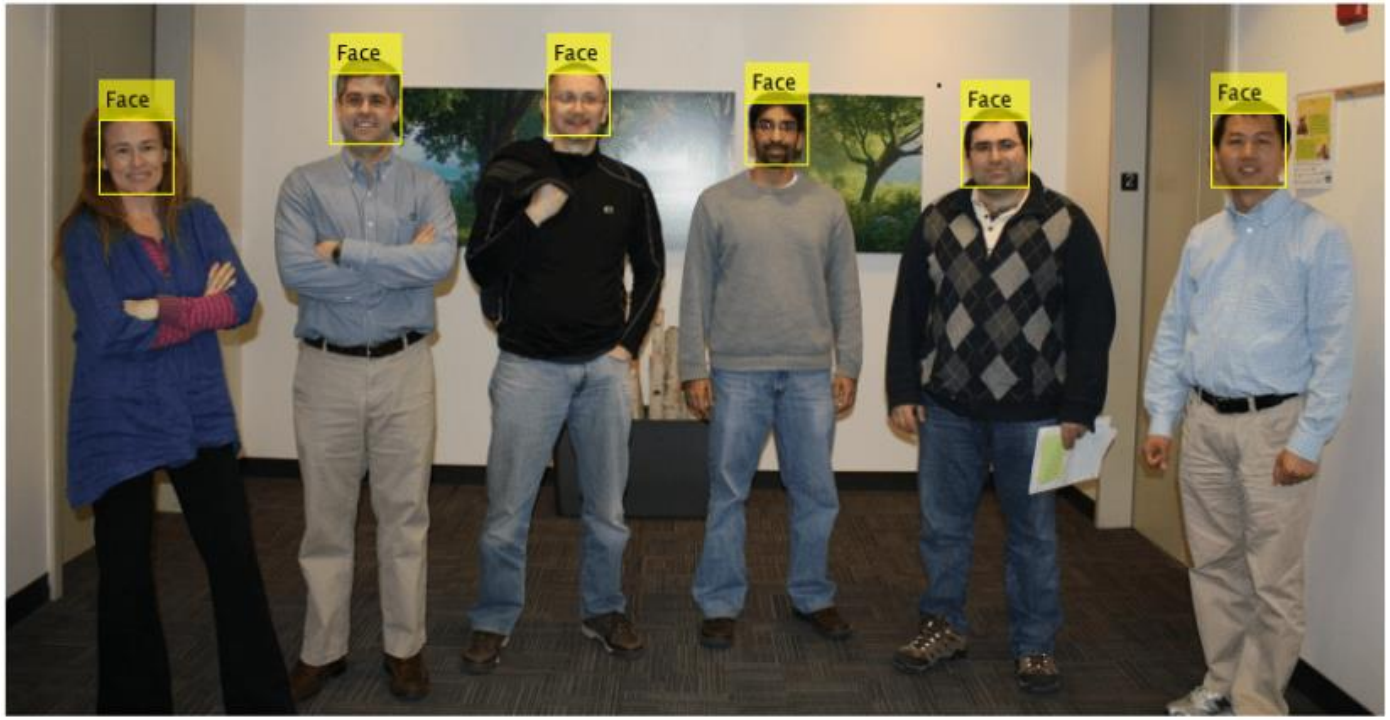
The role of MATLAB in PESMESS: vision.CascadeObjectDetector

Problem: too many faces

Solution: The ***cascade object detector*** uses the ***Viola-Jones algorithm*** *(2021)* to detect ***people's faces***, noses, eyes, mouth, or upper body

The role of MATLAB in PESMESS: vision.CascadeObjectDetector

*The **cascade object detector** uses the **Viola-Jones algorithm** to detect **people's faces**, noses, eyes, mouth, or upper body*



Detect Faces in an Image Using the Frontal Face Classification Model

Create a face detector object.

```
faceDetector = vision.CascadeObjectDetector;
```

Read the input image.

```
I = imread('visionteam.jpg');
```

Detect faces.

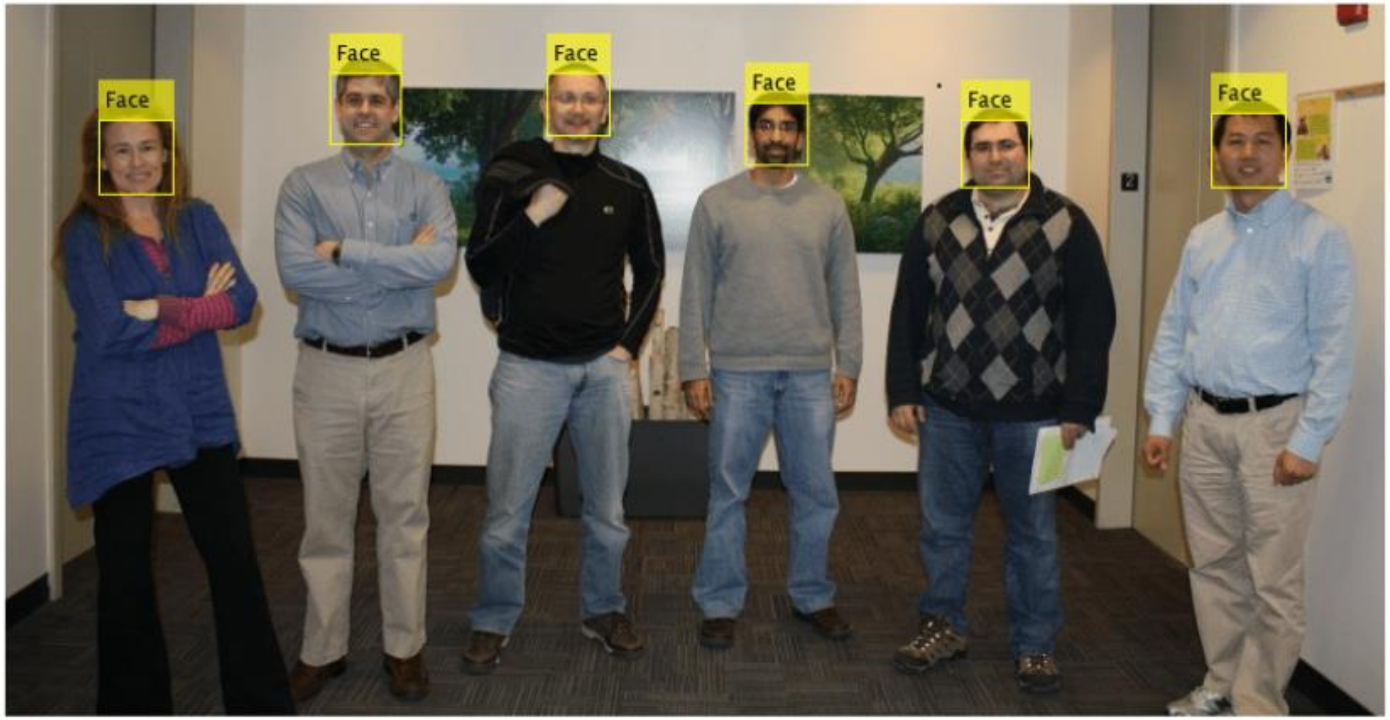
```
bboxes = faceDetector(I);
```

Annotate detected faces.

```
IFaces = insertObjectAnnotation(I,'rectangle',bboxes,'Face');
figure
imshow(IFaces)
title('Detected faces');
```

The role of MATLAB in PESMESS: vision.CascadeObjectDetector

*The **cascade object detector** uses the **Viola-Jones algorithm** to detect **people's faces**, noses, eyes, mouth, or upper body*



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The role of MATLAB in PESMESS: Web Service

video

Processed data

warning

The role of MATLAB in PESMESS: Web Service

video

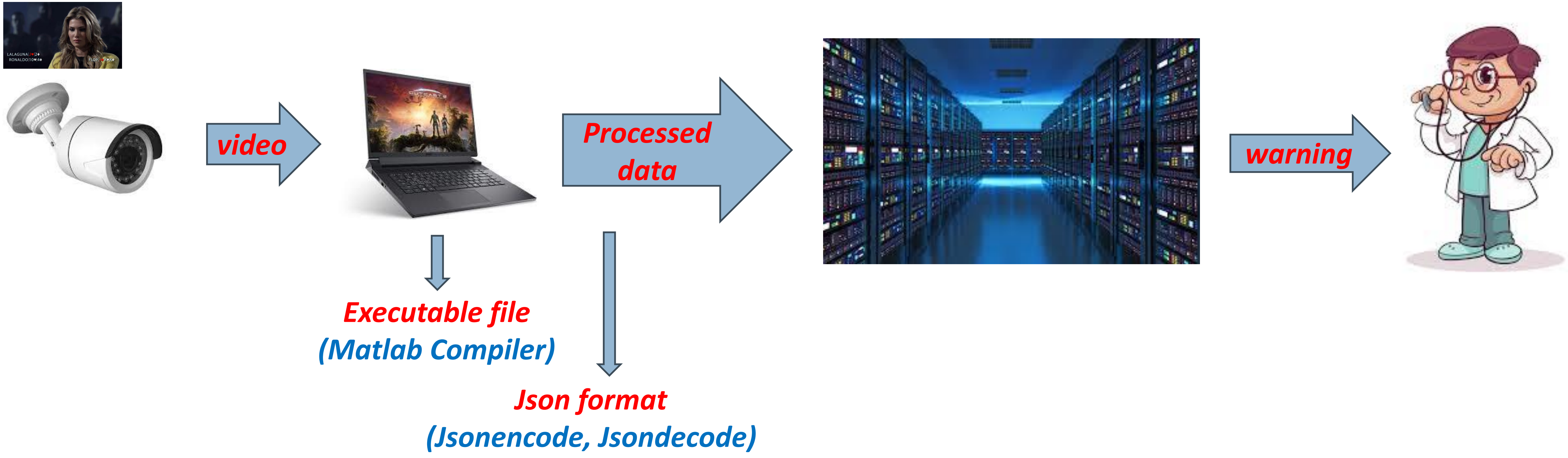
Executable file

(Matlab Compiler)

Processed data

warning

The role of MATLAB in PESMESS: Web Service



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The role of MATLAB in PESMESS: Web Service

video

Processed data

warning

Executable file
(Matlab Compiler)

Json format
(Jsonencode, Jsondecode)

http post request
(send in url='https://---.it/x/y/'
via token)

The role of MATLAB in PESMESS: Web Service

video

Processed data

warning

Executable file
(Matlab Compiler)

Json format
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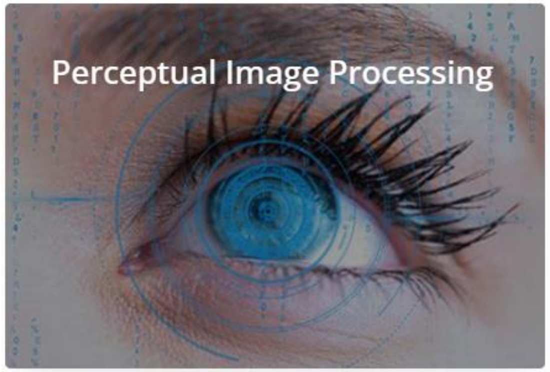
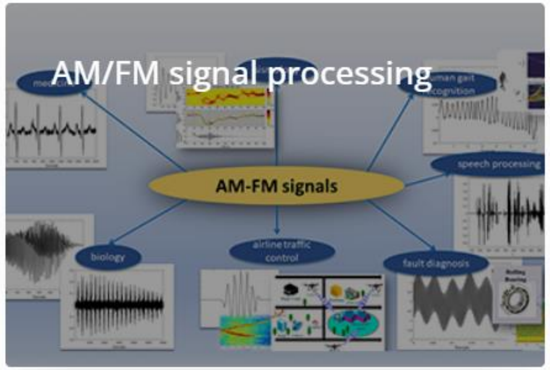
http post request
(send in url='https://---.it/x/y/' via token)

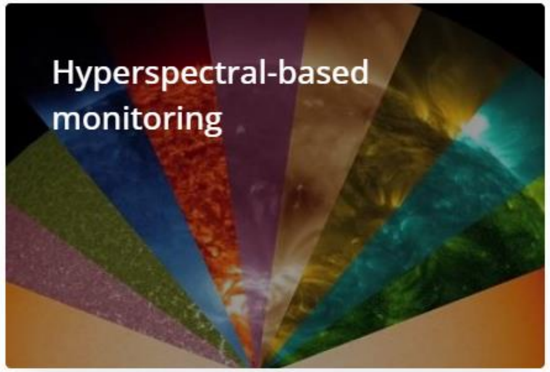
Web service:
Webread,
Websave,
Webwrite
.
.
.

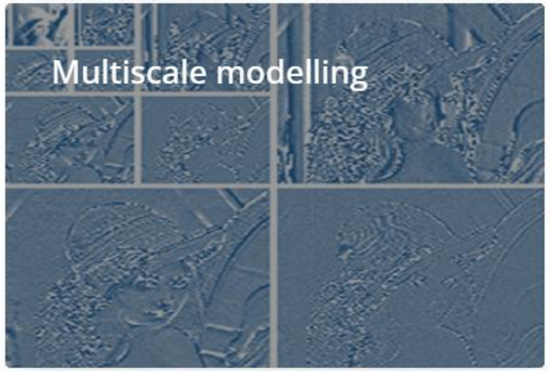
DIPLAB

www.diplab.it









Vittoria Bruni

THANKS A LOT FOR YOUR ATTENTION