Automatic Pediatric Otitis Detection by Classification of Global Image Features

I. Mironica, C. Vertan, D. C. Gheorghe

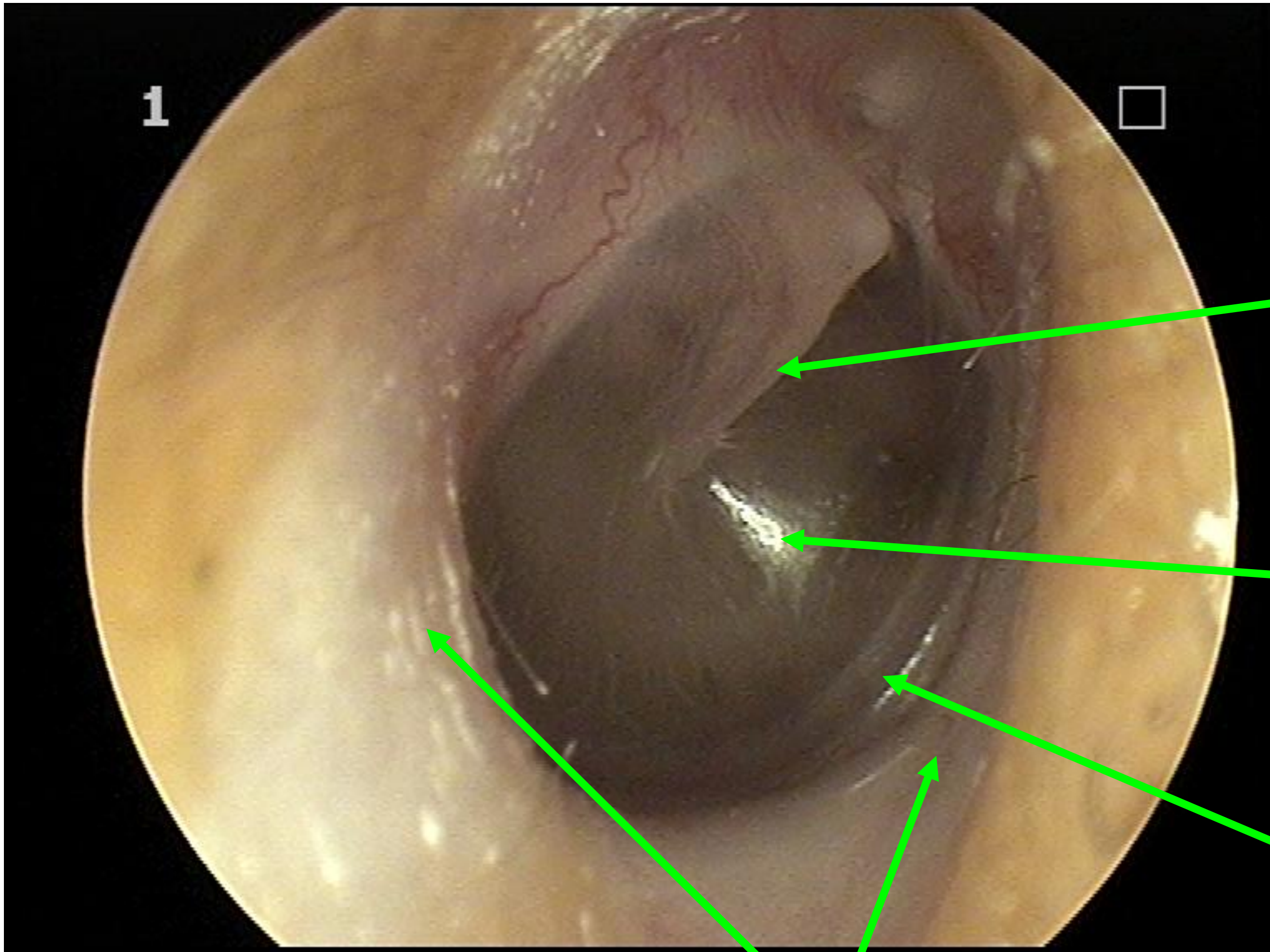
The Image Processing and Analysis Lab (LAPI)
Bucharest Politehnica University

Marie Curie Clinic of Pediatric Otorhinolaryngology
UMF Bucharest

Problem overview

- otoscopy remains the cornerstone in the diagnosis of otic (ear) diseases;
- the visual inspection of the eardrum is performed simply with an otoscope or video-otoscope;
-the interpretation of eardrum images is not straightforward; diagnostic aid may be useful in deploying unqualified personnel or telemedicine for remote areas.
- image processing may help in automatically detecting common ear diseases

Anatomic landmarks

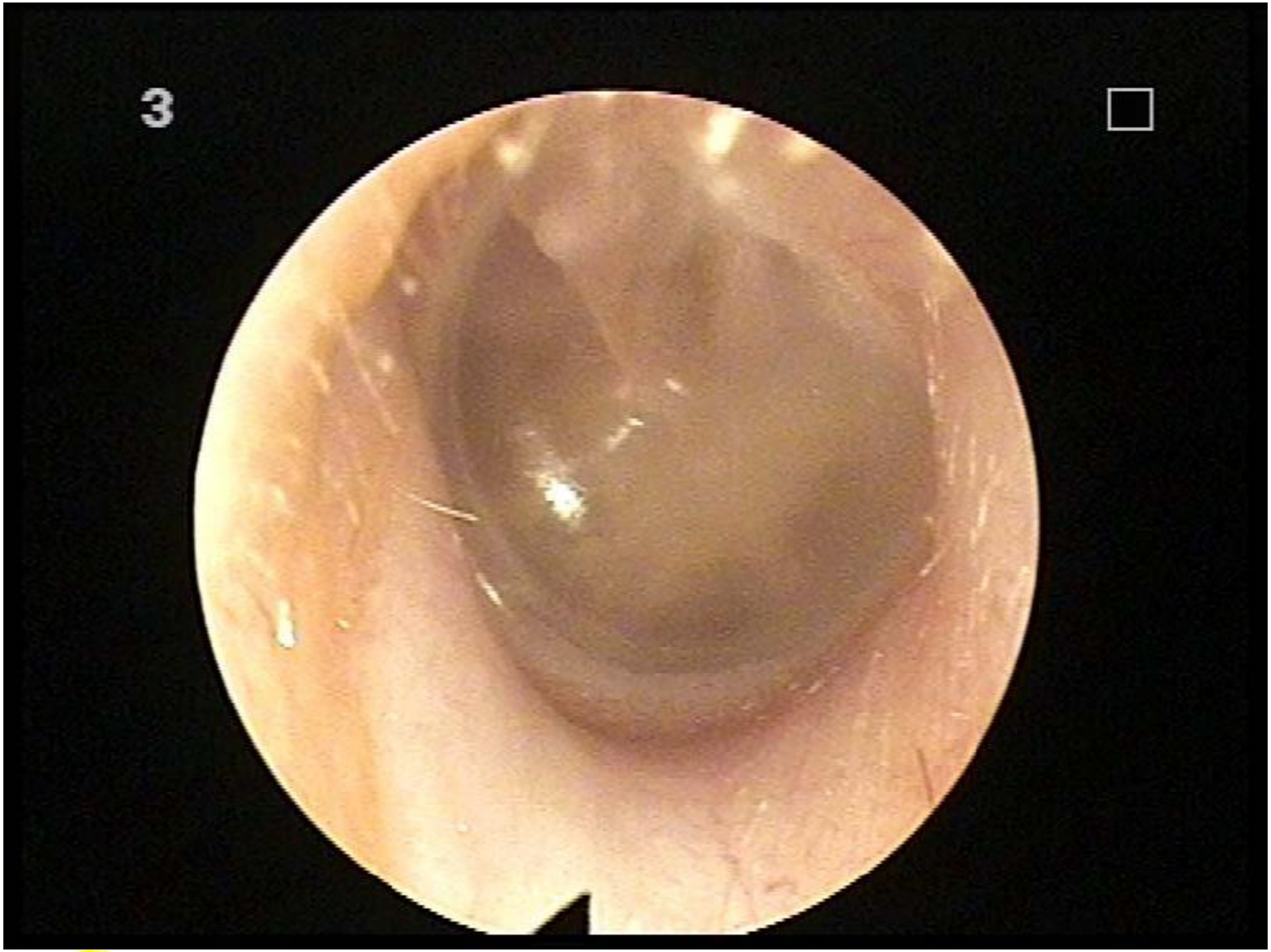


the handle of the malleus

the reflection triangle

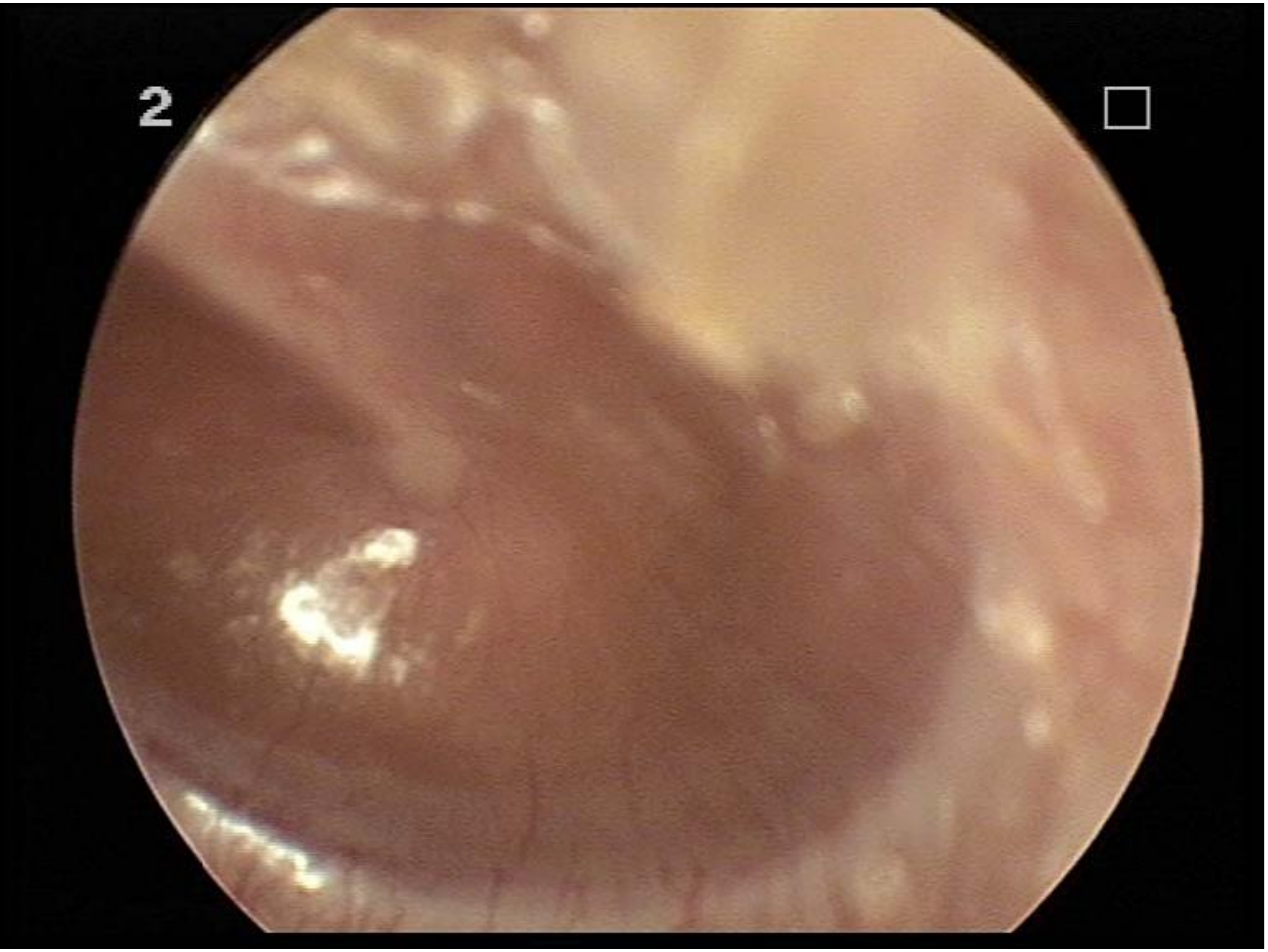
the tympanic annulus

the wall of the auditory canal

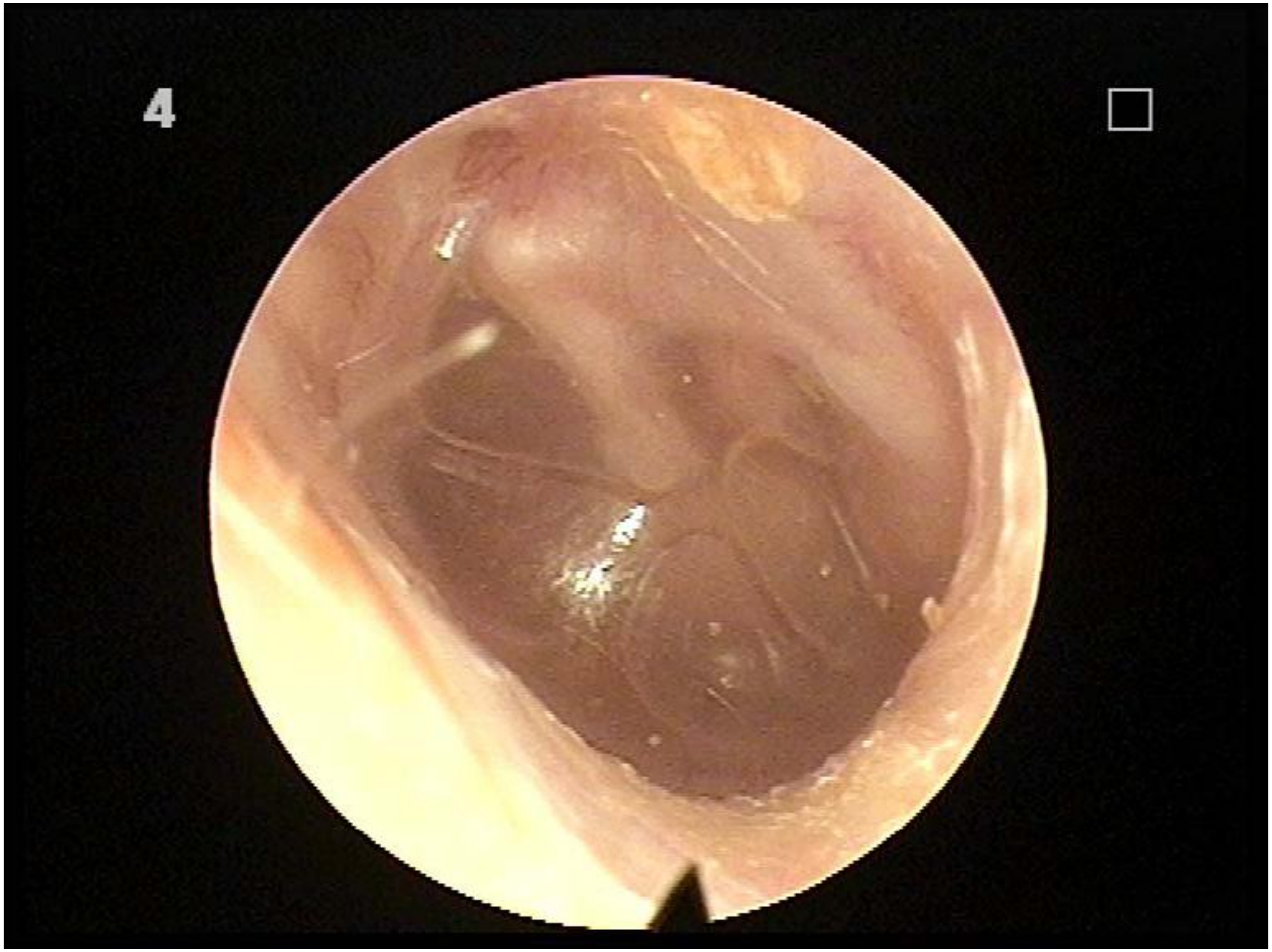


Typical cases: normal

Typical cases: otitis (1)



Typical cases: otitis (2)



Material and methods (1)

The images are extracted as still frames from the video recorded during the otoscopy performed by a specialist;

the images are 768 by 576 pixels;

two sets of 100 images; same video-otoscope, different settings (due to slight modifications in time and operator change)

almost equal parts of normal and pathologic ears (various types of otitis, other diseases, follow-ups,...)

Material and methods (2)

The current approach investigates the performance and limits of color image description using:

- Color Histogram
- Color Coherence Vectors

Classification is made using:

- k-Nearest Neighbor
- Decision Trees
- Linear Discriminant Analysis
- Naïve Bayes
- Multi Layer Neural Networks
- Support Vector Machine

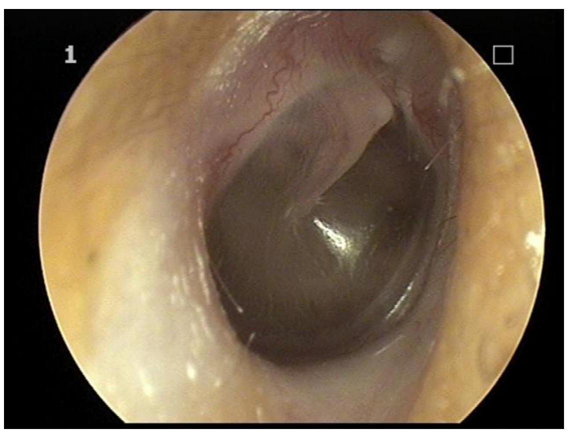
Color Descriptors - Color Histogram (1)

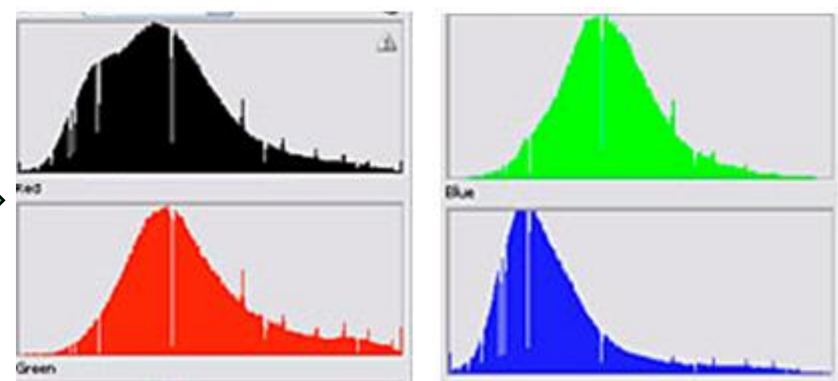
The histogram shows how many times a particular color intensity appears in an image.

0	1	1	2	4
2	1	0	0	2
5	2	0	0	4
1	1	2	4	1

Image

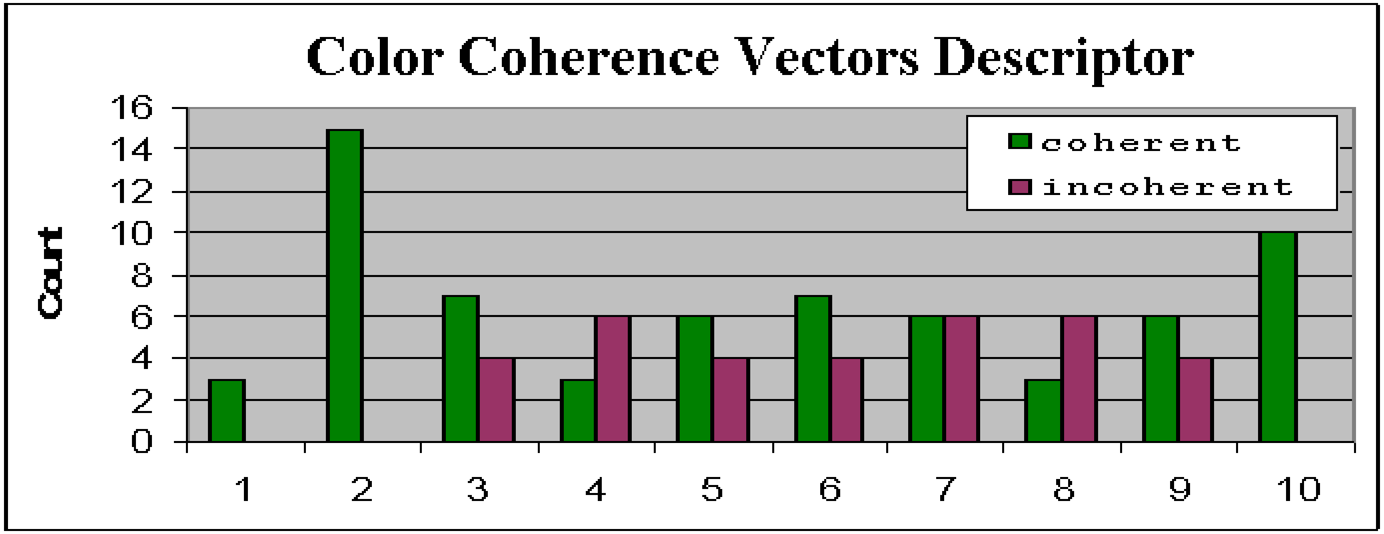
Histogram





Color Descriptors - Color Coherence Vectors (2)

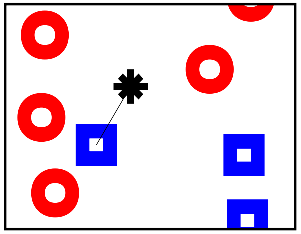
• Based on the color histogram
• Each pixel is checked if it is located in a large one-color region or not.
• If so, the pixel is called coherent, otherwise incoherent
• Creates two histograms
- one with coherent points
- one with incoherent points



Classifiers - k-Nearest Neighbor (1)

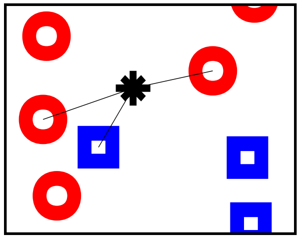
- For a given query point q, assign the class of the nearest neighbour.

$k = 1$



- Compute the k nearest neighbours and assign the class by majority vote.

$k = 3$

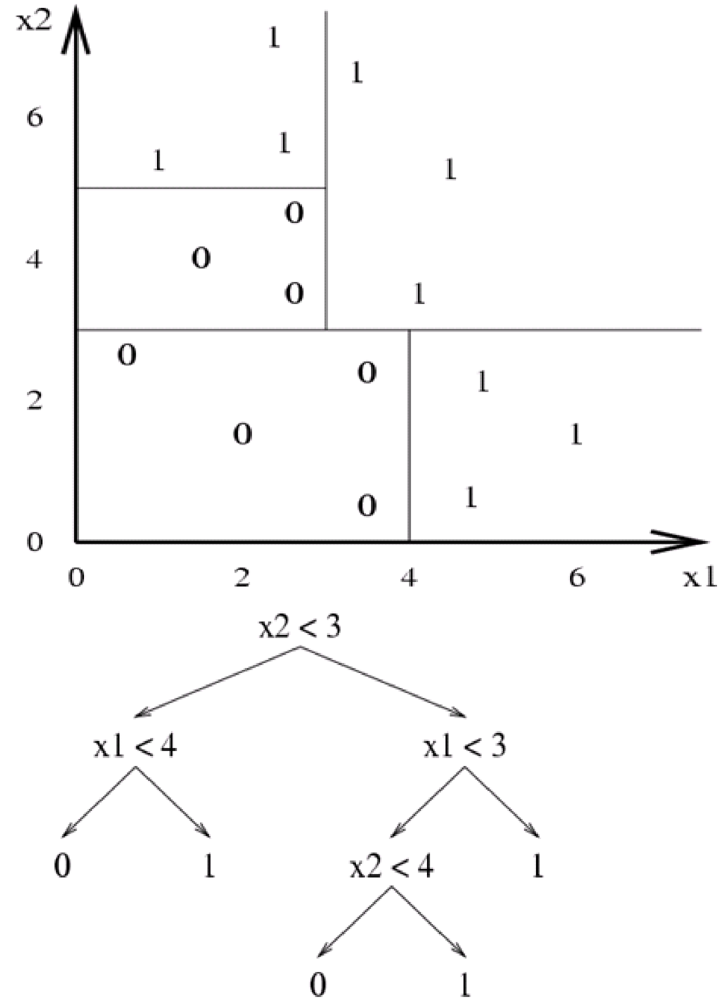


Properties:

- Easy to understand and to code,
- Training is very fast,
- Sensitive to noise, irrelevant features,
- Classification is computationally expensive O(nd),
- Large memory requirements,
- More frequent classes dominate results.

Classifiers - Decision Trees (2)

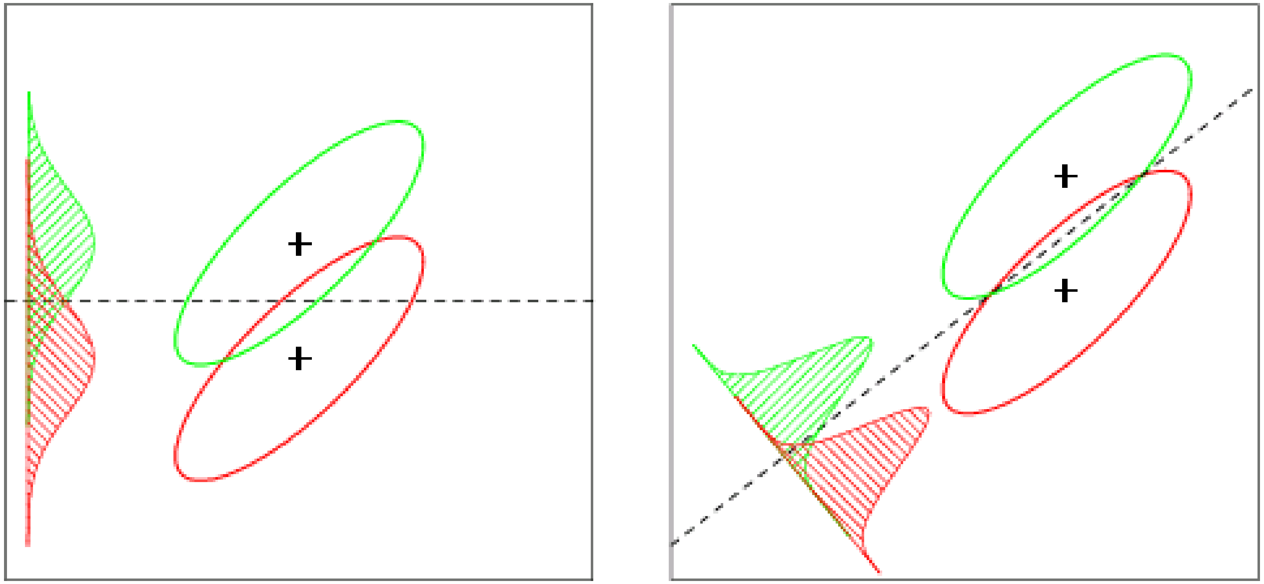
- Decision Trees divide the feature space into parallel rectangles
- Classification of an input vector is done by traversing the tree beginning with the root node, and ending with the leaf.
- Each node of the tree computes an inequality (ex. $X_2<3$, yes or no) based on a single input variable.
- Each leaf is assigned to a particular class.



Classifiers - Linear Discriminant Analysis (3)

• Find an optimal projection space along which the classes are best separated:

  • Maximizes the variance between different classes
  • Minimizes the variance of the individual classes



Classifiers - Naïve Bayes (4)

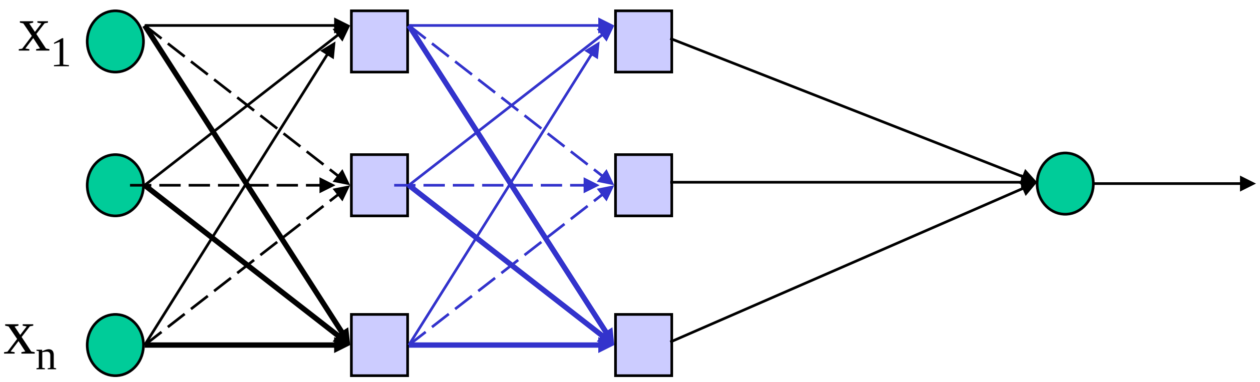
- A statistical classifier: performs probabilistic prediction using class membership probabilities
- Uses a simplified assumption: attributes are conditionally independent (no dependence relation between attributes):

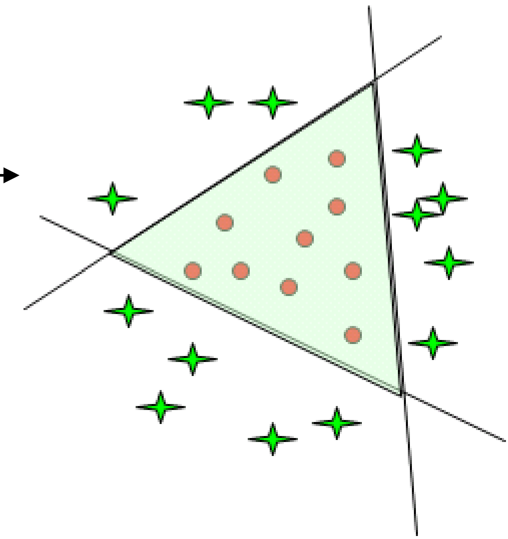
$$P(\mathbf{X}|C_i) = \prod_{k=1}^{n} P(x_k|C_i) = P(x_1|C_i) \times P(x_2|C_i) \times \ldots \times P(x_n|C_i)$$

- This greatly reduces the computation cost: Only counts the class distribution (mean and variance)
- The conditional probabilities are usually computed based on Gaussian distribution with a mean μ and standard deviation σ

$$g(x,\mu,\sigma) = \frac{1}{\sqrt{2\pi}\sigma} e^{-\frac{(x-\mu)^2}{2\sigma^2}}$$

Classifiers - Multi Layer Neural Networks (5)





• Information processing occurs at many simple elements called neurons;

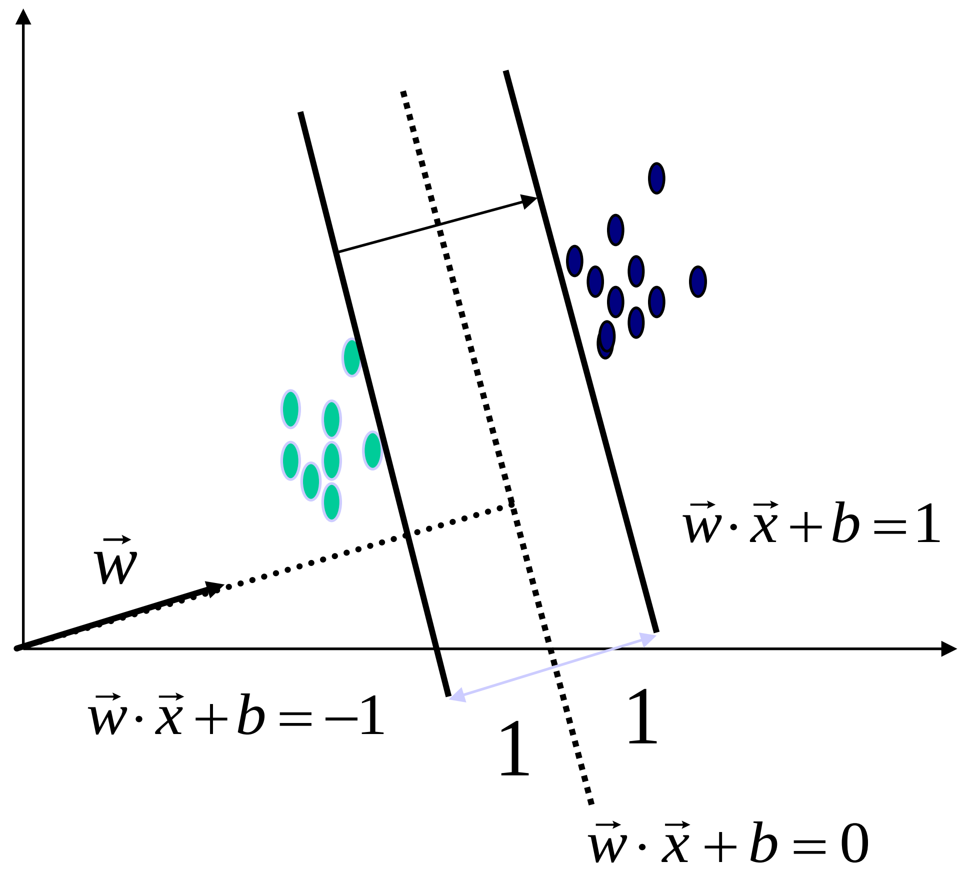
• Signals are passed between neurons over connection links;

• Each connection link has an associated weight, which multiplies the signal transmitted in a typical neural net; each neuron applies an activation function (usually nonlinear) to its net input to determine its output signal.

Classifiers - Support Vector Machine (6)

General idea: the original input space can be mapped to a higher-dimensional feature space where the training set is linear separable.

- Defines an optimal hyperplane that maximize margins

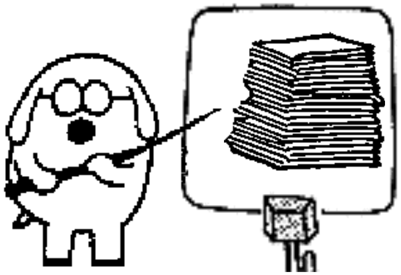


Implementation and Evaluation (1)

	Color Descriptor					
Classification Algorithm	**Color Histogram HSV**			**Color Coherence Vectors**		
	Normal cases	Otitis cases	Mean	Normal cases	Otitis cases	Mean
Without Classification	60.20	37.12	56.21	61.00	39.21	59.43
Nearest Neighbor	89.09	36.47	68.82	80.01	47.36	66.66
Decision Trees	100	0	59.13	23.63	71.05	29.04
LDA	55.26	72.72	65.59	63.15	69.09	66.66
Naive Bayes	81.81	47.36	67.74	100	0	59.13
Neural Networks	83.63	47.36	68.82	78.18	65.78	**73.11**
SVM	85.45	34.21	64.51	89.09	47.26	**72.04**

Implementation and Evaluation (2)

- SVM and neural networks improve the system's performance with the highest percentage, but they have the highest complexity during the training phase.
- Decision trees failed on classification tasks
- Naïve Bayes has medium performance for Color Histogram, and runs out for Color Coherence Vectors (it has recognized all the samples as normal cases).
- LDA has a little increase of performance and lower computational effort in classification phase.
- K-Nearest Neighbor performance is strongly conditioned by the number of selected neighborhood and it needs large memory requirements for medium efficiency.



Conclusions

Color alone does not provide a sufficient discriminative power for otitis identification.

The joint use of the tympanic color and auditory canal color is shown to significantly improve the performance.

Additional factors must be considered:

- the visual texture of the tympanic membrane,
- the contrast around the tympanic membrane
- the presence/absence of the light reflection triangle
- the presence/absence of any contours of air/liquid bubbles