Technical University of Lodz
Institute of Electronics

Convex Hull-based Feature Selection in Application to Classication of Wireless Capsule Endoscopic Images

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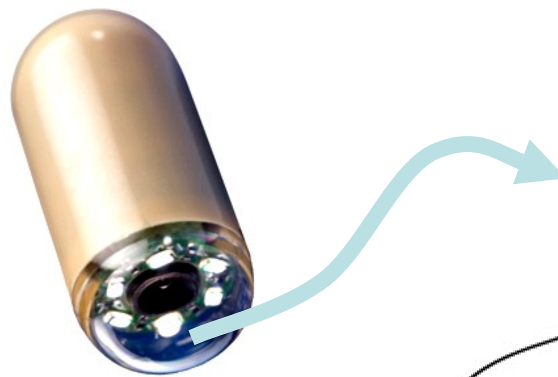
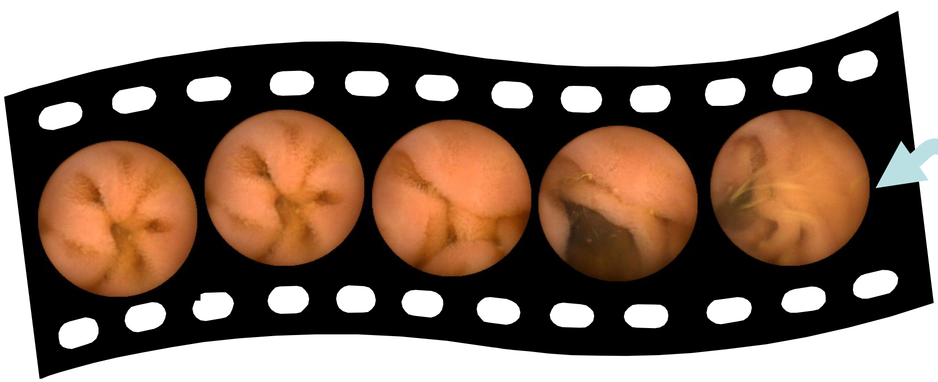
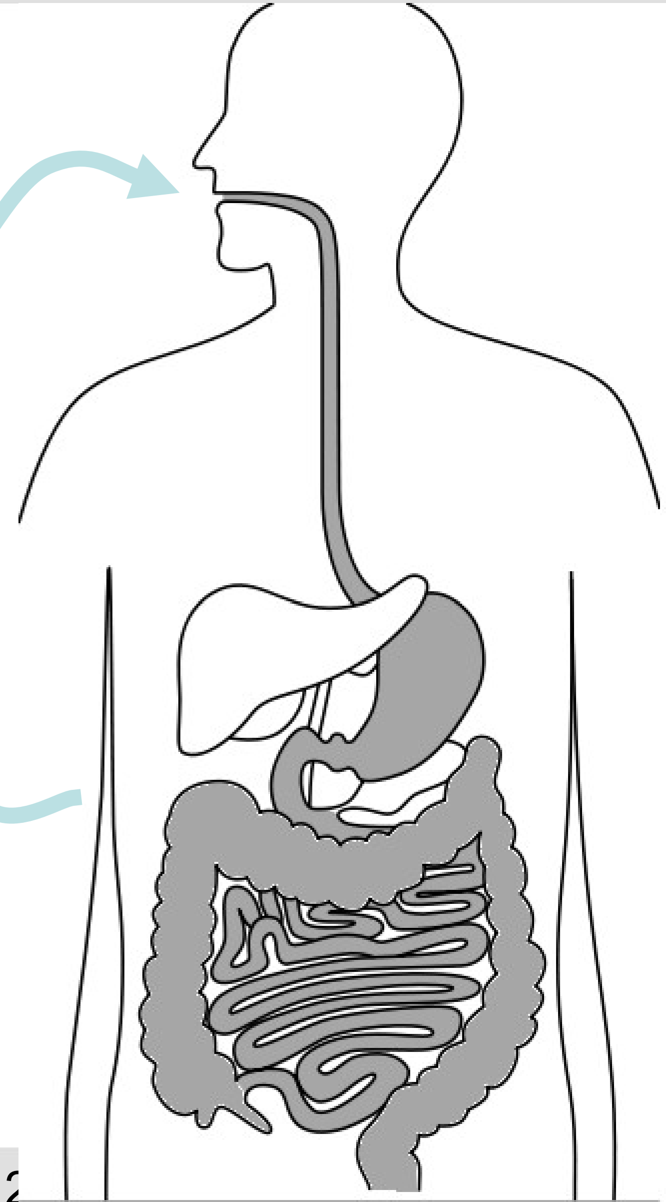
Scope of the presentation

- Wireless capsule endoscopy
- Aiding the WCE video interpretation
- Image descriptors and MaZda software
- Feature selection problems
- Vector supported convex hull
- Experiment
- Conclusions

Wireless capsule endoscopy

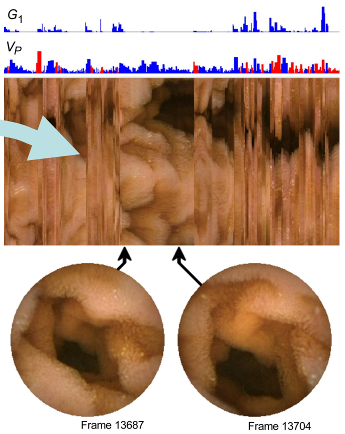






8-hour video
50000 frames
2-hour interpretation
high level of concentration required

Aiding the video interpretation (Image processing)



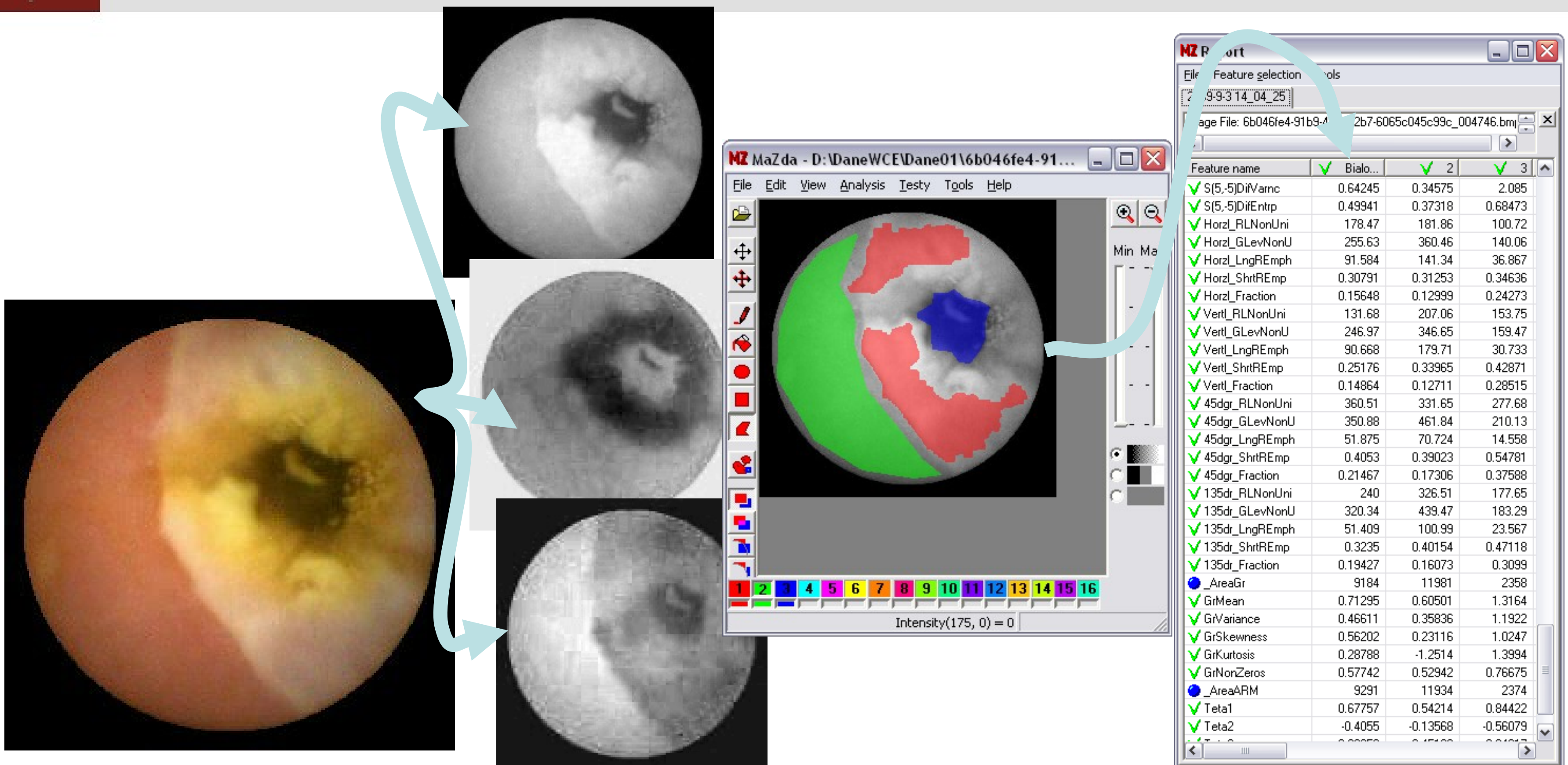
Motion analysis:

- scanning the image of intestine surface (*Szczypiński, et.al*)
- contraction detection and video playback control (*Vilariño, et.al*; *Szczypiński, et.al*)

Image color and texture descriptors:

- segmentation of gastro-intestinal tract into sections (*Coimbra, et.al*)
- image classification and pylorus detection (*Mackiewicz, et.al*)
- detection of pathology images (*GivenImaging®*; *Baopu Li, Max Q.-H. Meng*)

Color and texture descriptors

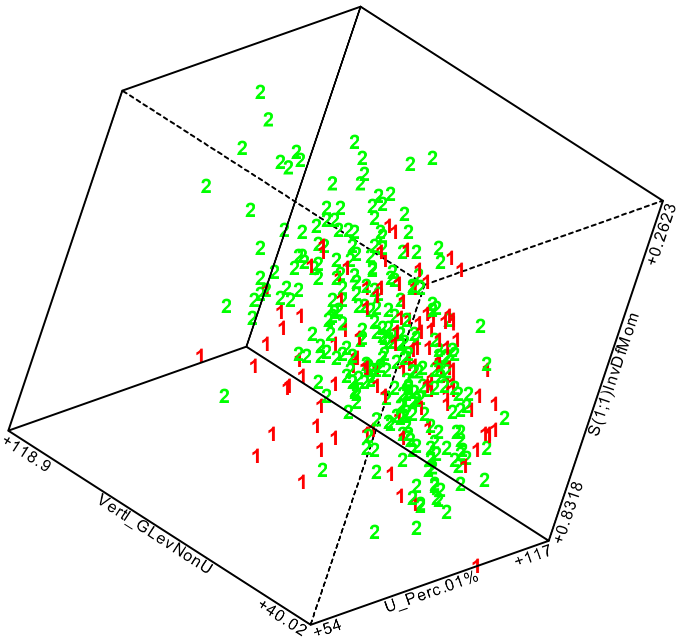


MaZda software:

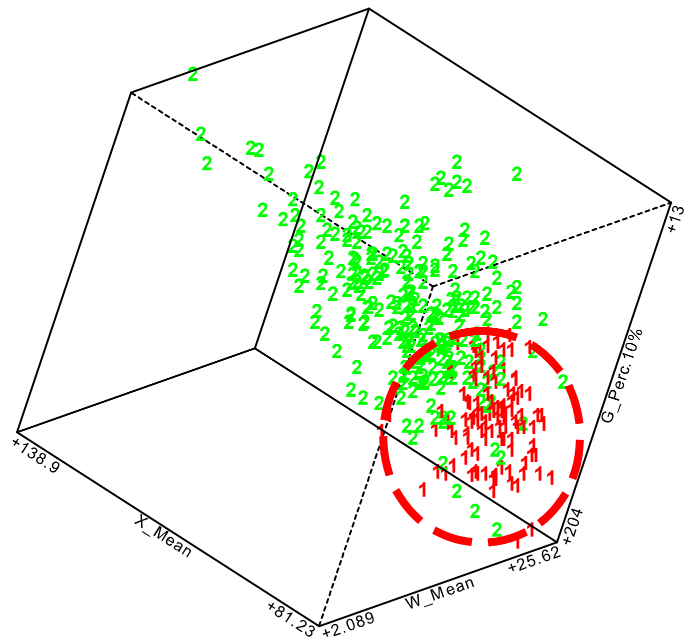
- color analysis **(R, G, B, U, V, I, Q, H…)**
- regions of interest
- texture descriptors **(histogram, co-occurrence, run-length, gradient, wavelet…)**

Color and texture descriptors (selection)

subspace with poor discrimination ability



subspace with stronger discrimination ability



- Goal and motivation
  - Need for development of image processing method for aiding the WCE video interpretation,
  - Methods developed for detection of pathology images are still unreliable (high FPR and FNR) and further research is required,

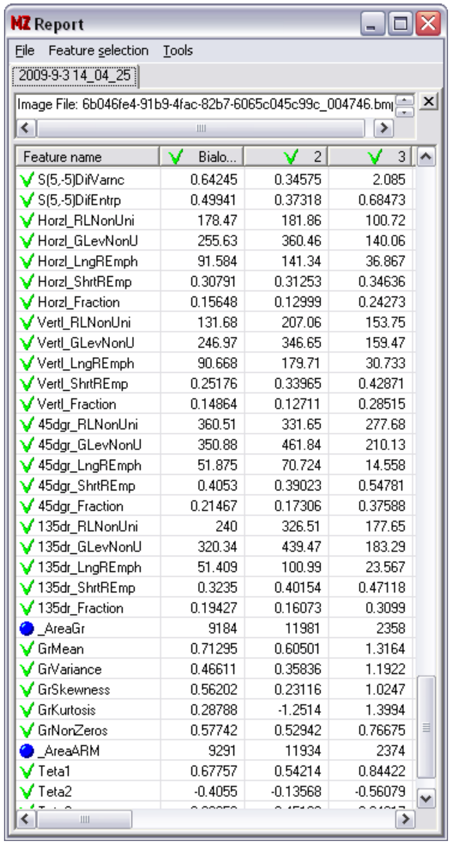
- Problems
  - Selection of images for machine learning and labeling of pathological regions,
  - Selection of features with high discriminative power,
  - Development of method for endoscopic image classification.

- Means and tools
  - Collected over 60 WCE videos from AIG India and Uniwersytet Medyczny in Łódź
  - Comprehensive tool (MaZda) for computation of color and texture descriptors verified in other medical image analysis applications
  - Tools for machine learning (feature selection and reduction, supervised learning and classification)

Selection of images

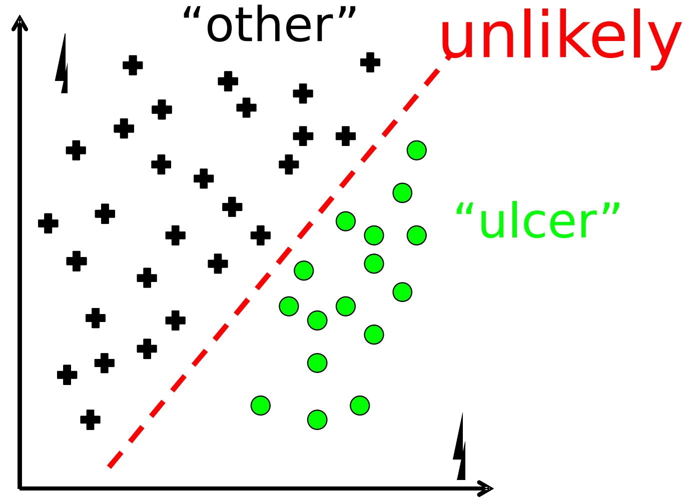
Expected vector distribution

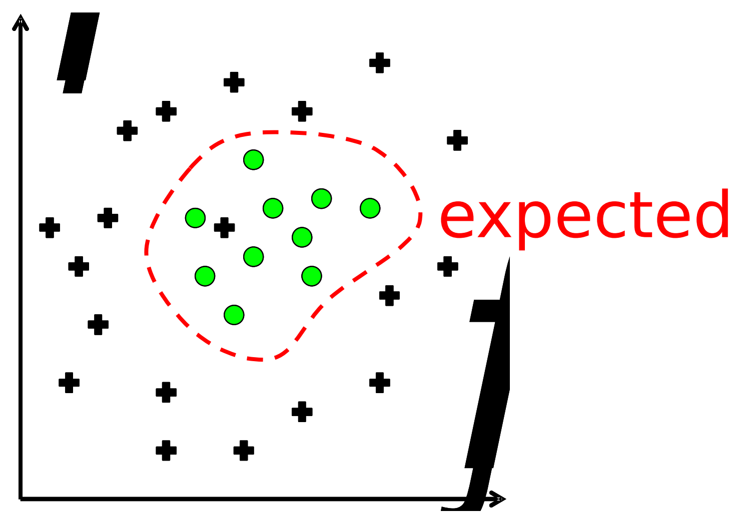
342 features per region
(342-dimensional space)



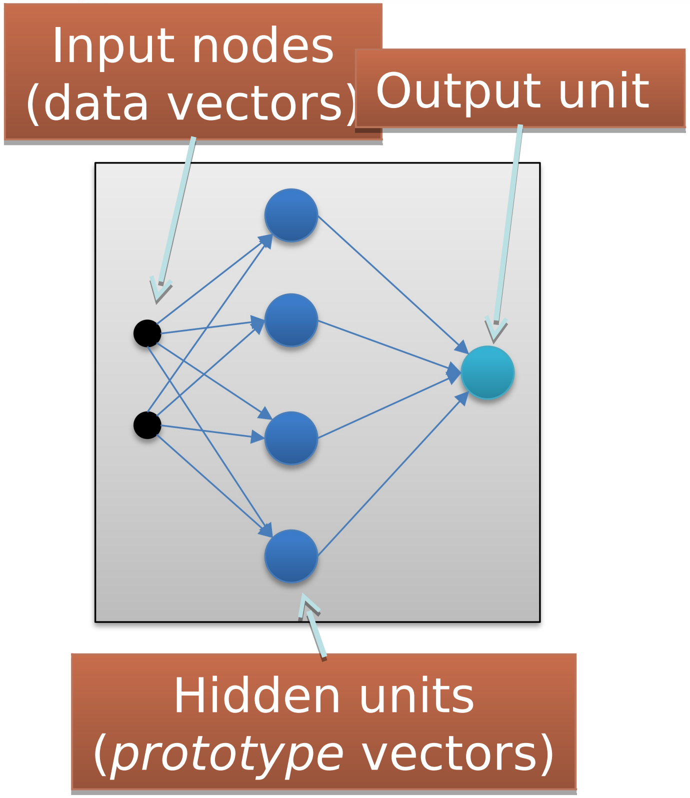
Feature name	Bialo...	2	3
S(5,-5)DifVarnc	0.64245	0.34575	2.085
S(5,-5)DifEntrp	0.49941	0.37318	0.68473
Horzl_RLNonUni	178.47	181.86	100.72
Horzl_GLevNonU	255.63	360.46	140.06
Horzl_LngREmph	91.584	141.34	36.867
Horzl_ShrtREmp	0.30791	0.31253	0.34636
Horzl_Fraction	0.15648	0.12999	0.24273
Vertl_RLNonUni	131.68	207.06	153.75
Vertl_GLevNonU	246.97	346.65	159.47
Vertl_LngREmph	90.668	179.71	30.733
Vertl_ShrtREmp	0.25176	0.33965	0.42871
Vertl_Fraction	0.14864	0.12711	0.28515
45dgr_RLNonUni	360.51	331.65	277.68
45dgr_GLevNonU	350.88	461.84	210.13
45dgr_LngREmph	51.875	70.724	14.558
45dgr_ShrtREmp	0.4053	0.39023	0.54781
45dgr_Fraction	0.21467	0.17306	0.37588
135dr_RLNonUni	240	326.51	177.65
135dr_GLevNonU	320.34	439.47	183.29
135dr_LngREmph	51.409	100.99	23.567
135dr_ShrtREmp	0.3235	0.40154	0.47118
135dr_Fraction	0.19427	0.16073	0.3099
_AreaGr	9184	11981	2358
GrMean	0.71295	0.60501	1.3164
GrVariance	0.46611	0.35836	1.1922
GrSkewness	0.56202	0.23116	1.0247
GrKurtosis	0.28788	-1.2514	1.3994
GrNonZeros	0.57742	0.52942	0.76675
_AreaARM	9291	11934	2374
Teta1	0.67757	0.54214	0.84422
Teta2	-0.4055	-0.13568	-0.56079

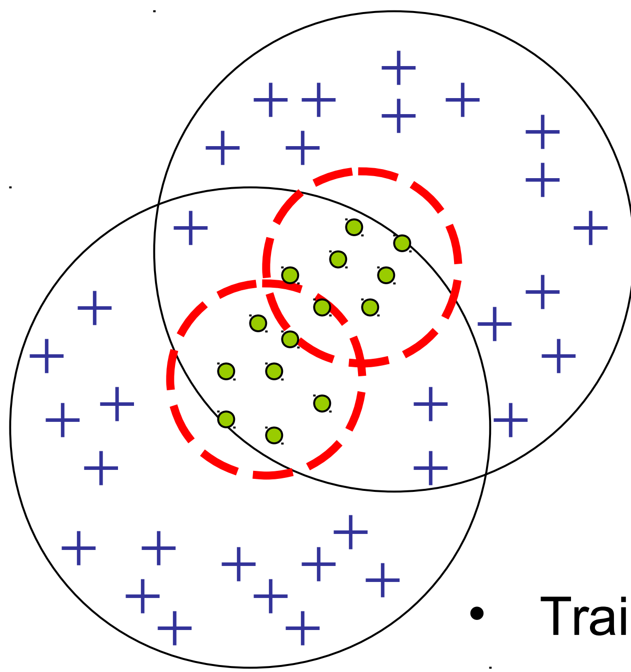
feature selection





Radial Basis Function Networks





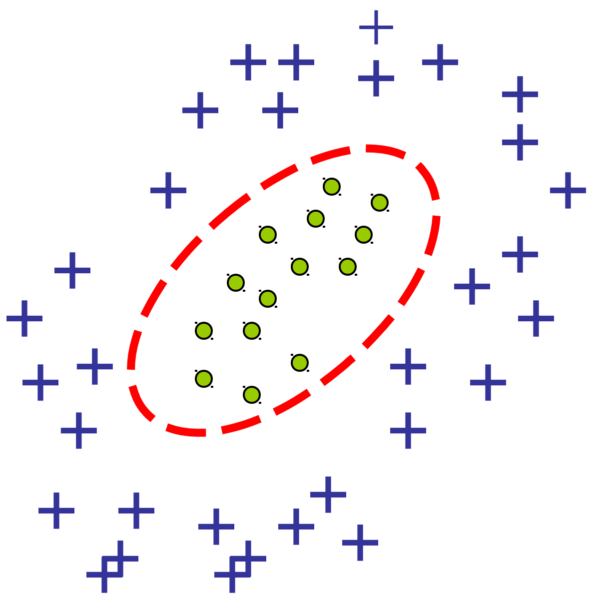
Hidden units perform nonlinear distance calculation according to Gaussian kernels:

$$\mathcal{G}_i(x) = \frac{1}{(2\pi)^{N/2}\sigma_i^N}\exp\left(-\frac{\|\mathbf{x}-\mathbf{c}_i\|^2}{2\sigma_i^2}\right)$$

- Training RBFs:
  - *K*-means clustering
  - $\mathbf{c}_i, \sigma, N$
- Training linear weights:
  - Linear or logistic regression

Support Vector Machines

Non-linearly separable classes



Linear decision boundary

$$y(\mathbf{x}) = b + \sum_{\alpha_i \neq 0} \alpha_i y_i \mathbf{x}_i \cdot \mathbf{x}$$

The kernel trick

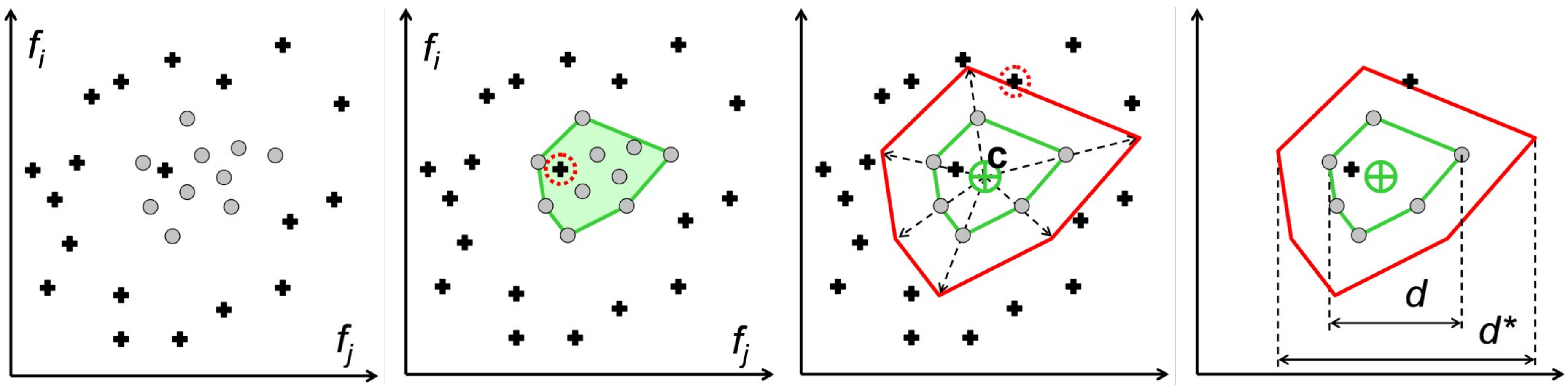
$$k(\mathbf{x}_i, \mathbf{x}_j) = \exp(-\gamma \|\mathbf{x}_i - \mathbf{x}_j\|^2)$$

How to choose the value of γ?

Finding α_i and b parameters requires solving a *constrained quadratic optimization* problem. This can be efficiently done through **sequential minimal optimization** (SMO) algorithm.

Vector Supported Convex Hull (concept)

vector distribution | convex hull of "ulcer" vectors | scaling up w.r.t. the centroid "c" | distance to closest "other" vector



$\boldsymbol{Q_1}$ – a number of "other" vectors enclosed by the convex hull

$\boldsymbol{Q_2} = d / d^*$

VSCH Penalty factor

$\boldsymbol{Q = Q_1 + Q_2}$

Vector Supported Convex Hull (algorithm)

Feature space reduction algorithm:

- Search of 1D, 2D and 3D feature subsets
- Computes the *Q* factor for each the subset
- Select features from subsets having the lowest *Q*

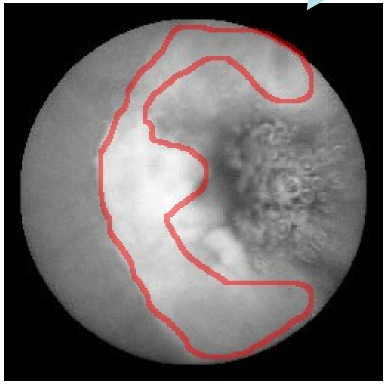
Classification rule:

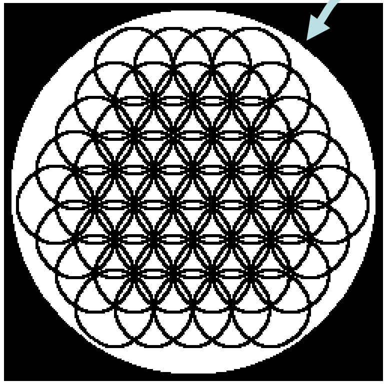
- Scale the convex hull up with respect to the centroid by the factor of $(Q_2)^{-2}$
- Vectors enclosed by the resulting convex hull are of “ulcer” class
- Vectors outside the convex hull are of “other” class

Method properties:

- Fast full search in case quick hull algorithm implemented
- Utilizes natural ability of convex hulls to separate vector clusters surrounded by other vectors

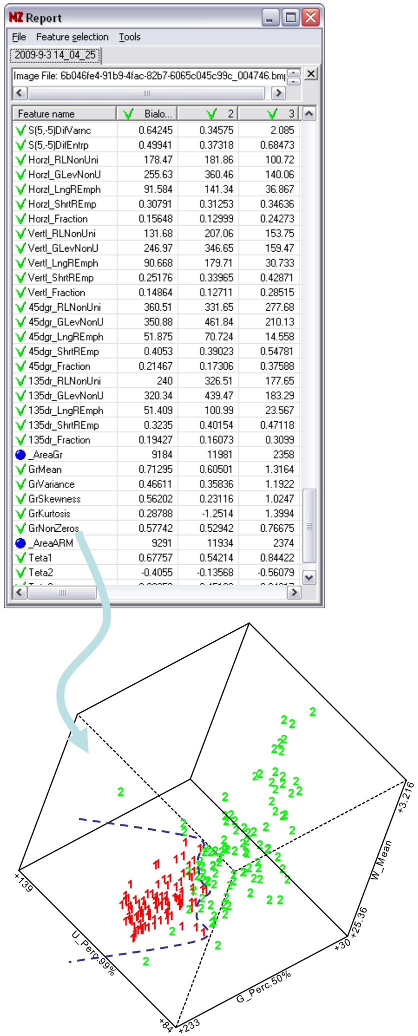
Experiment (feature computation)





- Selected 50 images with areas of ulceration
- Areas of ulceration manually depicted
- Randomly selected 200 images without ulceration
- Texture and color descriptors computed within 48 circular regions per image
- Feature vectors computed on images without ulceration labeled as “other”
- Feature vectors computed on ulceration images for regions covering ulceration areas labeled as “ulcer”

Experiment (selection)



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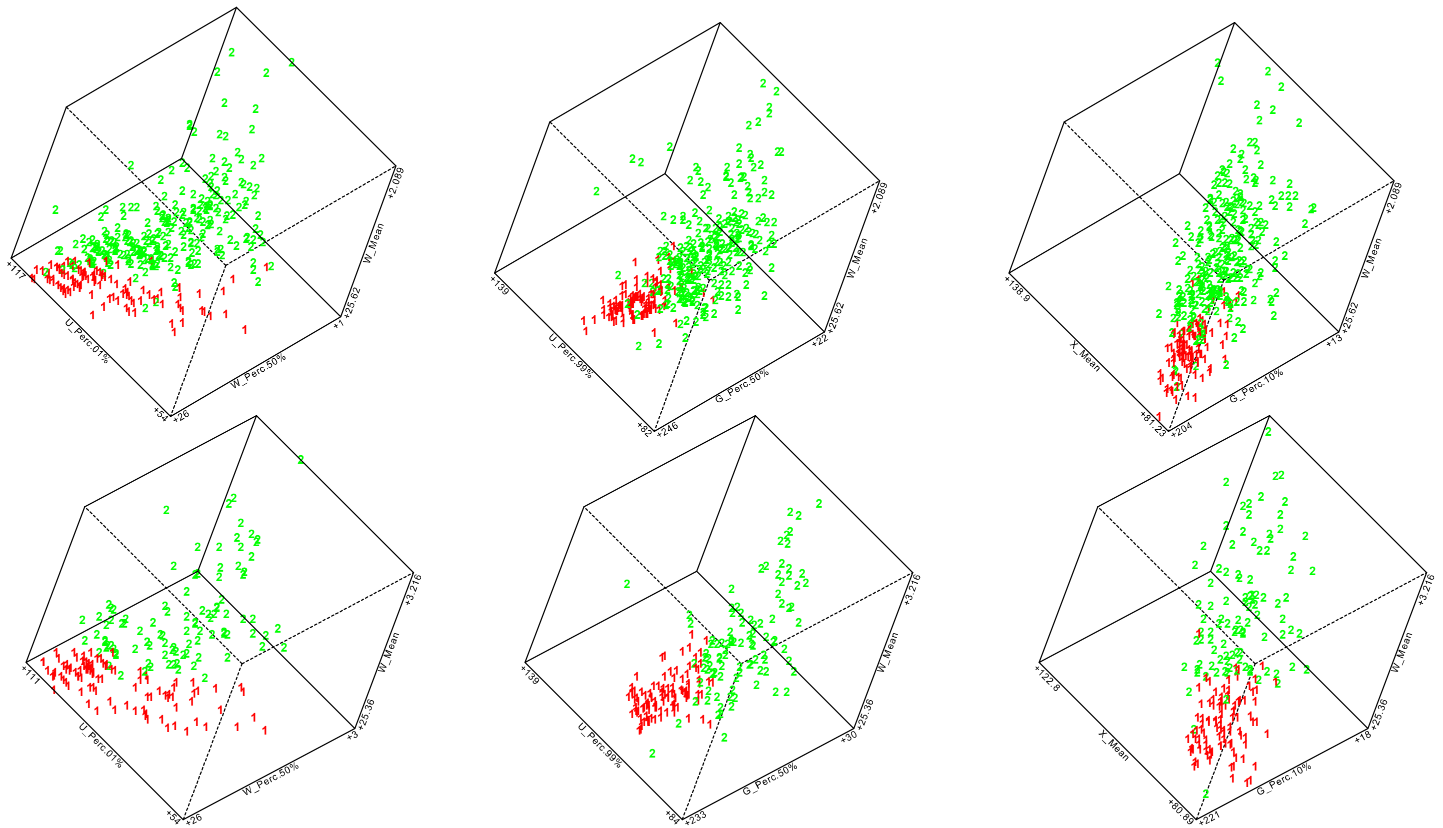
- Randomly selected training set of 109 vectors of class “ulcer” and 258 vectors of class “other”
- Randomly selected testing set of 100 vectors of class “ulcer” and 100 vectors of class “other”
- VSCH, SVM and RBF networks used for feature selection (3 features out of 342) and finding classification rules (the training set used)
- Results (vectors of selected features and classification rules) verified on the testing set of vectors

Experiment (selection results)

SVM | RBF Network | VSCH

training

testing



features

SVM

W_Mean – mean U/Y
U_Perc01% – 1st percentile U
W_Perc50% – 50th percentile U/Y

RBF Network

W_Mean – mean U/Y
U_Perc99% – 99th percentile U
G_Perc50% – 50th percentile G

VSCH

W_Mean – mean U/Y
X_Mean – mean V/Y
G_Perc10% – 10th percentile G

Experiment (classification results)

		FPR [%]	Specificity	FNR [%]	Sensitivity
VSCH	Training	9.3	0.91	0.0	1.00
	Testing	7.0	0.93	6.0	0.94
SVM	Training	4.3	0.96	6.4	0.94
	Testing	5.0	0.95	9.0	0.91
RBF	Training	3.9	0.96	10.1	0.90
	Testing	9.0	0.91	9.0	0.91

Computation times (selection of feature pairs)
Intel Core 2 Quad @2.83 GHz (single thread in both cases)

- **VSCH, C++ implementation of quick hull algorithm – 10 minutes**
- **RBF networks, Java implementation – 2 hours**
- **SVM, Java implementation – 3 hours**

Conclusions

- We found image descriptors and classification rules for detection of WCE images showing a chosen category of ulceration
- VSCH compared to RBF networks and SVM has low False Negative Ratio which might be useful in medical diagnosis
- VSCH is fast and does not require setting of any parameters or standardization of feature space

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