Introducing Space and Time

in Local Feature-Based

Endomicroscopic Image Retrieval

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Barbara André

<u>Supervision</u>

Tom Vercauteren   **Nicholas Ayache**

MKT Mauna Kea Technologies   INRIA SOPHIA ANTIPOLIS   ASCLEPIOS

- **Outline**

B. André, MSR-INRIA Workshop 2010

Medical Context

pCLE
Probe-based Confocal Laser Endomicroscopy

Colonic Polyp

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pCLE Principle

Laser source

Avalanche photodiode

Fiber bundle scanned by the laser

Oscillating mirror at 4 kHz

Fiber bundle

Surface scanned up to 600 × 600 μm

Frame rate: 12 Hz

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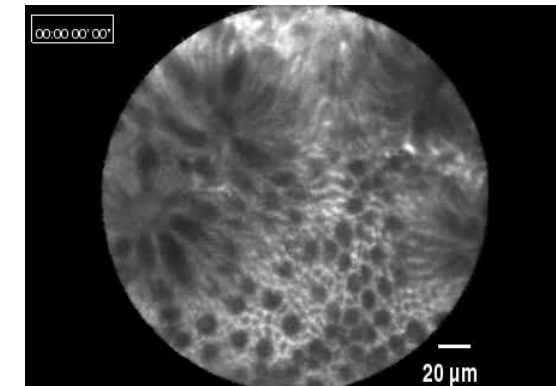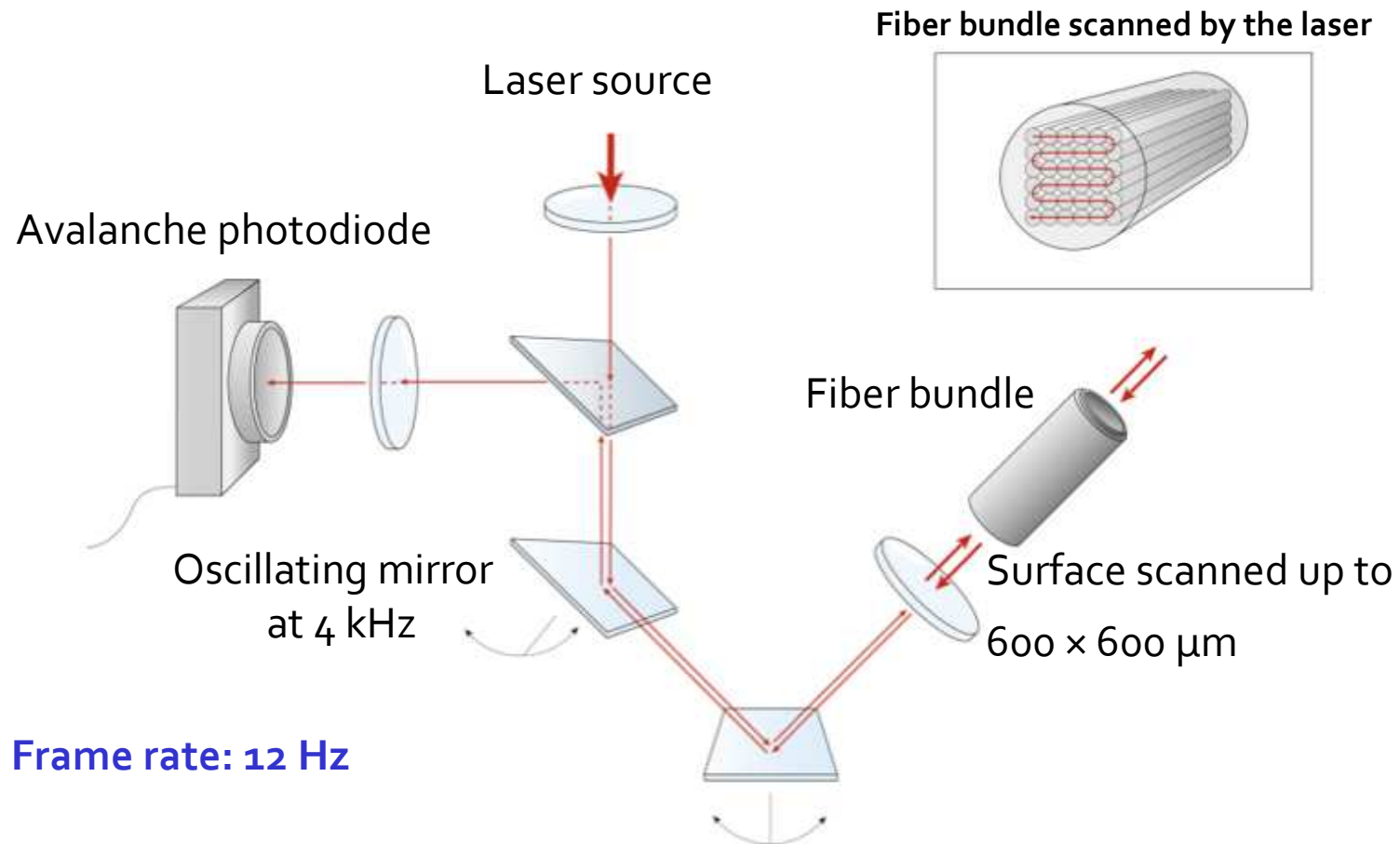
Explore the Entire GI Tract

Esophagus

Duodenum and
small intestine

Stomach

Bile duct

Colon

Rectum
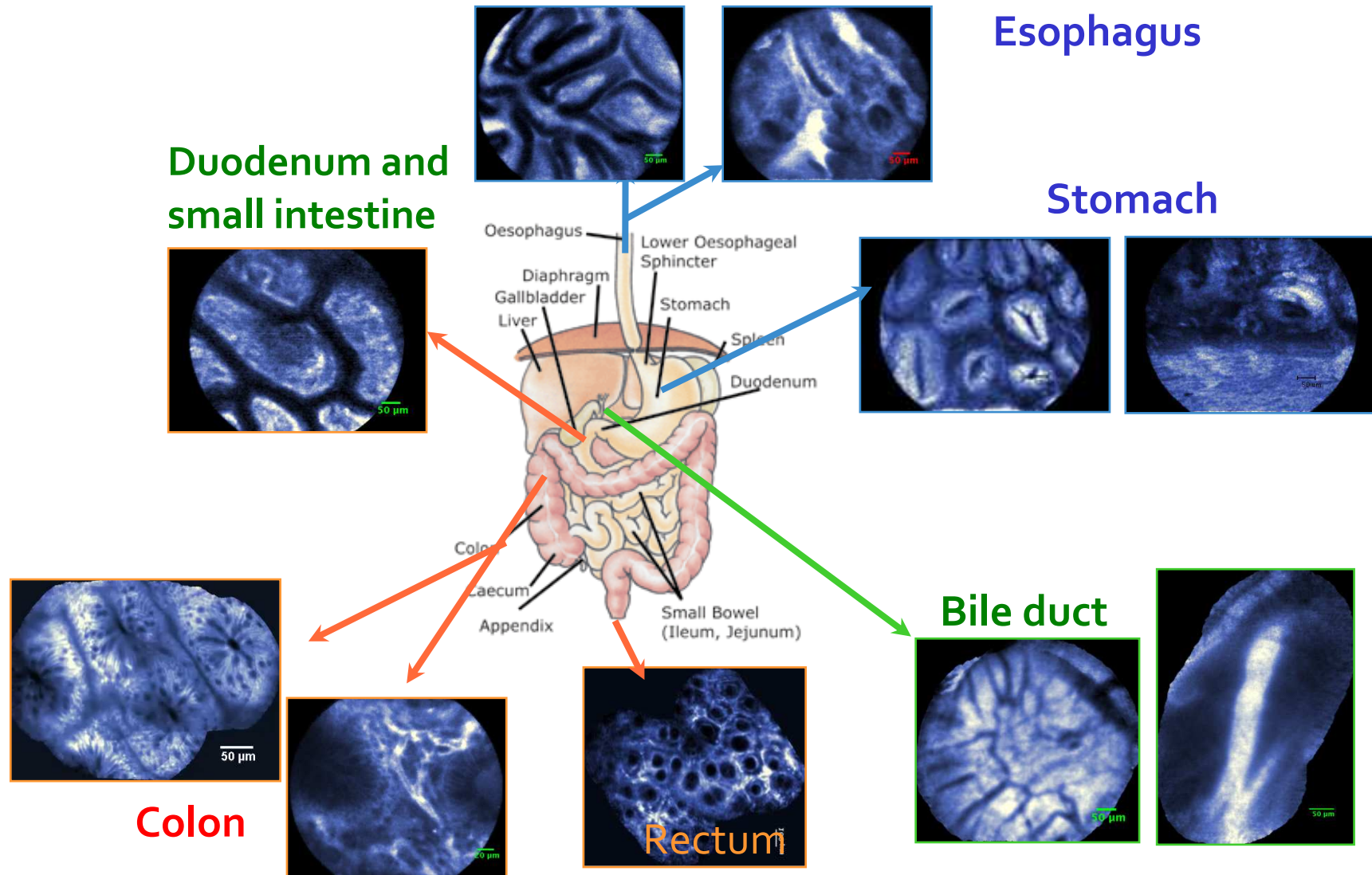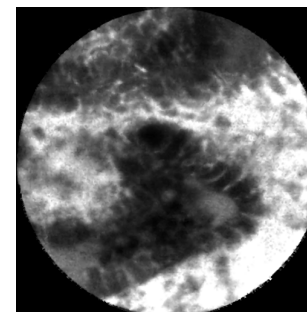
Differentiate

Benign
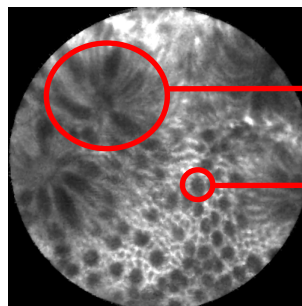
Crypt

Goblet Cell

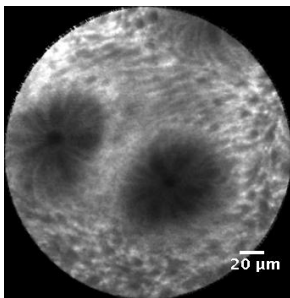**Neoplastic** (**pathological**)

Courtesy of
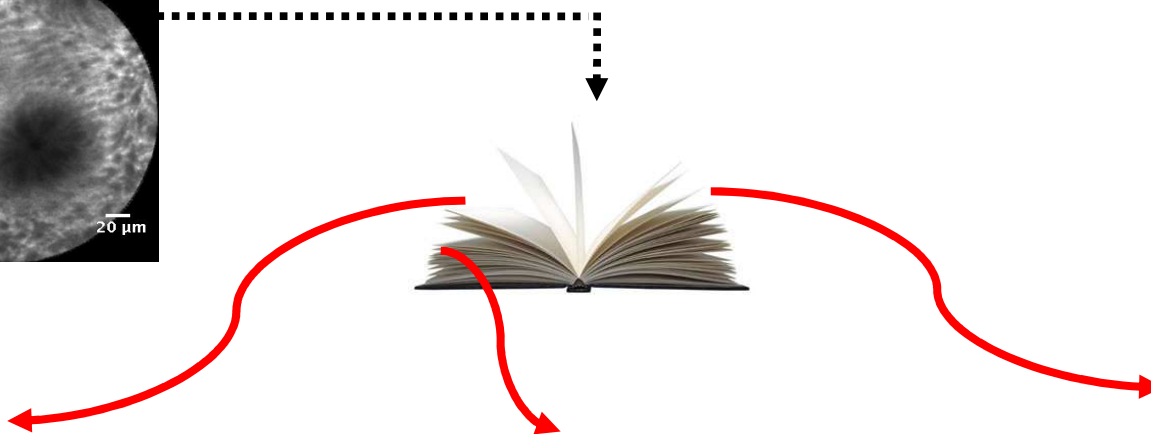**Pr. Michael Wallace**,
Mayo Clinic, Jacksonville, USA

Nuclei or membranes not visible… ~~**nucleo-cytoplasmic ratio**~~ **?**

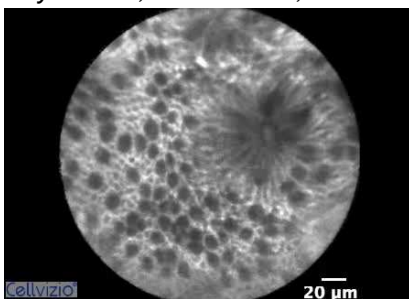**Combination of local texture & shape features in pCLE images ?**

Courtesy of **Pr. Charles Lightdale**
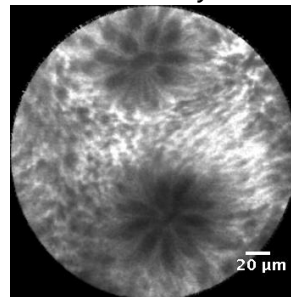*Columbia-Presbyterian MC, New York, USA*

Database Query

Courtesy of
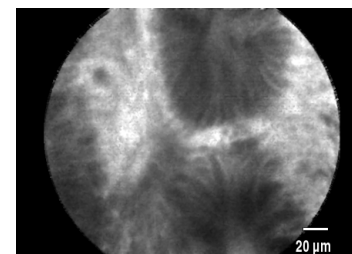**Pr. Michael Wallace**
Mayo Clinic, Jacksonville, USA

Courtesy of
Pr. Charles Lightdale
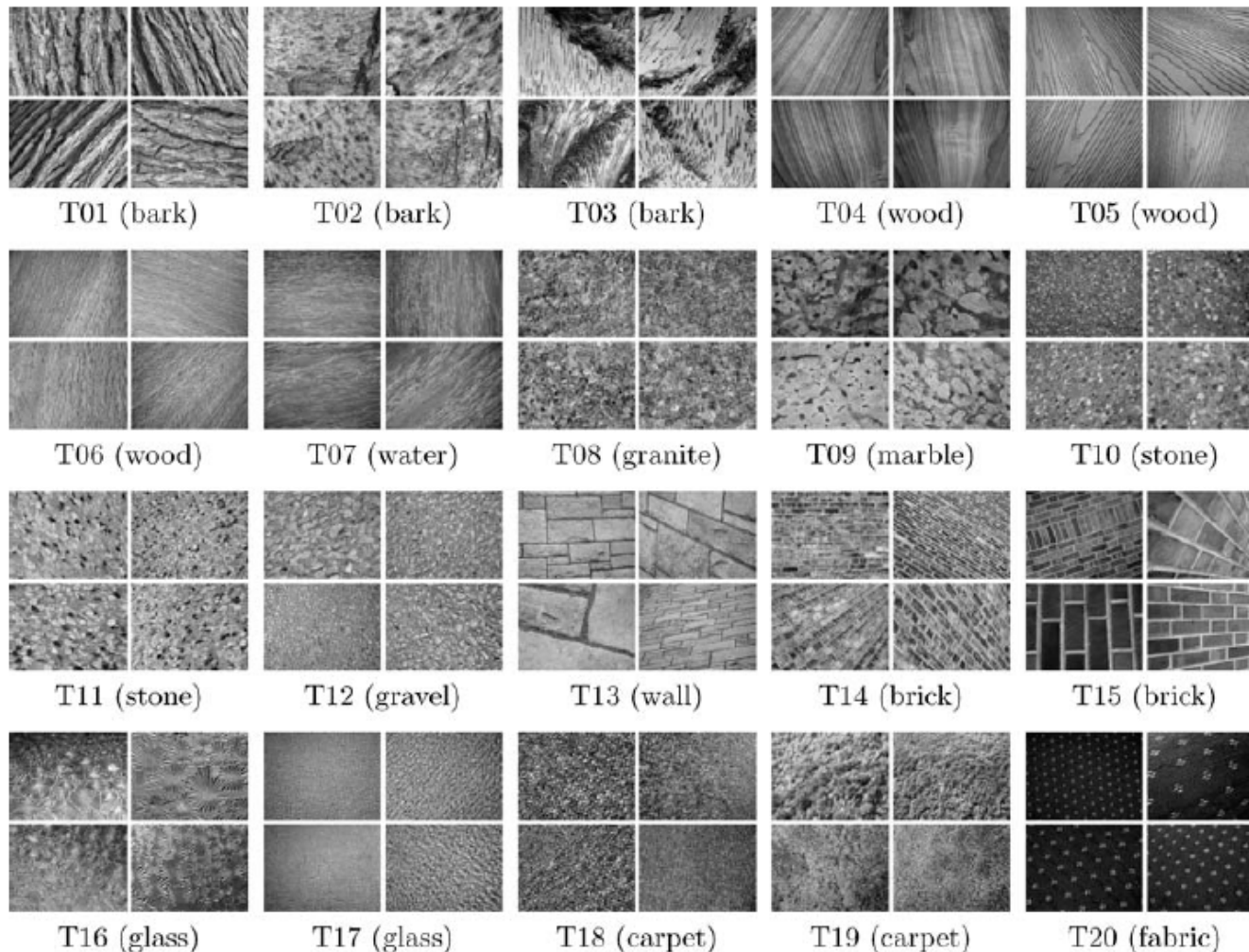*Columbia-Presbyterian MC, New York, USA*

Courtesy of
Dr. Caroline Loeser
Yale University, New Haven, USA

| Colon **Benign** | Colon **Benign** | Colon **Neoplastic** |

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State of the Art in Computer Vision

Texture classes of the UIUCTex dataset [1]
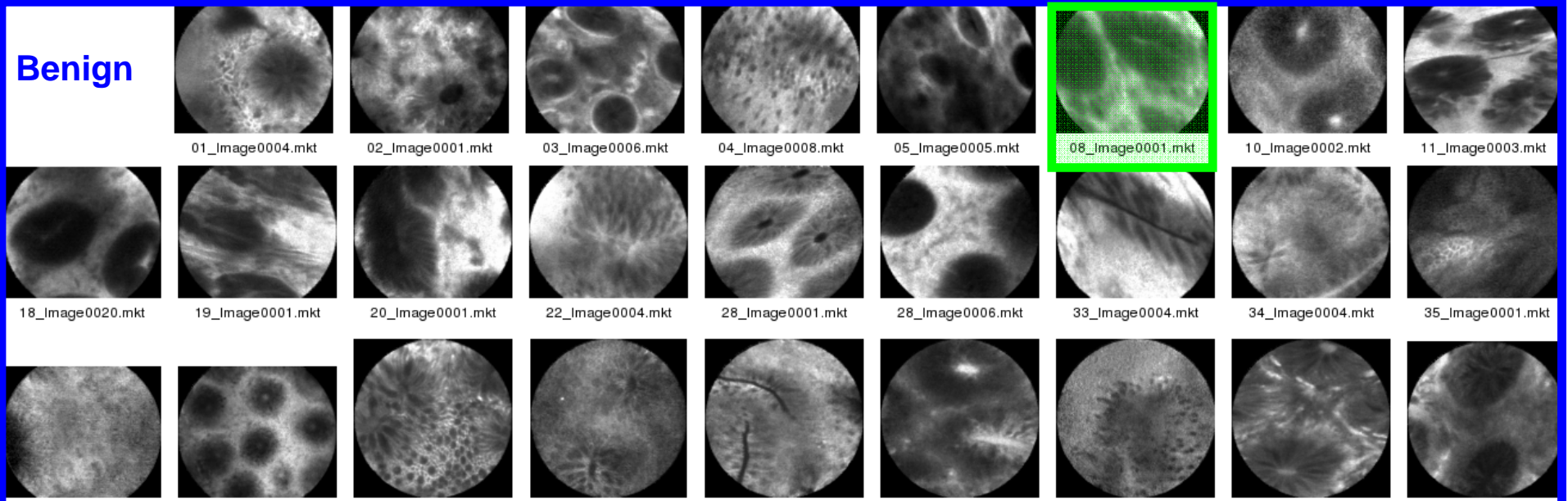

Classification accuracy

= 98.7 %

Database

25 classes

500 images

CBIR method:
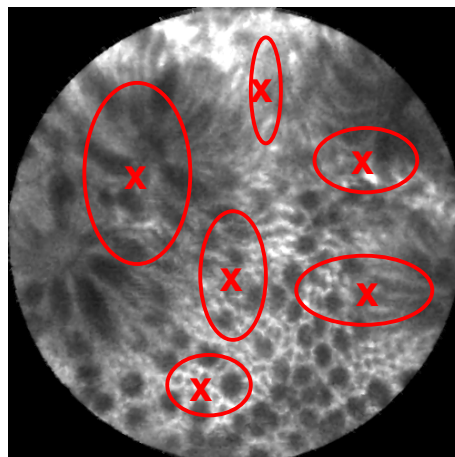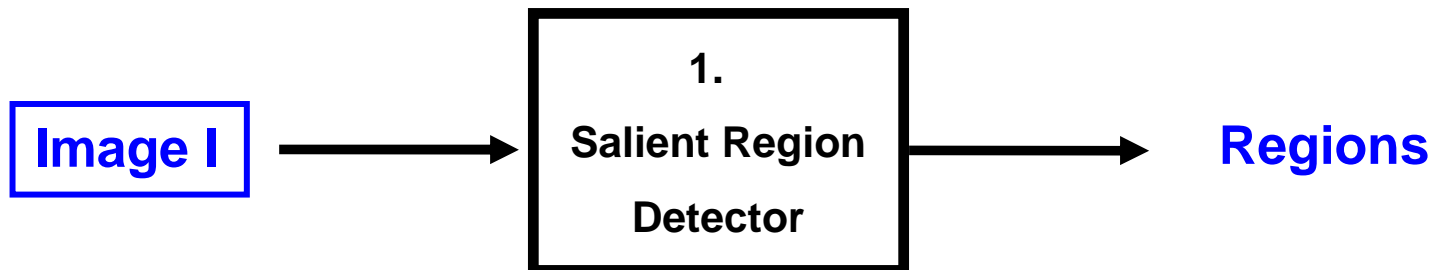
Bag-of-Visual Words

B. André, MSR-INRIA Workshop 2010   *[1] Zhang et al., IJCV 2007*   MKT Mauna Kea Technologies   INRIA SOPHIA ANTIPOLIS

Benign

01_Image0004.mkt 02_Image0001.mkt 03_Image0006.mkt 04_Image0008.mkt 05_Image0005.mkt 08_Image0001.mkt 10_Image0002.mkt 11_Image0003.mkt

18_Image0020.mkt 19_Image0001.mkt 20_Image0001.mkt 22_Image0004.mkt 28_Image0001.mkt 28_Image0006.mkt 33_Image0004.mkt 34_Image0004.mkt 35_Image0001.mkt

Neoplastic

01_Image0005.mkt 02_Image0005.mkt 03_Image0001.mkt 07_Image0002.mkt 23_Image0006.mkt 26_Image0003.mkt 29_Image0001.mkt 30_Image0001.mkt

31_Image0001.mkt 34_Image0006.mkt 37_Image0007.mkt 37_Image0009.mkt 37_Image0010.mkt 39_Image0001.mkt 42_Image0008.mkt 42_Image0011.mkt 43_Image0007.mkt

44_Image0010.mkt 45_Image0003.mkt 45_Image0005.mkt 45_Image0007.mkt 46_Image0001.mkt 50_Image0005.mkt 51_Image0003.mkt 51_Image0004.mkt 52_Image0002.mkt

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- **Outline**

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Image I → **1. Salient Region Detector** → **Regions**

(X) **Salient Region**

*Courtesy of **Pr. Michael Wallace**,*
Mayo Clinic, Jacksonville, USA

BVW Pipeline

Regions → 2. Salient Region Description → **Bag of features: region descriptions**

*Courtesy of **Pr. Michael Wallace**, Mayo Clinic, Jacksonville, USA*

Invariant Description

SIFT [1] **Vector**

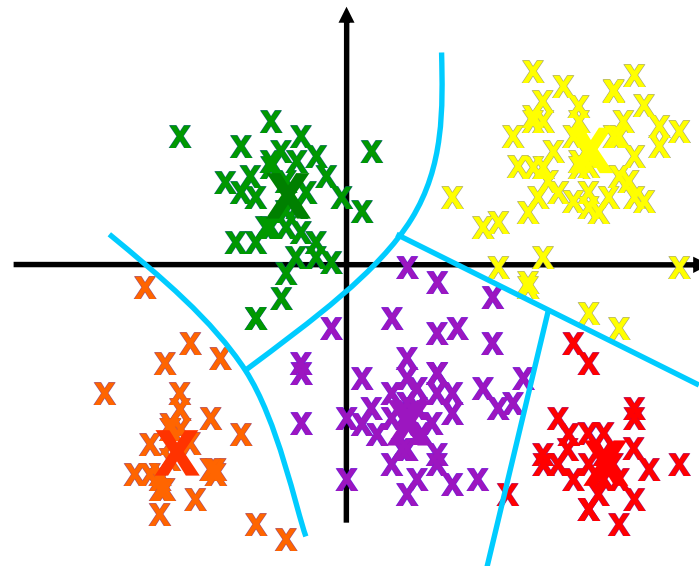$$\begin{pmatrix} v_1 \\ v_2 \\ . \\ . \\ v_{128} \end{pmatrix}$$ **Feature**

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BVW Pipeline

N training images

N bags of features: $\longrightarrow$

> **3.**
> **Clustering**

$\longrightarrow$ **(W_1 , ... , W_K)**

K visual words

" One Bag for all images "

" Visual Words are clusters "

Feature

Space

e.g. SIFT Space

BVW Pipeline

Regions

(W_1 , ... , W_K)

K visual words

4.

Mapping to

Visual Words

Image

Signature

*Courtesy of **Pr. Michael Wallace**,*
Mayo Clinic, Jacksonville, USA

Number of
occurrences

1 2 3 ... K

Visual word

*Courtesy of **Pr. Michael Wallace**,*
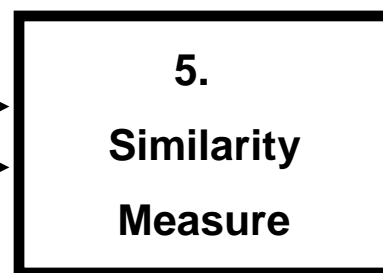*Mayo Clinic, Jacksonville, USA*

Image I_1

Image I_2

5.

Similarity

Measure

d (I_1 , I_2)

=

$\mathcal{X}^2$ **(Signature (I_1) , Signature (I_2))**
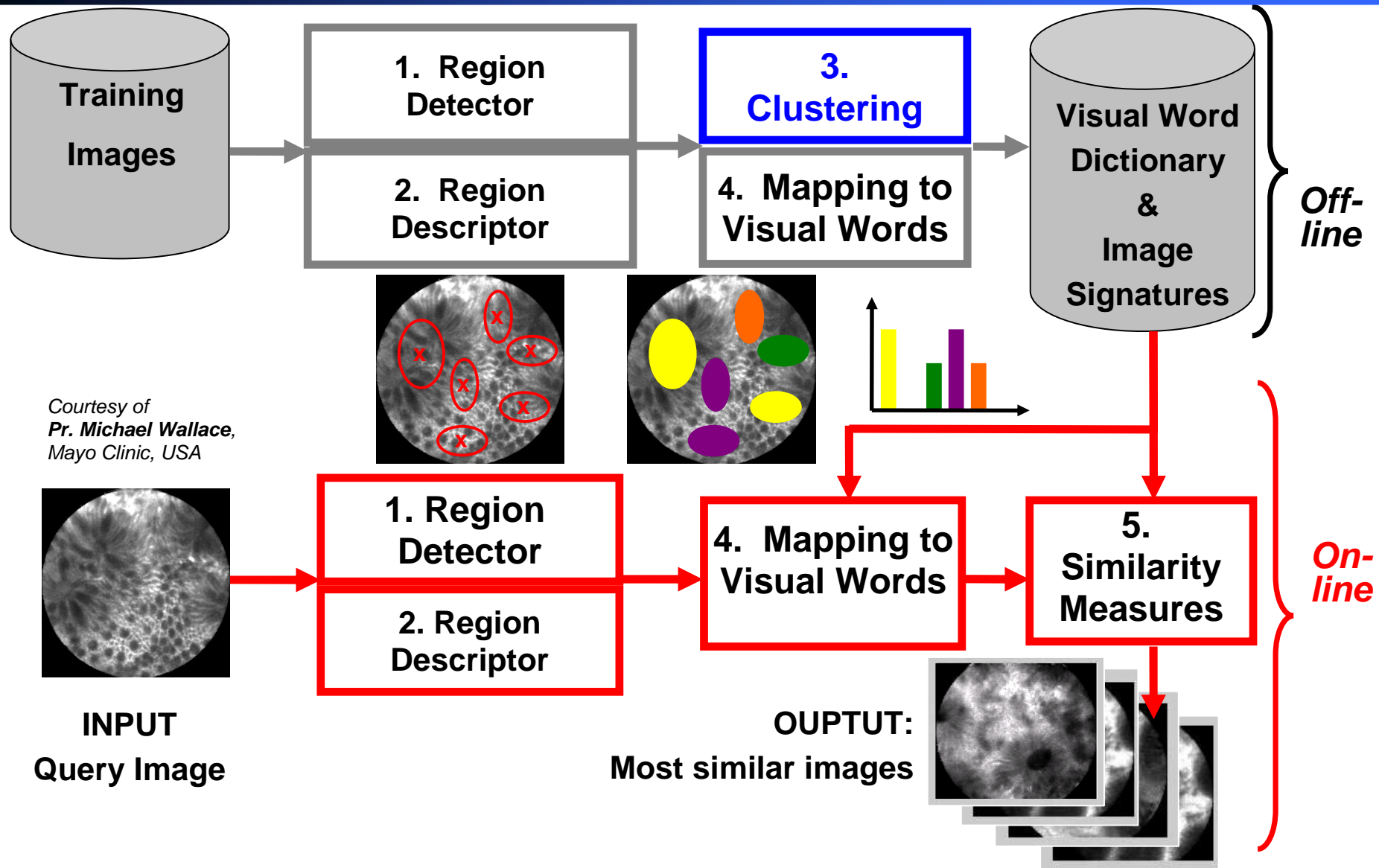
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Courtesy of
Pr. Michael Wallace,
Mayo Clinic, USA

Training Images

1. Region Detector

2. Region Descriptor

3. Clustering

4. Mapping to Visual Words

Visual Word Dictionary & Image Signatures

Off-line

INPUT Query Image

1. Region Detector

2. Region Descriptor

4. Mapping to Visual Words

5. Similarity Measures

On-line

OUPTUT: Most similar images

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- **Outline**

From Sparse to Dense Detector

time

*Courtesy of **Pr. Michael Wallace**,*
Mayo Clinic, Jacksonville, USA

Sparse detector…   inconsistency !

Clinically relevant information is densely distributed.
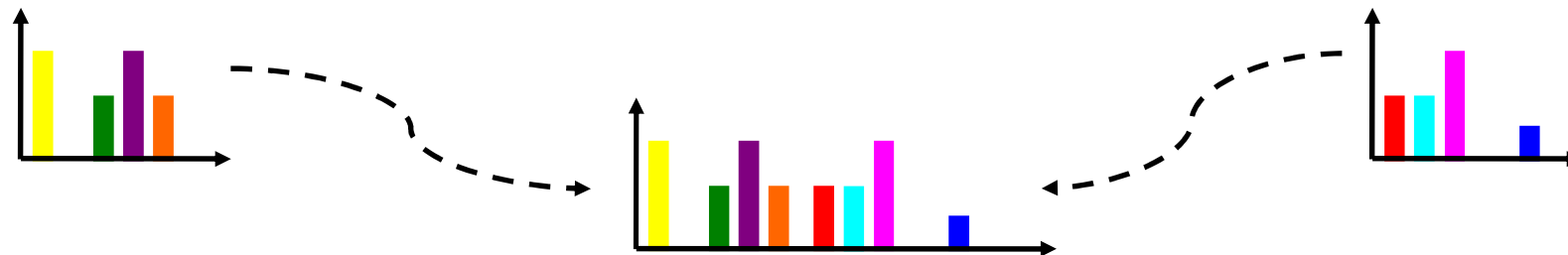
Dense Region Detection

Bi-Scale Disc Description

Dense regular grid

Disc Overlap

Large discs: groups of cells
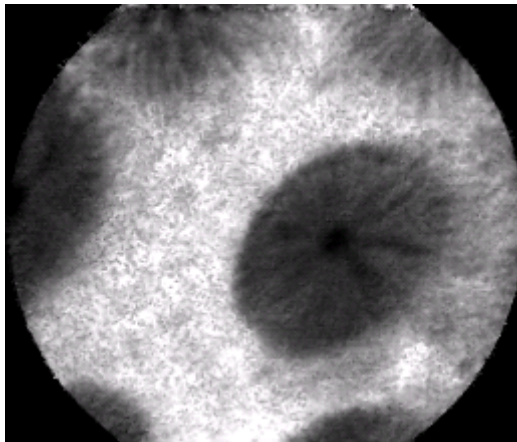
Small discs: individual cells

Bi-Scale Disc Description

*Courtesy of **Pr. Michael Wallace**, Mayo Clinic, Jacksonville, USA*

Observation:

Cellular architecture is substantial to establish a diagnosis
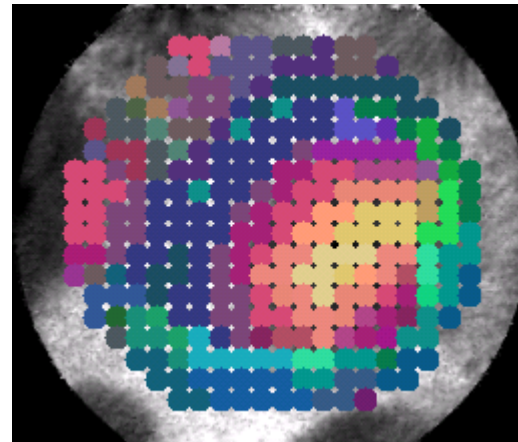
Courtesy of
Pr. Michael Wallace
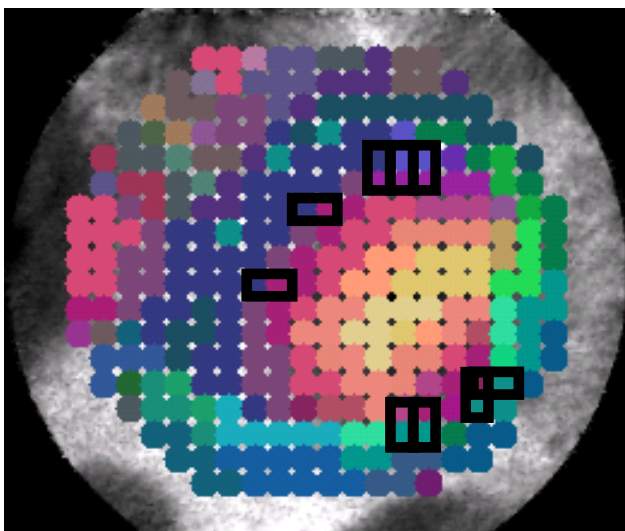*Mayo Clinic, Jacksonville, USA*

Assumption:

Spatial relationship between local features

statistically the same in the images with similar appearance

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Introducing Space

Idea:

Spatial relationship Feature = **Co-occurrence matrix of visual words**

Image I, K visual words

M of size K x K

	w_1	$\ldots$	w_i	$\ldots$	w_K
w_1					
w_j					
w_K					

Proba (w_i adjacent to w_j in I)

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Introducing Space

Supervised description of Spatial Features
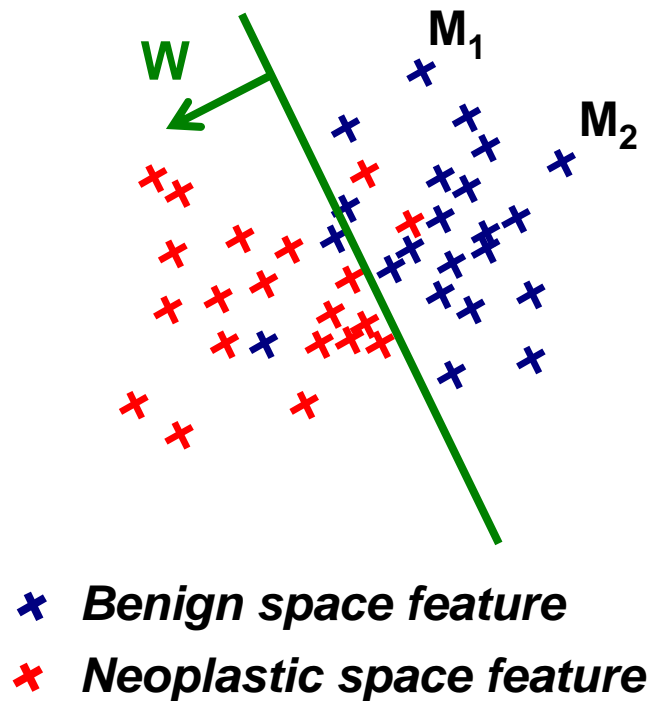
$$S (I) = W . M$$

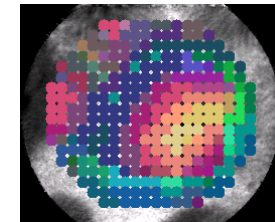**Discriminant linear combinaison (LDA)**

Co-occurrence matrix

W

M_1

M_2

✚ *Benign space feature*

✚ *Neoplastic space feature*
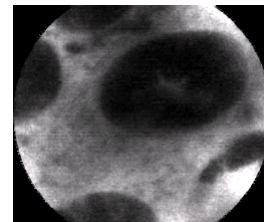
Image I_1

Image I_2
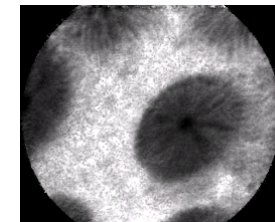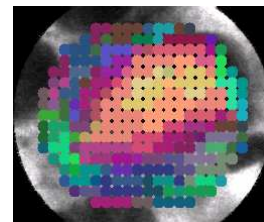
$S (I_1)$ ⟵ ┈┈┈┈┈┈┈ ⟶ $S (I_2)$

$$E = | S_1 - S_2 |$$

Space Feature Difference

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Introducing Space

Threshold on E =

| S (output) – S(input) |

Outlier Rejection

Nearest Neighbors

Retrieval Pipeline
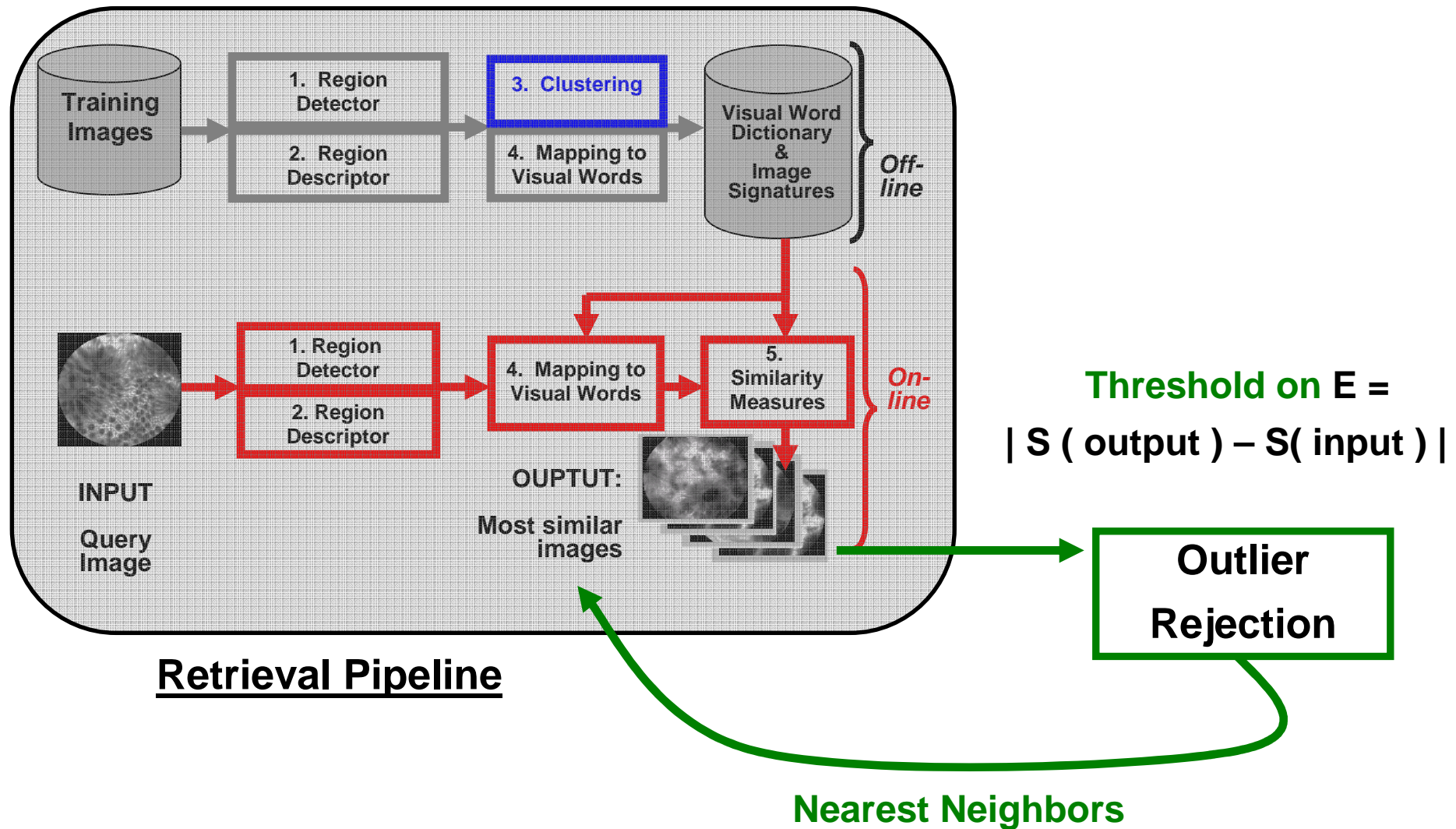
Results: Benign Query
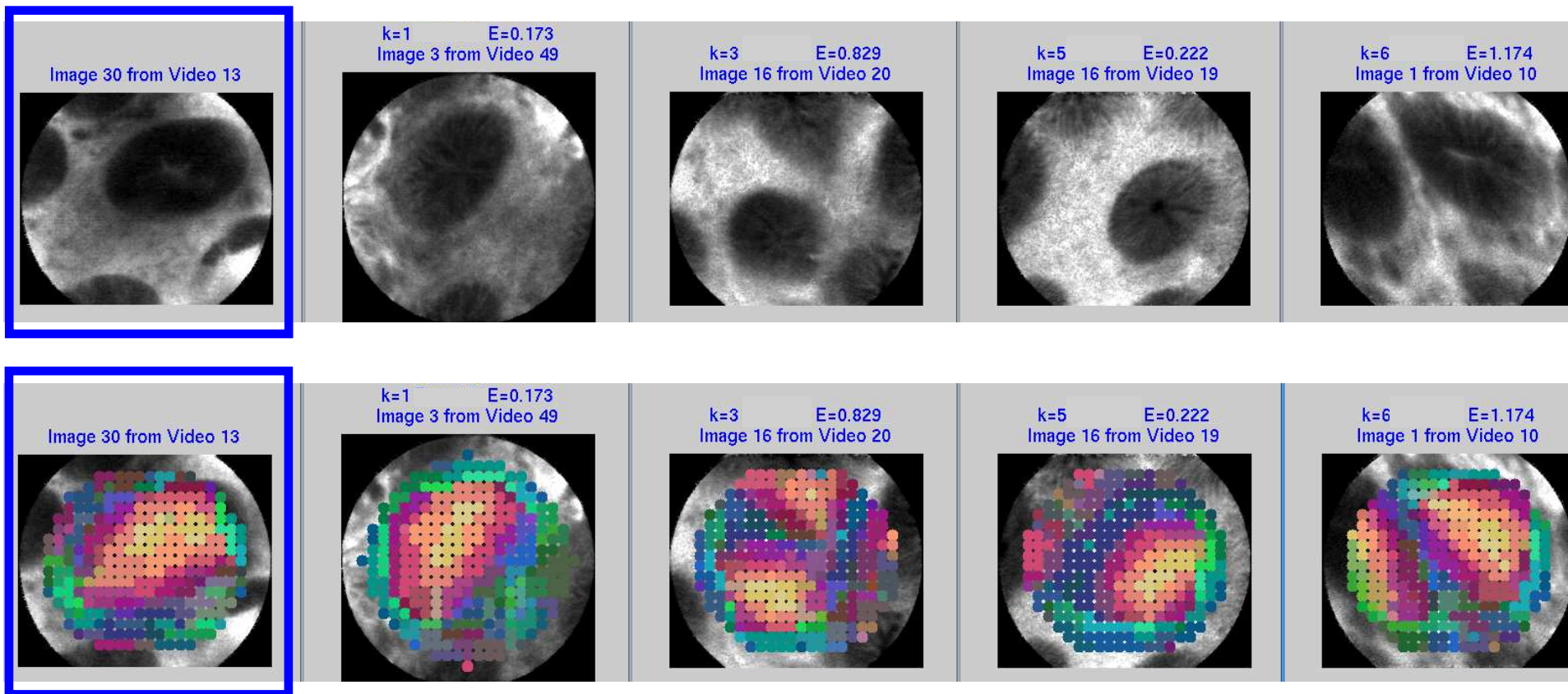
Benign Vote = 100 %

Query   **4 nearest neighbors**

Results: Benign Query
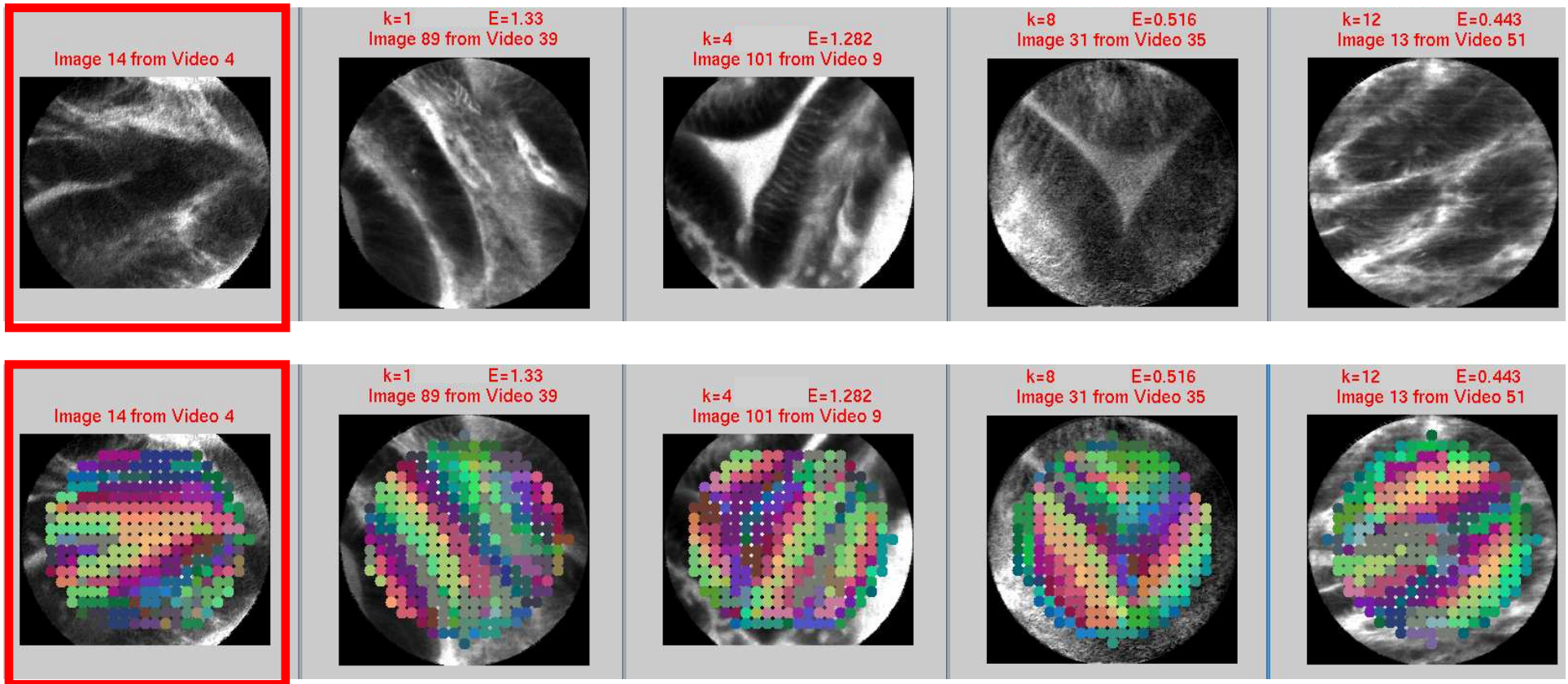
Benign Vote = ~~75~~ % 100 %

Outlier !
E > 2

E = 0.8   E = 1.8   E = 1.0   **E = 4.0**

Image 7 from Video 49

k=1   E=0.797
Image 29 from Video 24

k=2   E=1.829
Image 64 from Video 3

k=5   E=1.002
Image 72 from Video 1

k=11   E=4.034
Image 5 from Video 31

Query   *4 nearest neighbors*

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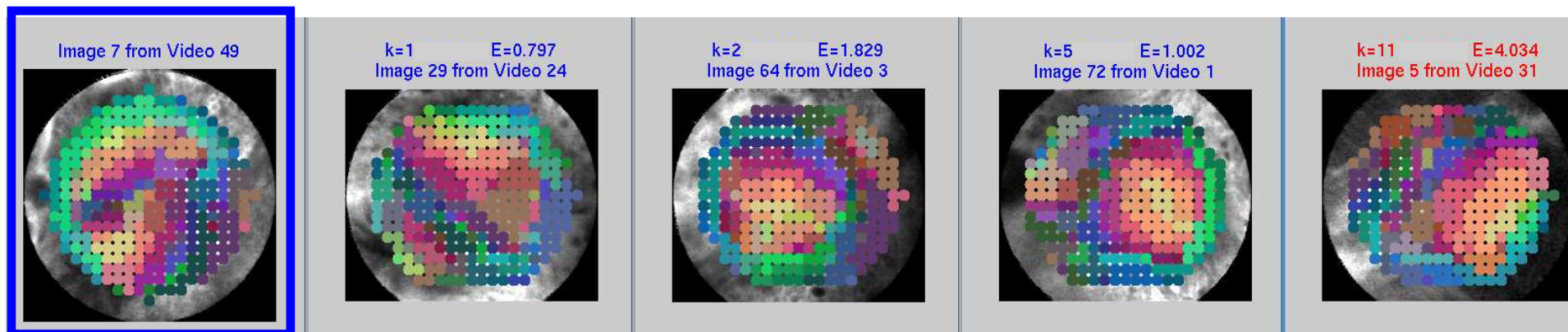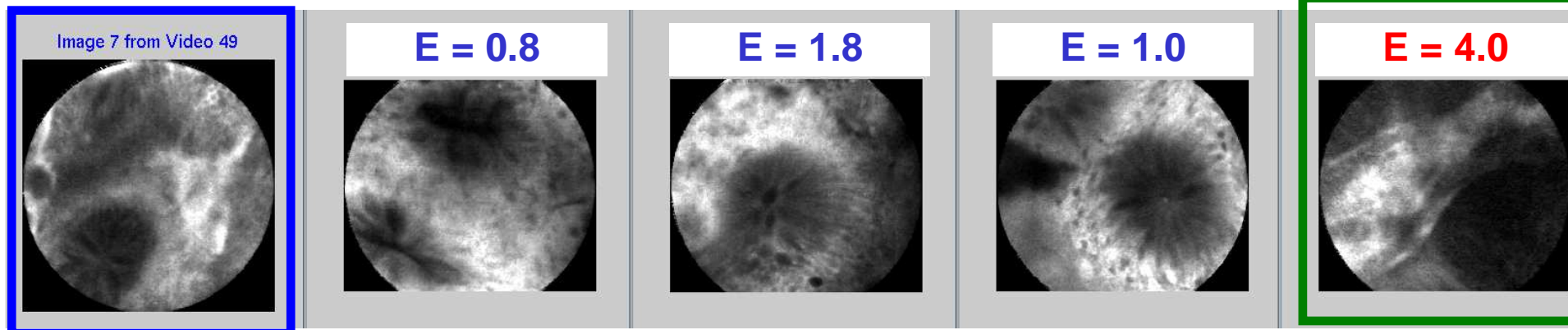
Results: Neoplastic Query

Neoplastic Vote = 100 %

Query   **4 nearest neighbors**

Results: Neoplastic Query
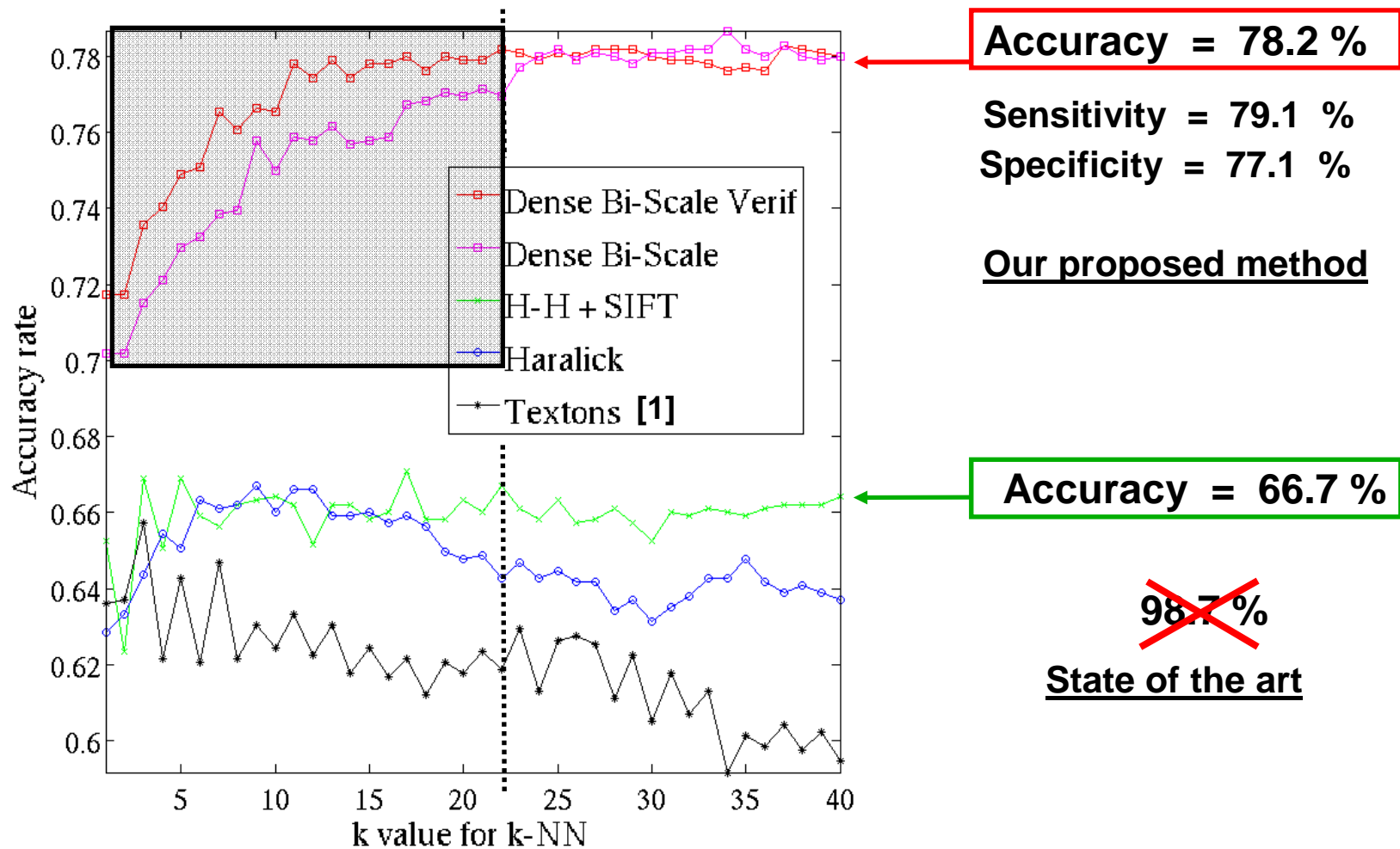

Outlier !
$E > 2$

Neoplastic Vote = ~~75 %~~ **100 %**

E = 2.1   E = 1.4   E = 0.6   E = 0.9

Image 17 from Video 50

k=1   E=2.127
Image 14 from Video 20

k=2   E=1.359
Image 64 from Video 5

k=3   E=0.619
Image 4 from Video 35

k=4   E=0.946
Image 124 from Video 23

Image 17 from Video 50

Query   **4 nearest neighbors**

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Database: 52 videos, 1036 images, 2 classes.
Leave-n-out cross-validation:

Accuracy = 78.2 %

Sensitivity = 79.1 %
Specificity = 77.1 %

Our proposed method

Accuracy = 66.7 %

98.7 %

State of the art

Results: Benign Query

Benign Vote = 0 %   Rare benign variety ?
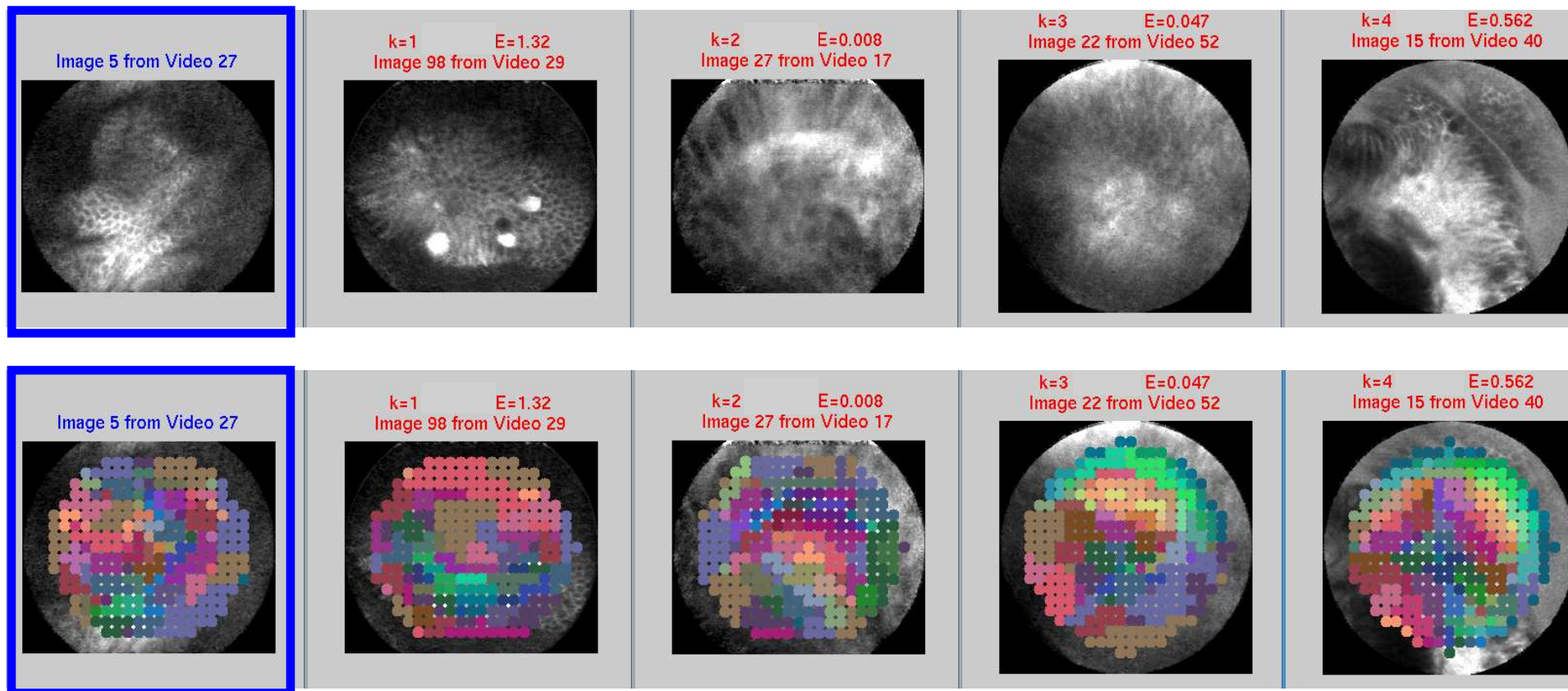
Query   4 nearest neighbors

Results: Neoplastic Query

Neoplastic Vote = 25 %   Too small FOV ?
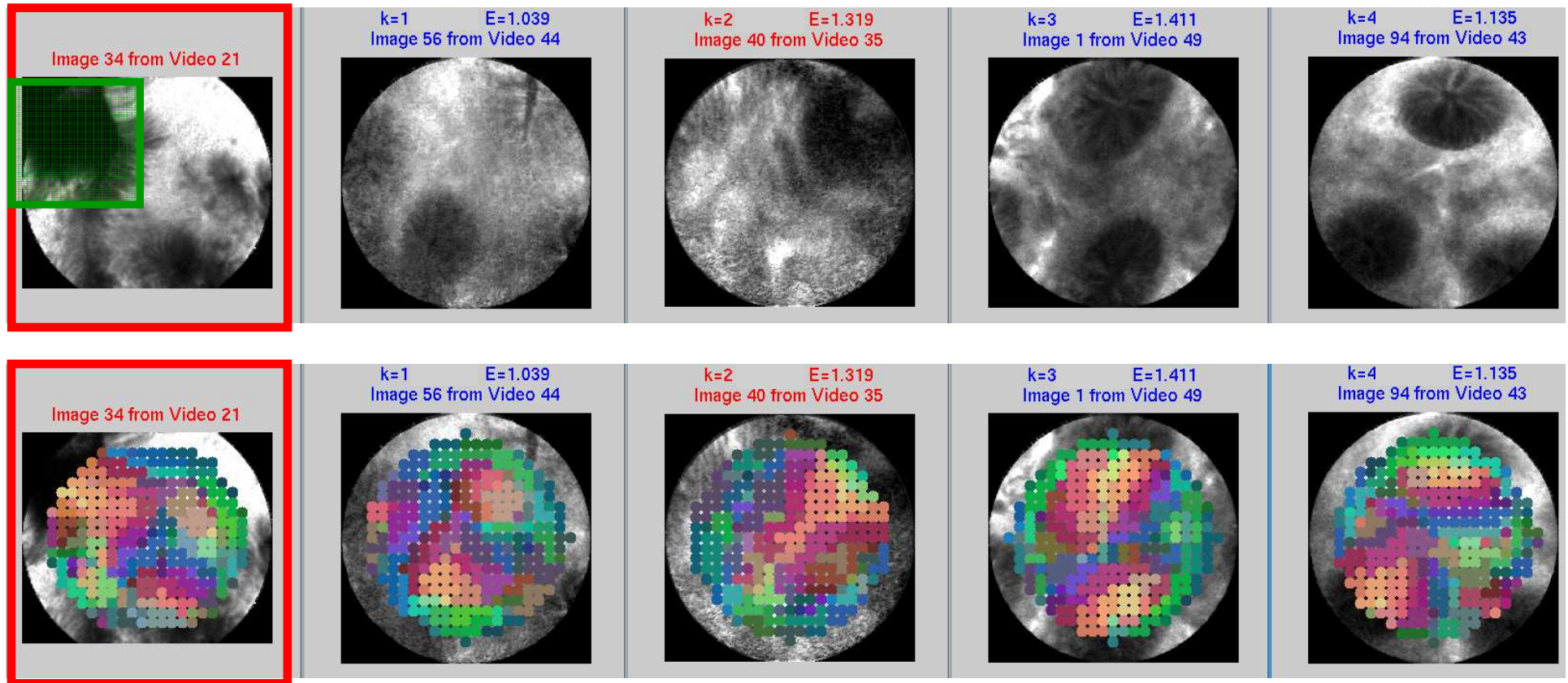
Query   ***4 nearest neighbors***

- **Outline**

  1. **Introduction**

  2. **The Bag-of-Visual Words Method**

  3. **Introducing Spatial Information**

  4. **Introducing Temporal Information**

  5. **Conclusion**

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Introducing Time

Problem:

Discriminative patterns may be partially visible on still images.

Why creating mosaics from pCLE data ?

- **viewpoint changes**
- **little real dynamics**
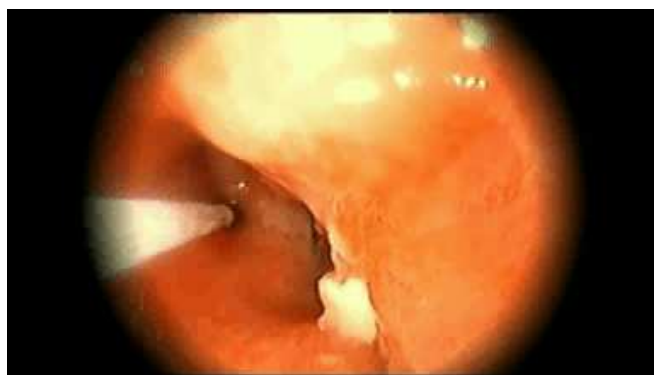
pCLE probe moving on epithelium
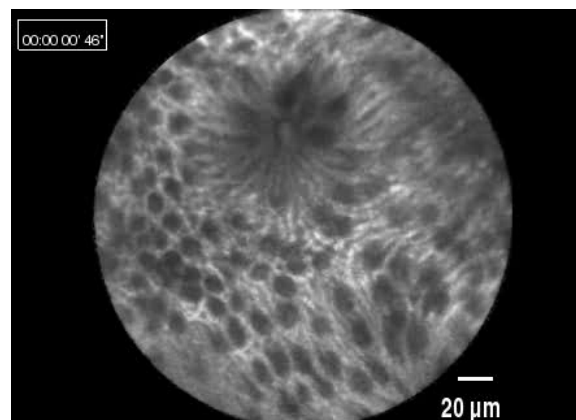
Idea: Combine Image Retrieval and Mosaicing

Introducing Time

" Mosaicing projects

temporal dimension of a video

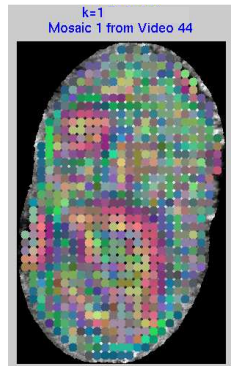## onto one larger image of higher resolution "

mosaicing

B. André, MSR-INRIA Workshop 2010

Vercauteren et al., MI...

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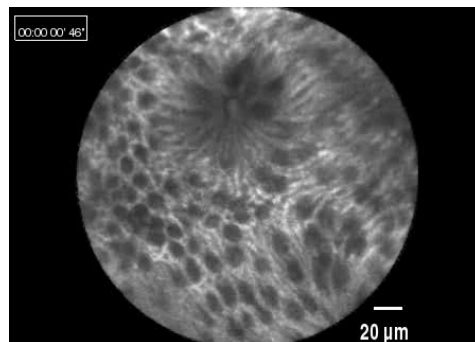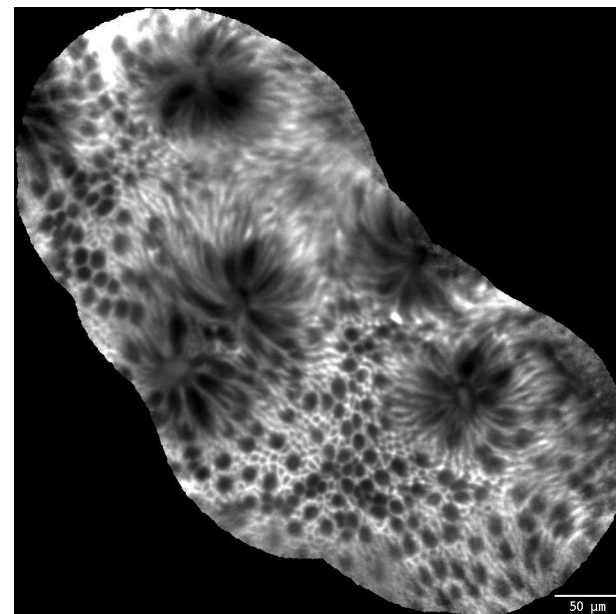
Mosaics: Benign Query

Benign Vote = 100 %

Query

150 μm

Mosaic 1 from Video 34

k=1
Mosaic 1 from Video 44

k=2
Mosaic 1 from Video 43

k=3
Mosaic 1 from Video 7

4 nearest

neighbors

k=4
Mosaic 1 from Video 24
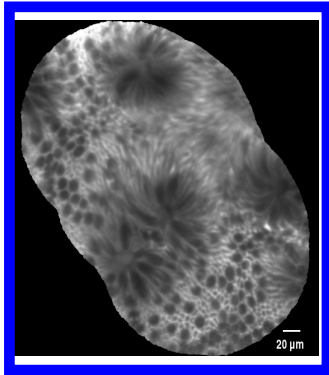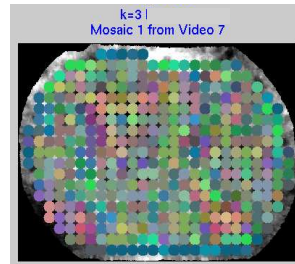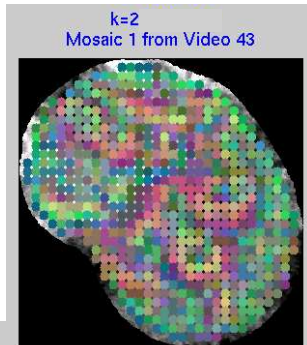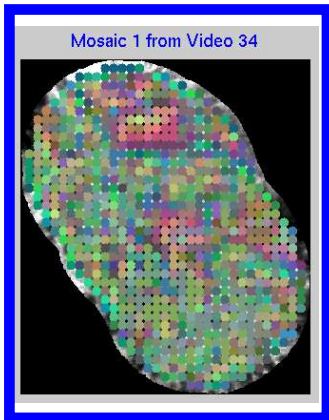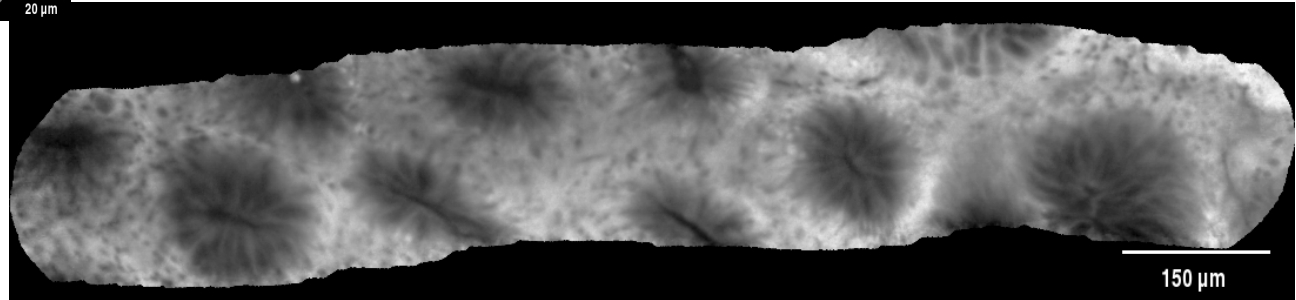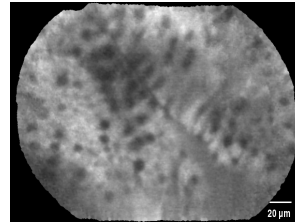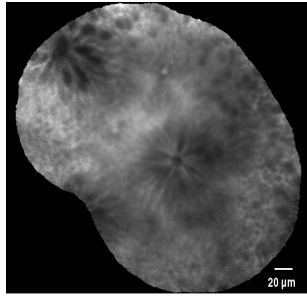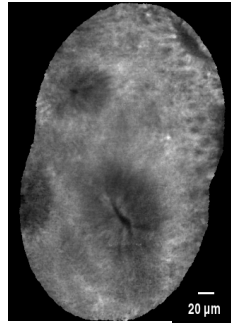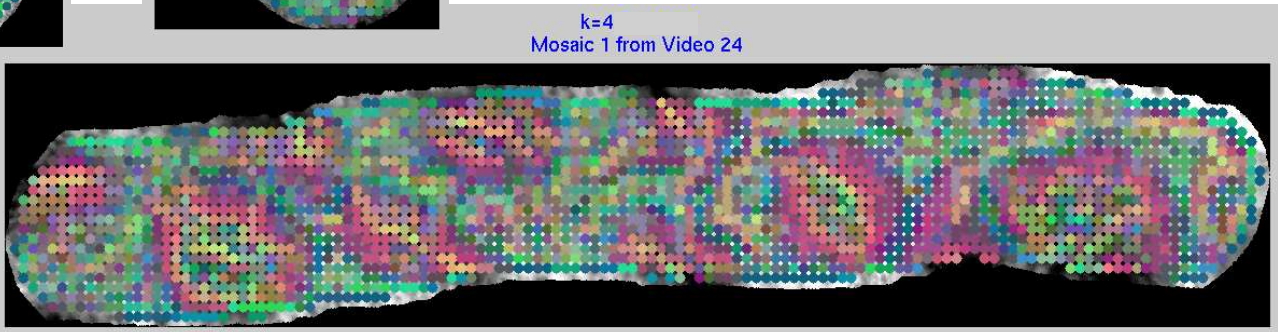
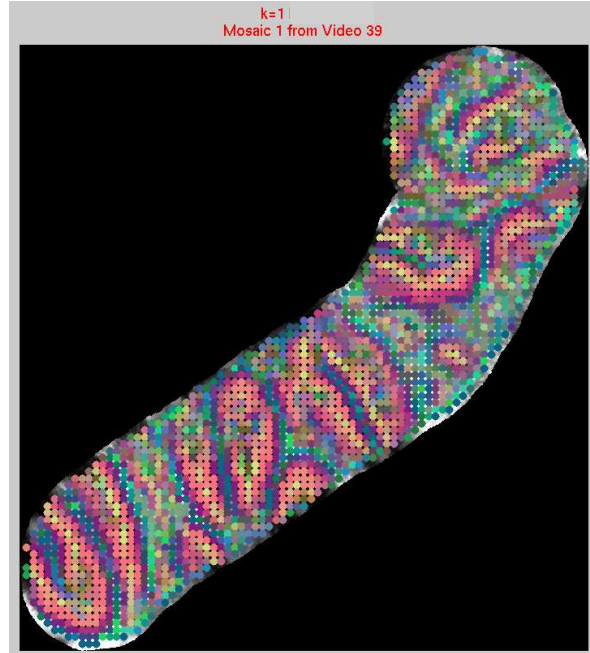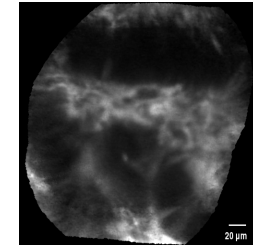**Mosaics: Neoplastic Query**

Neoplastic Vote = 100 %

Query

Mosaic 1 from Video 4

k=1
Mosaic 1 from Video 39

k=2
Mosaic 2 from Video 47

k=3
Mosaic 1 from Video 50

k=4
Mosaic 2 from Video 26

4 nearest neighbors

Method Comparison
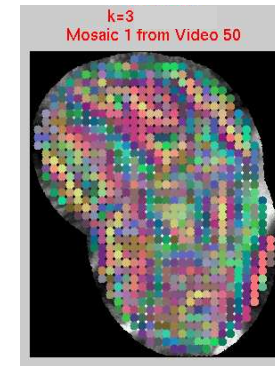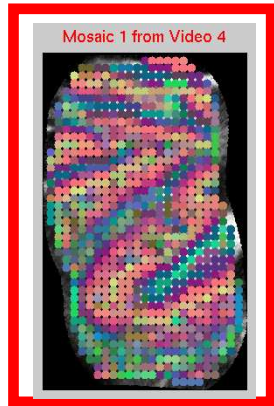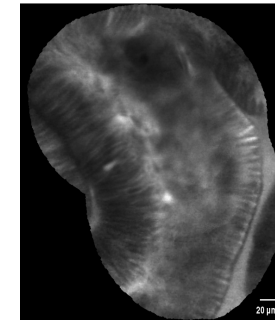
Database: 52 videos, 1036 images, 66 mosaics, 2 classes.
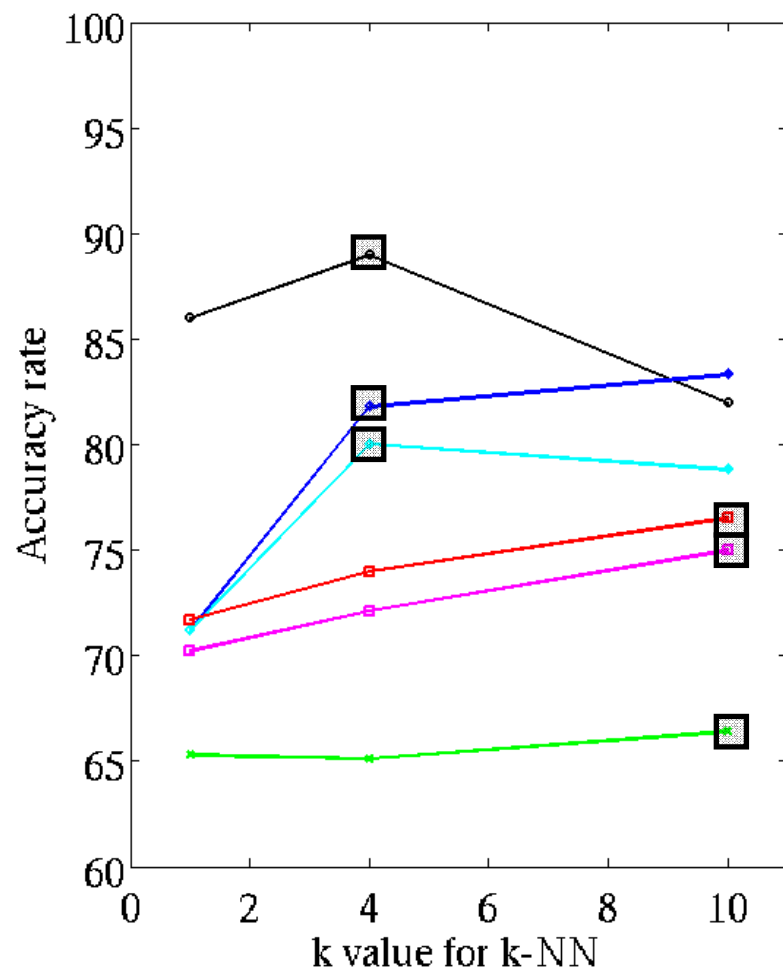
Leave-n-out cross-validation:

- **Outline**

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Methodological Contributions

- **Including Space Information**

- **Considering Time Information**

1st attempt to classify endomicroscopic videos using CBIR

Genericity: - various endomicroscopic retrieval applications

               - multiclass image classification

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Perspectives

- **Enrich training database to evaluate both contributions**

- **Other databases, on other organs / pathologies**

- **More robust validation with aid of medical expertise**

- **Use 2D + t to exploit biological dynamics**

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Questions

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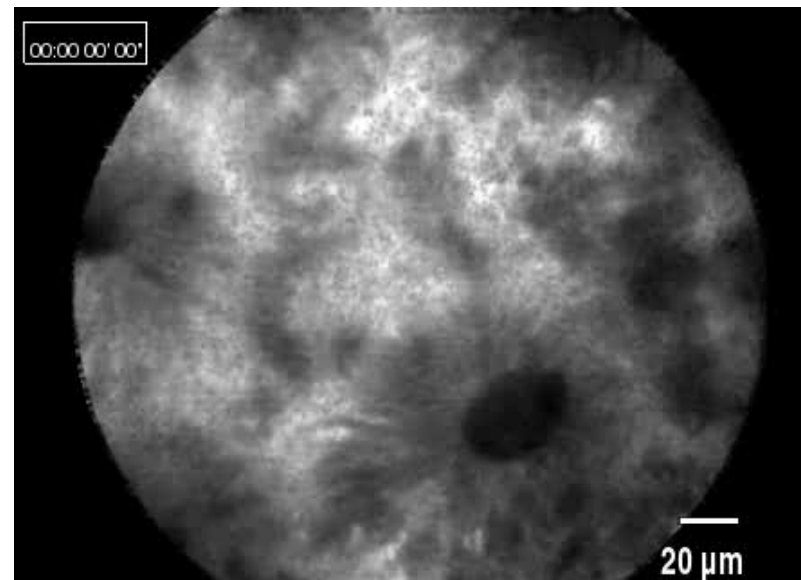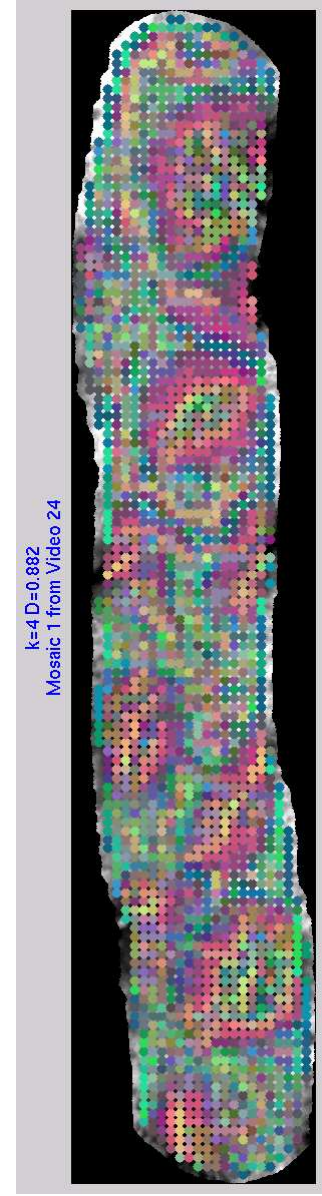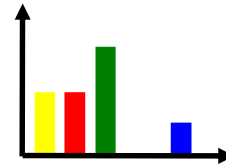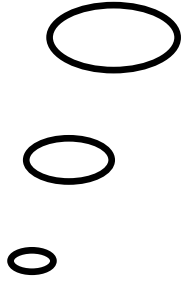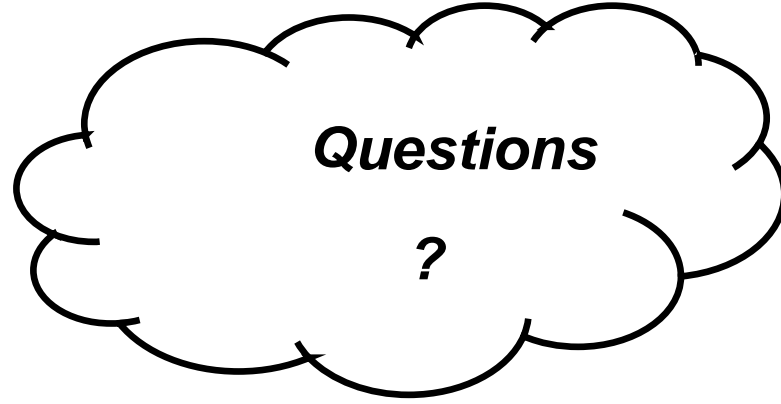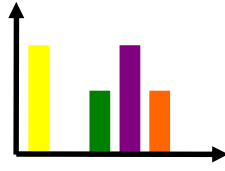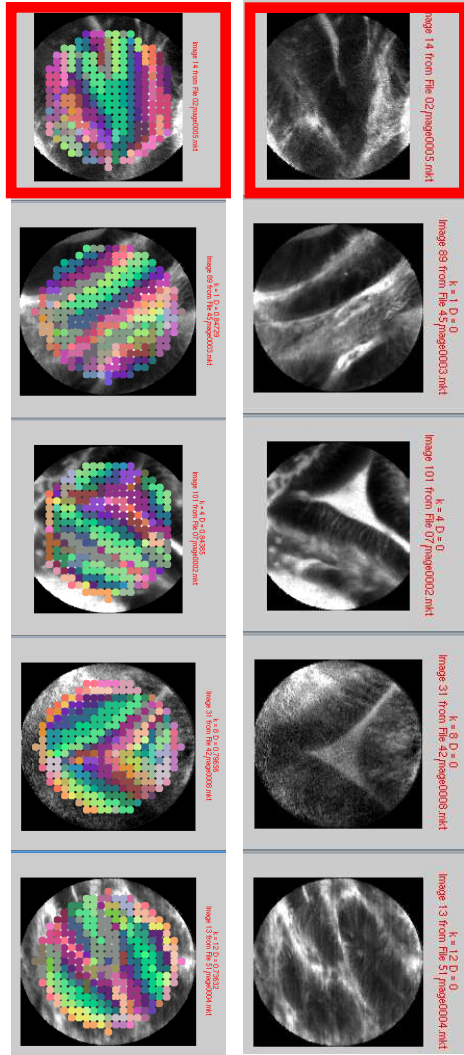
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