Detection of Caries in Panoramic Dental X-ray Images

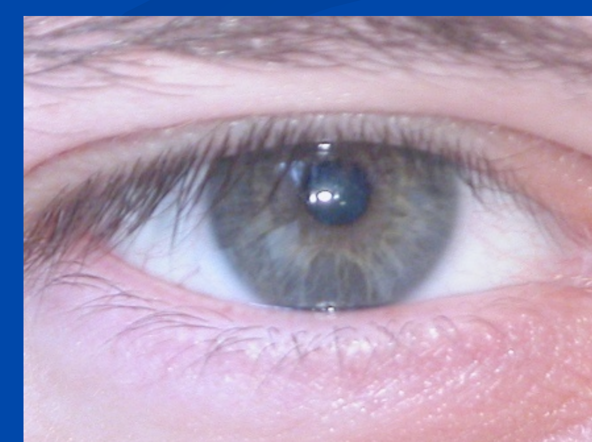
CIA Lab. – Soft Computing and Image Analysis Grou

ounded in September 2006, we accommodate 18 members, both faculty and students

e develop and apply soft computing methods (neural networks, support vector machi
etic algorithms, fuzzy logic) for data analysis, and in particular, image analysis.

- Medical Image Analysis, Object Detection, Video Annotation, …
- **Biometrics: iris recognition in non-cooperative environments.**

Cooperative Scenario



Non-Cooperative Scenario

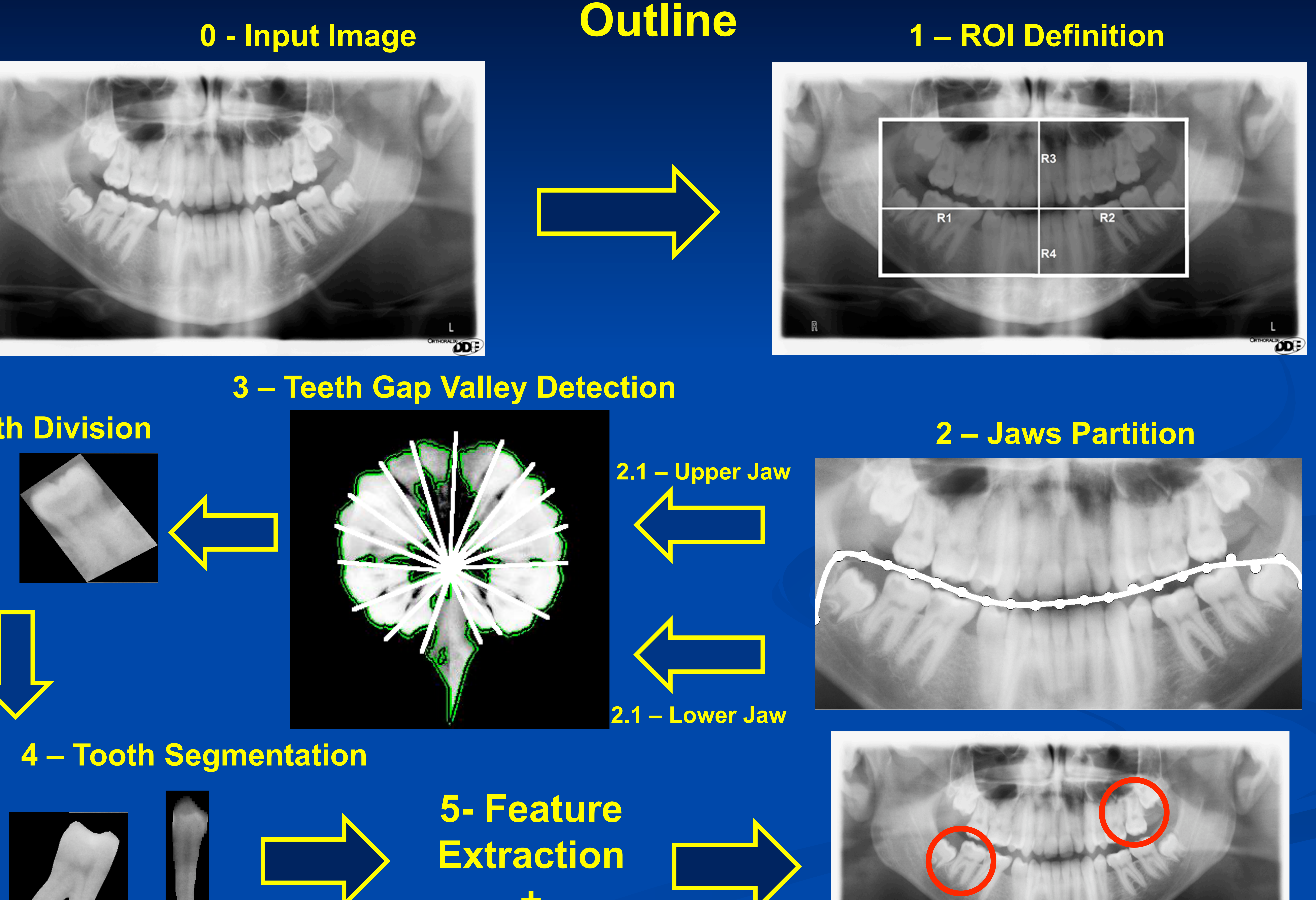
SOCIA Lab. – Soft Computing and Image Analysis Group

- M.Sc. Work: Detection of Caries in Panoramic Dental X-Ray Images

- Student: João Oliveira, Computer Science Engineer.

- Supervisor: Hugo Proença, IT – Instituto de Telecomunicaçõ
Department of Computer Science, University of Beira Interior.

- Valuable biological advices from Dr. Rui Conceição.


Outline
0 - Input Image
1 – ROI Definition
R3
R1
R2
R4
2 – Jaws Partition
2.1 – Upper Jaw
2.1 – Lower Jaw
3 – Teeth Gap Valley Detection
th Division
4 – Tooth Segmentation
5- Feature
Extraction

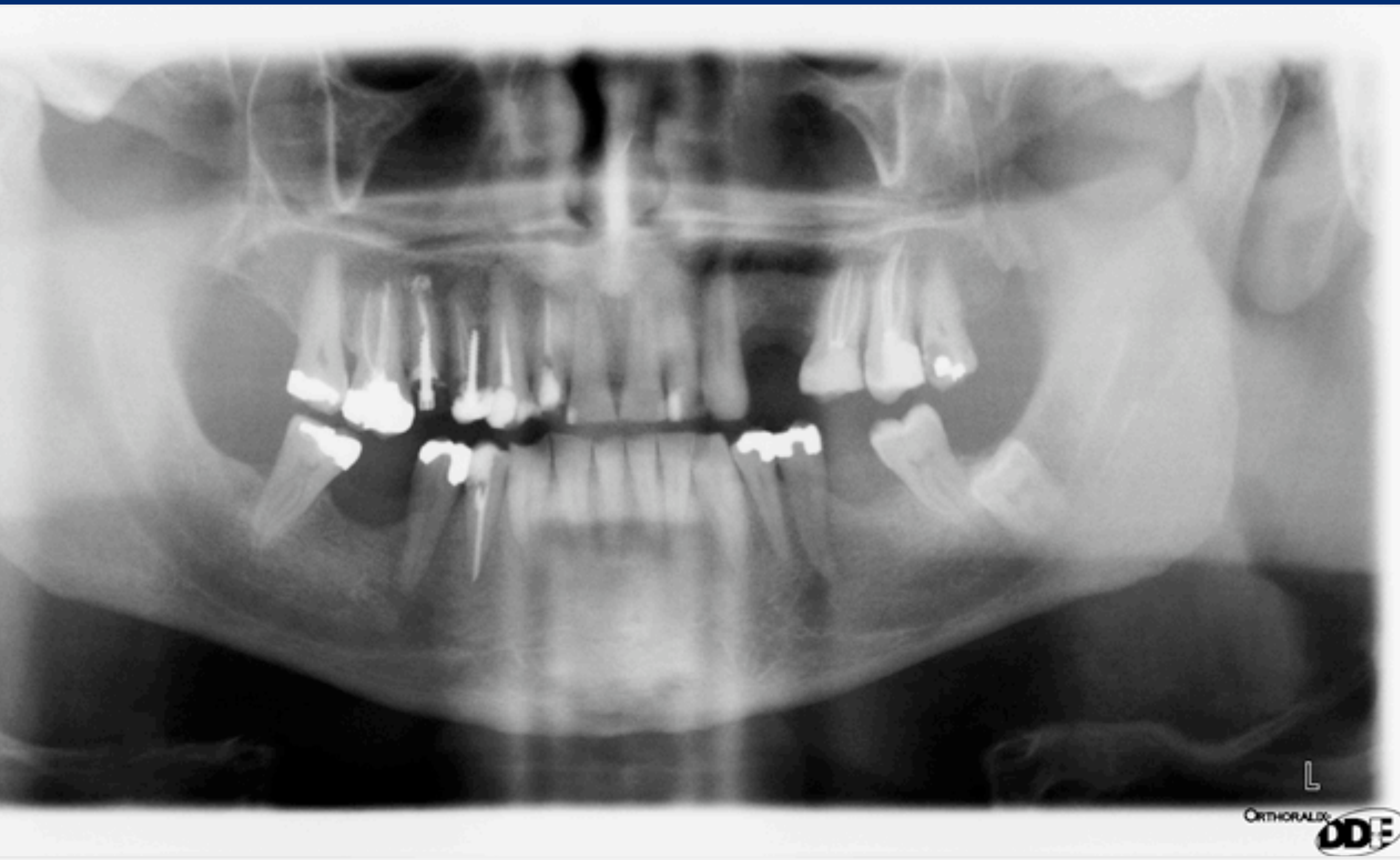
Input images

mensions – 2816W x 1540H;

Properties:

- Grayscale images [0 ; 255];
- Variable dental structure, mouth size and number of teeth per image;
- Complex morphologic and topologic properties:
  - Low contrast images;
  - Blur that difficults the proper detection of edges;
  - Spinal column that covers the central part of some images;

Examples of input images



1 – Region of Interest

ere, Image acquisition is a constrained process.

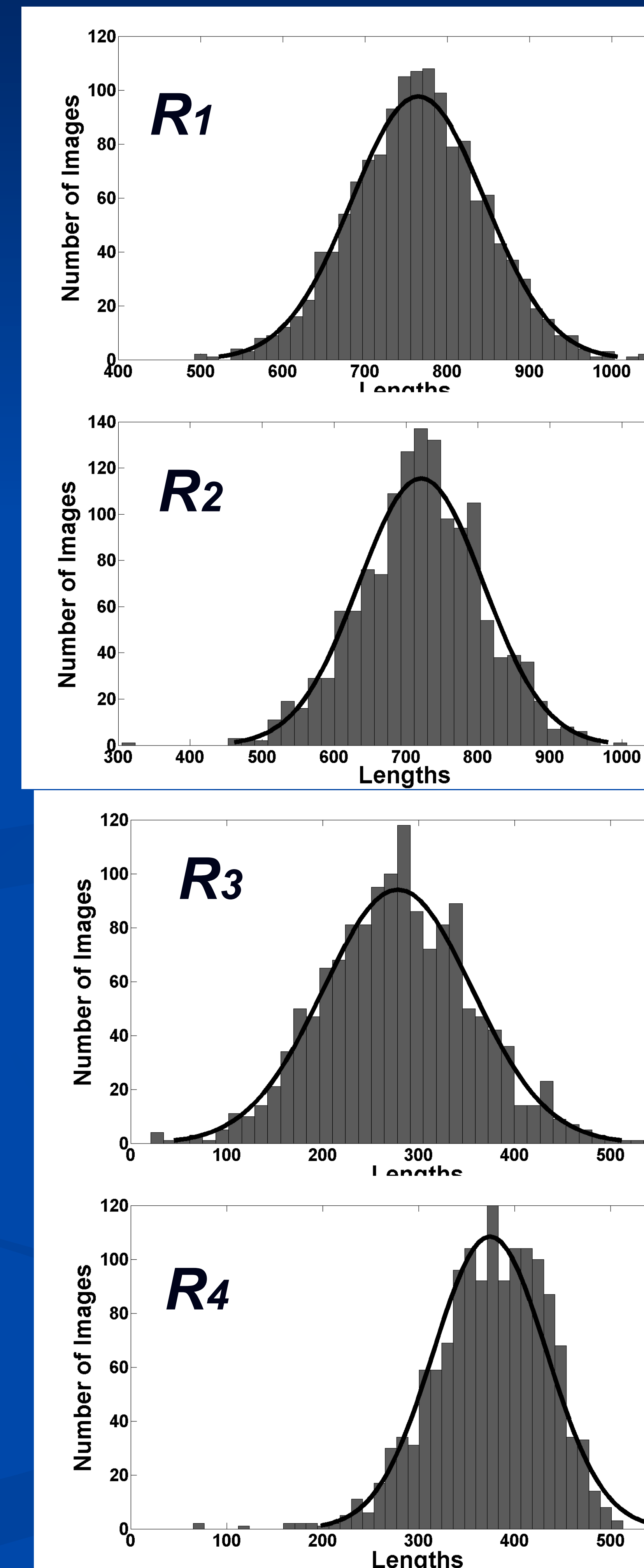
- Human morphology dictates that some regions

ever have usefull information.

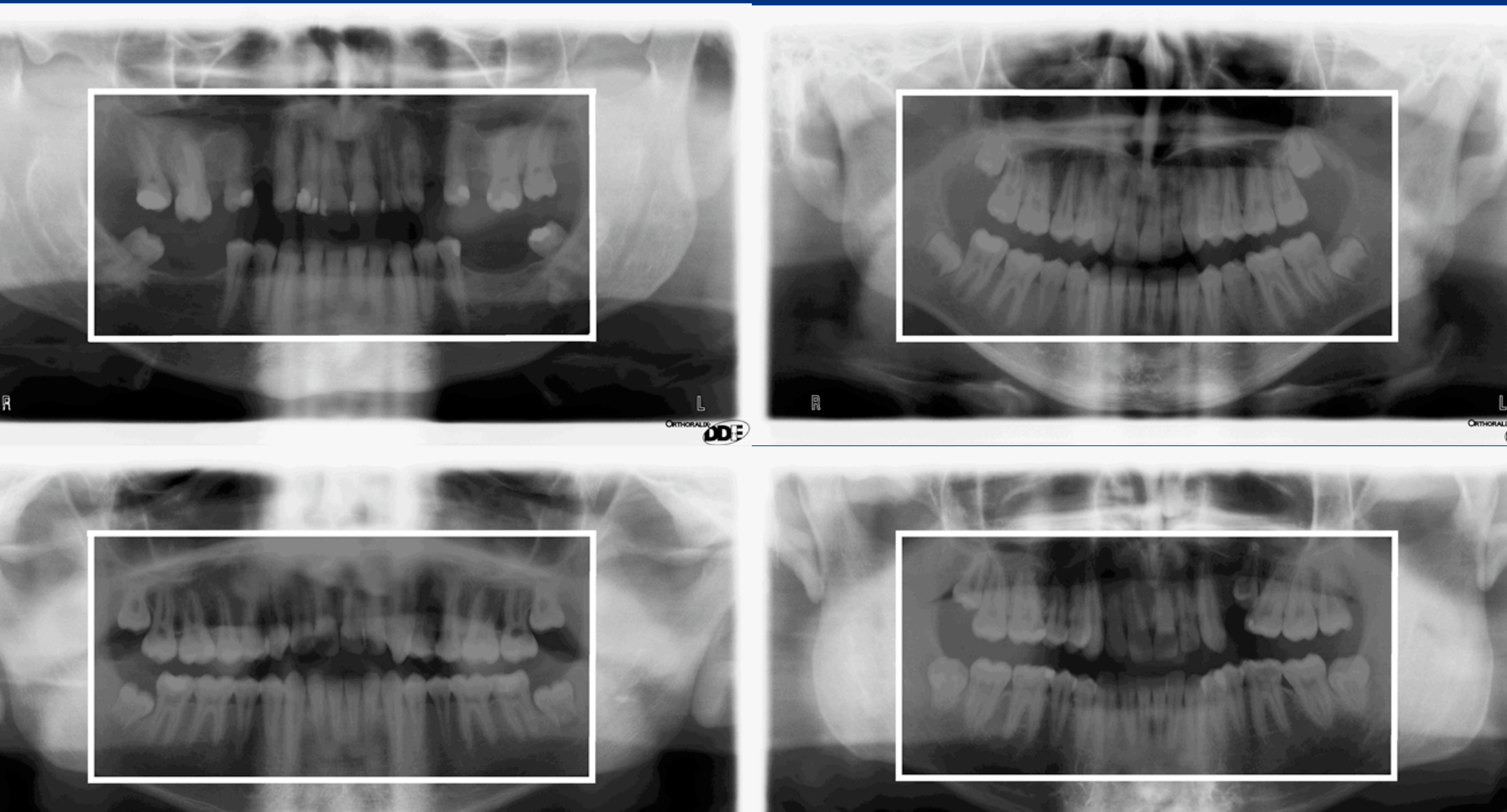
xtraction of four distances from the image center:

- $(x_c, y_c) = (w/2 = 1408, h/2 = 770)$;
- Asumed a normal distribution, (μ, σ);
- Crop images with *95%* certainty:

$R_1 \approx 897.77$; $R_2 \approx 863.36$; $R_3 \approx 406.31$; $R_4 \approx 471.27$;



– Roi Definition Examples:



– Partition of the Image Into Jaws

Extraction of T points (experimentally, $T = 20$) between the jaws:

Based on the horizontal projection – $v(u) = \sum_{i=0}^{w} I(x,i)$

Initial point is defined – $p_0(x_0, w-1) = \arg\min_x(v(u))$

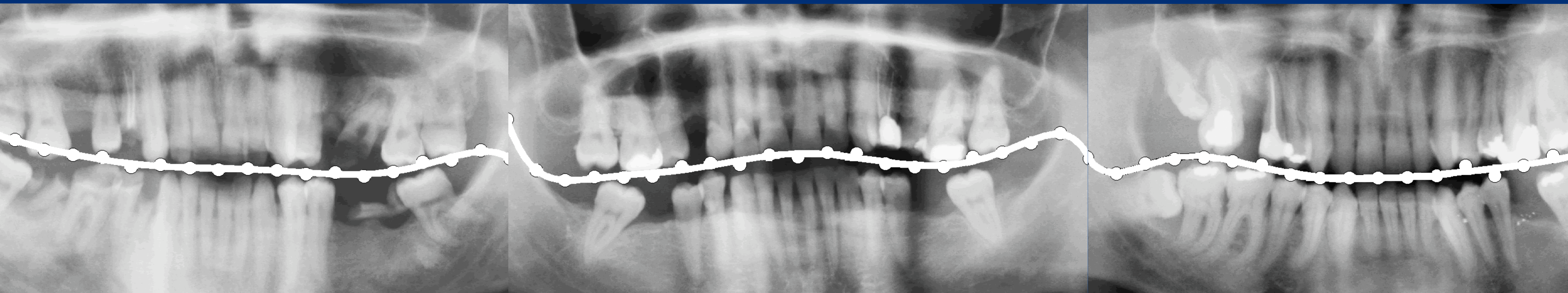
Remaining points p_i are regularly spaced – $p_0 : p_i(x_i, (w-1) - W/2$

Fitting process:

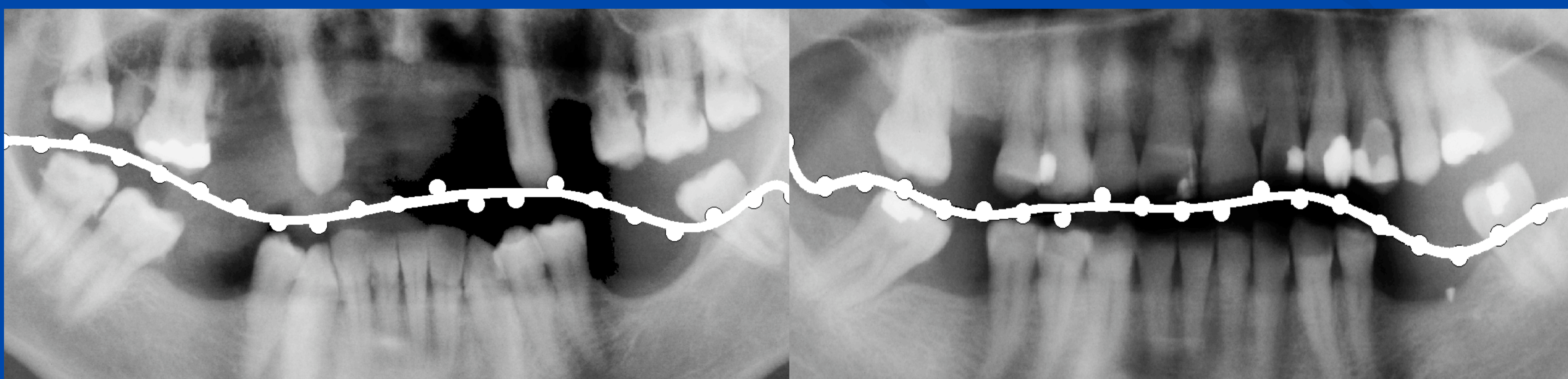
The division of jaws is given by the 10th order polynomial, defined

$(x) = a_0 + \ldots + a_{10}x^{10}$;

– Jaws Partition (examples):



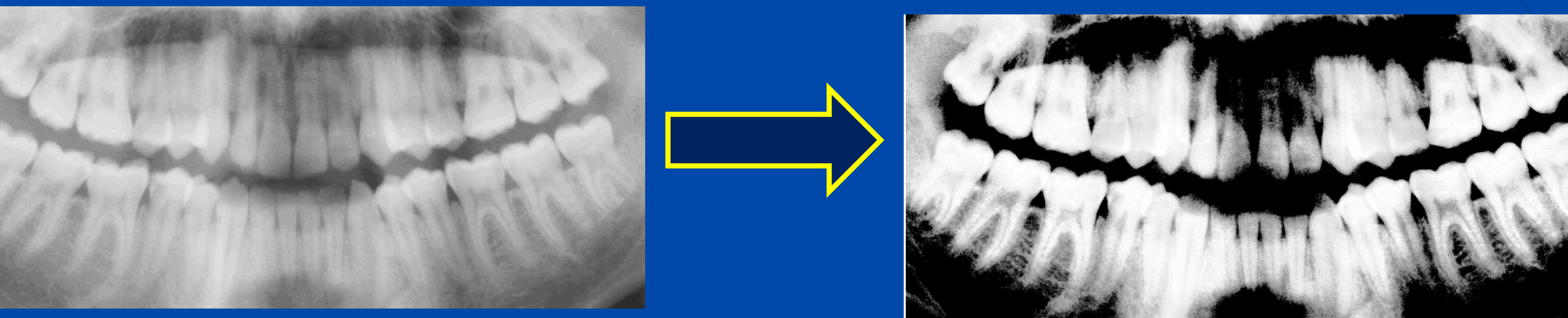
ailure examples, (Due to missing teeth)



3 – Detection of the Teeth Gap Valley

Morphologic pre-processing methods applied to the images:

- The Top-hat and Bottom-hat filtering; (computes the morpholog
opening of the image and then subtracts the result from the original ima

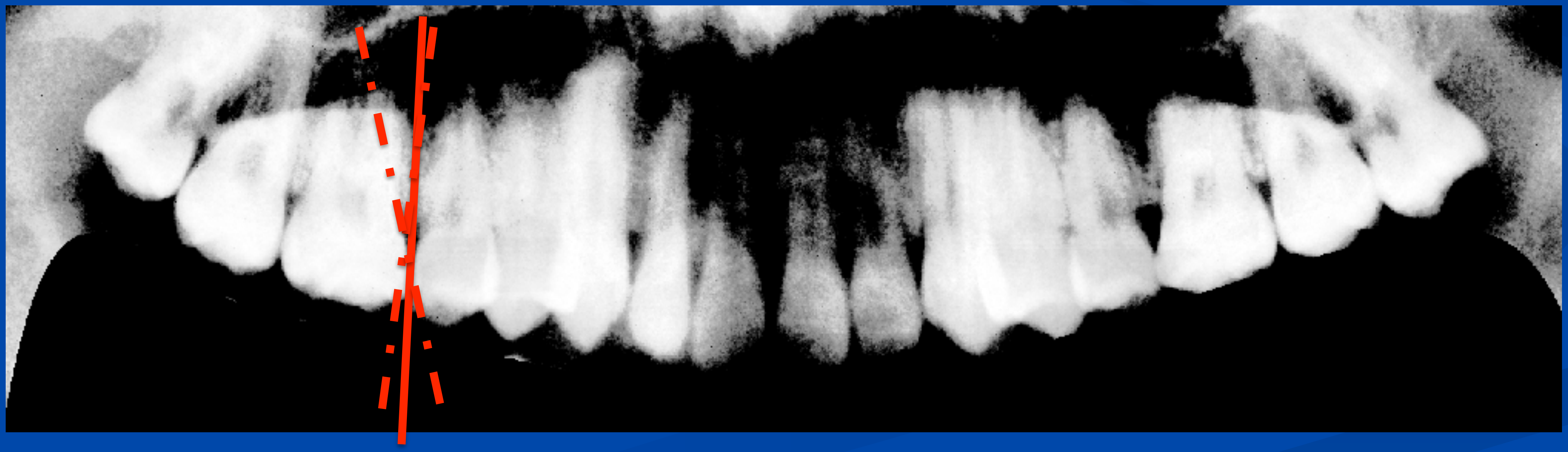


- Crop unusefull data (jaws)

– Detection of the Teeth Gap Valley

The next stage was problematic. The goal was to localize every va
tween teeth.

- Even assuming that lines can appropriately divide teeth, the orienta
and position of each line revealed one of the hardest stages of this wo
- Initial observation was that regions between teeth are darker.



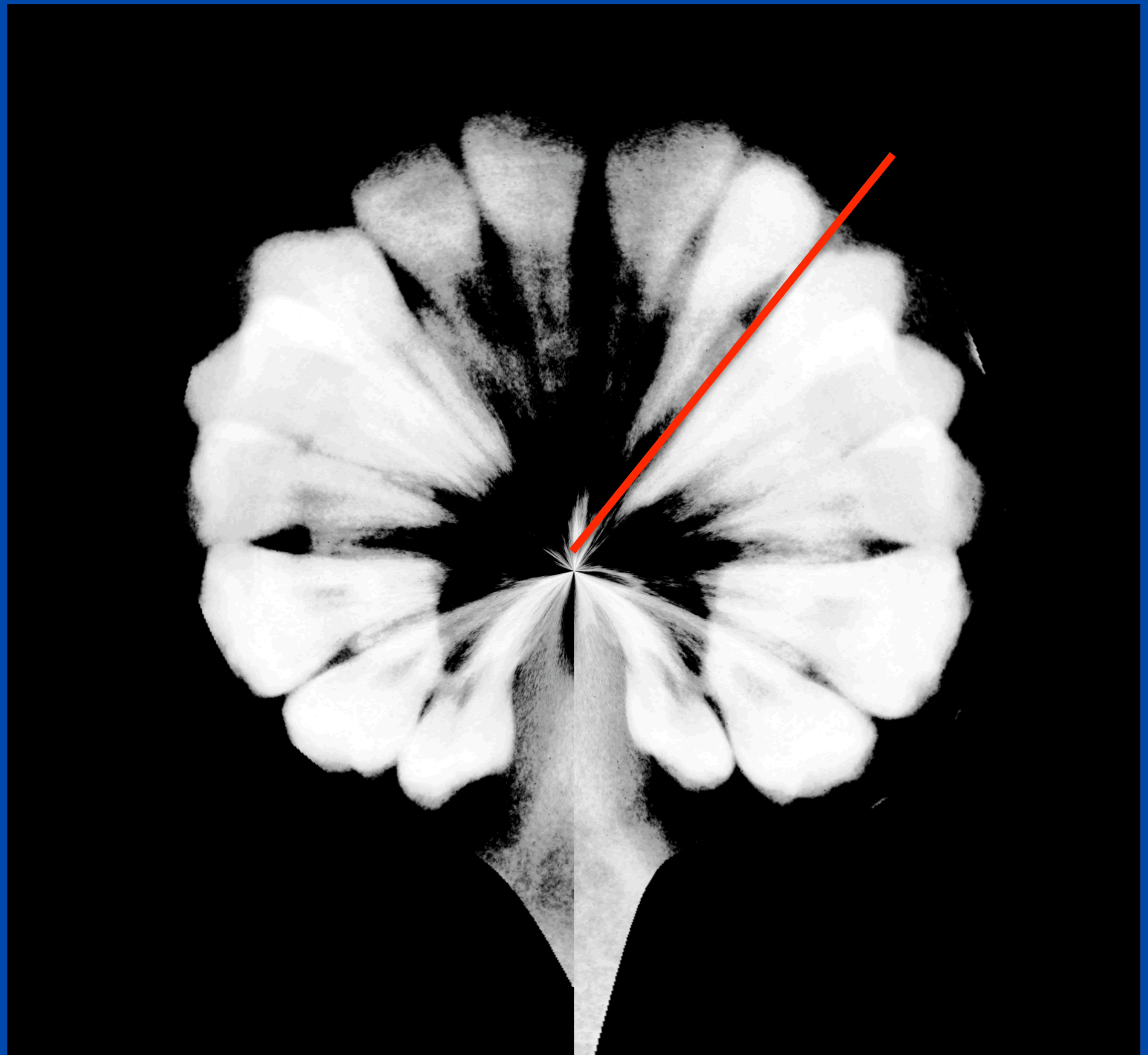
3 – Detection of the Teeth Gap Valley :

he chosen solution translates the original image represented in
rtesian space into polar coordinates;

- The image center was used as the reference point.

- The key insight is that lines that divide theeth are *mostly* radial.

  - Considerably reduces the dimension of the search space.



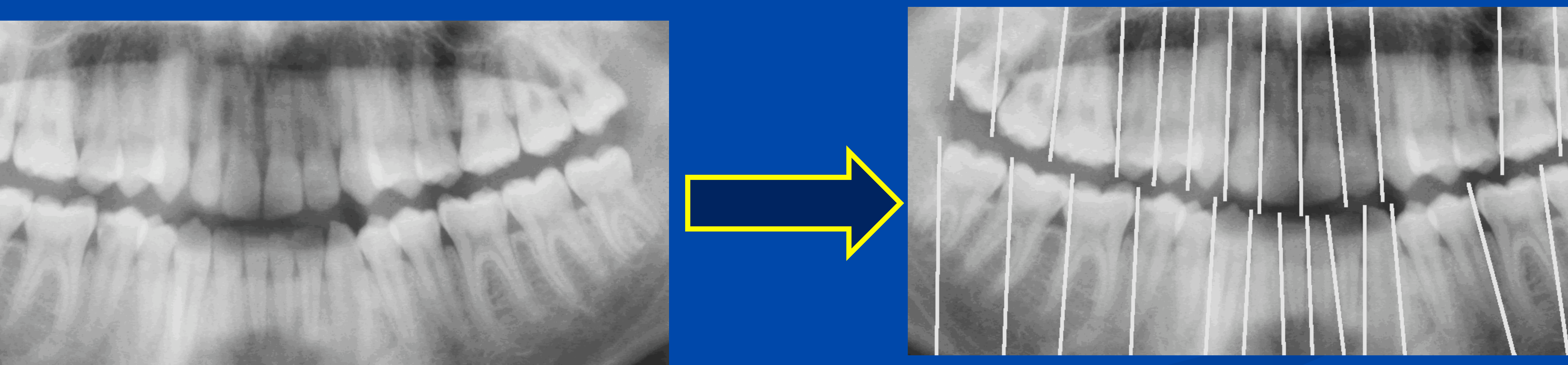
Example of an upper jaw in polar coordinates

3 – Detection of the Teeth Gap Valley :

For each tooth, search for the radial lines with mimimal avera

ensities.

Remapping these lines into cartesian coordinates gives the teeth divisio



4 – Tooth Segmentation

Having a corsely defined region that contains each tooth, the goal is
rform its segmentation

ome of the operations applied in this stage are similar to the previo
es (morphological pre-processing)

- The contour of each tooth is obtained with active contour techniques
  - Tested classical snakes variant, geodesic active contours and chos
    Chan and Vese; *Active Contours Without Edges*, IEEE Transactions
    Image Processing;

Examples:

5 – Dental Caries Features Extraction:

Having each tooth segmented, the problem is regarded as a classi

tern classification task (with two classes).

- Input: Segmented region that contains a tooth.
- Output:Either the tooth has a carie (Class 1) or not (Class 0)

ased in the statistical pattern recognition paradigm.

- Each tooth is regarded as a set of features in a high dimensional spac
- Hopefully, features have discriminating cappacity.
- Contour and regions descriptors.

1.32; 34.76; 67.42 -0.928
12.645 23.454 34.746 12.
4.5 4.854 0.012 0.001 12.

5 – Dental Caries Features Extraction:

A large number of features was extracted:

- Region-based (entropy, median, intensity statistics, moments,...)
- Contour-based (SIFT, chain codes,...)

	Mean	Median	Entropy (3x3)	Min	Max
	49.4690	50.0	0.69	78	236
					

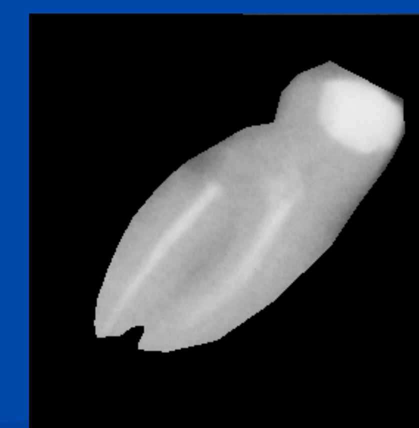
– Dental Caries Features Extraction:

Region-based features (area, hu moments, etc.);

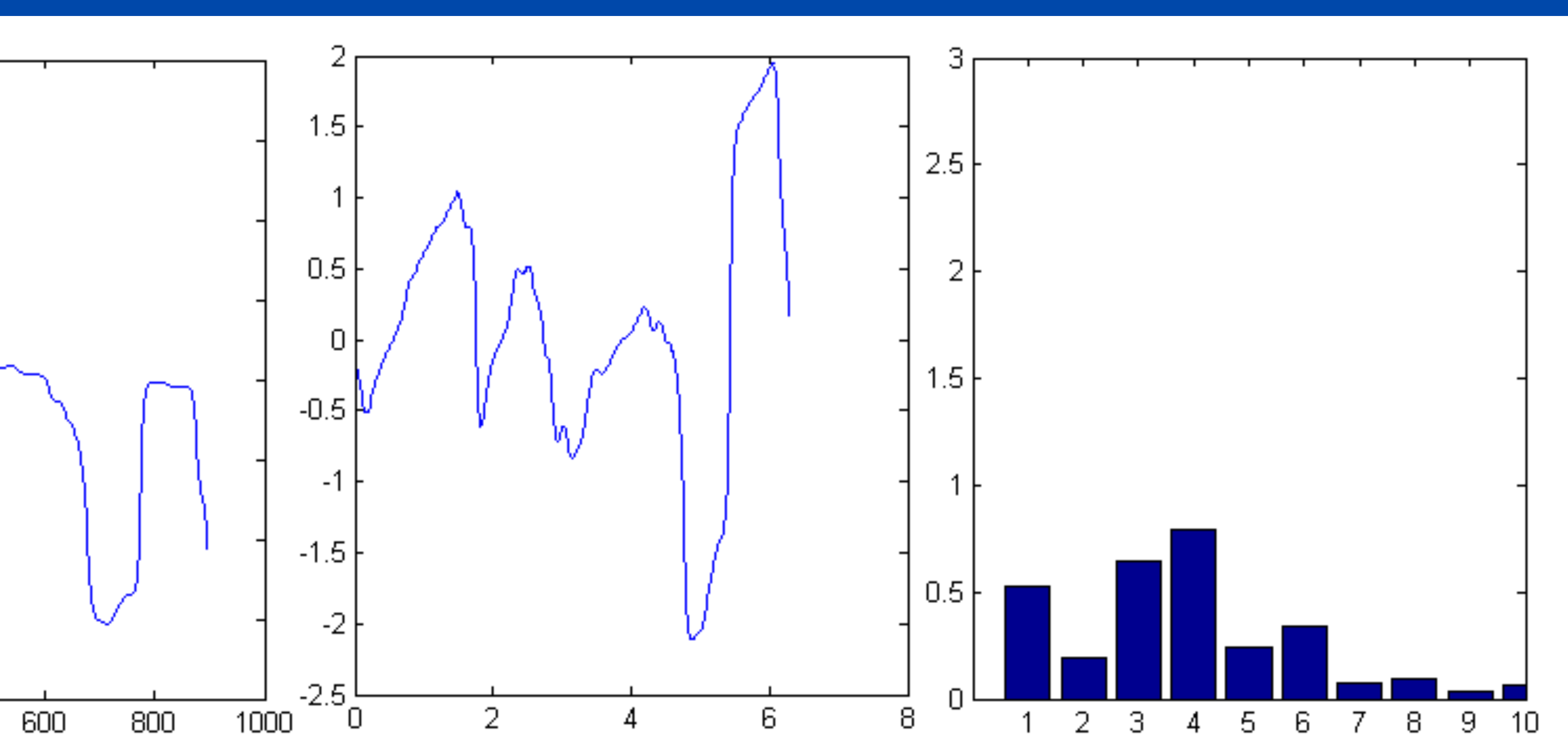
	$H\mu_1$	$H\mu_3$	$H\mu_3$	$H\mu_4$	$H\mu_5$	$H\mu_6$	$H\mu_7$	Area	Euler Number
	6.6236	13.9931	23.4765	26.2996	52.1814	33.7726	51.3743	21906	2
	6.8630	15.2387	23.0212	24.3041	47.9695	31.9239	50.6677	27512	1

– Dental Caries Features Extraction:

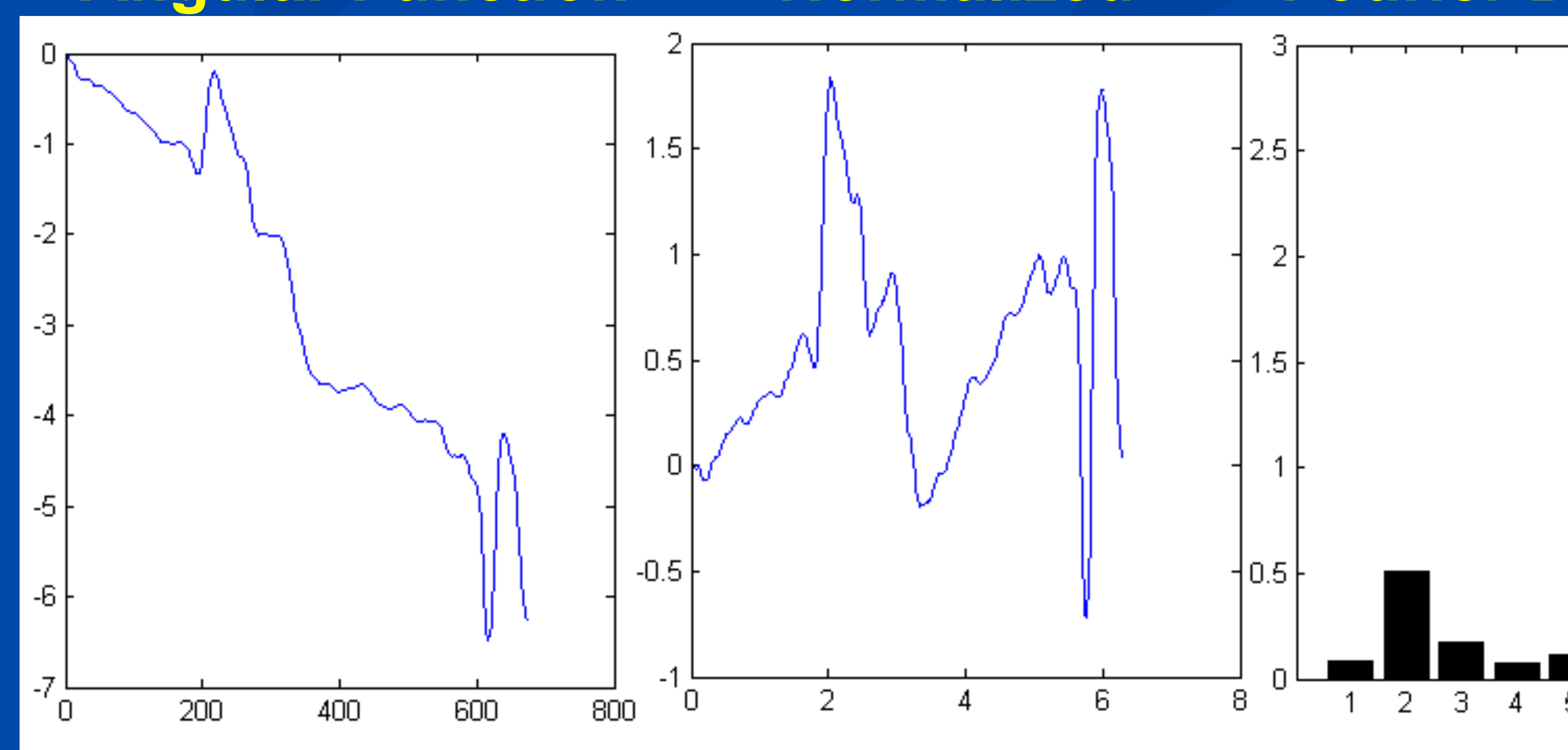
- exture-based features (energy, third moment, etc.);
- Contour-based features (fourier descriptors, MMP);



Function Normalized Fourier Descriptors



Angular Function Normalized Fourier D



5 – Dental Caries Feature Normalization and Selection

- Feature Normalization. Tested two normalization strategies:
  - Linear mapping to the unit interval.
  - Zero mean and unit variance: $\frac{x-\mu}{\sigma}$
- Feature Selection.
  - The high dimensionality of the feature space was a problem (over 50
  - It is known that such high dimensional feature spaces will deman

huge number of instances to be proper populated.

5 – Dental Caries Feature Normalization and Selection

- PCA: Principal Components Analysis

  - Transforms a number of possibly correlated features into a sma

    number of uncorrelated ones, called principal components.

  - Based in the eigenvalues / eigenvectors and covariance ma

    concepts, its operation can be thought of as revealing the inter

    structure of the data in a way which best explains the variance in

    data.

eature 1, Feature 2, ... Feature N → Feature 1'; 75%
Feature 2'; 12%
...
Feature N'; 0.01%

5 – Dental Caries Classification (Ongoing)

- Having a learning set:
  - Half divided between positive and negative examples.
  - Performed feature extraction for each example.
  - Reduce the dimensionality of the feature space (PCA).
- Experimented several types of classification methods:
  - Bayesian Classifiers, Neural Networks, Nearest Neighbors a Support Vector Machine;

Results:

Stages	Results (% of correct)
ge 1 – ROI definition	95.7
ge 2 – Jaws Partition	92.6
ge 3 – Teeth Gap Valley Detection ge 3.1 – Teeth Division	87.5
ge 4 – Tooth Segmentation	98,7
ge 5 – Dental Caries Classification	In Progress

Further Work

e improvement of the teeth segmentation stage by using active contour

he all process (undone due to computation concerns);

dd knowledge-rules to the feature extraction process:

- Examples:

  - The size of the dark area of the tooth in contact with the outer parts

    the crown;

  - Template matching of the tooth border, for cases where the dental ca

    artially or totally, damaged the tooth crown;