Multidimensional image selection and classification system based on visual feature extraction and scaling

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OVERVIEW

- Aims
- Choice of image features
- Definition of algorithms
- Business Intelligence (BI) structure
- Image similarity
- Psychophysical investigation
- Results and conclusions

AIMS

To provide an alternative method for classifying and searching images.

- **Innovative answer** by going beyond the use of text descriptors
- **Use of image feature extraction** as main browsing variable
- **Creation of relevant ‘feature’ scales** that correlate with visual perception.
- **Assist the selection** of test images employed in Image Quality investigations.

CHOICE OF VISUAL FEATURES

Image Analysis involves:

- ***Low-level* based:**

  Structural and visual analysis

- ***Global* analysis:**

  No use of local image / salience info

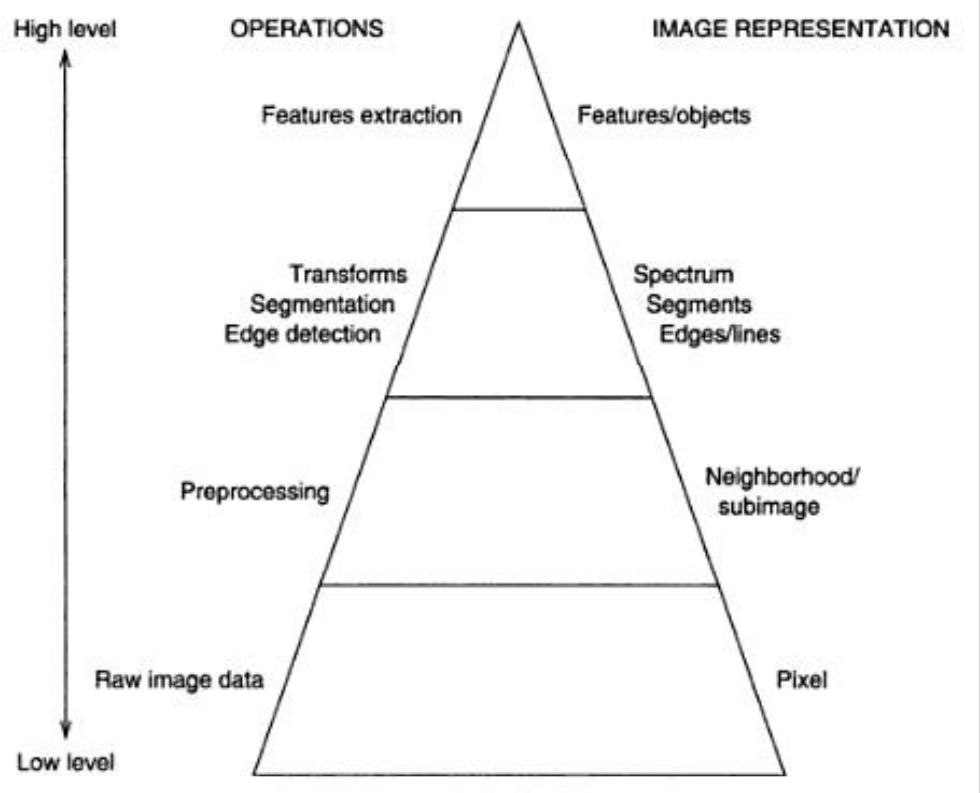


*Image analysis diagram on low and high level information from Umbaugh S. E. – "Computer Imaging: Digital Image Analysis and Processing"

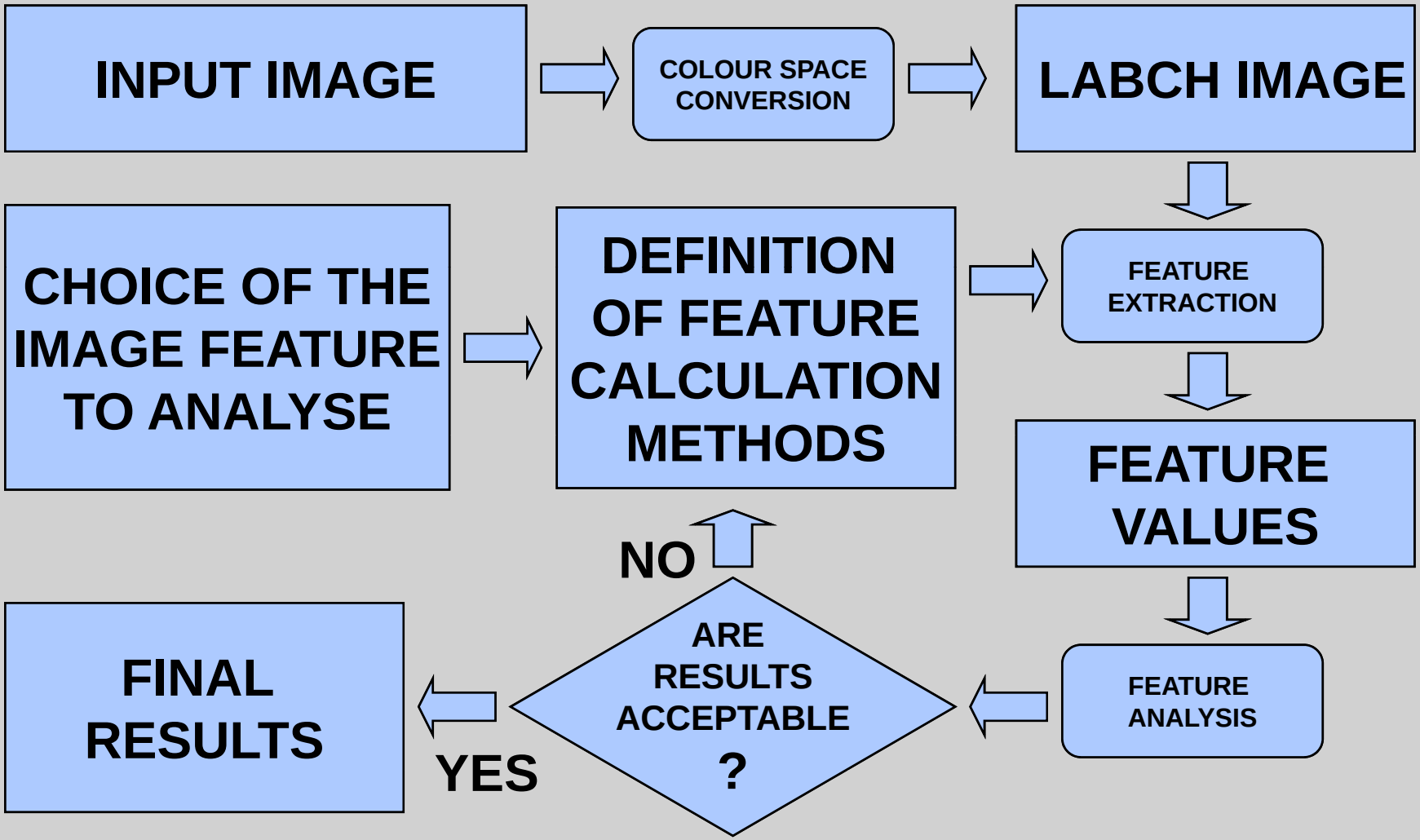
CHOICE OF VISUAL FEATURES

- **Tonal information:** retrieved from CIELAB L^* channel:
  - ***Lightness***
  - ***Contrast***

- **Chromatic information:** retrieved from CIELAB h^* and C^* channels:
  - ***Colourfulness***
  - ***Colour Contrast***
  - ***Dominant Hue(s)***

- **Amount of the detail:** retrieved from CIELAB L^* channel:
  - ***Busyness***

ALGORITHM DEFINITION



ALGORITHM DEFINITION

LABCH Colour Space specifications:

- Coordinates derived from CIELAB L^*_{ab}, a^*, b^* coordinates

- Values rescaled to fit a [0, 100] range

  - **L** $\in$ [0, 100] rescaled from L^*_{ab}
  - **A** $\in$ [-50, 50] rescaled from a^*
  - **B** $\in$ [-50, 50] rescaled from b^*
  - **C** $\in$ [0, 100] rescaled from C^*_{ab}
  - **H** $\in$ [-50, 50] rescaled from h^*_{ab}

ALGORITHM DEFINITION

Lightness = μ (μ(L), m(L))

Mean and median both contribute to our perception of Lightness

- **Contrast = 10^{*} (σ(L))**

  Standard deviation as index of contrast

- **Colourfulness = μ(10* σ(C), μ(C), m(C))**

  Colour contrast contributes to our perception of Colourfulness.

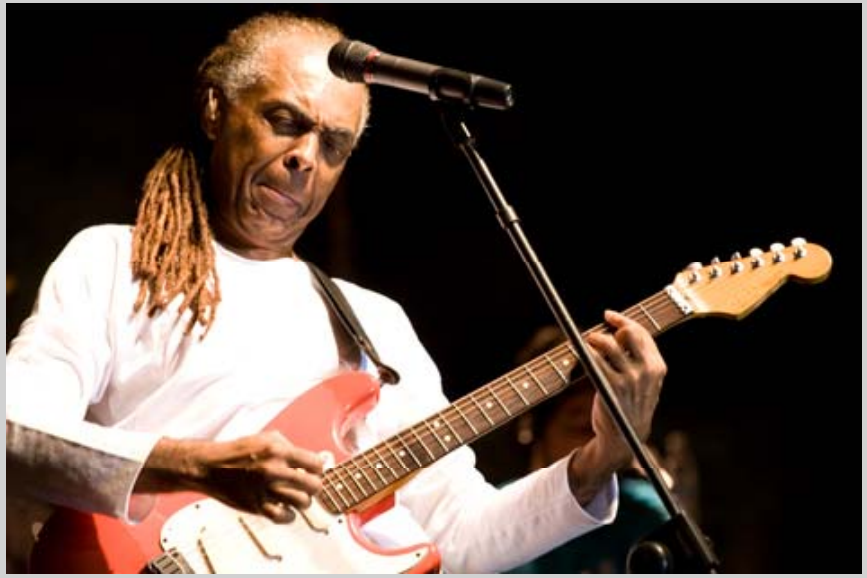
- **Colour Contrast = 10^{*} (σ(C))**

  Standard deviation as index of contrast

μ = mean, m = median, σ = standard deviation

ALGORITHM DEFINITION

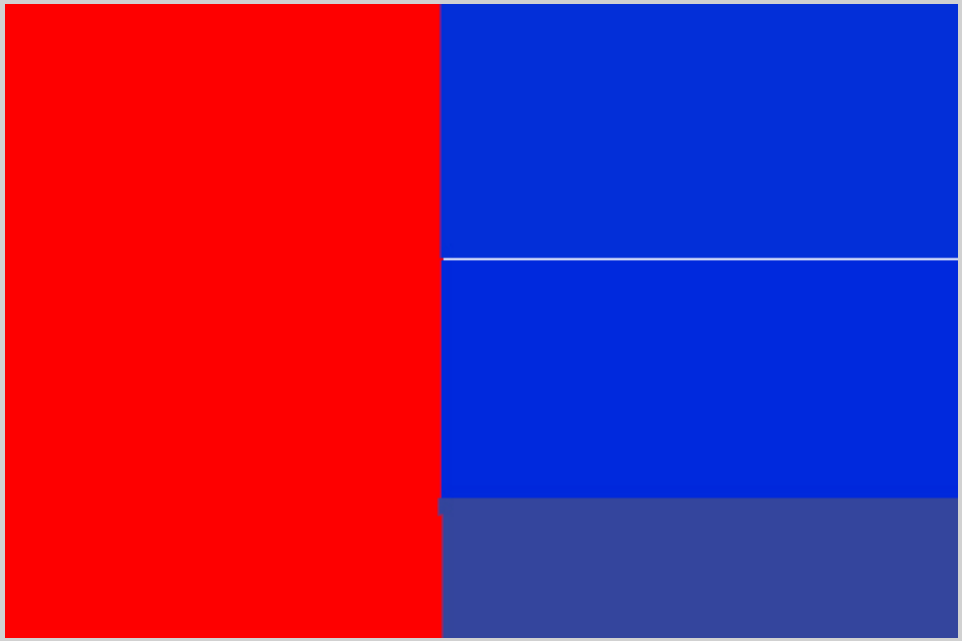
DARKER THAN THIS
IF USING MEDIAN



LIGHTER THAN THIS
IF USING MEAN

ALGORITHM DEFINITION

Which is the most dominant hue in this image?



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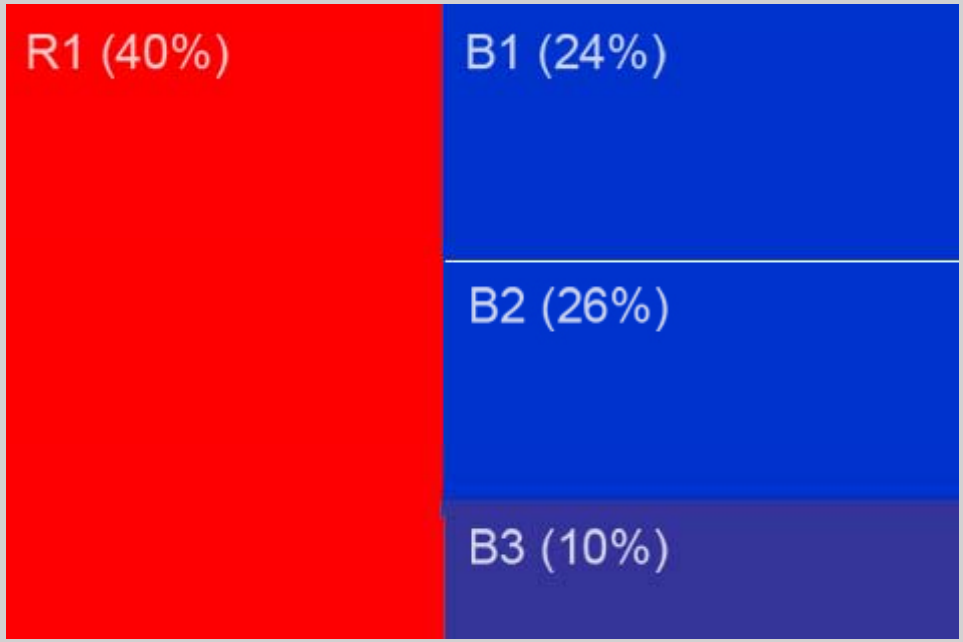
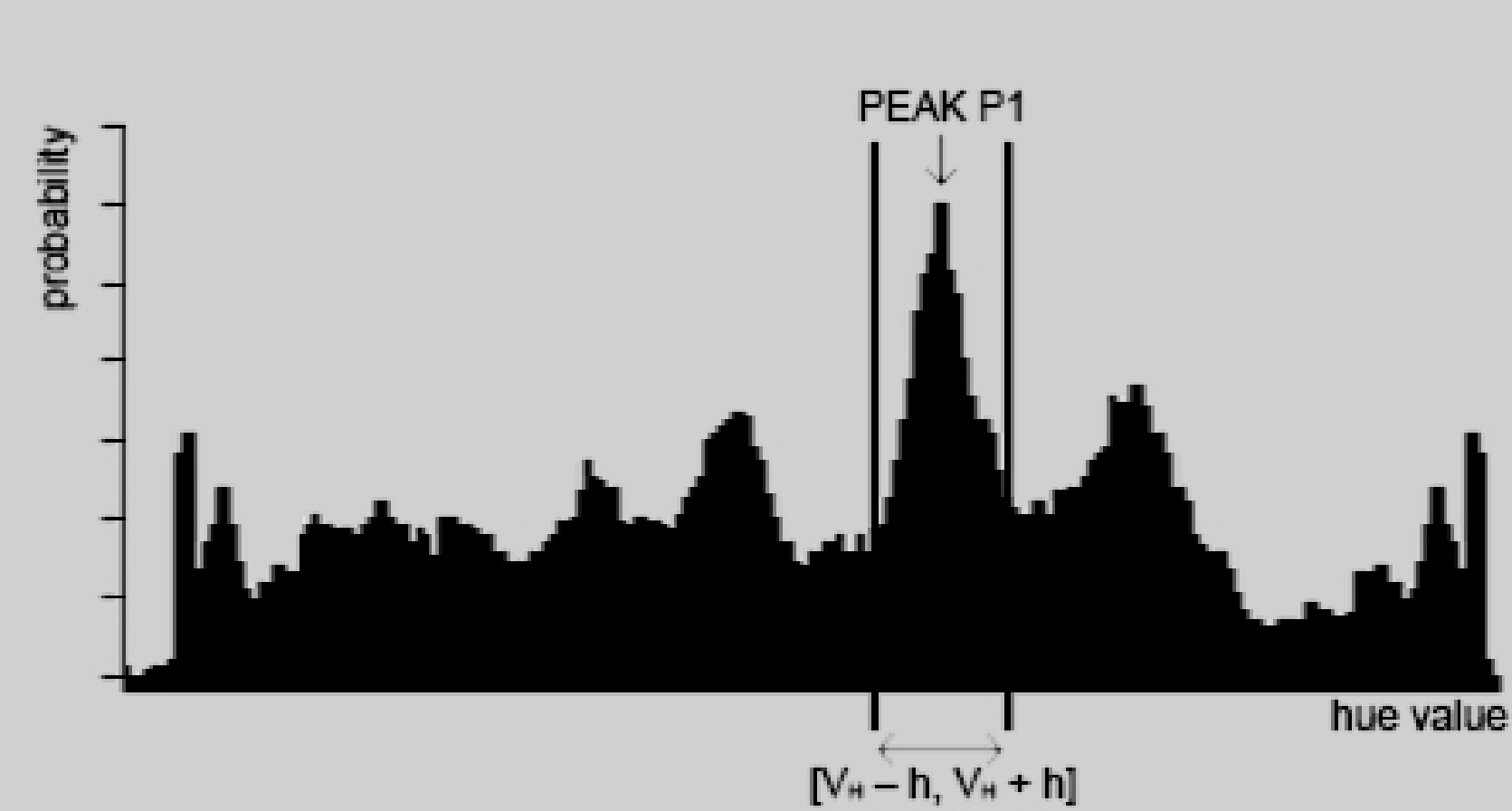


ALGORITHM DEFINITION



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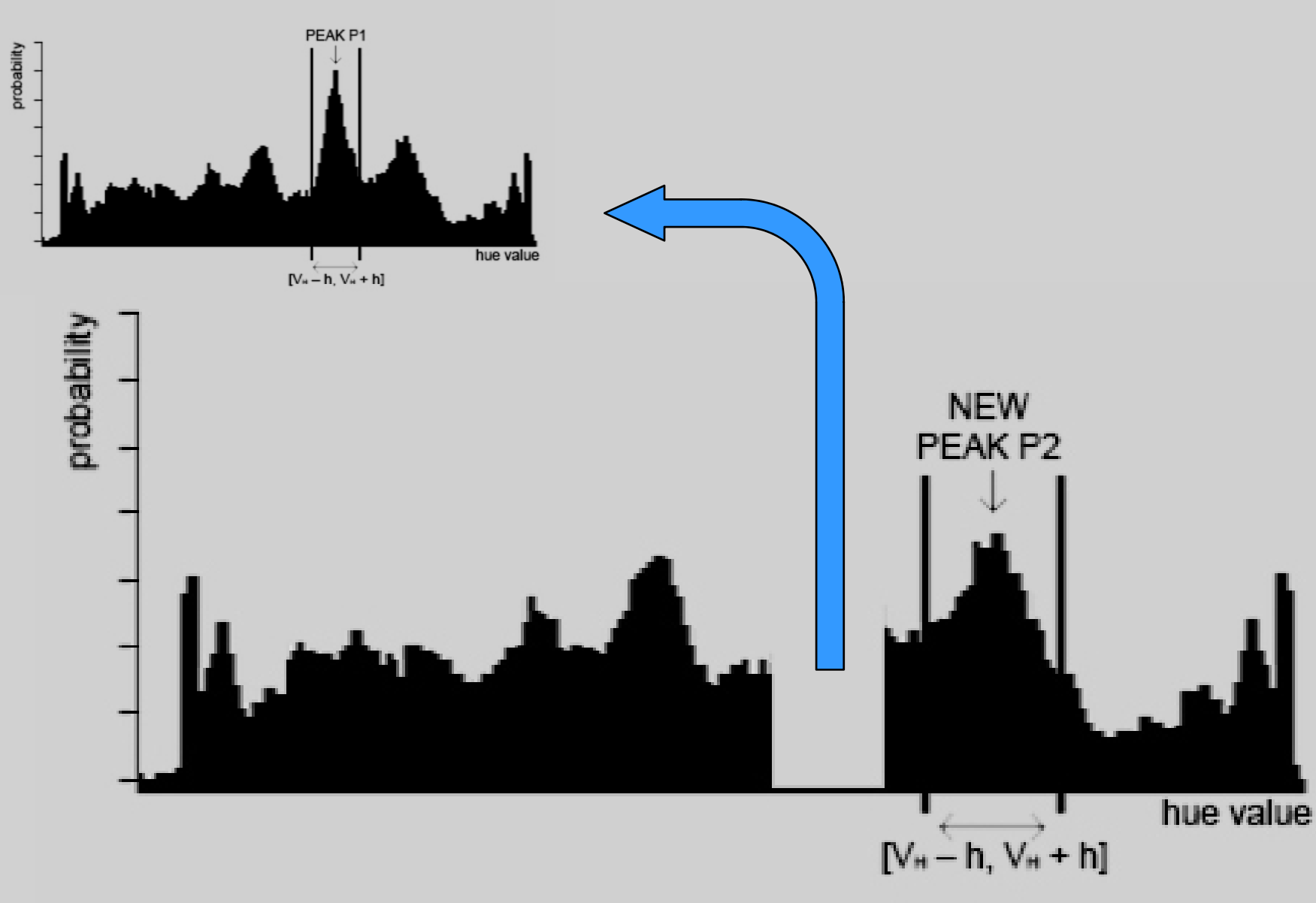

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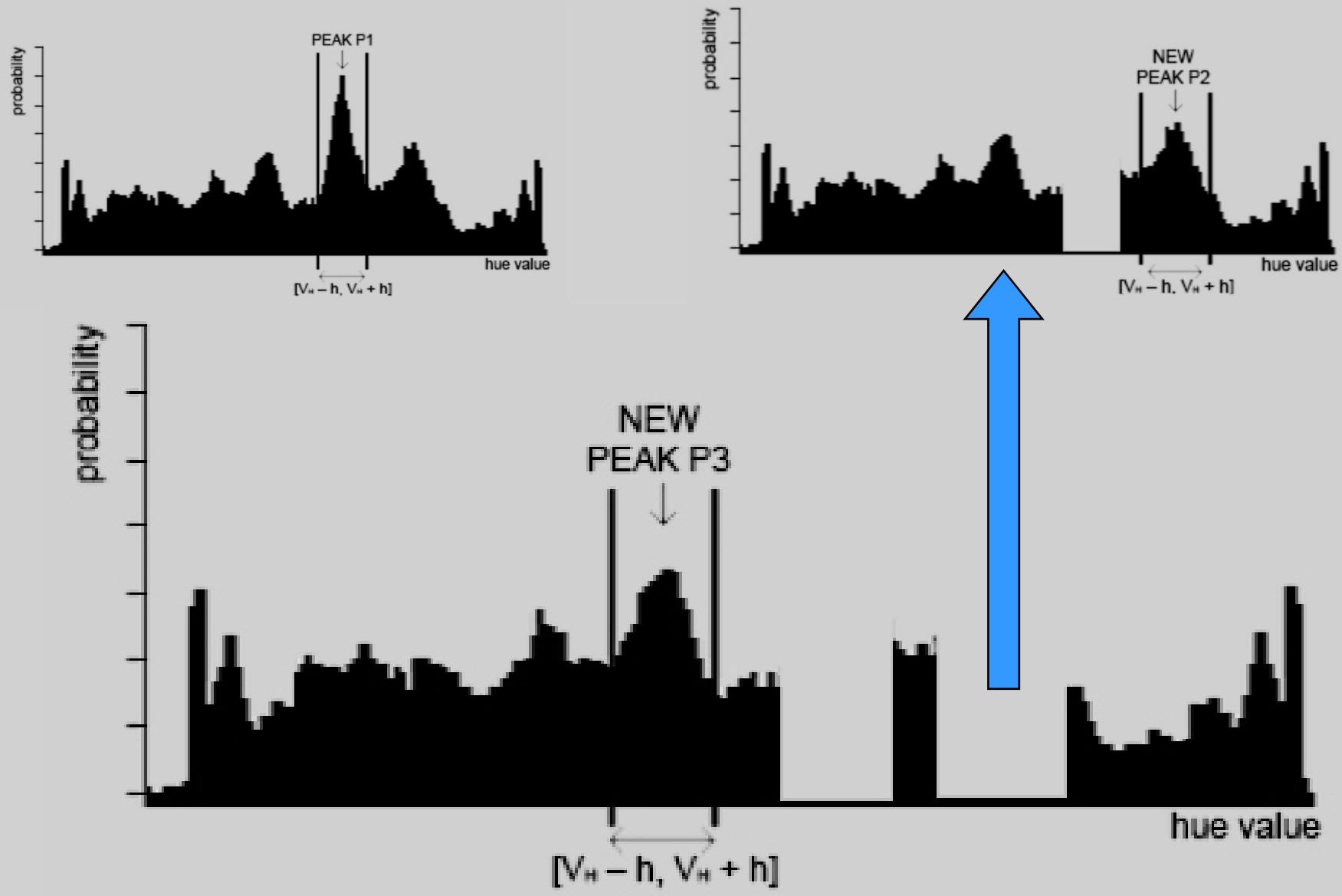


ALGORITHM DEFINITION

Given a HUE VALUE $\mathbf{V_H}$ and its width $\mathbf{W_H}$:

- **V_H = Hue value = MODE**
- **Width $W_H = [V_H – h, V_H + h]$**
  where h min that has $\mu(W_H) > P_{MIN}$
- **$P(W_H) = Sum\ (P(V_i))$**
  where $V_i \in [V_H – h, V_H + h]$

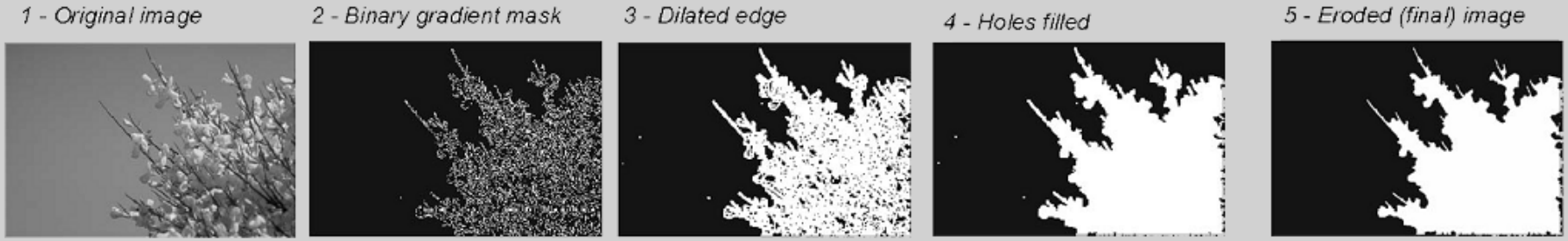
P1, P2 and P3 sorted according to cumulative **$P(W_{H1,2,3})$** to find:

Dominant Hue = Hue with Highest $P(W_H)$

ALGORITHM DEFINITION

Busyness was defined using segmental approach:

- **ratios** between “detailed” and “flat” areas
- **different sensitivity** achieved if changing thresholds

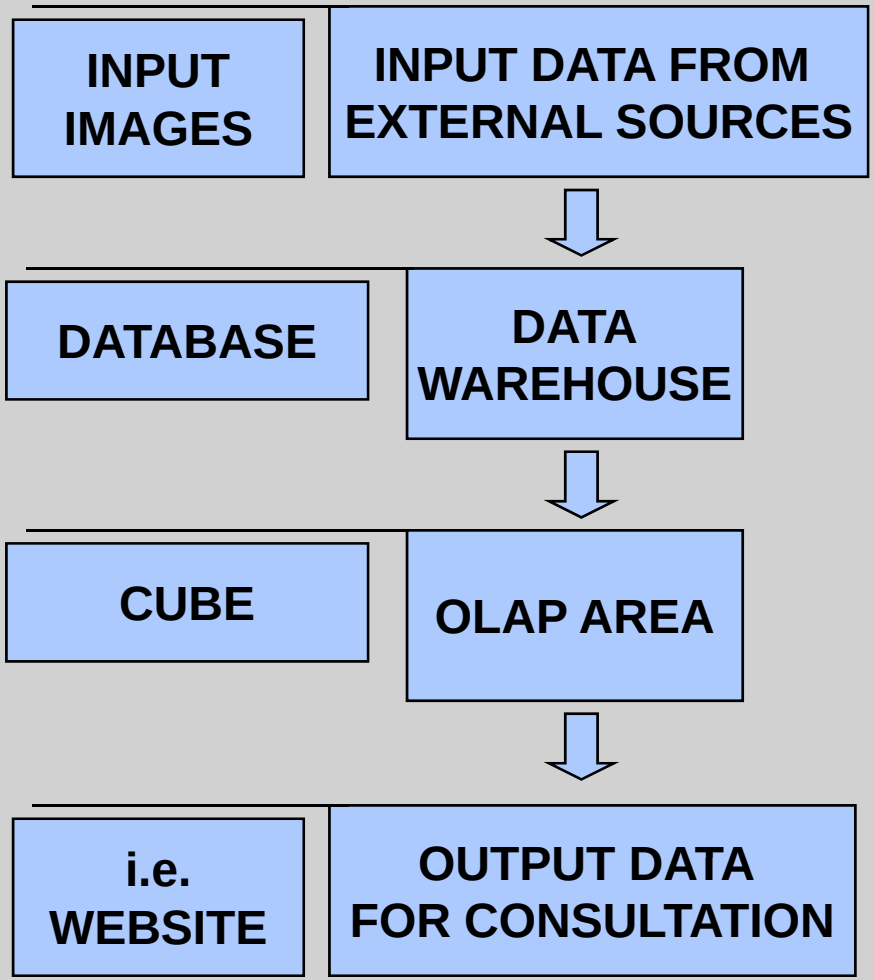


- ***Busyness = BUSY (white) AREA / IMAGE AREA***

*** Triantaphillidou S., Allen E. and Jacobson R. E. – “Image Quality Comparison between JPEG and JPEG2000 – II. Scene Dependency, Scene Analysis, and Classification”, Journal of Imaging science and technology, vol 51, n 3, MAY/JUN 2007.**

DATA STRUCTURE

Use of “Business Intelligence” (BI) structure.



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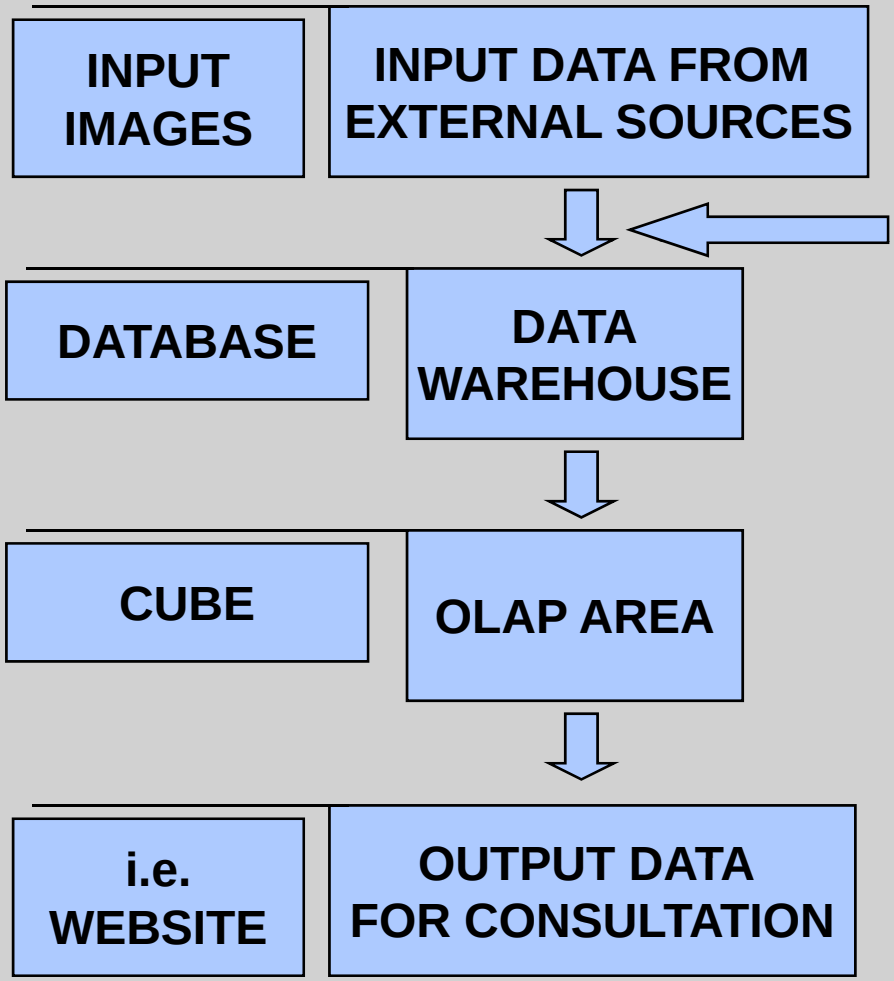

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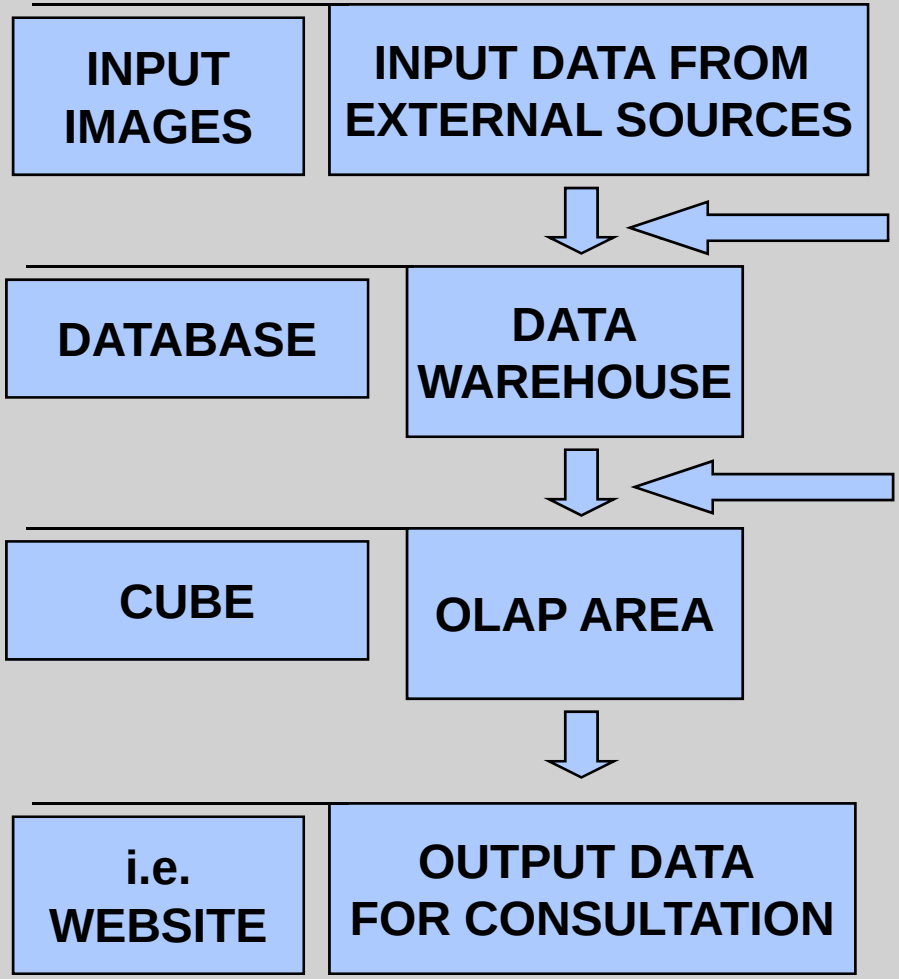

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- **OLAP ENGINE:** manages the multidimensional structure of the BI project: the **Cube**.

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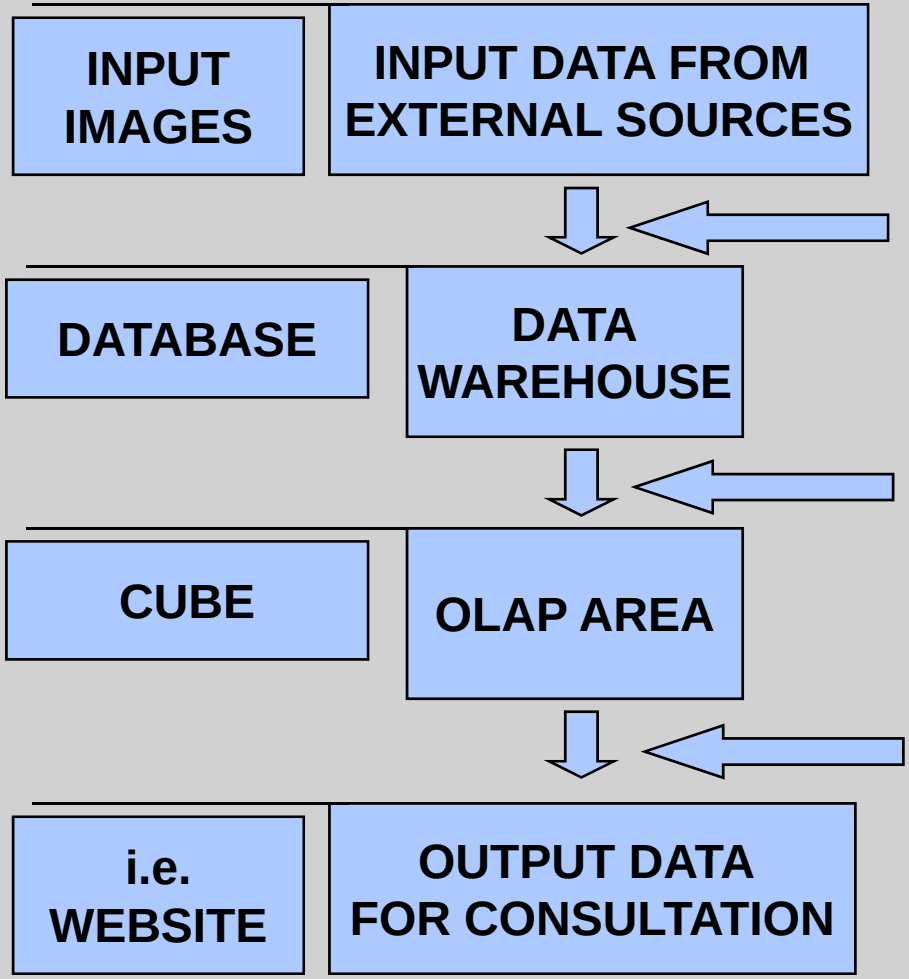
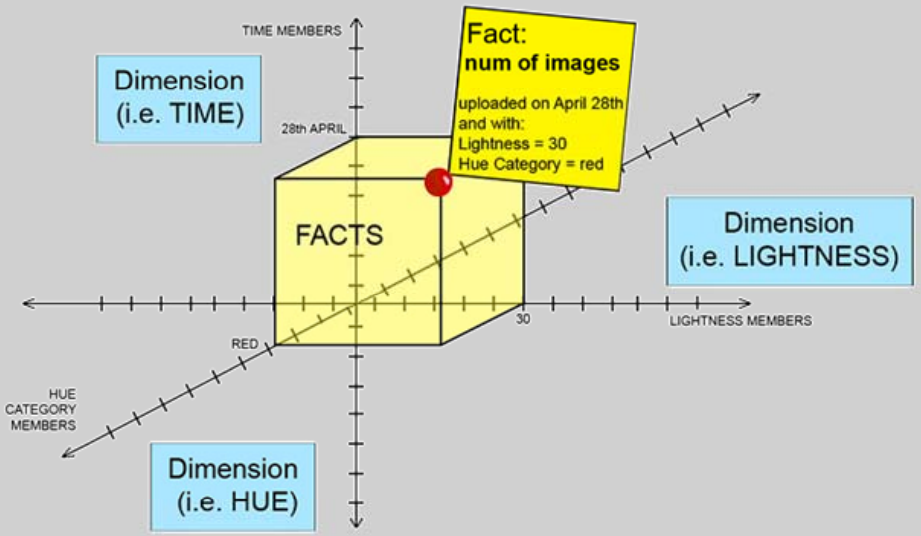


- **ETL:** sequence of operation to extract, transform and load data from sources into a Data Warehouse.
- **OLAP ENGINE:** manages the multidimensional structure of the BI project: the **Cube**.
- **REPORTING TOOLS:** allow the visualization of the information of the Cube.

DATA STRUCTURE

- ***Dimensions*:**
  feature descriptors, expressed in Cartesian space.
  - define *granularity*
  - grouped into hierarchical categories.
  - called *members*

- ***Facts*:**
  Co-domain space
  of the Cartesian space
  - numeric values
  - aggregation apply
  - e.g. # of images



SIMILARITY

- Browsing the cube by querying for ***facts*** (i.e. images)

- The condition of the query is a ***set of coordinates***

  e.g. # of “red” images = sum of images for all lightness levels that respond to “hue = red”

- **Euclidean distance** within facts:
  - calculated in the **Cartesian space**
  - defines **how “close”** two images are
  - used to derive an index of **similarity**

SIMILARITY

The ***similarity*** **factor:**

$$\textbf{SIMILARITY} = 100 - \left[\left(\Sigma^{6}_{i=1}\,(D_{1i} - D_{2i})^{2}\right)^{1/2} / \,(D_{\#})^{1/2}\right]$$

- $D_{\#} = 6$ = number of dimensions
- D_{1i} = value [0, 100]
- Smallest difference taken for hue angles

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- Hypothesis of visual closeness:
  - feature extraction is linear with perception and
  - features are weighted on their visual importance

PSYCHO-VISUAL TEST

- Feature extraction linear with perception:
  - Conduct psycho-visual tests
- Features weighted on their visual importance
  - Further work
- **Thesis:** Similarity = valid index for “visual closeness”

PSYCHO-VISUAL TEST

- Aim: derive perceptual scales for the individual image features, i.e.:
  - perceived image lightness
  - perceived image contrast
  - perceived busyness
  - etc

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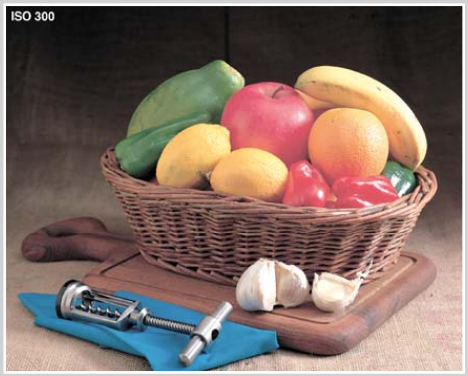
- Categorical scaled was employed - 5 categories ranging from 'low' to 'high'
- Internet-based studies
- Relevant user information was collected:
  - age, sex, visual ability/deficiencies
  - computer/display/system info
  - perceived brightness, hue shift, gamma

TEST IMAGES

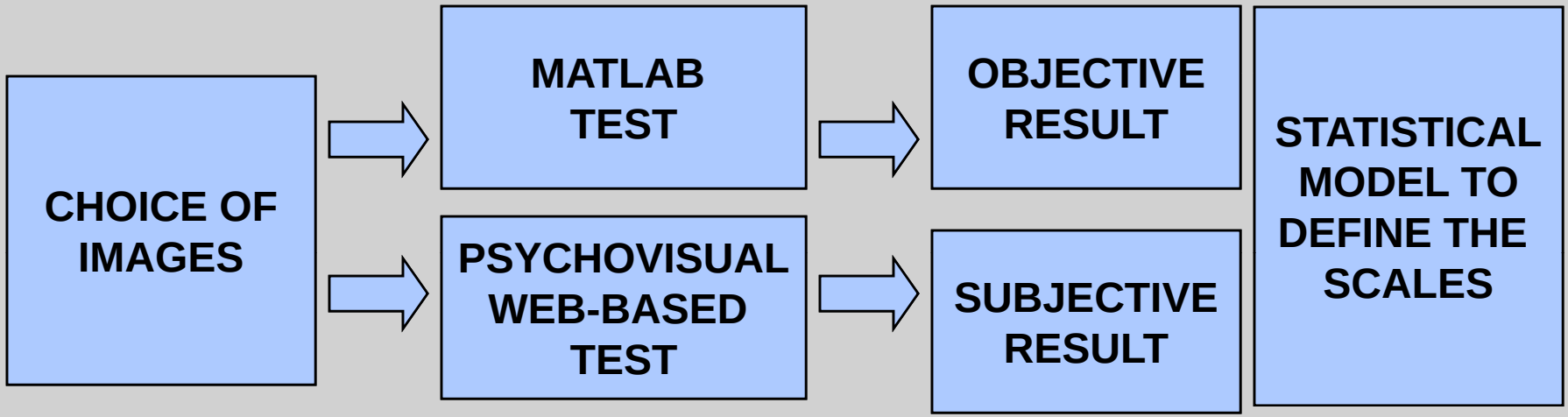

FIAT
marlboro
arexons
MAGNETI MARELLI
SKF
WEBER
PIONEER
Agip


ISO 300


ISO 300


ISO 300

PSYCHO-VISUAL TEST



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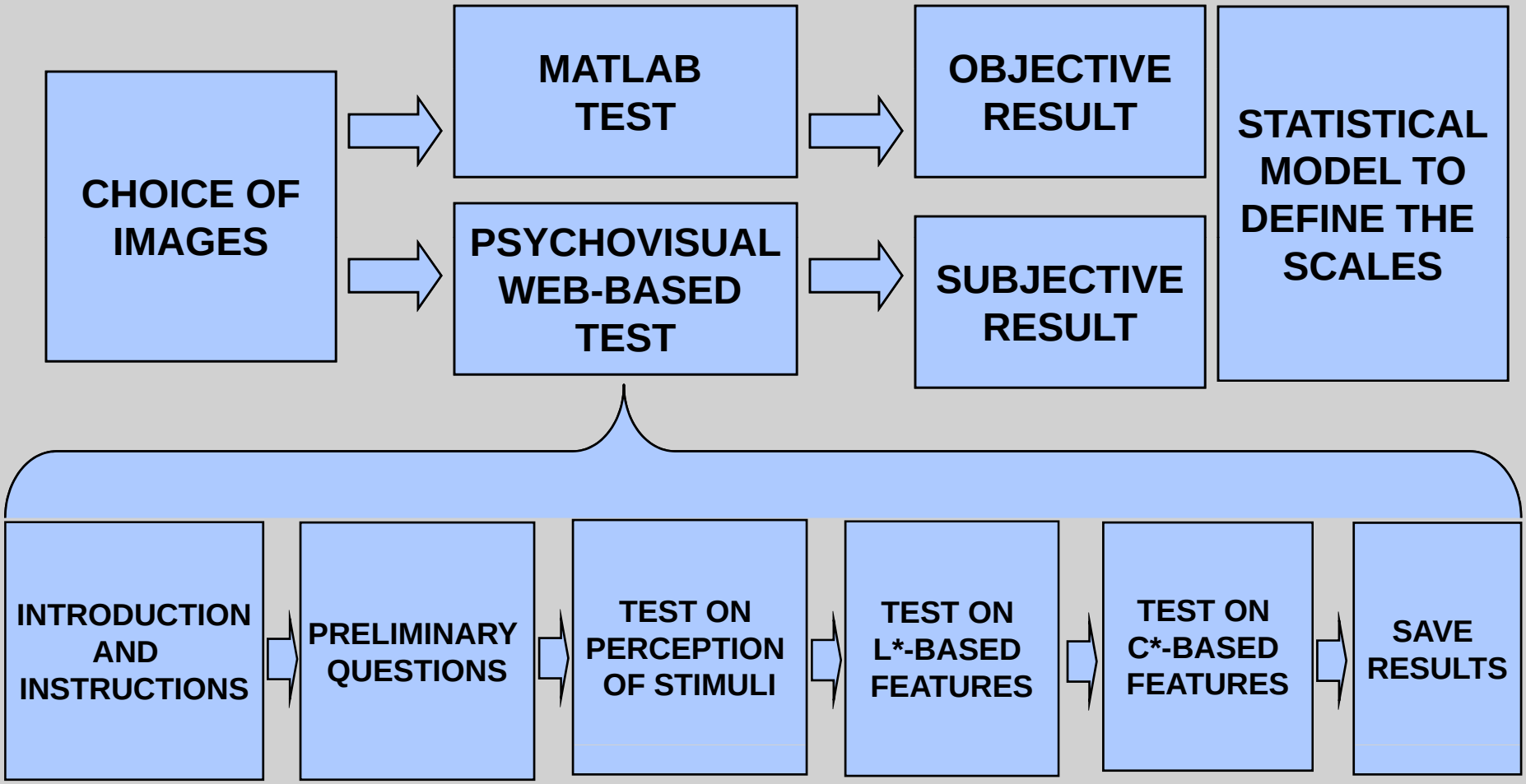


PSYCHO-VISUAL TEST

QUESTIONNAIRE

AGE <12

GENDER M

VISUAL CORRECTION NO CORRECTION NEEDED

COLOUR DEFICIENCY NO DEFICIENCY

OPERATING SYSTEM WINDOWS

BROWSER Internet Explorer

DISPLAY TYPE LCD

SCREEN SIZE 13" OR LESS

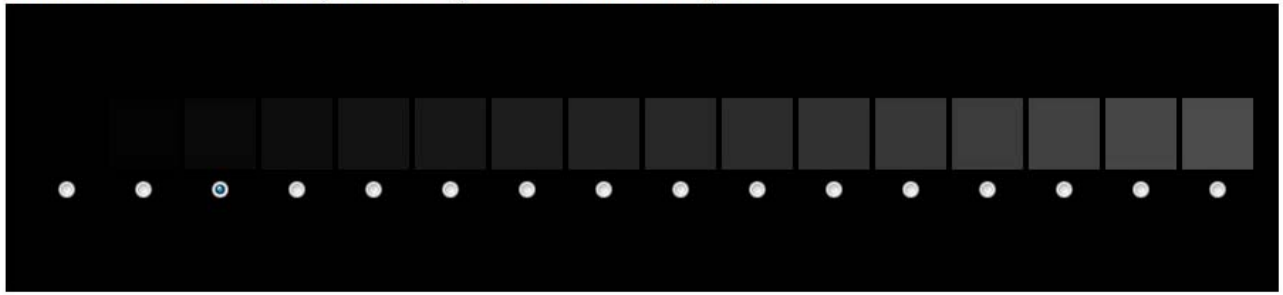
SURROUNDING ILLUMINATION Room/ambient

START WITH THE CALCULATION OF THE SCREEN PERFORMANCES

PSYCHO-VISUAL TEST

BLACK AND WHITE POINTS

Please select the darkest patch you can distinguish from the black background.



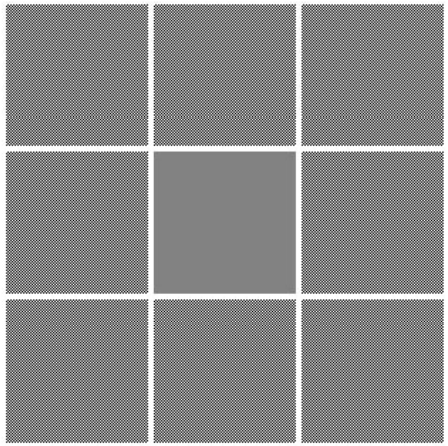
Please select the lightest patch you can distinguish from the white background.

NEXT

PSYCHO-VISUAL TEST

GAMMA CALCULATION

Please move the bar until the lightness of the inner patch matches the outer's one.

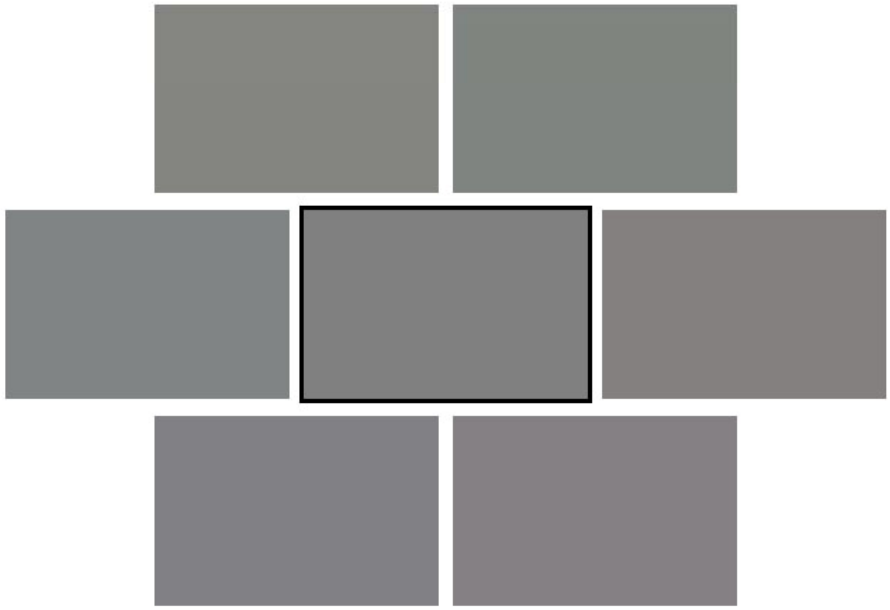


NEXT

PSYCHO-VISUAL TEST

HUE SHIFT CALCULATION

Please select the grey patch that you consider to be the closest to NEUTRAL.
In case you do not see any differences, please select the patch in the center.



START WITH THE PSYCHOVISUAL TEST

PSYCHO-VISUAL TEST

Image 4 / 38

LIGHTNESS:	○ Very low	○ Low	○ Medium	◉ High	○ Very high
CONTRAST:	○ Very low	◉ Low	○ Medium	○ High	○ Very high
BUSYNESS:	○ Very low	○ Low	◉ Medium	○ High	○ Very high

NEXT IMAGE

PSYCHO-VISUAL TEST

Image 1 / 36

COLOURFULNESS:	○ Very low	○ Low	○ Medium	◉ High	○ Very high	
COLOUR CONTRAST:	○ Very low	◉ Low	○ Medium	○ High	○ Very high	
MOST DOMINANT HUE:	○ Yellow	◉ Red	○ Green	○ Cyan	○ Blue	○ Magenta
	○ Neutral	○ Caucasian skin tones	○ More than two hues			

NEXT IMAGE

RESULTS

MODE/MEAN vs OBJECTIVE RESULTS (image Gilberto)				
	ID	**Mean Description**	**Mode Description**	**Objective**
		...		
L	33	Middle Lightness	Middle Lightness	Very Dark
		...		
C	33	High Contrast	High Contrast	Very High Contrast
		...		
B	33	Low Busyness	Medium Busyness	Low Busyness
		...		
CI	33	Low Colourfulness	Middle Colourfulness	Middle Colourfulness
		...		
CC	33	Medium Colour Contrast	Medium Colour Contrast	High Colour Contrast
		...		
H	33	N/N	Neutral	Neutral

CORRELATION TABLE

	% mode=mean	% obj=mean	% obj=mode
Lightness	60,53%	60,53%	42,11%
Contrast	55,26%	50,00%	28,95%
Busyness	55,26%	28,95%	44,74%
Colorfulness	63,16%	57,89%	47,37%
Color contrast	68,42%	42,11%	36,84%
Dominant Hue	0,00%	0,00%	42,11%

CONCLUSIONS

- **RESULTS ARE PRELIMINARY:**
  - need more images
  - need more observervations
  - statistical studies on possible models

- **FOLLOWING TASKS:**
  - Analysis of the scales
  - Evaluation of the feature weights
  - Evaluation of saliency to ameliorate measures

CONCLUSIONS

- **IMAGES CLASSIFICATION ON INNER FEATURES**
- **GLOBAL APPROACH ON LOW LEVEL ANALYSIS**
- **FLEXIBLE MULTIDIMENSIONAL STRUCTURE**
- **FEATURE CLOSENESS AS INDEX OF SIMILARITY**
- **PSYCHOVISUAL TEST TO CORRELATE GLOBAL PERCEPTION WITH OBJECTIVE MEASURES**
- **FURTHER WORK TO WEIGHT FEATURES ON THEIR VISUAL IMPORTANCE**

Many thanks for your attention

You can access the psycho-visual test
and learn more about by visiting:

www.francescomancusi.com/IGLHUE

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