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Content-Based Image Retrieval in Digital Libraries of Art Images Utilizing Colour Semantics

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Structure of My PhD Thesis

- Introduction
- CBIR in Art Image Collections – the State of the Art
- Real and Digitized Colour World
- Some Examples of CBIR Systems
- Proposed Set of Visual Attributes
- **The System APICAS**
- Experimental Results
- Conclusions and Future Work

1. Resource Discovery in Art

The growth of available digital resources increases the users' expectations for easy resource discovery by different criteria:

- specific movement or artist,
- particular theme or composition,
- purely aesthetic influence of the paintings.

The goals of the dissertation are:

- to provide a detailed analysis of the colour theories, especially on existing interconnections in successful colour combinations;
- to formalize them in order to implement automated extraction from digitized artworks.

2. Content-Based Image Retrieval (CBIR)

Content-based image retrieval is an area which applies methods for self-extracting knowledge from the image content of the digital picture archives.

... like in Baron Münchhausen adventure where he pulls himself out of a swamp by his hair.

2. Content Base Image Retrieval (CBIR)

CBIR - three components:

- Feature design - to make mathematical description of an image for the retrieval purposes as its signature
  - features: colour, texture, salient points, shape, spatial relations...
  - data reduction techniques - dimensionality, numerosity
- Indexing - organizing in a database
  - access methods
- Retrieval - the retrieval engines build the bridge between the internal space of the system and the user making requests which need to be satisfied
  - similarity - numerical, categorical, for probabilities, for structures...
  - techniques for improvement image retrieval, such as clustering, categorisation...

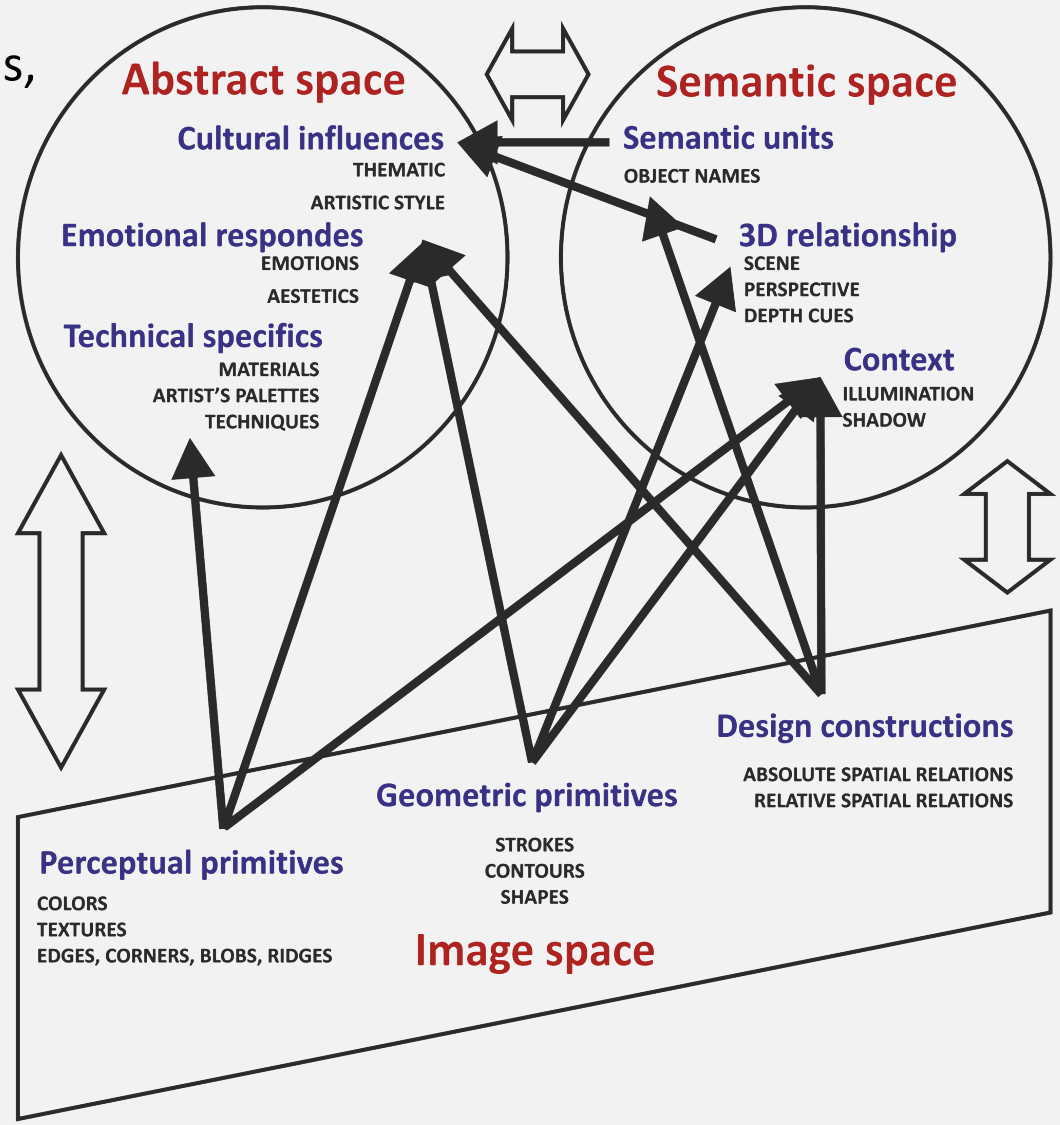
3. Art Image Content

Image space contains visual primitives, needed to record an image through visual perception.

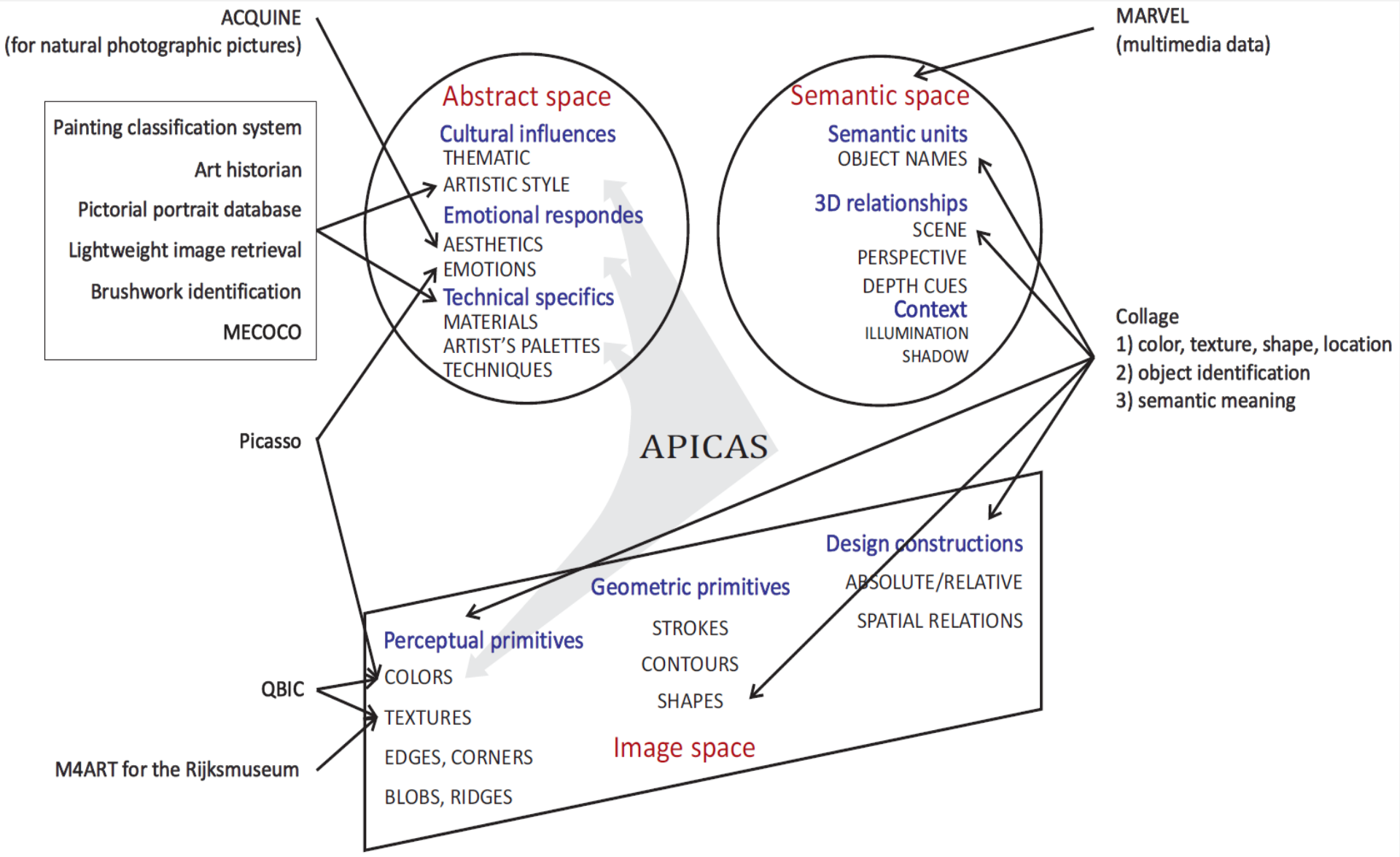
Semantic space is related to the meaning of the elements, their potential for semantic interpretation.

Abstract space reflects cultural influences, specific techniques, and emotional responses evoked by an image.

** Inspired by*
[Burford et al, 2003] and [Hurtut, 2010]



4. Some Examples of CBIR Systems



5. Colour Features

- Low level colour features, based on binning of HSL-artists colour space
- Harmonies and contrasts from the point of view of three main characteristics of the colour – hue, saturation and luminance
- Local features based on tiling the image and applying vector quantization of MPEG-7 descriptors over the tiles

5. Harmonies and Contrasts

Aristotle, Leonardo da Vinci (1510), Lambert, Schiffermüller (1772), Goethe (1810), ... , Seurat (1886), ...

- Simultaneous Contrast: when colours interact, they are capable of change in appearance, depending on particular relationships with adjacent or surrounding colours (1839 - Michel Eugène Chevreul)
- Successive contrast: the eye spontaneously generates the complementary colour even when the hue is absent
  (afterimage phenomenon)

Successive and simultaneous contrasts suggest that **the human eye is satisfied (in equilibrium) only when the complementary colour relation is established**.

- Adolf Hoelzel (1853-1934) :
  - Contrast of the Hue;
  - Light-Dark;
  - Cold-Warm;
  - Complementary;
  - Gloss-Mat;
  - Much-Little;
  - Colour-Achromatic .

- Johannes Itten (1888-1967) :
  - Contrast of hue;
  - Light-dark contrast;
  - Cold-warm contrast;
  - Complementary contrast;
  - Simultaneous contrast;
  - Contrast of saturation;
  - Contrast of extension.

5. Examples in Art

Contrast of Hue
Theotokos of the Passion
(13th-15th c.)

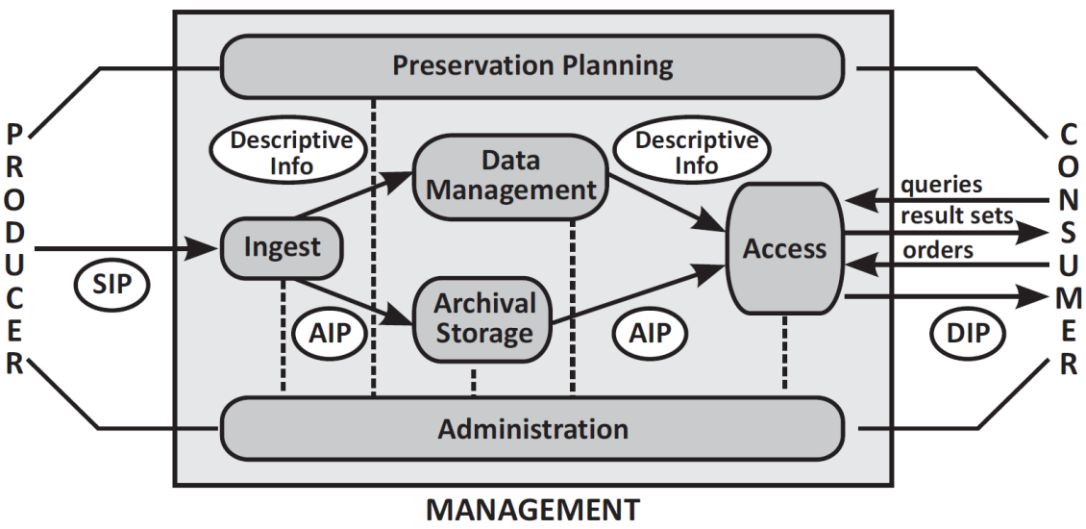
Primary triad of red, yellow, and blue
Rogier Van der Weyden:
Deposition (1436)

Light-Dark Contrast
Rembrandt:
Portrait of Saskia (1633)

Cold Intense Colours
El Greco: Purification of the Temple (1600)

Monochromatic Colour Scheme
Pablo Picasso: Self-Portrait in Blue Period (1901)

6. APICAS: CBIR Modules and DL



[OAIS, 2002] [OAIS, 2009]

- Within the context of such general digital archive architecture, CBIR-related implementations can be seen as a module which would best fit within the **Data Management** functional entity.
- It would also have influence on **Ingest** (on the structure of the submission information packages)
- CBIR also enriches the possibilities for delivery and will influence the **Access** functional entity which would accommodate more options for digital content discovery.

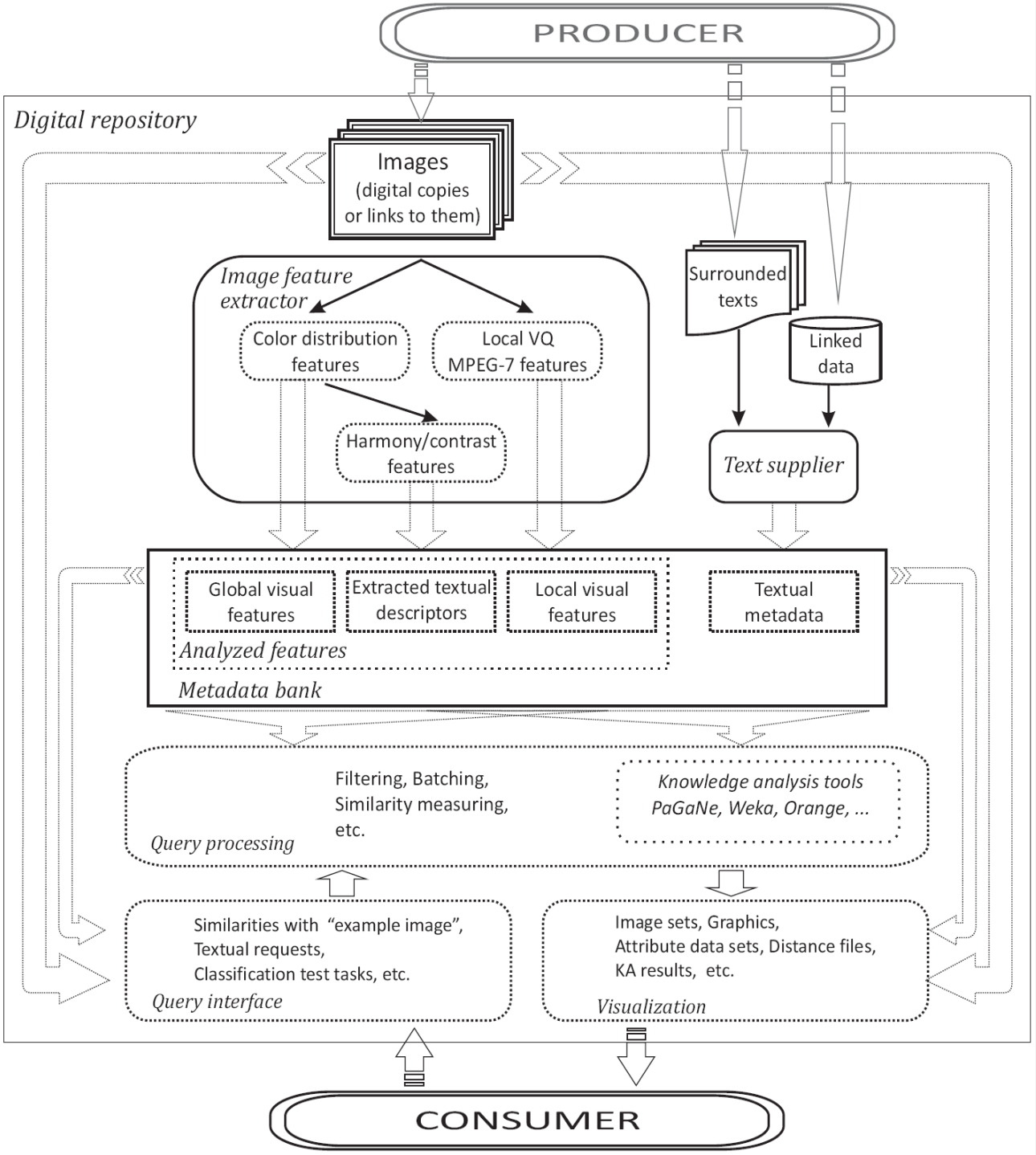
6. APICAS

The main functions:

data entry support:
choosing the collection;
setting up parameters;
selecting the LS samples;
test textual metadata;

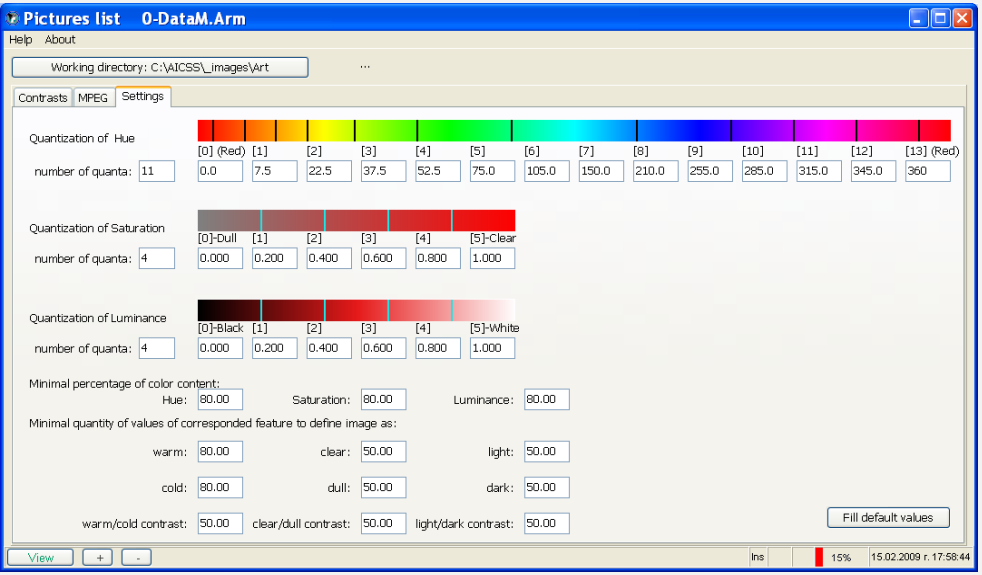
visual characteristics extraction:
colour distribution;
harm./contrasts' descriptors;
local VQ-MPEG7 features;

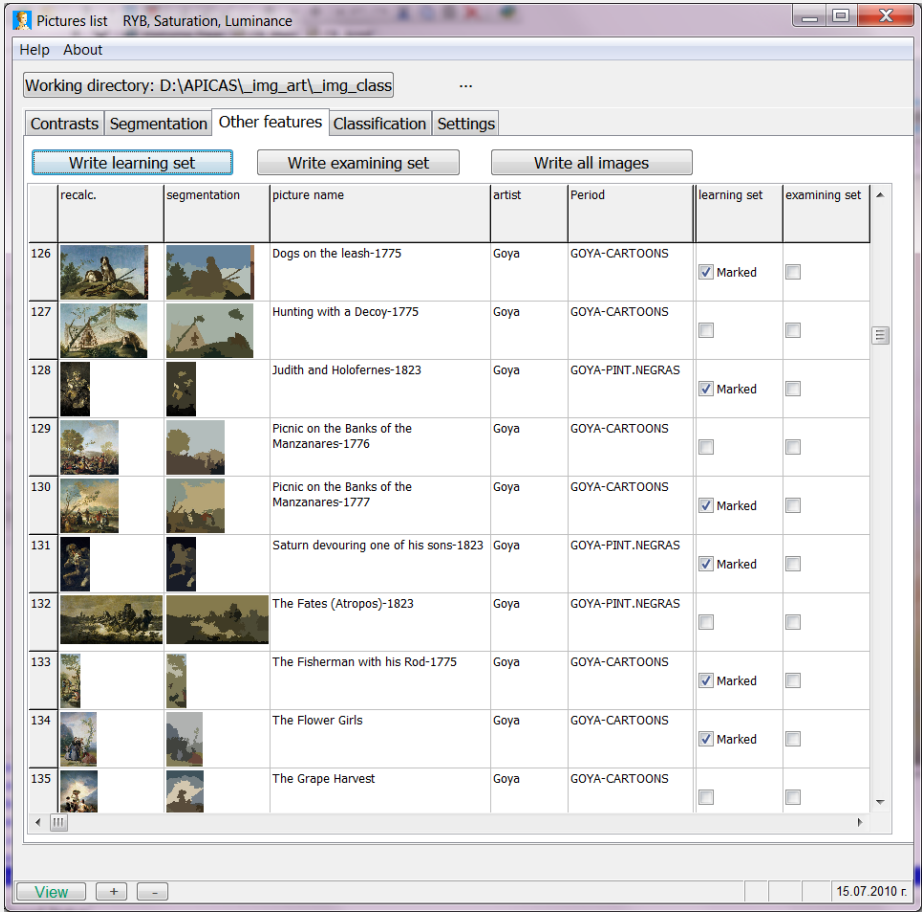
data delivery:
examining colour distribution;
multidimensional scaling;
knowledge analysis;
visualizing;
statistical and DM analysis.



6. APICAS - Data Entry Support

- Choosing the collection
- Setting up parameters and boundaries used by algorithms that calculates colour characteristics
- Selecting the samples of learning set
- Supplying textual metadata





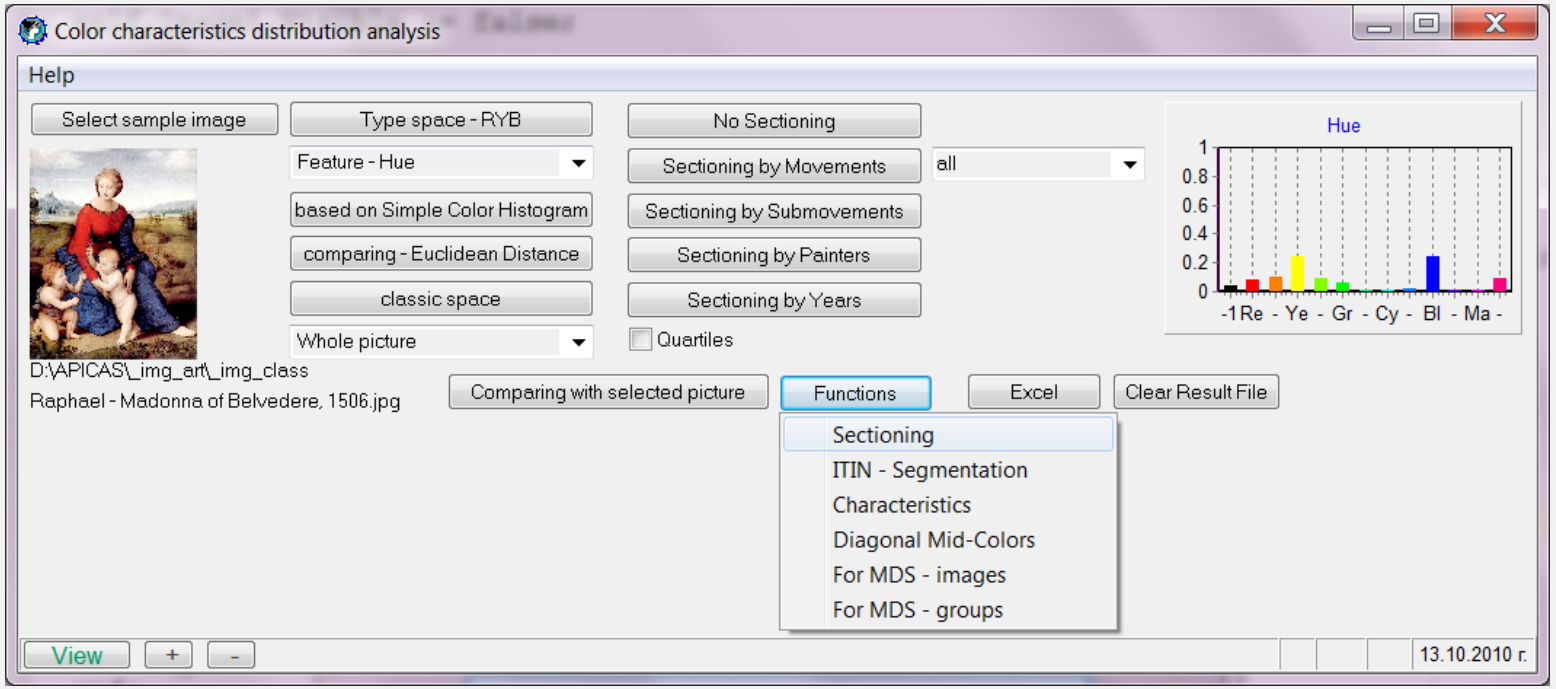
6. APICAS - Calculating Features

- Calculating Colour Distribution
- Estimating Harmonies' and Contrasts' Descriptors
- Establishing Local Features, Based on Vector Quantization of MPEG-7 Descriptors over the Tiles of the Image

  - Multimedia Content Management System MILOS (*obtaining the MPEG-7 descriptors*)
  - CLUTO open source software package (*clustering algorithm*)

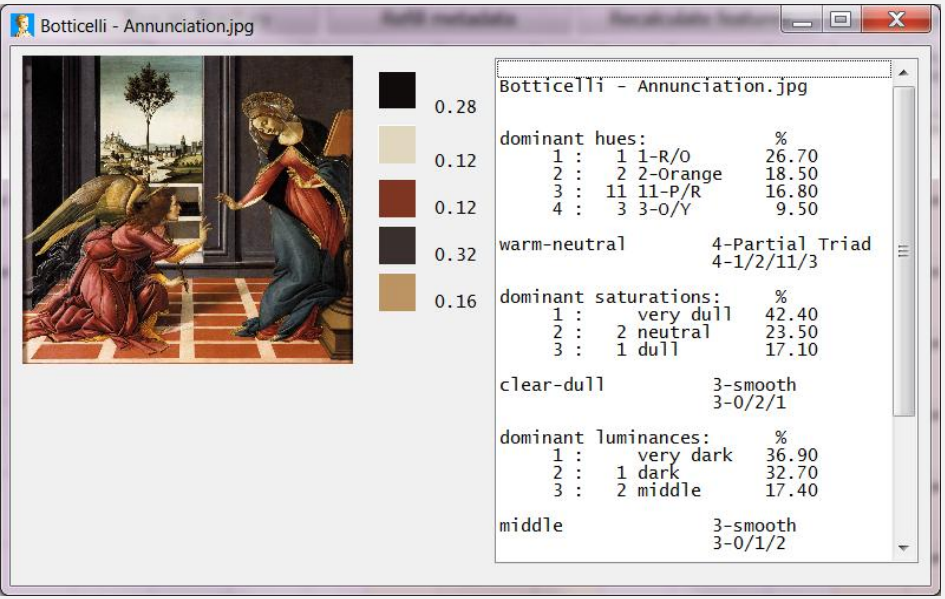
6. APICAS - Output

- Visualising Colour Distribution:
  - analysis of distribution of colour characteristics in the images – hue, saturation or luminance, or combination of them
  - analysis can be conducted over the whole array (all three dimensions); a simple projection of selected characteristics; or projection of two characteristics
  - the functions can be executed for: all images; for concrete movement/sub-movement/artist.

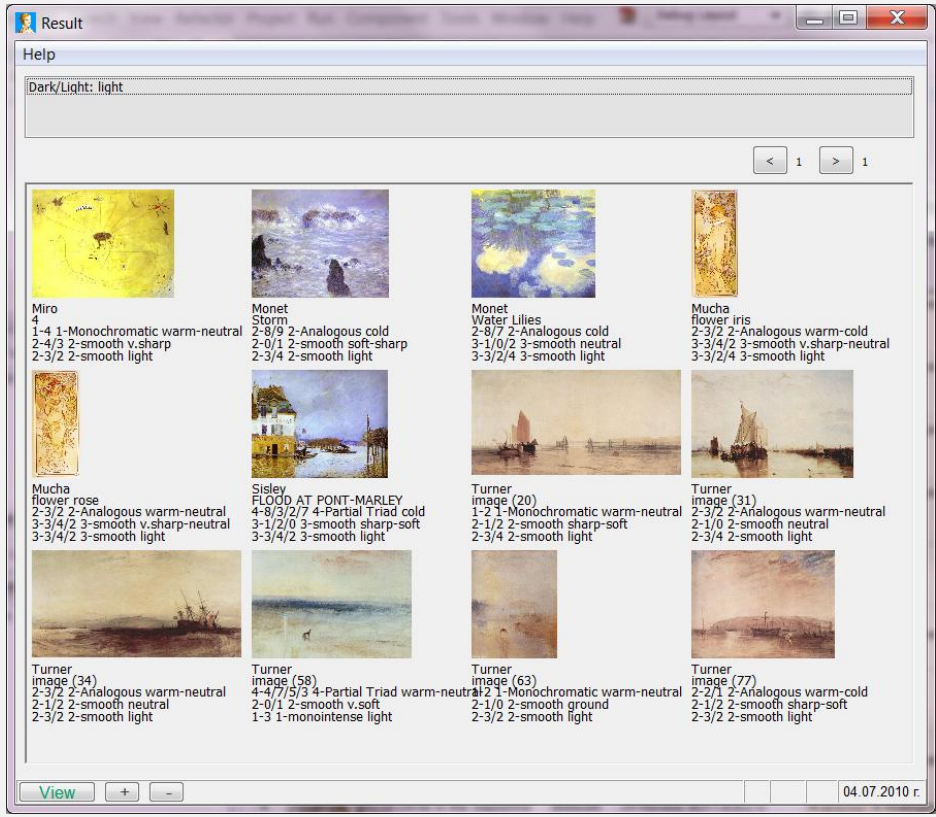


6. APICAS - Output

- Visualising Extracted Colour Harmonies and Contrast Features



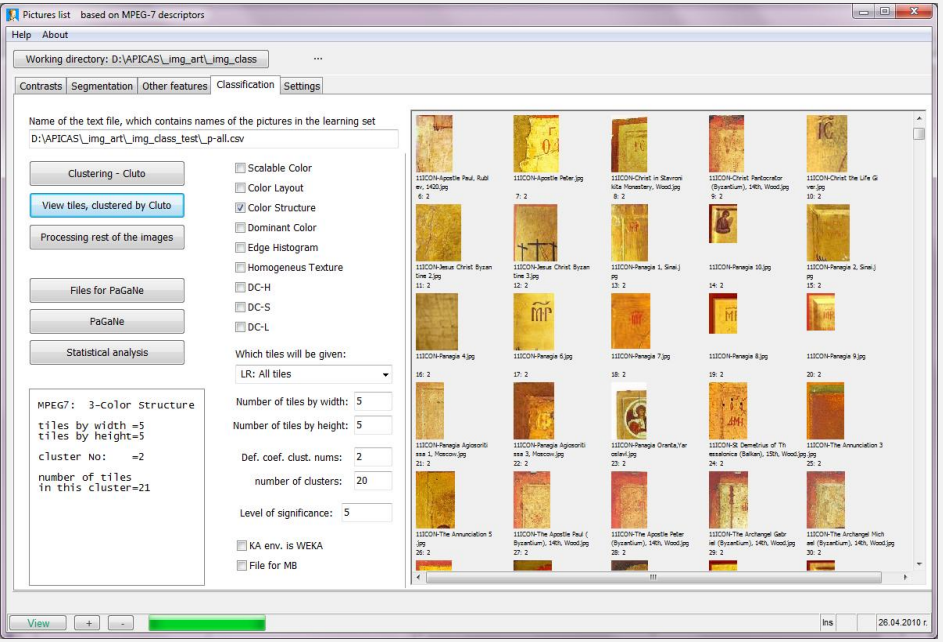
Results of calculating of harmonies/contrasts for the picture "Annunciation" by Botticelli

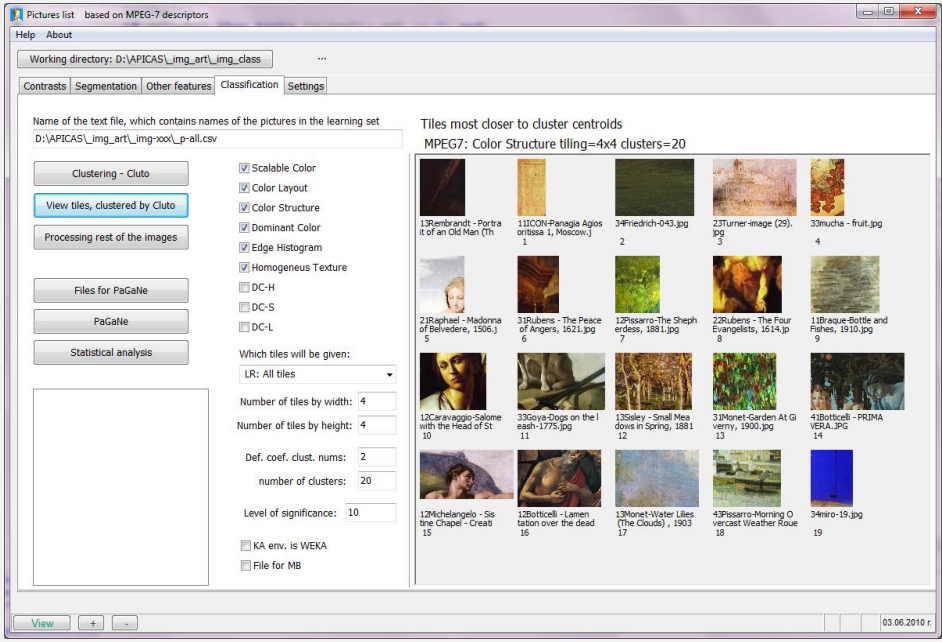


Result of retrieval from the image base with parameter:
"Dark/light contrast = Light"
(includes "smooth light" and "monointense light")

6. APICAS - Output

- Visualising the Results of Clustering





5x5 tiles, belonging to cluster No:2 of Colour Structure Descriptor

tiles, most closer to the centroids of Colour Structure Descriptor (4x4 tiling, 20 clusters)

6. APICAS - Connections with other tools

- Multimedia Content Management System **MILOS** (*obtaining the MPEG-7 descriptors*)
- **CLUTO** open source software package (*clustering algorithm*)

- Open component-based DM and ML software suite **ORANGE** (*multidimensional scaling*)
- Waikato Environment for Knowledge Analysis **WEKA** (*classification algorithms*)
- DM environment **PaGaNe** (*class-association rule classifier PGN*)

Interoperability in DM

Data mining gradually became an emergent technology across multiple industries and sectors. Such expanded and enlarged use means that it is necessary to design a data mining environment which meets the following requirements [Kouamou, 2011]:

- data interoperability (currently each system uses its own notation for data entry, for instance C4.5-standard, arff-standard, etc.);
- openness for adding new algorithms to the environment;
- modularity in order to allow combining of different techniques that became a part of a global process;
- the modules must allow use by different systems, not only a closed use within their own environment;
- user flexibility and possibility to guide the entire data mining process.

XML-based languages, esp. PMML (Predictive Model Markup Language), which provides a standard way to represent data mining models which allows sharing between different statistical applications.

Conclusion

- We have proposed architecture of an experimental CBIR lab-system, aimed at analyzing different types of visual features, which strive to narrow the semantic and abstraction gap between low-level automatic visual extraction and high-level human expression.
- We have explained the structure and functionality of the software system "Art Painting Image Colour Aesthetics and Semantics" (APICAS).
- The vividness of proposed features will open the door for indexing and searching in paintings repositories, according to such characteristics of their content.

- Some challenges:
  - It was difficult to choose a colour model as a basis (final decision was to combine 3)
  - Multiple data mining tools exist but making controlled experiments with them requires tweaking of data (lack of data interoperability - currently each system uses its own notation for data entry, e.g. C4.5-standard, arff-standard).

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Thank you for the attention

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