VK Multimedia Information Systems

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Projects for consideration

- Video Summarization
  - Finding the most important frames of a short video
- Java Face Detection
  - Finding faces in arbitrary images
- Cross-Platform QT 4.4 Media Player
  - Experiences …
- Automated Image Quality Measurements
  - blurriness, block artifacts, etc.
- Implementation of Image Features
  - E.g. region based (Blobworld)
- Non-Implementational
  - Subject to discussion …

Content Based Image Retrieval

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- Motivation & Semantic Gap
- Perception
- Color Based Features
- Texture Based Features
- Segmentation
- Object Recognition
- Vector Images
- Evaluation

Motivation

Lots of good reasons ...

- Visual information overload
  - Devices (cameras, mobile phones, etc.)
  - Communication (email, mo-blogs, etc.)
- Metadata not available
  - Time consuming
  - No automation

Question: What is so special ‘bout Mona Lisa’s smile?

Semantic Gap

- Also called **Sensory Gap**
- Defined as
  - Inability of automatic understanding
  - Gap between high- and low-level features / metadata
- Actually hard task for humans also




Semantic Gap (1)

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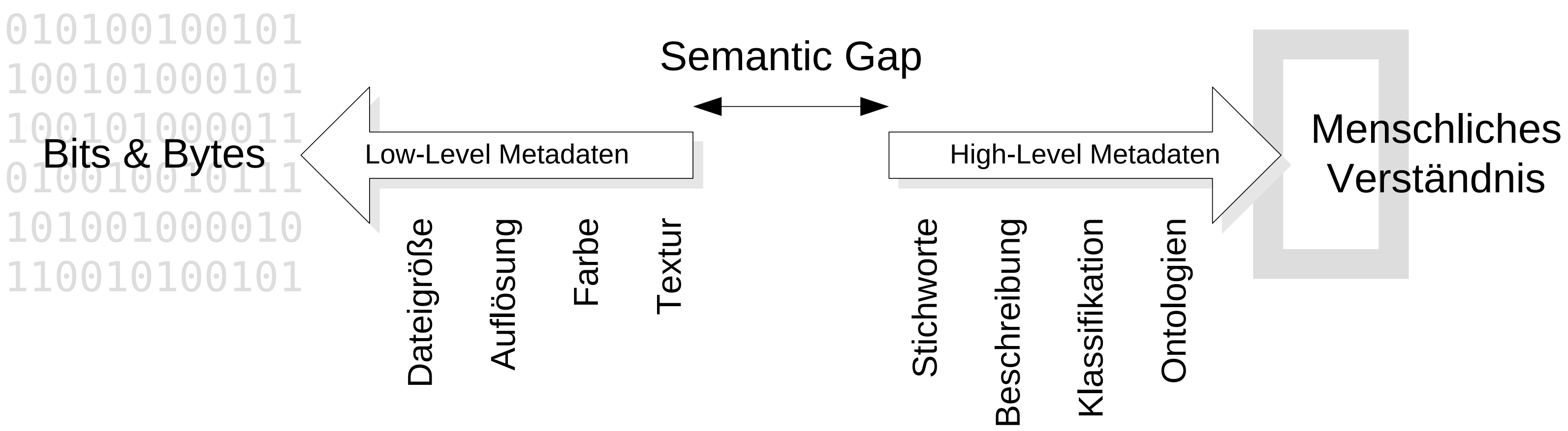
- General Definition: Santini & Jain (1998)



Semantic Gap (2)

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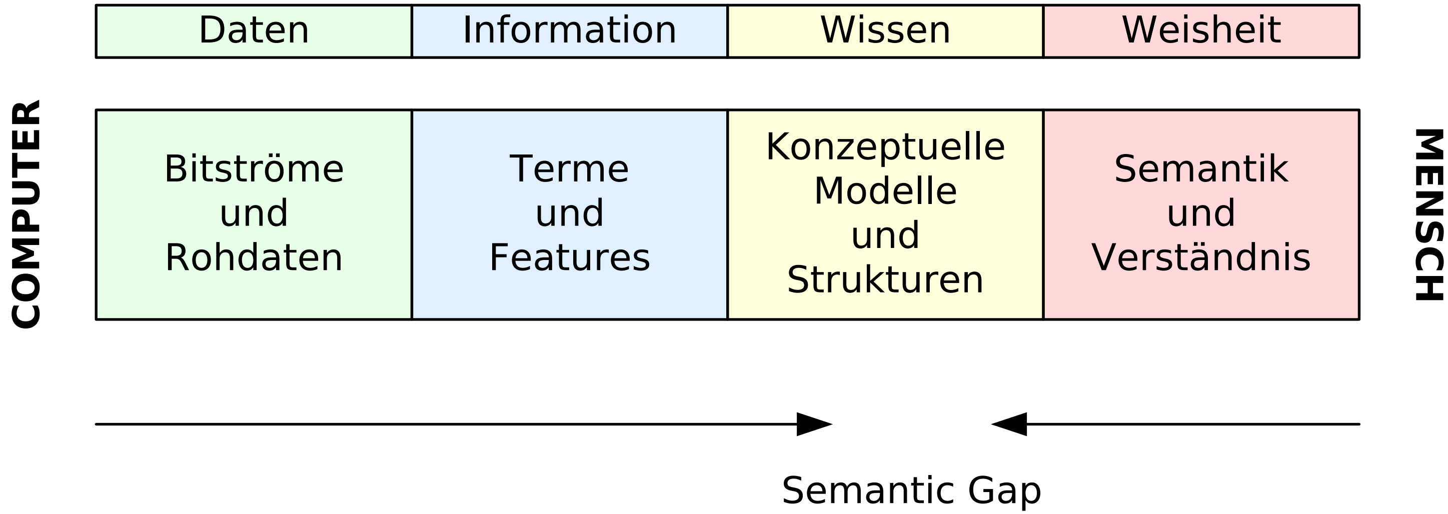

- Where actually is the Semantic Gap?
  - Classification based on Conceps
  - Segmentation & Object Recognition
  - ...

Applications

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- Home User & Entertainment
  - Find picture of / from / at ....
  - Search & browse personal digital library
- Graphics & Desgin
  - Find picture representing something (Color in CD/CI, feeling, etc.)
- Medical Applications
  - Diagnosis, segmentation & classification
  - X-Ray images, patient monitoring

Applications

- Accessibility
  - 'Explain' image to visually disabled people
- Industrial application
  - Select / Sort out products (chips, buns)
  - Monitor processes (e.g. sensors unavailable)
- Security
  - Match fingerprints
  - Search face database

Applications

- Biology
  - Analysing cell samples
  - Recognizing animals, insects & plants
- Astronomy
  - Classifying stars & events
- Weather forecasting
  - Satellite images, clouds
- Cartography
  - Mapping (e.g. aerial photo - earth model)

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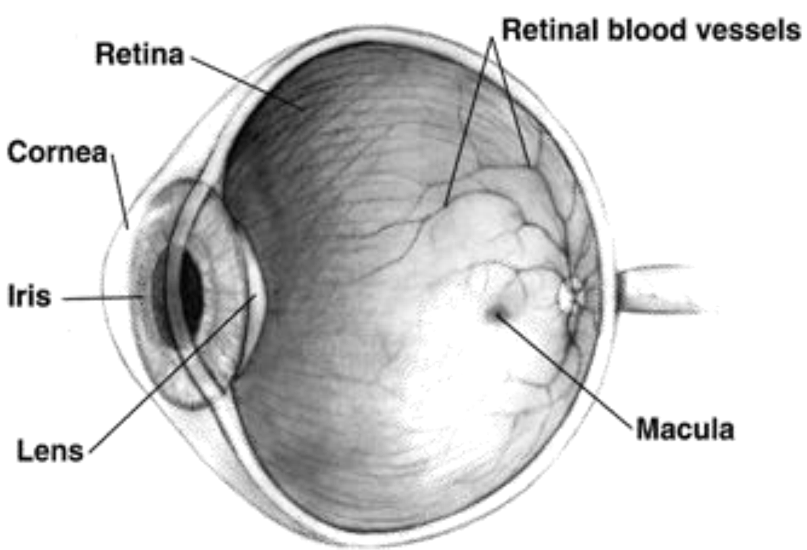
Perception

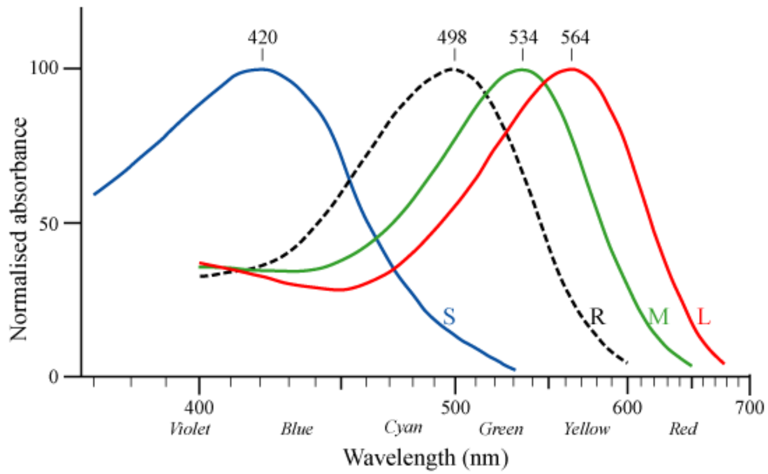
- The **eye** as instrument of perception
- Sensory capabilities
  - Cones (bright light): 6-7 Mio.
  - Rods (dim-light): 75-150 Mio.
  - Brain ‘corrects’ vision
    - e.g. blind spot



Color & Color Spaces

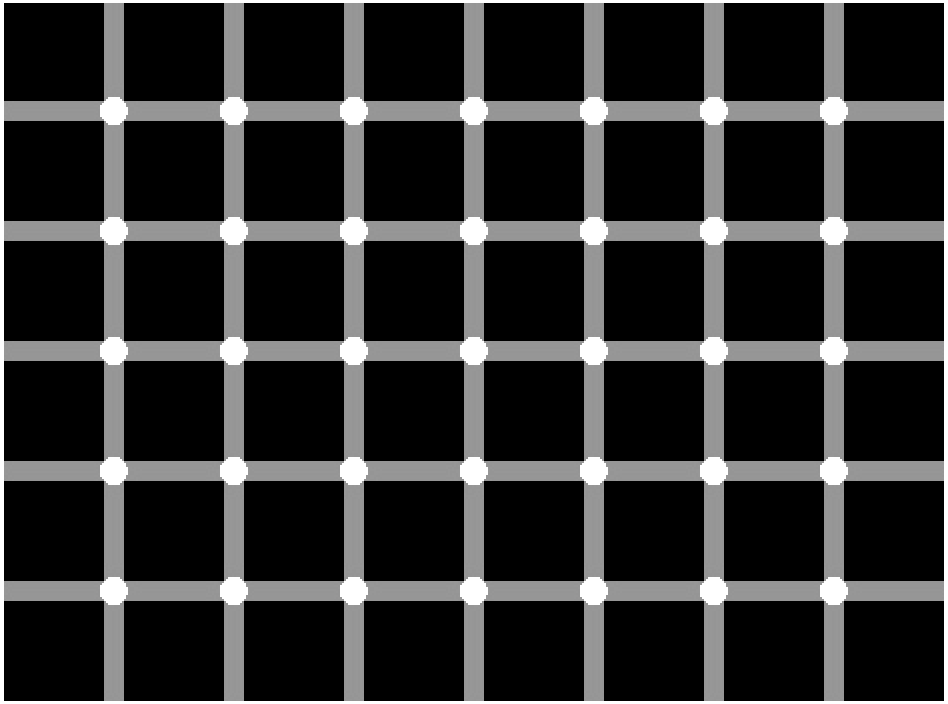
S-, M- and L-cones: Blue, green and red

- RGB based on these three colors
- CIE models perception better
  - Responsiveness of cone types
  - Number of cones / types
  - etc.



The human eye ...

- Count the black dots on the image:



The human eye ...

- Rabbit or duck?

The human eye ...

- Anamorphic illusions

What are (digital) images?

- An Image is
  - Created by a set of photons
    - With different frequency
    - Moving from different sources
    - Along different vectors
  - A representation of sensor unit activation
    - Activated by the set of photons
- Storing an image
  - Based on the set of photons ???

Sampling & Quantization

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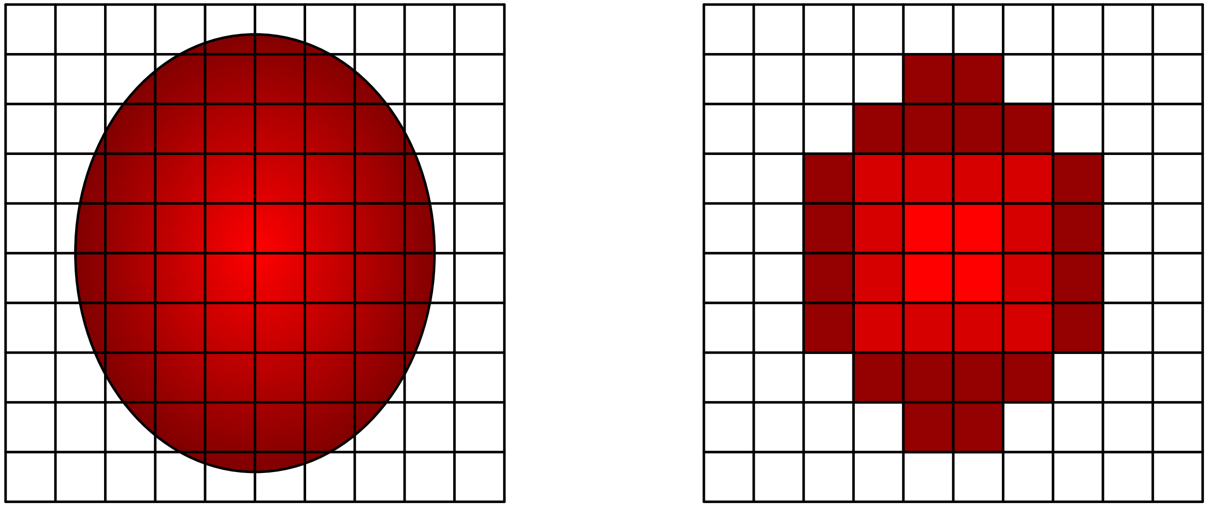
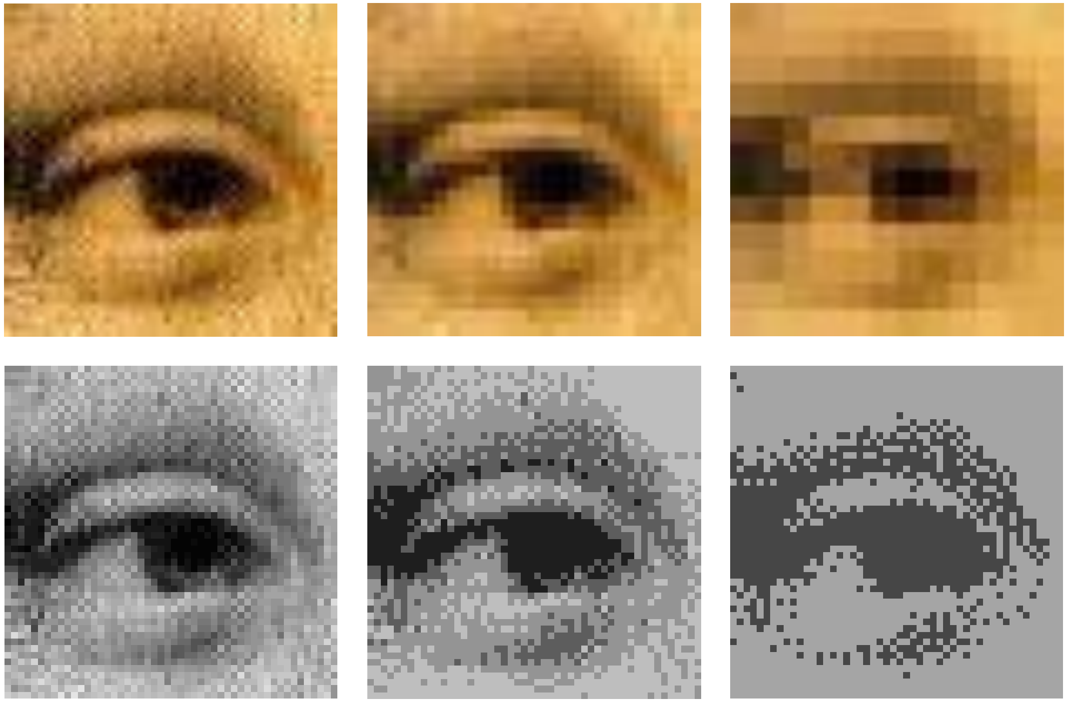
- Capturing continuous images on sensors
  - Sampling: Continuous to matrix
  - Quantization: Continuous color to value



Sampling & Quantization

- Size of a captured image:
  - # of samples (width*heigth) * # of colors



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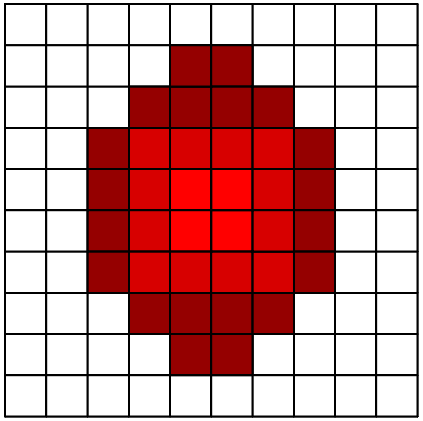
Color Histogram

- Count how often which color is used
- Algorithm:
  - Allocate int array h with dim = # of colors
  - Visit next pixel -> it has color with index i
  - Increment h[i]
  - IF pixels left THEN goto line 2
- Example: 4 colors, 10*10 pixels
  - histogram: [4, 12, 20, 64]



Color Histogram

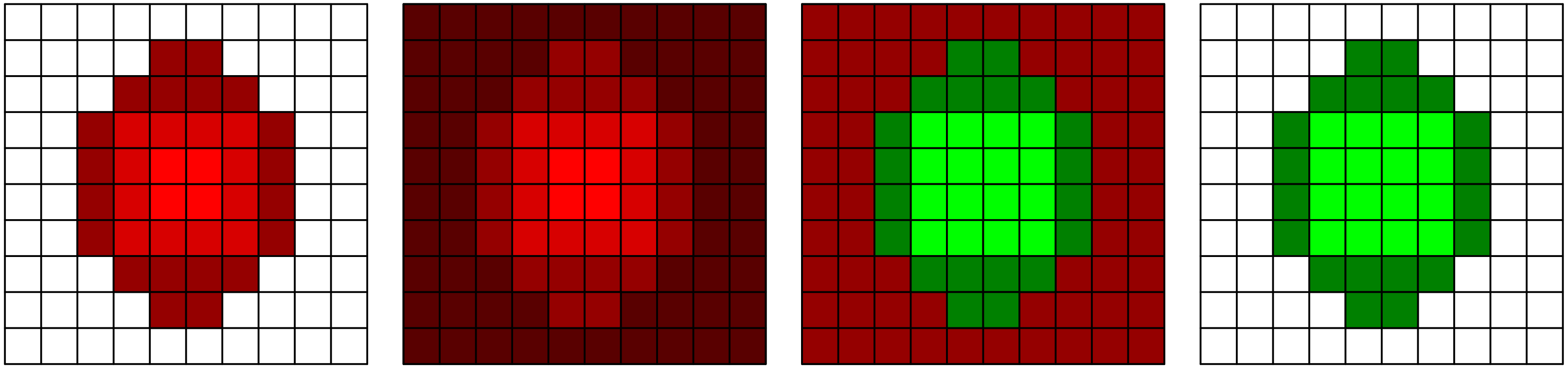
- Strategies:
  - Quantize if too many colors
  - Normalize histogram (different image sizes)
  - Weight colors according to use case
  - Use (part of) color space according to domain
- Distance / Similarity
  - Assumption: All images have the same colors
  - L_1 or L_2 is quite common

Color Histogram

- Benefits
  - Easy to compute, not depending on pixel order
  - Matches human perception quite good
  - Quantization allows to scale size of histogram
  - Invariant rotation & reflection
- Disadvantages
  - Distribution of colors not taken into account
  - Colors might not represent semantics
  - Find quantization fitting to domain / perception
  - Image scaling might be a problem

Color Histogram

- Example: 4 images, 7 colors
  - 1: [0, 4, 12, 20, 64, 0, 0]
  - 2: [66, 4, 12, 20, 0, 0, 0]
  - 3: [0, 0, 0, 64, 0, 20, 16]
  - 4: [0, 0, 0, 0, 64, 20, 16]



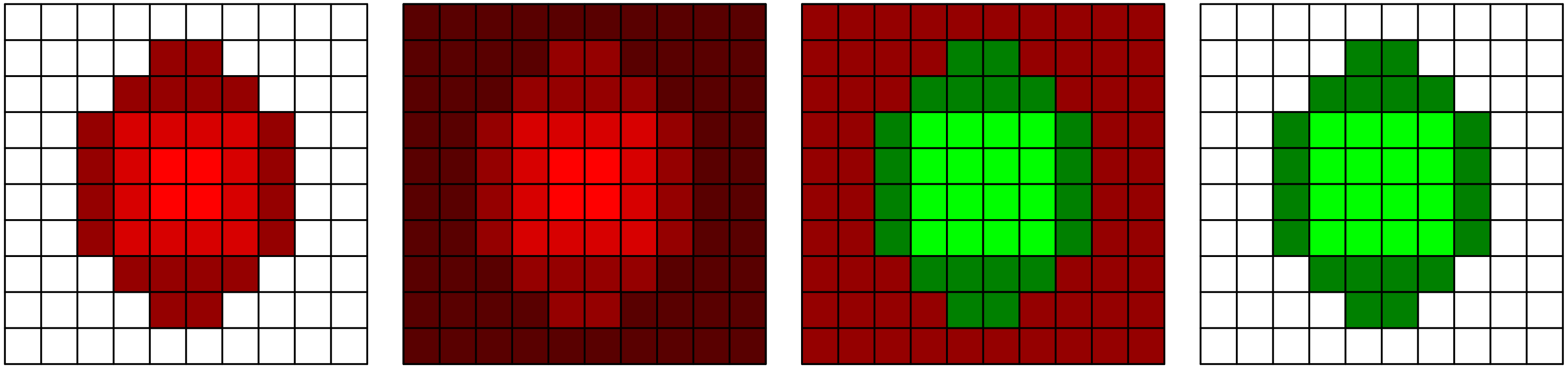
Color Histogram

Bilder:

- 1: [0, 4, 12, 20, 64, 0, 0]
- 2: [66, 4, 12, 20, 0, 0, 0]
- 3: [0, 0, 0, 64, 0, 20, 16]
- 4: [0, 0, 0, 0, 64, 20, 16]

Distanzfunktion d: L1

- d(1,2) = 130
- d(1,3) = 160
- d(1,4) = 52



Dominant Color

- Reduce histogram to dominant colors
  - e.g. for 64 colors c0-c63:
    - image 1: c12 -> 23%, c33 -> 6%, c2 -> 2%
    - image 2: c11 -> 43%, c2 -> 12%, c54 -> 10%
- Distance function in 2 aspects:
  - Difference in amount (percentage)
  - Difference between colors (c11 vs. c12)
- Further aspects:
  - Diversity and distribution

Dominant Color

- Benefits:
  - Small feature vectors
  - Easily understandable & intuitive
  - Similarity of color pairs (light vs. dark red, etc.)
  - Invariant to rotation & reflection
- Disadvantages
  - Similarity of color pairs no trivial problem
  - Colors might not represent semantics
  - Find quantization fitting to domain / perception

Color Distribution

- Index dominant color in image segment
  - e.g. 8*8 = 64 image segments
  - feature vector has 64 dimensions
    - One for each segment
  - color index is the entry on segment dimension
    - e.g. 16 colors [2, 0, 3, 3, 8, 4, ...]

Color Distribution

- Similarity
  - L_1 or L_2 are commonly used
- Benefits
  - Works fine for many scenarios
    - clouds in the sky, portrait photos, etc.
  - Mostly invariant to scaling
- Disadvantages
  - Colors might not represent semantics
  - Find quantization fitting to domain / perception
  - Rotation & reflection are a problem

Color Correlogram

- Histogram on
  - how often **specific colors** occur
  - in the **neighbourhood** of each other
- Histogram size is (# of colors)^2
  - For each color an array of neighboring colors

Color Correlogram

- Extraction algorithm
  - Allocate array h[#colors][#colors] all zero
  - Visit next pixel *p*
  - For each pixel *q* in neighborhood of *p*:
    - increment h[color(p)][color(q)]
  - IF pixels left THEN goto line 2
- Algorithm is rather slow
  - Depends on size of neighborhood
  - Typically determined by city block distance

Color Correlogram

- Similarity
  - L_1 or L_2 are commonly used
- Benefits
  - Integrates color as well as distribution
  - Works fine for many scenarios
  - Mostly invariant to rotation & reflection
- Disadvantages
  - Find appropriate neighborhood size
  - Find quantization fitting to domain / perception
  - Rather slow indexing / extraction

Color Correlogram

- Auto Color Correlogram
  - Just indexing how often *color(p)* occurs in neighborhood of pixel *p*
  - Simplifies the histogram to size # of colors

Color Correlogram

- Integrating different pixel features to correlate
  - **Gradient Magnitude** (intensity of change in the direction of maximum change)
  - **Rank** (intensity variation within a neighborhood of a pixel)
  - **Texturedness** (number of pixels exceeding a certain level in a neighborhood)

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Texture & Shape Features

- Indexing non color features in image
  - Outlines, edges of regions
  - Overall characteristics like coarseness and regularity

Spatial Filtering

- Methods for *enhancing* the image
- Normally a kernel or filter is used:
  - A matrix which is applied to the image
  - In a linear transformation

Spatial Filtering

194	128	102	197	69
162	68	103	144	115
121	85	57	27	14
24	183	192	239	150
92	93	154	138	170

1/9	1/9	1/9
1/9	1/9	1/9
1/9	1/9	1/9

194	128	102	197	69
162	68	103	144	115
121	85	122	27	14
24	183	192	239	150
92	93	154	138	170

Spatial Filtering

- This is a simple smoothing kernel
- Other operations
  - Sharpen
  - Unsharp Mask
  - Gradient

Edge Detection

- Based on the gradient
  - Denotes the amount of change at specific point
  - Can be estimated with Gradient $\nabla f \approx |G_x| + |G_y|$
- Different kernels based on estimation
  - Test e.g. with Gimp

Edge & Texture Features

- Edge based on gradient map
  - Aims to represent edges in number vector
  - e.g. Edge Histogram (MPEG-7)
  - Problems with rotation & reflection
- Texture features
  - Statistics on the image representing
  - Heavily depends on domain
  - Mostly invariant to rotation & reflection
  - Problems with scaling

Tamura Features

Tamura & Mori (1978)

- Widely used in CBIR
  - E.g. IBM QBIC
- 6 texture features
  - Coarseness, contrast, directionality
  - Line-likeness, regularity, and roughness
- Good overview is provided in:
  - Thomas Deselaers, “Features for Image Retrieval”, Thesis, RWTH Aachen, Dec. 2003

Tamura Features

Tamura & Mori (1978)

- Coarseness
  - Pixel diversity in neighborhoods
- Contrast
  - Using mean and variance of an image
- Directionality
  - Horizontal and vertical derivatives (like Sobel)

Shapes

- Indexing of
  - **Boundaries** and **Regions**
  - Invariant to scaling, rotation and translation
- Features depend on domain, e.g.
  - Length of outline w.r.t. the image
  - Convexity & Concavity
  - Holes & Connectivity

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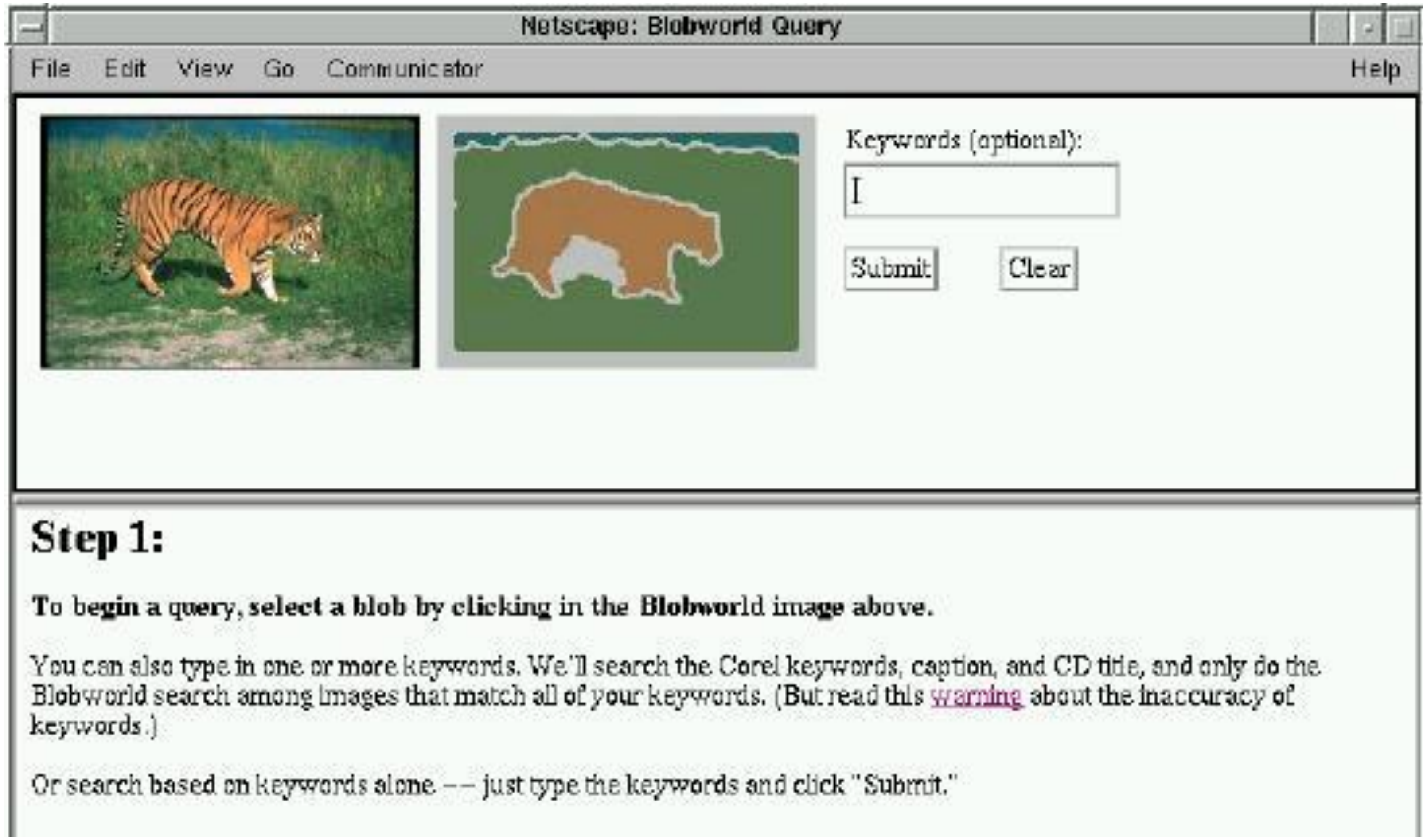
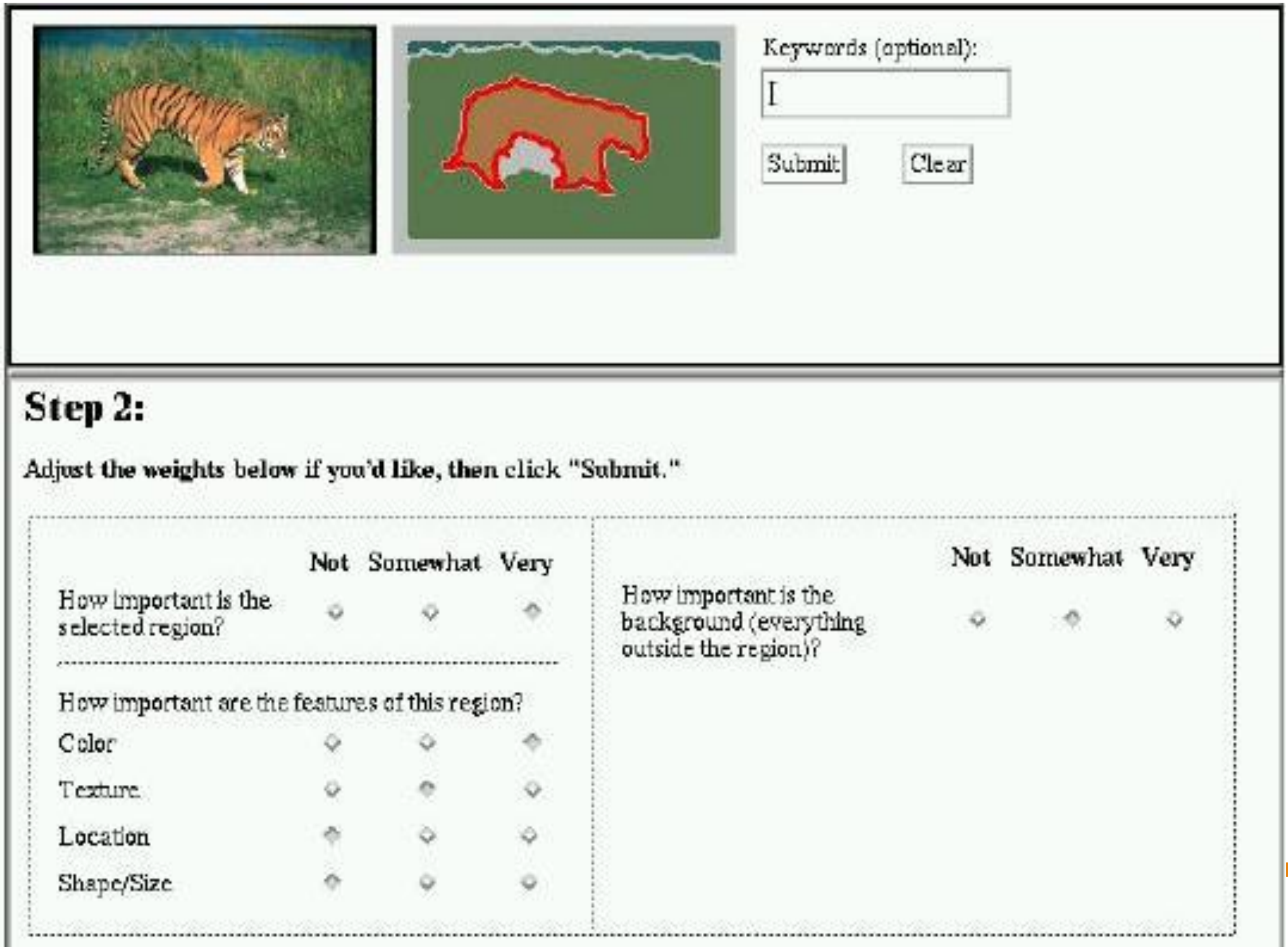
Segmentation

- Automatically decompose image
  - Foreground & background
  - Different objects & shapes
- Example applications
  - Computer vision in industry: Counting
  - Security: Erasing background

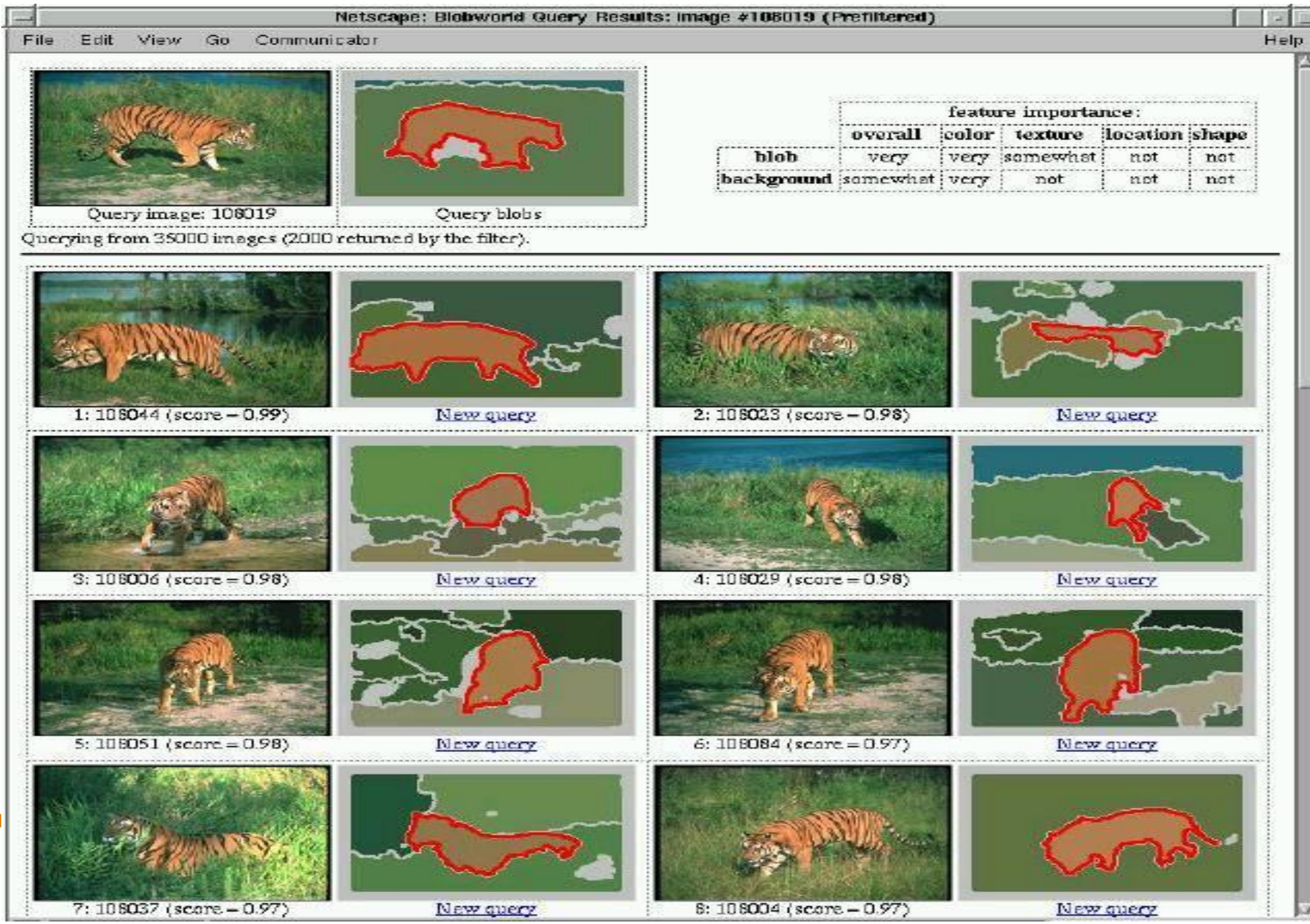
Application: Blobworld



Application: Blobworld



Application: Blobworld



	feature importance:				
	overall	color	texture	location	shape
blob	very	very	somewhat	not	not
background	somewhat	very	not	not	not

Application: Blobworld

- Segmentation Method: Pixel clustering
  - Each pixel has feature vector
    - Color, texture in neighbourhood, etc.
  - Disjunctive clusters group similar pixels
- Method available in MatLab source code

Segmentation Example: Region Growing - Flood Fill

- Image is represented by its gradient map
- Some pixel is selected as seed
- Imaginary water is poured onto this seed
  - Flooding pixels with lower or equal height

- Problems:
  - Dam breach vs. amount of water
  - Good seed

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Object Recognition

- Motivated by practical applications
  - License plate detection & recognition
  - Logo detection & classification (e.g. in TV)
  - Face detection & recognition
  - Identifying spatial regions of interest
    - possible tumors in medical imaging

Object Recognition

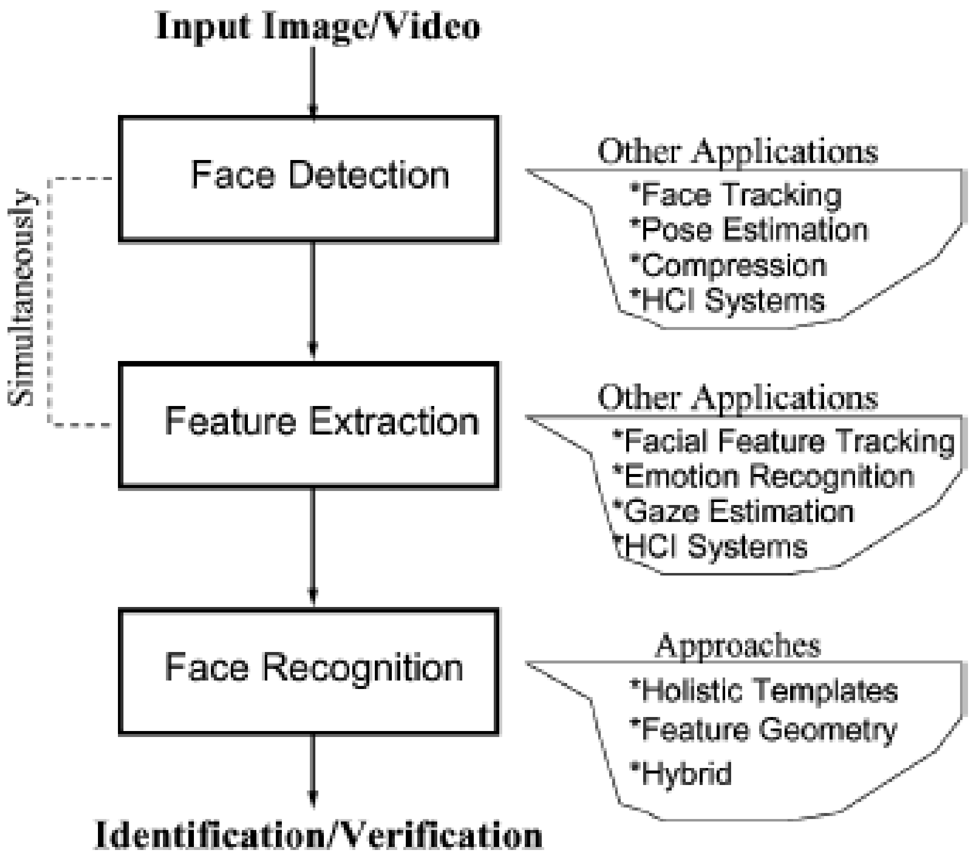
Weight of problem depends on domain ...

- License plate detection is rather easy
  - Plates always look the same
  - Small number of possible positions
  - Sensor fixed, background is separated easily

Face Recognition

Areas	Specific applications
Entertainment	Video game, virtual reality, training programs
	Human-robot-interaction, human-computer-interaction
Smart cards	Drivers' licenses, entitlement programs
	Immigration, national ID, passports, voter registration
	Welfare fraud
Information security	TV Parental control, personal device logon, desktop logon
	Application security, database security, file encryption
	Intranet security, internet access, medical records
	Secure trading terminals
Law enforcement and surveillance	Advanced video surveillance, CCTV control
	Portal control, postevent analysis
	Shoplifting, suspect tracking and investigation

Face Recognition



Face Detection

- Task:
  - Isolate face from background / other faces
- Problems:
  - Partially hidden
  - Point of view
- Methods:
  - Templates (whole face & feature based)
  - Skin color
  - Neural networks & machine learning

Feature Extraction

- Extraction of characteristics
  - Different approaches (e.g. *Eigenfaces* and *Fisherfaces*)
  - Psychological background
  - Index key facial features like position of nose, eyes and mouth
  - Also needed to normalize the holistic face

Face Recognition

- Holistic methods
  - Face as a whole is indexed (mostly PCA, then classification)
- Feature based
  - Eyes, mouth, nose, etc.
- Hybrid methods
  - Combination of both

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Vector Images

- In contrast to raster images
  - Description of boundaries, regions & effects
  - Raster is rendered at view time
  - Aspects: Size, scaling, modification
- Applications
  - Graphs & charts
  - Cliparts & illustrations
  - Logos & Fonts
  - 3D models and scenes

Vector Image Retrieval

- Same aspects as for raster images
  - Color, Shape & Texture
- Selection of aspects depends on domain
- Extraction might be easier
  - Shape, edge and texture features
  - Objects are not necessarily defined

```
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22.5h0.957 l-32.421,22.5l12.402-36.46l0.319,0.992L0.018,35.805L0.018,35.805zM34.034,57.348L22.27,91.931l-1.311-
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21.401l0.46,1.559H62.734L50.971,2.923h1.595L40.801,37.506H2.711l0.496-1.559 L34.034,57.348L34.034,57.348z"/> </g>
```
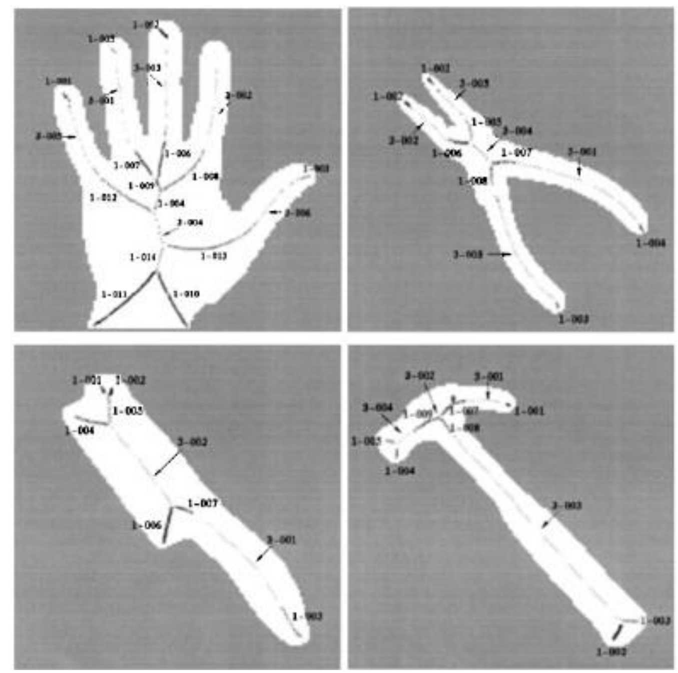
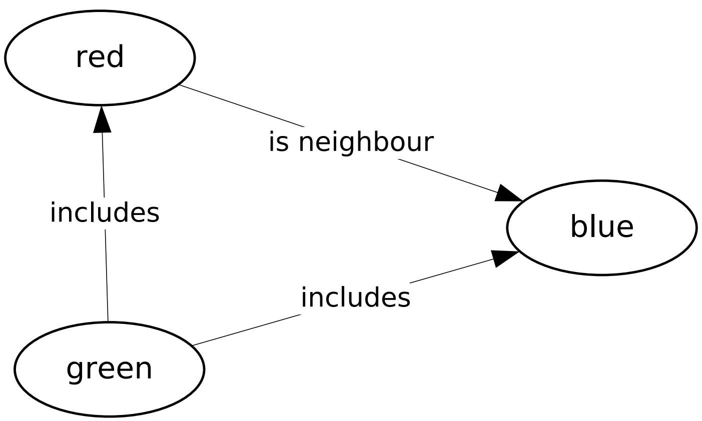

Example: Shock Graphs

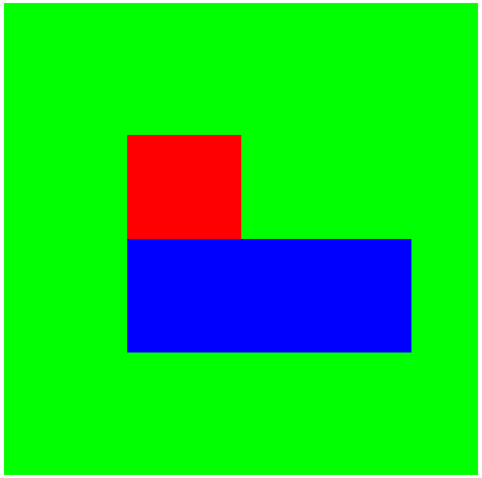
- Actual shape is reduced to a graph (tree)
  - Mostly preserving a characteristic
- Graphs are indexed
  - Using invariants
  - Low dimensional vector
- Retrieval is done by
  - Spatial access



Example: Graph Isomorphism

- Clipart is reduced to graph
  - Describing color & relation between regions
    - includes, is-neighbour





Example: Graph Isomorphism

- Graphs are compared pairwise
  - Based on the similarity of nodes (colors)
  - And structure (edges and types)
- Corpus is clustered hierarchically
  - Generates a “tree of images”
  - That’s called “metric index”
- Retrieval is based on pairwise check with cluster representatives
  - Efficiency depends on the index.

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Evaluation

- Evaluation methods are similar to information retrieval tasks:
  - Comparison of methods based on precision & recall
  - Evaluation of application user centered (subjective evaluation)
- For classification tasks
  - False/True Posititves/Negatives

	TRUE	FALSE
POS.	**TP**	**FP**
NEG.	**TN**	**FN**

User Centered Evaluation

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- Sample Evaluation on the use of content based organization of images
  - User were presented layouts of images
  - Compare the 3 types and a list representation

User Centered Evaluation

- Results:
  - Content based method good for “graphical tasks”
  - Metadata based method depends on annotation
  - Random organization also helps user
    - Identification of “strong” images
    - Stick out of surroundings

Exercise 06

- Rank all 7 images according to your subjective quality rating.
- Assume image 1 is the query and all other images are results
  - Rank the 6 result images according to their similarity to the query image
  - Use your own subjective similarity rating.






Exercise 06

- You will also find the images on the course homepage
- Send me an Excel / Calc / PDF until next lesson.

Thank you …

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… for your attention