

Domain Specific IR

Lecture 4 of 5: Beyond Text

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Yaroslavl, Russian Federation

Image retrieval

- The most obvious step beyond text retrieval is usually image retrieval, due to the ubiquity of images
- But general images can be similar in so many different ways...

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3

Contents

- Introduction to image retrieval
- Domain-specific image retrieval
 - Image search in the medical world
 - Image search in patents
- Challenges and conclusion

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2



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4

Search results from LTU technologies: <http://corbis.lutec.com/>

Retrieval of images

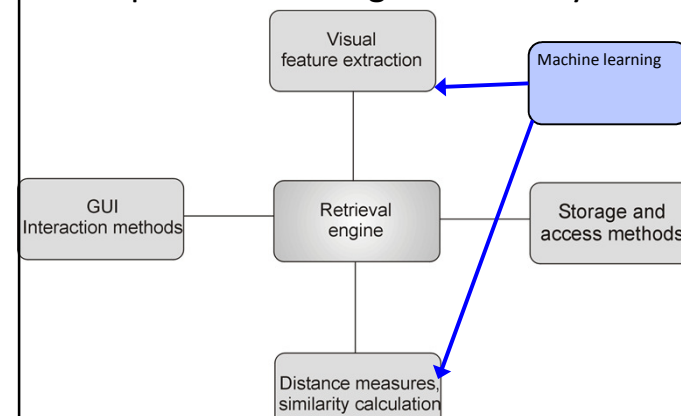
- **Text** retrieval of images
 - Is there any text attached to the images?
 - Doing this manually is expensive, subjective, **language** dependent, ...
 - Take text close to the images (such as captions)
 - Semantic **concepts** could help in some cases
- **Visual** retrieval of images
 - Using automatically extracted visual features
 - Content-based image retrieval (**CBIR**)
 - Query by Image Example(s) (QBE)
- **Multimodal** retrieval (text+images)

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5

Components of image retrieval systems



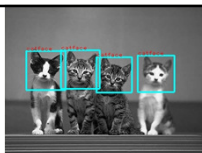
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7

Visual information for retrieval

- **Object detection**
 - Then potentially mapping the objects to an ontology
 - Usually works well for a small number of objects
- **Image classification**
 - Training data, limited set of classes
 - **Global** classification of images vs. **local** classification of pixels, regions
- **Similarity retrieval** of images
 - Global image information, regions of interest (ROIs), small
 - No training data, relevance as criterion for quality

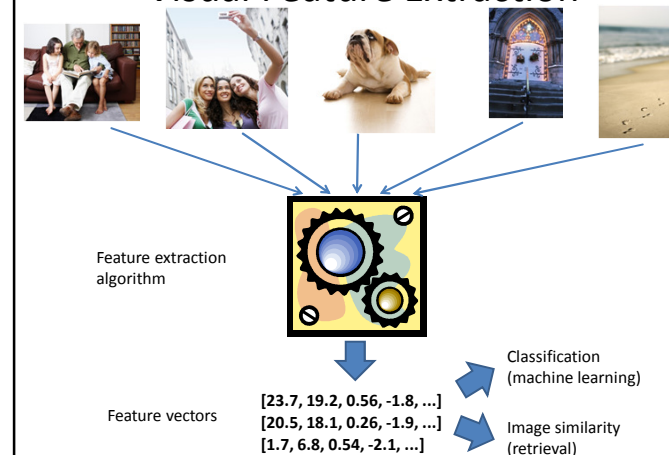


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6

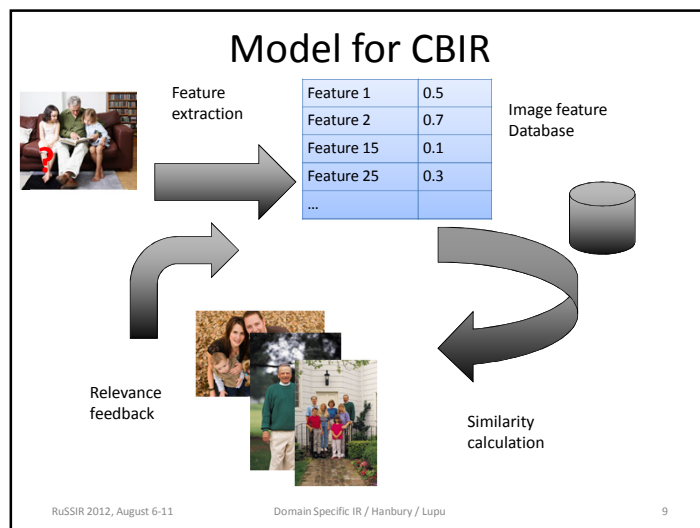
Visual Feature Extraction



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8



Types of visual feature

- Image thumbnails
- **Colors**
 - Different color spaces, human perception
- **Textures**
 - Many different models, no clear definition
- Shapes
 - Automatic segmentation is an ill defined problem
- **Visual words**
- Invariance of the extracted features
 - Rotation, shift, size, illumination, ...

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Steps of a retrieval system

- Image pre-processing
 - Normalization, background removal, ...
- **Salient region** or point detection
- Visual feature extraction
 - Feature selection
 - Then **feature modeling** in the case of visual words
- Distance calculation or similarity measurement
- Results **fusion** (text, visual, ...) for ranked list
- Results filtering (i.e. by modality)
- ...

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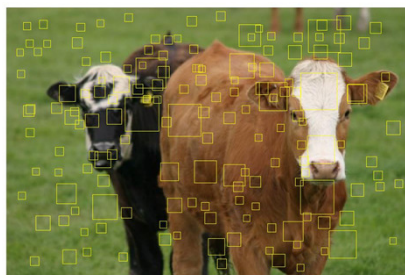
Similarity by colour

The image shows a 4x4 grid of 16 small images. These images are related by color, showing various scenes like beaches, people, and objects, all with similar color palettes (e.g., blue skies, sandy beaches, green grass). This illustrates the concept of similarity by color.

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<https://www.rocq.inria.fr/cgi-bin/imedia/circario/cgi/demos>

Interest point-based approaches

- A set of **interest points** is extracted from the image by an algorithm.
- Many algorithms are available to do this.



From Bishop ICPR talk

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13

Bags of keypoints (words)

- **Bags of keypoints** approaches are widely used to recognise objects based on interest points.

Object

Bag of 'words'



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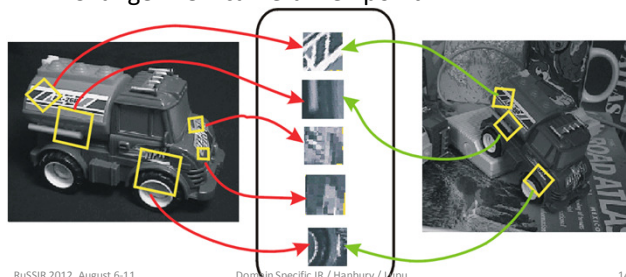
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15

Slide from Li Fei-Fei, CVPR 2007 Tutorial

- To be useful, these features should be invariant to:

- Image scaling
- Image rotation
- Change in illumination
- Change in 3D camera viewpoint.



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From D. Lowe, CVPR03 tutorial

14

Analogy to documents

Of all the sensory impressions proceeding to the brain, the visual experiences are the dominant ones. Our perception of the world around us is based essentially on these impressions. We reach the brain from our eyes, and we thought the point by which the cerebral cortex upon which the visual impression is now known as perception more complex. Through various cell layers, the visual impression is processed. Wiesel have been able to show the message about the image falling on the retina undergoes a step-wise analysis in a system of nerve cells stored in columns. In this system, each cell has its specific function and is responsible for a specific detail in the pattern of the retinal image.

sensory, brain,
visual, perception,
retinal, cerebral cortex,
eye, cell, optical
nerve, image
Hubel, Wiesel

China is forecasting a trade surplus of \$90bn (£51bn) to \$100bn this year, a threefold increase on 2004's \$32bn. The Commerce Ministry said the surplus would reach the predicted 30% jump in exports, which rose by 18% to further increase. China's deliberate the surplus, one factor in the rise in exports, is more to be seen. The value of the yuan has stayed within the band, but the US wants the yuan to be allowed to trade freely. However, Beijing has made it clear that it will take its time and tread carefully, allowing the yuan to rise further in value.

China, trade,
surplus, commerce,
exports, imports, US,
yuan, bank, domestic,
foreign, increase,
trade, value

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16

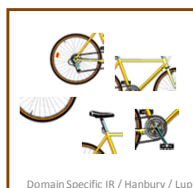
Slide from Li Fei-Fei, CVPR 2007 Tutorial

A clarification: definition of “BoW”

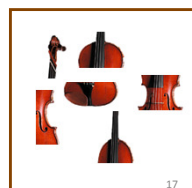
- Looser definition
 - Independent features



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17

Slide from Li Fei-Fei, CVPR 2007 Tutorial

Bag of Visual Words in Practice

Obtaining visual words:

1. Extract keypoints in a (large) set of images
2. Extract features at each keypoint
3. Cluster the features, producing the visual words
4. Assign each keypoint to a visual word (cluster)

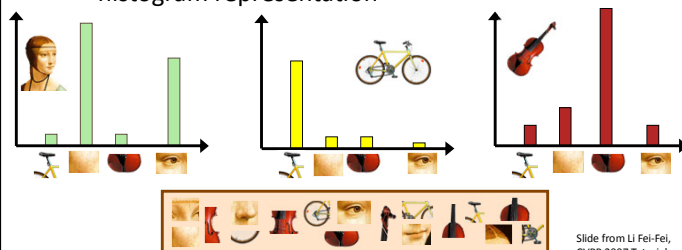
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19

A clarification: definition of “BoW”

- Looser definition
 - Independent features
- Stricter definition
 - Independent features
 - histogram representation



Slide from Li Fei-Fei, CVPR 2007 Tutorial

For a new (unseen) image:

1. Extract keypoints
2. Extract features at keypoints
3. Assign each feature to the closest visual word
4. (Text) classification or similarity measures can now be applied

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20

Distance measures

- Histogram **intersection**
 - For visual words, color features (X_i, Y_i)
- **TF/IDF** weighting
 - For binary/sparsely populated feature spaces/visual words
- **Euclidean** distance (L2), city block distance (L1)
 - Very frequently used, simple to employ
- Mahalanobis, Bhattacharyya, ...
 - Depending on the feature spaces this can lead to much better results
 - See article by Vasconcelos

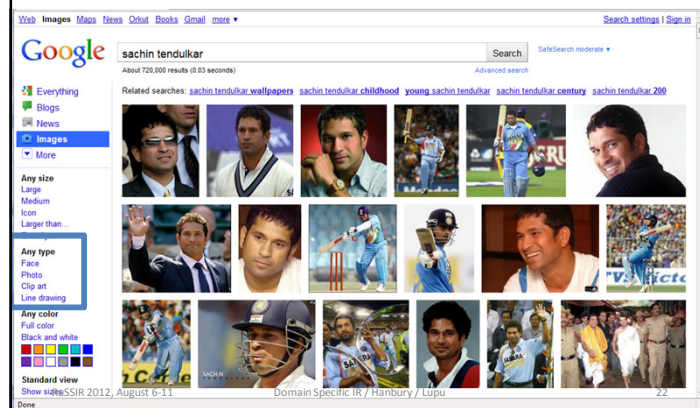
Nuno Vasconcelos, Andrew Lippman, "A Unifying View of Image Similarity," Pattern Recognition, International Conference on, p. 1038, 15th International Conference on Pattern Recognition (ICPR'00) - Volume 1, 2000

21

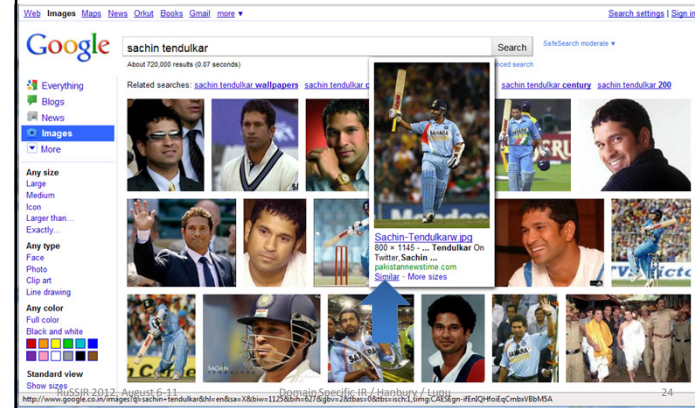
Example: Face Image



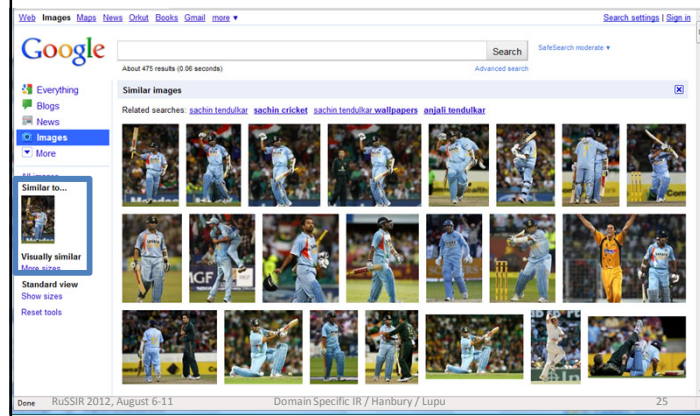
Example of contemporary image search



Example: Requesting a Similar Image



Example: Similar Image Result



Domain-specific image retrieval

- So far, the same methods as for general image retrieval have generally been used for domain-specific image retrieval
- For domain-specific retrieval, domain knowledge is generally available to guide the choice of:
 - Features
 - Similarity functions

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27

Contents

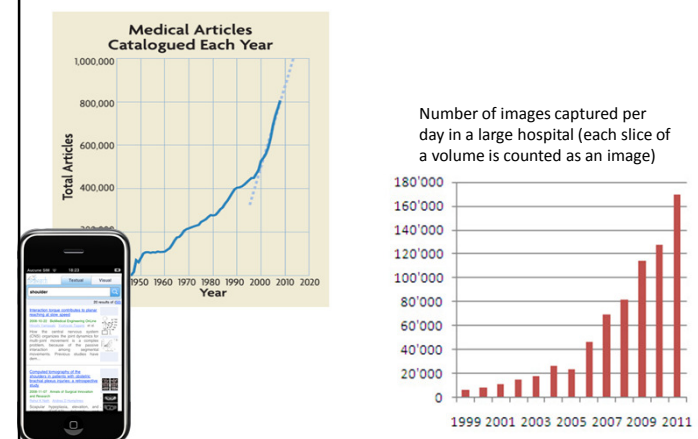
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26

Medical images



Medical imaging data production

- Medical imaging is estimated to occupy **30% of world storage** capacity in 2010!
- **Mammography** data in the US in 2009 amounts to **2.5 Petabytes**



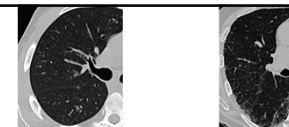
Riding the wave – how Europe can gain from the rising tide of scientific data, report of the European Commission, 10/2010.

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29

Content vs. context



- Most often text around images does not describe the image content itself
 - Unless specifically annotated for retrieval
 - Text often gives the **context** in which the images were taken (private, also medical)
- Image **content** is rarely described precisely and completely with text
 - Visual features describe the pure content
 - Low level of semantics
- Content and context are **complementary** for search

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31

Text used for image search

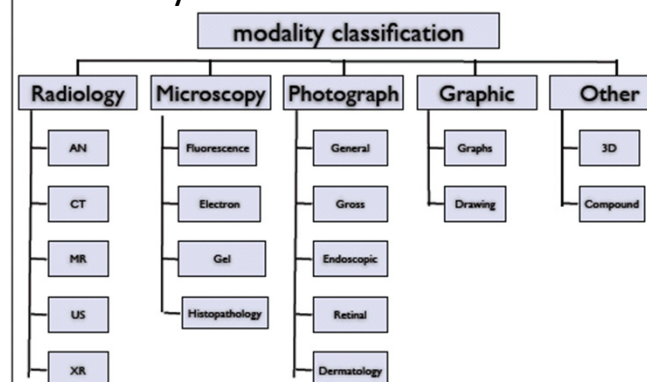
- Image **captions** (in longer texts, scientific articles)
 - Some journals require high quality of this
- Link names to the images (in html)
- URL names (sometimes cryptic)
- **Full text**
 - Not specific as often many images in a text
- Text close to the images
 - Often better than the full text
- Mapping of free text to **semantics**
 - MeSH, UMLS, WordNet

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30

Modality classification



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32

Goldminer.arrys.org (249,000 images)

GoldMiner® About Us Advanced Search GoldMiner Global "Top 42" images

270 images Filter: -Modality: -Age: -Sex: Reset

CT

Recurrent malignancy. Image from a 74-year-old woman with history of middle lobe NSCLC cancer 4 years ... (74 F)
Proc Am Thorac Soc Progress and reevaluation of lung cancer by positron emission tomography imaging.

CT

CT-scan, mediastinal window. -- The bifurcation of the pulmonary artery appears distended and enlarged probably due to the ... (57y M)
EURORAD Right Heart Failure in Idiopathic Pulmonary Fibrosis.

CT

CT-scan, lung window. -- The subpleural and peribronchovascular interstitial thickening exhibits multiple bullae. (57y M)
EURORAD Right Heart Failure in Idiopathic Pulmonary Fibrosis.

CT

CT-scan, lung window. -- Multiple central and peripheral traction bronchiectases are clearly demonstrated in both lungs. (57y M)
EURORAD Right Heart Failure in Idiopathic Pulmonary Fibrosis.

CT

CT-scan, lung window. -- Lung window shows diffuse interstitial thickening of pulmonary apex in both lungs. (57y M)
EURORAD Right Heart Failure in Idiopathic Pulmonary Fibrosis.

☐ Axial non-contrast HRCT images (right slice) ... ☐ HRCT image showing extensive fibrosis at the base of the right lung
 © 2010 American Thoracic Society

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Images

[Web](#) [Images](#) [Journals](#) [Books](#) [Analytics](#)

lung CT with fibrosis

Detailed Thumbnails Only

Yottalook Home

BREAKING NEWS: Yottalook to be acquired by [Montage Healthcare Solutions, Inc.](#)

Related terms: [pulmonary](#) (powered by Yottalook)

Radiograph: C:CT, 554 MIR, 0 NM, 0 US: 0 [Show All](#)

No Subscription Mode:

1 to 10 results out of 554 for **lung CT with fibrosis**

Fig. 6B. 51-year-old man after lung transplant for cystic fibrosis. Patient had free air on routine chest radiograph and no abdominal symptoms and normal laboratory results-benign cause of pneumatosis intestinalis (PI). Digital abdominal radiograph (A) and abdominal CT images (B and C) show free air (arrows, A and B) and...

[from APM: Pneumatosis Intestinalis in the Adult: Review in Life-Threatening Causes](#) | [View all images from this article](#)

[APM: pneumotisis this issue](#) | [radiopaedia this issue](#) [differential this issue](#)

Fig. 6C. 51-year-old man after lung transplant for cystic fibrosis. Patient had free air on routine chest radiograph and no abdominal symptoms and normal laboratory results-benign cause of pneumatosis intestinalis (PI). Digital abdominal radiograph (A) and abdominal CT images (B and C) show free air (arrows, A and B) and...

[from APM: Pneumatosis Intestinalis in the Adult: Review in Life-Threatening Causes](#) | [View all images from this article](#)

[APM: pneumotisis this issue](#) | [radiopaedia this issue](#) [differential this issue](#)

Figure 5a. Focal interstitial fibrosis in a 40-year-old woman. (A) Thin-section CT image at the level of the superior segmental bronchus shows a 25-mm well-defined nodular ground-glass opacity with no solid component in the lower lobe of the left lung.

[from Radiographics: Nodular Ground-Glass Opacity at Thin-Section CT: Interpretation and Evaluation of Causes at Follow-up](#) | [View all images from this article](#)

[APM: pneumotisis this issue](#) | [radiopaedia this issue](#) [differential this issue](#)

Figure 14a. Pseudonodule in a 56-year-old woman who underwent a previous percutaneous lung biopsy. (A) Thin-section CT image obtained at the level of the aortic arch shows a 8-mm well-defined nodular ground-glass opacity (arrows) in the right upper lobe.

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35

Medgift demo (300,000 images)

[Detection of emphysema progression in alpha 1-antitrypsin deficiency using CT densitometry: Methodological advances](#)

2008-2-13 Respiratory Research

Computer tomography (CT) densitometry is a potential tool for detecting the progression of emphysema but the optimum methodology is uncertain. The level of inspiration affects reproducibility but the ability to adjust for this variable is facilitated by whole lung scanning methods. However, emphysema is frequently localised to sub-regions of the lung and targeted densitometric sampling may be more informative than whole lung assessment.

[View full abstract](#) [Article in PDF-Version](#) [View all images / Visual search](#) [Similar articles](#)

Authors: [Hans G. Pien](#) [Martin Steenhouder](#) [Chuan-Gen Deng](#) [Barrett C. Stone](#) [Robert A. Stockley](#)

<http://respiratory-research.com>

[Bronchiolitis obliterans organizing pneumonia \(BOOP\) after thoracic radiotherapy for breast carcinoma](#)

2007-4-13 Radiation Oncology

Common complications of thoracic radiotherapy include esophagitis and radiation pneumonitis. However, it is important to be aware of uncommon post-radiotherapy complications such as bronchiolitis obliterans organizing pneumonia (BOOP). We report on two patients with carcinoma of the breast who developed an interstitial lung disease consistent with BOOP. BOOP responds to treatment with corticosteroids and the prognosis is generally good despite of the need for long-term administration of corticosis...

[View full abstract](#) [Article in PDF-Version](#) [View all images / Visual search](#) [Similar articles](#)

Authors: [Robert Cornelissen](#) [Sushesh Senoo](#) [Imogen E. Antonisse](#) [Hauw Liem](#) [Youke Koo](#)

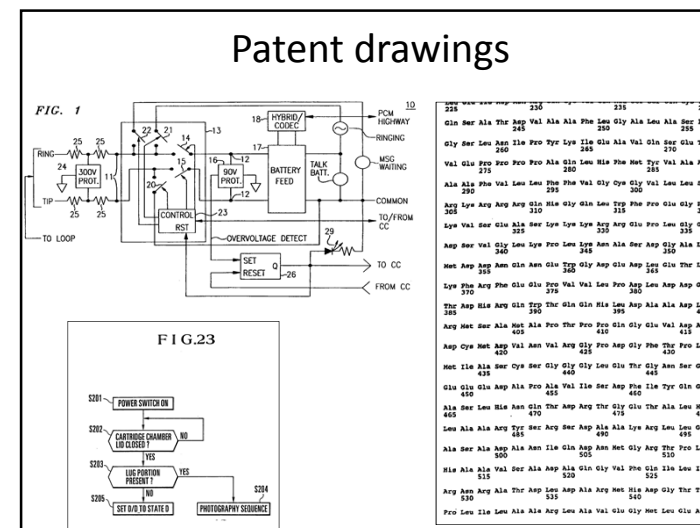
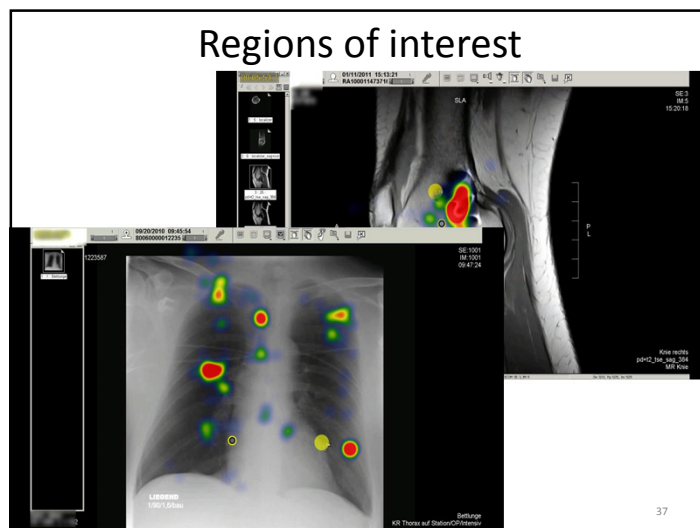
<http://www.rj-journal.com>

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Visual classification and retrieval

<http://www.youtube.com/watch?v=cMoONC0T2zc>

The screenshot displays the 3D Slicer software interface. The main window is divided into several panels. On the left, there is a 'Selected segment' list with options like 'Lung', 'Lung Nodule', and 'Lung Vessel'. Below this is a 'range' and 'region growing' toolbar. The central part of the interface shows a 3D reconstruction of a chest CT scan, with the lungs segmented into different colors (red, green, blue) representing different tissue types. A 'Long-Tissue Analysis Parameters' slider is visible, set to 16. The bottom status bar shows 'Memory Usage: 415.1 / 41.2MB' and 'Seed: (0 , 0 , 0)'.



Images in patents

- A patent application is required to contain drawings, if drawings are necessary to understand the subject matter to be patented.
- Most patent applications contain drawings.
- The drawings must show every feature of the invention as specified in the claims.
- Omission of drawings may cause an application to be considered incomplete and no application filing date will be granted by the USPTO.

The USPTO "Nonprovisional (Utility) Patent Application Filing Guide"

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38

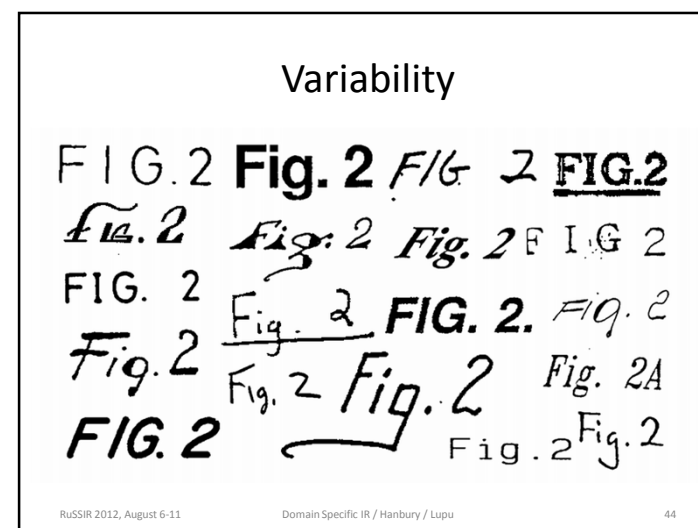
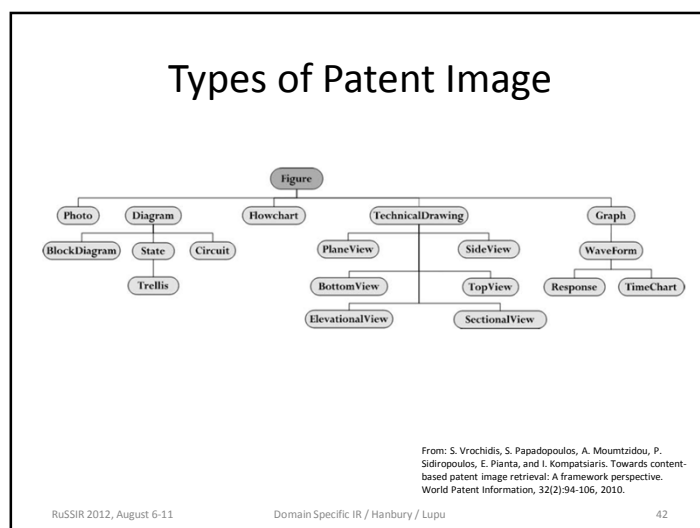
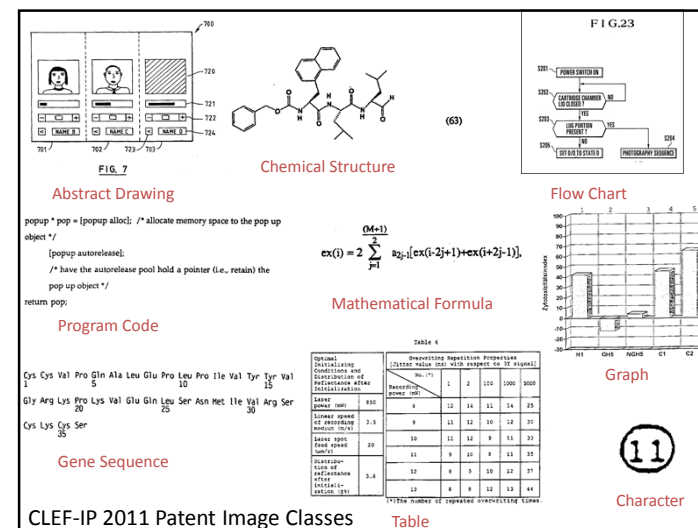
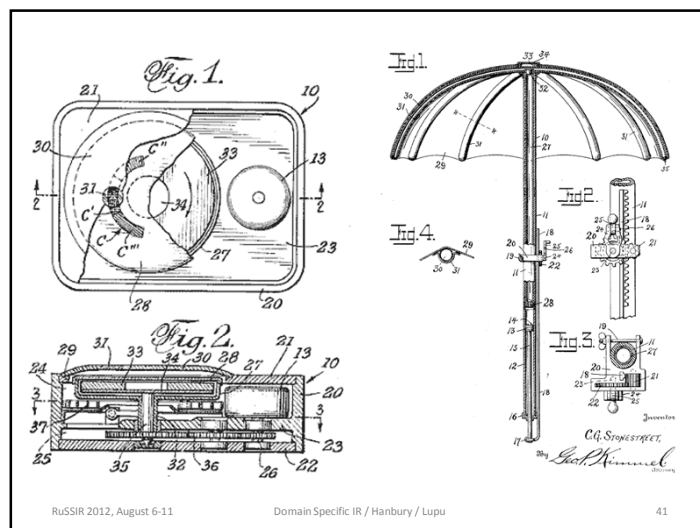
Characteristics

- Sometimes information is in the drawings that is not in the text (e.g. mechanical gearing)
- Drawings in older patents are often done by hand
- Drawings are usually in bitmap format from scanning, and not in vector format
- Drawings can be of poor quality in older patents due to poor scanning technology

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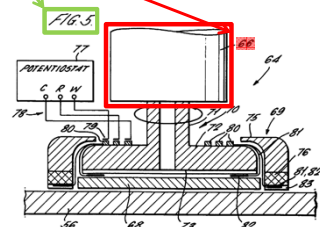
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40



Links between drawings and text

FIG. 5 illustrates, in schematic, cross-sectional view [...] rotatable drive shaft or spindle 56 [...]



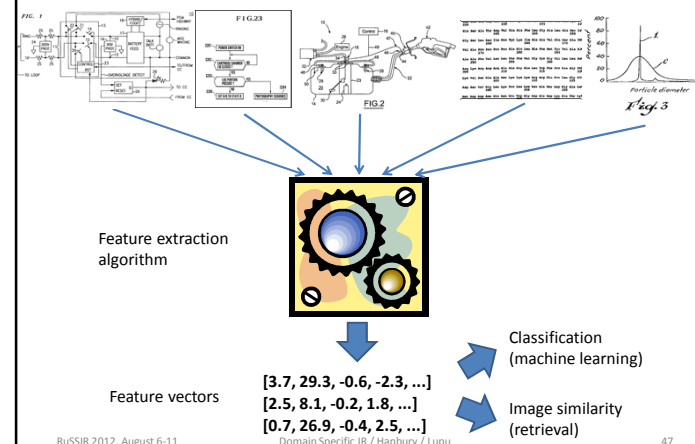
- Patent applicants discouraged from using words in drawing labels

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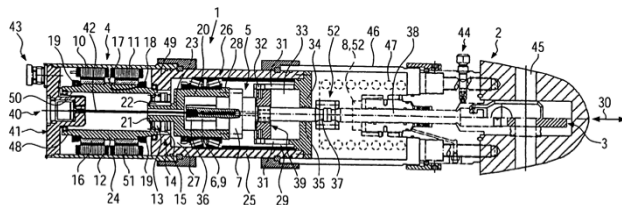
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45

Visual Feature Extraction



- Patents also contain brief descriptions of each drawing in the text (but not as a caption)
- Usually in a section headed *Brief Description of the Drawings*
- E.g. FIG. 1. shows a longitudinal section through a first embodiment of an actuator



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US2012/0153198 A1

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FIG. 1

46

Image similarity in patents

- Patmedia
 - Informatics and Telematics Institute, Greece
 - Adaptive Hierarchical Density Histogram
 - Focus on geometry
 - Sidiropoulos et al., 2011

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48

PatMedia

Informatics & Biomedicine Institute Multimedia Knowledge Laboratory

PatMedia FIGURES: 0/1-04

Insert New Image
Upload a new image and search...

Figure Text Search
Insert keywords (e.g. listed in search file) and search...

Patents Search
Insert a keyword to filter the results, e.g. "disc. laws..."

Text Filtering
Insert a keyword to filter the results, e.g. "disc. laws..."

Category Filtering
Diagram
Chemical
Mechanism
Flowchart
Graph
Table
Chemical Drawing
Chemical
Unknown

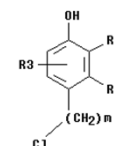
Select figure categories to filter the results, e.g. "Chemical..."

<http://mklab-services.itl.rz/patmedia/>

Similarity

- A difference in patents

– Markush Structures



Substituent Variation: R1 is methyl or ethyl

Homology Variation: R2 is alkyl

Position Variation: R3 is amino

Frequency Variation: m is 1-3

Example from Barnard and Downs:1997

- Potentially infinite combinations

- Extremely difficult to properly match image, table and free text

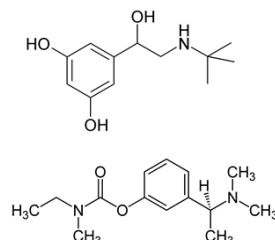
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51

Image similarity

- When images are not images (1)



- These images must be converted to a textual representation of chemical structure for search

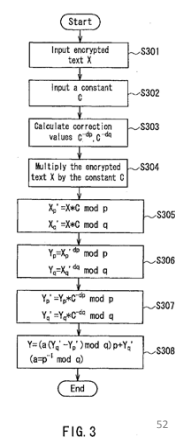
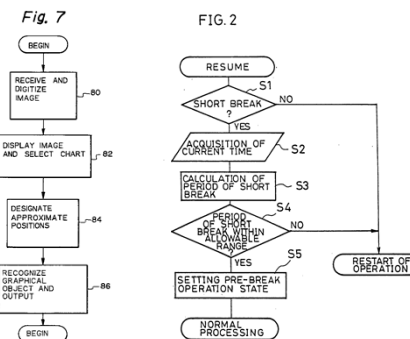
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50

Image similarity

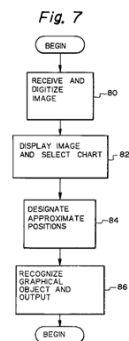
- When images are not images (2)



Similarity

- Flowchart representation

- MT Title "Fig. 7"
- MT Nodes 10
- MT Edges 9
- CO ===== Now comes the list of nodes =====
- CO == identifier type text =====
- NO 1 oval "BEGIN"
- NO 2 rectangle "RECEIVE AND DIGITIZE IMAGE"
- NO 3 rectangle "DISPLAY IMAGE AND SELECT CHART"
- NO 4 rectangle "DESIGNATE APPROXIMATE POSITIONS"
- NO 5 rectangle "RECOGNIZE GRAPHICAL OBJECT AND OUTPUT"
- NO 6 oval "BEGIN"
- NO 7 no-box "80"
- NO 8 no-box "82"
- NO 9 no-box "84"
- NO 10 no-box "86"
- CO ===== Here come the edges =====
- CO == start-node end-node type text =====
- EG 1 2 plain ""
- EG 2 3 plain ""
- EG 2 7 wiggly ""
- EG 3 4 plain ""
- EG 3 8 wiggly ""
- EG 4 5 plain ""
- EG 4 9 wiggly ""
- EG 5 6 plain ""
- EG 5 10 wiggly ""
- CO ===== THIS IS IT =====



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53

CLEF-IP 2011 Image-Based Prior Art Search

- 3 IPC sub-classes (of 631) used:

A43B	CHARACTERISTIC FEATURES OF FOOTWEAR; PARTS OF FOOTWEAR
A61B	DIAGNOSIS; SURGERY; IDENTIFICATION
H01L	SEMICONDUCTOR DEVICES; ELECTRIC SOLID STATE DEVICES NOT OTHERWISE PROVIDED FOR

- 47.000 xml files (patent documents),
290.000 tiff files – 5.5 GB
- 211 query patents
- Retrieval of patents within the same IPC class
(i.e. group of images)

55

Patent image search evaluation

- Patent image retrieval evaluations have been done on small datasets (max. 2000 images)
- Changed in 2011 with 3 patent image evaluations:
 - CLEF-IP Image-based Prior Art
 - CLEF-IP Image Classification
 - TREC-CHEM Chemical Structure Recognition
- Even more data is available for such tasks...

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54

Results

- Only 1 participant (Xerox)
- Best MAP for 3 types of runs are shown below:

Run Type	MAP
Image only	0.035
Text only	0.203
Text + Image	0.212

- Combining image and text search can improve the retrieval results

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56

CLEF-IP 2011 Patent Image Classification

Training images

5565 **Abstract drawing**
 5957 **Chemical structure**
 5573 **Program listing (code)**
 5983 **Gene sequence (dna)**
 310 **Flow chart**
 1663 **Graph**
 5950 **Mathematical formula**
 5502 **Table**
 1578 **Character (symbol)**

38081

1000
test images

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57

Patent drawing search: present and future

- Currently, much drawing search in practice is done by manual visual comparison
- There are initiatives to change the rules for patent drawing in patent submissions:
 - Why not use colour?
 - Why submit 2D cross-sectional black-and-white drawings when a 3D CAD model would be much more useful?
- For automated search, more effort is being put on specific search techniques for specific drawing classes

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59

Results

run	TPR
joanneum.alphacentauri	0.66
joanneum.arcturus	0.50
joanneum.betelgeuse	0.62
joanneum.canopus	0.65
joanneum.procyon	0.27
joanneum.rigel	0.63
joanneum.sirius	0.64
joanneum.vega	0.28
xerox-sas.RUNORH	0.85
xerox-sas.RUNORH_ROTRAIN	0.91
xerox-sas.FV_ORH_SP	0.85
xerox-sas.MEAN_ALL	0.85

True Positive
Rate

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58

Contents

- Introduction to image retrieval
- Domain-specific image retrieval
 - Image search in the medical world
 - Image search in patents
- Challenges and conclusion

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60

Some challenges

- Combining **text** retrieval, **visual** retrieval and visual **classification** based on needs, queries
 - Analysis of the query to estimate goal
 - Quick **learning** from small training data, changing images
 - Work on robustness of **fusion** techniques
 - Rank, not score based
- **Domain-specific** retrieval
 - Medical, expert search, ...
- ...

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61

Conclusion

- Many techniques for general image search are also used for domain-specific image search
- For domain-specific image search, it is usually possible to use domain knowledge to make informed choices on
 - Image features
 - Similarity functions
- Still much research to do, especially on combining information from different modalities

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63

Combinations of techniques

- **Classify** modalities, then search in sub space
 - Basically remove **noise**
 - Allow for tabbed browsing
 - Separate compound figures, separate them and reclassify the sub figures
- **Detect** important regions
 - Segment areas, visualize the results
- Retrieve similar cases/documents based on structured data, free text and the visual information
 - **Case/document-based retrieval** is much more realistic than **image-based retrieval**

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62