

# Big Data Scale Multimodal Medical Image Retrieval

Sameer Antani, Zhiyun Xue



U.S. National Library of Medicine



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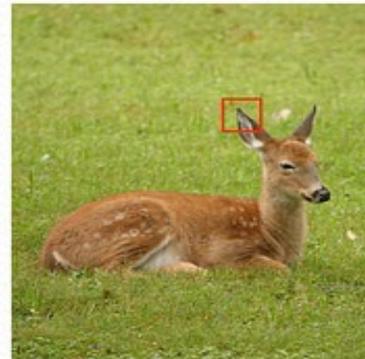
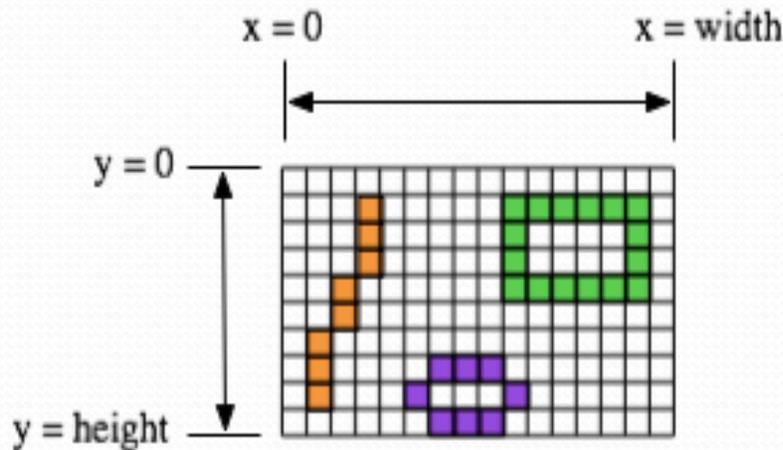
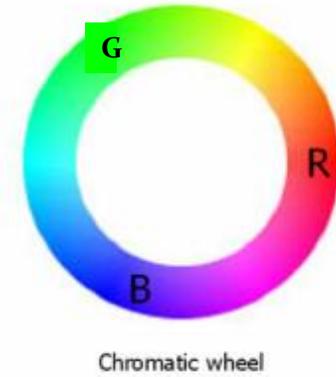
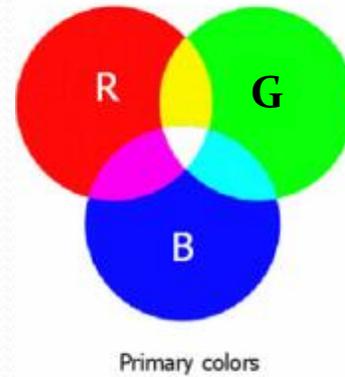
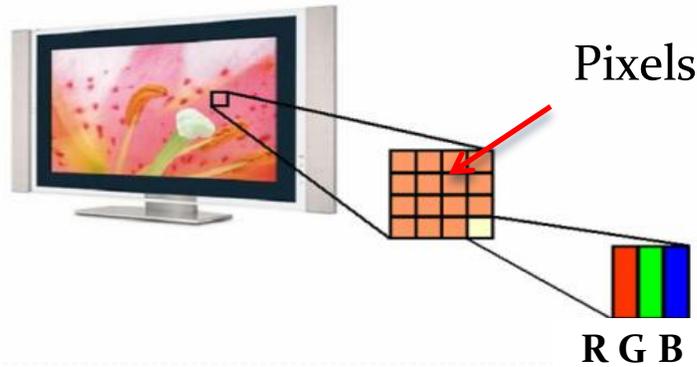
# Big Data Scale Multimodal **Medical** Image Retrieval

Sameer Antani, Zhiyun Xue

OPEN  <sup>SM</sup>  
Open Access Biomedical  
Image Search Engine



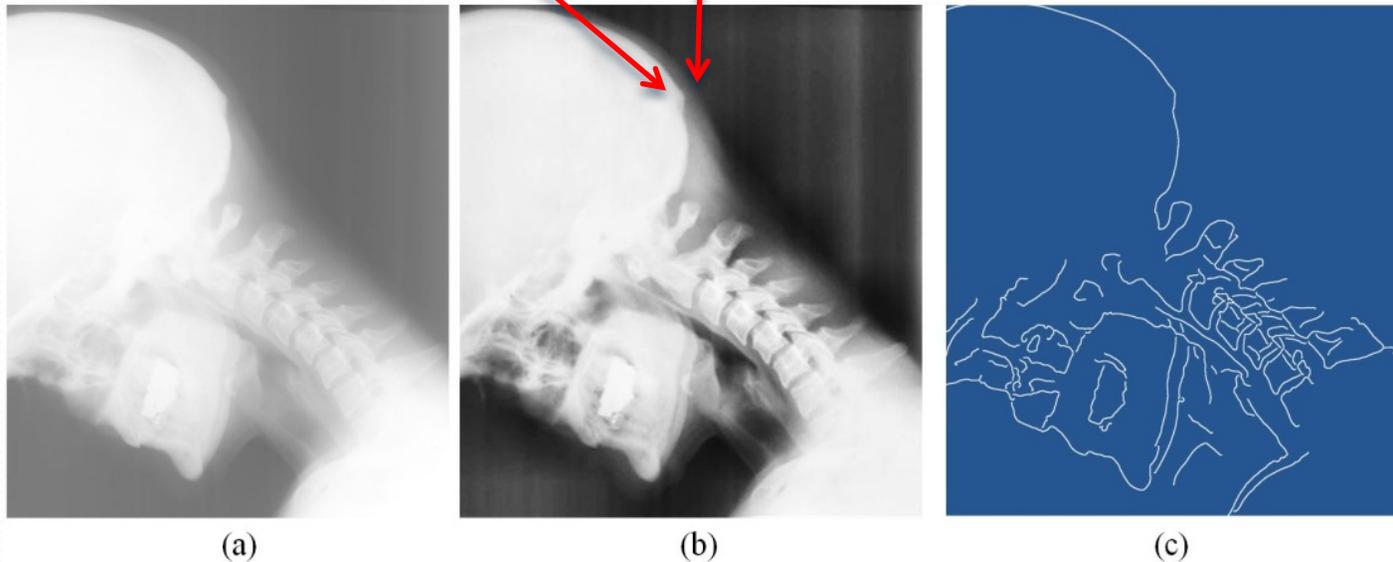
# What is a digital image?



- Remember pixels are numbers, so MATH can be used for computer processing of images

# Finding “stuff” in images ...

If  $\text{Pixel}(X_1, Y_1) > \text{Pixel}(X_2, Y_2)$  then it “might” be an edge



**Objects have edges, or boundaries, so if we can find an edge, we could find the object**

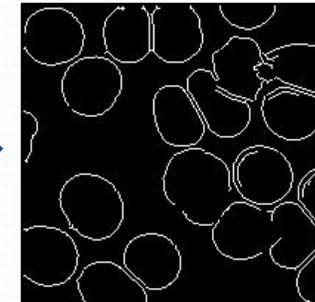
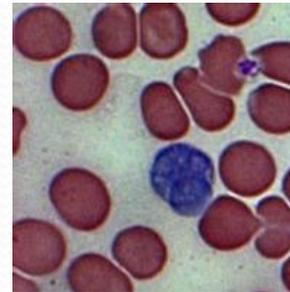
# Images are matrices



```
42 18 21 22 21 17 113 232 246
22 0 0 0 5 116 229 245 243
22 0 0 9 127 238 243 241 243
22 0 42 18 21 21 22 21 85 151 150
21 17 22 0 0 0 2 77 135 134 136
50 133 22 0 0 5 82 133 130 135 133
149 190 22 0
174 207 21 10
176 213 40 79
177 223 96 94
184 224 103 96
180 219 100 96
184 223 103 99
182 223 106 96
179 220 97 88
180 222 94 83
174 215 89 79
176 212 88 77
181 214 89 69
184 205 94 67
96 66
98 67
122 77
42 18 21 22 22 22 84 145 131
22 0 0 0 2 66 120 114 113
22 0 1 8 78 118 112 116 114
22 0 7 78 112 117 110 110 110
22 8 66 89 85 114 103 103 106
38 70 85 81 96 101 103 100 103
87 71 83 94 99 102 97 97 100
100 80 100 118 114 107 96 92 92
99 82 95 120 112 125 98 91 92
100 87 98 105 107 111 97 91 95
103 84 93 97 97 96 95 93 73
97 79 95 97 95 97 94 91 85
101 83 95 100 98 97 97 89 85
99 82 94 99 101 102 98 88 81
93 79 94 98 106 107 100 91 84
88 75 95 102 112 109 106 100 90
87 71 91 103 125 122 116 105 97
86 68 85 108 149 144 127 112 104
87 69 89 122 155 166 159 120 111
```

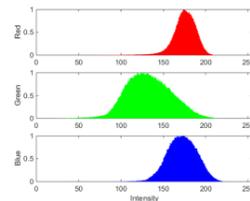
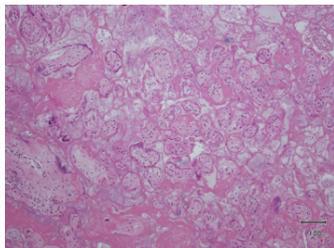
# Image Processing

Image In → Image Out



# Feature Extraction

Image In → Features Out



# Image Classification

Image In → Label Out



Xray

# Image retrieval

- Goal
  - To find the images you need
- Why?
  - Images are powerful
  - Images are prevalent
  - Often need to search images

**A Picture**



is worth

**=**

Creamy, delicious, yummy, fudge ice cream, smooth, chocolate-chip mint ice cream, strawberry ice cream with real chunks of strawberry, colored sugar sprinkles, waffle sugar cone, sweet, wonderful, tastes great, cold, nice to eat, dessert, good yummy toppings, chocolate sprinkles, comforting, good, fun, dipping, terrific,

**A thousand words.**

©2003 E. Aoyama

# Image retrieval

How ?

- Google Images
  - <https://www.google.com/imghp>

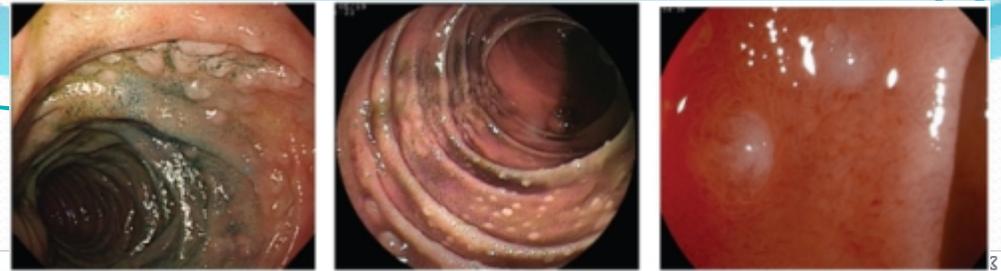
What if there was no google?

Good question.  
Google it.





# Image retrieval



(a)

(c)

Query Image

Google Search

https://www.google.com/search?hl=en&tbs=simg:CAESxQEawgELEKjU2AQaBAGCCAgMCxCwjKcIGmIKYAgDEijxBckP1

Google

All Images News Shopping Maps More Search tools

Size Color Type Time Visually similar Usage rights More tools Clear

# Image retrieval

How 

- Text-based image retrieval
- Content-based image retrieval

# Text-based image retrieval

- **Keywords** (or concepts) match
  - Represent images by related text
  - Images need to be pre-annotated
  - Text saved in pre-determined metadata regions
  - Searching for images is reduced to text search



```
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<subset>CXR</subset>
<MedlineCitation Status="supplied by publisher"
Owner="Indiana University">
- <Article PubModel="Electronic">
- <Journal>
- <JournalIssue>
- <PubDate>
- <Year>2013</Year>
- <Month>08</Month>
- <Day>01</Day>
- </PubDate>
- </JournalIssue>
- </Journal>
<ArticleTitle>Indiana University Chest X-ray
Collection</ArticleTitle>
- <Abstract>
- <AbstractText
Label="COMPARISON">None.</AbstractText>
- <AbstractText Label="INDICATION">Positive TB
test.</AbstractText>
- <AbstractText Label="FINDINGS">The cardiac
silhouette and mediastinum size are within
normal limits. There is no pulmonary edema.
There is no focal consolidation. There are no
XXXX of a pleural effusion. There is no
evidence of pneumothorax.</AbstractText>
- <AbstractText Label="IMPRESSION">Normal chest
x-XXXX.</AbstractText>
- </Abstract>
- <Affiliation>Indiana University</Affiliation>
- <AuthorList CompleteY="Y">
```



# Text-based image retrieval

- Strengths

- Good contextual relevance
- Fast

- Weaknesses

- Requires pre-annotated images
  - May require manual work and sometimes it is impractical
  - Not everything can be well expressed with words
- Limited to text annotations (not text on image)

# Text-based image retrieval system

NCBI Resources How To Sign in to NCBI

PMC congenital heart defect Search

US National Library of Medicine National Institutes of Health Save search Journal List Limits Advanced Help

Display Settings: Summary, 20 per page, Sorted by Default order Send to: Filter your results:

Results: 1 to 20 of 39602 All (39602) NIH grants (10094) Manage Filters

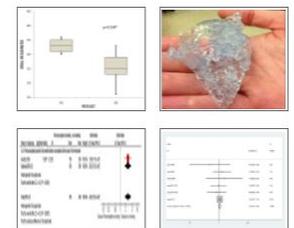
1. [Rare Variants in NR2F2 Cause Congenital Heart Defects in Humans](#)  
Saeed Al Turki, Ashok K. Manickaraj, Catherine L. Mercer, Sebastian S. Gerety, Marc-Phillip Hitz, Sarah Lindsay, Lisa C.A. D'Alessandro, G. Jawahar Swaminathan, Jamie Bentham, Anne-Karin Arndt, Jacoba Low, Jeroen Breckpot, Marc Gewillig, Bernard Thienpont, Hashim Abdul-Khaliq, Christine Harnack, Kirstin Hoff, Hans-Heiner Kramer, Stephan Schubert, Reiner Siebert, Okan Toka, Catherine Cosgrove, Hugh Watkins, Anneke M. Lucassen, Ita M. O'Kelly, Anthony P. Salmon, Frances A. Bu'Lock, Javier Granados-Riveron, Kerry Setchfield, Chris Thornborough, J. David Brook, Barbara Mulder, Sabine Klaassen, Shoumo Bhattacharya, Koen Devriendt, David F. FitzPatrick, UK10K Consortium, David I. Wilson, Seema Mital, Matthew E. Hurler  
Am J Hum Genet. 2014 April 3; 94(4): 574-585. doi: 10.1016/j.ajhg.2014.03.007  
Correction in: Am J Hum Genet. 2014 July 3; 95(1): 126.  
PMCID: PMC3980509  
[Article](#) [PubReader](#) [PDF-2.4M](#) [Citation](#)

2. [Maternal obesity and congenital heart defects: a population-based study](#)  
James L Mills, James Troendle, Mary R Conley, Tonia Carter, Charlotte M Druschel  
Am J Clin Nutr. 2010 June; 91(6): 1543-1549. Published online 2010 April 7. doi: 10.3945/ajcn.2009.28865  
PMCID: PMC2869507  
[Article](#) [PubReader](#) [PDF-79K](#) [Citation](#)

3. [Mice Carrying a Hypomorphic Evi1 Allele Are Embryonic Viable but Exhibit Severe Congenital Heart Defects](#)  
Emilie A. Bard-Chapeau, Dorota Szumska, Bindya Jacob, Belinda Q. L. Chua, Gouri C. Chatterjee, Yi Zhang, Jerrold M. Ward, Fatma Urun, Emi Kinameri, Stéphane D. Vincent, Sayadi Ahmed, Shoumo Bhattacharya, Motomi Osato, Archibald S. Perkins, Adrian W. Moore, Nancy A. Jenkins, Neal G. Copeland  
PLoS One. 2014; 9(2): e89397. Published online 2014 February 27. doi: 10.1371/journal.pone.0089397  
PMCID: PMC3937339  
[Article](#) [PubReader](#) [PDF-6.2M](#) [Citation](#)

4. [Observed Prevalence of Congenital Heart Defects From a Surveillance Study in China](#)  
Yali Zhang, Tiffany Riehle-Colarusso, Adolfo Correa, Song Li, Xinheng Feng, Jacqueline Gindler, Hui Lin, Catherine Webb, Wei Li, Jean Trines, Robert J. Berry, Lorraine Yeung, Ying Luo, Meifang Jiang, Hua Chen, Xiamei Sun, Zhu Li  
J Ultrasound Med. Author manuscript; available in PMC 2015 June 17.  
Published in final edited form in: J Ultrasound Med. 2014 July 20; 33(7): 600-605.

PMC Images search for congenital heart defect



See more (78)...

Find related data Database: Select Find items

Search details "heart defects, congenital"[MeSH Terms] OR ("heart"[All Fields] AND "defects"[All Fields] AND "congenital"[All Fields]) OR



# Content-based image retrieval

- **Visual feature** match
  - Aim to find images that look similar
  - Images are represented by feature vectors extracted from the images themselves
  - Different types of visual features
    - Color, Edges, Texture, Shape, Size, Location

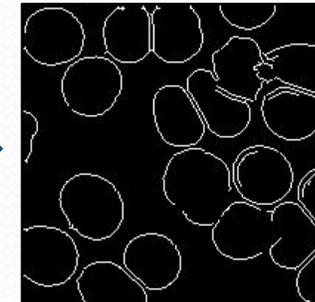
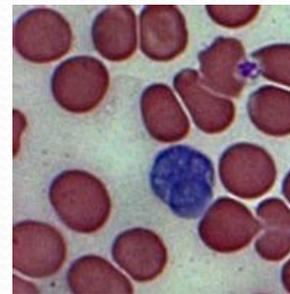
# Images are matrices



```
42 18 21 22 21 17 113 232 246
22 0 0 0 5 116 229 245 243
22 0 0 9 127 238 243 241 243
22 0 42 18 21 21 22 21 85 151 150
21 17 22 0 0 0 2 77 135 134 136
50 133 22 0 0 5 82 133 130 135 133
149 190 22 0
174 207 21 10 42 18 21 22 22 22 84 145 131
176 213 40 79 22 0 0 0 2 66 120 114 113
177 223 96 94 22 0 1 8 78 118 112 116 114
184 224 103 96 22 0 7 78 112 117 110 110 110
180 219 100 96 22 8 66 89 85 114 103 103 106
184 223 103 99 38 70 85 81 96 101 103 100 103
182 223 106 96 87 71 83 94 99 102 97 97 100
179 220 97 88 100 80 100 118 114 107 96 92 92
180 222 94 83 99 82 95 120 112 125 98 91 92
174 215 89 79 100 87 98 105 107 111 97 91 95
176 212 88 77 103 84 93 97 97 96 95 93 73
181 214 89 69 97 79 95 97 95 97 94 91 85
184 205 94 67 101 83 95 100 98 97 97 89 85
96 66 99 82 94 99 101 102 98 88 81
98 67 93 79 94 98 106 107 100 91 84
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86 68 85 108 149 144 127 112 104
87 69 89 122 155 166 159 120 111
122 77
```

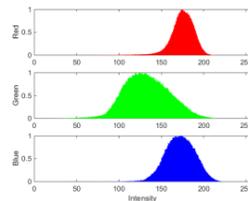
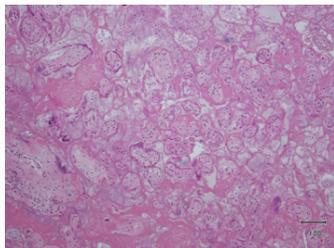
# Image Processing

Image In → Image Out



# Feature Extraction

Image In → Features Out



# Image Classification

Image In → Label Out

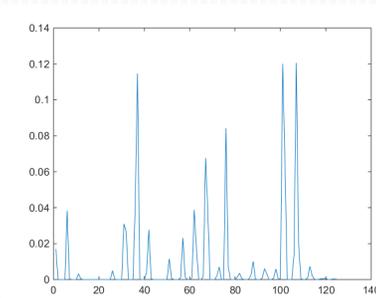
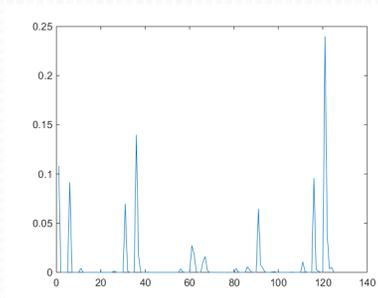
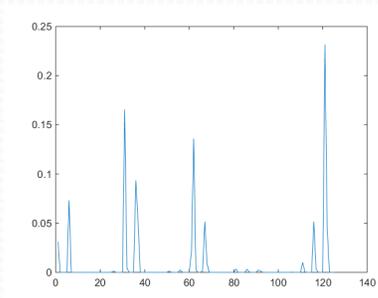


Xray

# Content-based image retrieval

- Feature extraction

Color histogram: describes the color distribution of the image

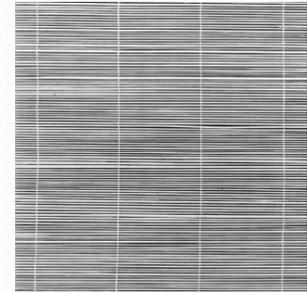
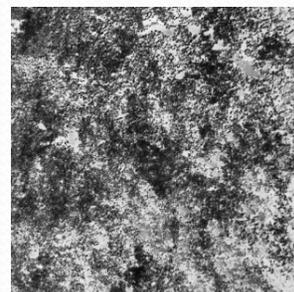
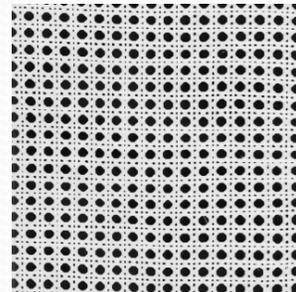
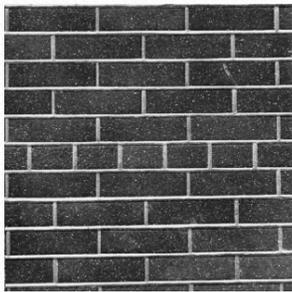


# Content-based image retrieval

- Feature extraction

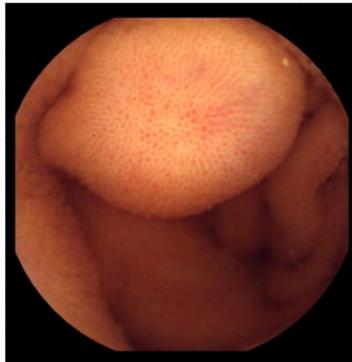
## Texture

- Determine visual appearance but is difficult to be described by text
- Similar structures being repeated
- Often has some degree of randomness



# Content-based image retrieval

- Strengths
  - Find “look alike”
- Weaknesses
  - Semantic gap: visually similarity does not mean being semantically close



Video capsule endoscopy image showing a bulge falsely interpreted as submucosal mass

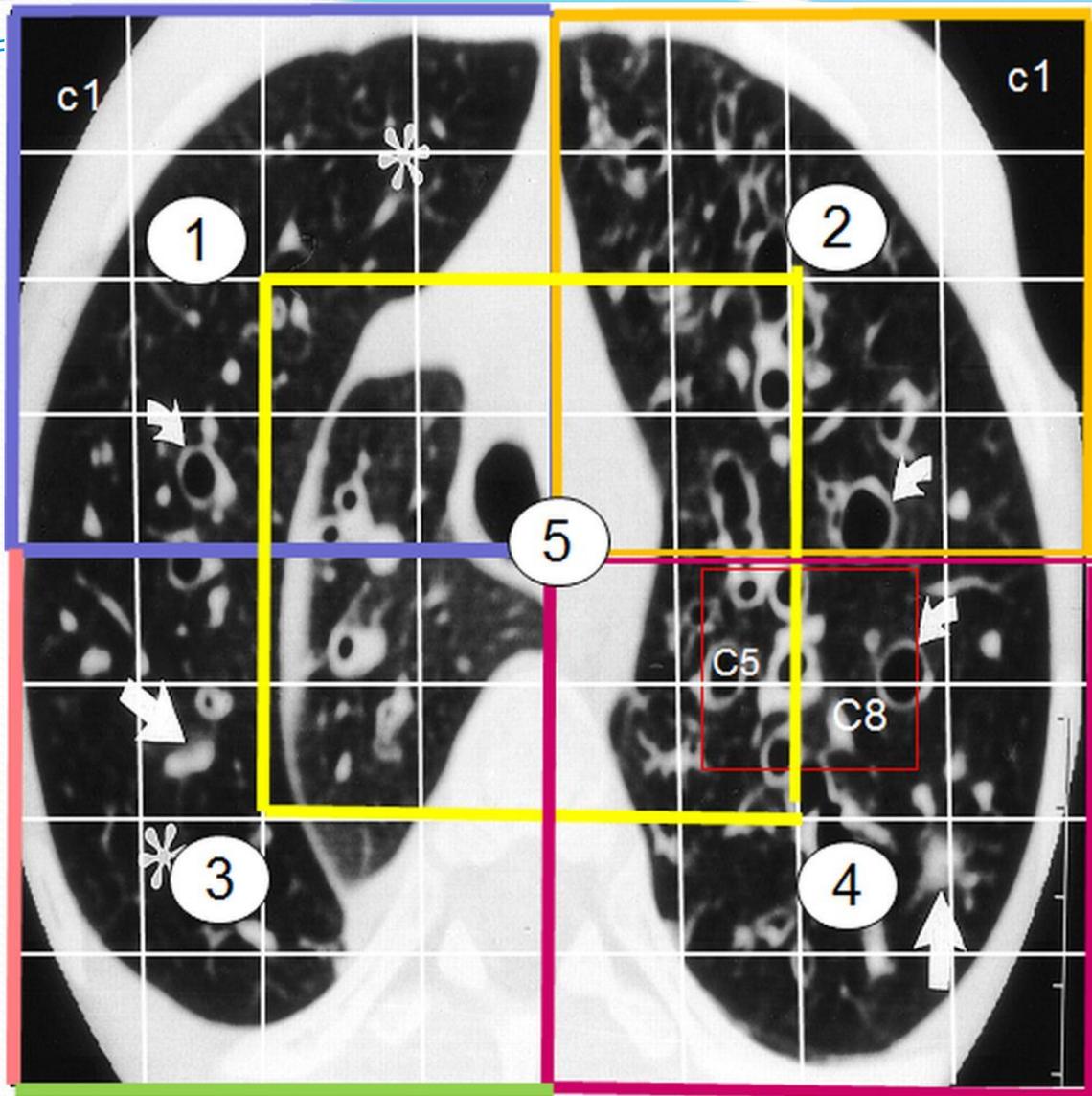


Ocular fundus of the left eye of a German White Fleckvieh

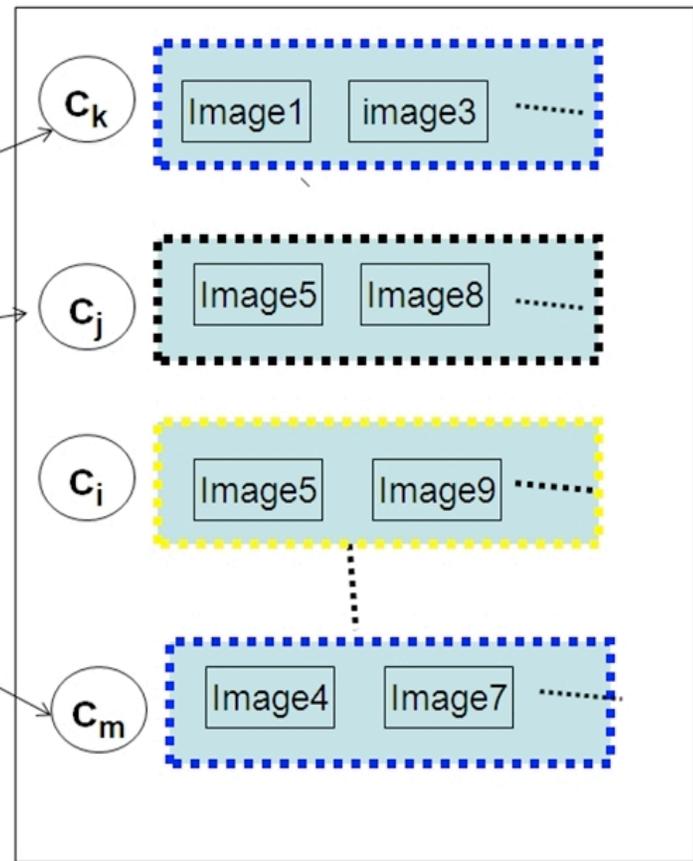
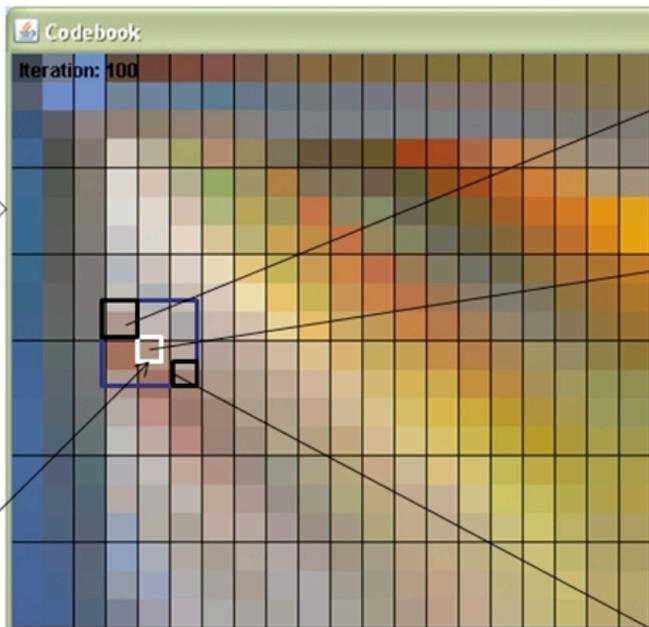
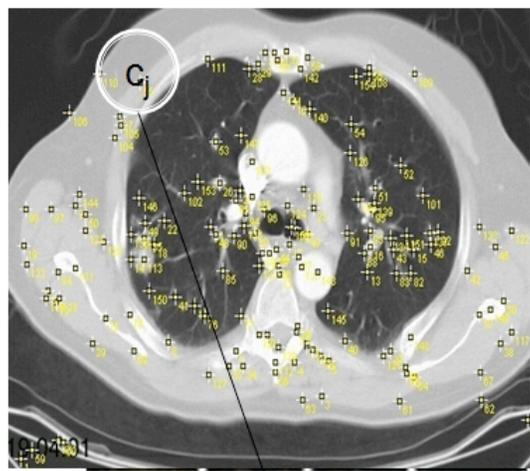
# Content-based image retrieval System

The screenshot displays the SPIRS-IRMA Combined Retrieval interface. At the top, there are logos for the National Library of Medicine (NLM) and the IRMA system. The main title is "SPIRS-IRMA Combined Retrieval". Below the title is a search bar and a toolbar with various icons. The central area shows a large image of a hand with the ID "693491" and a "Relevance: 5" indicator. Below this, a status bar indicates "Found: 100 (1-12) - Query Time: 2.43 s". The bottom section displays a grid of 12 image thumbnails, each with its ID and a score. The scores are as follows:

ID	Score
693491	8.987915e-01
693925	9.010063e-01
694104	9.023381e-01
693933	9.025636e-01
693938	9.031531e-01
693852	9.033863e-01
693636	9.036745e-01
694105	9.038011e-01
693937	9.038186e-01
693621	9.038193e-01
693935	9.040159e-01
694017	9.040649e-01



Extract Visual Patches (64 pixels x 64 pixels)



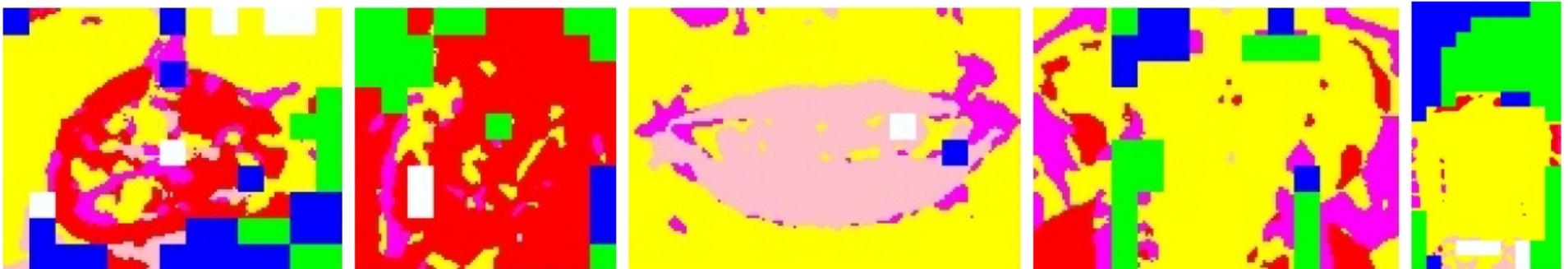
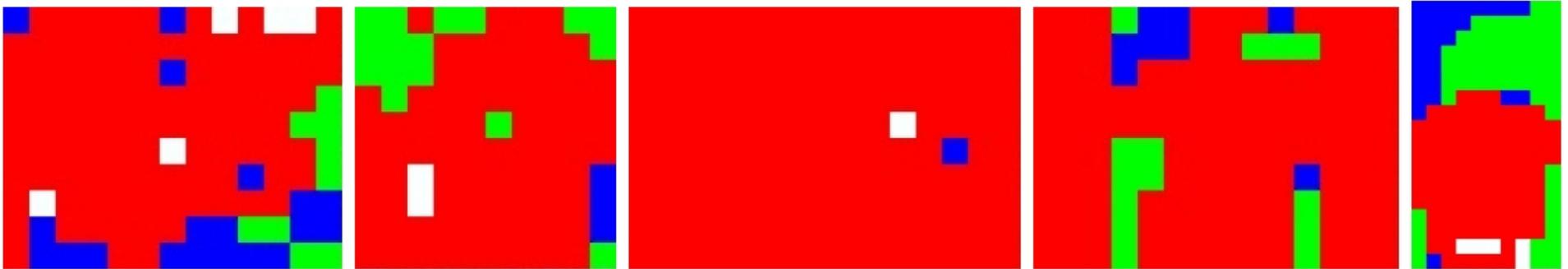
$$[W_{1q}, W_{2q}, \dots, W_{jq}, \dots, W_{Nq}]^T$$

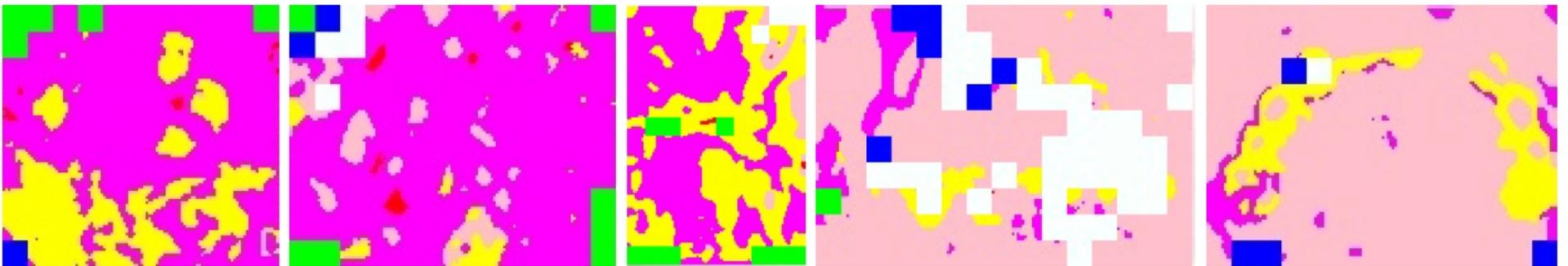
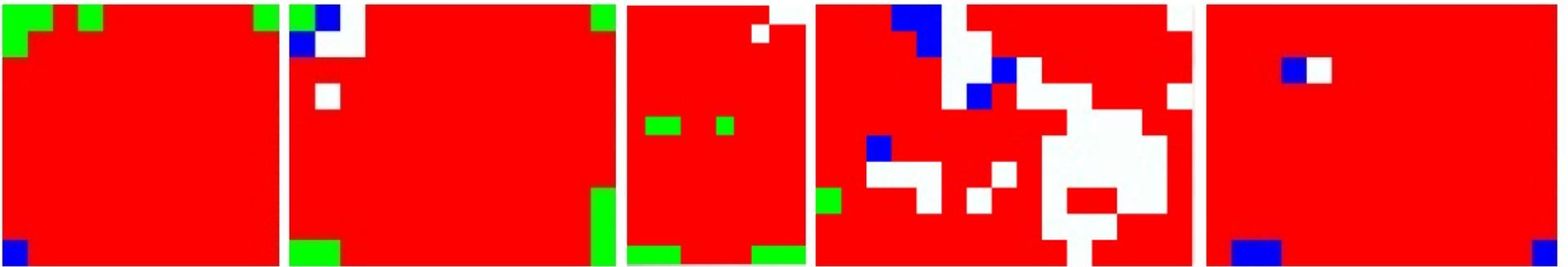
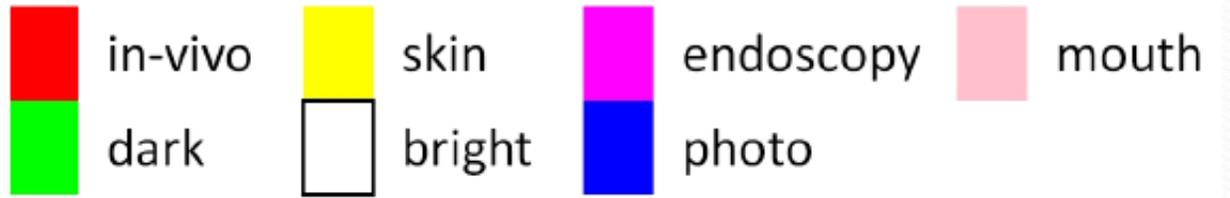
Query Vector

Inverted Index

# Searching using the codebook

	in-vivo		skin		endoscopy		mouth
	dark		bright		photo		







# Multimodal image retrieval

- Combination of above two approaches
  - Represent images by related text and content-based feature vectors
  - Combine text-based and content-based relevance (e.g., with re-ranking or filtering)



# Multimodal image retrieval

- Strengths
  - Semantic retrieval with visual similarity
- Challenges
  - Difficult to meaningfully combine features

# Image and text queries



Query Image

Feature extraction

CEDD [7.0, 0.0, 1.0, .....]  
 FCTH [7.0, 7.0, 0.0, .....]  
 EdgeHistogram [5.0, 6.0, 2.0, 5.0, .....]  
 ColorLayout [60.0, 17.0, 16.0, .....]  
 SemanticContext30 [0.0, 0.0, 1.0, .....]

Get representing cluster

f0p0k72  
 F1p0k1893  
 F2p0k84  
 F3p0k1134  
 f4p0k110

( F0p0k72 OR  
 F1p0k1893 OR  
 F2p0k84 OR  
 F3p0k1134 OR  
 f4p0k110 )

AND

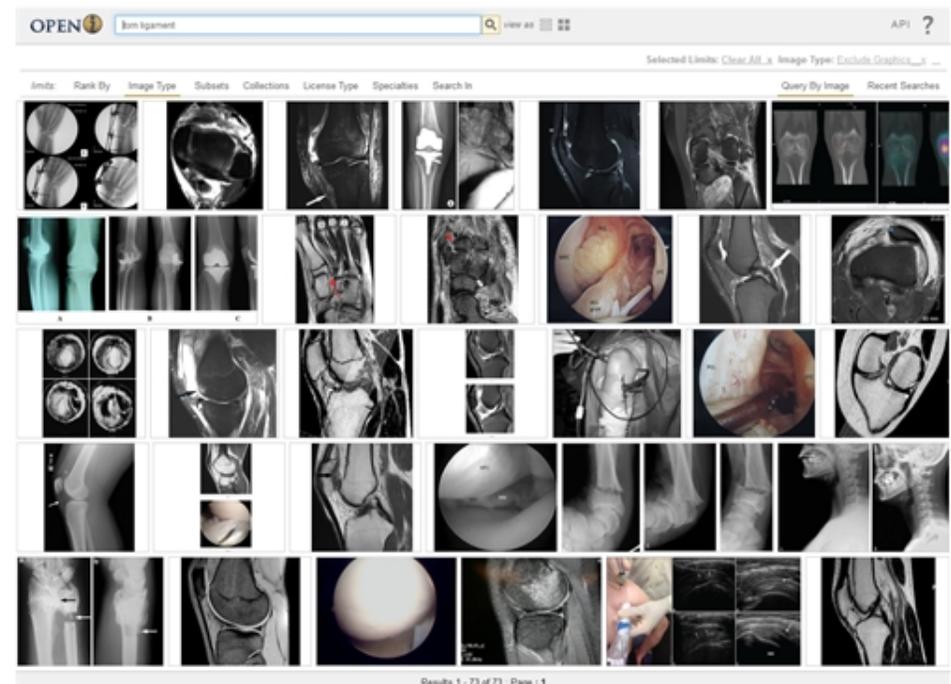
Torn Ligament

Image cluster words  
 and  
 Query text

Text search



Results



Open-i<sup>SM</sup>



<https://openi.nlm.nih.gov>



<http://openi.nlm.nih.gov>

- A **biomedical image** search engine
- Provide **Open-Access** to biomedical literature
- ~3.2M images and ~1M biomedical articles from NLM's PubMed Central<sup>®</sup>
- ~4000 chest x-ray studies and radiology reports from Indiana University School of Medicine
- 1591 illustrations from **Orthopedic Surgical Anatomy Teaching Collection** from University of Southern California, Norris Medical Library

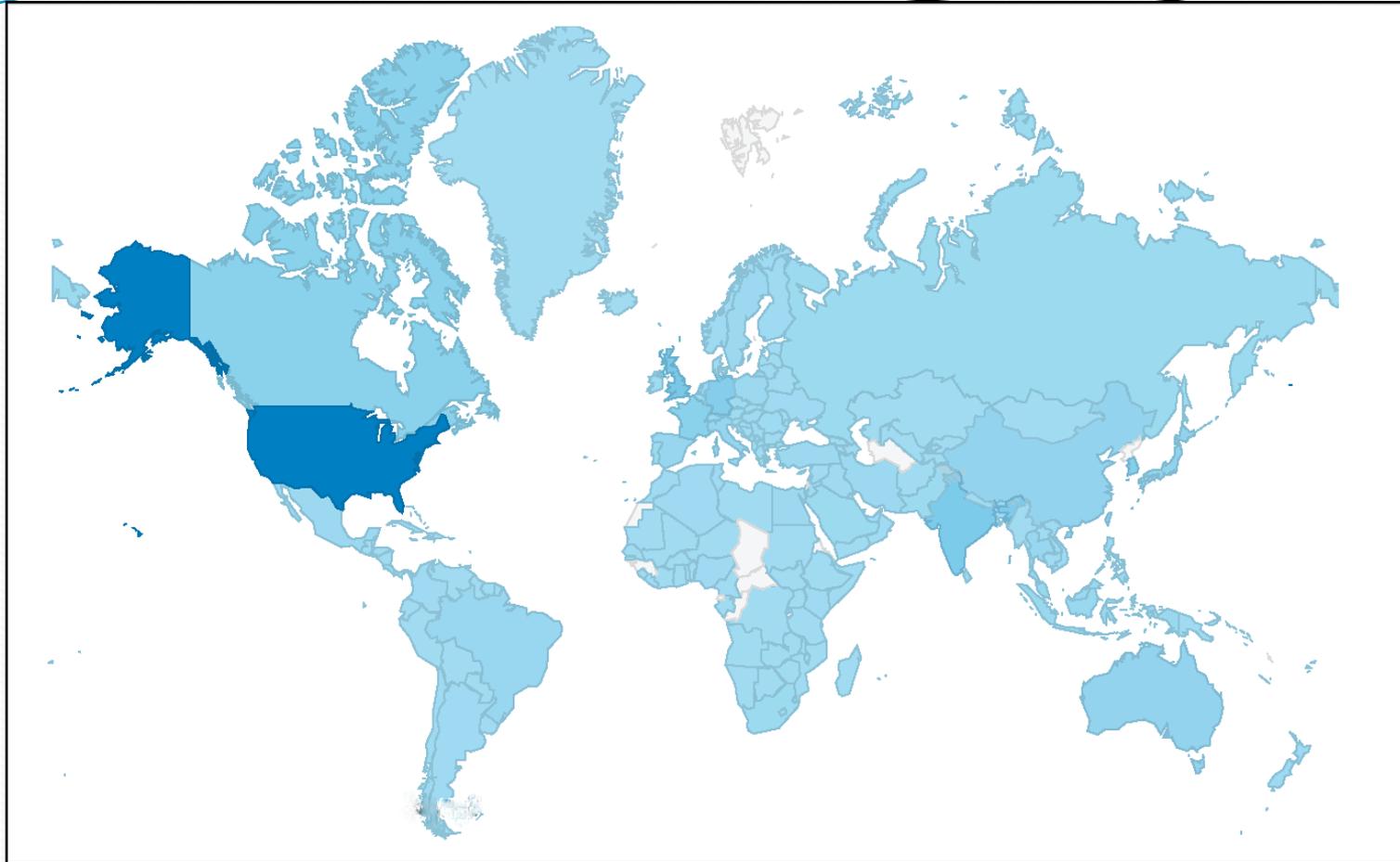
**Big Data Scale**



<http://openi.nlm.nih.gov>

- Direct access to relevant figures from an image and literature database
- Unique ability to index image content in addition to text
- Integrates R&D from text processing, image processing and information retrieval programs at NLM

*Multimodal*



- ~ 10,000 unique visitors daily
- Hits (including bots): ~ 700,000
- Top Countries: USA (32%), UK (7%), India (6%), Germany (5%), S. Korea(4%)

<http://openi.nlm.nih.gov>

The screenshot displays the Open Image Library (OPEN) website interface. At the top, the search bar contains the term "tumor". Below the search bar, a navigation menu includes options like "limits:", "Rank By", "Article Type", "Image Type", "Subsets", "Collections", "License Type", "Specialties", and "Search In". A grid of histological images is shown, with a central image selected. A text box provides details for this image, including the title "Prostatic adenocarcinoma metastatic to pleomorphic liposarcoma, a 'collision phenomenon': report of a case with review of pelvic collision tumors.", the authors "Roy S, Hrebinko RL, Cleply KM, Panwani AV, Rao UN", the journal "Patholog Res Int (2011)", and a detailed description of the pathology. A "fig1" caption describes the sarcomatoid urothelial carcinoma. Annotations include a "Text Query" box pointing to the search bar, a "Filters" box listing "Image Type", "Subset", and "Specialties" with a dropdown menu showing options like "CT Scan", "Graphics", "MRI", "Microscopy", "PET", "Photographs", "Ultrasound", "Video", "X-ray", and "Exclude Graphics" and "Exclude Multipanel" checked. An "Image Query" box points to a specific image in the grid. An "Information on Hover" box points to the text box, and a "Detail on Click" box points to the "Browse..." button in the image options menu.

**Text Query**

**Filters:**

- Image Type
- Subset
- Specialties

**Image Query**

**Information on Hover**

**Detail on Click**

Prostatic adenocarcinoma metastatic to pleomorphic liposarcoma, a "collision phenomenon": report of a case with review of pelvic collision tumors.

Roy S, Hrebinko RL, Cleply KM, Panwani AV, Rao UN *Patholog Res Int* (2011)

**Bottom Line:** Pathological examination revealed a large liposarcoma with prostatic carcinoma embedded in it. Immunohistochemistry and fluorescence in situ hybridization studies were performed to reach to a conclusive diagnosis. To the best of our knowledge, this is the second case reported till date.

**fig1 :** Sarcomatoid urothelial carcinoma. **Tumor** comprised of sheets of epithelioid and plump spindle cells which are highly pleomorphic with nuclear hyperchromasia. There is prominent stromal inflammatory response to the invading **tumor** with destruction of the bladder wall. (Hematoxylin-eosin, original magnification ×100).

<http://openi.nlm.nih.gov>

The screenshot shows the OPEN search results page for the query 'tumor'. The browser address bar displays the URL: <https://openi.nlm.nih.gov/query.php?q=tumor&it=xg,xm&qimg=0.794594001448998207a&m=1&n=10&req=1>. The search bar contains the word 'tumor'. The page features a navigation menu with options like 'limits:', 'Rank By', 'Article Type', 'Image Type', 'Subsets', 'Collections', 'License Type', 'Specialties', and 'Search In'. There are also buttons for 'Query By Image' and 'Recent Searches'. The main content area displays four search results, each with a thumbnail image, a title, author information, and a brief description. To the right of each result, there are links for 'Related in:', 'View Article:', and 'Show All Figures - Show MeSH'. Two red arrows point to the 'view as' menu icon and the 'API ?' link. Two yellow callout boxes with black text are overlaid on the page: 'Switch Views' points to the 'view as' menu, and 'API for Web services' points to the 'API ?' link. At the bottom of the page, it says 'Results 1 - 10 of 1167 : Page : 1 2 3 4 5 6 7 8 9 10'.

OPEN  view as API ?

Selected Limits: Clear All x Image Type: Exclude Graphics x Exclude Multipar x ...

limits: Rank By Article Type Image Type Subsets Collections License Type Specialties Search In Query By Image Recent Searches

**Mixed germ cell-sex cord-stromal tumor with a concurrent interstitial cell tumor in a ferret.**  
Inoue S, Yonemaru K, Yanai T, Sakai H - *J Vet Med Sci* (2014)  
Histopathological findings of the tumor. The neoplasm consisted of diffuse proliferation of intimately admixed germ cell-like cells and Sertoli cell-like cells. Interstitial...

**Atypical primary meningioma in the nasal septum with malignant transformation and distant metastasis.**  
Baek BJ, Shin JM, Lee CK, Lee JH, Lee KH - *BMC Cancer* (2012)  
Histopathology of the recurrent and metastatic tumours. (A) Atypical cells having round-to-oval nuclei, with prominent nucleoli and frequent mitoses in the nasal cavity recurring...

**Recurrent retroperitoneal Schwannomas displaying different differentiation from primary tumor: case report and literature review.**  
Li ZQ, Wang HY, Li J, Teng L - *World J Surg Oncol* (2010)  
Images of HE staining showing the schwannoma undergoing malignant transformation. High-power view of the spindle cell component showing bland cytologic features with a suggestion of palisading...

**Complete response to FOLFOX4 therapy in a patient with advanced urothelial cancer: a case report.**  
Seo YR, Kim SH, Kim HJ, Kim CK, Park SK, Koh ES, Hong DS - *J Hematol Oncol* (2010)  
A: The polycystical tumor of the kidney reveals high grade urothelial carcinoma

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**Atypical primary meningioma in the nasal septum with malignant transformation and distant metastasis.**

Baek BJ, Shin JM, Lee CK, Lee JH, Lee KH - *BMC Cancer* (2012)

**Bottom Line:** The subcutaneous mass was resected and showed histological evidence of malignant transformation. Several months after the last operation, the patient died. To our knowledge, this is the first reported case of an atypical PEM originating from the nasal septum that recurred with malignant transformation and extracranial metastasis.

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**Affiliation:** Department of Otolaryngology-Head and Neck Surgery, Soonchunhyang University School of Medicine, Cheonan Hospital, 23-20 Bongmyung-Dong, Cheonan 330-721, Chungcheongnam-do, Korea. baekbj@schmc.ac.kr

**ABSTRACT**

**Background:** Primary extracranial meningiomas (PEMs) originating from the nasal septum are extremely rare, as are extracranial metastases of meningiomas.

**Case presentation:** A 44-year-old male presented with a 2-month history of left-side nasal obstruction and frequent episodes of epistaxis. A friable mass originating from the nasal septum was resected completely via an endoscopic endonasal approach. According to WHO criteria, the tumor was diagnosed as an atypical meningioma radiologically and histopathologically. Two years later, a tumor recurred at the primary site with the same histopathological findings, and the patient was given local external radiotherapy (6840 cGy in 38 fractions). Two months after this local recurrence, a left anterior chest wall mass and a left parietal area scalp mass were observed. The subcutaneous mass was resected and showed histological evidence of malignant transformation. Several months after the last operation, the patient died.

**Conclusions:** We describe the clinical, radiological, and bio-pathological features of this case. We also review the literature on atypical PEMs originating in the nasal septum. To our knowledge, this is the first reported case of an atypical PEM originating from the nasal septum that recurred with malignant transformation and extracranial metastasis.

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**Figure 4:** Histopathology of the recurrent and metastatic tumours. (A) Atypical cells with round-to-oval nuclei, with prominent nucleoli and frequent mitoses in the nasal recurrent tumour. (B) The metastatic tumour had a higher mitotic index (up to 40 mitoses within 10 HPF) and Ki-67 labeling index (40%) than the primary tumour (×400, H&E). (C) Geographic tumoural necrosis and hemorrhage (×400, H&E).

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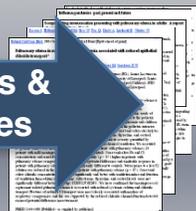
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# PMC

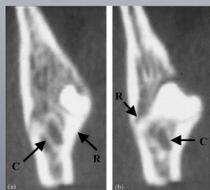
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## ENRICHED CITATION

[Oxford unicompartmental knee arthroplasty: medial pain and functional outcome...](#)



**Figure 8:** An example of a knee with a poor radiographic score.

**Bottom Line:** In our experience results of the Oxford unicompartmental knee replacement have not been as good as had been expected. During assessment patients were asked specifically whether or not they still experienced medial knee discomfort or pain. The mean 'Oxford score'...

Edmondson MC, Isaac D, Vijeratna M, Brink S, et al. - J Orthop Surg Res (2011)  
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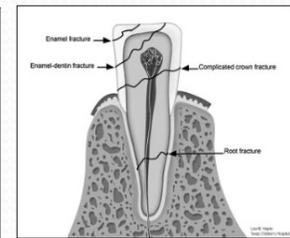
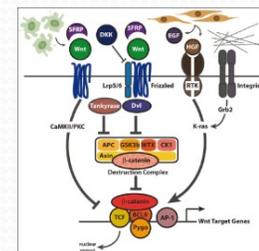
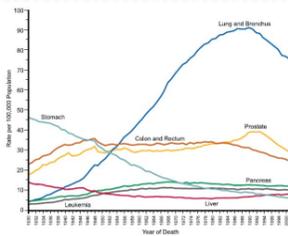
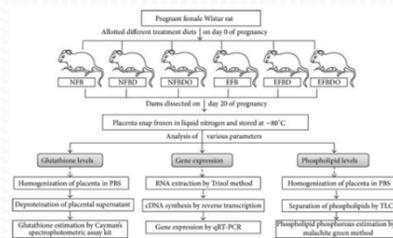
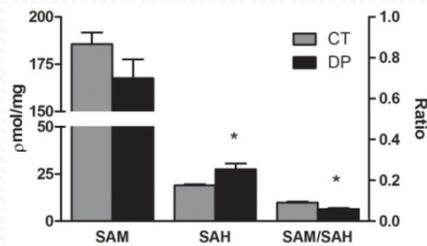
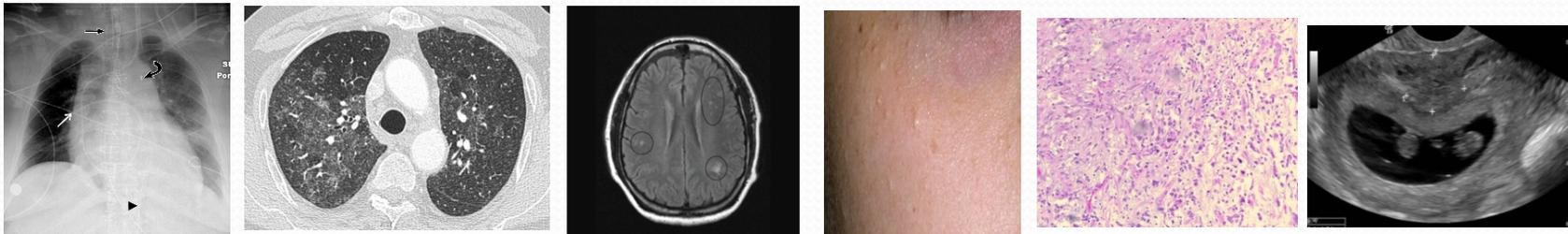


# Image Pre-processing in Open-i

1. Image modality classification
2. Multi-panel figure separation
3. Image marker extraction

# 1. Image modality classification

- **Aim?**
- Automatically separate images into different types



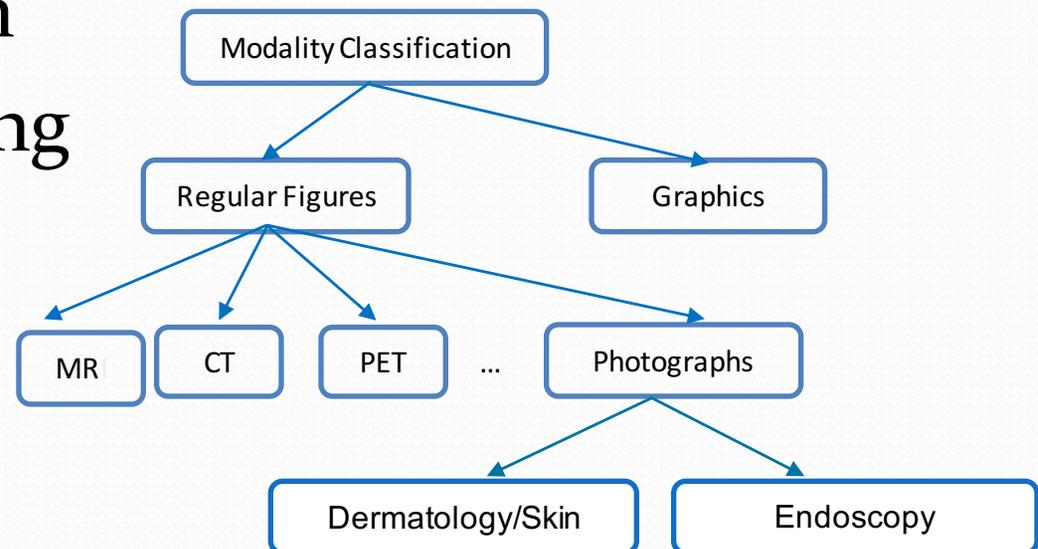
# 1. Image modality classification

- **Why?**
  - To limit the search space
  - To make retrieval more effective and the retrieved images more relevant to a query



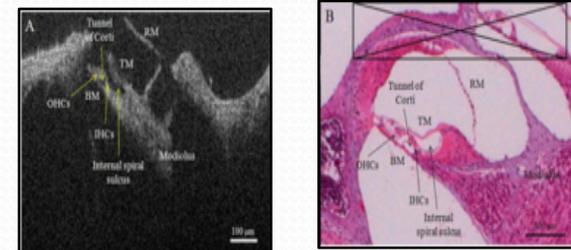
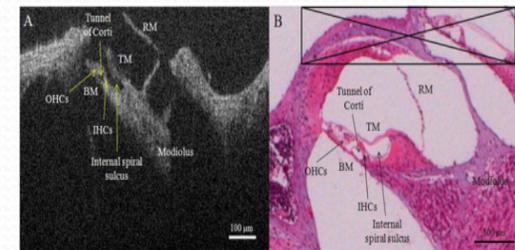
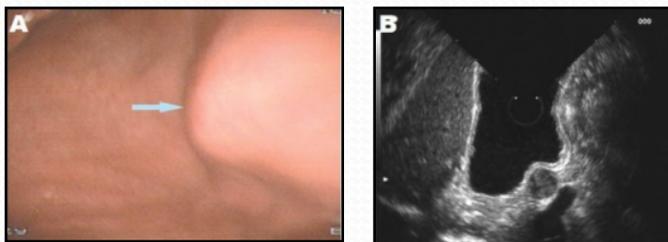
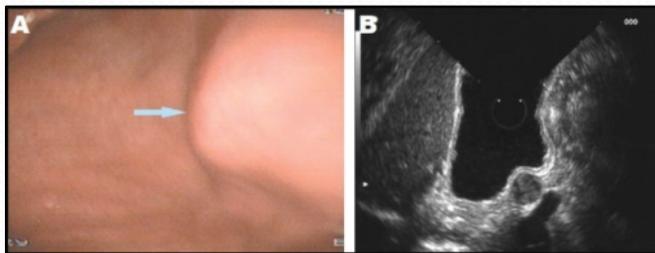
# 1. Image modality classification

- **How?**
  - Hierarchical classification
  - Feature extraction
  - Supervised learning



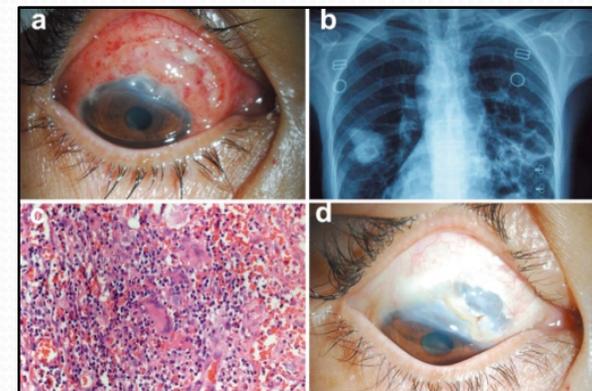
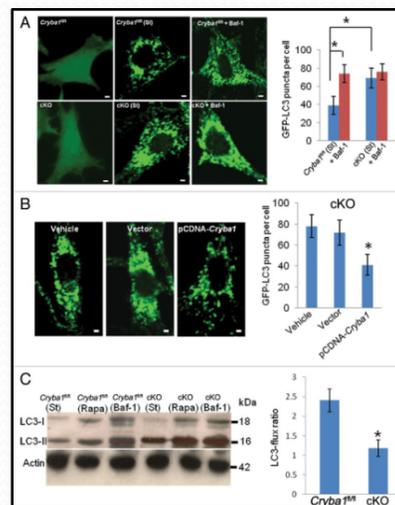
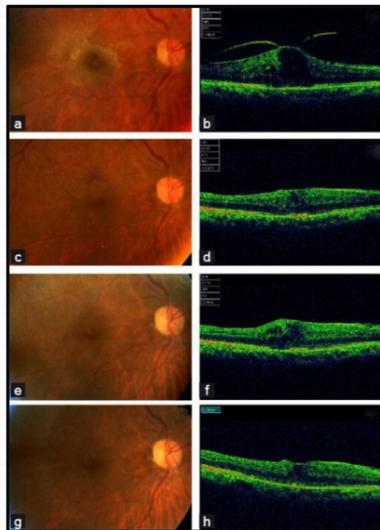
## 2. Multi-panel figure separation

- Aim?
- Automatically split a multi-panel figure into individual subfigure panels



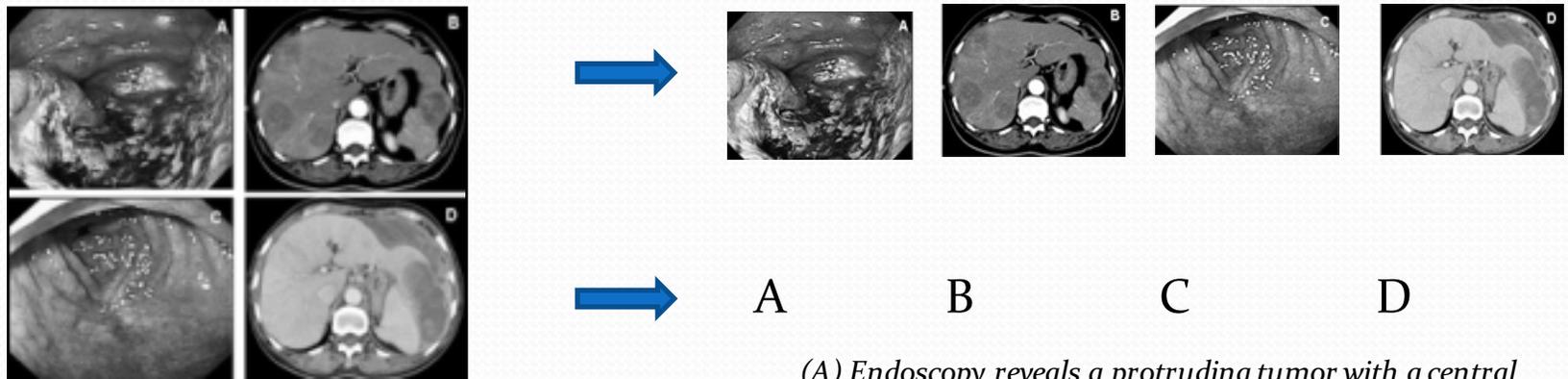
## 2. Multi-panel figure separation

- **Why?**
  - To improve image modality classification
  - Such compound figures are very common in the dataset



## 2. Multi-panel figure separation

- **How?**
- Three major steps: image panel segmentation, label extraction, and sub-caption extraction

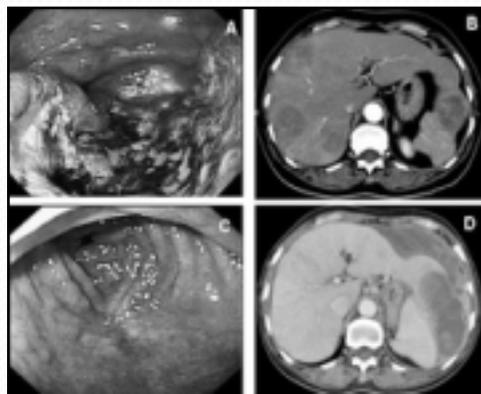


(A) Endoscopy reveals a protruding tumor with a central ulceration at the great curvature extending from the low body to antrum of the stomach. (B) Abdominal CT shows multiple hepatic tumors in the bilateral lobes of the liver and wall thickening in the stomach. (C) Endoscopy reveals complete remission of the gastric tumor after chemotherapy. (D) Abdominal CT shows the recurrence of the liver metastases with tumor rupture.

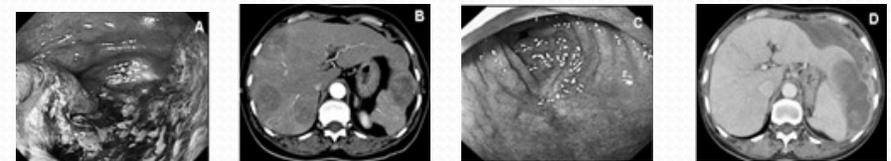
(A) Endoscopy reveals a protruding tumor with a central ulceration at the great curvature extending from the low body to antrum of the stomach.  
 (B) Abdominal CT shows multiple hepatic tumors in the bilateral lobes of the liver and wall thickening in the stomach.  
 (C) Endoscopy reveals complete remission of the gastric tumor after chemotherapy.  
 (D) Abdominal CT shows the recurrence of the liver metastases with tumor rupture.

## 2. Multi-panel figure separation

- How?
- Three major steps: image panel segmentation, label extraction, and sub-caption extraction



(A) Endoscopy reveals a protruding tumor with a central ulceration at the great curvature extending from the low body to antrum of the stomach. (B) Abdominal CT shows multiple hepatic tumors in the bilateral lobes of the liver and wall thickening in the stomach. (C) Endoscopy reveals complete remission of the gastric tumor after chemotherapy. (D) Abdominal CT shows the recurrence of the liver metastases with tumor rupture.



A B C D

(A) Endoscopy reveals a protruding tumor with a central ulceration at the great curvature extending from the low body to antrum of the stomach.

(B) Abdominal CT shows multiple hepatic tumors in the bilateral lobes of the liver and wall thickening in the stomach.

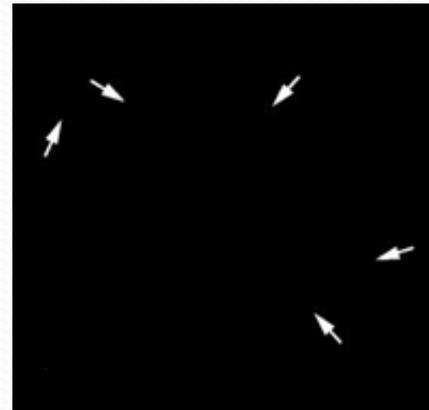
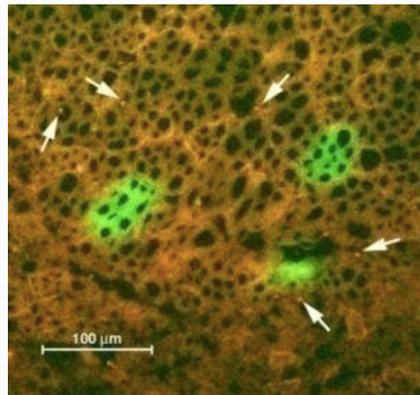
(C) Endoscopy reveals complete remission of the gastric tumor after chemotherapy.

(D) Abdominal CT shows the recurrence of the liver metastases with tumor rupture.



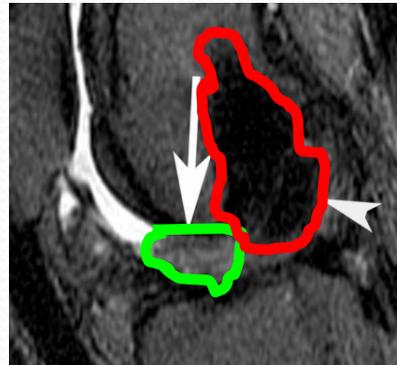
### 3. Image marker extraction

- Aim?
- To automatically extract markers such as arrows in the figures



### 3. Image marker extraction

- Why?
- The author annotated regions are often correlated with relevant text in figure captions



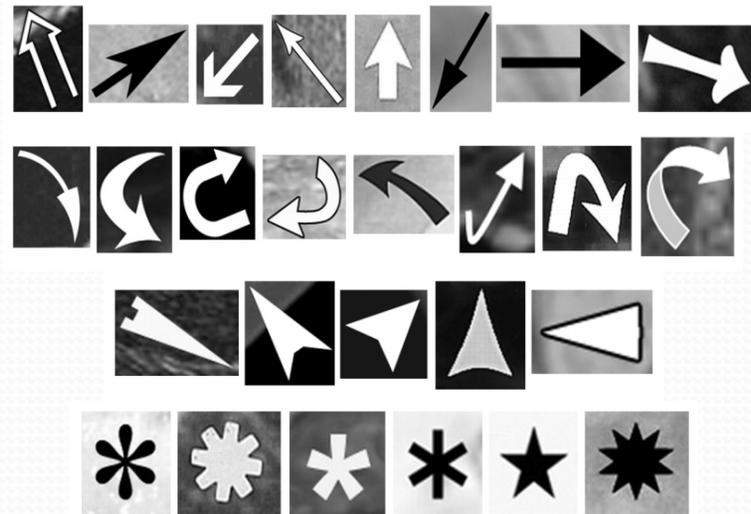
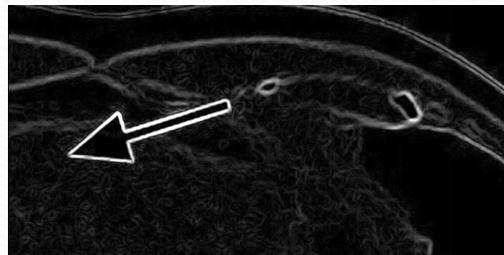
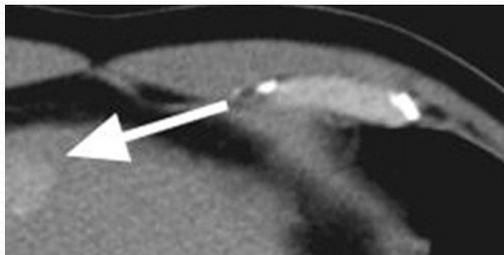
#### MR imaging evaluation of the postoperative knee

McCauley, Thomas R. *Radiology* (2004).

**Figure 7B:** Cyclops lesion in a 26-year-old man with decreased range of motion after ACL reconstruction. Sagittal T2-weighted SE (1800/80) MR arthrograms show cyclops lesion (arrow) anterior to ACL graft (arrowhead). Note that cyclops lesion has intermediate signal intensity even though it is a fibrous lesion.

# 3. Image marker extraction

- **How?**
  - Segmentation of the regions of the pointers
  - Recognition of the shapes of the pointers



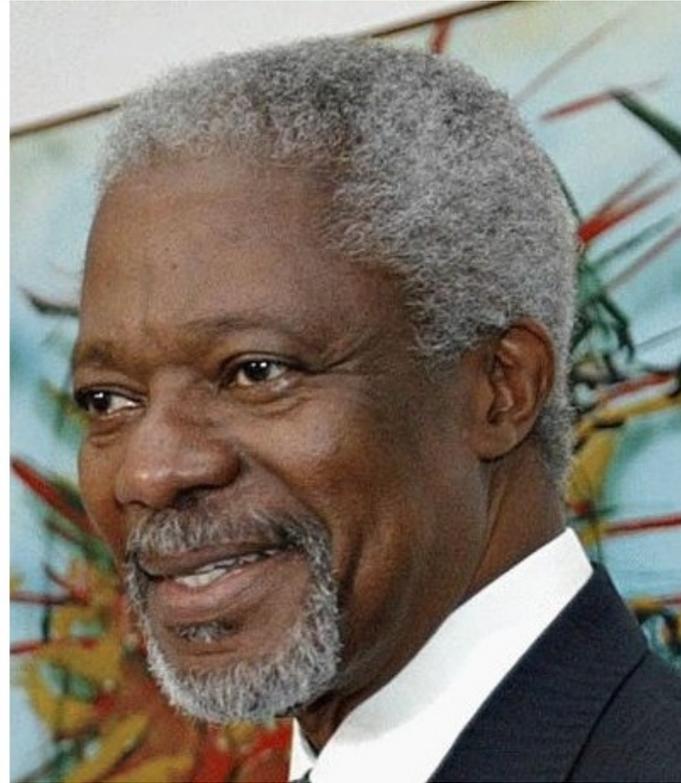


# Conclusion

- Big data
- Multimodal image retrieval
- Medicine

**"Knowledge is power.  
Information is liberating.  
Education is the premise  
of progress, in every  
society, in every family."**

**- Kofi Annan**



**One learns by asking questions ...**

# Thanks! Questions?

