



An IDEAL
app



Searchable datasets in Python: images across domains, experiments, algorithms and learning

pyCBIR



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Face recognition based on facial features



Agenda

1. Introduction;
2. pyCBIR: signatures, similarity and retrieval;
3. Human interaction;
4. Experiments:
 - a. Fibers
 - b. Material
 - c. Cells
 - d. CIFAR
5. What's next?



1.		
2.		
3.		
4.		

Introduction

- CBIR, QBIC, CBVIR, CBMIR = computer vision to image retrieval;
- Content-based (**color**, **shape**, **texture**) vs. Metadata (keyword, tag);
- Image properties – semantic gap – human queries

History

- 1992: T. Kato introduces term CBIR*;
- 1994: C. Faloutsos *et al* @IBM releases 1st CBIR system = QBIC;
- 2016:
 - good at **collecting** images, but is search better?
 - **organize/retrieve** images using images: tools available only to very specific problems, e.g., recommendation systems.

Commercial CBIR search engines [edit]

Name	Description	External Image Query	Metadata Query	Index Size (Estimate, Millions of Images)	Organization Type	License (Open/Closed)
JustVisual (formerly known as Superfish)	pure image-to-image search	yes	yes	Billions	Start-up	API
Pixolution	CBIR search engine, by pixolution	No	No	32M	Private Company	Closed
Picalike	CBIR engine for Mobile and eCommerce	No	No (additional filters can be added)		Private Company	Closed
Elastic Vision	Smart image searcher with content-based clustering in a visual network.	No	No		Private Company	Closed
Yandex Image Search	Yandex CBIR system	Yes	Yes	10000M	Public Company	Closed
Baidu Image Search	Baidu's CBIR system	Yes	Yes	1000M	Public Company	Closed
Imense Image Search Portal	CBIR search engine, by Imense.	No	Yes	3M	Private Company	Closed
Imprezzeo Image Search	CBIR search engine, by Imprezzeo.	No	Yes		Private Company	Closed
Incogna Image Search	CBIR search engine, by Incogna Inc.	No	Yes	100M	Private Company	Closed
Chic Engine	Visual fashion search engine (CBIR)	Yes	No		Private Company	Closed
MiPai similarity search engine	Online similarity search engine	Yes	Yes	100M	Individual	Closed
Piximilar	Demo engine, developed by Idee Inc.	No	No	3M	Private Company1	Closed
Empora	Product comparison & shopping using CBIR for product images. Previously known as Pixsta	No	Yes	0.5M	Private Company	Closed
Shopachu	Shopping & fashion CBIR engine, by Incogna Inc.	No	Yes	1M	Private Company	Closed
TinEye	CBIR site for finding variations of web images, by Idee Inc.	Yes	No	12100M	Private Company	Closed
Galaxy	CBIR engine for finding product/catalogue/video frames, by Odd Concepts Inc.	Yes	Yes	35M	Private Company	Closed
Tiltomo	CBIR system using Flickr photos	No	Yes		Private Company	Closed
eBay Image Search	Image Search for eBay Fashion	No	Yes	20M	Public Company	Closed
IMMENSELAB	CBIR search engine by KBKGROUP .	Yes	No	10M	Private Company	Closed
Macroglossa Visual Search	CBIR visual search engine	Yes	No		Private Company	Closed
NoClone	PC image search engine and classification based on content	Yes (a set)	No		Private Company	Closed
Querbie	General purpose CBIR visual search engine	Yes	Yes	20M	Private Company	Closed
Google Image Search	Google's CBIR system with reverse image search	Yes	Yes		Public Company	Google Custom Search API access
ID My Pill	Automatic prescription pill identification (CBIR)	Yes	No		Private Company	Open (via API)
PicScout	CBIR service tracks image usage across the web.	Yes	Yes	270M	Private Company (Getty Images)	Open (via API)

CBIR research projects

CBIR research projects/demos/open source projects [\[edit\]](#)

Name	Description	External Image Query	Metadata Query	Index Size (Estimate, Millions of Images)	Organization Type	License (Open/Closed)
akiwi	akiwi is a semi-automatic image keywording tool using CBIR techniques. It was developed by HTW Berlin / pixolution GmbH	Yes	Yes	15M	University	Closed
ALIPR	Developed by Penn State University researchers	Yes	Yes		University	Closed
ISSBP	Similar Image Search by Imense plugin for Adobe Bridge, free beta.	Yes	Yes	free-beta limited to 4k images	Private Company	Closed
img(Rummager)	Image retrieval Engine (Freeware Application).	Yes	No	Desktop-based	Individual	Closed
IKONA	Generic CBIR system - INRIA - IMEDIA	Yes	Yes		University	Closed
IOSB	Image retrieval demonstration software of Fraunhofer IOSB (Germany)	Yes	No	Desktop-based	Research Institute	Closed
Lucignolo	Image similarity search engine using only the native full-text search engine Lucene.	Yes	Yes	106M	Research Institute	Closed
MUVIS	CBIR System at TUT- Tampere University of Technology.	Yes	No	Desktop-based	University	Closed
PIRIS	CBIR tool developed at CEA-LIST, LVIC (Vision and Content Engineering Laboratory).	Yes	Yes	130M	University	Closed
PicsLikeThat	Image search using visual similarity search and sorting combined with a recommender system. (Cooperation of pixolution GmbH, fotolia and HTW Berlin)	No	No	12M	University	Closed
Pixcavator	Similar image search based on topological image analysis	Yes	No	Desktop-based	Private company	Closed
QuickLook	Visual information retrieval system with relevance feedback	No	Yes		University	Closed
RETIN	Interactive Images retrieval system - CNRS - ETIS Lab., MID Team	No	No		University	Closed
Retriever	Search and explore in a selection of Flickr images by drawing a rough sketch or uploading an image.	No	No		University	Closed
SIMBA	demo of system by the Albert-Ludwigs-Universität Freiburg (Germany) Inst. for Pattern Recognition and Image Processing	Yes	No	0.002M	University	Closed
TagProp	The demonstration of image annotation tool TagProp in ICCV2009 for image set: Corel 5k ESP Game IAPR TC-12 and MIR Flickr.	No	Yes		Institute	Closed
VIRaL	Visual Image Retrieval and Localization: A visual search engine that, given a query image, retrieves photos depicting the same object or scene under varying viewpoint or lighting conditions. Using Flickr photos of urban scenes, it automatically estimates where a picture is taken, suggests tags, identifies known landmarks or points of interest, and links to relevant Wikipedia articles. It currently supports 39 cities around the world.	Yes	Yes	2.221M	University	Closed
PIBE	An adaptive image browsing system that provides users with an intuitive, easy-to-use, structured view of an image collection and complements it with ideas from the field of adaptable content-based similarity search. A hierarchical view of images (the Browsing Tree) that can be customized according to user preferences is provided.	Yes	No		University	Closed
SHIATSU	A novel system for automatic video tagging which is based on shot boundaries detection and hierarchical annotation processes. The tagging phase assigns semantic concepts to both shot sequences and whole videos, by exploiting visual features extracted from key frames.	Yes	Yes		University	Closed
BRISC	BRISC is a recursive acronym for BRISC Really IS Cool, and is (conveniently enough) also an anagram of Content-Based Image Retrieval System.	Yes	No		University	GPL
digikam	Extensive photo management application build on top of KDE libraries. It provides, besides many other features, reverse searches for images in the local collection, detection of duplicates and a fuzzy search by drawings.	Yes	Yes	Desktop-based	KDE	GPL
Caliph & Emin	Creation and Retrieval of images based on MPEG-7.	Yes	No	Desktop-based	University	GPL
GNU Image Finding Tool	Query by example image search system.	Yes	No	Desktop-based	GNU	GPL
imgSeek	photo collection manager and viewer with content-based search and many other features.	Yes	No		Individual	GPL
LIRE	Java GPL library for content based image retrieval based on Lucene including multiple low level global and local features and different indexing strategies including bag of visual words and hashing.	Yes	Yes		University	GPL
Pastec	C++ LGPL index and search engine for near-duplicate image retrieval that uses bag of visual words with ORB features.	Yes	Yes		Private company	LGPL
Anakysis	This Web-Solution implements a new family of CBIR descriptors. These descriptors combine in one histogram color and texture information and are suitable for accurately retrieving images.	Yes	No	0.225M	University	Open
FIRE	Open source query by visual example CBIR system. Developed at RWTH Aachen University. FIRE is a research system developed with extensibility in mind and can easily be combined with textual information retrieval systems.	No	No		University	Open
MIFile	Image similarity search engine based on MI File (Metric Inverted File) developed at ISTI-CNR. Source code of the MI File.	No	No	100M	Research Institute	Open
Windsurf	A general framework for efficiently processing content-based image queries with particular emphasis to the region-based paradigm; it provides an environment where different alternatives of the paradigm can be implemented, allowing such implementations to be compared on a fair basis, from the points of view of both effectiveness and efficiency.	Yes	No		University	Open but not free

CBIR research projects

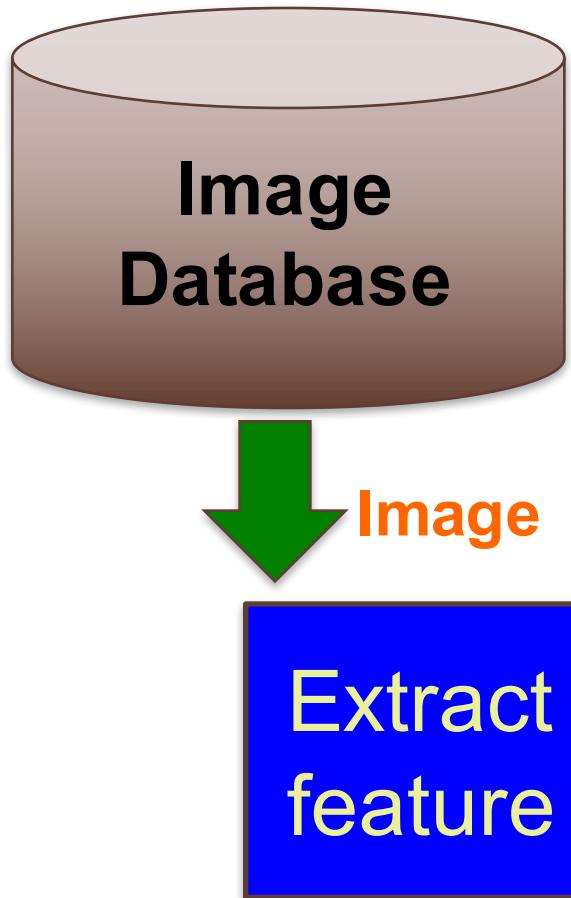
CBIR research projects/demos/open source projects [edit]

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BRISC	using CBIR techniques. It was developed by HTW Berlin / pixolution GmbH	Yes	Yes	15M	University	Closed
digiKam	's	Yes	Yes		University	Closed
Caliph & Emin	be Bridge, free beta.	Yes	Yes	free-beta limited to 4k images	Private Company	Closed
GNU Image Finding Tools	hofer IOSB (Germany)	Yes	No	Desktop-based	Individual	Closed
imgSeek	ative full-text search engine Lucene.	Yes	Yes	106M	University	Closed
LIRE	chnology.	Yes	No	Desktop-based	Research Institute	Closed
Pastec	and Content Engineering Laboratory).	Yes	Yes	130M	University	Closed
Anaktisi	orting combined with a recommender system. (Cooperation of pixolution GmbH, fotolia and HTW Berlin)	No	No	12M	University	Closed
FIRE	pe analysis	Yes	No	Desktop-based	Private company	Closed
MIFile	ce feedback	No	Yes		University	Closed
Windsurf	FIS Lab., MIDI Team	No	No		University	Closed
	es by drawing a rough sketch or uploading an image.	No	No		University	Closed
	tet Freiburg (Germany) Inst. for Pattern Recognition and Image Processing	Yes	No	0.002M	University	Closed
	jProp in ICCV2009 for image set: Corel 5k ESP Game IAPR TC-12 and MIR Flickr.	No	Yes		Institute	Closed
	al search engine that, given a query image, retrieves photos depicting the same object or scene under varying viewpoint or lighting conditions. Using Flickr photos of urban scenes, it suggests tags, identifies known landmarks or points of interest, and links to relevant Wikipedia articles. It currently supports 39 cities around the world.	Yes	Yes	2.221M	University	Closed
	es users with an intuitive, easy-to-use, structured view of an image collection and complements it with ideas from the field of adaptable content-based similarity search. A hierarchical view of ized according to user preferences is provided.	Yes	No		University	Closed
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	on top of KDE libraries. It provides, besides many other features, reverse searches for images in the local collection, detection of duplicates and a fuzzy search by drawings.	Yes	Yes	Desktop-based	KDE	GPL
	EG-7.	Yes	No	Desktop-based	University	GPL
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	CBIR descriptors. These descriptors combine in one histogram color and texture information and are suitable for accurately retrieving images.	Yes	No	0.225M	University	Open
	item. Developed at RWTH Aachen University. FIRE is a research system developed with extensibility in mind and can easily be combined with textual information retrieval systems.	No	No		University	Open
	(Metric Inverted File) developed at ISTI-CNR. Source code of the MI File.	No	No	100M	Research Institute	Open
	content-based image queries with particular emphasis to the region-based paradigm; it provides an environment where different alternatives of the paradigm can be implemented, allowing such	Yes	No		University	Open but not free

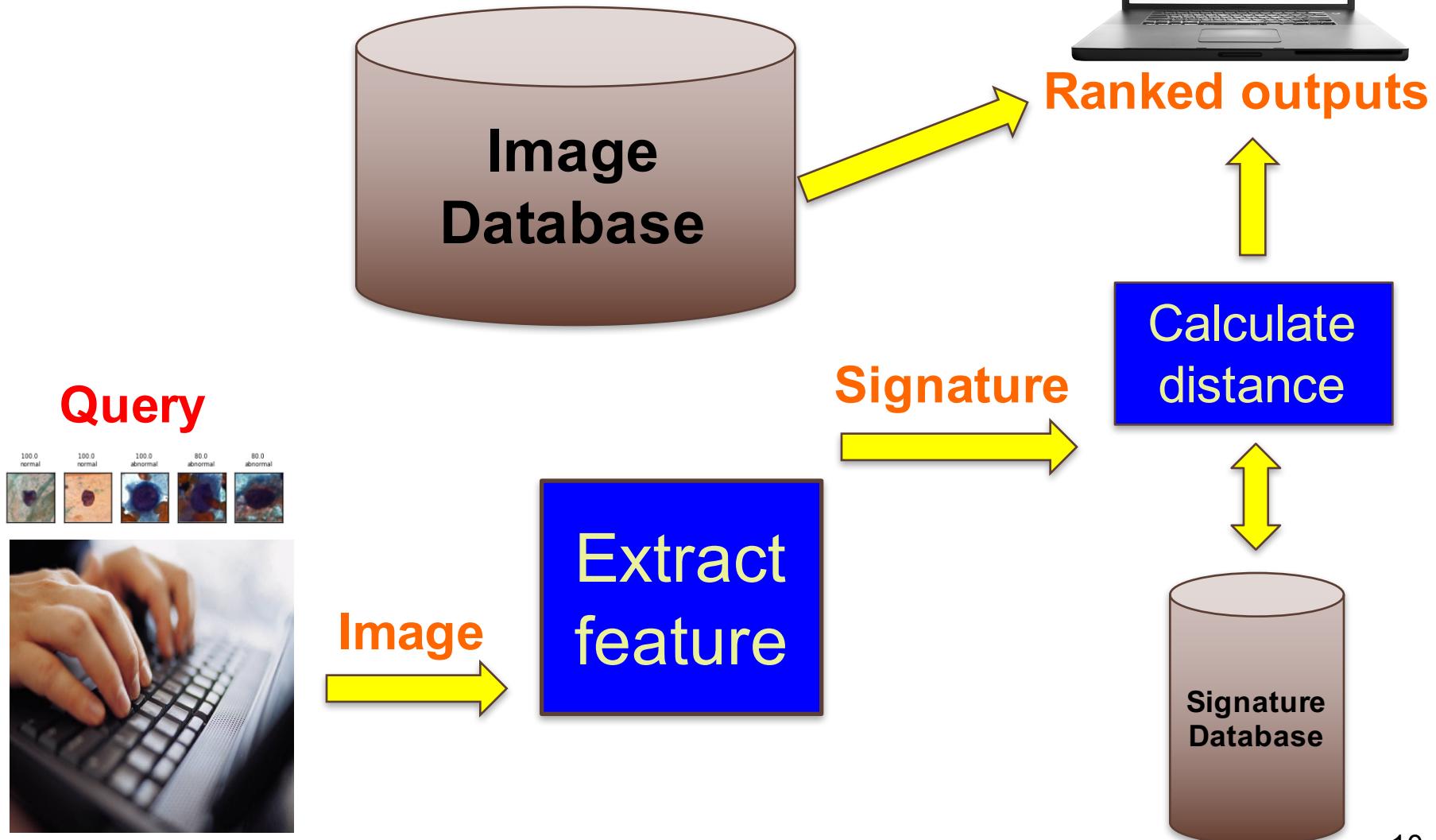
Why pyCBIR?

- pyCBIR: a new python tool for content-based image retrieval (CBIR);
- Query by example: capable of searching relevant items in large databases, given unseen samples;
- pyCBIR allows general purpose investigation across image domains;
- Our experiments: can we recover high-level abstraction from data using:
 - a. Color, texture, shape?
 - b. Learn signatures using CNN?
 - c. Similarity = distance?

pyCBIR workflow



pyCBIR workflow



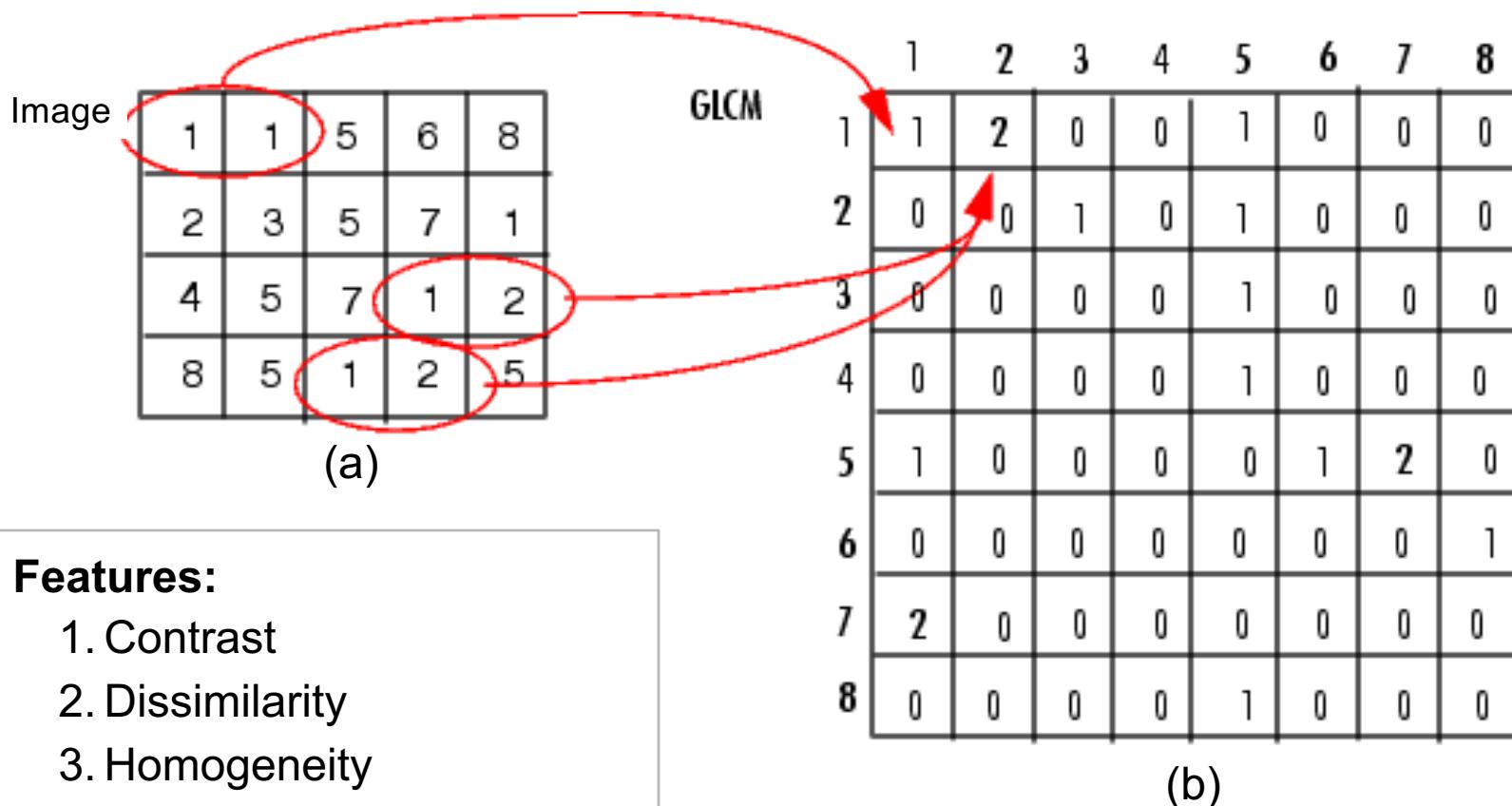
Feature Extraction Methods

Signature = index = feature vector = descriptors;

1. Gray Level Co-Occurrence Matrix;
2. Histogram of Oriented Gradient;
3. First Order Texture Features;
4. Local Binary Pattern;
5. Convolutional Neural Network.



Gray Level CO-Occurrence Matrix (GLCM)



Features:

1. Contrast
2. Dissimilarity
3. Homogeneity
4. Energy
5. Correlation
6. Angular Second Moment

Figure 1. GLCM. (a) grayscale image. (b) GLCM matrix.

Histogram of Oriented Gradients

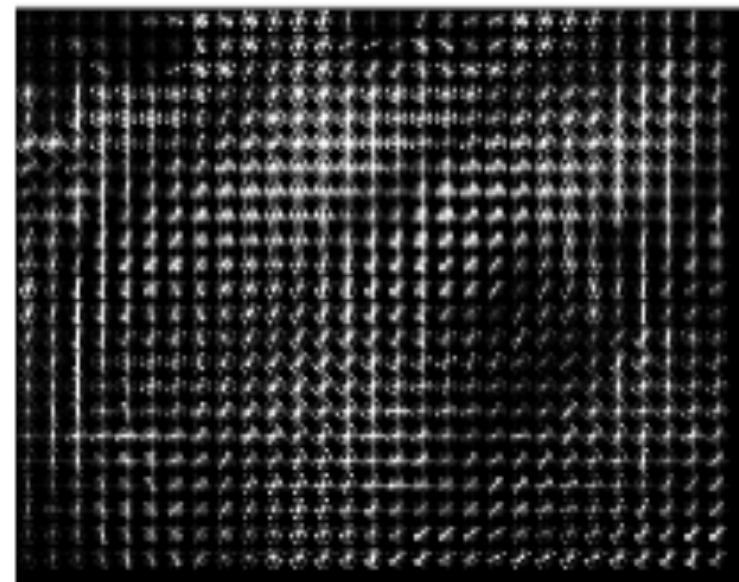


Input image



(a)

Histogram of Oriented Gradients



(b)

Figure 2. Histogram of oriented gradients of a Describable Textures Dataset (DTD) image.
(Dataset available in: <https://www.robots.ox.ac.uk/~vgg/data/dtd/>)

First Order Texture Features

Mean

$$\mu = \sum_{i=0}^{G-1} ip(i)$$

Variance

$$\sigma^2 = \sum_{i=0}^{G-1} (i - \mu)^2 p(i)$$

Skewness

$$\mu_3 = \sigma^{-3} \sum_{i=0}^{G-1} (i - \mu)^3 p(i)$$

Kurtosis

$$\mu_4 = \sigma^{-4} \sum_{i=0}^{G-1} (i - \mu)^4 p(i) - 3$$

Energy

$$H = - \sum_{i=0}^{G-1} p(i) \log_2[p(i)]$$

Entropy

$$E = \sum_{i=0}^{G-1} [p(i)]^2$$

Local Binary Pattern (LBP)



70	66	58
69	65	60
68	64	60

Example

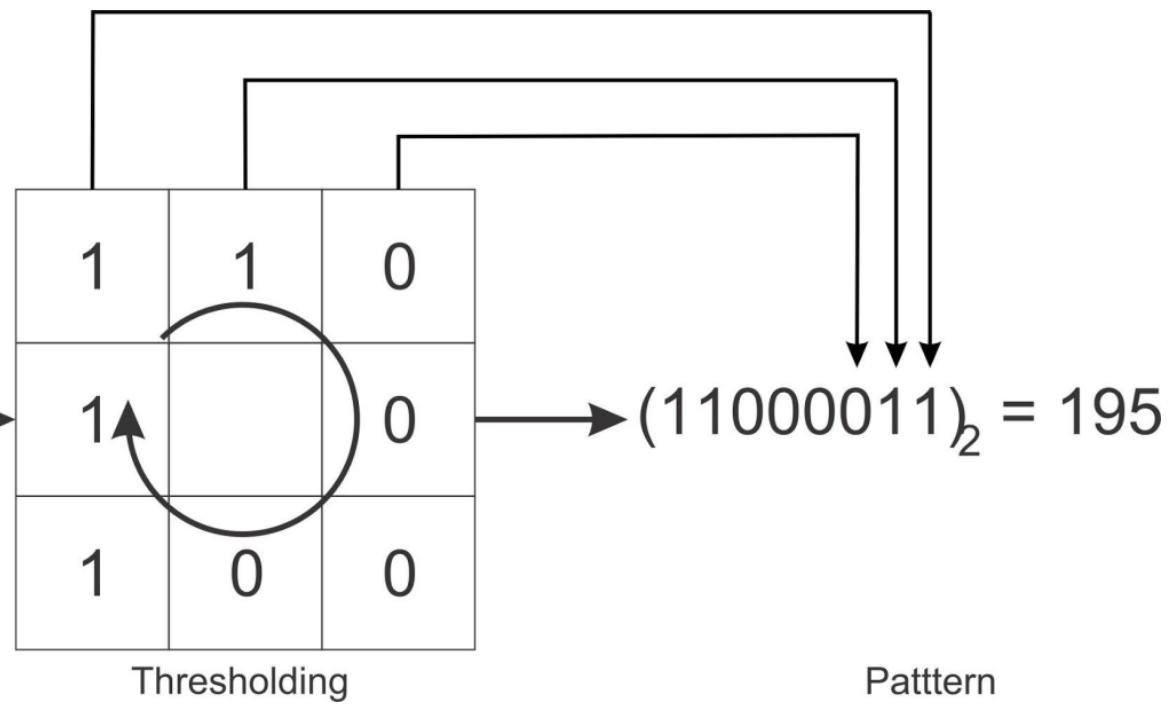


Figure 3. Local Binary Pattern.

Convolutional Neural Network (CNN)

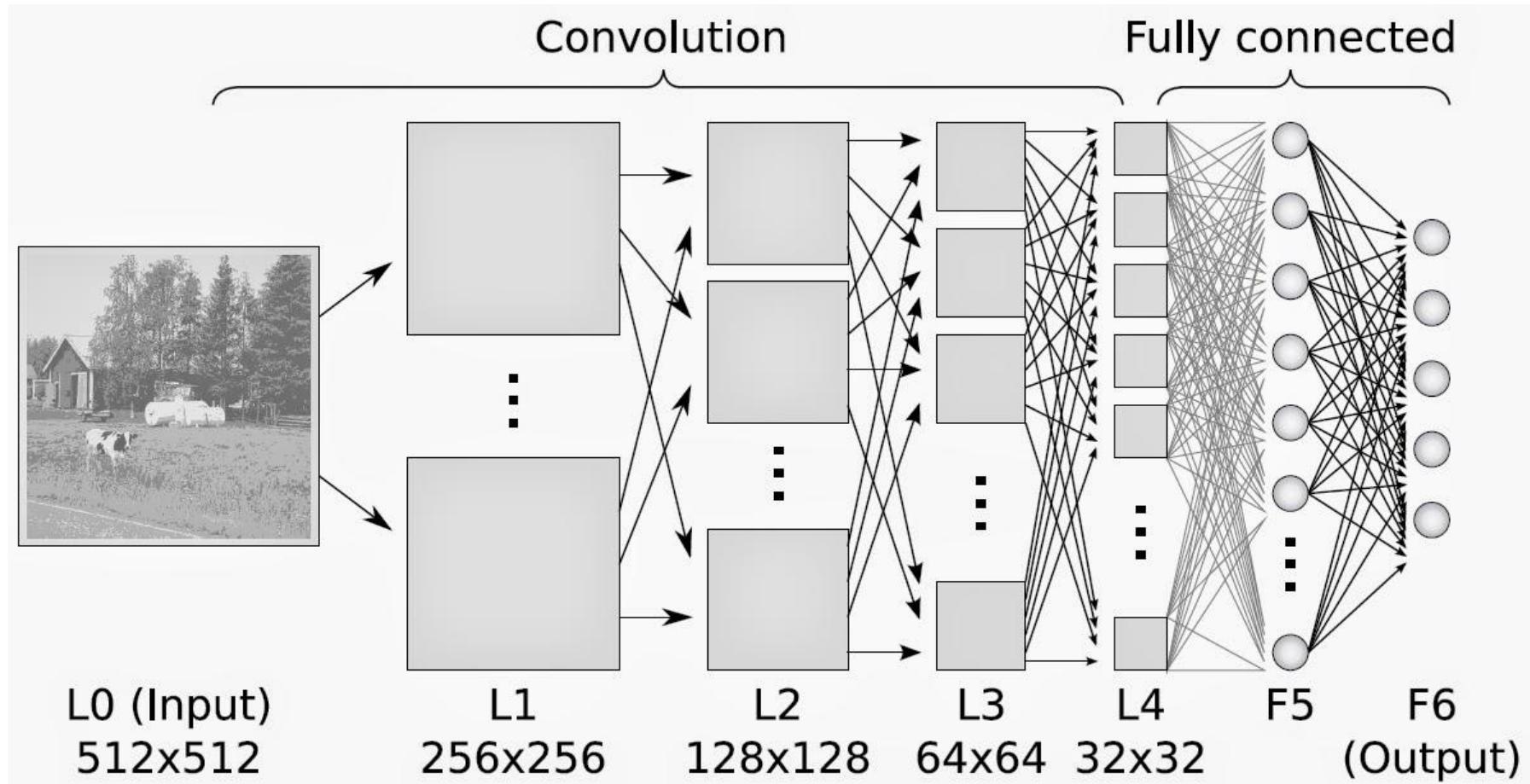


Figure 4. Convolutional Neural Network.
(http://www.ais.uni-bonn.de/deep_learning/)

Convolutional Neural Network (CNN)



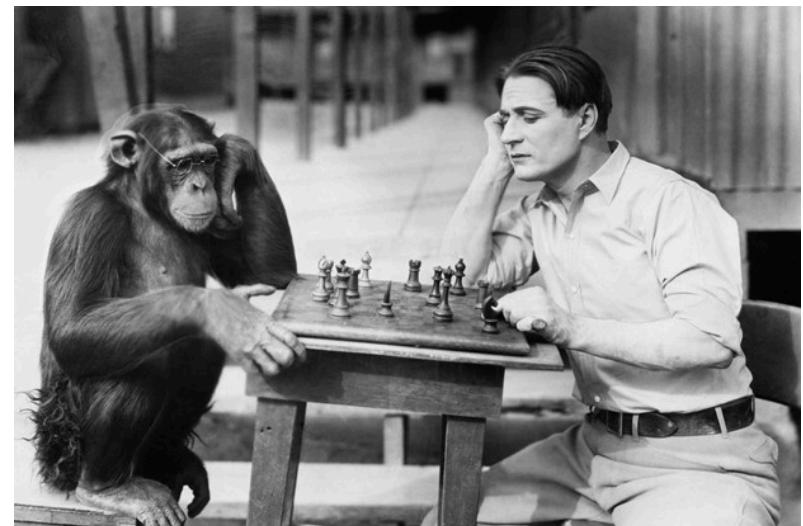
We used the CNN in two different ways:

1. Trained with the **same** database of the image retrieve;
 - 2 convolutional layers;
2. Trained with the **imageNet** Database: CNN Inception*
 - 6 convolutional layers;

*Available in: <http://arxiv.org/pdf/1602.07261v1.pdf>

Similarity

- **IF** Features = multidimensional vector, **THEN** similarity = distance!
1. Euclidean
 2. Infinity
 3. Cosine
 4. Pearson
 5. Chi-Square
 6. Kullback-Liebler Divergence
 7. Jeffrey Divergence
 8. Kolmogorov-Smirnov Divergence
 9. Cramer-von Mises Divergence
 10. Cityblock Distance



Distance Metrics



Euclidean Distance

$$d(\mathbf{x}, \mathbf{y}) = \sqrt{\sum_{i=1}^n (x_i - y_i)^2}$$

Infinity Distance

$$d(\mathbf{x}, \mathbf{y}) = \max_{i=1}^n |x_i - y_i|$$

Cosine Similarity

$$s(\mathbf{x}, \mathbf{y}) = \frac{\mathbf{x} \cdot \mathbf{y}}{\|\mathbf{x}\| \|\mathbf{y}\|}$$

Pearson Correlation Coefficient

$$d(\mathbf{x}, \mathbf{y}) = \frac{\sum_{i=1}^n (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^n (x_i - \bar{x})^2 (y_i - \bar{y})^2}}$$

Chi-Square Dissimilarity

$$d(x, y) = \sum_{i=1}^n \frac{(x_i - y_i)^2}{y_i}$$

Distance Metrics



Kullback-Liebler Divergence

$$d(\mathbf{x}, \mathbf{y}) = \sum_{i=1}^n x_i \log \frac{x_i}{y_i}$$

Jeffrey Divergence

$$d(\mathbf{x}, \mathbf{y}) = \sum_{i=1}^n x_i \log \frac{x_i}{\mu_i} + y_i \log \frac{y_i}{\mu_i}$$

Kolmogorov-Smirnov Divergence

$$d(\mathbf{x}, \mathbf{y}) = \max_{i=1}^n |X_i - Y_i|$$

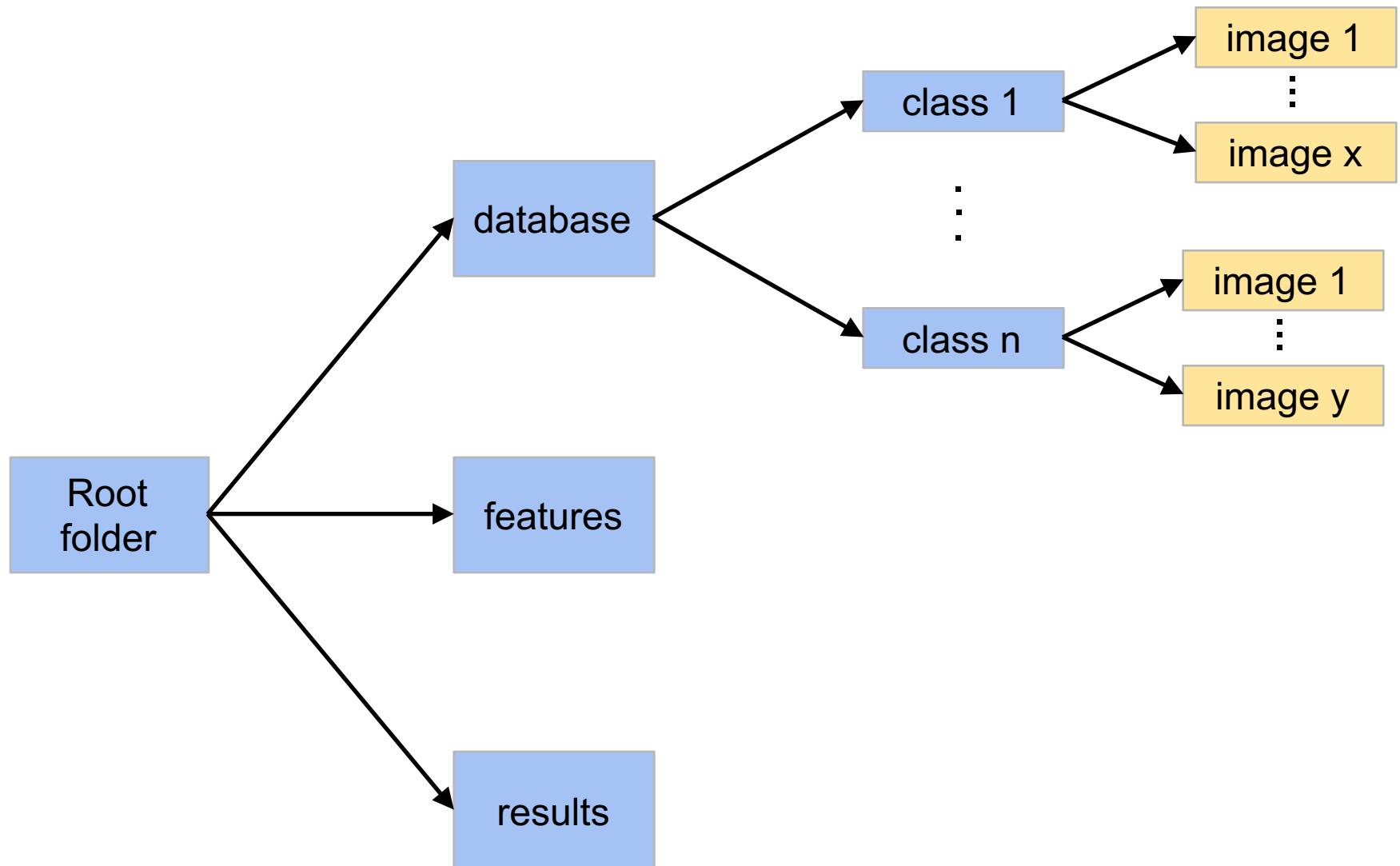
Cramer-von Mises Divergence

$$d(\mathbf{x}, \mathbf{y}) = \sum_{i=1}^n (X_i - Y_i)^2$$

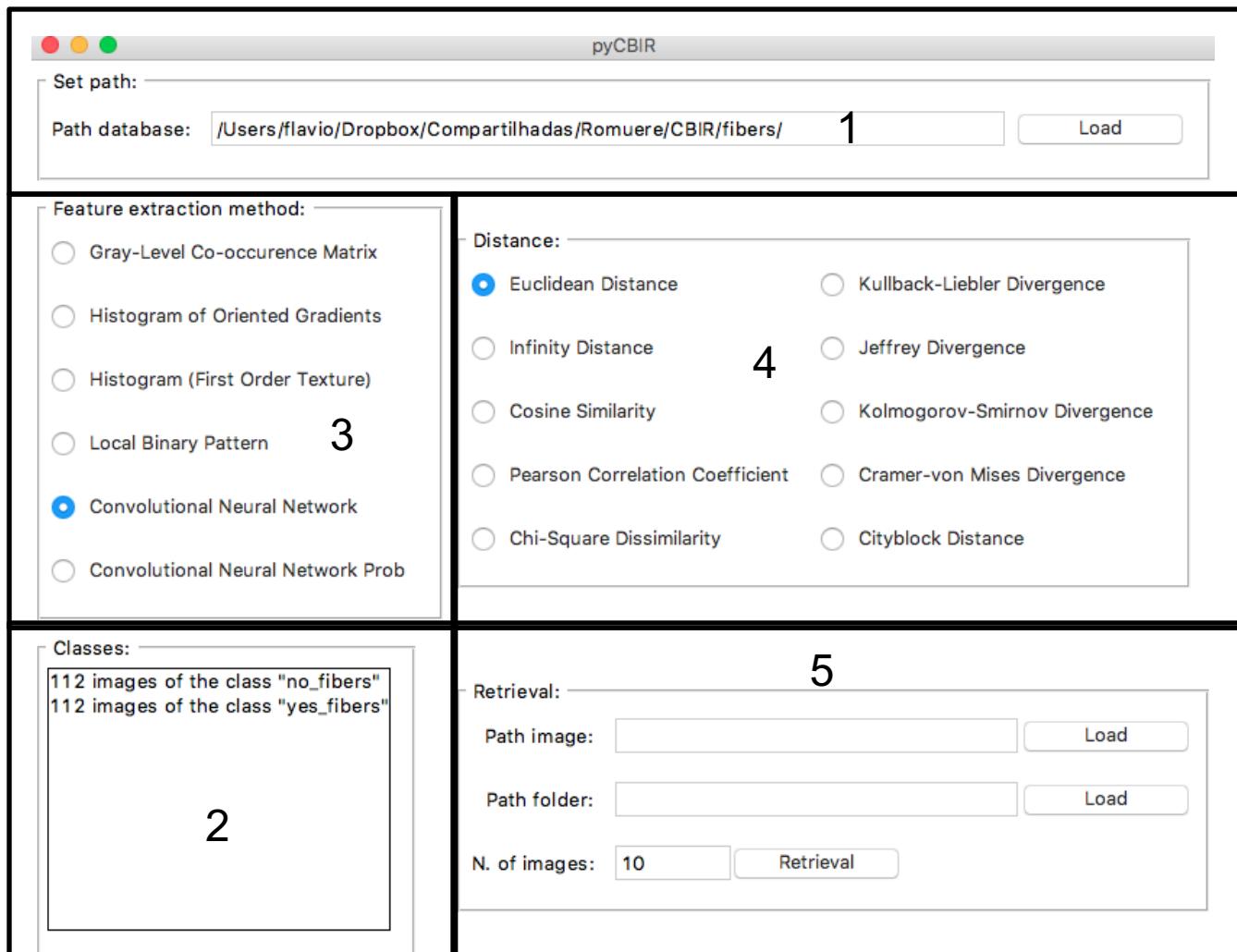
Cityblock Distance

$$(L_1) \quad d(\mathbf{x}, \mathbf{y}) = \sum_{i=1}^n |x_i - y_i|$$

How to organize the database?



Graphical User Interface

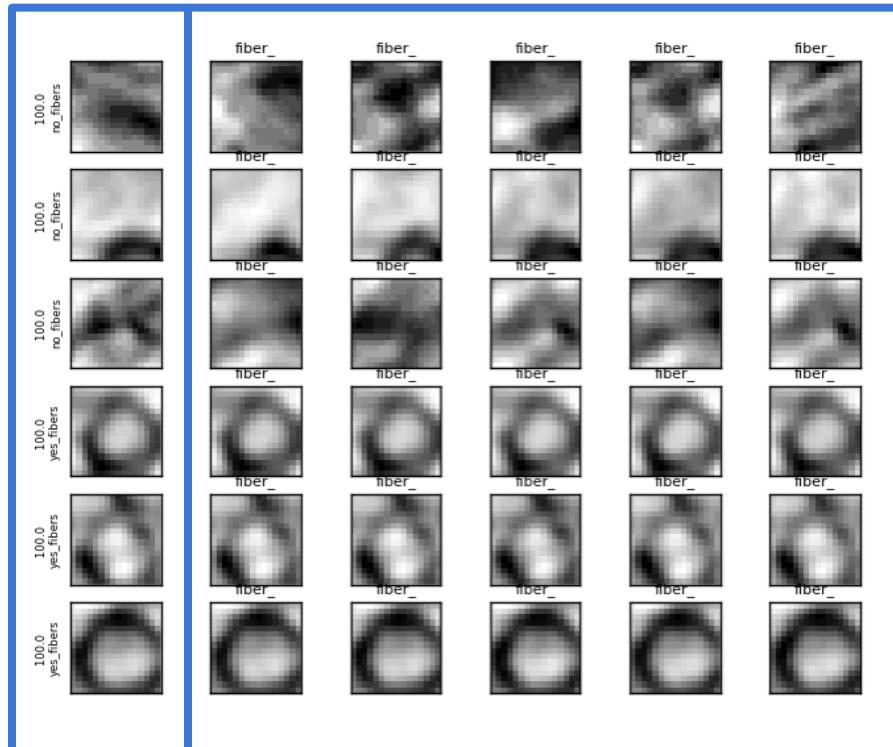


Experiments - Fibers dataset

4,000 images of 16 X 16 for two balanced classes.

Query

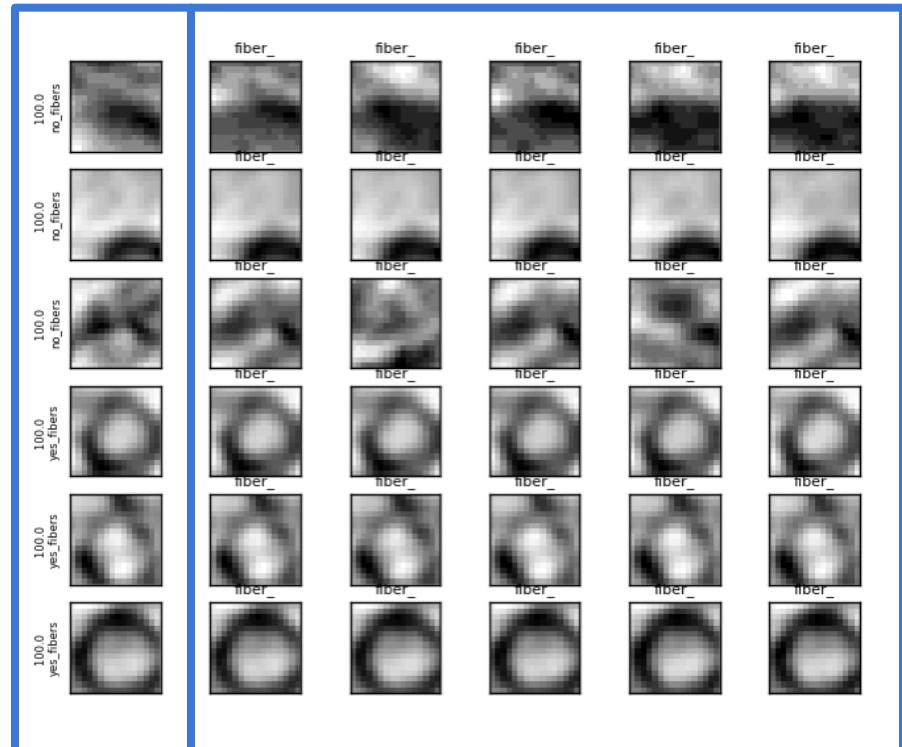
Top 5 retrieved



Result obtained using the cnn trained with the same dataset.

Query

Top 5 retrieved



Result obtained using the inception network.

Experiments - Time

	Training	Extraction of features for the whole database	Top 10 retrieved for a query image
Approach 1 (same DB)	3.4 minutes	9 seconds	4 seconds
Approach 2 (inception)	-	29 minutes	15 seconds

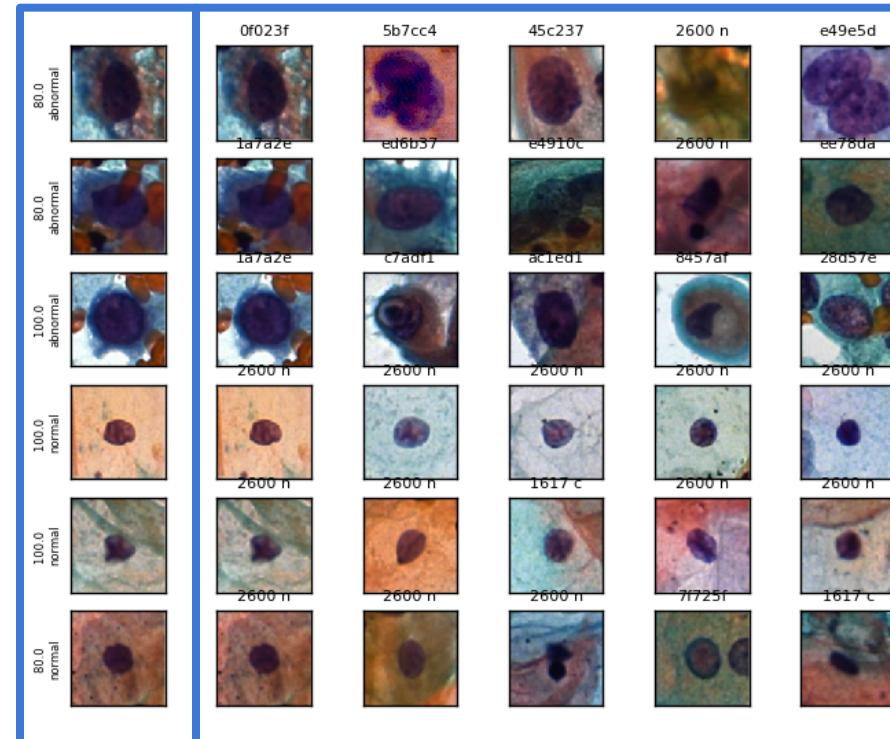
Experiments - Cells dataset

1,886 images of normal cells and 1,509 of abnormal;

100 X 100;

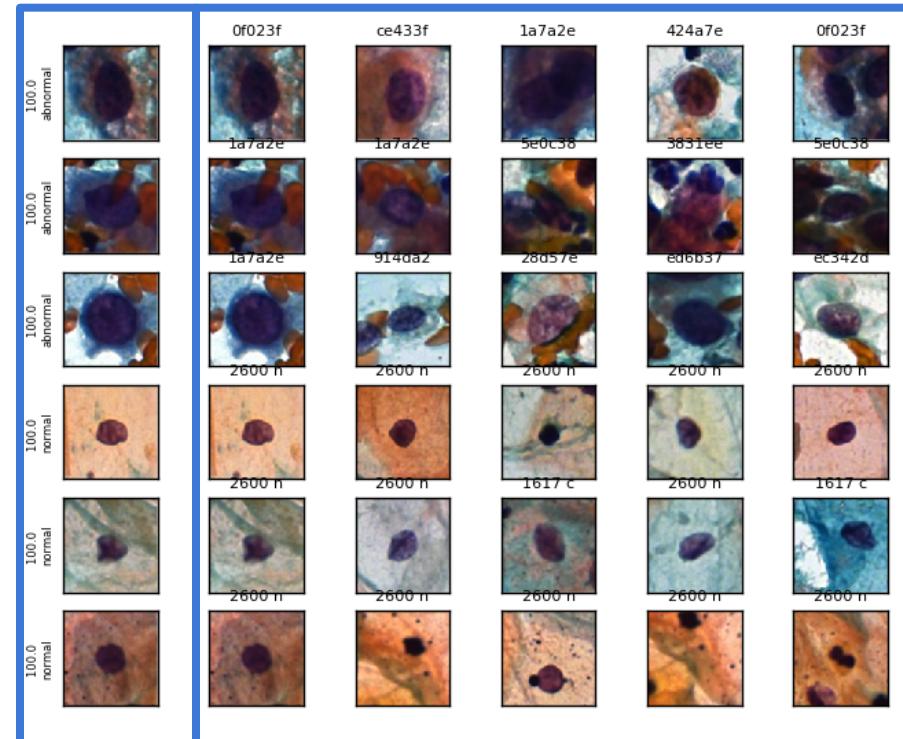
Query

Top 5 retrieved



Query

Top 5 retrieved



Result obtained using the cnn trained with the same dataset.

Result obtained using the inception network.

Experiments - Time

	Training	Extraction of features for the whole database	Top 10 retrieved for a query image
Approach 1	94 minutes	48 seconds	5 seconds
Approach 2	-	23 minutes	12 seconds

Results

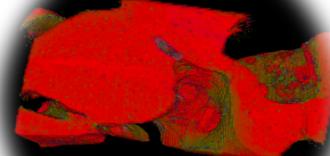
Approach 1 (same DB)	Approach 2 (inception)
Advantages	
Feature extraction is fast after training	Doesn't need training
Training done only once	
Each image = 256 features	
Disadvantages	
For datasets with big images and a lot of classes the training is slow	Feature extraction is slow
	Each image = 2,048 features

Next Steps

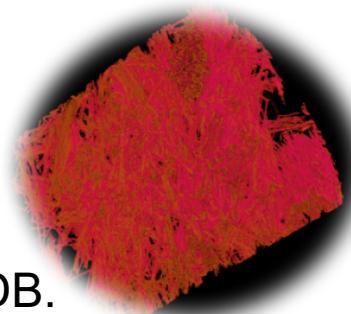
1. Ability to query **scientific** image databases using images itself;
2. Learn (*automatically*) the **best set** of: parameters, descriptor and distance for different databases (supervised);
3. Suggest **accuracy** metric based on the the class label;
4. Investigate strategies to **speed up** signature/similarity calculation;
5. Improve **ranking** algorithm (current: K-nn);
6. **Customize** for different applications, e.g. materials searchable DB.



rock



bone



composite

Thank you

Dani, Rom and Flavio

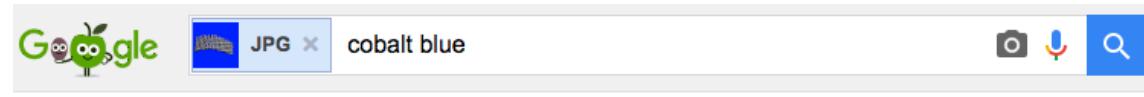
happy to take questions!



Google image search 😞

The screenshot shows a Google Images search results page. At the top, the search bar contains the text "fiber...38_468.tif". To the right of the search bar are three icons: a camera, a microphone, and a magnifying glass. Below the search bar, there are four navigation tabs: "All", "Images" (which is highlighted in blue), "More", and "Search tools". A horizontal line indicates the active tab. The main content area displays a large, dark, blurry image thumbnail. A speech bubble points from the bottom left towards the center of the image, containing the text "I am tiny:
16 × 16". Below the image, a message states: "The image is too large (over 8000 by 6000 pixels), or Google can't read its encoding."

Google image search 😞



About 6 results (0.80 seconds)

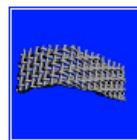


Image size:
1024 × 1024

No other sizes of this image found.

Best guess for this image: [cobalt blue](#)

[Cobalt blue - Wikipedia, the free encyclopedia](#)

https://en.wikipedia.org/wiki/Cobalt_blue ▾

Cobalt blue is a blue pigment made by sintering cobalt(II) oxide with alumina at 1200 °C. Chemically, cobalt blue pigment is cobalt(II) oxide-aluminium oxide, ...

[Malcolm Thawne \(New Earth\) - DC Database - Wikia](#)

[dc.wikia.com/wiki/Malcolm_Thawne_\(New_Earth\)](dc.wikia.com/wiki/Malcolm_Thawne_(New_Earth)) ▾

Malcolm drew his power from this talisman, and adopted a costume as the super-villain Cobalt Blue. When he faced the Flash and Kid Flash, he had the ability to ...

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