



UNIVERSITAT POLITÈCNICA DE CATALUNYA  
BARCELONATECH

School of Professional & Executive Development

POSTGRADUATE COURSE

## ARTIFICIAL INTELLIGENCE WITH DEEP LEARNING

WWW.TALENT.UPC.EDU



#DLUPC

# Image Retrieval



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# This lecture objective

Content Based Image Retrieval (CBIR)

Deep Learning approaches in CBIR

Practical session

# More material online

**DEEP LEARNING  
FOR COMPUTER VISION**

Summer School at UPC Telecom+DCU Sur/Vislab, June 18-July 6, 2018

**Day 1 Lecture 5**  
**Content-based  
Image Retrieval**

**Instructors**

Organized by:

Supported by:

+ info: <http://bit.ly/dlcv2018>

<http://bit.ly/dlcv2018>

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[DLCV2018](http://bit.ly/dlcv2018)

# This lecture objective

## **Content Based Image Retrieval (CBIR)**

Deep Learning approaches in CBIR

Practical session

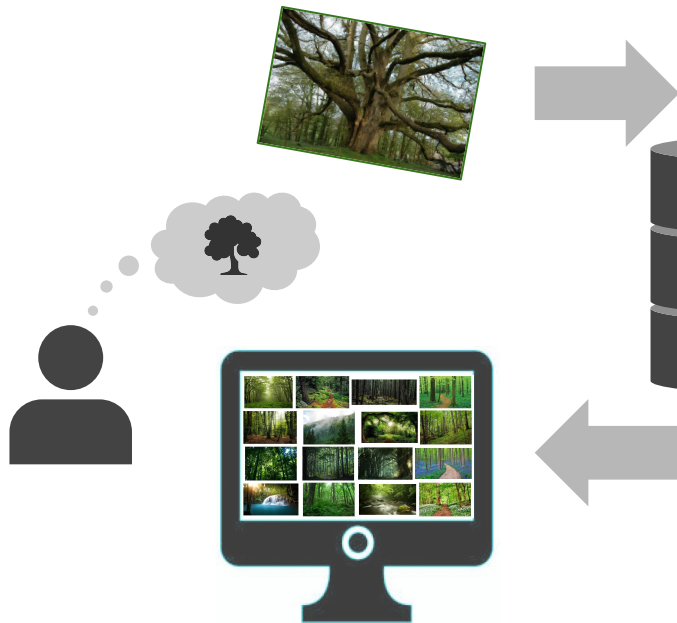
# The Problem: Query by Example

## Given:

- An example query image that illustrates the user's information need
- A very large dataset of images

## Task:

- Rank all images in the dataset according to how likely they are to fulfil the user's information need



# Applications

## e-commerce



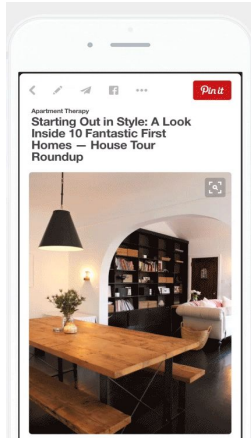
Related Images [See All >](#)



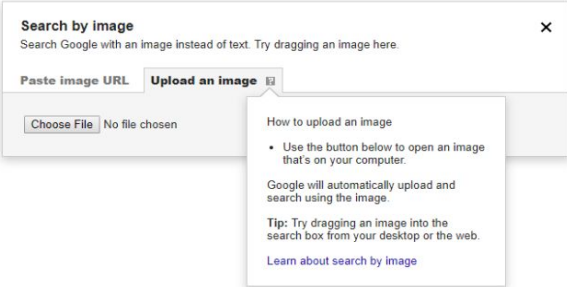
Web Results

**white wooden planters | eBay**  
Find great deals on eBay for white wooden planters and white square wooden planters. Shop with confidence.  
[www.ebay.co.uk](http://www.ebay.co.uk)

**Amazon.co.uk: Window Boxes: Garden & Outd**  
Online shopping for Window Boxes from a great selection at *Garden & Outdoor Store*.



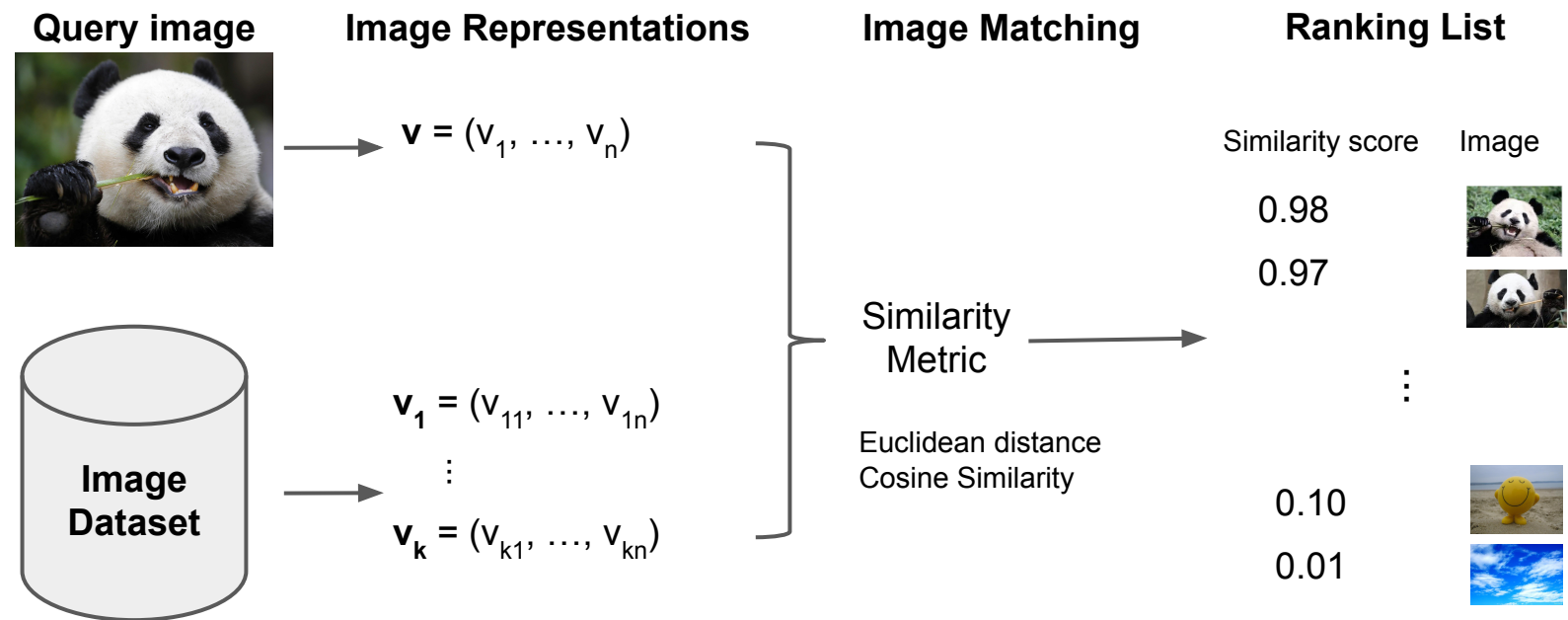
## seeking information



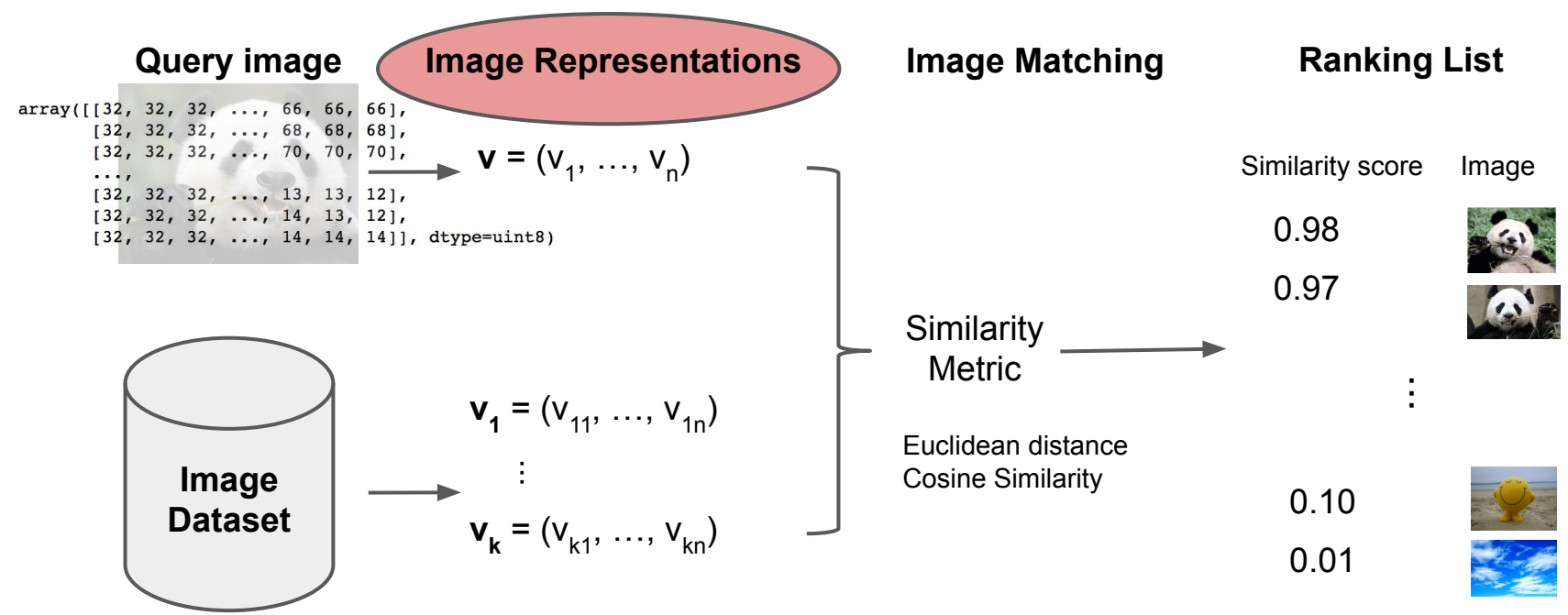
## personal photo organization



# CBIR Pipeline



# CBIR Pipeline





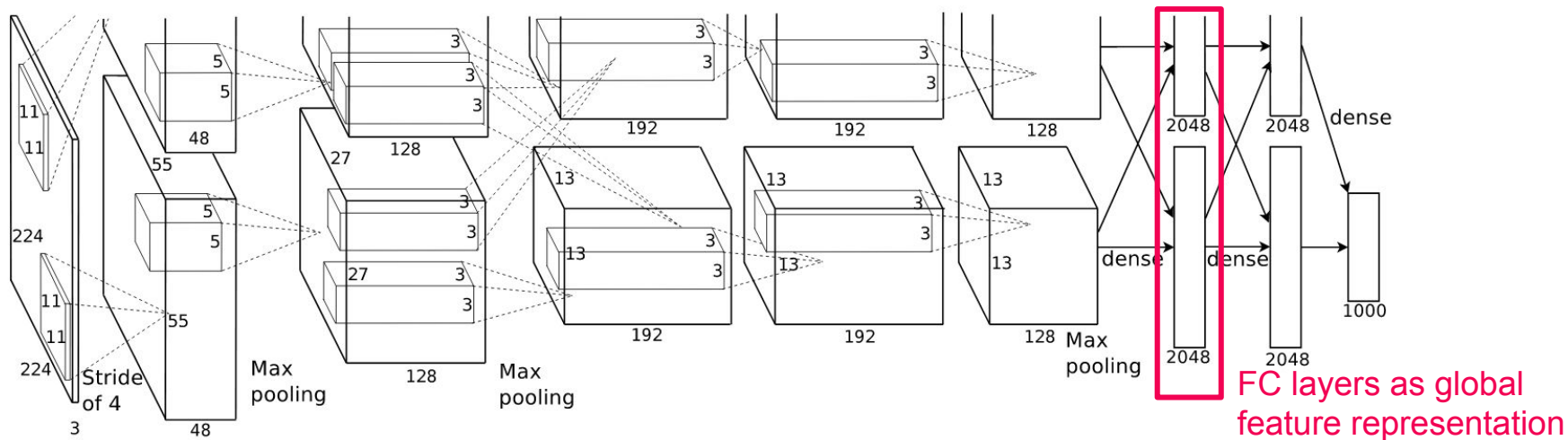
# This lecture objective

Content Based Image Retrieval (CBIR)

**Deep Learning approaches in CBIR**

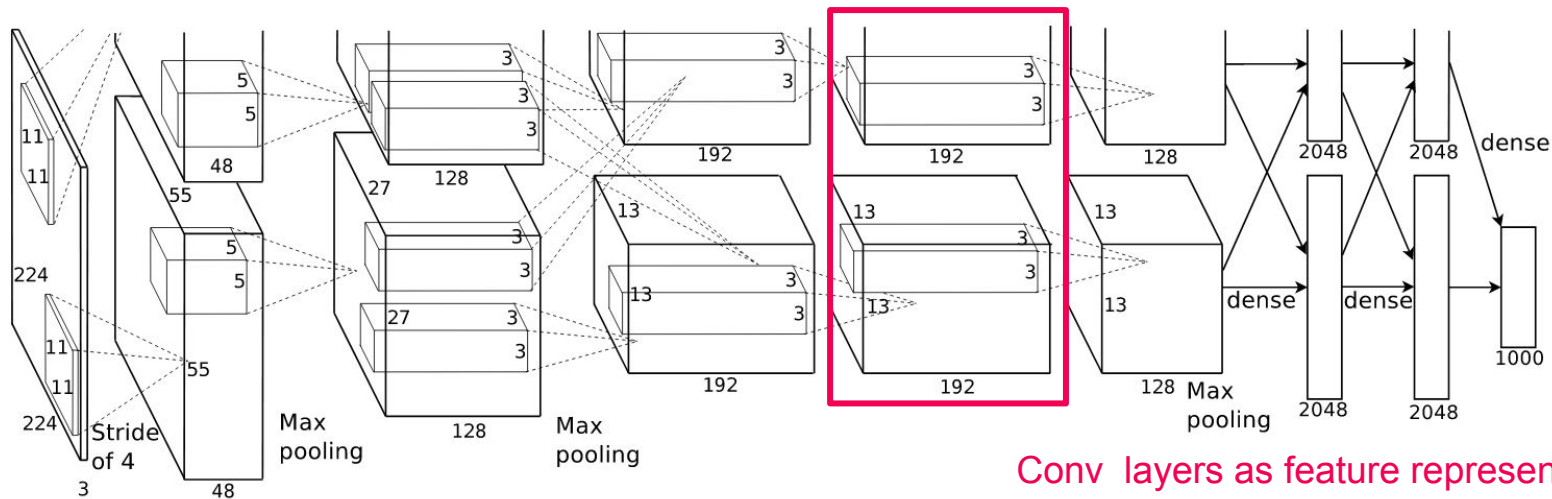
Practical session

# “Off-the-shelf” classification models



- Descriptors too biased to the final classification task
- No spatial information
- Performance no better than traditional hand-crafted approaches!

# “Off-the-shelf” classification models



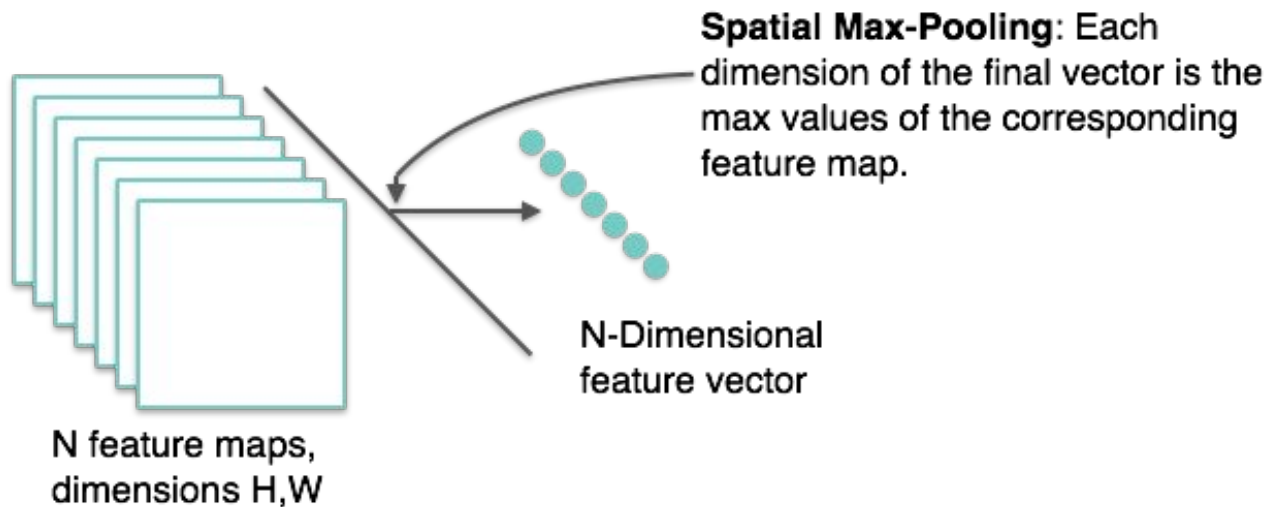
- Spatial information is encoded
- Need to aggregate local information into a single vector
- Better performance than traditional approaches

Babenko and Lempitsky, [Aggregating local deep features for image retrieval](#). ICCV 2015

Tolias et al. [Particular object retrieval with integral max-pooling of CNN activations](#). arXiv 2015.

Kalantidis et al. [Cross-dimensional Weighting for Aggregated Deep Convolutional Features](#). ECCV 2016 Workshops.

# Representation from Conv layers

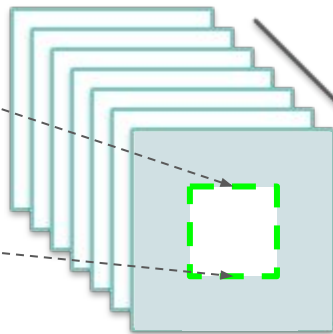
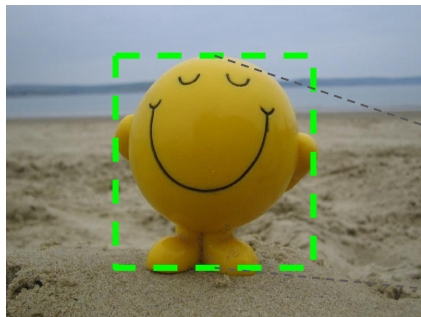


Lower level of abstraction (off-the-self model)

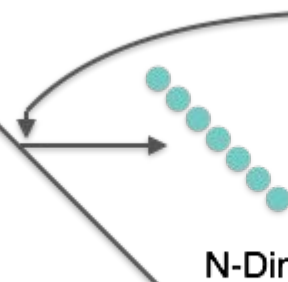
Allow processing images at higher resolution 12

# Representation from Conv layers

Aggregate information over specific regions



N feature maps,  
dimensions H,W



N-Dimensional  
feature vector

**Spatial Max-Pooling:** Each dimension of the final vector is the max values of the corresponding feature map.

# “Off-the-shelf” network limitations

## Classification

Query: This chair



Results from dataset classified as “chair”

# “Off-the-shelf” network limitations

Query: This chair



Retrieval

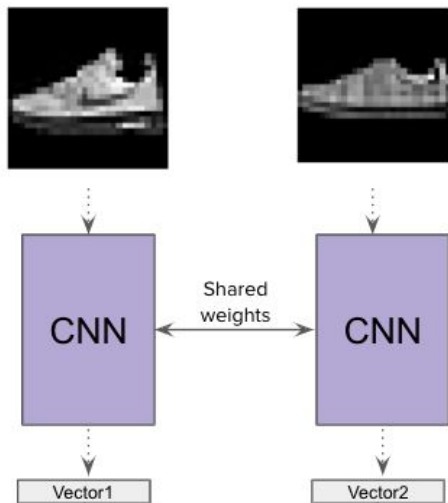


Results from dataset **ranked** by similarity to the query

# Siamese Networks for retrieval

$$l(\mathbf{x}_1, \mathbf{x}_2, \delta) = \delta \cdot l_P(d_D(\mathbf{x}_1, \mathbf{x}_2)) + (1 - \delta) \cdot l_N(d_D(\mathbf{x}_1, \mathbf{x}_2))$$

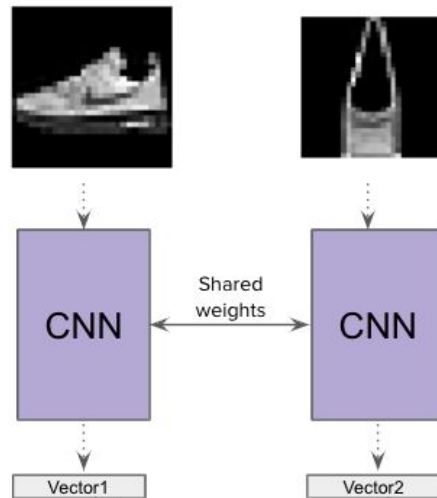
Positive Pairs



Make distance small

$$l_P(d_D(\mathbf{x}_1, \mathbf{x}_2)) = d_D(\mathbf{x}_1, \mathbf{x}_2)$$

Negative Pairs



Make distance large

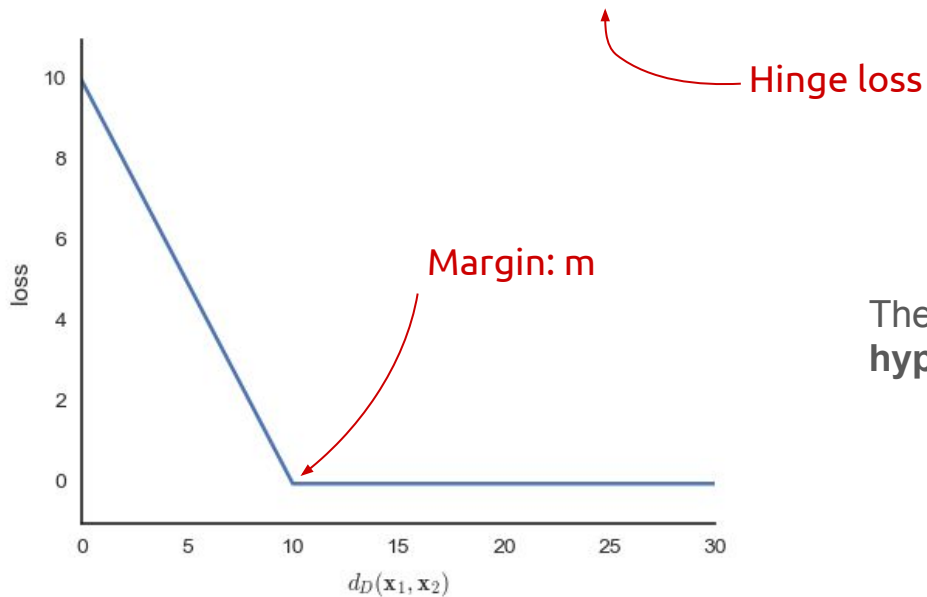
$$l_N(d_D(\mathbf{x}_1, \mathbf{x}_2)) = \max(0, m - d_D(\mathbf{x}_1, \mathbf{x}_2))$$



# Hinge loss

**Negative pairs:** if nearer than the margin, pay a linear penalty

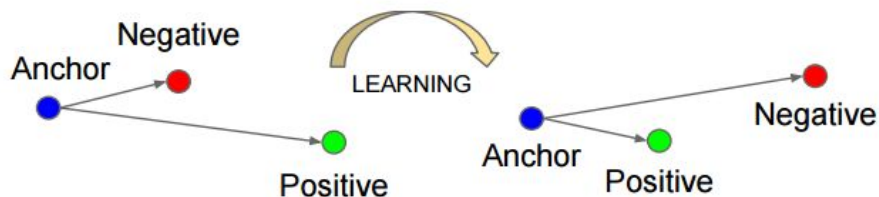
$$l_N(d_D(\mathbf{x}_1, \mathbf{x}_2)) = \max(0, m - d_D(\mathbf{x}_1, \mathbf{x}_2))$$



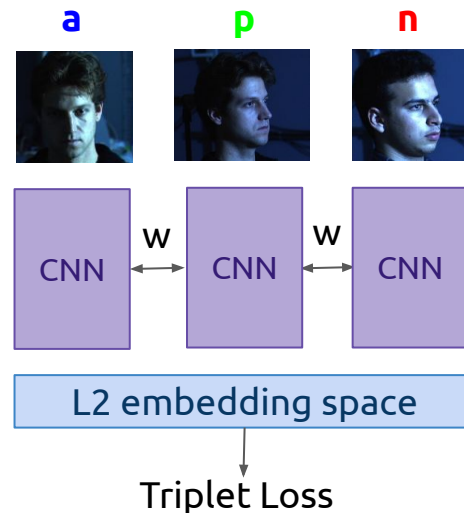
The margin is a **hyperparameter**

# Triplet Networks

**Siamese network with triplet loss:** loss function minimizes distance between query and positive and maximizes distance between query and negative

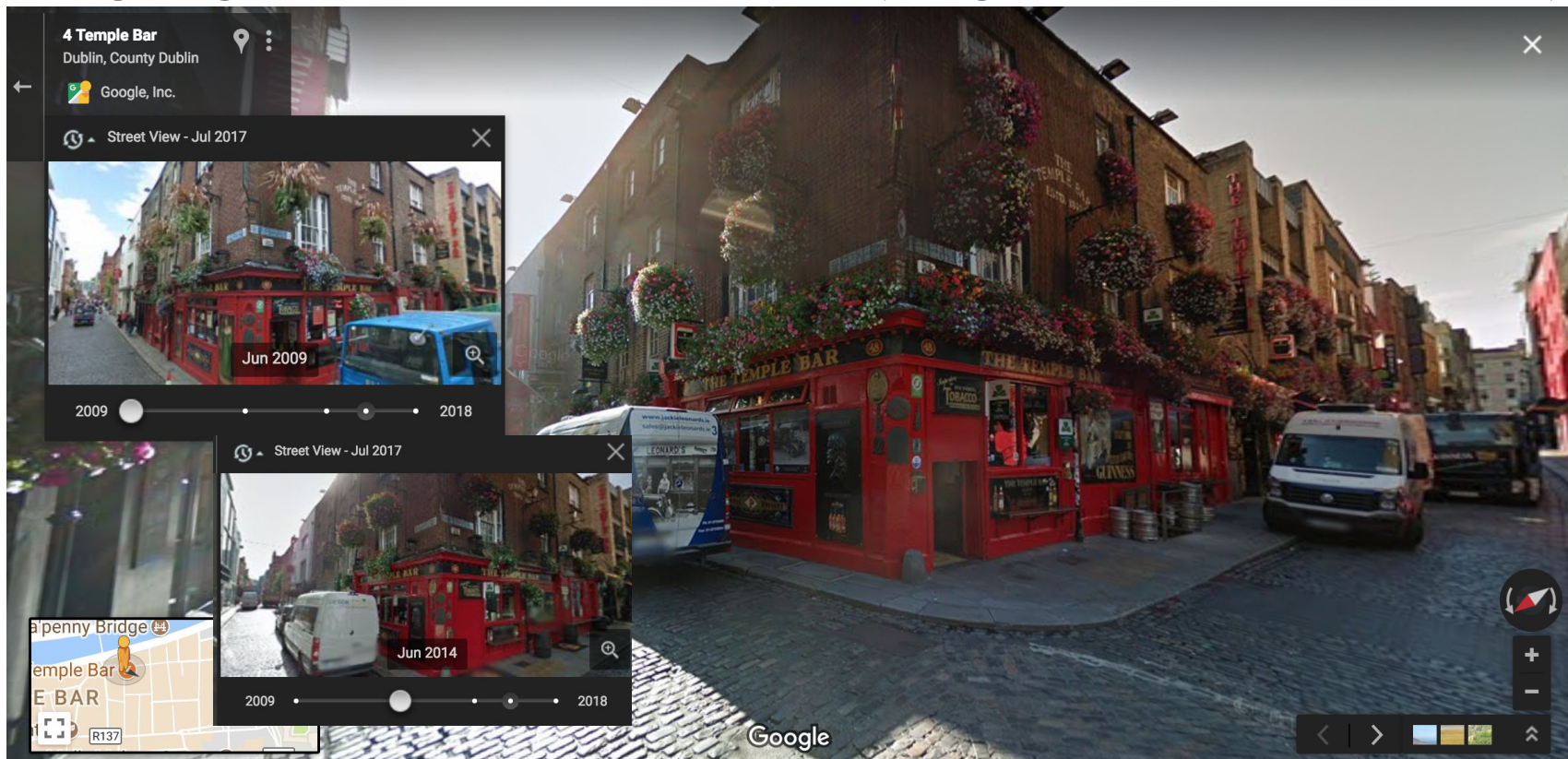


$$\|f(x_i^a) - f(x_i^p)\|_2^2 + \alpha < \|f(x_i^a) - f(x_i^n)\|_2^2$$

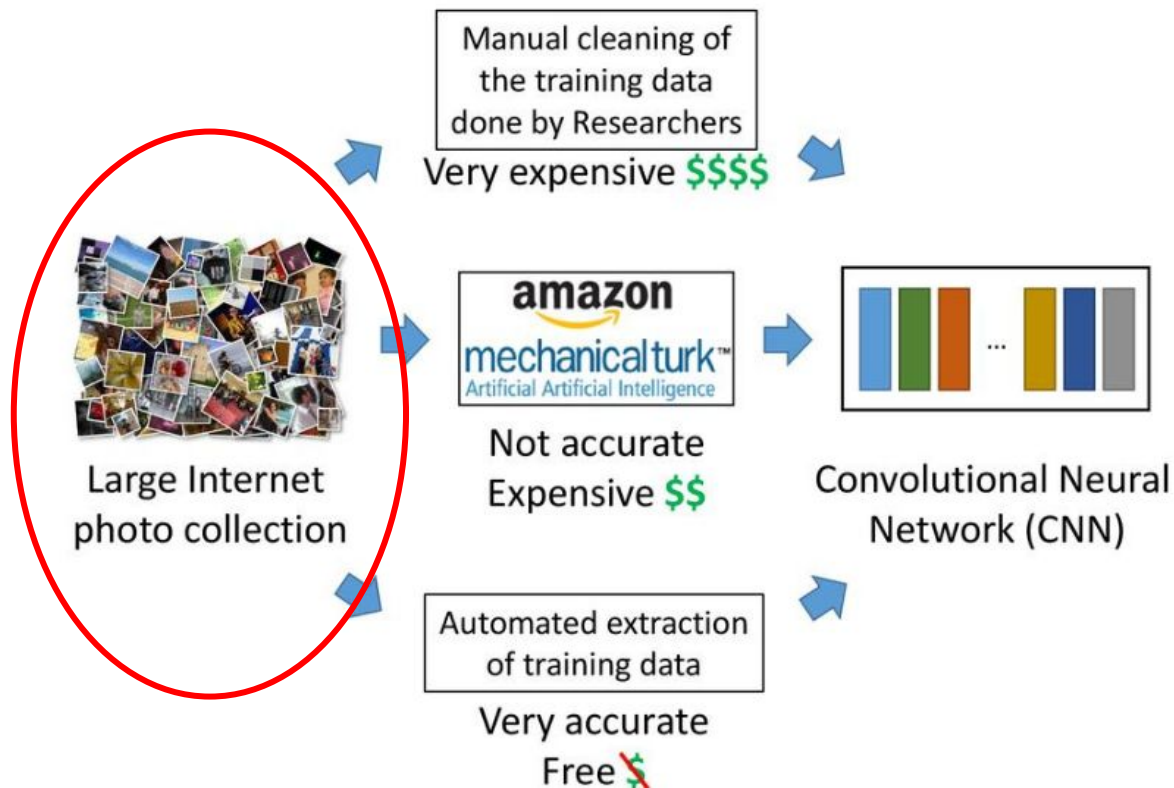


# GT data generation example

Exploring Image datasets with GPS coordinates (Google Street View Time Machine)



# GT data generation example



## Automatic data cleaning

Strong baseline (SIFT) +  
geometric verification + 3D  
camera estimation[1]

## Further manual inspection

Further manual inspection

Radenović et al., [CNN Image Retrieval Learns from BoW: Unsupervised Fine-Tuning with Hard Examples](#), CVPR 2016

Gordo et al., [Deep Image Retrieval: Learning global representations for image search](#), CVPR 2016

[1] Schonberger et al. [From single image query to detailed 3D reconstruction](#), CVPR 2015

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# Google Colab

The screenshot shows the Google Colaboratory web interface. At the top, there's a header with the Google Colab logo and the text "Hello, Colaboratory". Below this is a menu bar with options: Archivo, Editar, Vista, Insertar, Entorno de ejecución, Herramientas, and Ayuda. On the right side of the header, there's a "COMPARTIR" button. Below the menu bar, there's a toolbar with icons for "CÓDIGO", "TEXTO", "CELDA", "COPIAR EN DRIVE", "CONECTAR", and "EDICIÓN". The main content area is divided into two panels. The left panel, titled "Índice", contains a list of links: "Welcome to Colaboratory!", "Local runtime support", "Python 3", "TensorFlow execution", "Visualization", "Forms", "Examples", and "For more information:". The right panel, titled "Fragmentos de código", displays the "Welcome to Colaboratory!" message. This message states that Colaboratory is a Google research project for machine learning education and research, runs entirely in the cloud, and is free to use. It also mentions that notebooks are stored in Google Drive and can be shared like Google Docs or Sheets. Below the welcome message, there's a section titled "Local runtime support" which explains that Colab can connect to a local Jupyter runtime. Further down, there's a section titled "Python 3" which states that Colab supports both Python 2 and Python 3. It lists two bullet points: "When creating a new notebook, you'll have the choice between Python 2 and Python 3." and "You can also change the language associated with a notebook; this information will be written into the .ipynb file itself, and thus will be preserved for future sessions." At the bottom of the right panel, there's a code editor showing a Python script that imports sys and prints a message: "Hello, Colaboratory from Python {}". The output of this script is shown below the code: "Hello, Colaboratory from Python 3!".

co Hello, Colaboratory

Archivo Editar Vista Insertar Entorno de ejecución Herramientas Ayuda

CÓDIGO TEXTO CELDA CELDA COPIAR EN DRIVE

CONECTAR EDICIÓN

Índice Fragmentos de código

**Welcome to Colaboratory!**

Local runtime support

Python 3

TensorFlow execution

Visualization

Forms

Examples

For more information:

SECCIÓN

**Welcome to Colaboratory!**

Colaboratory is a Google research project created to help disseminate machine learning education and research. It's a Jupyter notebook environment that requires no setup to use and runs entirely in the cloud.

Colaboratory notebooks are stored in [Google Drive](#) and can be shared just as you would with Google Docs or Sheets. Colaboratory is free to use.

For more information, see our [FAQ](#).

**Local runtime support**

Colab also supports connecting to a Jupyter runtime on your local machine. For more information, see our [documentation](#).

**Python 3**

Colaboratory supports both Python2 and Python3 for code execution.

- When creating a new notebook, you'll have the choice between Python 2 and Python 3.
- You can also change the language associated with a notebook; this information will be written into the .ipynb file itself, and thus will be preserved for future sessions.

```
[ ] import sys
    print('Hello, Colaboratory from Python {}'.format(sys.version_info[0]))
```

Hello, Colaboratory from Python 3!

<https://colab.research.google.com/>

# This lecture objective

- Implement a retrieval pipeline
- Qualitative and quantitative evaluation of results
- Training a Siamese network



<https://colab.research.google.com/drive/1nZ35NdTILmegBcOLdEXzUJkAHedfh8-K>