IEMS 5780 / IERG 4080
Building and Deploying Scalable Machine Learning Services

Lecture 6 - Image Classification

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11th October, 2018

Image Classification

Image Classification

- In **image classification**, the task is to categorize incoming images into one of the pre-defined classes/labels
- It can be a **binary classification problem** or a **multi-class classification problem**
- Example:
  - Which of the following are images of a **star ferry**?




Image Classification

- Some well-known image classification tasks:
  - MNIST Hand-written digits classification
  - ImageNet Large Scale Visual Recognition Challenge

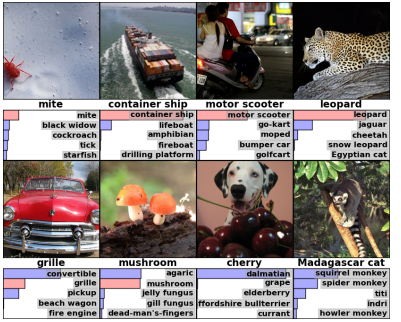


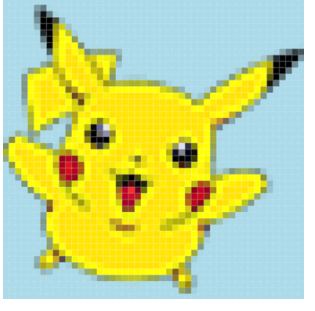
Image Classification

Challenges

1. **High dimensionality**
   - Images are represented digitally as a matrix of **pixels**
   - If we use **RGB** to represent the colour of a pixel, a 300 x 300 image has 270,000 values
2. **Representation**
   - Representing an image using a feature vector of all the pixels is of little use
   - The scale and perspective of the object inside an image can vary a lot
3. **Noise**
   - A picture of an object usually have something in the background
   - An object may appear with another irrelevant object in the same image

What is an Image

- An image is represented digitally by **pixels** (picture elements)
- Each pixel contains the values of the colour of the corresponding component of the image
- Resolution refers to the **number of pixels** used to represent the image
- The values of the pixels can represent the intensity of light, the RGB values, hue, saturation, brightness, etc.



An image with 48 x 48 pixels with RGB channels

What is an Image

A grey scale version of the previous image
Each pixel has a value between 0 and 255

What is an Image

RGB (Red, Green, Blue)

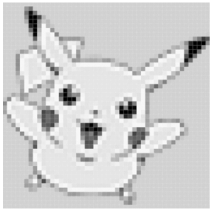
- One of the most commonly used colour model
- Each pixel is represented by **three integer values**, each of **8 bits (0 to 255)**
- This allows 16,777,216 (256^3) combinations for a pixel

(R, G, B) = (84, 130, 53)
HEX = 548235

Image Classification

Why is image classification difficult?

- Semantics is **lost** in an image represented as a matrix of pixels
- We need to bridge the **gap between pixels and meanings**
- What are the **features** that can be used to represent an image?



What a human sees

1	9	2	45	76	9	5	2
0	99	32	4	1	21	2	97
0	7	43	35	64	43	35	41
0	36	4	72	8	45	12	36
86	12	57	7	6	6	66	8
41	1	2	26	5	12	20	0
3	23	4	96	4	2	93	46
21	23	8	3	3	0	12	2

What a computer sees

Representation and Feature Extraction

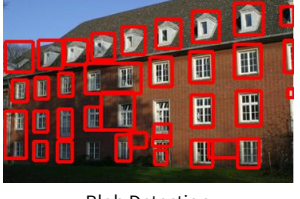
- In order to perform computation on images, we need an **appropriate representation** of the images.
- Some **representations** are:
  - Use the values of the **raw pixels**
  - Use **keywords (metadata)** to describe an image, and thus an image can be represented as a bag of words
  - Extract **visual features** from the image and use a vector of features to represent an image
- Finding a **good representation** is hard!

Image Features

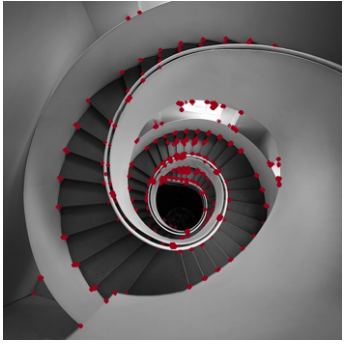
- A **feature** is a piece of information relevant for solving a certain computational task
- In **computer vision**, features can be pixels, points, edges, shapes, or other more complex **visual structures**
- **Feature detection** – the process of identifying features in an image that is representative of the image itself
- Ref: https://en.wikipedia.org/wiki/Feature_detection_(computer_vision)

Feature Extraction

Edge Detection
https://en.wikipedia.org/wiki/Edge_detection



Blob Detection
http://www.ipb.uni-bonn.de/projects/etrims/results/blob-detection-Dateien



Corner Detection
https://dzone.com/articles/corner-detection-opencv

SIFT

- SIFT stands for **Scale-Invariant Feature Transform**
- Published by **David Lowe** (now at Google) in 1999/2004
- An algorithm for detecting and describing **local features** in images
- One of the most widely used feature extraction algorithm in computer vision
- Able to detect features when the **scales** and **rotations** are different
- Ref: Distinctive Image Features from Scale-Invariant Keypoints

Problem Definition

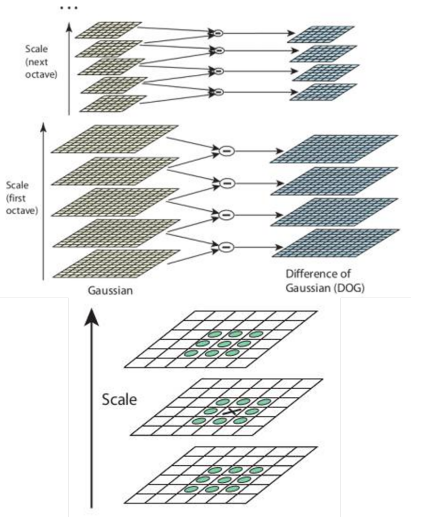
- What are the criteria of **good features**?
  - Distinctive
  - Easy to extract
  - Invariant to noise, illumination ,scaling, rotation, viewing direction
  - Easy to match against a large database of features

SIFT

- SIFT is an approach for detecting (determine what is a feature) and describing local features with the following steps:
  1. Scale-space extrema detection
  2. Keypoint localization
  3. Orientation assignment
  4. Generation of keypoint descriptors
- Ref: http://docs.opencv.org/trunk/da/df5/tutorial_py_sift_intro.html

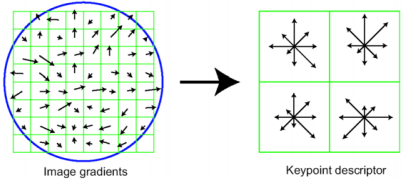
SIFT

- **1. Scale-space extrema detection**
  - Search for stable features across different scales
  - An image is rescaled and smoothed by a Gaussian (blurring) filter
  - Find out interesting points by selecting the local maxima or minima among different scales
- **2. Keypoint localization**
  - Remove points with low contrasts or edges (not necessary interesting features)



SIFT

- **3. Orientation assignment**
  - Assign an orientation to each keypoint, so that the features detected are invariant to image rotation
- **4. Generation of keypoint descriptors**
  - A **16x16** neighbourhood around the keypoint is taken, and a histogram of orientations of the gradients are calculated
  - Finally, each keypoint is represented by **a vector of length 128**



SIFT in OpenCV

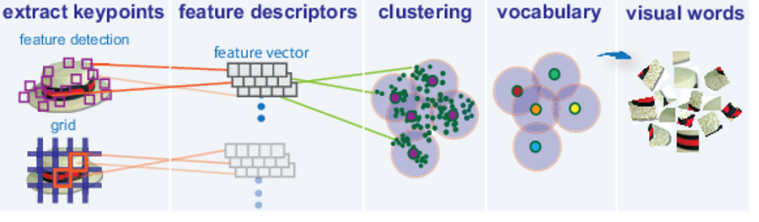
```
import cv2
import numpy as np

img = cv2.imread('star-ferry.jpg')
gray= cv2.cvtColor(img,cv2.COLOR_BGR2GRAY)

sift = cv2.xfeatures2d.SIFT_create()
kp = sift.detect(gray,None)

flag = cv2.DRAW_MATCHES_FLAGS_DRAW_RICH_KEYPOINTS
img = cv2.drawKeypoints(gray, kp, img, flags=flag)
cv2.imwrite('keypoints.jpg', img)
```

SIFT

- Keypoints can be used to **match objects** across different images

Visual Bag-of-Words

- In text classification, a document can be represented by a **bag of words**
- Similar approach can be used in image classification



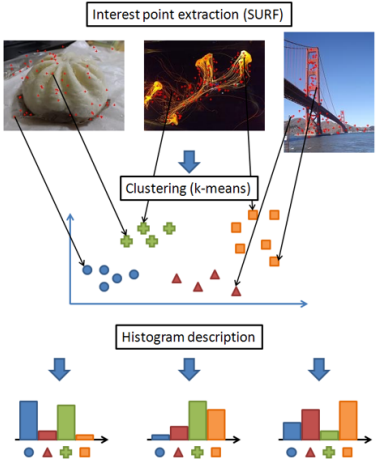
- Ref: http://www.mathworks.com/help/vision/ug/image-classification-with-bag-of-visual-words.html

Visual Bag-of-Words

Steps

1. Extract **keypoints** from images using SIFT
2. **Cluster** the keypoints to create a **visual dictionary** using a clustering algorithm (e.g. K-means)
3. For a given image, check the cluster to which each keypoint is in, and create a **histogram** of the distribution of clusters
4. Images are then represented by **vectors by normalizing the histograms**

Visual Bag-of-Words



- Ref: http://www.olivier-augereau.com/blog/?p=358

Limitations

- SIFT aims at identifying interesting points automatically, but keypoints are still relatively **primitive** and are not usually good enough for **classification tasks**
- The visual BoW approach does not consider **spatial relations** among visual words
- SIFT cannot be easily adapted to **different domains** to extract distinct features, as it is not based on **machine learning**
- SIFT is computationally expensive

We need better algorithms to extract image features!

Deep Learning

To Be Continued

End of Lecture 6