Generic Object Recognition

12 Classification by Support Vector Machine

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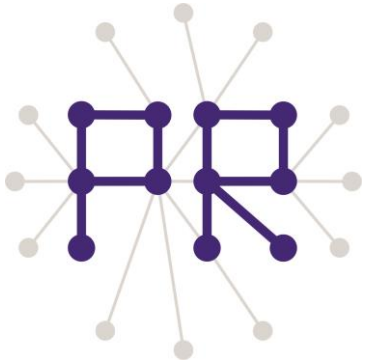


Overview of Today's Lesson

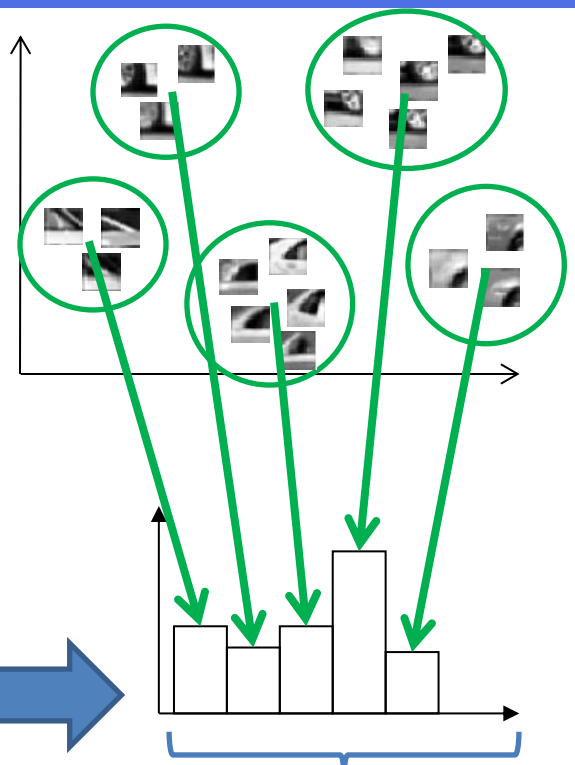
- Support Vector Machine (SVM) on BoVWs
  - Characteristics of SVM
- LIBSVM (famous SVM software)
  - How to use LIBSVM
- Finishing a generic object recognition method by applying LIBSVM to BoVWs
  - Loading the information of images
  - Preparing files for LIBSVM
  - Setting parameters of LIBSVM
  - Reading a LIBSVM result
- Suggestions to improve the recognition performance

Overview of Generic Object Recognition Using Bag of Visual Words (BoVW)

1. Visual word extraction: Organise local features into groups of similar features

➡ *The center of each group becomes a visual word*

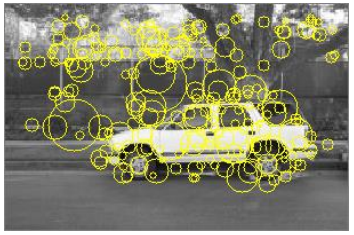
More than 100,000 local features are organised into more than 1,000 groups. In other words, more than 1,000 visual words are extracted



2. BoVW representation: Assign local features in each image to the most similar visual words

➡ For each visual words, the number of assigned local features becomes the value of a bin

The number of dimensions of a histogram (vector) is more than 1,000.

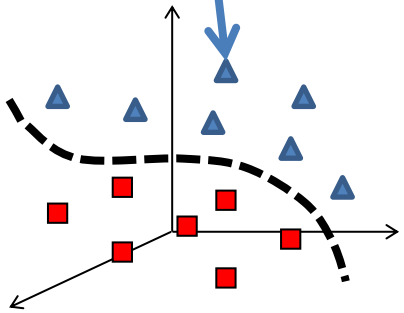


Today

3. Classification: Extract the boundary between images where a certain object is shown and images where it is absent

➡ One image represented by BoVW is represented as a point in the high-dimensional vector space

Because of the high-dimensionality, simple similarity measures (e.g., Euclidian distance and cosine distance) do not work. Support Vector Machine (SVM) or other effective classifiers for high-dimensional data must be used.
I spent more than one year to find this point ☹



Support Vector Machine on BoVWs
- My Personal Interpretation of SVM -

SVM extracts a useful similarity measure which combines weighted similarities of a test example to training examples

(Decision function of SVM)

$$h(\boldsymbol{x}) = \sum_{i=1}^{N} \alpha_i y_i K(\boldsymbol{x}, \boldsymbol{x}_i) - b$$

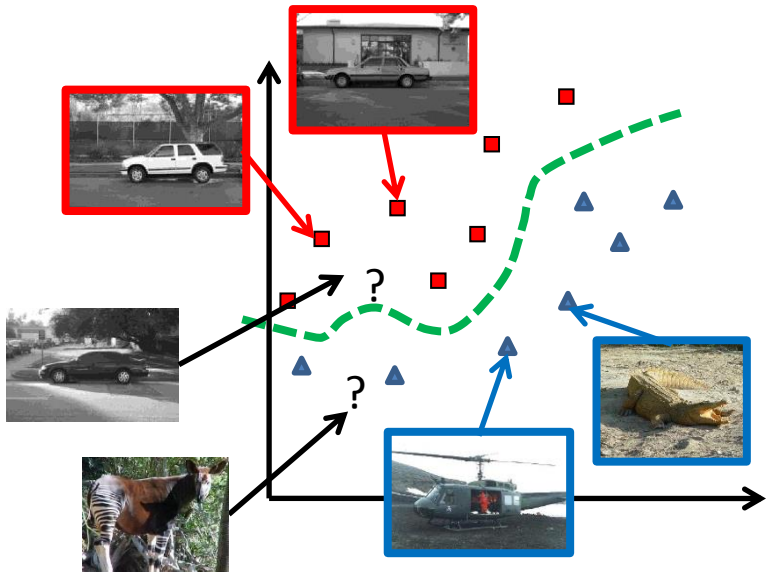
Weight

Kernel function (similarity between x_i and x)

The optimal set of weight is computed using training examples

$$K(x, x_i) = \exp\left(-\frac{\| x - x_i \|^2}{\gamma}\right)$$

Euclidian distance



Training examples
(having the information from humans:
A machine learns from these examples)

- Positive examples: Images where a target object is shown
- Negative examples: Images where the target object is not shown
- Test examples: Images where displayed objects are unknown
  (not-having the information from humans)

Characteristics of SVM

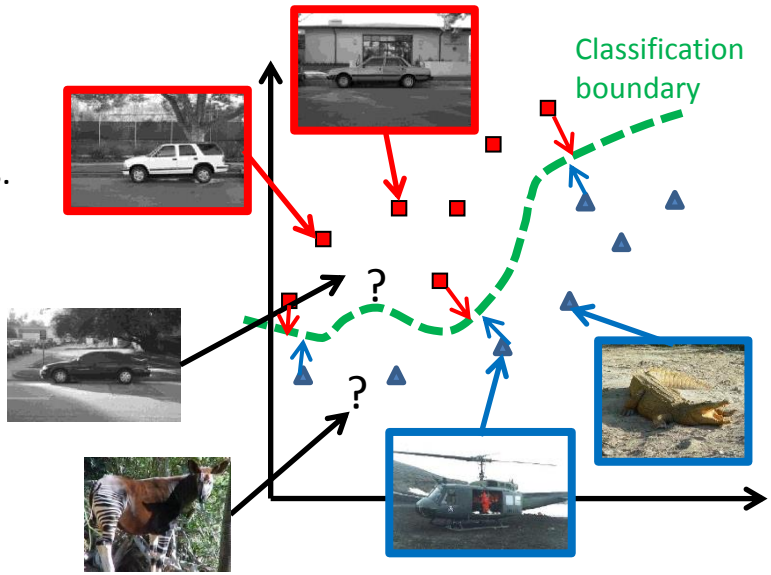
Advantage

1. Effectiveness for high-dimensional data: Placing a classification boundary in the middle between positive and negative examples, is theoretically proven to be independent of the number of dimensions.

2. Effectiveness for a small number of training data: A classification boundary is not probabilistically determined, but determined based on the geometry of positive and negative examples.

3. Convergence to the optimal solution: The objective function for SVM training is convex.

4. Reduction of the computational cost for SVM test: Only training examples selected as support vectors are needed to test the SVM.



Disadvantage

1. Quadratic increase of the computation time and the memory space depending on the number of training examples: In the case of extracting a non-linear classification boundary (non-linear SVM), it is needed to compute the similarity for each pair of training examples.

2. Difficulty of understanding results: Because of the high-dimensionality, it is difficult to know why good or bad classification is obtained. Especially, this is much difficult for non-linear SVMs.

LIBSVM

- One of the most famous SVM software (http://www.csie.ntu.edu.tw/~cjlin/libsvm/)
- A lot of SVM variations and options are supported
- Fast SVM training technique is implemented

- Another most famous software is SVM^{light}
- To my best knowledge, over-flow sometimes happens in SVM in OpenCV

How to Use LIBSVM

1. Download LIBSVM from http://www.csie.ntu.edu.tw/~cjlin/libsvm/
2. Run LIBSVM

   Windows: Run executable files in the folder "windows"
   Linux and Mac: Compile the source codes with "make" to create executable files

   Open a command prompt or terminal

   SVM training: svm-train (or ./svm-train) [options] training_set_file [model_file]
   training_set_file: A file where training examples are written
   model_file: A file where a trained SVM is output (if this is not specified, "training_set_file.model" is generated)

   Example: svm-train ..\heart_scale

   SVM test: svm-predict (or ./svm-predict) [options] test_file model_file output_file
   test_file: A file where test examples are written
   model_file: A file generated by SVM training
   output_file: A file where classification results of test examples are written

   Example: svm-predict ..\heart_scale.t ..\heart_scale.model ..\heart_scale.t.res.txt

   NOTE: I created two files, the one named "heart_scale" contains the first 180 examples in the original "heart_scale", the remaining 90 examples are contained in "heart_scale.t".

Overview of a Code Using LIBSVM

Purpose: Perform classification (generic object recognition) by running LIBSVM in a C++ code

1. Load the information of all images together with their BoVW representations

for each object category

2. Output text files used for SVM training and test

3. Run LIBSVM commands to train and test an SVM *(Use "system" to run terminal commands in a C or C++ code)*

4. Read the result from the file output by LIBSVM

5. Sort images based on SVM outputs and make an HTML file of the result

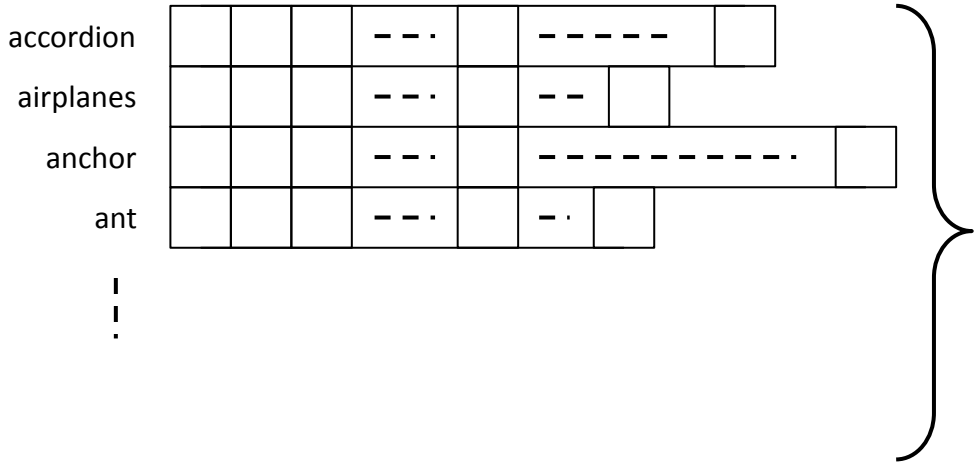
end of for

Loading the Information of All Images

My code stores the information of all images using a 2-dimensional vector, where each element is defined by the following structure:

```
struct ImageInfo{
    string label;       // Object class such as accordion, airplanes etc.
    int id;             // XXXX in "image_XXXX.jpg"
    string filename; // Image filename
    vector<double> bovw; // BoVW representation
    double val; // Initialised as "-1"
};
```

vector< vector<ImageInfo> > imgs



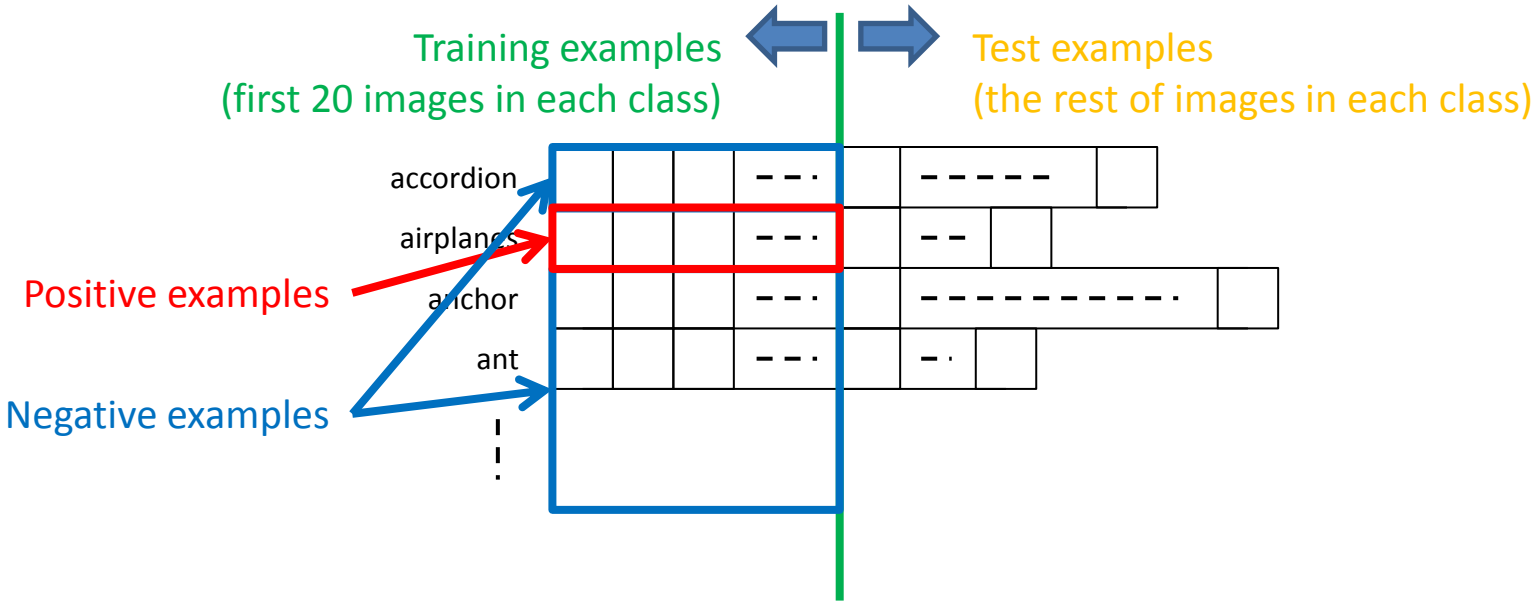
Each row is vector<ImageInfo>, and has a different number of "ImageInfo"s

Each element can be accessed by imgs[i][j]

Preparing Files for LIBSVM (1/2)

For each object class, I define training examples (positive and negative), and test examples in the following way:

An example case where images in which airplanes are shown are distinguished from the other images



Preparing Files for LIBSVM (2/2)

One line of a LIBSVM file has the following format:

<label> 1:<1st dimension value> 2:<2nd dimension value> … 1000:<1000th dimension value>

I set labels of positive, negative and test examples to +1, -1 and 0, respectively. Any value can be used for labels of test examples, because we evaluate the performance on test examples using our C++ code.

(File of training examples)

Positive examples

+1 1:0.00404858 2:0 3:0 4:0.0242915 5:0 6:0.00404858 7:0 8:0 9:0 10:0 11:0 12:0 13:0 14:0.00404858 15:0 16:0.00404858 …

…

Negative examples

-1 1:0.00632911 2:0.0126582 3:0.00632911 4:0.00632911 5:0 6:0 7:0 8:0 9:0 10:0 11:0 12:0 13:0 14:0 15:0 16:0 17:0 18:0 …

…

(File of test examples)

Test examples

0 1:0 2:0 3:0 4:0 5:0 6:0 7:0.00766284 8:0 9:0 10:0 11:0 12:0.00383142 13:0 14:0 15:0 16:0 17:0.00383142 18:0.00766284 …

0 1:0.0044843 2:0 3:0 4:0 5:0 6:0 7:0.00896861 8:0 9:0 10:0.0044843 11:0 12:0 13:0 14:0.00896861 15:0 16:0 17:0 18:0 …

…

NOTE:

1. If you want, you can use the “sparse” file format where only values other than 0 are written.
2. To further improve the computational efficiency, you can use the “pre-computed kernel” format.
3. Moreover, you don’t have to output data into a file if you use LIBSVM as a library in C++.
   See README of LIBSVM for more details.

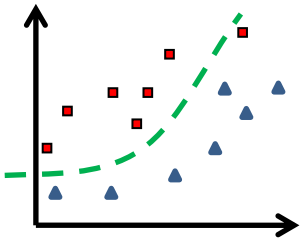
Setting Parameters of LIBSVM

I set three parameters of LIBSVM as follows:

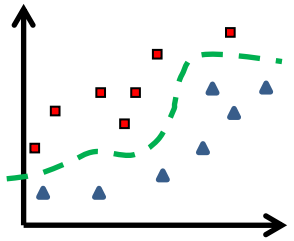
1. γ: This determines the complexity of a classification boundary

$$K(x, x_i) = \exp\left(-\frac{\| x - x_i \|^2}{\gamma}\right) = \exp(-\gamma \| x - x_i \|^2)$$

Usual formulation *LIBSVM formulation*



Small γ
Training examples which are difficult to classify, are ignored (The boundary may be too simple to accurately classify test examples)



Large γ
Training examples are forced to be correctly classified (The complex boundary does not necessarily work for test examples (*over-fitting*))

One reasonable choice is to set γ to the inverse of the average (squared) Euclidian distance among training examples

➡ For any $\| x - x_i \|^2$, its scaling by γ is probably reasonable.

2. C: This determines the tolerance of miss-classified training examples
In my experience, **C=2** is a reasonable choice.

3. -b 1: This is needed to let LIBSVM output continuous values for test examples
If this is not set, LIBSVM just output the predicted class label for each test example
If "-b 1" is used, LIBSVM outputs the probability that each test example belongs to a class.
This probability approximates the distance of the test example to the classification boundary.

Reading a Result by LIBSVM

(A result file output by LIBSVM)

```
labels 1 -1
-1 0.289552 0.710448
1 0.952875 0.0471254
-1 0.12747 0.87253
-1 0.0421646 0.957835
1 0.757121 0.242879
1 0.999989 1.08845e-005
...
```

- The first column represents the predicted class label for a test example:
  If the probability for the class “1” is more than 0.5, “1” is assigned, otherwise, “-1” is assigned.
- The second column represents the probability that a test example belongs to the class “1”
- The third column represents the probability that a test example belongs to the class “-1”

Probability that a target object is shown in a test example

Read values in the second column and set them to the “val” fields for test examples.
The list where test examples are sorted in terms of “val” fields, is a recognition result.

Please refer to the 10-th slide in the 4-th lesson for sorting a vector of ImageInfo.
In addition, by referring to the slides in the 6-th lesson, you can compute the average precision as the recognition performance.

To Further Improve the Recognition Performance

1. Currently, we only use the first 10 images for visual word extraction.

- Extract visual words using more than 1,000,000 SURF features, which are randomly sampled from all of 9,144 images.

2. Change SURF features to Color SIFT features, which are more robust to illumination changes.

- The “colordescriptor” on the following URL is very useful for this purpose.
  http://koen.me/research/colordescriptors/
  In my experience, I recommend you to use Opponent SIFT or RGB SIFT features for densely sampled local regions

3. Use more training examples. You can use addition images that are collected on image sharing sites like Flickr.

- I recommend to use more than 10,000 training examples. To reduce the computational cost, it is necessary to use LIBSVM with the pre-computed kernel in the library mode

Thank you!

All contents in this course (Multimedia Retrieval Exercise) have been finished.

On next Thursday, only if you have some questions or problems in your implementation, please come to the lesson. Otherwise, you don’t have to come.