CAP5415
Computer Vision

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HEC-241
Administrative details
Programming assignment 2

• Optional
• BONUS points

• Due on 15\textsuperscript{th} November
• No extension
Programming assignment 3

• Start date?
  • You will need time for course project
• 5\textsuperscript{th} Nov
• 8\textsuperscript{th} Nov
• 10\textsuperscript{th} Nov
Questions?
Object Detection

Lecture 13
Agenda

• Object detection
• Sliding window
• Image pyramid
• Evaluation
Object Recognition

• **Problem**: Given an image A, does A contain an image of a person?
Object localization
Human Detection

- UAV images
- Surveillance images
Object detection

• Multiple objects
Why detection?

• Self-driving car
A simple solution

Sliding window
Sliding window

• Slide a box around image and classify each crop

• There are many interesting papers
  • Viola and Jones (2001): Face detector (22K citations)
  • Dalal and Triggs (2005): HOG (33K citations)
  • Felzenswalb et al. (2010): Deformable part-based model (10K citations)
Naïve approach: Template Matching

Find the chair in this image

Output of correlation

This is a chair
Template Matching

Find the chair in this image

Epic fail!
Simple template matching is not going to make it
Sliding window

• General approach
  • Scan all possible locations
  • Extract features
  • Classify features
  • Post-processing
Sliding window

• General approach
  • Scan all possible locations
    • Extract features
    • Classify features
    • Post-processing

• Inspect all windows
• Size of window is fixed
Sliding window

• General approach
  • Scan all possible locations
    • Extract features
    • Classify features
    • Post-processing

• People at different sizes?

Objects can be of very different sizes (scales), even in the same image. How do we deal with that?
Sliding window

• General approach
  • **Scan all possible locations**
    • Extract features
    • Classify features
    • Post-processing

• Down-scale the image
Sliding window

• General approach
  • **Scan all possible locations**
    • Extract features
    • Classify features
    • Post-processing

• Keep shrinking
Scale-space pyramid

• Full image pyramid
Gaussian pre-filtering

Solution: filter the image, *then* subsample
Gaussian pre-filtering

Solution: filter the image, then subsample
A bar in the big images is a hair on the zebra’s nose; in smaller images, a stripe; in the smallest, the animal’s nose.
Gaussian pyramid construction

Repeat
• Filter
• Subsample

Until minimum resolution reached
• can specify desired number of levels (e.g., 3-level pyramid)

The whole pyramid is only $\frac{4}{3}$ the size of the original image!
Challenges

• Different aspect-ratio?
Sliding window

• General approach
  • Scan all possible locations
  • **Extract features**
    • Classify features
    • Post-processing

• **HOG/SIFT**
Sliding window

• General approach
  • Scan all possible locations
  • **Extract features**
    • Classify features
    • Post-processing

• **Extract features**
Sliding window

- General approach
  - Scan all possible locations
  - Extract features
  - **Classify features**
  - Post-processing

- Linear/SVM/NN

positive training examples

negative training examples
Sliding window

• General approach
  • Scan all possible locations
  • Extract features
  • **Classify features**
  • Post-processing

• Linear/SVM/NN
Sliding window

• General approach
  • Scan all possible locations
  • Extract features
  • **Classify features**
  • Post-processing

• Run classifier at all scales
• Use a threshold
• Detect all positives
Sliding window

• General approach
  • Scan all possible locations
  • Extract features
  • Classify features
  • Post-processing

• Multiple detections
• Non-maxima suppression
Non-maximum suppression

\[ M(x, y) = \begin{cases} 
|\nabla S|(x, y) & \text{if } |\nabla S|(x, y) > |\Delta S|(x', y') \\
& \quad \& |\Delta S|(x, y) > |\Delta S|(x'', y'') \\
0 & \text{otherwise}
\end{cases} \]

\( x' \) and \( x'' \) are the neighbors of \( x \) along normal direction to an edge
Non-maxima suppression (NMS)

• Iterate over all detections
  • Pick the highest scoring box
• Find overlap
  • with all other boxes
• Remove boxes with high overlap
  • Threshold, usually 0.5

\[ \text{IoU} = \frac{\text{Area of Overlap}}{\text{Area of Union}} \]
Non-maxima suppression (NMS)

- Iterate over all detections
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Non-maxima suppression (NMS)

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Non-maxima suppression (NMS)

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Evaluation

• How do we know if our approach is doing well?
Evaluation

- Intersection over union

Intersection over union (IoU)

\[
\text{IoU} = \frac{\text{size of intersection}}{\text{size of union}}
\]

“Correct” if IoU ≥ 0.5
Sample IoU scores

0.905  0.532  0.391  0.143  0.0
Evaluation

• True positives
Evaluation

• True positives
• False positives
Evaluation

• True positives
• False positives
Evaluation

• True positives
• False positives
• False negatives
Evaluation

- True positives
- False positives
- False negatives
Evaluation

• Only one is correct
Evaluation

• Precision
  • Precision is the ability of a model to identify **only** the relevant objects.
  • It is the percentage of correct positive predictions and is given by:

\[
\text{precision} = \frac{\text{true positives}}{\text{true positives} + \text{false positives}}
\]

• Recall
  • Recall is the ability of a model to find all the relevant cases
  • It is the percentage of true positive detected among all relevant ground truths and is given by:

\[
\text{recall} = \frac{\text{true positives}}{\text{true positives} + \text{false negatives}}
\]
Evaluation

• Sort all predicted boxes (for all images)
  • According to scores
• For each k (location) in the list
  • Compute recall and precision
Precision recall curve
Pop Quiz?
Precision recall curve

• Which is better?
Average precision (AP)

mAP: average AP over multiple classes
Questions?

Sources for this lecture include materials from works by Abhijit Mahalanobis, Alexei Efros, Sanja Fidler, and Fei Fei Li