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INDEPENDENT COURSE WORK REPORT

**Object Detection with Bounding Boxes
through Machine Learning**

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Abstract

Today where computer software and technologies are developing fast and new usages are being discovered frequently, Machine Learning is evolving and redefining Image Processing and Object / Image Detection as we knew it.

In this report I will talk about visual information retrieval (computer vision) through machine learning where I will use state of the art object detection systems depending on region proposal algorithms such as faster region-based convolutional neural networks (Faster R-CNN) and single shot detection (SSD) or also known as you only look once (YOLO) networks.

The end goal is to understand how the training proces of these models work and have a application which will utilize the Tensorflow framework with the Neural Network Models it uses to perform Object Detection on visual media. The result of this Object Detection will be an image, video or live footage with objects highlighted through bounding boxes.

Introduction

While humans effortlessly recognize shapes and objects through our complex visual cortex system where we have millions of neurons and billions of connections between them, which were fine tuned through generations. The difficulty of visual pattern detection becomes apparent when you try implemented the logic in a algorithm.[?]

Object detection which is a technology related to computer vision or image processing is a field that deals with the detection of objects in a digital image or video.

Machine Learning on the other hand is a subset of Artificial Intelligence where the computer will perform tasks through algorithms and models without explicit instructions, relying on patterns and models instead.

Combining these two technologies and the recent advances in object detection through region proposal methods and region-based convolutional neural networks opened up new possibilities which were impossible to achieve before through low level feature analysis only such as mean color comparison, shape and filter analysis or other methods which were common before.

Region proposal methods typically rely on inexpensive features and economical inference schemes. Selective Search, one of the most popular methods, greedily merges superpixels based on engineered low-level features. Yet when comparing to efficient detection networks, Selective Search takes 2 seconds per Image on a CPU implementation, where as fast region-based CNN's take advantage of the GPU and therefore are not applicable for comparison.[?]

Object Detection

3.1 Brief introduction to Neurons and Networks

Similar to the neurons in the human brain, neurons in computer science are approaching the same concept and same ideology.

The functionality of a neuron is to retrieve data, possibly and ideally multiple at the same time, process and output a single result. There are many types of neurons, for introduction purposes I am just gonna mention two here.

- Perceptrons
- Sigmoids

The more commonly used artificial neuron in Neural Network models is the Sigmoid. The reasons for that will be mentioned in the chapters belowe.

3.1.1 Percpetrons

Perceptrons were developed in 1950 to 1960 by the scientist Frank Rosenblatt, inspired by earlier works from Waren McCulloch and Walter Pitts. In this example our neuron has 2 input variables and one output, in theory it can have more or less. Further more Frank Rosenblatt proposes the concept of weights for each input variable defining how important a variable is compared to another.

$$output = \begin{cases} 0 & \text{if } \sum_j w_j x_j \leq threshold \\ 1 & \text{if } \sum_j w_j x_j > threshold \end{cases}$$

A single neuron is by no means comparable to a decision making possibilities of a human being, but it can weigh variables and make decisions accordingly by defining a threshold for when a true or false gets output. Another way to create a conditional behavior is to use a bias instead of a threshold.

$$output = \begin{cases} 0 & \text{if } \sum_j w_j x_j + b \leq 0 \\ 1 & \text{if } \sum_j w_j x_j + b > 0 \end{cases}$$

Making it obvious that they are able to perform more complex decisions in layers. The columns in this network are called layers, the first column is referred to as the first layers and the last one as the output one all the ones in between are called hidden layers.

Since the result of a perceptron can only be one or zero (true or false), one major problem someone faces when using perceptrons in more complex neural networks is that biases and weights can have weird and unwanted effects. Making perceptrons trigger where they should not, that's where sigmoids come in handy and build on top of the concept of perceptrons.

3.1.2 Sigmoids

The core principle of a sigmoid neuron is the same as the perceptrons. Just like perceptrons, sigmoids have input and output variables but instead of just being 0 or 1 it can be anything in between 0 and 1 so 0.5234 is a valid output of a sigmoid.

It also has weights and biases but the arithmetic function looks as follow: is called the sigmoid function or sometimes called the logistic function.

$$\sigma(z) = \frac{1}{1 + e^{-z}}$$

or to put it more explicit with input variables, weights and bias:

$$\frac{1}{1 + \exp(-\sum_j w_j x_j - b)}$$

Since the algebraic form of σ is smoothed And not a step function: It is the only place where sigmoid differs from the perceptron.

3.2 Current state

Object Detection in dealing with two major problems and therefore can be split into two processes, these are object localization and object classification of multiple objects in one image. There are many approaches in current Neural Network models to perform these actions. There are models which have a multi layer architecture, each performing complex tasks such as analyzing, localizing and classifying each sections individually, making the cost high and the network in general slow but accurate. There models that combine functionality in one layer so that one layer for instance localizes and classifies at the same time, is making the model more flexible, smaller and therefore faster but less accurate. The trade off between accuracy and speed is something that all networks deal with nowadays especially if the goal is to have a near real life object detection system which is still reliable and accurate when doing so.

There are multiple algorithms covering various forms of this formula, called RCNN, F-RCNN, SSD, YOLO but first we will cover the approach of detecting interesting regions in an image because this is a key problem in object detection.

3.2.1 Approaches to Object Localization

The segmentation of an image is the key approach to Object Localization, since images are always hierarchical the segmentation as well has to be hierarchical. It has to be able to cover different criteria and forms, where maybe objects are part of a bigger total or just single parts inside another one. Since is not feasible to compute every possibility inside an image there has to be some kind of separation through grids and scales.

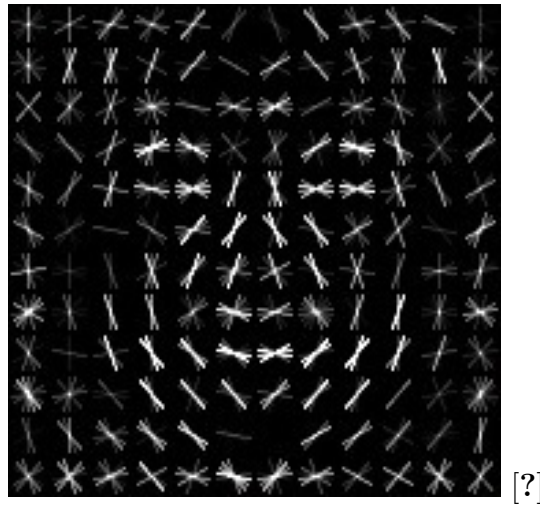
As there are many approaches to algorithms how to analyze and classify regions, there are many approaches for algorithms to detect interesting sections of an image which may contain objects.

Exhaustive Search

Since an object can be located anywhere in an image the scope to look for it is enormous making the computational cost for such search very expensive. To compensate for this cost most exhaustive search approaches such as the sliding window approach, constraint the size and aspect ratio of the window over the grid, also using weak classifiers and economic image features such as histogram of oriented gradients (HOG).[?]

HOG approaches the problem of recognizing and detecting objects in an unknown image through detecting corners, their distribution and their orientation. Analyzing these you are able to separate the image in multiple partitions or detect similar regions in different images. Robert K. McConnell described the concept in a patent in 1986. It became known

in 2005 through a publication from Navneet Dalal and Bill Triggs.[?]



Selective Search

Region Proposal Network

3.2.2 Approaches to Object Classification

Tensorflow

Application

Conclusion

Bibliography