Human Pedestrian Detection using Histograms of Oriented Gradients

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Abstract

Detecting humans in images is a difficult task because of the wide range of variability such as pose, illumination and backgrounds. However, this is an important task as many industries could benefit from reliable human detection (automobiles, law enforcement, etc). A number of methods for detecting humans exist that have proven to be somewhat reliable. For our project we wanted to explore one of these methods and how it compared to existing techniques. We chose *Human Pedestrian Detection Using Histograms of Oriented Gradients* by Navneet Dalal and Bill Triggs[1]. This method proposes a simpler and more reliable way of detecting humans. Dalal et al wanted to find a robust feature set that "allows the human form to be discriminated cleanly, even in cluttered backgrounds under difficult illumination." We set out to reproduce their results by developing our own implementation that they outline in their paper.

1 Previous Work

To understand the importance of the preceding work we will briefly discuss some of the existing methods:

- A technique involving Haar Wavelets was researched by Papageorgiou et al[2]. The goal of their work was to detect and recognize various classes of objects (faces, automobiles and pedestrians for this experiment). They use Haar Wavelets to "describe an object class in terms of a large set of local oriented intensity differences between adjacent regions."
- Gavrila et al[3] created a real-time pedestrian detection application by extracting edge images and matched them to a collection of learned examplers using the chamfer distance.
- SIFT based feature detection was improved upon by Ke et al[4] by using Principal Components Analysis (PCA) instead of SIFT's smooth weighted histograms. These PCA-based descriptors "are more distinctive, more robust to image deformations, and more compact than the standard SIFT representation."
- And numerous others.

These methods have been fairly successful already but by using Dalal et el's Histograms of Oriented Gradients(HOGs) method we could potentially arrive at a solution that produces higher performance[1] with a simpler implementation.

[1]When we mention performance we are speaking of performance in terms of accuracy. More specifically, one algorithm is more performant if it yields fewer false positives and/or a lower miss rate than another algorithm.

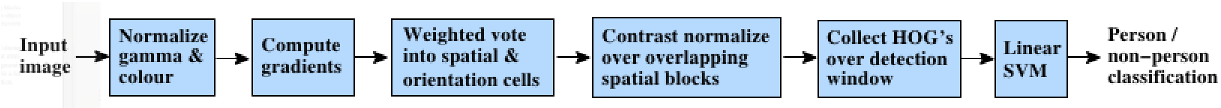

Figure 1: HOG processing pipeline

2 Approach Outline

The simplicity of HOGs is that there are no key-points to identify. HOG descriptors are produced from a dense grid of uniformly spaced cells. Given an image, the algorithm will divide the image into small spatial regions known as cells. A one dimensional histogram of directional gradients is computed for each cell. The cells are grouped into blocks. The blocks are normalized by accumulating the local histogram energy and using the results to normalize each of the cells in the block. These normalized blocks are what become the Histogram of Oriented Gradient descriptors. The blocks are overlapped across the detection window so that cells are used multiple times in different contexts (we discuss the benefits of this in the results section). The feature vectors are then fed into an SVM where a person/non-person classification is made. An overview of the pipeline is shown in figure 1.

Dalal et el's experiments showed that color normalization had a small affect on performance. In our implementation we used gray scale which had slightly lesser performance than RGB, but the implementation is also slight simpler.

3 Advantages

Histograms of oriented gradients provide several advantages over the previous approaches. In general the HOGs approach provides for a simpler implementation. At the heart of the algorithm is the calculation of gradients and their orientation. The remainder of the algorithm is grouping the gradients into blocks and normalizing.

HOGs is robust against translation and rotation so long as the rotation/translation is smaller than the local spatial or orientation bin size.

Partial occlusion does not hinder HOG's ability to identify targets. By using overlapping blocks (a dense grid of cells), robust feature descriptors are created that do not rely on the entire target being visible. This is a particular advantage over previous methods in which specific key-points had to be visible in order for a positive identification to be made. Additionally, by using overlapping blocks a cell is given multiple contexts. For example, perhaps a block that yields the correct descriptors for a positive human detection includes both a shoulder and an elbow. The first block may only include the shoulder, but a subsequent block may include both the should and elbow.

Lastly, but most importantly, Dalal et al showed that HOGs is more performant than the existing methods discussed; in some cases, 10-100 times better. They remark that this is "because none of the key-point detectors that we are aware of detect human body structures reliably." Intuitively, this makes sense given the wide variance of human forms. Relying on specific key-points from one human to the next would not be robust.

4 What We Accomplished

We originally set out to replicate the results of the experiments Dalal et al originally performed in their 2005 paper. Tangentially, we were trying to better understand how pedestrian detection is performed and what are some of the challenges specifically with this kind of detection. This would include creating an implementation of their algorithm from scratch, training an SVM and running the experiment with the various parameters (e.g., block size, normalization functions, etc).

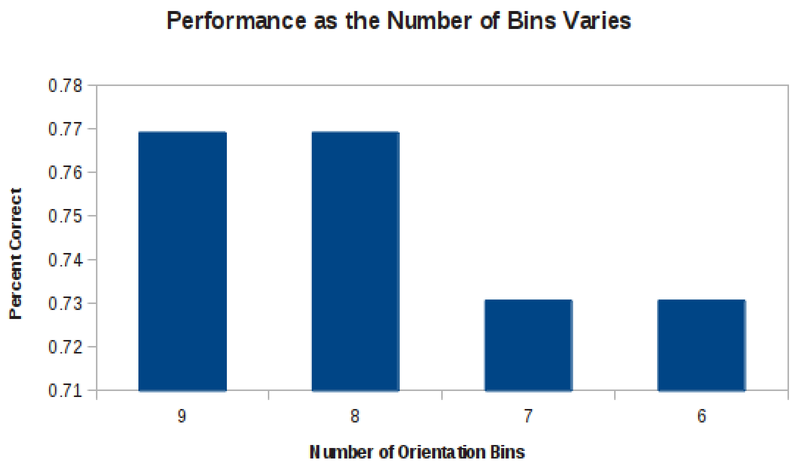

Figure 2: Performance as Number of Orientation Bins Varies

5 Implementation

By design, the HOGs algorithm is not terribly complex. As stated previously, this is one of the benefits over existing solutions. Contrary to how Dalal et al developed their implementation, we used OpenCV wherever possible. Although writing the code was a straightforward task, verifying correctness was more complicated.

One thing we knew going into the project was that we wanted to have unit tests wherever possible. We started creating unit tests for methods that had well defined inputs and outputs. As we got further into the implementation, unit tests became less effective. We needed to test the result of several methods and if the results were visually correct. For example, given an image, are the gradient orientations visually correct? A unit test could be written for this, but its a fair amount of setup and we needed a way to test many images quickly. We also wanted a way to manually verify the numbers our algorithm was generating. Taking inspiration from one of the images referenced in the HOGs paper, we created output images that annotated the gradient orientations directly in the image (for each cell). This served its purpose quite well, allowing us to visually verify any image that went through the algorithm.

6 Training the SVM

Dalal et al used with a linear kernal and we originally anticipated doing the same. However, after implementing the algorithm using OpenCV, we realized that OpenCV provides an internal SVM as well (which shares the common underlying library LibSVM with SVM-Light). We chose to use the OpenCV SVM out of simplicity. Using the SVM in OpenCV allowed us to perform all of the work in memory, as opposed to having to write the descriptors to file before training or classifying.

We trained the SVM with a set of 90 positive and 90 negative images. The positive test set contains both images and their mirrors. The images are approximately the size of the detection window, so we restricted our training to a single centered detection window. The negative test set does not contain mirrored images and the images are much larger than the size of the detection window. We thus handle the negative training images differently, creating mirrors and then tiling the detection window across the image to create a number of detection window sized images.

Unfortunately, as the quarter is short, and training the SVM is long (we settled on a configuration that took only an hour for each training), we did not have much time to determine the optimal SVM configuration for our application. Our choice of SVM parameters is thus unlikely to be optimal.

7 Experimental Method

The one experiment that we had time to conduct was to vary the number of orientation bins. Because varying the number of bins modifies the descriptors generated, we needed to retrain the SVM between tests. Performing the experiment was straightforward: our system is deterministic so no repetitions were needed and only a minor modification was needed for each test. The difficult part of the test is the time cost to retrain the SVM.

8 Results

From our single experiment, we found similar results to those of Dalal et al: more orientation bins performs better than less (within the range that we tested).

9 Summary

The ability to automatically detect humans in a given image has vast applications. Automobiles could use it for increasing traffic safety or security organizations could use it to identify people of interest. However, computer scientists still struggle to produce an accurate and efficient way of detecting humans; even more so than other types of object recognition. The reason for this is the wide variety of shapes humans can take. People are naturally shaped fairly differently, but they can also take on different poses. This makes detection quite difficult.

The Histogram of Oriented Gradients attempts to limit the significance of this variance by focusing on smaller contexts. By looking at these smaller regions (blocks) we begin to get a more normalized set of descriptors for a human.

Still, the approach makes some very large assumptions. First, we assume the human is standing up right. Although we did not test this, we should safely assume that a human who is sitting or laying down will not be detected correctly. We hypothesize, however, that this is a fault of the training data and not HOGs. Had we trained our SVM with humans in the sitting or laying position, HOGs could perhaps work just as well. It would be interesting to see if a single SVM could be used for vastly different positions or if the 'noise' of sitting humans disrupts the accuracy of detecting standing humans. Second, the human accounts for a large portion of the window. We did not have time to experiment with this but citing the Dalal et al paper, results differed based on the amount of space (padding) surrounded the human. Specifically, they found the best results to have 16 pixels of padding around the target (human). Many real-world images are not such that a human accounts for the majority of the space. A future implementation could likely solve this problem by using varying sizes of windows and sliding the window across the image.

Overall the project was both interesting and challenging. It was interesting to discover the variety of methods for detecting pedestrians and realizing that no single solution had yet become a 'standard' approach. We were impressed with the simplicity (in hindsight) of the HOGs approach and hope that it can continue to be refined so that pedestrian detection can become a reliable problem to solve.

References

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