Computer Vision

Assignment 1

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Investigating the efficacy of edge detection algorithms in helping diagnose autoimmune diseases by means of immunofluorescence

In this report we will be working to investigate the efficacy of edge detection algorithms in helping to diagnose autoimmune diseases. Algorithms will be tested on their ability to detect fluorescing cells seen after indirect immunofluorescence on HEp-2 cells.
We want to find the best edge detection algorithms for detecting these cells, and the best method of implementing and running these algorithms to obtain optimal results.
This report will contain the investigations that we carry out and detail their aim, method, results and conclusions.
Results throughout investigations will be assessed objectively and finalised for conclusion using ROC (Receiver Operator Characteristic) analysis.

Aim
The aim of this investigation is to compare the efficacy of various edge detectors by comparing the results of these edge detectors applied to images of fluorescing cells, with images of manually detected edges for these cells.
The edge detector algorithms that we will be testing are simple gradient, Roberts, Sobel, first order Gaussian, Laplacian and Laplacian of Gaussian.

Method
To test each edge detection algorithm, we will first implement them into functions in MatLab. Before we can apply the edge detection functions to the images that we have been provided of the fluorescing cells, we will first import the images into MatLab so that they are represented as matrices of pixel intensities for the RGB channels.
Since the images that we have show green cells, we need only take the green channel intensity matrix (greyscale of all green intensity in the original image).

Next, we will apply a Gaussian matrix filter in order to remove reduce noise in the image. Smoothing and removing noise from an image using a Gaussian filter should improve the performance of edge detection algorithms since this process will blur the image, making edges more prominent and therefore increasing the probability that they are be detected

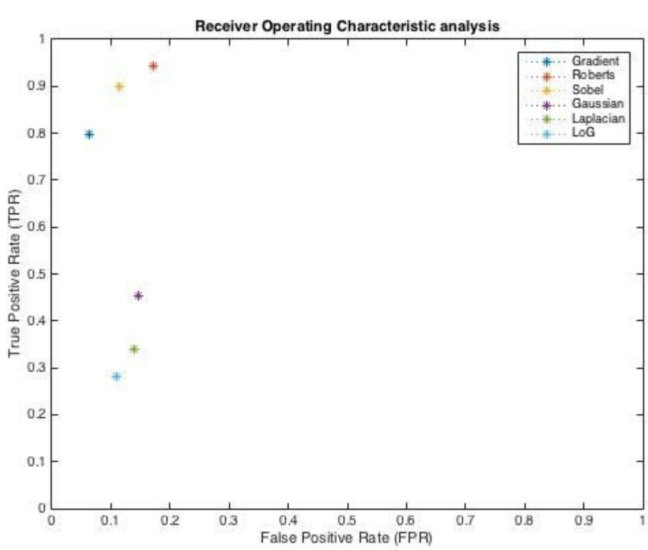
Once a Gaussian matrix filter has been convolved with the image for smoothing, we apply a sharpening filter to enhance the quality of the edges by making them more distinct from the background.

We can then apply our edge detection functions to this matrix in order to produce a binary matrix of the detected edges that can be shown as a black and white image.
We will need to manually adjust the threshold of the values that will be output as edges to find the results that we are looking for, this will have to be done for each individual edge detection method.

Once we have a matrix of detected edges for each edge detection algorithm, we will be able to apply an ROC function comparing the provided detected edges image with our outputted detected edges images that will count up all true positives, true negatives, false positives and false negatives and then use those to calculate the sensitivity and specificity of each edge detection algorithm.
We will also be able to demonstrate the effectiveness of each edge detection algorithm by plotting the true positive rates against the false positive rates on a graph. For an edge detection algorithm to be seen as effective, we need the line graph to tend towards higher true positive values.

Results
The values in the table below are the specificity and sensitivity obtained from ROC analysis and the threshold applied to the images in order to produce clear edges.

Image\Filter	**Gradient**	**Roberts**	**Sobel**	**Gaussian**	**Laplacian**	**Laplacian of Gaussian**
9343 AM	0.97, 0.73, 5	0.86, 0.84, 8	0.79, 0.9, 60	0.42, 0.89, 2	0.45, 0.82, 1	0.40, 0.86, 1.5
10905 JL	0.8, 0.94, 20	0.94, 0.83, 8	0.9, 0.89, 60	0.45, 0.85, 2	0.34, 0.86, 1.5	0.28, 0.89, 1.5
43590 AM	0.73, 0.89, 7	0.8, 0.84, 4	0.77, 0.87, 25	0.41,0.87, 1	0.27, 0.88, 1	0.3, 0.83, 0.5



On the left is a graph to show the rate of false positives to the rate of true positives for each edge detection algorithm.
A line drawn from (0,0) to (1,1) represents the line of no discrimination, namely a random guess. Any point above this line can be considered to be better than a random guess of edge points and anything lower is worse than random guessing.
We can see that all the points in our graph are above the line of no discrimination, meaning that the

edge detection algorithms are working as we'd hope.
The first-order derivative edge detection algorithms have produced better results than the second derivative algorithms, we can see this from their high 'true positive rate' values and low 'false positive rate' values. The first-order derivative edge detectors are Simple Gradient, Sobel, Roberts and First-order Gaussian, second-order derivative edge detectors being Laplacian and Laplacian of Gaussian. First-order Gaussian is of course the exception to this observation, we can see that it positions itself with a lower 'true positive rate' value with the second-order derivative edge detectors.

Conclusions

From the results we have achieved it is clear that for the three images that the study was conducted upon, first-order derivative edge detectors performed best.

Since first-order derivative operators are very sensitive to noise, applying smoothing prior to detection of edges makes a big difference, as we observed from the ROC analysis scores. The edges detected by first order operators are thicker than those detected by second order detectors, and should therefore be 'thinned' using the non-maxima suppression algorithm.

One explanation for the second-order derivative edge detectors doing so poorly, is that the differentiation occurring amplifies noise and so for this reason, a much larger level of smoothing must be applied before running edge detection filters. The test images were each very different but they are all quite noisy, especially with non-fluorescing sections existing within the cells.

Since the images that we were testing the edge detectors on varied in their quality, it is likely that some of our smoothing and threshold values were not optimal and so did not reveal the full potential of some detectors. One possible way of improving our values for smoothing and thresholding would be to create a function that can manipulate the values and test them with the distance in the ROC graph from the perfect classification point and choose the best one.

In conclusion we have determined that first-order derivative edge detectors are the most suitable of the edge detectors that we tested for diagnosis of autoimmune diseases, through the detection of fluorescing cells.
In particular, the Sobel and Roberts edge detectors showed the best results with the shortest distance to the perfect classification (0,1) on our ROC graphs.