Improvement to Canny Edge Detector using Median Filter

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Abstract

This paper deals with some of the limitations of the famous Canny Edge Detector by changing one step of the algorithm in an attempt to eliminate the limitation. The discovery of the problem is inspired by the authors' personal experiences during assignment 4 of CSC320 at the University of Toronto. The success of edge detection described in this paper is based on human observation. The goal is to reduce the noise in the image, while at the same time detect enough important edged that the result still has a resemblance to the original image. The proposed improvement is experimented on several different cases with widely different situations and controlled parameters. These experiments will demonstrate the advantages and success of the proposed improvement to the Canny Edge Detection method. However, the experiments will also showcase the limitations and situationality of the proposed improvement.

1.Introduction

Edge detection is a common yet important part of many computer vision system. Edge detection can be used to reduce information on an image to its essentials, thus greatly reducing the necessary power needed to process such information. At the same time, edge detection method preserves important structural information about the objects in said image. Because of these, edge detection methods and algorithms are taught early in university courses that serve as an introduction to the world of computer vision and image processing. This is also the reason why we chose an edge detection algorithm as a target for potential improvement. During experiments with a non-local mean denoising algorithm using a generalized PatchMatch algorithm, we have a very hard time trying to capture images with significant amount of noise. Before trying with a specialized camera and getting the necessary noisy images in the end, we tried to create noises and adding them into images. One of these noisy we tried was salt and pepper noise. During our experimentation, we found that the non-local mean noise reduction algorithm we were working with did not achieve great denoise effects with the salt and pepper noise. Worried about our implementation's feasibility, we tried a Gaussian filter, another noise reduction filter that uses means, on the same image. The Gaussian filter did not work too well either. Although we were able to get better images and got nonlocal mean denoise algorithm working, this experience got us thinking about a very common algorithm Gaussian filter is used in, the Canny Edge Detection algorithm. Is there a limitation of the algorithm on salt and pepper noises, and if so, is there a way to bypass this limitation by changing part of the algorithm?

2. Canny Edge Detection algorithm

The Canny Edge was developed by John F. Canny in 1986.[Canny,1986] In his paper titled "A computational approach to edge detection", he outlined a general way to detection edges for a diverse range of computer vision systems. The steps to a Canny Edge detector are as follows. First, apply a Gaussian filter to reduce the noise in the image. Then, find the gradients of the image. Next, apply non-maximum suppression to get rid of spurious response. Finally, apply double thresholding and tracking by hysteresis to eliminate weak edges and weaker edges that are not connected to any strong edges. The strongest limitation to a good edge detector is noise on an image. Noises in the image and interfere with the detection of edge and they can be detected as edges. In the steps of the Canny edge detector, only one step is on finding edges, all the rest are to reduce noise or reduce the edge created by noise left in the image. While gaussian noise is discussed thoroughly in this paper, there are no mention of salt and pepper noise. The gaussian filter is the first step and the main step in eliminating noise. However, the Gaussian filter is a double edge sword. On image that is too noisy, especially with salt and pepper noise, the Gaussian filter may not be able to do its job. If the filter strength is not enough, there will be too much noise, but if the noise is most eliminated, the leftover result may become too blurred that major edges becomes undetectable. While the other steps of the algorithm can be used to reduce the negative effects from this, when it comes to salt and pepper noise, the Gaussian filter simply does not work very well at reducing noise, leaving the result both noisy and blurred. Thus, we decided to find another algorithm to replace gaussian filter especially in situations consisting of salt pepper noise and compare the result.

3. Median Filter

The Median filter is a non-linear filtering technique. In comparison to the linear filter technique Gaussian filter, it works with the Median of a patch instead of the weighted mean.[Leavline,2013] When using a Median filter, each pixel is replaced by the Median of a patch consisting of its neighbouring pixels. When the pixel is on the edge of an

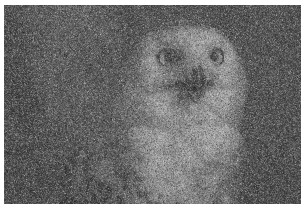
image and there is not enough neighbouring pixels to fill the enough patch, the first and last values of the patch can be repeated to complete the patch. Other than this way, the patch can also be shrank near the boulder or the pixels can be fetched from the other side of the image. Due to the way that this filter works, it can filter out salt and pepper noise much better than the Gaussian filter can. This is because salt and pepper noise come in multiple colours for coloured images and black and white for grayscale images. This cause the mean to be balanced out if there happen to be similar number of salt and pepper noises in the patch. For Median filter however, the salt and pepper noises are very unlikely to be the Median of the whole patch. For this reason, we chose the Median filter as a replacement for the Gaussian filter when the Canny Edge Detector is used on an image with lots of salt and pepper noise.

4.Experiments and Results:

4.1 Salt and Pepper Noise

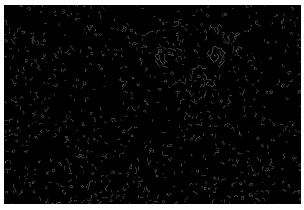
4.1.1 Experiments

Assuming Median filter has a better performance than Gaussian filter in edge detection of images with Salt and Pepper Noise, we designed the experiments to start with tuning the parameters of Gaussian filter, such as the patch size, the low threshold and the high threshold, then we applied the optimized parameters of Gaussian filter onto the Median filter.



Source Image Salt and Pepper Noise

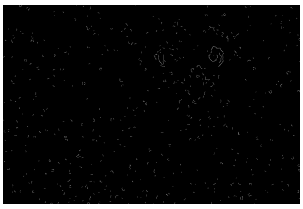
E1.1 Outputs on Gaussian filter with patch size = 25, low threshold = 20, high threshold = 30:



Gaussian filtered Edges with Gaussian filter

It is very obvious that there are a lot of noisy edges on the final edge detection result image. The outlines of the head and the eyes of the owl are still noticeable but pretty merged into the noises. In the following experiment, we tried to increase both thresholds to eliminate more noisy edges from the result image.

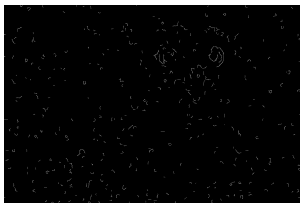
E1.2 Outputs on Gaussian filter with patch size = 25, low threshold = 30, high threshold = 33:



Gaussian filtered Edges with Gaussian filter

Along with the reduced noisy edges, the details on the face of the owl are reduced as well, for example, the outline of the head is not noticeable any more; we can only see the outline of one of the eyes of the owl; the mouth is barely recognizable. Concluded from the above experiment outputs, we decided to use the thresholds from E1.1 and tune the value of patch size in the following experiment.

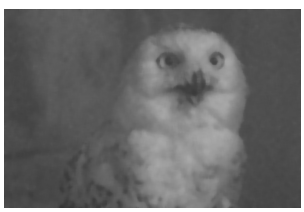
E1.3 Outputs on Gaussian filter with patch size = 27, low threshold = 20, high threshold = 30:

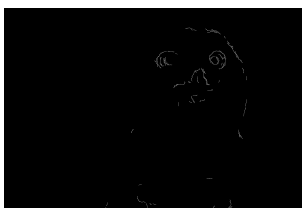


Gaussian filtered Edges with Gaussian filter

By increasing the patch size, obviously there are much less noisy edges on the background with less loss on the details of the face. In other words, there are more details on the face such as the outlines of both eyes and the mouth. Even though the edge detection result using these parameters is not ideal, this set of parameters is very close to the optimized parameters for edge detection of images with Salt and Pepper Noise using Gaussian filter. In this case, we decided to apply this set of parameters onto edge detection of images with Salt and Pepper Noise using Median filter in the following experiment.

E1.4 Outputs on Median filter with patch size = 27, low threshold = 20, high threshold = 30:



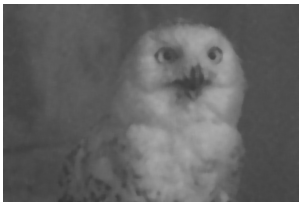


Median filtered Edges with Median filter

Before comparing the result edge detection image produced by Median filter with that from Gaussian filter, we should take a look at the filtered result image first. The previous Gaussian filtered result images have the Salt and Pepper Noise reduced at a pretty low level so the noise level on the filtered image is still too high to result in a good performance in Canny Edge Detection. Yet the Median filtered result image has the Salt and Pepper Noise reduced at a relatively high level so that it looks like the source image, but a bit blurred. Base on the comparisons conducted on the filtered result images, we can move forward and take look at the edge detection result image using Median filter to prove our assumption.

Apparently there is not much noisy edges on the output edge detection image while the main edges of the details on the face are preserved. However, this set of parameters might not be the optimized set for Canny Edge Detection using Median filter.

E1.5 Outputs on Median filter with patch size = 25, low threshold = 14, high threshold = 15:



Median filtered Edges with Median filter

After decreasing the patch size and both thresholds, not only the details on the face became more significant, the details on the body became more recognizable as well.

1.2 Comments and Conclusion

Note: The low threshold eliminates the edges below this threshold. An edge beyond the high threshold are considered as a strong edge. Any edge that is not connected to a strong edge but between the low threshold and the high threshold will be eliminated a well.

For Gaussian filter, we could not decrease the patch size to a lower value, since it will result in a more noisy filtered image than the filtered images in E1.1, E1.2 and E1.3. For the same reason, the lower low threshold will cause the Canny Edge Detection algorithm to preserve more noisy edges. With the patch size and low threshold settled, if we choose to stick to the rule — high threshold is approximately 3 times the low threshold, then our main edges will be eliminated as well because no edge will be defined as strong edge, in which case no edge will be connected to a strong edge either. Similar reasoning applies to Median filter as well, however, choices of values on thresholds for Median filter differ from the choices for Gaussian filter. Compared to Gaussian filter, we chose a relatively lower value for the thresholds for Median filter because the filtered images are less noisy than the filtered images resulted from Gaussian filter. Therefore, we will lose the details on the edge detection result image if we set the low threshold to a greater value.

Gaussian filter applies a weighted average on the image. However the grayscale Salt and Pepper Noise contains white pixels and black pixels. In such case, they will cancel out each other in weighted average, resulting in bad performance using Gaussian filter. On the other hand, Median filter will take the Median value within its patch. Since the grayscale Salt and Pepper Noise has either a value of 0 or 255, the Median will never be the value of the Salt and Pepper pixel.

Based on the above experiments and arguments, the evidence is strong that the Median filter performs better than Gaussian filter in term of detecting edges of images with Salt and Pepper Noise.

4.2 Gaussian Noise

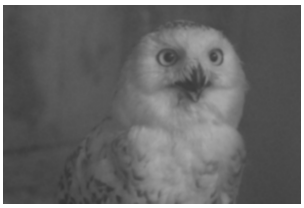
4.2.1 Experiments

After proving Median filter performs better than Gaussian filter in the case of Salt and Pepper Noise, we wanted to conduct experiments using Median filter on Gaussian Noise that traditional Canny Edge Detection with Gaussian filter performs well with.

E2.1 Low Gaussian Noise

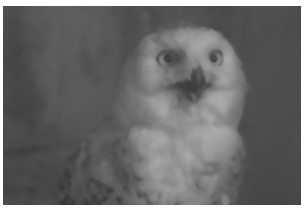
Source image Low Gaussian Noise

E2.1.1 Outputs on Gaussian filter with patch size = 15, low threshold = 15, high threshold = 25:



Gaussian filtered Edges with Gaussian filter

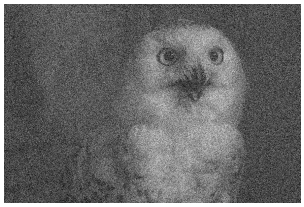
E2.1.2 Outputs on Median filter with patch size = 15, low threshold = 8, high threshold = 30:



Median filtered Edges with Median filter

From the experiments above, Median filter performs well but Gaussian filter outperforms Median filter. We will try with image with higher Gaussian Noise in the next experiment.

E2.2 High Gaussian Noise

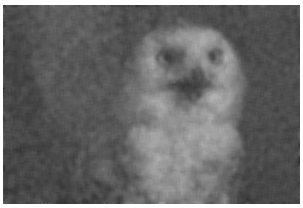
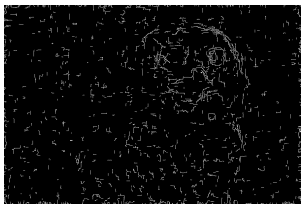



Source image High Gaussian Noise

E2.2.1 Outputs on Gaussian filter with patch size = 23, low threshold = 15, high threshold = 25:

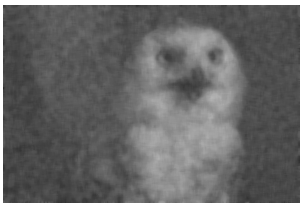

Gaussian filtered Edges with Gaussian filter

E2.2.2 Outputs on Median filter with patch size = 17, low threshold = 25, high threshold = 35:

Median filtered Edges with Median filter

E2.2.3 Outputs on Median filter with patch size = 17, low threshold = 35, high threshold = 50:




Median filtered Edges with Median filter

From the above experiment results, it is straightforward that Gaussian filter performs better than Median filter in terms of filtering high Gaussian Noise. Gaussian Noise will dramatically influence the Median within the patch, therefore, Median filter does not work as well as in Salt and Pepper Noise and low Gaussian Noise.

5. Conclusion and Limitations

After conducting the above experiments, we conclude that replacing Gaussian Filter in Canny Edge Detector with Median filter can increase the performance of Canny Edge Detector when dealing with Salt and Pepper Noise. However, the Median filter does not perform as well as Gaussian filter in terms of eliminating Gaussian noise from source image and perform Canny Edge Detection from there.

For natural images that contain both Salt and Pepper Noise and Gaussian Noise, using both Gaussian filter and Median filter may achieve a better result.

6. References

Canny, J. (1986). A Computational Approach to Edge Detection. IEEE Transactions on Pattern Analysis and Machine Intelligence, PAMI-8(6), 679–698. https://doi.org/10.1109/tpami.1986.4767851

Leavline, E. J., & Singh, D. A. A. G. (2013). Salt and Pepper Noise Detection and Removal in Gray Scale Images: An Experimental Analysis. International Journal of Signal Processing, Image Processing and Pattern Recognition, 6(5), 343–352. https://doi.org/10.14257/ijsip.2013.6.5.30

Image Source:
Rasp, D., & Rasp, D. (2019, April 14). Salt And Pepper Noise. Retrieved December 8, 2019, from Raspository website: https://raspository.com/salt-and-pepper-noise