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Edge Extraction using Modulation and Demodulation: A Simple Technique

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Abstract

This paper discusses a simple but effective technique to extract edge information from an image. The method uses pulse amplitude modulation (PAM) together with differential phase shift keying (DPSK).

Keywords: Pulse amplitude modulation, differential phase shift keying, morphological filters.

1 Introduction

Modulation techniques [1, 2] are used to change the properties of the signal associated with its frequency. In case of amplitude modulation the original signal behaves as an envelope for the high frequency signal, while for frequency and phase modulation



Figure 2.1: Image as matrix coefficients.

the contents are saved in frequency or phase change respectively. In case of digital modulation pulse amplitude modulation corresponds to amplitude modulation. Phase shift keying corresponds to phase modulation in continuous domain.

In the present paper we introduce a technique to extract edges from an image using PAM modulation and DPSK demodulation techniques.

2 Procedure

Let us assume that the image under consideration is represented by I . Every pixel of the image is represented by 8 bits; that is, the range of values for grey scale image is from 0 to 255 (though the procedure is general in nature but for simplicity we consider a gray scale image).

Image I is shown in Figure 2.1. The figure is showing image in terms of matrix coefficients.

PAM modulation is applied on the image thus obtained. PAM modulation reassigns the amplitude of the image coefficients to newer ones. Figure 2.2 shows a comparison between original image and PAM modulated image. It is clear from the figure that matrix coefficients are assigned new values. To find out what changes after PAM

| | | | | | | |
|-----|-----|-----|-----|---|---|---|
| 107 | 33 | 25 | 13 | 0 | 0 | 0 |
| 123 | 139 | 95 | 9 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 149 | 89 | 189 | 207 | 9 | 0 | 0 |
| 231 | 231 | 235 | 71 | 0 | 0 | 0 |
| 247 | 231 | 173 | 19 | 0 | 0 | 0 |

Modulated Image

| | | | | | | |
|-----|-----|-----|-----|-----|-----|----|
| 181 | 144 | 140 | 134 | 86 | 57 | 54 |
| 189 | 197 | 175 | 132 | 101 | 116 | 92 |
| 86 | 79 | 67 | 64 | 57 | 65 | 63 |
| 72 | 51 | 54 | 72 | 68 | 67 | 68 |
| 84 | 79 | 111 | 125 | 93 | 86 | 84 |
| 202 | 172 | 222 | 231 | 132 | 70 | 75 |
| 243 | 243 | 245 | 163 | 69 | 83 | 80 |
| 251 | 243 | 214 | 137 | 112 | 120 | 89 |

Original Image

Figure 2.2: Original and PAM modulated image.

modulation we have to look at the PAM modulation procedure.

An image can be represented as a 1D signal by replacing all the rows as one row. This gives us our image as a 1D signal. Suppose $x(t)$ is the 1D signal with amplitude values varying between 0 – 255.

If we apply PAM modulation on this signal, the resulting waveform will be represented by

$$\begin{aligned}
 x_{PAM}(t) &= \Re[A_m x(t) e^{j2\pi f_c t}] \\
 &= A_m x(t) \cos(2\pi f_c t)
 \end{aligned}$$

where $m = 1, 2, 3, \dots, M$; A_m is the set of M possible amplitude corresponding to $M = 2^k$ possible k -bit blocks of symbols.

We know that the shape of $x(t)$ influences the spectrum of the transmitted signal, because of the mapping or Gray encoding operation.

Similarly, if we apply PAM modulation on an image with symbol order 2 or higher; we shall receive an image with new spectrum of the signal. A part of image after PAM modulation is shown in Figure 2.3. The image is considered to be 1D signal for comparison purpose. Modulated and original images are shown in Figures 2.4 and 2.5,

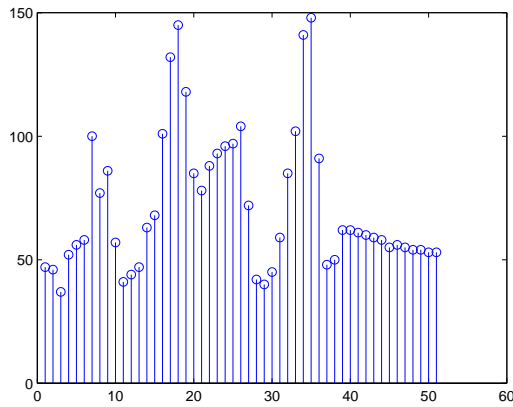


Figure 2.3: Image as 1D signal.



Figure 2.4: Original image.

respectively.

DPSK is a noncoherent communication technique and thus does not require an estimation of phase of the carrier. To regenerate the original signal received signal is compared, at any given signalling interval, with the phase of the received signal from preceding signalling interval. Therefore, we can demodulate any received signal using DPSK irrespective of how it was modulated. After performing DPSK demodulation the image becomes as shown in Figure 2.6. Corresponding 1D signal together with original and PAM modulated signal is shown in Figure 2.7.



Figure 2.5: Modulated image.



Figure 2.6: Demodulated image.

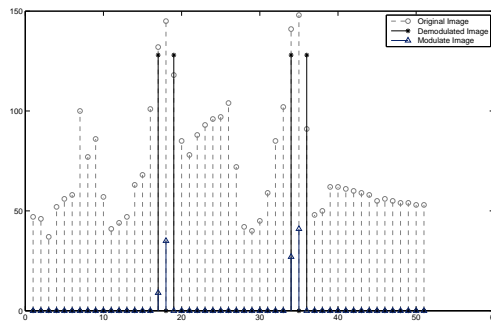


Figure 2.7: Original, PAM modulated and DPSK demodulated image.



Figure 3.1: Example-1



Figure 3.2: Example-2

3 Discussion

Thus after performing PAM modulation and DPSK demodulation we get an image which contains only major edges of the original image.

Algorithms for PAM modulation and DPSK demodulation are easily available from open source communities, blogs and forums; therefore, one can easily write a program to extract edges from an image using these readily available programs in almost all the languages. This makes the discussed technique very handy and easy to implement.

Some results are shown in Figures 3.1 to 3.5 by applying the discussed technique.

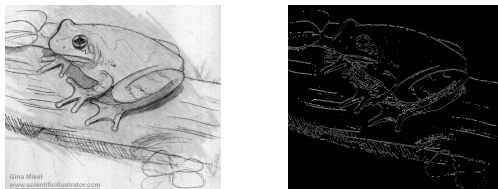


Figure 3.3: Example-3

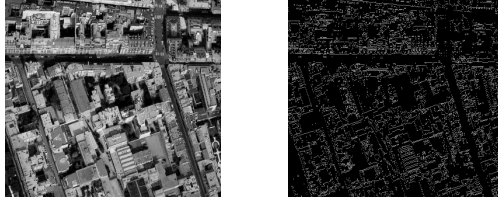


Figure 3.4: Example-4

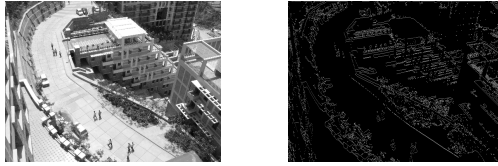


Figure 3.5: Example-5

The only shortcoming of the discussed technique is nonavailability of handling the amount of edges we need. A possible way to control them is use of morphological filters together with the proposed algorithm.

Figures 3.6 to 3.10 represent outcomes when the outcome of proposed techniques are passed through different types of morphological filters. From Figures 3.6 to 3.10 the structuring element are, correspondingly, as follows (while \circ represents absence of element, \bullet shows presence of element value.)

$$\begin{bmatrix} \bullet & \bullet & \bullet \\ \bullet & \circ & \bullet \\ \bullet & \bullet & \bullet \end{bmatrix} \text{ for Figure 3.6}$$

$$\begin{bmatrix} \circ & \bullet & \circ \\ \circ & \bullet & \circ \\ \circ & \bullet & \circ \end{bmatrix} \text{ for Figure 3.7}$$

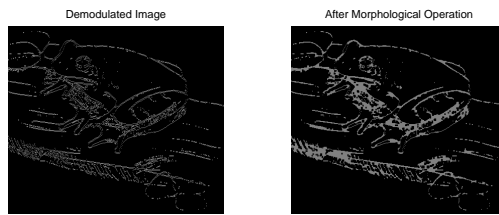


Figure 3.6: Example with morphological filter-1.

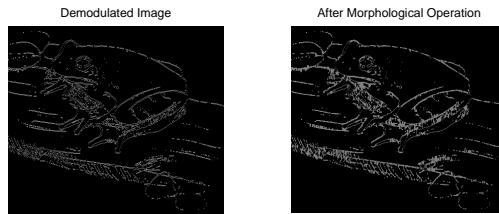


Figure 3.7: Example with morphological filter-2.

$$\begin{bmatrix} \circ & \circ & \circ \\ \bullet & \bullet & \bullet \\ \circ & \circ & \circ \end{bmatrix} \text{ for Figure 3.8}$$

$$\begin{bmatrix} \bullet & \circ & \bullet \\ \circ & \circ & \circ \\ \bullet & \circ & \bullet \end{bmatrix} \text{ for Figure 3.9}$$

$$\begin{bmatrix} \bullet & \bullet & \bullet & \bullet \\ \bullet & \circ & \circ & \bullet \\ \bullet & \circ & \circ & \bullet \\ \bullet & \bullet & \bullet & \bullet \end{bmatrix} \text{ for Figure 3.10}$$

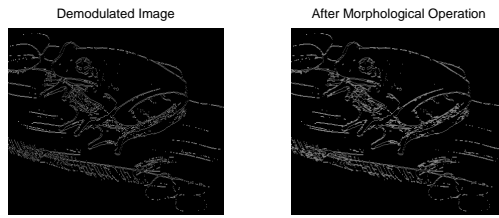


Figure 3.8: Example with morphological filter-3.

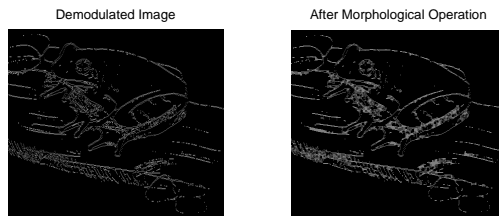


Figure 3.9: Example with morphological filter-4.

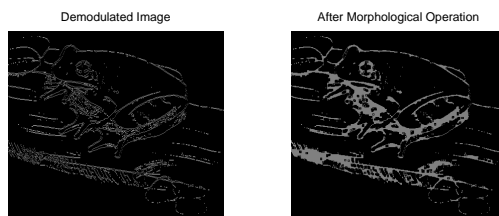


Figure 3.10: Example with morphological filter-5.

Original Image



Demodulated Image



After Morphological Operation



Edges due to Prewitt Operator



Edges due to Canny Operator



Edges due to Sobel Operator



Figure 4.1: Lena image with various edge detection methods

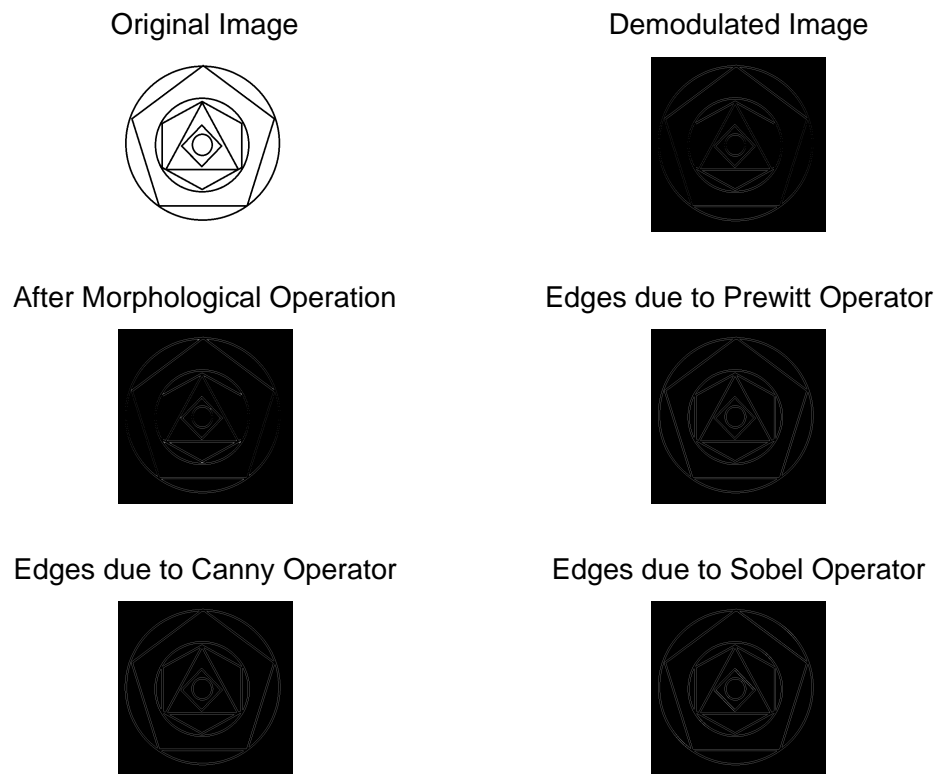


Figure 4.2: A Pattern with various edge detection methods

4 Comparison with other techniques

From Figures 4.1 4.2 we can make the following observations.

While Prewitt and Sobel operators detect the places with sharp transitions, Prewitt operator is more sensitive to information (more edges are detected). Random edges (artifacts) are more profound in image obtained by application of Sobel operator.

Prewitt operator might have minor errors at the intersection of lines. Moreover edges with vertical slant (Figure 4.2) lose their precision and there are artifacts around the intersections. Canny operator is the most sensitive operator with respect to soft transitions in pixel intensity value. Therefore, the number of edges detected by this operator is also large and includes various unwanted edges.

Proposed algorithm fairly detects the ‘thinned’ edges with least artifacts (among all the major operators). It gives an enhanced version of Sobel and Prewitt operator. It is more sensitive even to smooth transitions that other operators do not figure out. However, edges in the pattern that are vertical or have vertical components did not appear in the output. One can overcome this defect by applying the proposed operator twice, first on the original image and then rotating image by 90° and applying the operator again. Finally both images must be superimposed to get the final image.

5 Conclusion

The technique under discussion is a very simple way to extract edges from an image. The algorithm could be used for those applications which needs all major edges from the image; that is, palm recognition, object recognition, printed word recognition, etc.

We are working to modify the proposed algorithm to keep its simplicity and introduce image quantity and quality control parameter.

References

- [1] J.G.Proakis, *Digital Communication*. McGraw Hill, 2001.
- [2] B. Sklar, *Digital Communications: Fundamentals and Applications*. Prentice Hall, 2001.