School of Engineering and Applied Science (SEAS)
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Laboratory Assignment-1

1. **Title: Edge Detection using Kirsch Operator**

2. **Abstract:** In this document we have experimented edge detection of an image using kirsch operator with user defined function for convolution. Kirsch operator works with compass directions (8 directions). There are 8 kernels belongs to all the 8 directions in kirsch. In other words, there is one operator which takes a single kernel mask and it is rotated in 45 degree increments through all 8 compass directions: N, NW, W, SW, S, SE, E, and NE.

3. **Keywords:** Kirsch Operator, Edge Detection, Single derivative, Directional, Compass.

4. **Introduction/ Motivation, Background:** Edge detection is used for detecting the discontinuity in image and there are many algorithms with different operators. The motivation behind this is to get some information from an image using kirsch operator. Now there are 8 kernels in Kirsch operator based on all the directions of compass. After convolution with all the 8 kernels we can go for the best of all 8.
   North Direction Mask

$$\begin{bmatrix} -3 & -3 & 5 \\ -3 & 0 & 5 \\ -3 & -3 & 5 \end{bmatrix}$$

   West Direction Mask

$$\begin{bmatrix} 5 & 5 & 5 \\ -3 & 0 & 3 \\ -3 & -3 & -3 \end{bmatrix}$$

   North West Direction Mask

$$\begin{bmatrix} -3 & 5 & 5 \\ -3 & 0 & 5 \\ -3 & -3 & -3 \end{bmatrix}$$

   South West Direction Mask

$$\begin{bmatrix} 5 & 5 & -3 \\ 5 & 0 & -3 \\ -3 & -3 & -3 \end{bmatrix}$$

   South Direction Mask

$$\begin{bmatrix} 5 & -3 & -3 \\ 5 & 0 & -3 \\ 5 & -3 & -3 \end{bmatrix}$$

   South East Direction Mask

$$\begin{bmatrix} -3 & -3 & -3 \\ 5 & 0 & -3 \\ 5 & 5 & -3 \end{bmatrix}$$

East Direction Mask

$$\begin{bmatrix} -3 & -3 & -3 \\ -3 & 0 & -3 \\ 5 & 5 & 5 \end{bmatrix}$$

North East Direction Mask

$$\begin{bmatrix} -3 & -3 & -3 \\ -3 & 0 & 5 \\ -3 & 5 & 5 \end{bmatrix}$$

5. **Detailed Mathematical analysis of the algorithm:** To detect edge there are be four steps:
   i) Converting continuos image to digital image (f)
   ii) Selection of kernel (k)
   iii) Convolution of image and kernel (f**k)
   iv) Smoothing to reduce noise (s)

   $$s**(f**k)$$

   $$\nabla(f**k)$$

   But here 2 times convolution with image (which is a big matrix) is computationally costly.

   $$\therefore (s**f)**k$$

   $$\therefore (\nabla f)**k$$

6. **Discussions and Conclusion:** There are three criteria for optimal edge detectors. First good detection where the optimal detector must minimize the probability of false positives, as well as that of false negatives. Second, good localization where the edges detected must be as close as possible to the true edges and finally, single response constraint where the detector must return one point only for each true edge point; that is, minimize the number of local maxima around the true edge. From the results we have generated, we can conclude that higher the deviation of kernel values from origin increase the noise factor higher.

   we can compare the time complexity, space complexity, sensitivity to noise for above algorithms used.

Operator	time complexity	space complexity	Noise Sensitivity
Kirsch Operator	$O(n^2)$	$8 * k$ + imagesize	Higher noise sensitivity
Sobel Operator	$O(n^2)$	$2 * k$ + imagesize	lesser noise sensitivity
Prewitt Operator	$O(n^2)$	$2 * k$ + imagesize	lesser noise sensitivity
Robinson Operator	$O(n^2)$	$8 * k$ + imagesize	lesser noise sensitivity

Also for conclusion we can say that time complexity for all the algorithms are at order of n^2 for convolution purpose and it depends on the kernels we use for each algorithm. Also if we do the convolution of image and then take derivative of it then it may consume double time for all the convolutions.

7. **References:**

(a) Wikipedia: `https://en.wikipedia.org/wiki/Kirsch_operator`

(b) Tutorials Point: `https://www.tutorialspoint.com/dip/krisch_compass_mask.htm`

(c) ukessays: `https://www.ukessays.com/essays/information-technology/edge-detection-using-kirsch-al` `php`

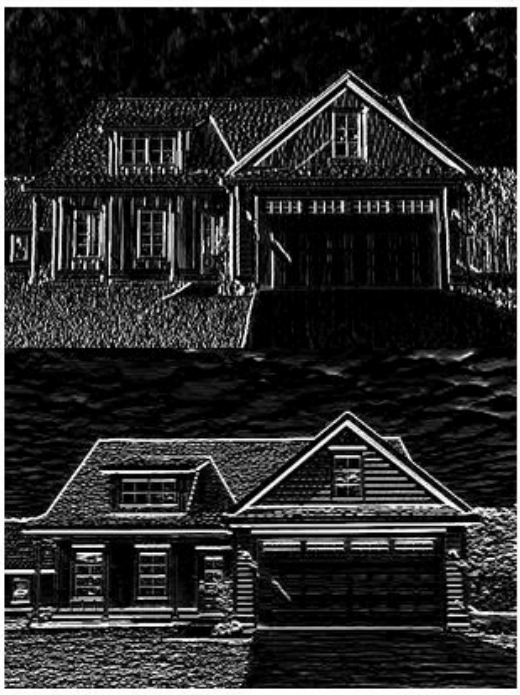
8. **Experiments and Results:**

(a) Here are all the Kirsch kernel images.

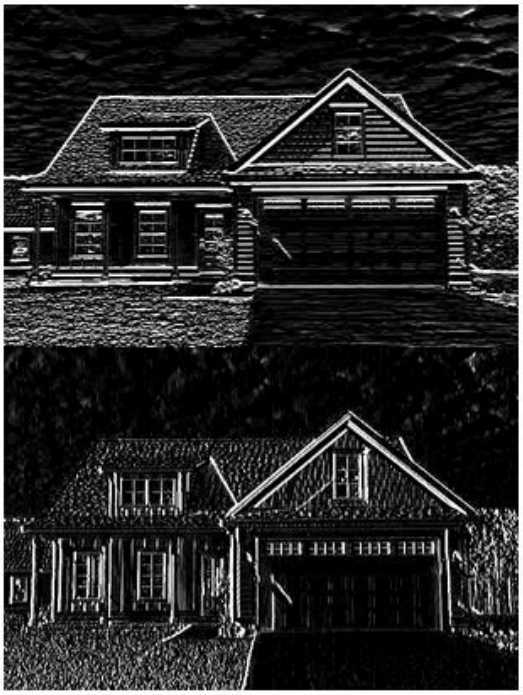
(b) Here are the comparisons of Prewitt vertical kernel, Sobel vertical kernel, Robinson east kernel with East Kirsch:

(a) North and West

(b) South and East



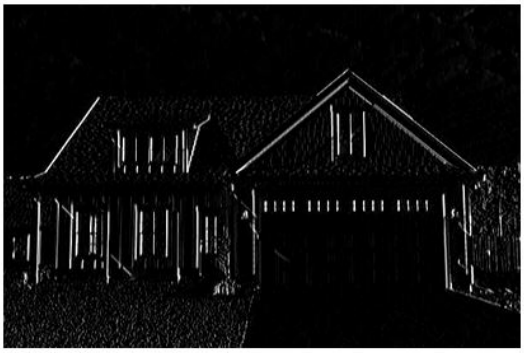
(c) Northwest and Southwest



(d) Northeast and Southeast

Figure 1: Kirsch kernels

(a) Sobel vertical operator



(b) Prewitt vertical operator

(c) Robinson East operator

(d) Northeast and Southeast

Figure 2: Comparison of East Kirsch kernel with Sobel vertical, Prewitt vertical, Robinson east kernel