I. The Visual Machinery of the human Brain

- Create your own edge operators to mimic the behavior (operational structure) of simple cells
- Indicate what angular resolution you have achieved (10^o is ideal but others are also acceptable) and what threshold should be chosen whether a pixel is an edge point or not
- Contrast these results to the directional Kirsch operator
- Contrast these results to another arbitrary edge operator with the 8 gradient directions and again superimpose the results.

Make use of multiple operators (mimicking simple cells) but with different degrees of fuzziness on blurred images or on images that have things like clouds, waves in an ocean.

Solution: Visual cortex consists of myriad of edge operators to detect edges of surrounding environment. The primary function of the visual cortex is to process visual information. There are several edge operators to mimic the behavior of simple cells of visual cortex.

%Vertical Line **edge_op1 =** **-1 2 -1** **-1 2 -1** **-1 2 -1**	**% Horizontal Line** **edge_op2 =** **-1 -1 -1** **2 2 2** **-1 -1 -1**
% Vertical Gap **edge_op3 =** **1 -2 1** **1 -2 1** **1 -2 1**	**% Horizontal Gap** **edge_op4 =** **1 1 1** **-2 -2 -2** **1 1 1**
% Falling Vertical **edge_op5 =** **1 0 -1** **1 0 -1** **1 0 -1**	**% falling horizontal** **edge_op6 =** **1 1 1** **0 0 0** **-1 -1 -1**
% Rising Vertical **edge_op7 =** **-1 0 1** **-1 0 1** **-1 0 1**	**% Rising Horizontal** **edge_op8 =** **-1 -1 -1** **0 0 0** **1 1 1**

Fig. 1: Edge Operators

Secondly, the 0 to 20 degrees of angle resolution are achieved using a certain threshold. In this scenario, mean of the pixels are used as the threshold to find edge points. Figure 3, 4 and 5 yield combined edge extraction for 0, 10- and 20-degree angle resolution, respectively.

Fig. 2: Original Image

Fig. 3: Combined Edge Extraction at 0° angle resolution

Fig. 4: Combined Edge Extraction at 10° angle resolution

Fig. 5: Combined Edge Extraction at 20° angle resolution

Comparing with Kirsch operator and simple cell edge operator: Kirsch operator (function given by Sarojkumar) gives much better edge information on that original image. Fig. 6 shows the edges found by Kirsch operator. Here the tree leaves and clouds become more identifiable than the combined edge information of created edge operation mimicking simple cells. The Kirsh operator is less sensitive to small changes of information in edge detection.

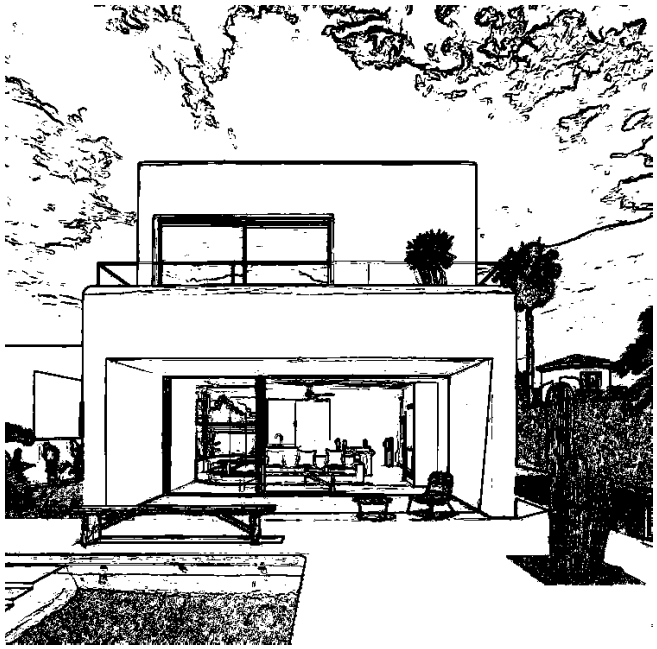


Fig. 6: Edge Extraction by Kirsch operator

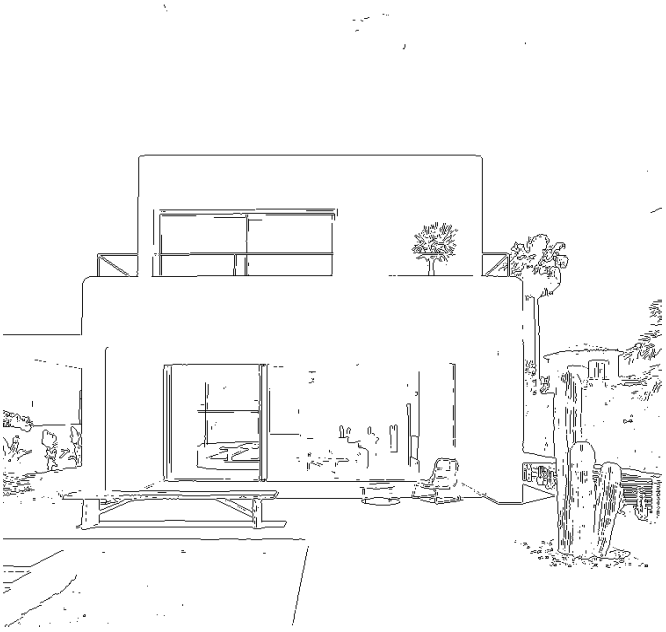


Fig. 7: Prewitt Filter Edge Extraction

Comparing with Prewitt compass and simple cell edge operator: Whereas, Prewitt filter is worse than Kirsch operator. However, it yields better result than the combined edge operators. From the figure 7, the filter cannot recognize relatively low sharp changes from the image effectively.

Working with Fuzziness: Four edge operators have been chosen to introduce high degree of fuzziness into the image. The operators are listed below

% Horizontal Line fuzz_1 =	% Vertical Line fuzz_2 =
-3 -3 -3 -3 -3 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 -3 -3 -3 -3 -3	-3 2 2 2 -3 -3 2 2 2 -3 -3 2 2 2 -3 -3 2 2 2 -3 -3 2 2 2 -3
% Horizontal Rising Edge fuzz_3 =	% Vertical Rising Edge fuzz_4 =
-1 -1 -1 -1 -1 -1 -1 -1 -1 -1 0 0 0 0 0 1 1 1 1 1 1 1 1 1 1	-1 -1 0 1 1 -1 -1 0 1 1 -1 -1 0 1 1 -1 -1 0 1 1 -1 -1 0 1 1

Fig. 8: Degree of Fuzziness

The fuzziness is introduced in the house image. The four edge operators' superimposed result are given in figure 9.

Fig. 9: Combined Degree of Fuzziness

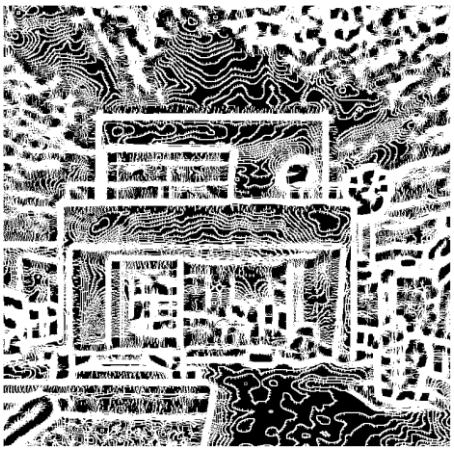
Blurred Image	1st Degree of Fuzziness
	
Combined Fuzzines	3rd Degree of Fuzziness
	

Fig. 10: Degree of Fuzziness with Blurred Image

Similarly, synthetic image has been experimented using the method applied in this work.

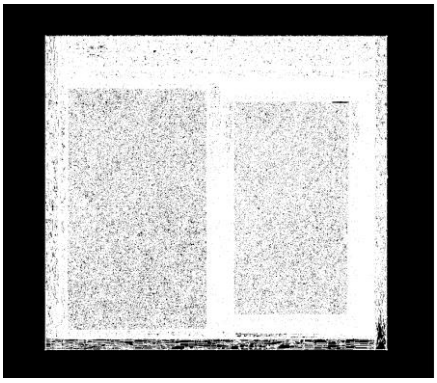
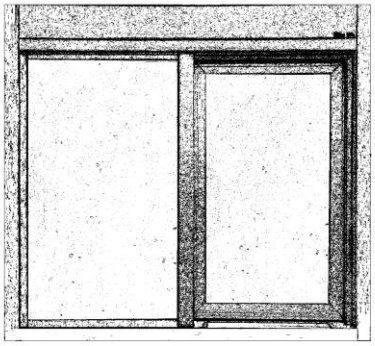
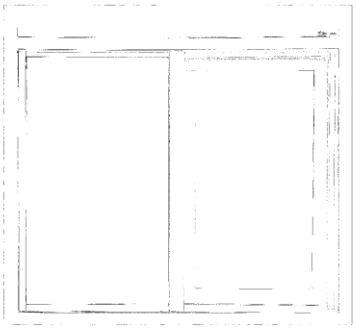
Original Image	Edge at 0 degree rotation
	
Kirsch Edge	Prewitt Compass
	

Fig. 11: Synthetic Image of Window and Corresponding edge detection

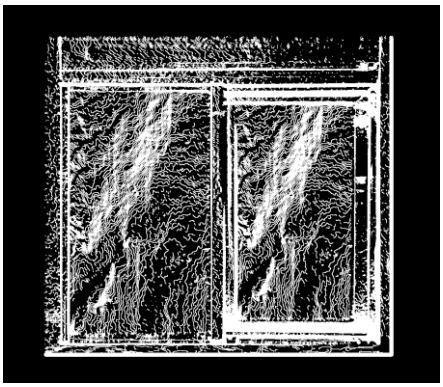
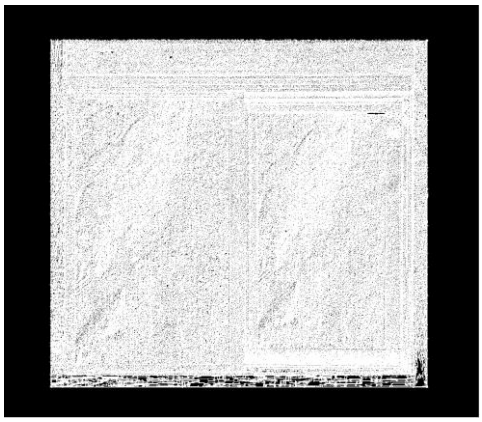
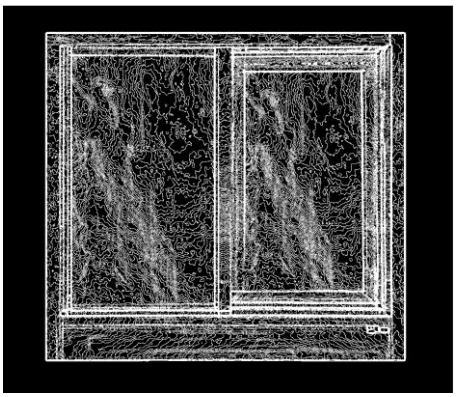
Blurred Image	1st Degree of Fuzziness
	
Combined Fuzziness	3rd Degree of Fuzziness
	

Fig. 12: Synthetic Image of Window and corresponding Degree of Fuzziness

Insight: Degree of fuzziness allows to extract more sharp changes in the image. As the given image contains clouds and swimming pool water, the operator with fuzziness is successful to find them from image. Third degree keeps more edges with details although it looks noisy as the ground section has not texture in the original image. Whereas, 1st degree fuzziness is less noisy and smoother than 3rd degree of fuzziness.