Some Applications of First and Second Order Derivative Operators in Machine Learning and Clinical Diagnosis

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Motivation

1) Measuring the Degree of Suitability of Edge Detection Operators Prior to an Application

- Traditionally, edge detectors are compared by means of visible perception of edged output.
- In case of non-trivial images, it is nearly impossible and unreliable to conclude which edge detector is best by looking at edged outputs.
- Obtaining ideal edges from complex real-life images can be more complicated than it seems.
- As they are often obstructed by fragmentation such as missing edges as well as false edges.
- Hence, visual perception to interpret the edges can prove to be a difficult task.
- Also, the selection of an edge detector depends on the nature of edges.

Motivation (Contd...)

2) COVID-19 Detection on Chest X-Ray and CT Scan Images of Suspected Individuals Using CNN and Image Processing based Data Augmentation

- COVID-19 is an infectious disease which has so far infected millions of people and deaths are increasing day by day.
- The test for COVID-19 takes hours to give the results.
- Sometimes the test gives false positive and true negative results .
- Moreover, shortage of test kits compared to coronavirus infected persons make it inefficient.
- In highly affected regions, it is difficult to provide sufficient number of test kits for testing COVID-19 infection.
- Therefore, to test COVID-19 rapidly and in a efficient way, chest X-Ray or CT scan images of the suspects are used.

Problem Definition

Problem Definition-1

(1) To avoid the difference in opinion of users about the edged outputs.
(2) To design and develop a novel edge detector called Hybrid operator.
(3) To determine the degree of suitability of the edge detectors on the basis of Regression Models.
(4) To determine the best suitable edge detector for a particular application.
(5) To compute the RMSE for the respective edge detector.

Problem Definition-2

(1) To detect COVID-19 on chest X-Ray and CT Scan images of suspected individuals.
(2) To develop a model which uses CNN fused with the image processing based data augmentation.
(3) To resolve the issue of smaller number of images for training the deep-model, which does not gives the desired accuracy.
(4) To increase the data by using multiple representations of the same X-Ray and CT scan images, produced through sharpening filters.

Methodology 1 (Suitability of Edge Detectors)

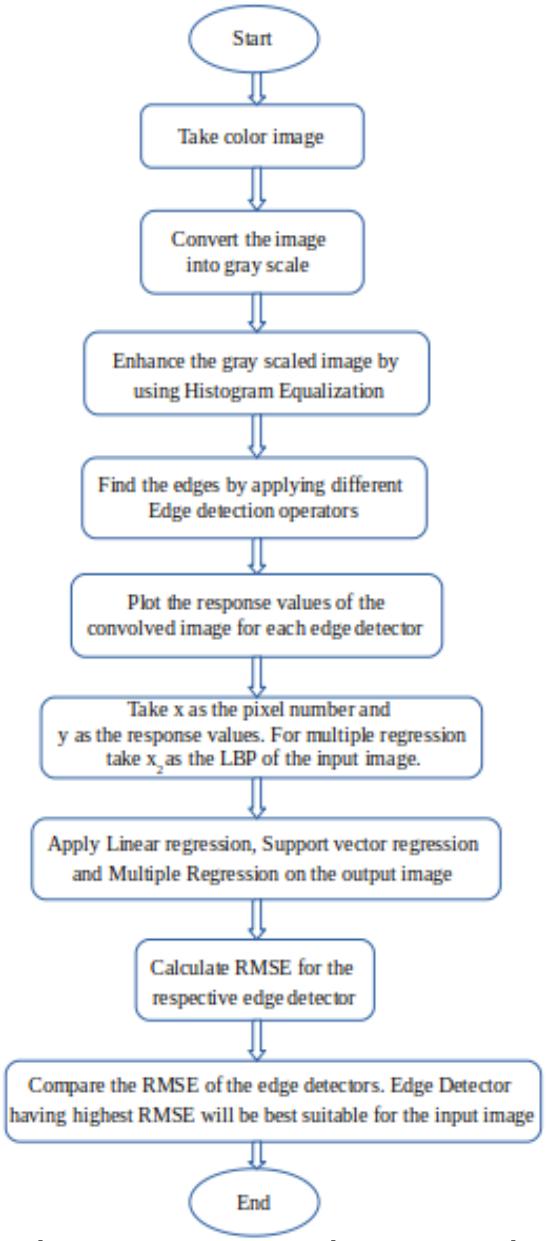


Figure: Flow graph for determining the suitability of an edge detector

Methodology 1 (Contd...)

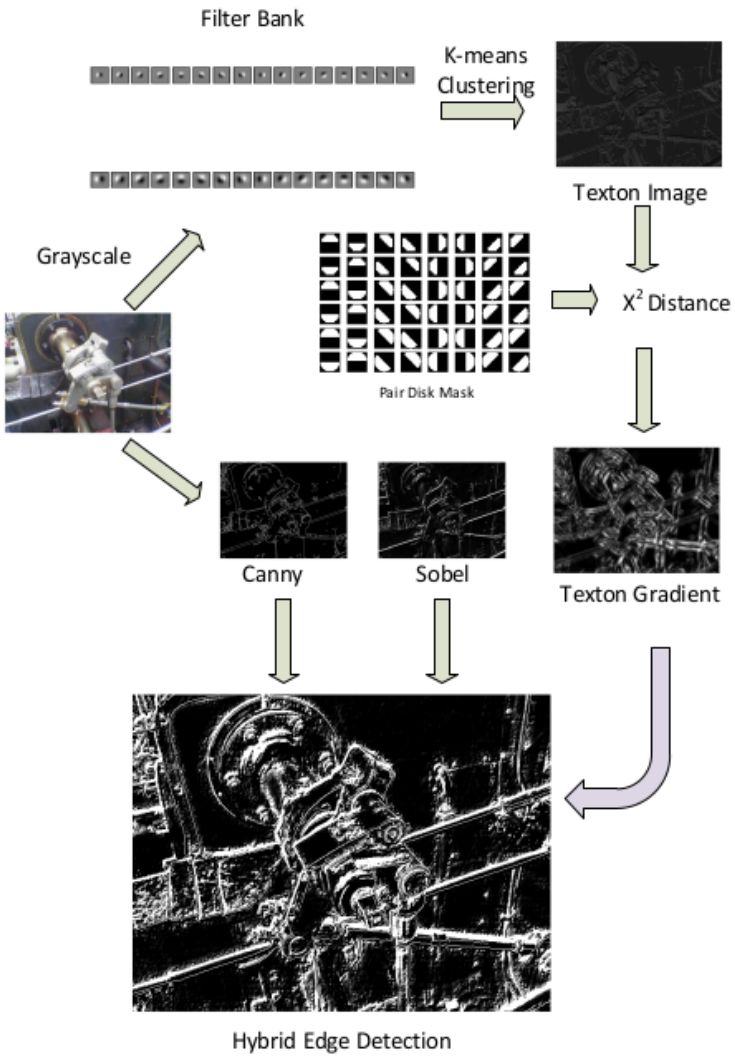


Figure: Proposed Hybrid Edge Detector

Methodology 1 (Contd...)

Edge Detectors used

Sobel, Prewitt, Roberts, Scharr, Laplacian, Canny and Hybrid.

Models Used

- Linear Regression
- Support Vector Regression
- Multiple Regression

Performance Metric

- RMSE is directly related to the strength of the discontinuity.
- More the RMSE for a edge detector, more sharp the discontinuity.

Database Description

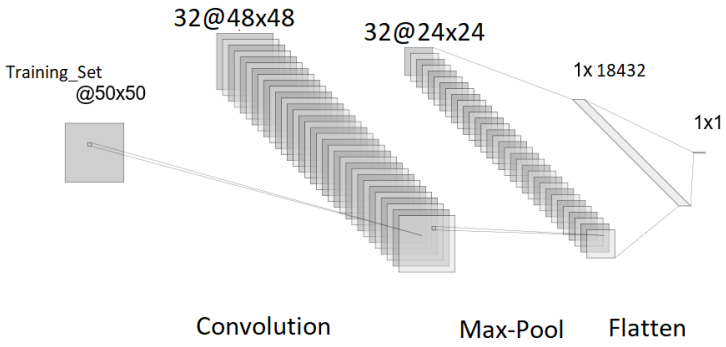
- The BSDS300, and the Multi-cue dataset are used for experiment.
- 200 images are selected randomly from BSDS300 for experiment.
- From Multicue, 10 scenes, each containing 20 images, are considered.

Methodology 2 (Detection of Covid-19)

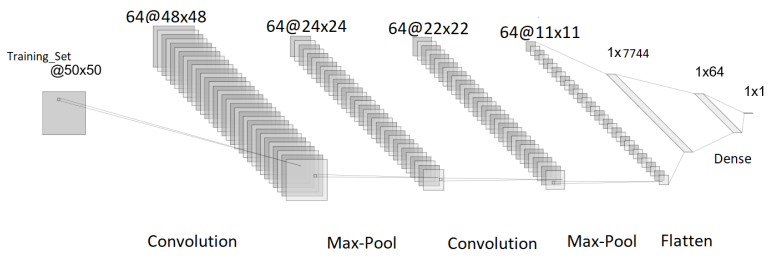
Data Augmentation using Image Processing consists of the following steps:

Step 1: Accept the coloured input image from the data set.
Step 2: Convert the image into grayscale.
Step 3: Histogram Equalization is initiated to correct the contrast of the given grayscale input image.
Step 4: Find edges by applying edge detection operators, viz. Sobel, Prewitt, Roberts, Scharr, Laplacian, Canny, and Hybrid (combination of Canny and Sobel edge detector).
Step 5: Mix the result obtained after applying Edge Detection Operators to the data set.

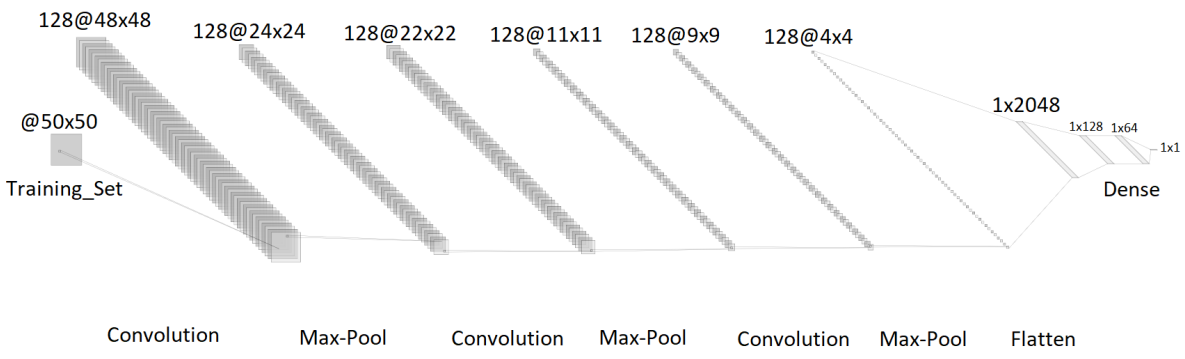
Methodology 2 (Contd...)



(a) Layer Size 32



(b) Layer Size 64



(c) Layer Size 128

Figure: Convolutional Neural Network of Layer Size 32, 64 and 128.

Methodology 2 (Contd...)

Edge Detectors used for data Augmentation

Sobel, Prewitt, Roberts, Scharr, Laplacian, Canny and Hybrid.

Models Used

- Deep Learning CNN model
- ratios applied for training & testing - 90:10, 85:15, 80:20, 75:25, 70:30, 65:35, 60:40, 55:45 and 50:50
- Optimizer Used- Stochastic Gradient Descent, batch size- 32, epochs- 30, loss function- binary cross entropy
- Activation function- Relu after Convolution, Sigmoid for classification
- dense layers=[0,1,2], layer sizes=[32,64,128], conv layers=[1,2,3]

Performance Metric

Accuracy, Loss, AUC, Precision, Sensitivity, Specificity and F1 score.

Database Description

- X-Ray database(Augmented)- 536 Covid, 536 non-Covid images
- CT Scan database(Augmented)- 2760 Covid, 2760 non-Covid images

Results and Analysis-1 (Suitability of Edge Detector)

Table 1. RMSE on BSDS300 dataset

Edge Detector Operators	Linear Regression					Support Vector Regression					Multiple Regression				
	RMSE values					RMSE values					RMSE values				
	Image-1	Image-2	Image-3	Image-4	Image-5	Image-1	Image-2	Image-3	Image-4	Image-5	Image-1	Image-2	Image-3	Image-4	Image-5
Sobel	67.16	79.24	89.44	78.56	87.45	72.48	83.65	91.23	80.61	91.94	60.58	74.70	101.33	76.33	86.98
Prewitt	59.66	69.56	79.58	67.77	78.61	64.27	72.96	81.50	69.30	83.31	50.49	64.47	85.23	63.08	74.95
Roberts	28.82	30.59	48.14	40.66	37.56	31.25	31.73	52.54	44.10	38.83	21.71	29.53	37.09	29.31	19.68
Scharr	102.34	111.46	107.01	107.84	113.31	106.02	115.24	123.47	109.93	120.40	120.44	133.85	164.56	136.98	145.68
Laplacian	67.12	81.20	91.79	86.74	92.42	73.22	93.66	107.89	100.81	109.48	40.24	70.11	84.85	80.27	86.32
Canny	92.72	117.33	120.65	119.45	121.71	98.99	135.42	141.98	138.94	144.47	43.39	79.30	86.95	83.18	90.14
Hybrid	1904.81	2420.90	3113.05	2294.91	2432.38	1982.51	2504.75	3282.15	2396.15	2535.72	847.61	1273.96	1783.85	1130.62	1397.27

Table 2. RMSE on Multi-cue dataset

Edge Detector Operators	Linear Regression					Support Vector Regression					Multiple Regression				
	Mean of RMSE values of 20 images					Mean of RMSE values of 20 images					Mean of RMSE values of 20 images				
	Multi-cue Subject-1	Multi-cue Subject-2	Multi-cue Subject-3	Multi-cue Subject-4	Multi-cue Subject-5	Multi-cue Subject-1	Multi-cue Subject-2	Multi-cue Subject-3	Multi-cue Subject-4	Multi-cue Subject-5	Multi-cue Subject-1	Multi-cue Subject-2	Multi-cue Subject-3	Multi-cue Subject-4	Multi-cue Subject-5
Sobel	80.22	81.19	82.02	82.29	78.54	83.19	86.75	82.97	87.16	83.03	82.17	75.18	81.97	78.75	69.07
Prewitt	70.40	73.58	70.41	73.14	68.84	73.16	78.76	71.82	77.92	72.37	68.66	66.07	67.51	67.60	56.06
Roberts	39.27	46.71	32.70	33.23	33.88	41.29	50.45	33.59	34.83	35.79	47.46	37.48	27.05	27.83	26.05
Scharr	110.60	112.83	112.96	110.67	108.35	115.93	114.90	116.42	111.77	113.01	144.05	130.75	140.50	136.66	123.87
Laplacian	86.82	93.62	80.08	83.48	75.49	101.43	109.83	92.04	96.36	84.22	127.54	86.02	82.31	68.41	57.36
Canny	121.03	122.44	118.64	116.22	109.73	142.88	146.14	138.09	132.74	121.32	127.46	137.57	122.53	75.83	128.26
Hybrid	2451.29	2189.57	2374.61	2429.39	2503.49	2419.95	2213.87	2618.78	2632.04	2652.86	1444.44	1273.12	1317.54	1286.35	1114.34

Table: RMSE on BSDS300 dataset and Multicue Datasets

- Hybrid operator outperforms other edge detectors with extremely high RMSE value as shown in the above tables.

Results and Analysis-2 (Detection of Covid-19)

	Original						Augmented					
	CT Scan Images			X Ray Images			CT Scan Images			X Ray Images		
Train-Test	Layers			Layers			Layers			Layers		
80%-20%	**32**	**64**	**128**	**32**	**64**	**128**	**32**	**64**	**128**	**32**	**64**	**128**
Accuracy (%)	94.06	95.22	94.35	99.05	97.01	99.05	96.47	96.99	95.45	99.07	98.88	99.16
Loss (%)	18.93	17.16	41.09	3.84	6.27	12.05	13.79	16.39	21.58	7.63	5.18	4.87
AUC (%)	98.1	98	96.8	100	100	98.6	98.6	99	98.2	99.5	99.7	99.8
Precision	0.93	0.95	0.94	0.99	1	0.99	0.96	0.97	0.95	0.99	0.99	0.99
Sensitivity (%)	95.07	95.65	94.78	100	94.03	100	96.73	97.39	95.83	99.25	99.25	99.44
Specificity (%)	93.04	94.78	93.91	98.51	100	98.51	96.2	96.6	95.07	98.88	98.52	98.89
F1 Score	0.94	0.95	0.94	0.99	0.97	0.99	0.96	0.97	0.95	0.99	0.99	0.99

	Original						Augmented					
	CT Scan Images			X Ray Images			CT Scan Images			X Ray Images		
Train-Test	Layers			Layers			Layers			Layers		
75%-25%	**32**	**64**	**128**	**32**	**64**	**128**	**32**	**64**	**128**	**32**	**64**	**128**
Accuracy (%)	91.16	93.19	88.26	97.76	99	97.76	95.99	95.76	94.38	99.53	99.72	98.41
Loss (%)	26.25	23.52	43.35	9.38	2.81	13.11	15.18	27.09	36.36	4.13	1.39	8.95
AUC (%)	97.1	97.1	92.6	99.8	100	100	98.3	98.4	98	99.9	100	99.8
Precision	0.96	0.93	0.91	0.96	1	0.98	0.96	0.97	0.95	0.99	1	0.98
Sensitivity (%)	86.38	93.91	85.22	100	100	97.01	96.16	94.96	93.37	99.62	99.63	98.5
Specificity (%)	95.94	92.46	91.3	95.52	100	98.51	95.83	96.56	95.4	99.44	99.81	98.32
F1 Score	0.91	0.93	0.88	0.98	1	0.98	0.96	0.96	0.94	0.99	1	0.98

Table: Results of proposed models with Original and Data Augmented images with CT Scan and X-Ray images for train-test ratio-80:20 and 75:25

Results and Analysis-2 (Contd...)

	Original						Augmented					
	CT Scan Images			X Ray Images			CT Scan Images			X Ray Images		
Train-Test	Layers			Layers			Layers			Layers		
70%-30%	**32**	**64**	**128**	**32**	**64**	**128**	**32**	**64**	**128**	**32**	**64**	**128**
Accuracy (%)	89.57	92.03	90.29	98.25	97.1	97	96.05	96.38	95.46	98.97	99.44	98.69
Loss (%)	29.79	26.81	50.84	5.21	12.09	2.22	19.44	26.97	37.33	7.4	1.91	8.05
AUC (%)	94.8	95.9	95.7	100	99.8	100	97.8	98.4	97.2	99.7	100	99.6
Precision	0.91	0.93	0.87	0.99	0.99	0.99	0.96	0.96	0.95	0.99	0.99	0.99
Sensitivity (%)	87.25	91.01	95.07	100	94.03	100	93.64	94.78	89.38	99.07	99.07	98.33
Specificity (%)	91.88	93.04	85.51	98.51	100	100	96.48	95.98	95.54	98.88	99.81	99.06
F1 Score	0.89	0.92	0.91	0.99	0.97	0.99	0.95	0.95	0.92	0.99	0.99	0.99

Table: Results of proposed models with Original images and Data Augmentation with CT Scan and X-Ray images datasets for train-test ratio-70:30

- We can see that after augmentation we achieved higher accuracy compared to the original dataset.
- Our model exhibits higher classification accuracy around 96% and 98% for CT scan and X-Ray images respectively.

Conclusion

- Hybrid operator outperforms other edge detection operators with extremely high RMSE value.
- Edge detector which gives higher RMSE value, would be considered as efficient edge operator.
- Sharpening Filters can be used for data augmentation in detection of Coronavirus using deep learning CNN model.
- For making the learning of the model about the patterns more effective, multiple representations of the same X-Ray and CT scan images are produced using sharpening filters.
- Our model overcomes the issues of shortage of test kits, minimizes the cost of testing, easy to use by diagnostic and medics persons, and can be used for rapid testing.