PCB Classification

Task: Classification of defective and non-defective PCB boards.

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Final Model Used:
The model that gave the best result consisted of following layers:

1. Conv2D (6, (3, 3), input_shape=(300,300,3), activation='tanh', padding='valid'),
2. AveragePooling2D (pool_size=(2,2), strides=(2,2)),
3. Conv2D (16, (3, 3), activation='tanh', padding='valid'),
4. AveragePooling2D (pool_size=(2,2), strides=(2,2)),
5. Flatten (),
6. Dense (120, activation='tanh'),
7. Dense (84, activation='tanh'),
8. Dense (2, activation='softmax')

Optimizer = SGD
Loss = sparse categorical crossentropy

My Observation:

- The models that was used for experimenting were slight modifications of LeNet and AlexNet. Most of the models consisted of an input layer followed by 2 or 3 pairs of Convolutional and Subsampling Layers. Then, 1 or 2 fully connected layer followed by an output layer of two classes, one for each, Defective and Non-Defective PCB.
- Increasing the number of filters in a convolutional layer doesn't always increase the accuracy.
- It doesn't matter what activation function we use, whether it's tanh, relu or elu, there is not much deviation in the accuracy.
- Applying Zero-padding to the training data decreased the accuracy.
- Dimension of the Filter in the initial convolutional layers should be low, bigger size might decrease the accuracy.
- Two pairs of Convolutional and Subsampling layers are sufficient for this assignment, more than that was just redundant, time consuming and didn't really increase the accuracy.
- For the subsampling layers both Average pooling and Max pooling seemed to give same or almost similar results.
- Two fully connected dense layers in the end with x and x/2 ($100 < x < 200$) neurons followed by an output layer will give good accuracy. More neurons didn't seem to increase the accuracy.

Experiments Performed:
All the experiments are performed on slight modifications of the LeNet or Alexnet model architecture.
All the models were trained on 90% of the Aug_PCB data. Each of table below show the architecture of the model and the accuracy obtained with 10% of the Aug_PCB data, normalized Raw_PCB data and normalized Bal_PCB data of both defective and non-defective PCB's.

Model 1						
Layer No:	**Name**	**No: of neurons/filters**	**Filter/pool size**	**Activation function**	**Stride**	**Padding**
1.	Conv2D	6	3x3	tanh	1	valid
2.	Averagepooling2D		2x2	-	2	-
3.	Conv2D	16	3x3	tanh	1	valid
4.	Averagepooling2D		2x2	-	2	-
5.	Flatten	-	-	-	-	-
6.	Dense	120		tanh	-	-
7.	Dense	84		tanh	-	-
8.	Dense	2		softmax	-	-
Loss : Sparse Categorical Crossentropy Optimizer : SGD Batch Size : 10 Epochs: 20						
Accuracy Obtained:						

	Defective Accuracy	**Non-Defective Accuracy**
Aug_PCB	97.70	91.73
Balanced_PCB	98.65	99.32
Raw_PCB	98.65	99.20

Model 2						
Layer No:	**Name**	**No: of neurons/filters**	**Filter/pool size**	**Activation function**	**Stride**	**Padding**
1.	Conv2D	6	5x5	tanh	1	valid
2.	Averagepooling2D		2x2	-	2	-
3.	Conv2D	16	5x5	tanh	1	valid
4.	Averagepooling2D		2x2	-	2	-
5.	Flatten	-	-	-	-	-
6.	Dense	120		tanh	-	-
7.	Dense	84		tanh	-	-
8.	Dense	2		softmax	-	-
Loss : Sparse Categorical Crossentropy Optimizer : SGD Batch Size : 10 Epochs: 20						
Accuracy Obtained:						
	Defective Accuracy	**Non-Defective Accuracy**				
Aug_PCB	95.41	92.14				
Balanced_PCB	95.97	99.32				
Raw_PCB	95.97	99.16				

Model 3						
Layer No:	**Name**	**No: of neurons/filters**	**Filter/pool size**	**Activation function**	**Stride**	**Padding**
1.	Conv2D	6	3x3	tanh	1	same
2.	Averagepooling2D		2x2	-	2	-
3.	Conv2D	32	5x5	tanh	1	valid
4.	Averagepooling2D		2x2	-	2	-
5.	Flatten	-	-	-	-	-
6.	Dense	120		tanh	-	-
7.	Dense	42		tanh	-	-
8.	Dense	2		softmax	-	-
Loss : Sparse Categorical Crossentropy Optimizer : SGD Batch Size : 10 Epochs: 20						
Accuracy Obtained:						
	Defective Accuracy	**Non-Defective Accuracy**				
Aug_PCB	95.41	92.14				
Balanced_PCB	95.97	99.32				
Raw_PCB	95.97	99.16				

Model 4						
Layer No:	**Name**	**No: of neurons/filters**	**Filter/pool size**	**Activation function**	**Stride**	**Padding**
1.	Conv2D	20	5x5	relu	-	same
2.	Maxpooling2D		2x2	-	2	-
3.	Conv2D	50	5x5	relu	-	same
4.	Maxpooling2D		2x2	-	2	-
5.	Flatten	-	-	-	-	-
6.	Dense	300		relu	-	-
7.	Dense	2		softmax	-	-
Loss : Sparse Categorical Crossentropy Optimizer : Adam Batch Size : 10 Epochs: 20						
Accuracy Obtained:						
	Defective Accuracy		**Non-Defective Accuracy**			
Aug_PCB	93.57		94.90			
Balanced_PCB	95.30		99.32			
Raw_PCB	95.30		99.40			

Model 5						
Layer No:	**Name**	**No: of neurons/filters**	**Filter/pool size**	**Activation function**	**Stride**	**Padding**
1.	Conv2D	12	5x5	elu	1	valid
2.	Averagepooling2D		2x2	-	3	-
3.	Conv2D	32	3x3	elu	1	valid
4.	Averagepooling2D		2x2	-	3	-
5.	Flatten	-	-	-	-	-
6.	Dense	120		elu	-	-
7.	Dense	60	-	elu	-	-
8.	Dense	2		softmax	-	-
Loss : Sparse Categorical Crossentropy Optimizer : SGD Batch Size : 10 Epochs: 20						
Accuracy Obtained:						
	Defective Accuracy	**Non-Defective Accuracy**				
Aug_PCB	98.84	93.44				
Balanced_PCB	97.31	99.32				
Raw_PCB	97.31	99.24				

Model 6						
Layer No:	**Name**	**No: of neurons/filters**	**Filter/pool size**	**Activation function**	**Stride**	**Padding**
1.	Conv2D	50	5x5	elu	1	same
2.	Averagepooling2D		2x2	-	3	-
3.	Conv2D	80	5x5	elu	1	valid
2.	Averagepooling2D		2x2	-	3	-
8.	Flatten	-	-	-	-	-
9.	Dense	180		elu	-	-
9.	Dense	90		elu	-	-
10.	Dense	2		softmax	-	-
Loss : Sparse Categorical Crossentropy Optimizer : SGD Batch Size : 10 Epochs: 20						
Accuracy Obtained:						

	Defective Accuracy	**Non-Defective Accuracy**
Aug_PCB	98.84	93.44
Balanced_PCB	95.30	100
Raw_PCB	95.30	99.36

Model 7						
Layer No:	**Name**	**No: of neurons/filters**	**Filter/pool size**	**Activation function**	**Stride**	**Padding**
1.	Conv2D	50	5x5	tanh	1	same
2.	Averagepooling2D		2x2	-	3	-
3.	Conv2D	80	5x5	tanh	1	same
4.	Averagepooling2D		2x2	-	3	-
5.	Flatten	-	-	-	-	-
6.	Dense	300		elu	-	-
7.	Dense	160		elu	-	-
8.	Dense	2		softmax	-	-
Loss : Sparse Categorical Crossentropy Optimizer : SGD Batch Size : 10 Epochs: 20						
Accuracy Obtained:						
	Defective Accuracy	**Non-Defective Accuracy**				
Aug_PCB	99.61	94.26				
Balanced_PCB	97.98	100				
Raw_PCB	97.98	99.16				

Model 8						
Layer No:	**Name**	**No: of neurons/filters**	**Filter/pool size**	**Activation function**	**Stride**	**Padding**
1.	Conv2D	60	5x5	relu	1	same
2.	Averagepooling2D		2x2	-	3	-
3.	Conv2D	40	5x5	tanh	1	same
4.	Averagepooling2D		2x2	-	3	-
5.	Flatten	-	-	-	-	-
6.	Dense	240		tanh	-	-
7.	Dense	120		relu	-	-
8.	Dense	2		softmax	-	-
Loss : Sparse Categorical Crossentropy Optimizer : SGD Batch Size : 10 Epochs: 20						
Accuracy Obtained:						
	Defective Accuracy	**Non-Defective Accuracy**				
Aug_PCB	99.61	95.08				
Balanced_PCB	95.97	100				
Raw_PCB	95.97	99.52				

Model 9						
Layer No:	**Name**	**No: of neurons/filters**	**Filter/pool size**	**Activation function**	**Stride**	**Padding**
1.	Conv2D	96	11x11	relu	4	same
2.	Maxpooling2D		3x3	-	2	-
3.	Conv2D	256	5x5	relu	1	same
4.	Maxpooling2D		3x3	-	2	-
5.	Conv2D	384	3x3	relu	1	same
6.	Conv2D	256	3x3	relu	1	same
7.	Conv2D	256	3x3	relu	1	same
8.	Maxpooling2D		3x3	-	2	-
9.	Flatten	-	-	-	-	-
10.	Dense	9216		relu	-	-
11.	Dense	4096	-	relu	-	-
12.	Dense	4096	-	relu	-	-
13.	Dense	2		softmax	-	-

Loss : Sparse Categorical Crossentropy
Optimizer : SGD
Batch Size : 10
Epochs: 20

Accuracy Obtained:

	Defective Accuracy	**Non-Defective Accuracy**
Aug_PCB	99.60	96.40
Balanced_PCB	97.31	97.31
Raw_PCB	97.31	99.80

Model 10						
Layer No:	**Name**	**No: of neurons/filters**	**Filter/pool size**	**Activation function**	**Stride**	**Padding**
1.	Conv2D	96	5x5	relu	4	same
2.	Maxpooling2D		3x3	-	2	-
3.	Conv2D	256	5x5	relu	2	same
4.	Maxpooling2D		3x3	-	2	-
5.	Conv2D	384	3x3	relu	2	same
6.	Conv2D	256	3x3	relu	2	same
7.	Maxpooling2D		3x3	-	2	-
8.	Flatten	-	-	-	-	-
9.	Dense	4096	-	tanh	-	-
10.	Dense	4096	-	relu	-	-
11.	Dense	2		softmax	-	-

Loss : Sparse Categorical Crossentropy
Optimizer : SGD
Batch Size : 10
Epochs: 20

Accuracy Obtained:

	Defective Accuracy	**Non-Defective Accuracy**
Aug_PCB	99.60	97.20
Balanced_PCB	97.31	99.32
Raw_PCB	97.31	99.44

Model 11						
Layer No:	**Name**	**No: of neurons/filters**	**Filter/pool size**	**Activation function**	**Stride**	**Padding**
1.	Conv2D	48	5x5	relu	4	same
2.	Maxpooling2D		3x3	-	2	-
3.	Conv2D	96	5x5	relu	2	same
4.	Maxpooling2D		3x3	-	2	-
5.	Conv2D	192	3x3	relu	2	same
6.	Conv2D	128	3x3	relu	2	same
7.	Maxpooling2D		3x3	-	2	-
8.	Flatten	-	-	-	-	-
9.	Dense	1024	-	relu	-	-
10.	Dense	1024	-	relu	-	-
11.	Dense	2		softmax	-	-
Loss : Sparse Categorical Crossentropy Optimizer : SGD Batch Size : 10 Epochs: 20						
Accuracy Obtained:						
	Defective Accuracy	**Non-Defective Accuracy**				
Aug_PCB	98.42	98.80				
Balanced_PCB	96.64	99.32				
Raw_PCB	96.64	99.64				

Model 12						
Layer No:	**Name**	**No: of neurons/filters**	**Filter/pool size**	**Activation function**	**Stride**	**Padding**
1.	Conv2D	24	5x5	relu	4	same
2.	Maxpooling2D		3x3	-	2	-
3.	Conv2D	64	5x5	relu	2	same
4.	Maxpooling2D		3x3	-	2	-
5.	Conv2D	96	3x3	relu	2	same
6.	Conv2D	64	3x3	relu	2	same
7.	Maxpooling2D		3x3	-	2	-
8.	Flatten	-	-	-	-	-
9.	Dense	256		relu	-	-
10.	Dense	2		softmax	-	-
Loss : Sparse Categorical Crossentropy Optimizer : SGD Batch Size : 10 Epochs: 20						
Accuracy Obtained:						
	Defective Accuracy	**Non-Defective Accuracy**				
Aug_PCB	98.81	92.80				
Balanced_PCB	100	97.31				
Raw_PCB	100	96.66				

Model 13						
Layer No:	**Name**	**No: of neurons/filters**	**Filter/pool size**	**Activation function**	**Stride**	**Padding**
1.	Conv2D	48	5x5	tanh	4	same
2.	Maxpooling2D		3x3	-	2	-
3.	Conv2D	96	5x5	tanh	2	same
4.	Maxpooling2D		3x3	-	2	-
5.	Conv2D	64	3x3	tanh	2	same
6.	Conv2D	128	3x3	tanh	2	same
7.	Maxpooling2D		3x3	-	2	-
8.	Flatten	-	-	-	-	-
9.	Dense	256		tanh	-	-
10.	Dense	2		softmax	-	-
Loss : Sparse Categorical Crossentropy Optimizer : SGD Batch Size : 10 Epochs: 20						
Accuracy Obtained:						

	Defective Accuracy	**Non-Defective Accuracy**
Aug_PCB	94.48	99.20
Balanced_PCB	83.22	100
Raw_PCB	83.22	99.92

Model 14						
Layer No:	**Name**	**No: of neurons/filters**	**Filter/pool size**	**Activation function**	**Stride**	**Padding**
1.	Conv2D	48	3x3	tanh	2	valid
2.	Maxpooling2D		3x3	-	2	-
3.	Conv2D	96	3x3	tanh	2	valid
4.	Maxpooling2D		3x3	-	2	-
5.	Conv2D	64	3x3	tanh	2	valid
6.	Conv2D	128	3x3	tanh	2	valid
7.	Maxpooling2D		3x3	-	2	-
8.	Flatten	-	-	-	-	-
9.	Dense	256		tanh	-	-
10.	Dense	2		softmax	-	-
Loss : Sparse Categorical Crossentropy Optimizer : SGD Batch Size : 10 Epochs: 20						
Accuracy Obtained:						

	Defective Accuracy	**Non-Defective Accuracy**
Aug_PCB	97.24	98.80
Balanced_PCB	93.28	100
Raw_PCB	93.28	99.84

Model 15						
Layer No:	**Name**	**No: of neurons/filters**	**Filter/pool size**	**Activation function**	**Stride**	**Padding**
1.	Conv2D	20	3x3	relu	2	valid
2.	Maxpooling2D		3x3	-	2	-
3.	Conv2D	50	3x3	relu	2	valid
4.	Maxpooling2D		3x3	-	2	-
6.	Conv2D	128	3x3	relu	2	valid
7.	Maxpooling2D		3x3	-	2	-
8.	Flatten	-	-	-	-	-
9.	Dense	256		relu	-	-
10.	Dense	2		softmax	-	-
Loss : Sparse Categorical Crossentropy Optimizer : SGD Batch Size : 10 Epochs: 20						
Accuracy Obtained:						

	Defective Accuracy	**Non-Defective Accuracy**
Aug_PCB	95.67	95.20
Balanced_PCB	89.93	97.98
Raw_PCB	89.93	98.88

Final Results:

After training the model on Aug_PCB data, the best accuracy achieved so far when tested against the normalized Raw_PCB data set is stated below :-

	Defective Accuracy	**Non-Defective Accuracy**
Raw_PCB	98.65	99.20