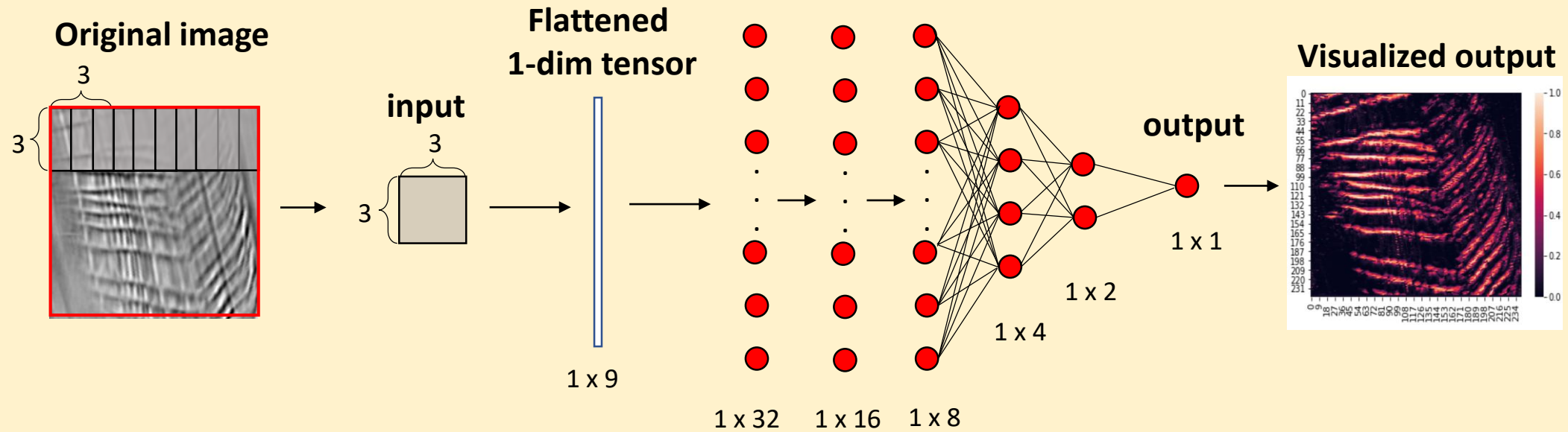
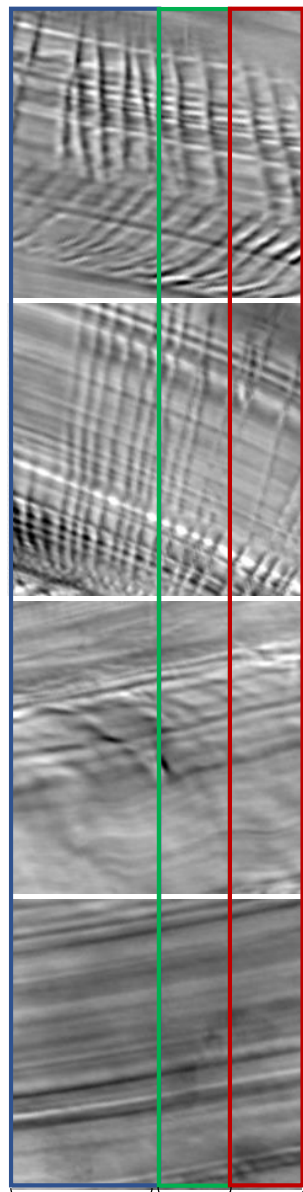


Model setup (Neural Network)



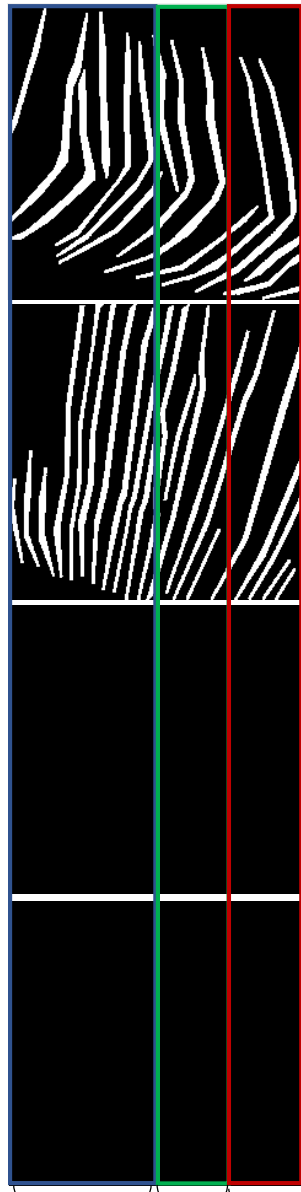
Input



train

valid test

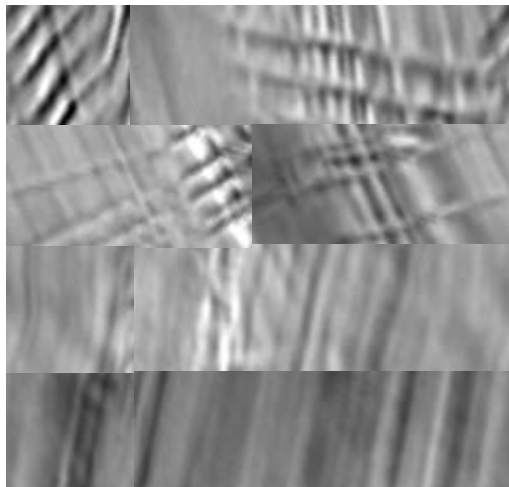
Output



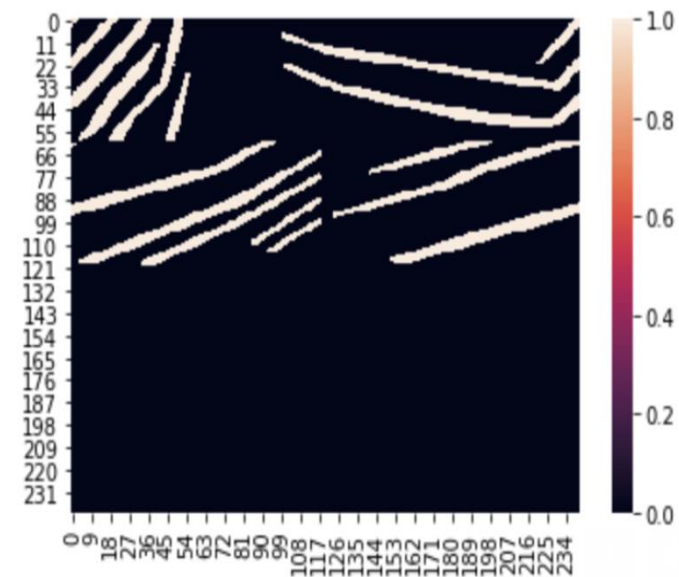
train

valid test

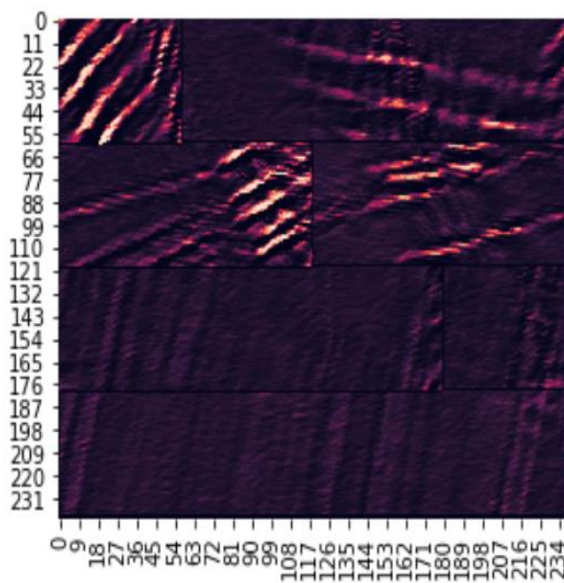
Test input



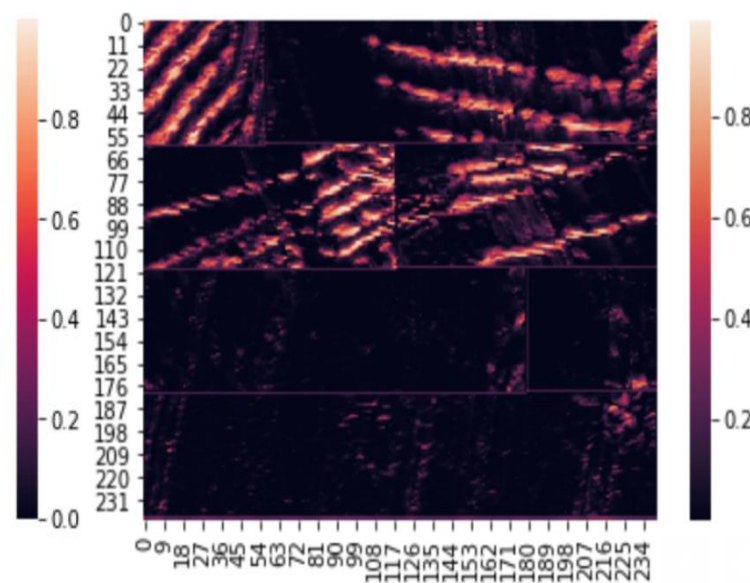
Test output (for comparison)



Prediction (linear regression)



Prediction (neural network)

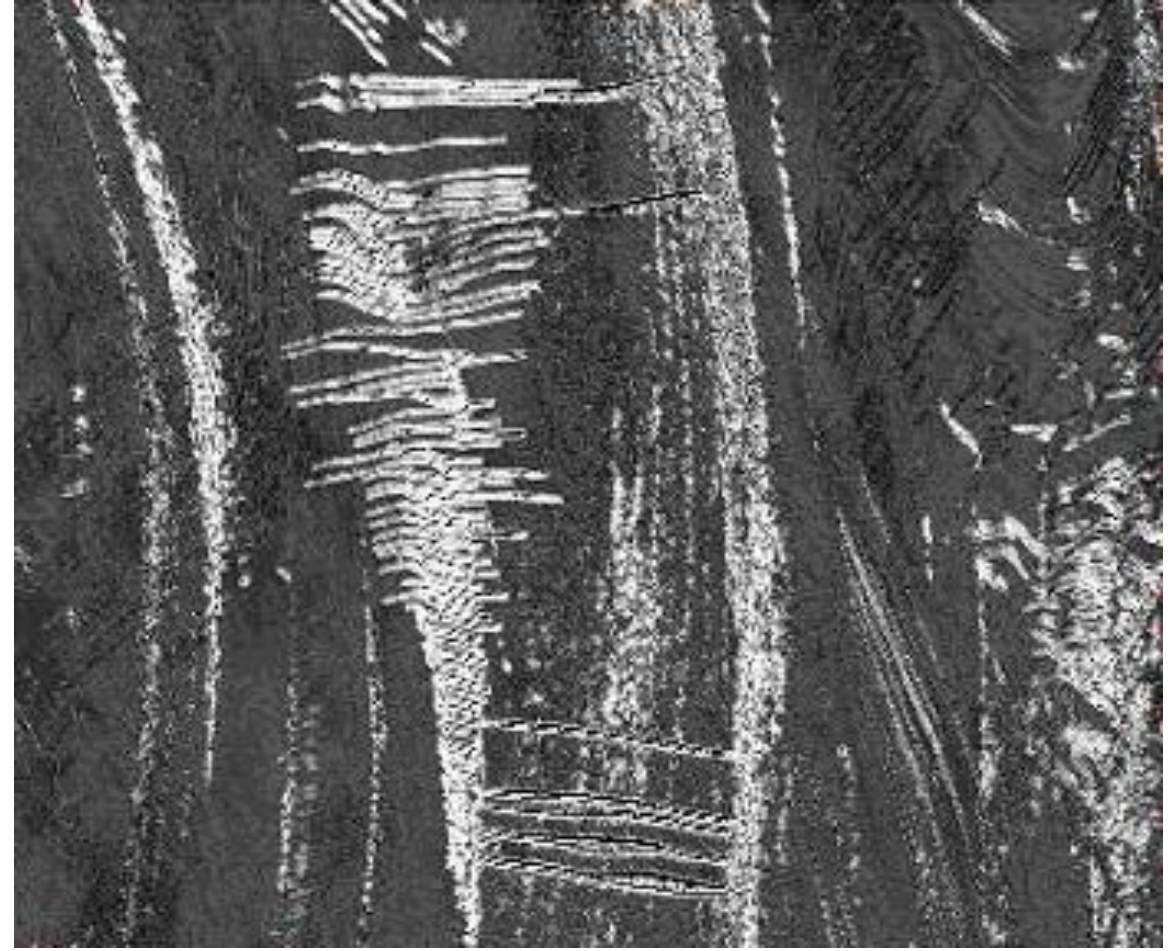


Apply model

Test input



Prediction (neural network)



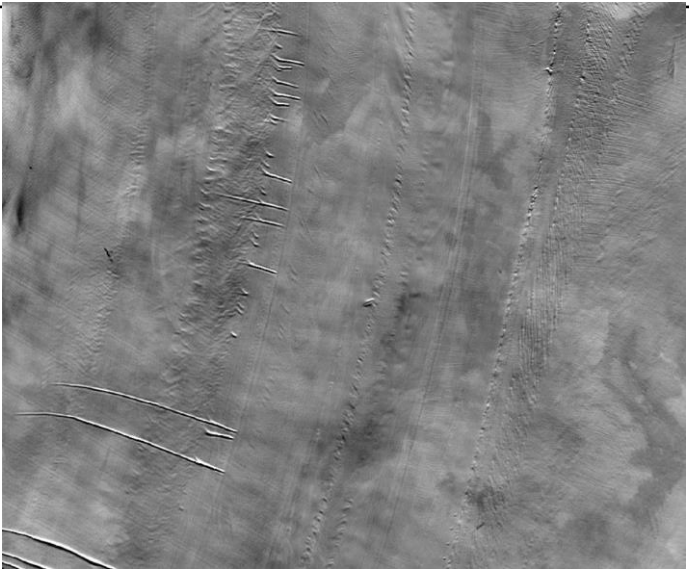
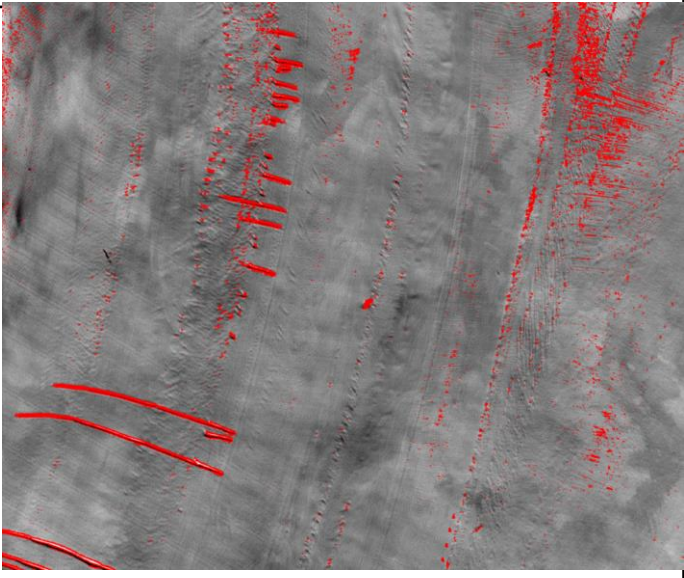
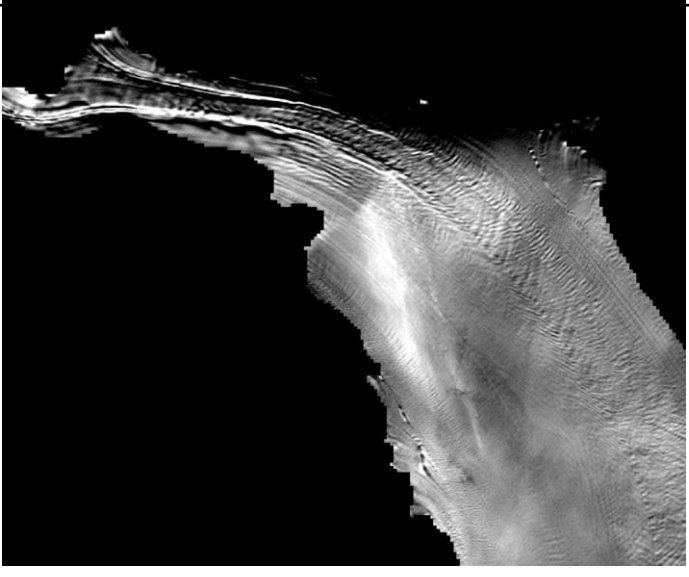
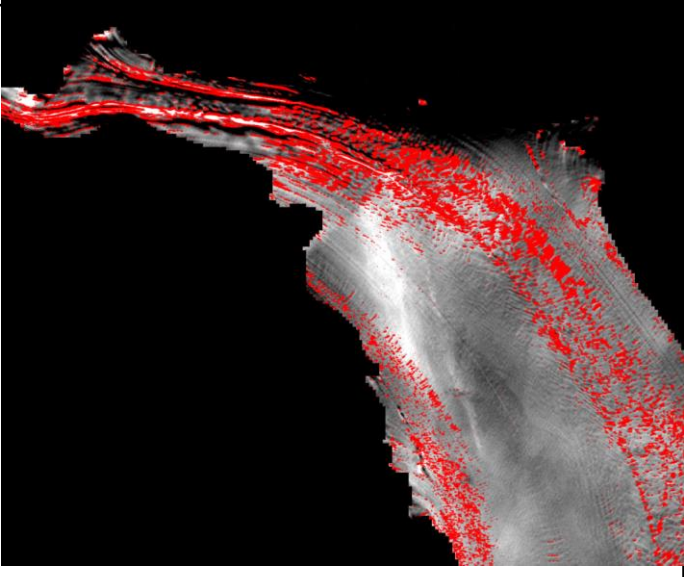
1.0

0.5

0.0

Apply Threshold to Get Binary Output

**Threshold
probability = 0.5**

	Raw image (125 m/pixel)	Fracture location identified by deep neural network
Examples of True Positive (Patterns identified as fractures are indeed fractures)		
Examples of False Positive (Patterns identified as fractures are not fractures)		

Measures of model performance

	Reality: fracture	Reality: no fracture
Prediction: fracture	True Positive (TP)	False Positive (FP)
Prediction: no fracture	False Negative (FN)	True Negative (TN)

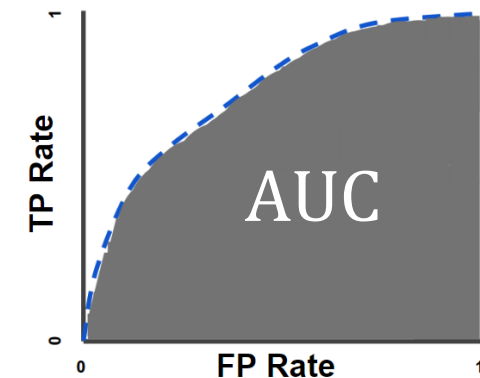
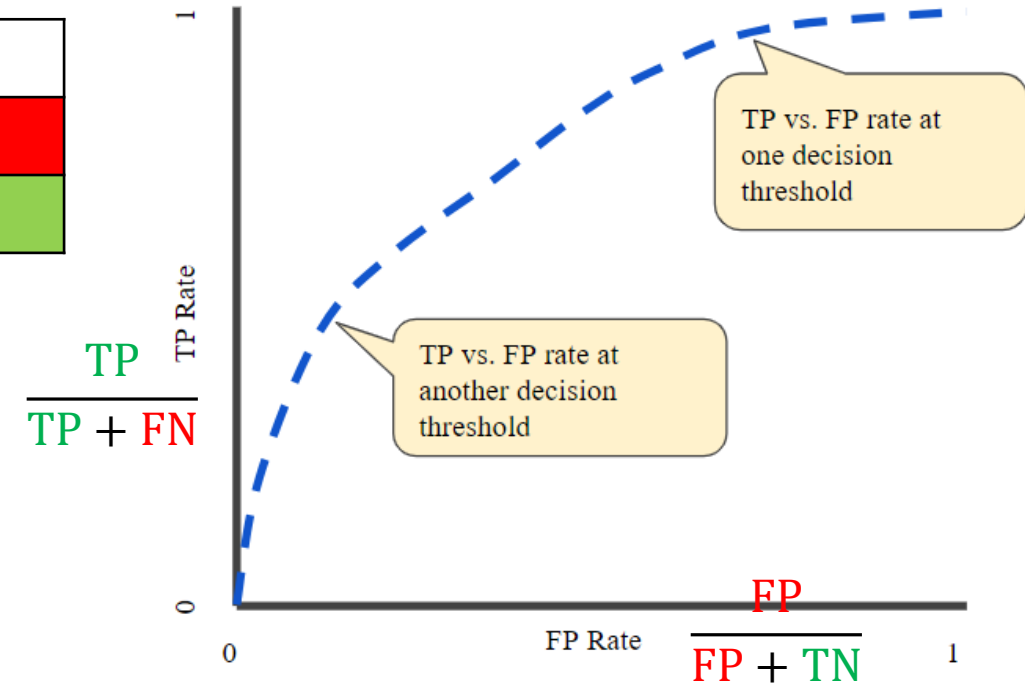
$$\text{Accuracy} = \frac{\# \text{ of correct predictions}}{\text{Total \# of predictions}} = \frac{\text{TP} + \text{TN}}{\text{TP} + \text{TN} + \text{FP} + \text{FN}}$$

$$\text{Precision} = \frac{\# \text{ of correct positive predictions}}{\# \text{ of positive predictions}} = \frac{\text{TP}}{\text{TP} + \text{FP}}$$

$$\text{Recall} = \frac{\# \text{ of correct positive predictions}}{\# \text{ of positive realities}} = \frac{\text{TP}}{\text{TP} + \text{FN}}$$

$$\text{F-score} = \frac{2 \times \text{Recall} \times \text{Precision}}{\text{Recall} + \text{Precision}}$$

AUC = the probability that the model ranks a actual positive example more highly than a actual negative example

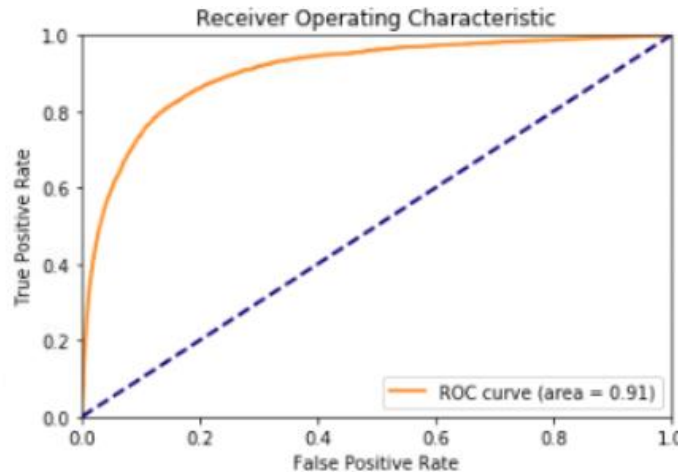
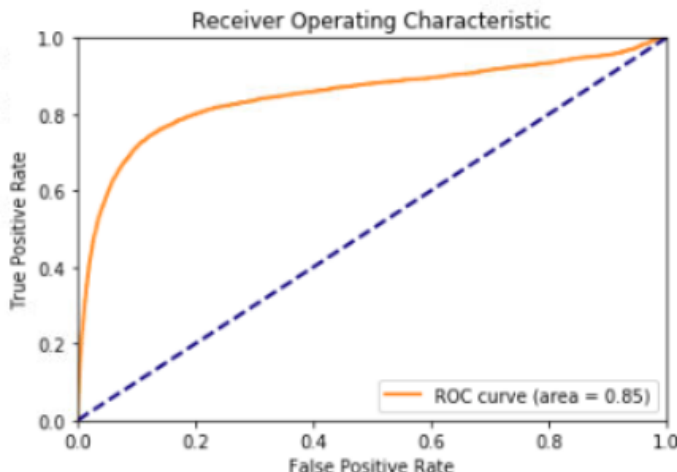
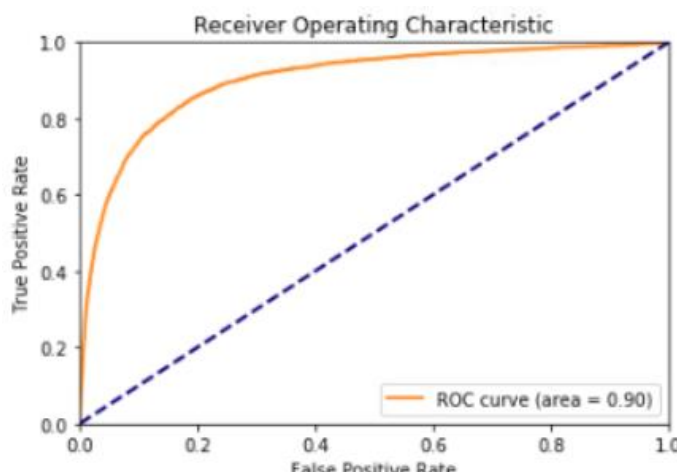
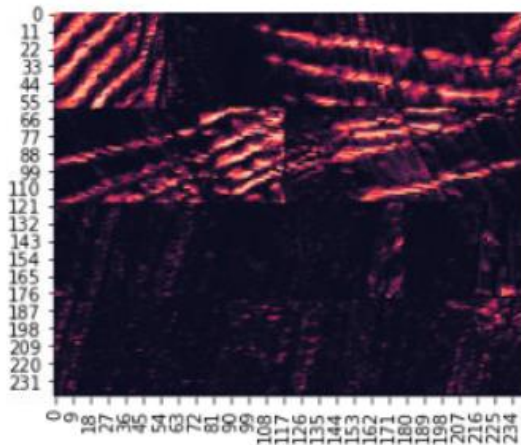
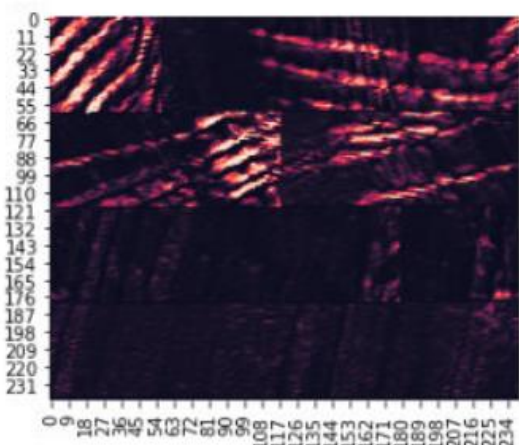
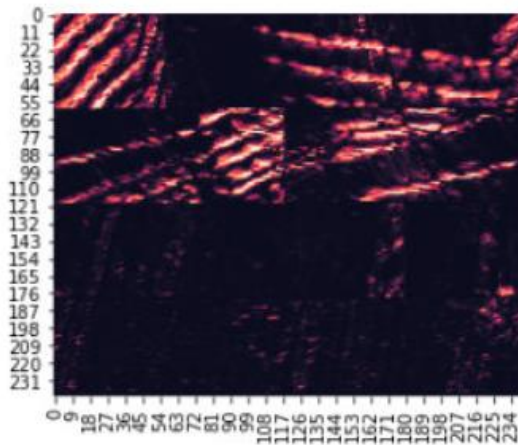


Model Performance Comparison

A. Input shape: 3 x 3, Model summary

Deep Neural Net	1-layer Neural Net	Deep Covolutional Neural Net																																												
<table><tr><th>Layer (type)</th><th>Output Shape</th></tr><tr><td>flatten_1 (Flatten)</td><td>(None, 9)</td></tr><tr><td>dense_1 (Dense)</td><td>(None, 32)</td></tr><tr><td>dense_2 (Dense)</td><td>(None, 16)</td></tr><tr><td>dense_3 (Dense)</td><td>(None, 8)</td></tr><tr><td>dense_4 (Dense)</td><td>(None, 4)</td></tr><tr><td>dense_5 (Dense)</td><td>(None, 2)</td></tr><tr><td>dense_6 (Dense)</td><td>(None, 1)</td></tr></table>	Layer (type)	Output Shape	flatten_1 (Flatten)	(None, 9)	dense_1 (Dense)	(None, 32)	dense_2 (Dense)	(None, 16)	dense_3 (Dense)	(None, 8)	dense_4 (Dense)	(None, 4)	dense_5 (Dense)	(None, 2)	dense_6 (Dense)	(None, 1)	<table><tr><th>Layer (type)</th><th>Output Shape</th></tr><tr><td>flatten_1 (Flatten)</td><td>(None, 9)</td></tr><tr><td>dense_1 (Dense)</td><td>(None, 32)</td></tr><tr><td>dense_2 (Dense)</td><td>(None, 1)</td></tr></table>	Layer (type)	Output Shape	flatten_1 (Flatten)	(None, 9)	dense_1 (Dense)	(None, 32)	dense_2 (Dense)	(None, 1)	<table><tr><th>Layer (type)</th><th>Output Shape</th></tr><tr><td>conv2d_2 (Conv2D)</td><td>(None, 1, 1, 16)</td></tr><tr><td>activation_2 (Activation)</td><td>(None, 1, 1, 16)</td></tr><tr><td>flatten_1 (Flatten)</td><td>(None, 16)</td></tr><tr><td>dense_7 (Dense)</td><td>(None, 32)</td></tr><tr><td>dense_8 (Dense)</td><td>(None, 16)</td></tr><tr><td>dense_9 (Dense)</td><td>(None, 8)</td></tr><tr><td>dense_10 (Dense)</td><td>(None, 4)</td></tr><tr><td>dense_11 (Dense)</td><td>(None, 2)</td></tr><tr><td>dense_12 (Dense)</td><td>(None, 1)</td></tr></table>	Layer (type)	Output Shape	conv2d_2 (Conv2D)	(None, 1, 1, 16)	activation_2 (Activation)	(None, 1, 1, 16)	flatten_1 (Flatten)	(None, 16)	dense_7 (Dense)	(None, 32)	dense_8 (Dense)	(None, 16)	dense_9 (Dense)	(None, 8)	dense_10 (Dense)	(None, 4)	dense_11 (Dense)	(None, 2)	dense_12 (Dense)	(None, 1)
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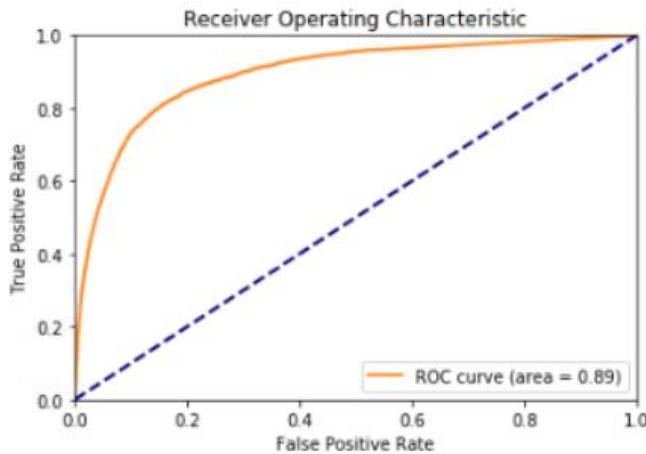
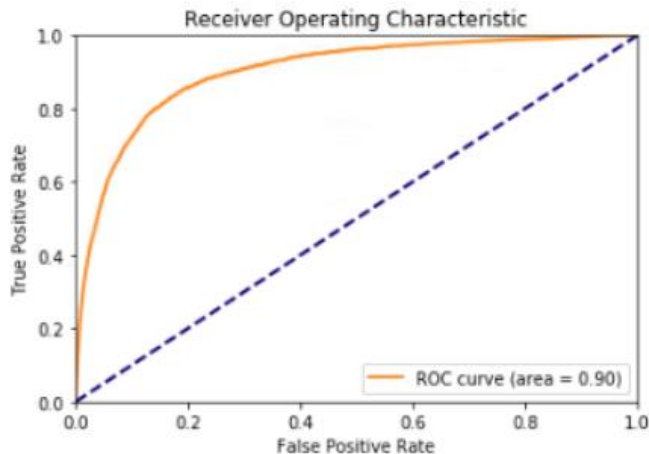
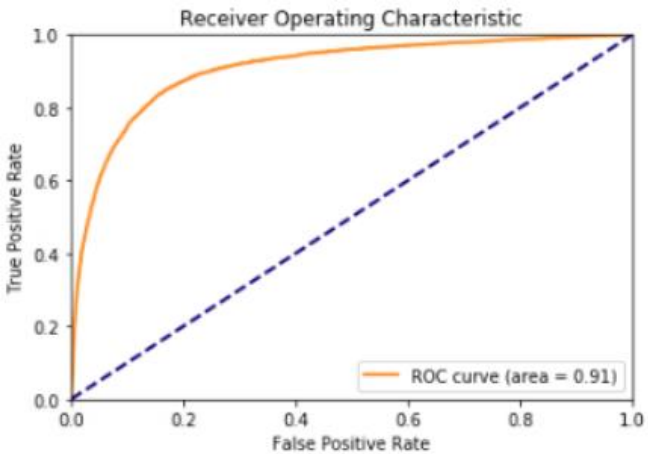
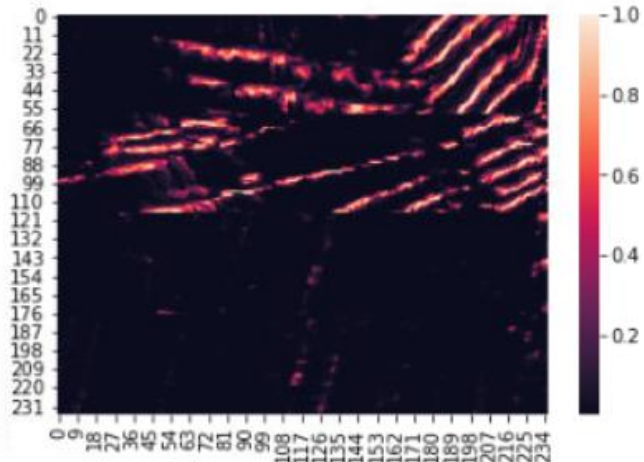
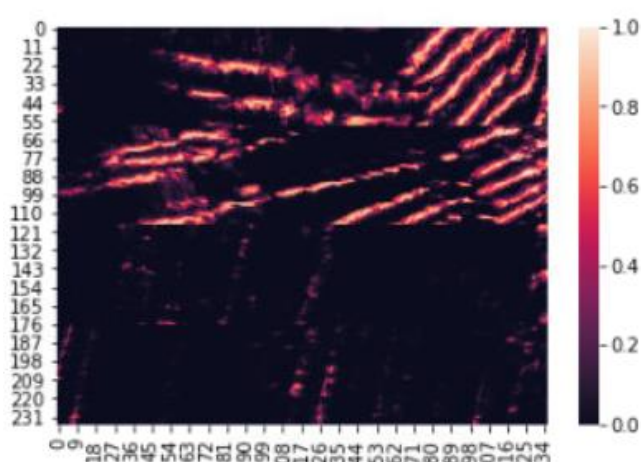
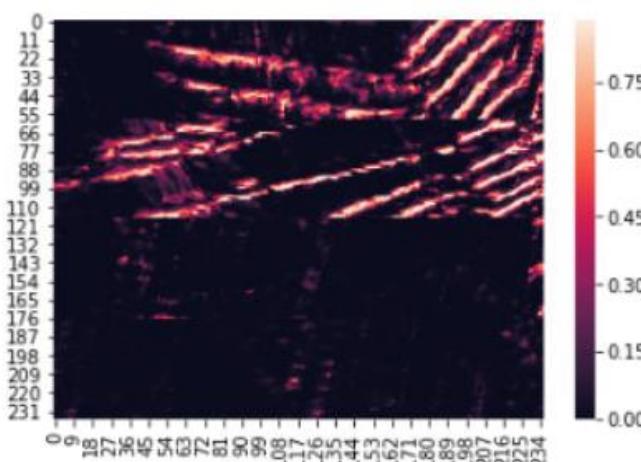
A. Input shape: 3 x 3, Model performance

Deep Neural Net					1-layer Neural Net					Deep Covolutional Neural Net							
		precision	recall	f1-score	support			precision	recall	f1-score	support			precision	recall	f1-score	support
0.0		0.96	0.95	0.95	52589	0.0		0.95	0.97	0.96	52589	0.0		0.95	0.96	0.96	52589
1.0		0.57	0.58	0.57	5495	1.0		0.61	0.52	0.56	5495	1.0		0.58	0.57	0.57	5495
micro avg		0.92	0.92	0.92	58084	micro avg		0.92	0.92	0.92	58084	micro avg		0.92	0.92	0.92	58084
macro avg		0.76	0.77	0.76	58084	macro avg		0.78	0.74	0.76	58084	macro avg		0.77	0.76	0.76	58084
weighted avg		0.92	0.92	0.92	58084	weighted avg		0.92	0.92	0.92	58084	weighted avg		0.92	0.92	0.92	58084
																	
																	

B. Input shape: 5 x 5, Model summary

Deep Neural Net	Deep + 1 Covolutional layer	Deep + 2 Covolutional layers																																																												
<table><tr><th>Layer (type)</th><th>Output Shape</th></tr><tr><td>flatten_1 (Flatten)</td><td>(None, 25)</td></tr><tr><td>dense_1 (Dense)</td><td>(None, 32)</td></tr><tr><td>dense_2 (Dense)</td><td>(None, 16)</td></tr><tr><td>dense_3 (Dense)</td><td>(None, 8)</td></tr><tr><td>dense_4 (Dense)</td><td>(None, 4)</td></tr><tr><td>dense_5 (Dense)</td><td>(None, 2)</td></tr><tr><td>dense_6 (Dense)</td><td>(None, 1)</td></tr></table>	Layer (type)	Output Shape	flatten_1 (Flatten)	(None, 25)	dense_1 (Dense)	(None, 32)	dense_2 (Dense)	(None, 16)	dense_3 (Dense)	(None, 8)	dense_4 (Dense)	(None, 4)	dense_5 (Dense)	(None, 2)	dense_6 (Dense)	(None, 1)	<table><tr><th>Layer (type)</th><th>Output Shape</th></tr><tr><td>conv2d_1 (Conv2D)</td><td>(None, 3, 3, 16)</td></tr><tr><td>activation_1 (Activation)</td><td>(None, 3, 3, 16)</td></tr><tr><td>flatten_1 (Flatten)</td><td>(None, 144)</td></tr><tr><td>dense_1 (Dense)</td><td>(None, 32)</td></tr><tr><td>dense_2 (Dense)</td><td>(None, 16)</td></tr><tr><td>dense_3 (Dense)</td><td>(None, 8)</td></tr><tr><td>dense_4 (Dense)</td><td>(None, 4)</td></tr><tr><td>dense_5 (Dense)</td><td>(None, 2)</td></tr><tr><td>dense_6 (Dense)</td><td>(None, 1)</td></tr></table>	Layer (type)	Output Shape	conv2d_1 (Conv2D)	(None, 3, 3, 16)	activation_1 (Activation)	(None, 3, 3, 16)	flatten_1 (Flatten)	(None, 144)	dense_1 (Dense)	(None, 32)	dense_2 (Dense)	(None, 16)	dense_3 (Dense)	(None, 8)	dense_4 (Dense)	(None, 4)	dense_5 (Dense)	(None, 2)	dense_6 (Dense)	(None, 1)	<table><tr><th>Layer (type)</th><th>Output Shape</th></tr><tr><td>conv2d_1 (Conv2D)</td><td>(None, 3, 3, 16)</td></tr><tr><td>activation_1 (Activation)</td><td>(None, 3, 3, 16)</td></tr><tr><td>conv2d_2 (Conv2D)</td><td>(None, 1, 1, 32)</td></tr><tr><td>activation_2 (Activation)</td><td>(None, 1, 1, 32)</td></tr><tr><td>flatten_1 (Flatten)</td><td>(None, 32)</td></tr><tr><td>dense_1 (Dense)</td><td>(None, 32)</td></tr><tr><td>dense_2 (Dense)</td><td>(None, 16)</td></tr><tr><td>dense_3 (Dense)</td><td>(None, 8)</td></tr><tr><td>dense_4 (Dense)</td><td>(None, 4)</td></tr><tr><td>dense_5 (Dense)</td><td>(None, 2)</td></tr><tr><td>dense_6 (Dense)</td><td>(None, 1)</td></tr></table>	Layer (type)	Output Shape	conv2d_1 (Conv2D)	(None, 3, 3, 16)	activation_1 (Activation)	(None, 3, 3, 16)	conv2d_2 (Conv2D)	(None, 1, 1, 32)	activation_2 (Activation)	(None, 1, 1, 32)	flatten_1 (Flatten)	(None, 32)	dense_1 (Dense)	(None, 32)	dense_2 (Dense)	(None, 16)	dense_3 (Dense)	(None, 8)	dense_4 (Dense)	(None, 4)	dense_5 (Dense)	(None, 2)	dense_6 (Dense)	(None, 1)
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B. Input shape: 5 x 5, Model performance

Deep Neural Net	Deep + 1 Covolutional layer	Deep + 2 Covolutional layers																																																																																										
<table><tr><td></td><td>precision</td><td>recall</td><td>f1-score</td><td>support</td></tr><tr><td>0.0</td><td>0.95</td><td>0.95</td><td>0.95</td><td>50336</td></tr><tr><td>1.0</td><td>0.55</td><td>0.54</td><td>0.55</td><td>5360</td></tr><tr><td>micro avg</td><td>0.91</td><td>0.91</td><td>0.91</td><td>55696</td></tr><tr><td>macro avg</td><td>0.75</td><td>0.75</td><td>0.75</td><td>55696</td></tr><tr><td>weighted avg</td><td>0.91</td><td>0.91</td><td>0.91</td><td>55696</td></tr></table>		precision	recall	f1-score	support	0.0	0.95	0.95	0.95	50336	1.0	0.55	0.54	0.55	5360	micro avg	0.91	0.91	0.91	55696	macro avg	0.75	0.75	0.75	55696	weighted avg	0.91	0.91	0.91	55696	<table><tr><td></td><td>precision</td><td>recall</td><td>f1-score</td><td>support</td></tr><tr><td>0.0</td><td>0.95</td><td>0.95</td><td>0.95</td><td>50336</td></tr><tr><td>1.0</td><td>0.55</td><td>0.56</td><td>0.56</td><td>5360</td></tr><tr><td>micro avg</td><td>0.91</td><td>0.91</td><td>0.91</td><td>55696</td></tr><tr><td>macro avg</td><td>0.75</td><td>0.76</td><td>0.75</td><td>55696</td></tr><tr><td>weighted avg</td><td>0.91</td><td>0.91</td><td>0.91</td><td>55696</td></tr></table>		precision	recall	f1-score	support	0.0	0.95	0.95	0.95	50336	1.0	0.55	0.56	0.56	5360	micro avg	0.91	0.91	0.91	55696	macro avg	0.75	0.76	0.75	55696	weighted avg	0.91	0.91	0.91	55696	<table><tr><td></td><td>precision</td><td>recall</td><td>f1-score</td><td>support</td></tr><tr><td>0.0</td><td>0.95</td><td>0.96</td><td>0.96</td><td>50336</td></tr><tr><td>1.0</td><td>0.58</td><td>0.57</td><td>0.58</td><td>5360</td></tr><tr><td>micro avg</td><td>0.92</td><td>0.92</td><td>0.92</td><td>55696</td></tr><tr><td>macro avg</td><td>0.77</td><td>0.76</td><td>0.77</td><td>55696</td></tr><tr><td>weighted avg</td><td>0.92</td><td>0.92</td><td>0.92</td><td>55696</td></tr></table>		precision	recall	f1-score	support	0.0	0.95	0.96	0.96	50336	1.0	0.58	0.57	0.58	5360	micro avg	0.92	0.92	0.92	55696	macro avg	0.77	0.76	0.77	55696	weighted avg	0.92	0.92	0.92	55696
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C. Input shape: 10 x 10, Model summary

Deep Neural Net	Deep + 1 Covolutional layer	Deep + 2 Covolutional layers																																																												
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C. Input shape: 10 x 10, Model performance

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