



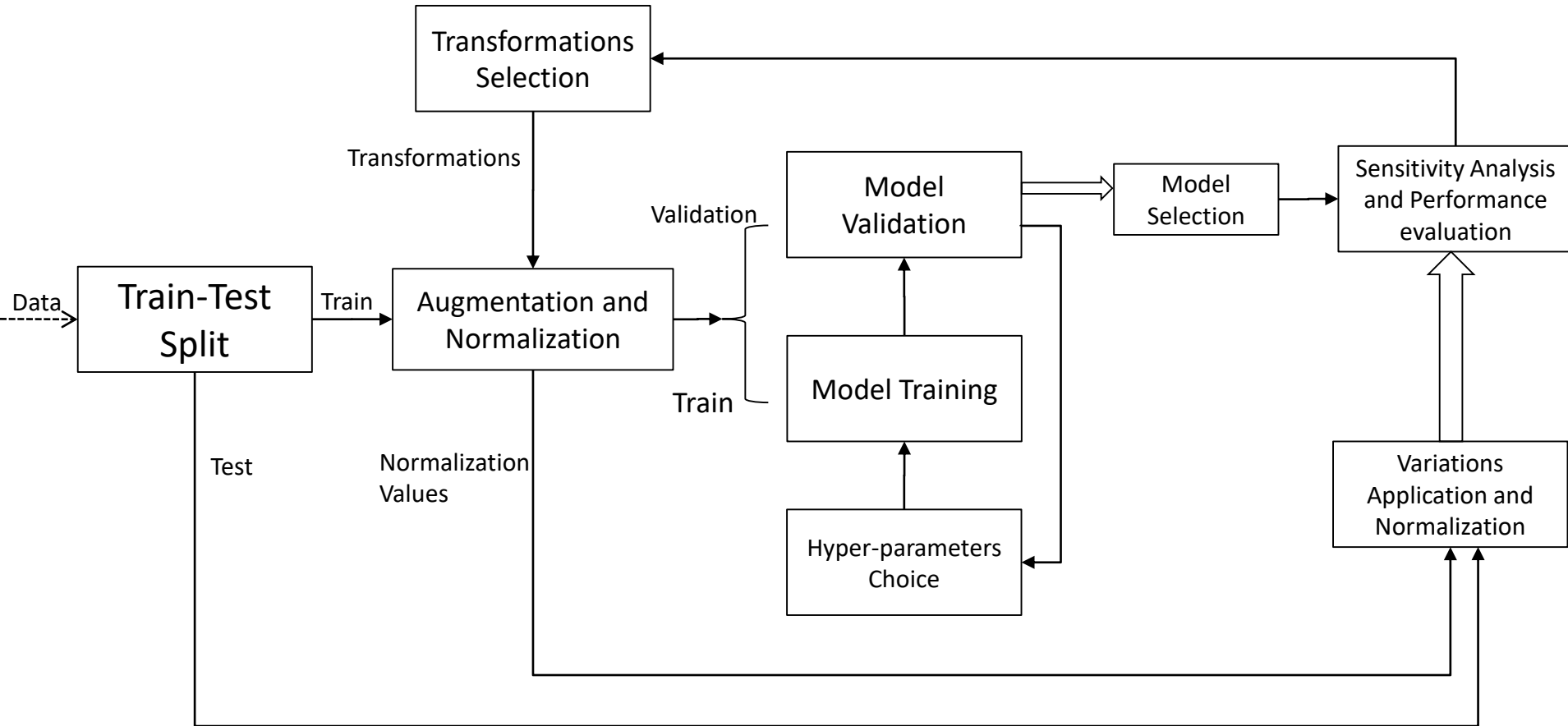
POLITECNICO
MILANO 1863

Deep Learning approach to Tomato Plant Diseases Recognition and related Sensitivity Analysis

Deep Learning: Theory, Techniques and Applications
A.Y. 2017/2018

Alessandro Erba, Mirco Manzoni, Giuseppe Mascellaro

Proposed Workflow Approach



Dataset



Bacterial Spot
2.127 samples



Early Blight
1.000 samples



Healthy
1.590 samples



Late Blight
1.909 samples



Leaf Mold
952 samples



Septoria leaf spot
1.771 samples



**Two Spotted
Spider mite**
1.676 samples



Target Spot
1.404 samples



**Tomato Mosaic
Virus**
373 samples



**Tomato Yellow
Leaf Curl virus**
5.356 samples

Data Augmentation and Normalization

Before the Training and Validation phases data are augmented and Normalized.

Each sample is transformed taking two transformations from this pool:

- Flip Top Bottom,
- Flip Left Right,
- Rotate 90° ,
- Rotate 180° ,
- Rotate 270° ,
- Flip Top Bottom and Rotate 90° ,
- Flip Top Bottom and Rotate 270° .

Data are normalized in two different ways:

- Dataset Normalization
- Per-leaf Normalization

Binary Classification - Setup

- Healthy vs Infected
- Architecture: LeNet
- Xavier initialization
- Rectified linear unit (ReLU) activation function
- Binary cross-entropy Loss
- Adam Optimizer
- 10-Fold cross Validation

Binary Classification - Results

Accuracy 99.92%

Precision 99.34%

Recall 99.67%

F1 - measure 99.5%

Confusion Matrix

TP = 300	FN = 1
FP = 2	TN = 3375

Multi-class Classification

- AlexNet architecture
 - Train from scratch
 - Transfer Learning
- Xavier initialization
- Rectified linear unit (ReLU) function
- Cross-entropy Loss
- Adam Optimizer
- Cross-validation

Multi-class Classification - Results

Accuracy: 99.85%

Macro precision: 99.83%

Macro recall (Trues Rate): 99.82%

Falses Rate: 0.18%

Macro F1: 99.83%

(A) Bacterial Spot

(B) Early Blight

(C) Late Blight

(D) Leaf Mold

(E) Septoria Leaf Spot

(F) Two-spotted Spider Mites

(G) Target Spot

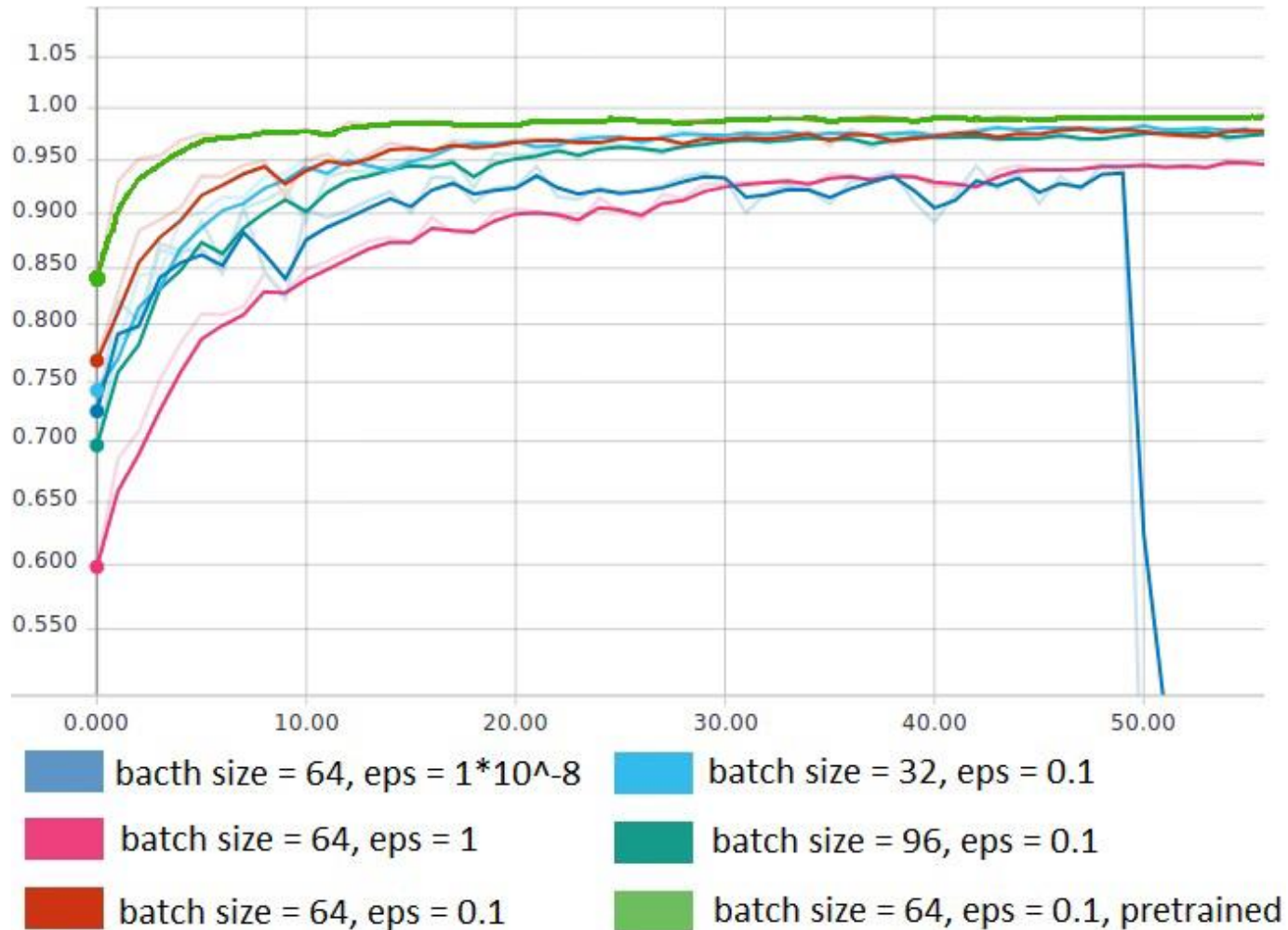
(H) Tomato Yellow Leaf Curl Virus

(I) Tomato Mosaic Virus

(J) Healthy

True label	A -	1e+02	0	0	0	0	0	0	0	0	
	B -	0	99	0.33	0	0.33	0	0	0	0	
	C -	0	0.17	1e+02	0	0.17	0	0	0	0	
	D -	0	0	0	1e+02	0.36	0	0	0	0	
	E -	0	0	0	0	1e+02	0	0	0	0	
	F -	0	0	0	0	0	1e+02	0.2	0	0	
	G -	0	0	0	0	0	0	1e+02	0	0	
	H -	0.059	0	0	0	0	0	0	1e+02	0	
	I -	0	0	0	0	0	0	0	0	1e+02	
	J -	0	0	0	0	0	0	0.22	0	0	1e+02
		A	B	C	D	E	F	G	H	I	J
Predicted label											

Multiclass Classification - Training accuracy with different setup



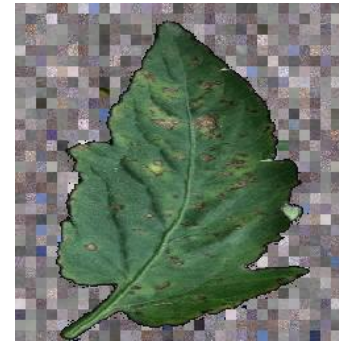
Sensitivity Analysis Datasets



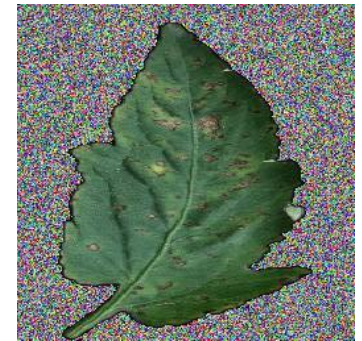
Original dataset



Segmented dataset



Random Background
Crop dataset



Random Noise
Background
dataset



Random Noise Background dataset

Sensitivity Analysis

Normal Train vs Segmented Test

Train



Original dataset

Test



Segmented dataset

Accuracy: 39.01%
Macro precision: NaN
Macro recall (Trues Rate): 28.58%
Falses Rate: 71.41%
Macro F1: NaN

Sensitivity Analysis

Normal Train vs Segmented Test

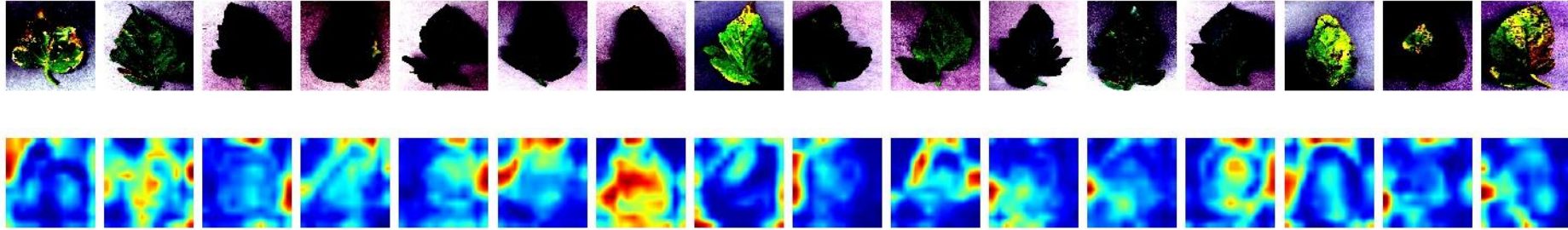
- (A) Bacterial Spot
- (B) Early Blight
- (C) Late Blight
- (D) Leaf Mold
- (E) Septoria Leaf Spot
- (F) Two-spotted Spider Mites
- (G) Target Spot
- (H) Tomato Yellow Leaf Curl Virus
- (I) Tomato Mosaic Virus
- (J) Healthy

True label	A -	5.8	12	76	0.67	5.5	0	0	0	0	0
	B -	0	31	68	0	0.33	0	0	0	0	0
	C -	0	0	1e+02	0	0	0	0	0	0	0
	D -	0	0	66	34	0	0	0	0	0	0
	E -	0.19	0.37	63	0	37	0	0	0	0	0
	F -	0	0	87	0	0	12	0.6	0.2	0	0
	G -	0	0.44	97	0	0	0	2.9	0	0	0
	H -	0	0	36	0.82	0	0	0	63	0	0
	I -	0	0	95	0	0	0	0	5.2	0	0
	J -	0	0	1e+02	0	0	0	0	0	0	0
		A	B	C	D	E	F	G	H	I	J
		Predicted label									

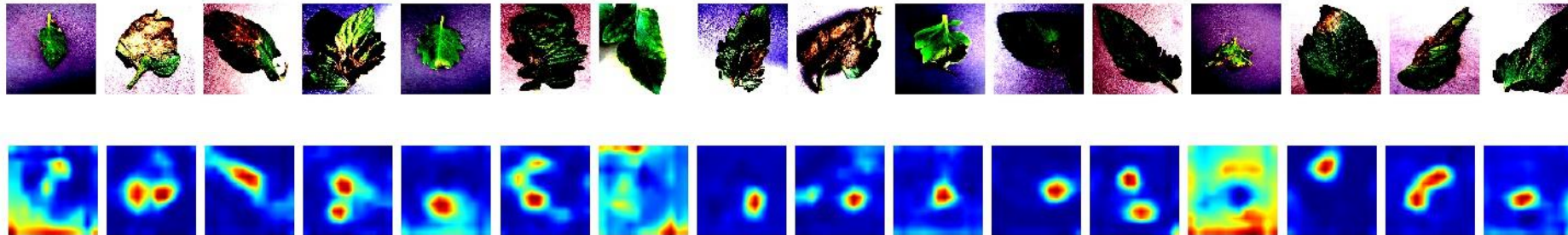
Sensitivity Analysis

Normal Train vs Normal Test Activation Visualization

Bacterial Spot Class



Late Blight Class



Sensitivity Analysis - Segmented Test vs Normal Train

Train



Segmented dataset

Test



Original dataset

Accuracy: 61.79%
Macro precision: 73.02%
Macro recall (Trues Rate): 49.41%
Falses Rate: 50.59%
Macro F1: 48.69%

Sensitivity Analysis

Segmented Train vs Normal Test

- (A) Bacterial Spot
- (B) Early Blight
- (C) Late Blight
- (D) Leaf Mold
- (E) Septoria Leaf Spot
- (F) Two-spotted Spider Mites
- (G) Target Spot
- (H) Tomato Yellow Leaf Curl Virus
- (I) Tomato Mosaic Virus
- (J) Healthy

True label	A	71	2	17	0	10	0	0	0.67	0	0
	B	5.3	56	38	0	0.99	0	0	0	0	0
	C	0.84	8.4	84	0.17	6.1	0	0.17	0	0	0
	D	18	32	39	8.6	1.4	0.36	0	0.36	0	0
	E	0.93	8.2	11	0	79	0.19	0.56	0	0	0
	F	0.4	1.6	70	0	0.2	24	0	0	0	3
	G	0.88	18	52	0	5.5	1.3	16	0	0	6.4
	H	0.23	2.3	18	0	0.18	0.059	0	80	0	0
	I	0.87	25	53	0	1.7	0.87	0	13	4.3	0.87
	J	0	2.4	6	0	1.5	9.1	9.1	0	0	72
		A	B	C	D	E	F	G	H	I	J
		Predicted label									

Sensitivity Analysis

Random Background Crop Train vs Normal Test

Train



Random Background
Crop dataset

Test



Original dataset

Accuracy: 76.92%
Macro precision: 76.92%
Macro recall (Trues Rate): 79.43%
Falses Rate: 32.70%
Macro F1: 67.15%

Sensitivity Analysis

Random Background Crop Train vs Normal Test

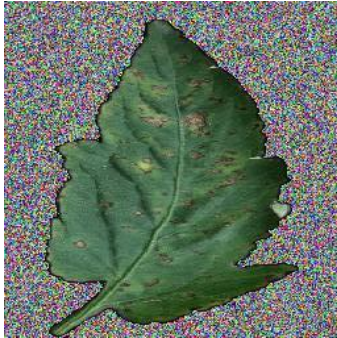
- (A) Bacterial Spot
- (B) Early Blight
- (C) Late Blight
- (D) Leaf Mold
- (E) Septoria Leaf Spot
- (F) Two-spotted Spider Mites
- (G) Target Spot
- (H) Tomato Yellow Leaf Curl Virus
- (I) Tomato Mosaic Virus
- (J) Healthy

True label	A	80	13	4.7	0	1.3	0	0	0.5	0	0
	B	2.3	84	8.2	0	0.66	3	1.3	0	0	0.33
	C	14	10	74	0	0.51	0.51	0	0.84	0	0
	D	0.36	24	15	51	2.5	6.4	0	0.71	0	0
	E	5.2	6	2.1	0.37	79	7.1	0.37	0.19	0	0
	F	0	0.6	19	0	0	76	0	0	0	5
	G	1.3	9.3	5.3	0	0.66	44	20	0	0	20
	H	0.29	2	1.1	0	0.059	1.4	0	95	0.059	0
	I	0	3.5	1.7	0.87	0	48	0	20	26	0
	J	0	0.43	1.5	0	0	9.9	0	0	0	88
		A	B	C	D	E	F	G	H	I	J
		Predicted label									

Sensitivity Analysis

Random Noise Background Train vs Normal Test

Train



Random Noise
Background dataset

Test



Original dataset

Accuracy: 57.89 %
Macro precision: 66.68%
Macro recall (Trues Rate): 49.01%
Falses Rate: 50.99%
Macro F1: 49.93%

Sensitivity Analysis

Random Noise Background Train vs Normal Test

- (A) Bacterial Spot
- (B) Early Blight
- (C) Late Blight
- (D) Leaf Mold
- (E) Septoria Leaf Spot
- (F) Two-spotted Spider Mites
- (G) Target Spot
- (H) Tomato Yellow Leaf Curl Virus
- (I) Tomato Mosaic Virus
- (J) Healthy

True label	A	18	7.8	61	0	12	0	0.33	0.5	0	0
	B	0.33	42	54	0	1.3	1.3	0.66	0	0	0.33
	C	0.34	23	72	0	3.2	0.34	0	0.84	0	0.34
	D	0	14	44	25	6.1	8.2	0	2.5	0	0.36
	E	0	1.3	17	0	73	4.3	3.7	0	0	0.93
	F	0	0	26	0	0	53	0.2	0.4	0.2	21
	G	0	0.22	38	0	0	19	22	0	0	21
	H	0.12	1.1	14	0.23	0.64	0.76	0	80	1.8	1.2
	I	0	0	58	0	0	0.87	0	2.6	37	0.87
	J	0	0	8.4	0	0.43	23	0.43	0	0	68
		A	B	C	D	E	F	G	H	I	J
		Predicted label									

Sensitivity Analysis – Per Leaf Normalization

Random Background Image Train vs Normal Test

Train



Random Noise
Background dataset

Per Leaf Normalization

Test



Original dataset

Accuracy: 97.77%
Macro precision: 97.52%
Macro recall (Trues Rate): 96.69%
Falses Rate: 3.31%
Macro F1: 97.04%

Sensitivity Analysis

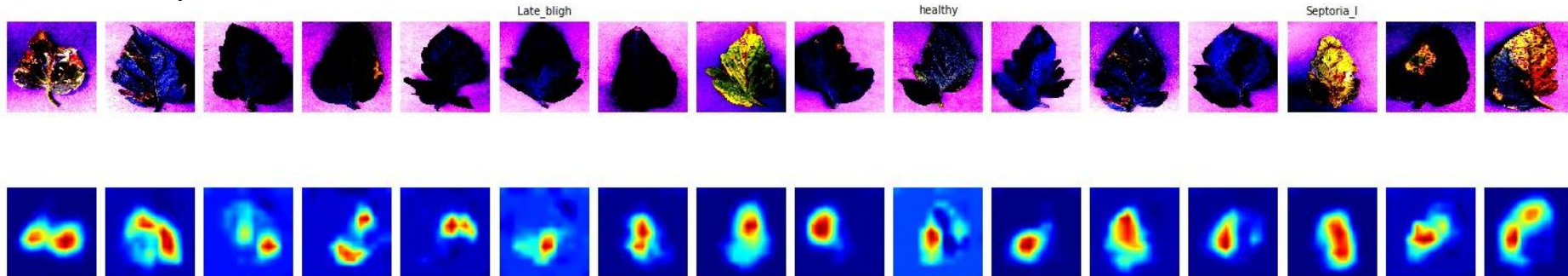
Random Background Image Train vs Normal Test

- (A) Bacterial Spot
- (B) Early Blight
- (C) Late Blight
- (D) Leaf Mold
- (E) Septoria Leaf Spot
- (F) Two-spotted Spider Mites
- (G) Target Spot
- (H) Tomato Yellow Leaf Curl Virus
- (I) Tomato Mosaic Virus
- (J) Healthy

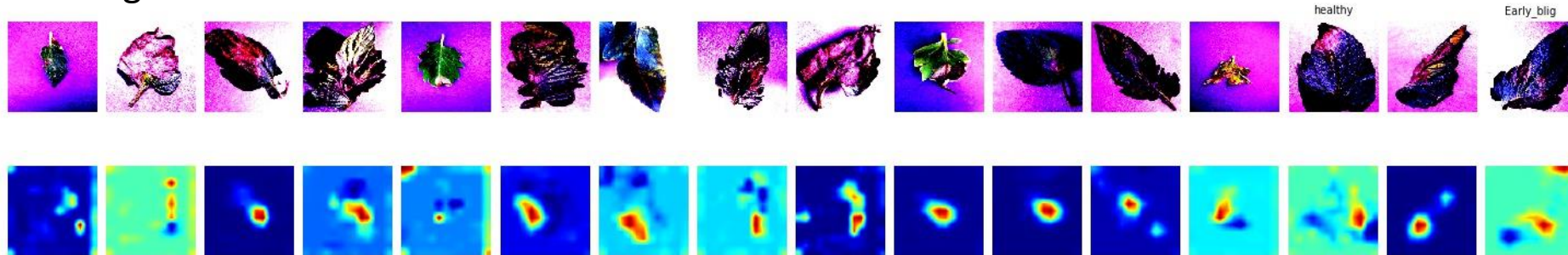
True label	A	99	0	0	0	0.17	0	0.5	0.33	0	0
	B	4.6	84	1.3	0.33	3.6	0.33	5.3	0.33	0	0.33
	C	0.51	0.67	98	0.34	0.34	0.17	0.17	0.17	0	0
	D	1.1	0.36	0	97	0.36	0.71	0.36	0	0	0
	E	0.37	0	0	0.19	99	0	0.37	0	0	0.56
	F	0	0	0.2	0	0	99	1.2	0	0	0
	G	0	0	0	0	0.66	3.1	95	0	0	0.88
	H	0.23	0	0	0	0	0.18	0	1e+02	0	0
	I	0	0.87	0	0	0.87	0	0	0.87	97	0
	J	0	0	0	0	0	0.22	0	0	0	1e+02
		A	B	C	D	E	F	G	H	I	J
		Predicted label									

Random Background Image Train vs Normal Test Activation Visualization

Bacterial Spot Class



Late Blight Class



Extension: Test against Real Plantation Images

We built a set of 256 found on internet.



Bacterial Spot
26 samples



Early Blight
41 samples



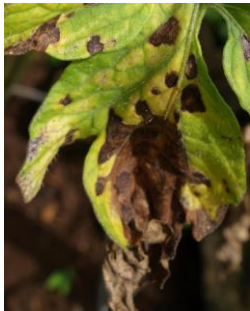
Healthy
27 samples



Late Blight
31 samples



Leaf Mold
33 samples



Septoria leaf spot
36 samples



**Two Spotted
Spider mite**
12 samples



Target Spot
12 samples



**Tomato Mosaic
Virus**
18 samples



**Tomato Yellow
Leaf Curl virus**
29samples

Test against Real Plantation Images

Results

- AlexNet

Accuracy: 29.81%

Macro precision: 30.36%

Macro recall (Trues Rate): 25.86%

Falses Rate: 74.13%

- VGG11

Accuracy: 35.85%

Main Limitation: the set is not validated by a domain expert.