Dermatology

Algorithm

Cancerous or not

whether a region of skin
tissue is cancerous or not.

Images

Labels

Cancerous

...

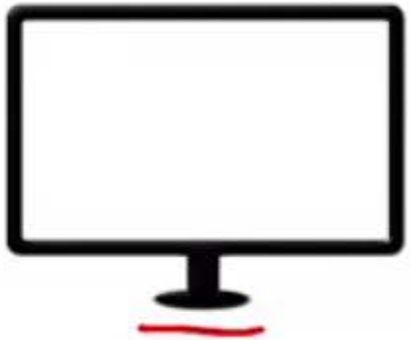
Non-cancerous

129,000 images

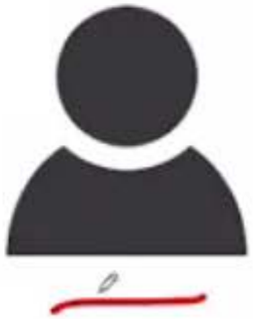
Convolutional Neural Network

such an algorithm in the course.

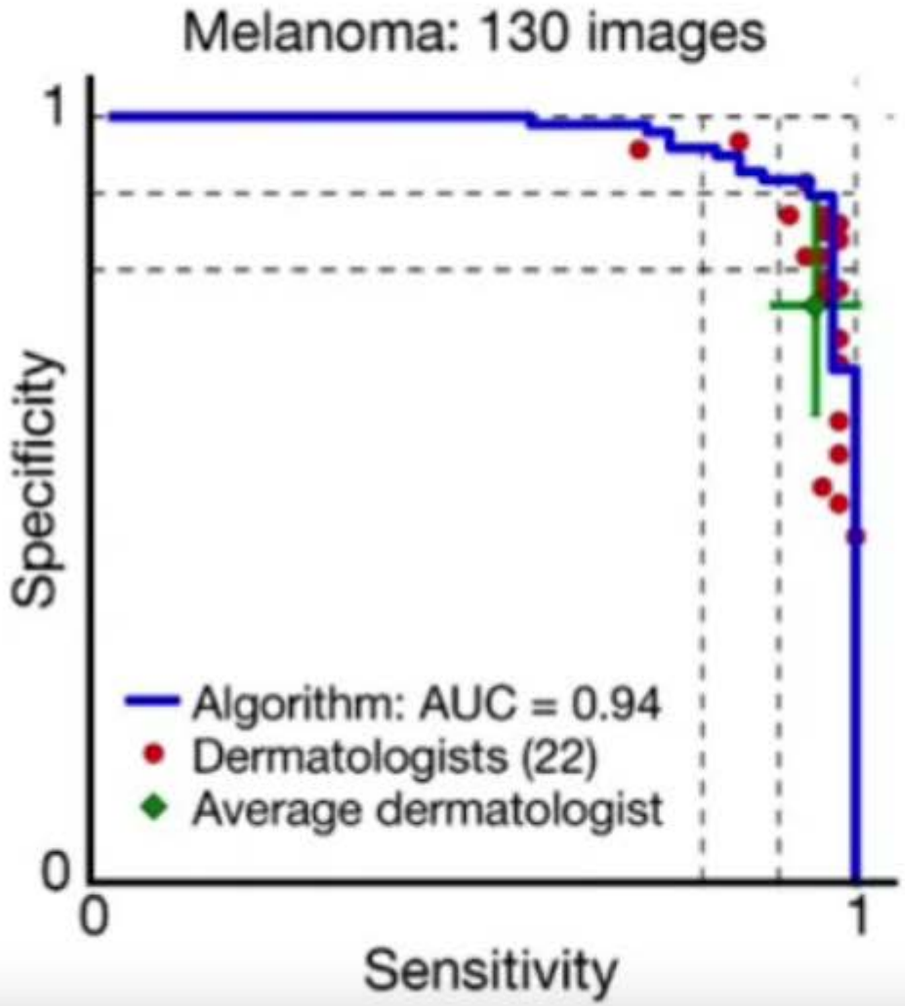
Cancerous or not

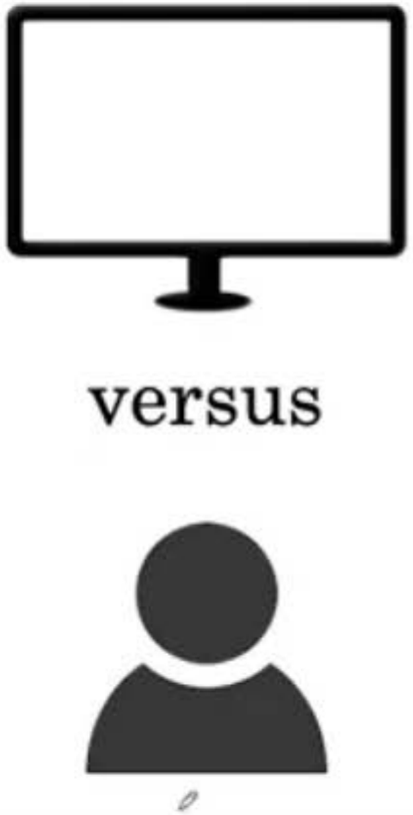


versus



on a new set of images.





In this study, it was found that the algorithm

1.00

Ophthalmology

Retinal Fundus Photos

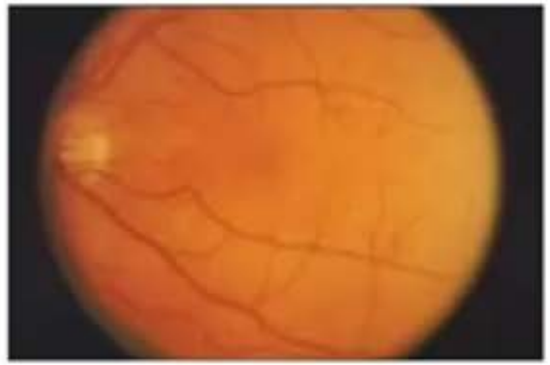
→ Diabetic Retinopathy (DR)

Our second example
is an ophthalmology,

1.00

Images

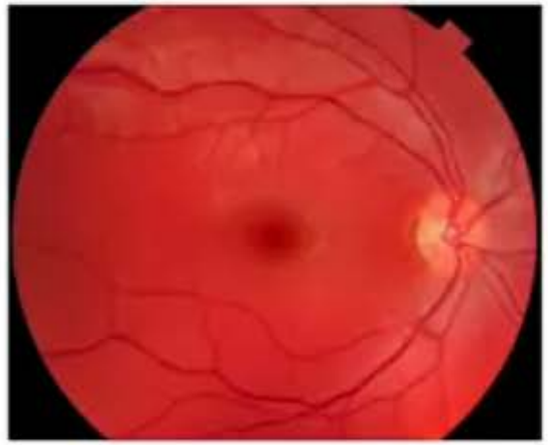
Labels



DR

30%

...

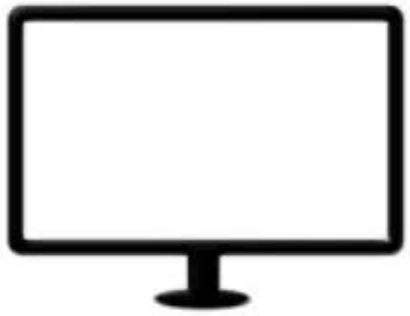


No DR

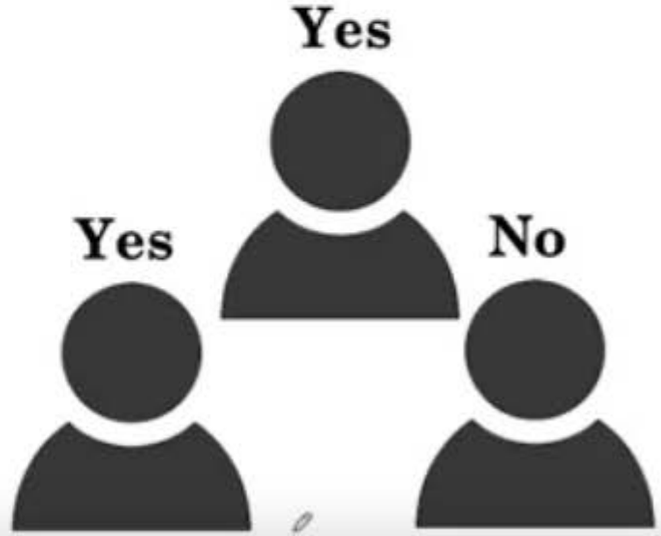
Convolutional Neural Network

128,000 images

We'll see some methods for tackling this challenge.



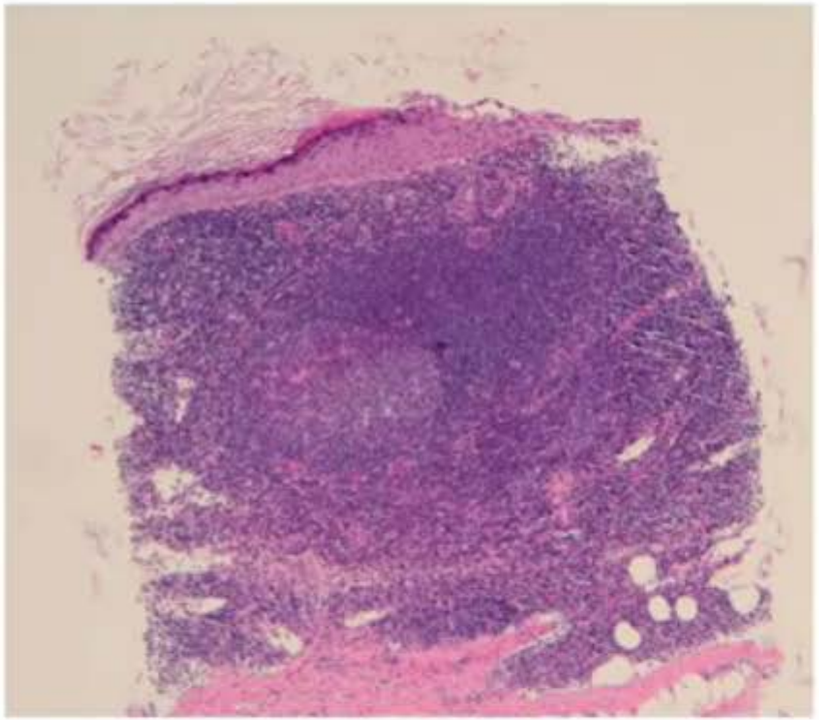
Comparable to



In the study, a majority vote of

1.00

Histopathology



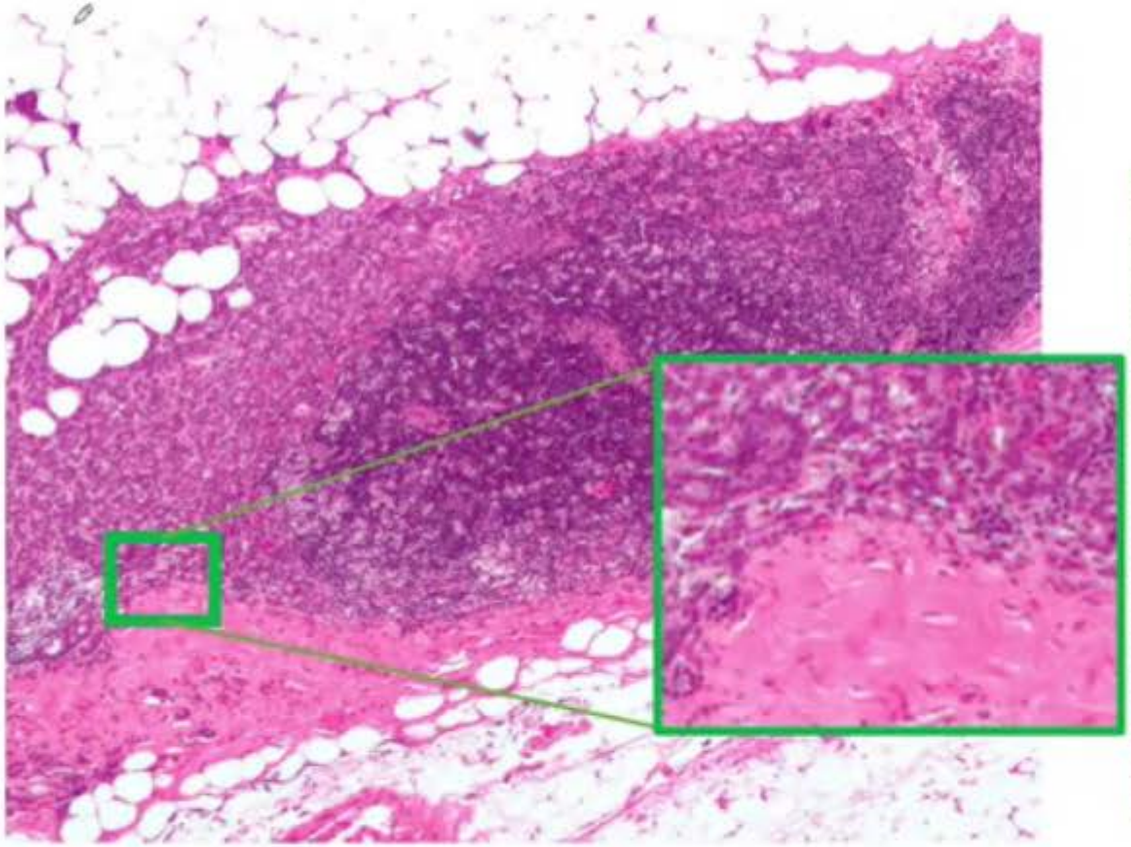
Whole-slide image

Cancer Spread
To Lymph Nodes?

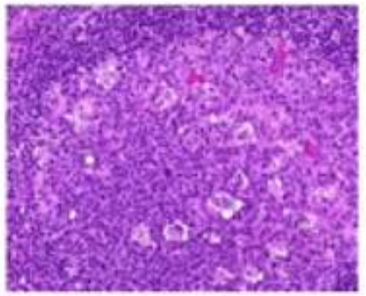
and the chance of recovery.

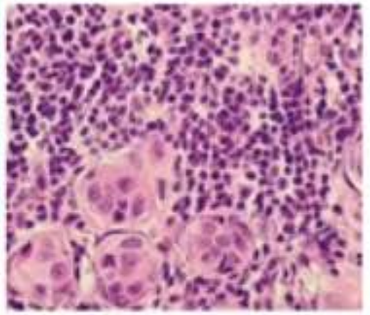
1.00

Histopathology



Images





Labels

Not Spread

Spread

270 whole-slide images

500,000+ patches

that instead of
feeding in one large,

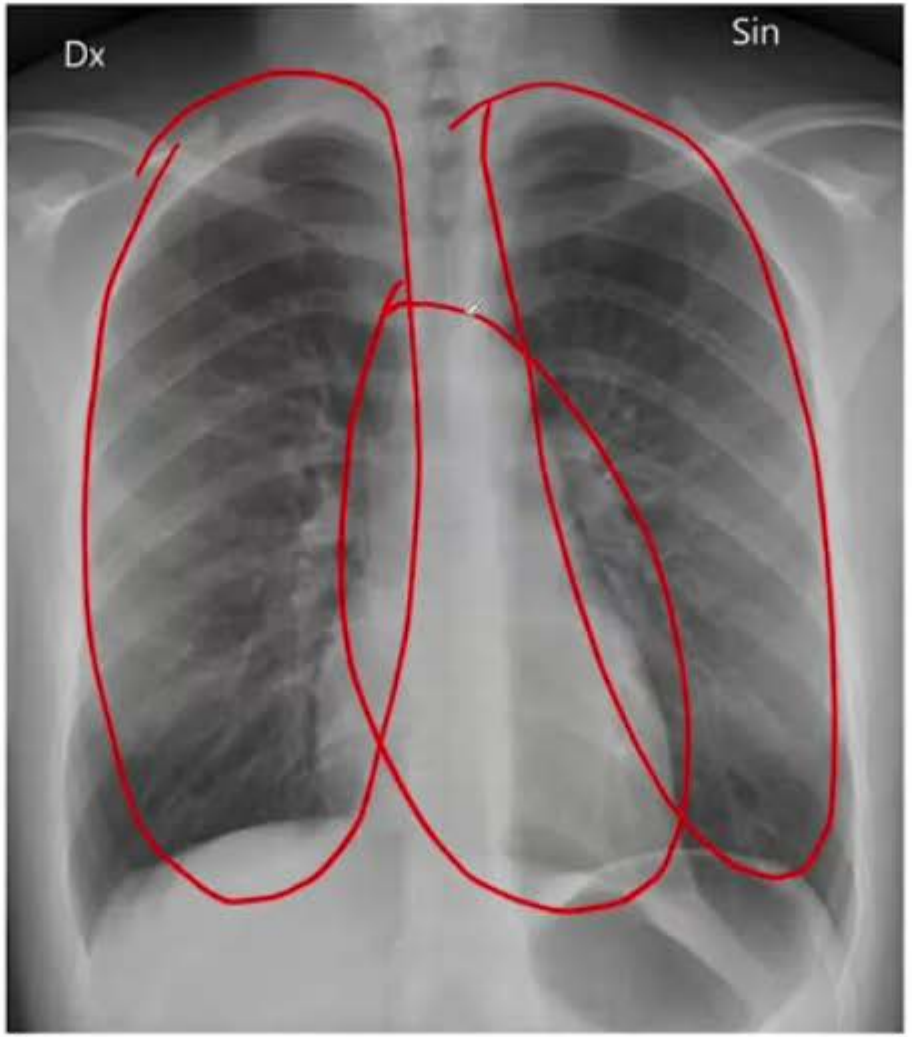
1.00

2 billion per year

in medicine with about 2 billion chest X-rays that are taken for a year.

1.00

Critical for detection Of pneumonia, lung cancer etc



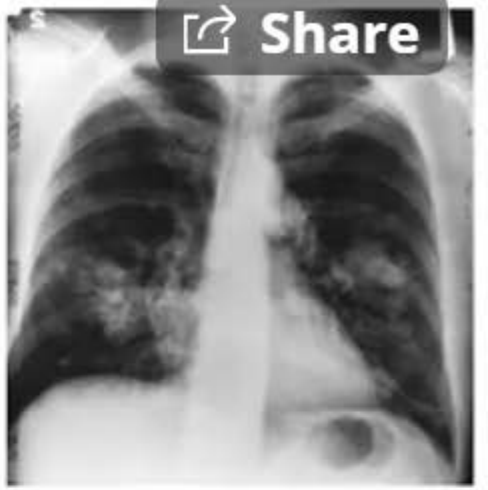
if a patient has pneumonia or lung cancer or another condition.

1.00

Share

Mass



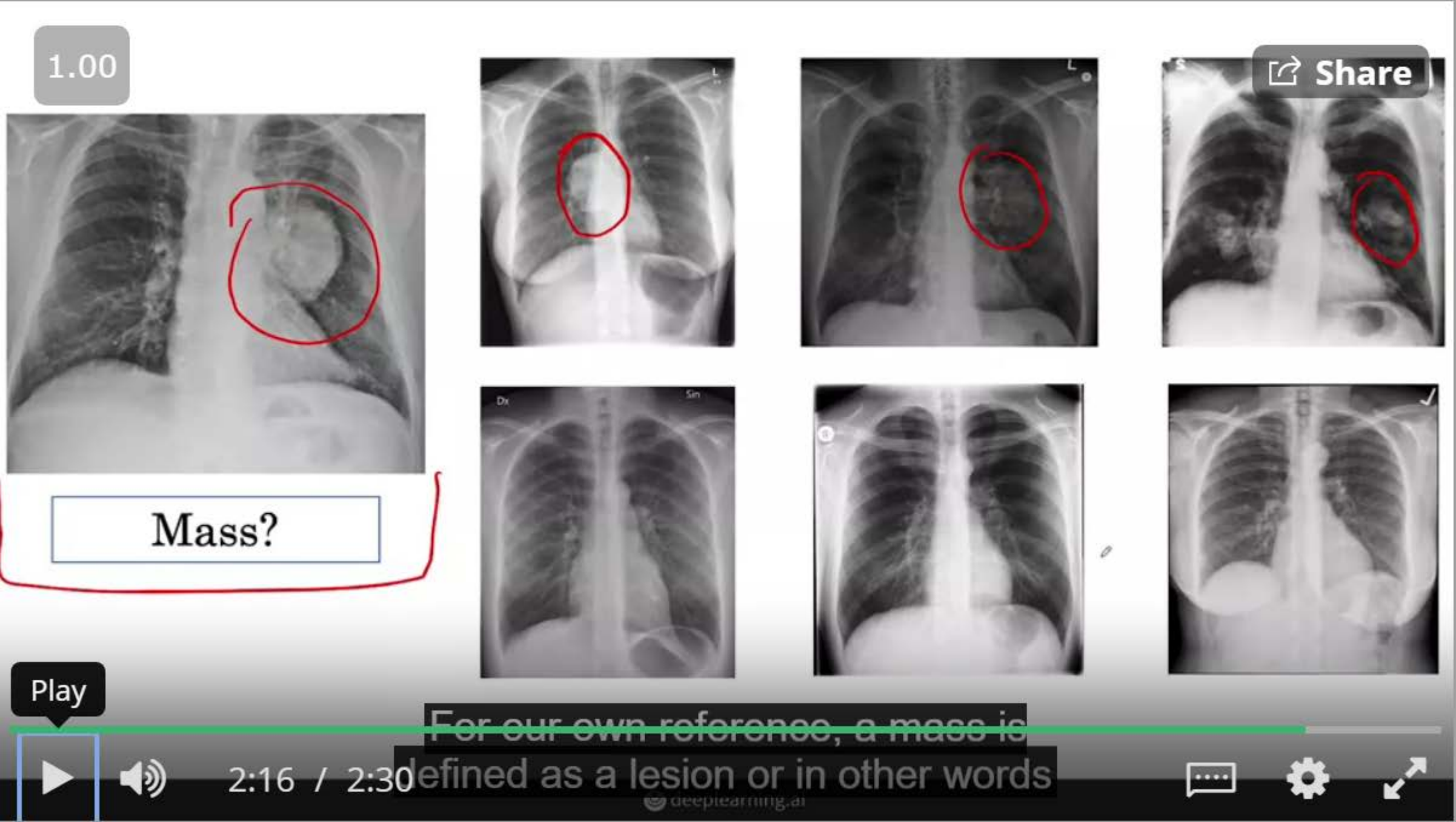


Normal


Play

three chest X-rays that are normal.

1:36 / 2:30


1.00
Share
Mass?
Play
2:16 / 2:30
For our own reference, a mass is
defined as a lesion or in other words

1.00

Train

Images

Learn

Algorithm

Labels

Mass

Normal

1.00

Share

Algorithm

Mass?

deep learning algorithm
model
neural network
convolutional neural network

Play

0:32 / 1:52

deeplearning.ai

1.00

Train

Images

Algorithm

Update

Prediction Probabilities

Desired Label: 1 (Mass)

0.48

Error (Loss) = 0.32

Error (Loss) = 0.31

0.51

Desired Label: 0 (Normal)

Share

1:30 / 1:52

deeplearning.ai

1.00

Train

Images

Algorithm

Updated

Prediction Probabilities

Desired Label: 1 (Mass)

0.60

Error (Loss) = 0.22

Error (Loss) = 0.15

0.30

Desired Label: 0 (Normal)

Algorithm

Penguin?

Algorithm

Mass?

3 Key Challenges

Class Imbalance	Multi-Task	Dataset Size
Weighted Loss / Resampling	Multi-Label Loss	Transfer Learning + Data Augmentation

Class Imbalance




Normal	Normal	Mass	Normal

prevalence

1.00

Algorithm

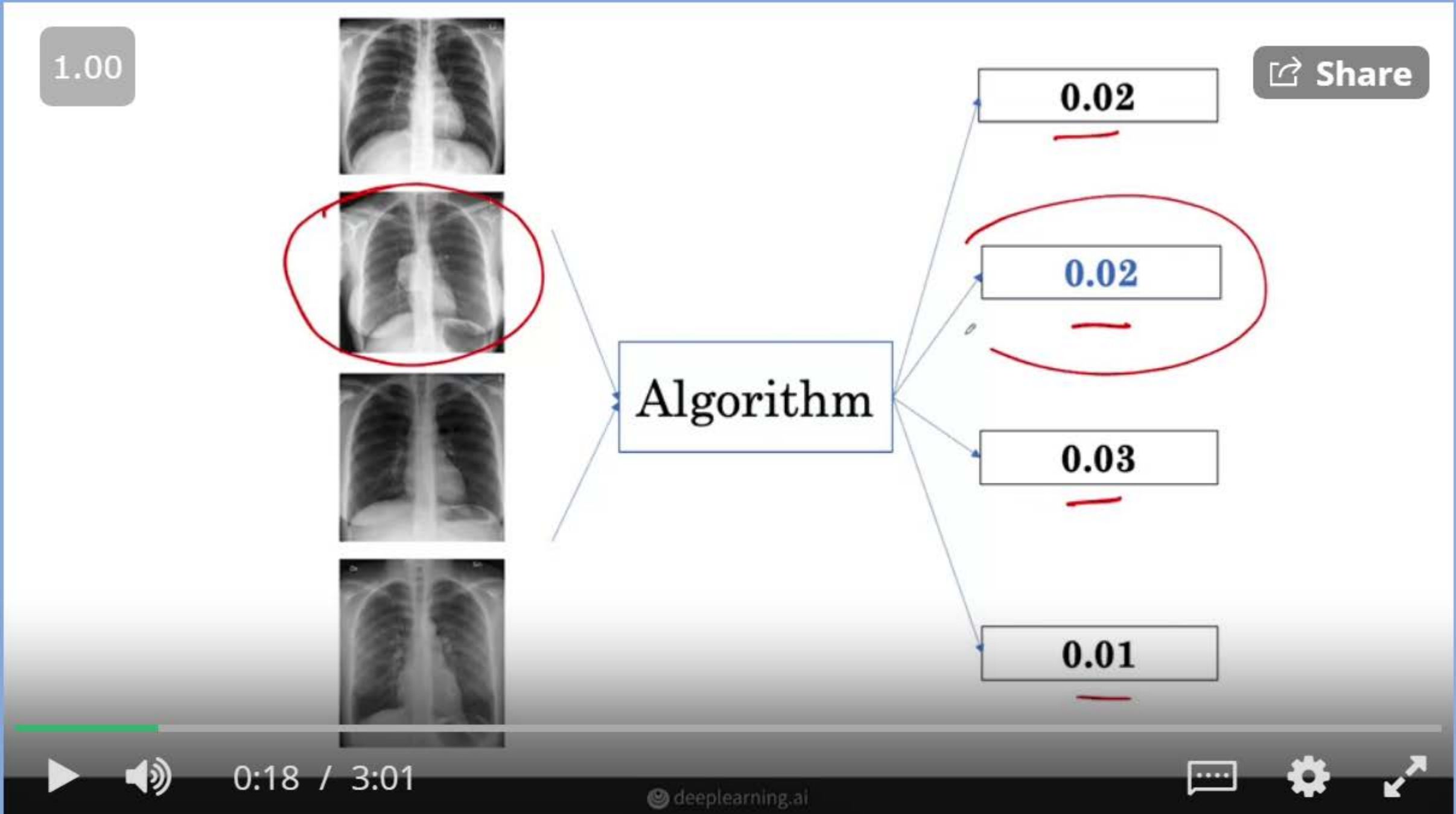
Poor Learning

Normal

Mass

Normal

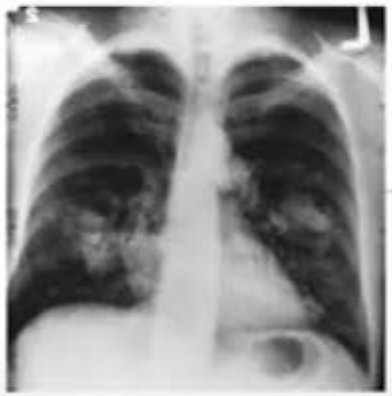
Normal


1.00
Share
0.02
0.02
Algorithm
0.03
0.01
0:18 / 3:01
deeplearning.ai

Binary cross-entropy loss

$$L(X, y) = \begin{cases} -\log P(Y = 1|X) & \text{if } y = 1 \\ -\log P(Y = 0|X) & \text{if } y = 0 \end{cases}$$

0 → 1



Algorithm

0.2 → $P(Y=1|X)$

Label 1

$L = -\log 0.2$

$= 0.70$

$P(Y=0|X) = 1 - P(Y=1|X)$

$$L(X,y) = \begin{cases} -\log P(Y=1|X) & \text{if } y=1 \\ -\log P(Y=0|X) & \text{if } y=0 \end{cases}$$

Algorithm

0.7

Label 0

$L = -\log(1-0.7)$

$P(Y=1|X)$

$= 0.52$

1.00

$$L(X, y) = \begin{cases} -\log P(Y = 1|X) & \text{if } y = 1 \\ -\log P(Y = 0|X) & \text{if } y = 0 \end{cases}$$

Share

Examples	Prediction Probabilities	Loss
P1 Normal	0.5	0.3
P2 Normal	0.5	0.3
P3 Normal	0.5	0.3
P4 Mass	0.5	0.3
P5 Normal	0.5	0.3
P6 Normal	0.5	0.3
P7 Mass	0.5	0.3
P8 Normal	0.5	0.3

$-\log(1-0.5) = 0.3$

$-\log 0.5$

0:46 / 3:18

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1.00

$$L(X, y) = \begin{cases} -\log P(Y = 1|X) & \text{if } y = 1 \\ -\log P(Y = 0|X) & \text{if } y = 0 \end{cases}$$

Examples		Loss
P1 Normal		0.3
P2 Normal		0.3
P3 Normal		0.3
P4 Mass	Total Loss From Mass Examples $0.3 \times 2 = 0.6$	0.3
P5 Normal	Total Loss From Normal Examples $0.3 \times 6 = 1.8$	0.3
P6 Normal		0.3
P7 Mass		0.3
P8 Normal		0.3

Examples

P1 Normal
P2 Normal
P3 Normal
P4 Mass
P5 Normal
P6 Normal
P7 Mass
P8 Normal

$$L(X, y) = \begin{cases} -\log P(Y = 1|X) & \text{if } y = 1 \\ -\log P(Y = 0|X) & \text{if } y = 0 \end{cases}$$

$$L(X, y) = \begin{cases} w_p \times -\log P(Y = 1|X) & \text{if } y = 1 \\ w_n \times -\log P(Y = 0|X) & \text{if } y = 0 \end{cases}$$

1.00

$$L(X,y) = \begin{cases} w_p \times -\log P(Y=1|X) & \text{if } y=1 \\ w_n \times -\log P(Y=0|X) & \text{if } y=0 \end{cases}$$

Share

Examples		Loss
P1 Normal		2/8 × 0.3 = 0.075
P2 Normal		2/8 × 0.3 = 0.075
P3 Normal		2/8 × 0.3 = 0.075
P4 Mass	Total Loss From Mass Examples == 0.225 × 2 = 0.45 Total Loss From Normal Examples = 0.075 × 6 = 0.45	6/8 × 0.3 = 0.225
P5 Normal		2/8 × 0.3 = 0.075
P6 Normal		2/8 × 0.3 = 0.075
P7 Mass		6/8 × 0.3 = 0.225
P8 Normal		2/8 × 0.3 = 0.075

Examples

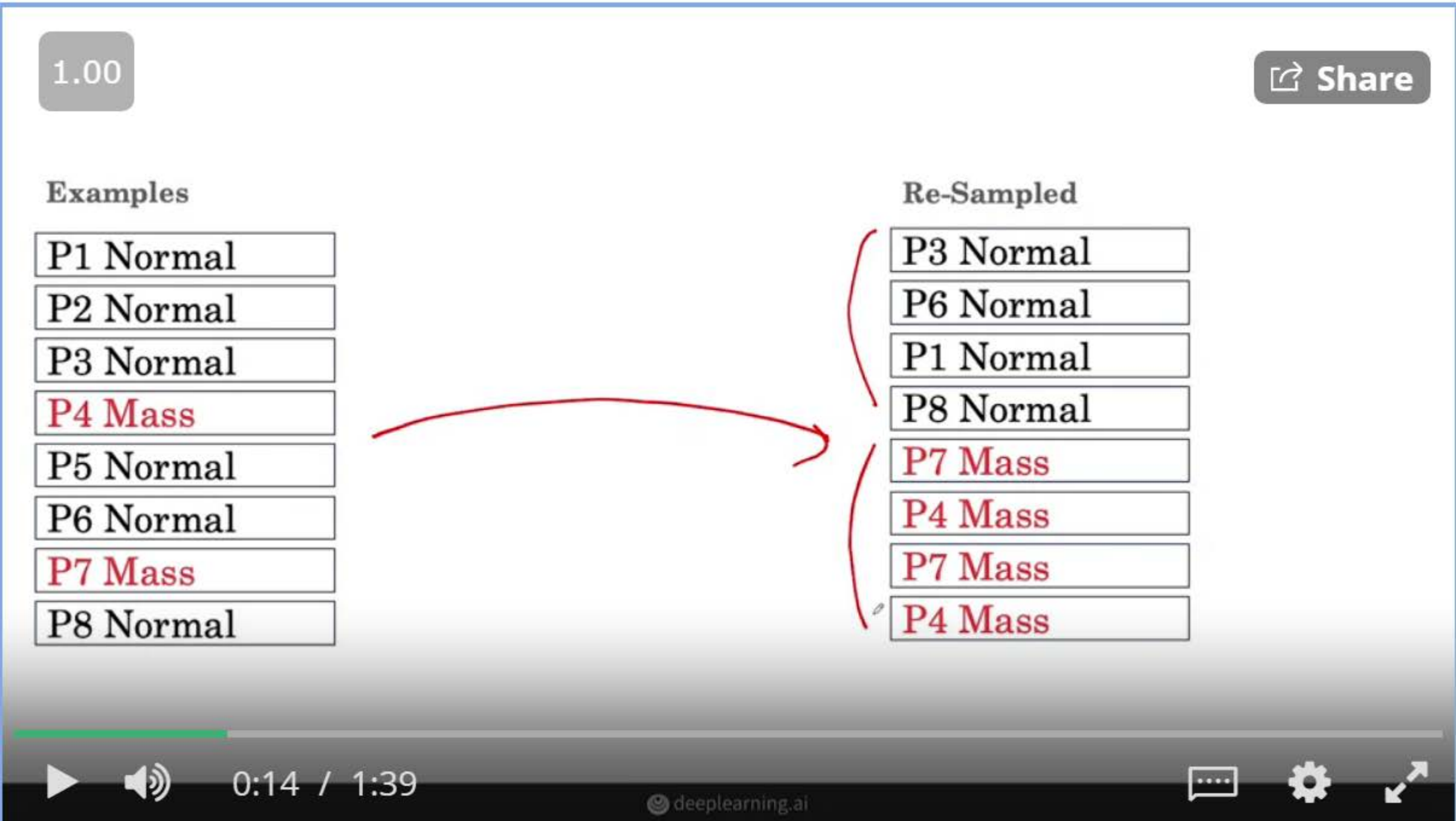
P1 Normal
P2 Normal
P3 Normal
P4 Mass
P5 Normal
P6 Normal
P7 Mass
P8 Normal

$$L(X, y) = \begin{cases} w_p \times -\log P(Y = 1|X) & \text{if } y = 1 \\ w_n \times -\log P(Y = 0|X) & \text{if } y = 0 \end{cases}$$

$$w_p = \frac{\text{num negative}}{\text{num total}} \qquad w_n = \frac{\text{num positive}}{\text{num total}}$$

$\frac{6}{8}$ $\frac{2}{8}$

Weighted Loss


1.00
Share
Examples
P1 Normal
P2 Normal
P3 Normal
P4 Mass
P5 Normal
P6 Normal
P7 Mass
P8 Normal
Re-Sampled
P3 Normal
P6 Normal
P1 Normal
P8 Normal
P7 Mass
P4 Mass
P7 Mass
P4 Mass
0:14 / 1:39
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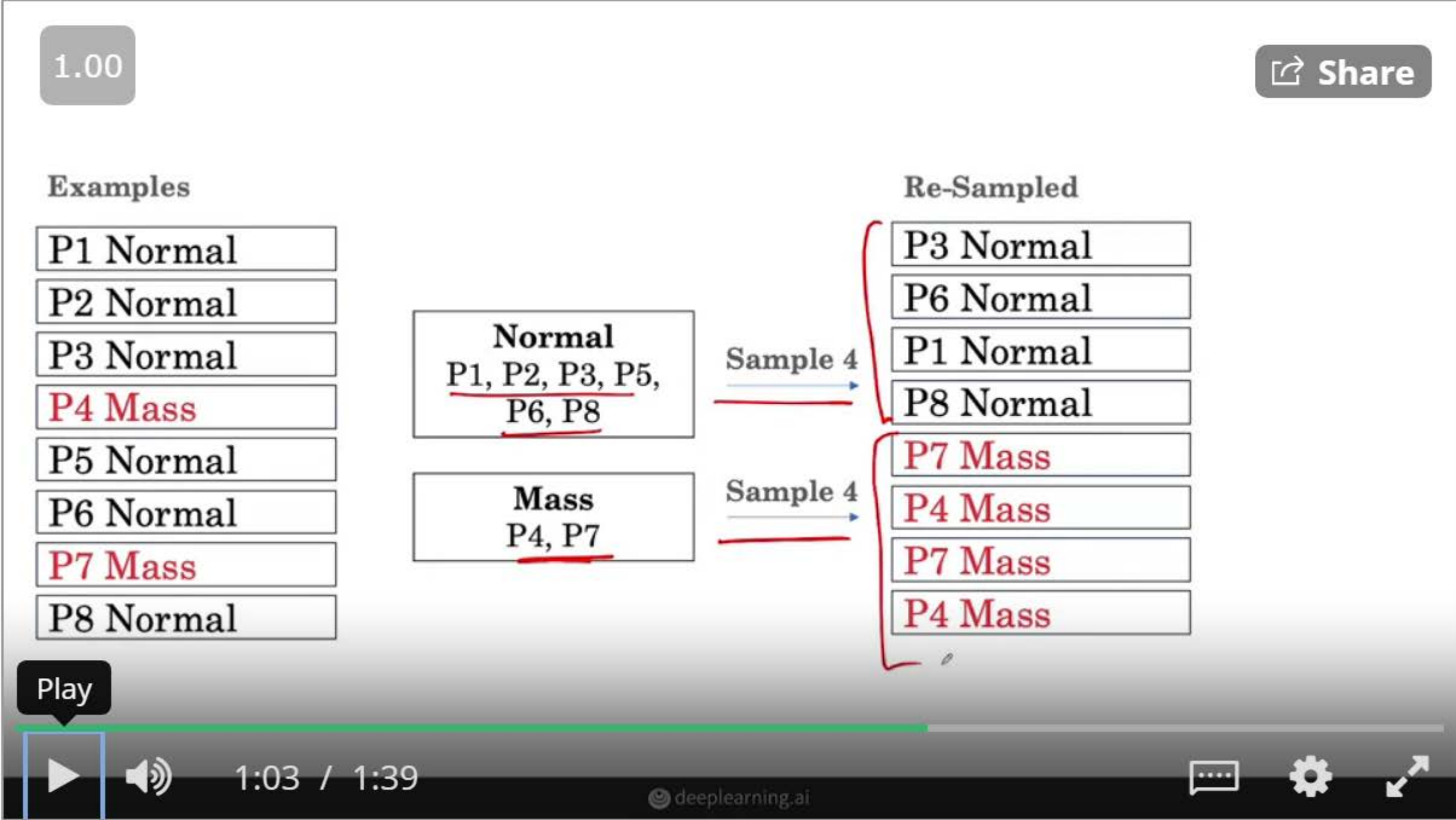

1.00
Share
Examples
P1 Normal
P2 Normal
P3 Normal
P4 Mass
P5 Normal
P6 Normal
P7 Mass
P8 Normal
Normal
P1, P2, P3, P5, P6, P8
Sample 4
Mass
P4, P7
Sample 4
Re-Sampled
P3 Normal
P6 Normal
P1 Normal
P8 Normal
P7 Mass
P4 Mass
P7 Mass
P4 Mass
Play
1:03 / 1:39
deeplearning.ai

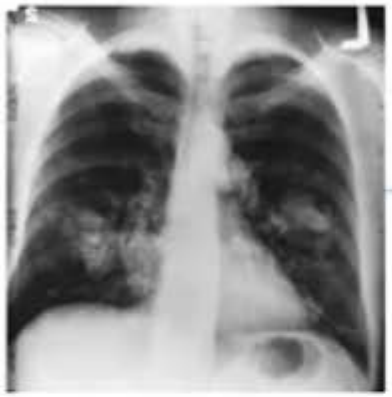
$$L(X, y) = \begin{cases} -\log P(Y = 1|X) & \text{if } y = 1 \\ -\log P(Y = 0|X) & \text{if } y = 0 \end{cases}$$

Re-Sampled	Prediction Probabilities	Loss
P3 Normal	0.5	0.3
P6 Normal	0.5	0.3
P1 Normal	0.5	0.3
P8 Normal	0.5	0.3
P7 Mass	0.5	0.3
P4 Mass	0.5	0.3
P7 Mass	0.5	0.3
P4 Mass	0.5	0.3

Total Loss From Mass Examples = $0.3 \times 4 = 1.2$

Total Loss From Normal Examples = $0.3 \times 4 = 1.2$

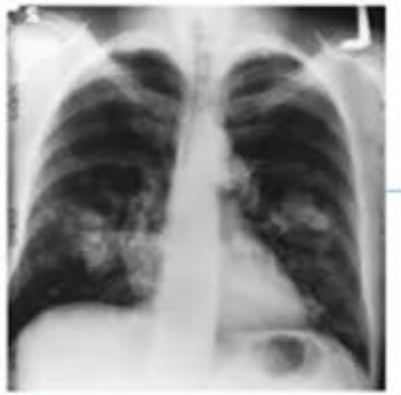
Re-sampling methods
(Undersampling, Oversampling)



Algorithm → Mass?

3 Key Challenges

- Class Imbalance
- **Multi-Task**
- Dataset Size

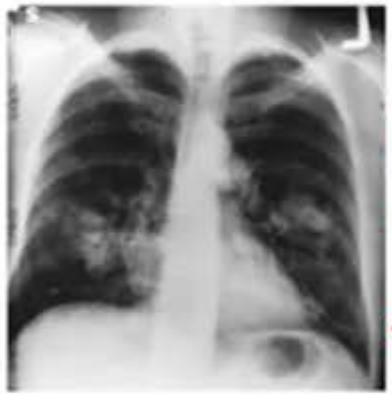


Algorithm

Mass or No Mass

Binary Task

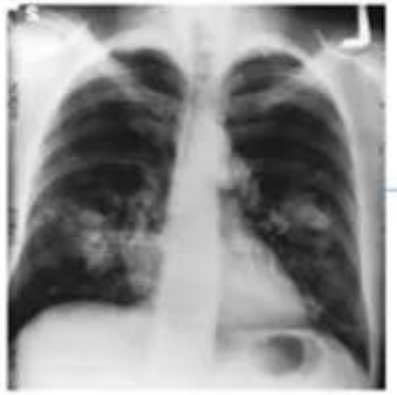
1.00



Mass or No Mass

Pneumonia or No Pneumonia

Edema or No Edema



Algorithm

Multi-Task

- Mass or No Mass
- Pneumonia or No Pneumonia
- Edema or No Edema

1.00

Examples (mass, pneumonia, edema)	Prediction Probabilities
P1 0, 1, 0	0.3, 0.1, 0.8
P2 0, 0, 1	0.1, 0.1, 0.8
P3 0, 1, 1	0.2, 0.2, 0.7
P4 1, 0, 1	0.6, 0.3, 0.8
P5 1, 1, 1	0.7, 0.7, 0.9
P6 1, 0, 0	0.8, 0.1, 0.2
P7 0, 1, 1	0.3, 0.9, 0.8
P8 0, 0, 0	0.1, 0.1, 0.2

$$L(X, y)$$

?

1.00

$$L(X, y_{\text{mass}}) + L(X, y_{\text{pneumonia}}) + L(X, y_{\text{edema}})$$

Examples (mass, pneumonia, edema)	Prediction Probabilities
P1 0, 1, 0	0.3, 0.1, 0.8
P2 0, 0, 1	0.1, 0.1, 0.8
P3 0, 1, 1	0.2, 0.2, 0.7
P4 1, 0, 1	0.6, 0.3, 0.8
P5 1, 1, 1	0.7, 0.7, 0.9
P6 1, 0, 0	0.8, 0.1, 0.2
P7 0, 1, 1	0.3, 0.9, 0.8
P8 0, 0, 0	0.1, 0.1, 0.2

$$L(X, y)$$

Multi-Label / Multi-Task Loss

1.00

$$L(X, y_{\text{mass}}) + L(X, y_{\text{pneumonia}}) + L(X, y_{\text{edema}})$$

Share

Examples (mass, pneumonia, edema)	Prediction Probabilities	Loss
P1 0, 1, 0	0.3, 0.1, 0.8	0.52 + 1.00 + 0.70
P2 0, 0, 1	0.1, 0.1, 0.8	0.05 + 0.05 + 0.10
P3 0, 1, 1	0.2, 0.2, 0.7	0.10 + 0.70 + 0.15
P4 1, 0, 1	0.6, 0.3, 0.8	0.22 + 0.52 + 0.10
P5 1, 1, 1	0.7, 0.7, 0.9	0.15 + 0.15 + 0.05
P6 1, 0, 0	0.8, 0.1, 0.2	0.10 + 0.05 + 0.10
P7 0, 1, 1	0.3, 0.9, 0.8	0.52 + 0.05 + 0.10
P8 0, 0, 0	0.1, 0.1, 0.2	0.05 + 0.05 + 0.10

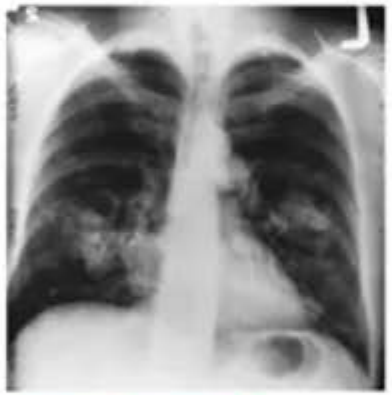
1.00

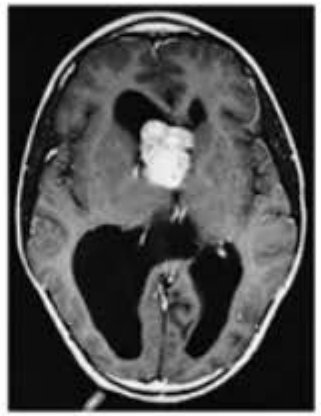
Multi-Task

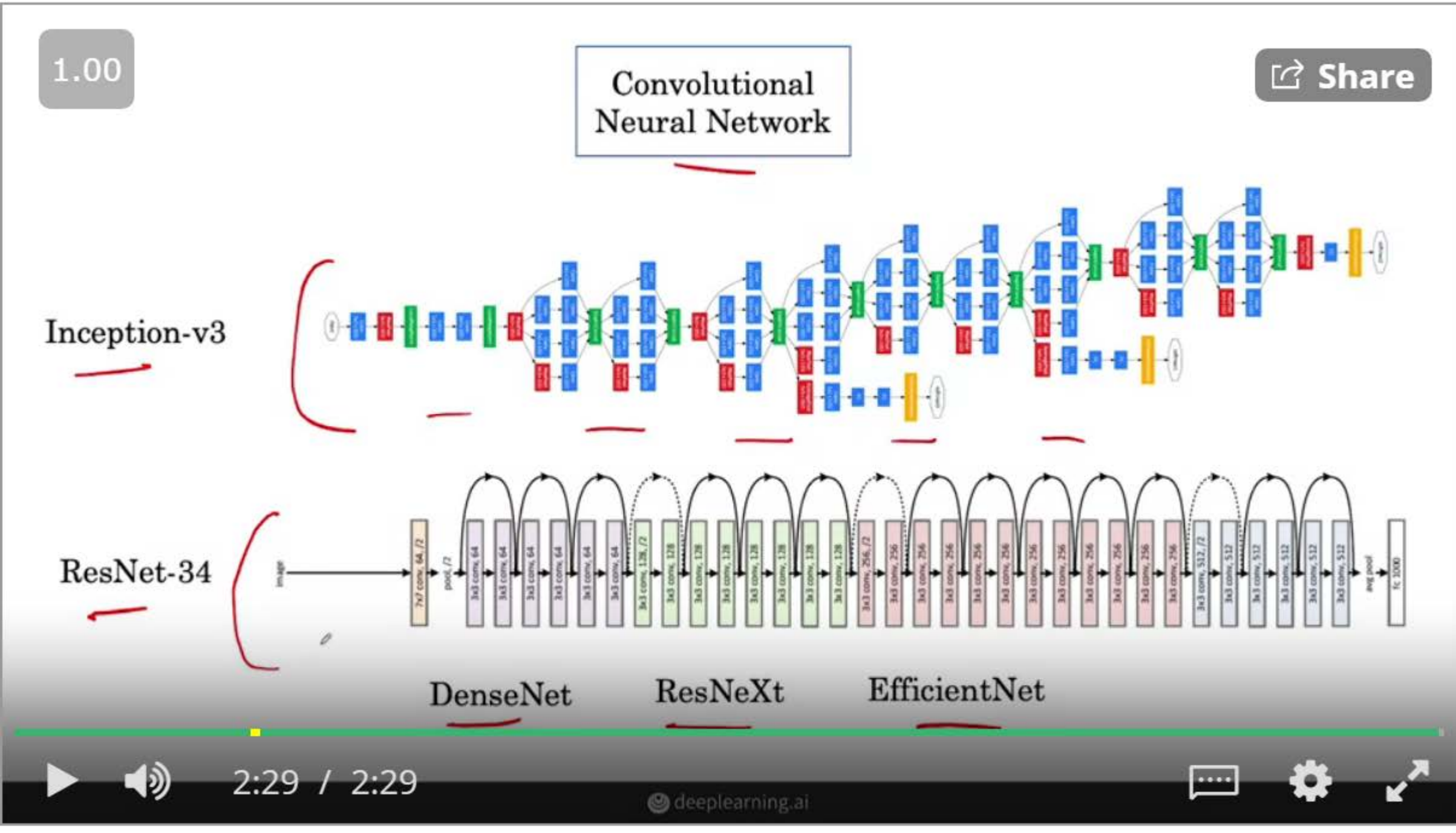
$$L(X, y_{\text{mass}}) + L(X, y_{\text{pneumonia}}) + L(X, y_{\text{edema}})$$

$$L(X, y_{\text{mass}}) = \begin{cases} -w_{\text{p,mass}} \log P(Y = 1|X) & \text{if } y = 1 \\ -w_{\text{n,mass}} \log P(Y = 0|X) & \text{if } y = 0 \end{cases}$$

Convolutional Neural Network





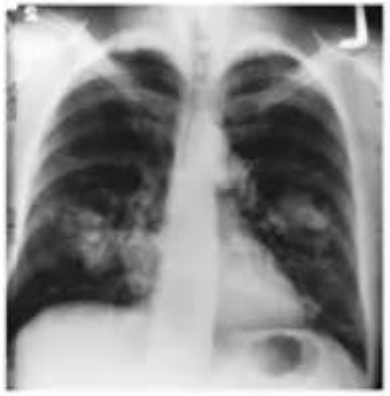

1.00
Share
Convolutional Neural Network
Inception-v3
ResNet-34
DenseNet
ResNeXt
EfficientNet
2:29 / 2:29
deeplearning.ai

1.00

Share

Millions of Images with Labels

~10k or ~100k Images with Labels



0:13 / 2:54

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1. Pretraining

Convolutional Neural Network

Penguin or Cat or Dog

Copy / Transfer learned features

Convolutional Neural Network

1. Pretraining

Convolutional Neural Network

Penguin or Cat or Dog

2. Fine-tuning

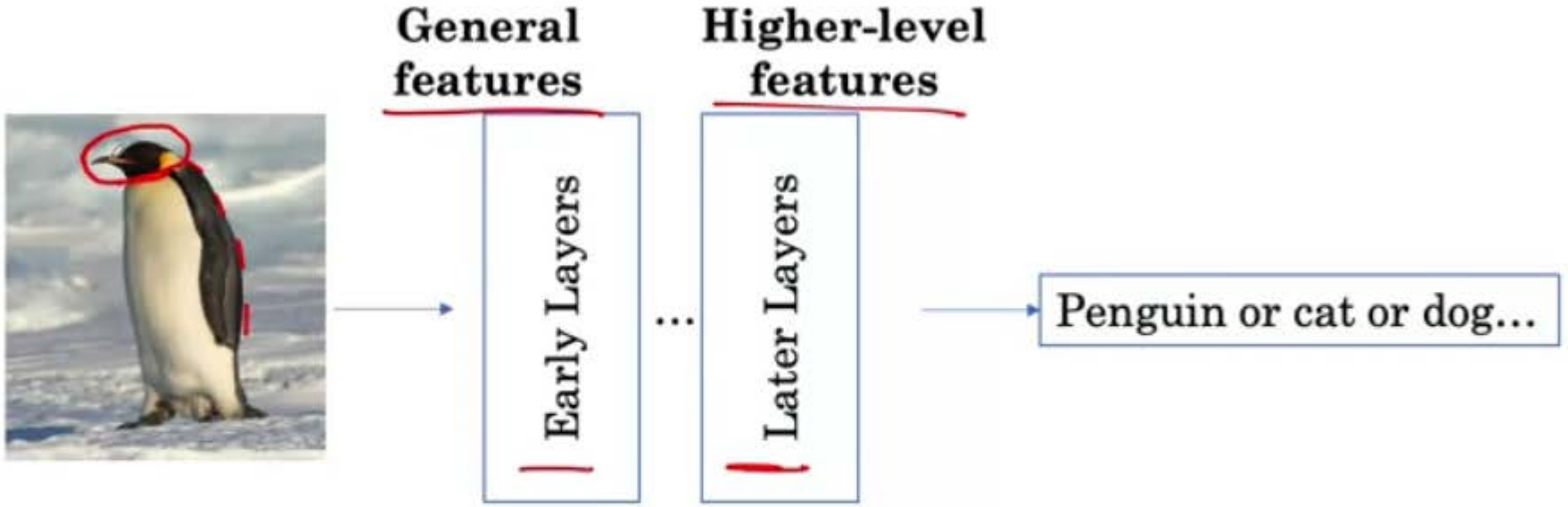
Convolutional Neural Network

Mass or No Mass

Pneumonia or No Pneumonia

Edema or No Edema

Update



2. Fine-tuning

General features

Higher-level features

Early Layers

...

Later Layers

Mass or No Mass

Pneumonia or No Pneumonia

Edema or No Edema

Option 1	Update	Update
Option 2	Do not Update	Update

Pretraining + Fine-tuning

Transfer Learning

Mass

Mass

Mass

Mass

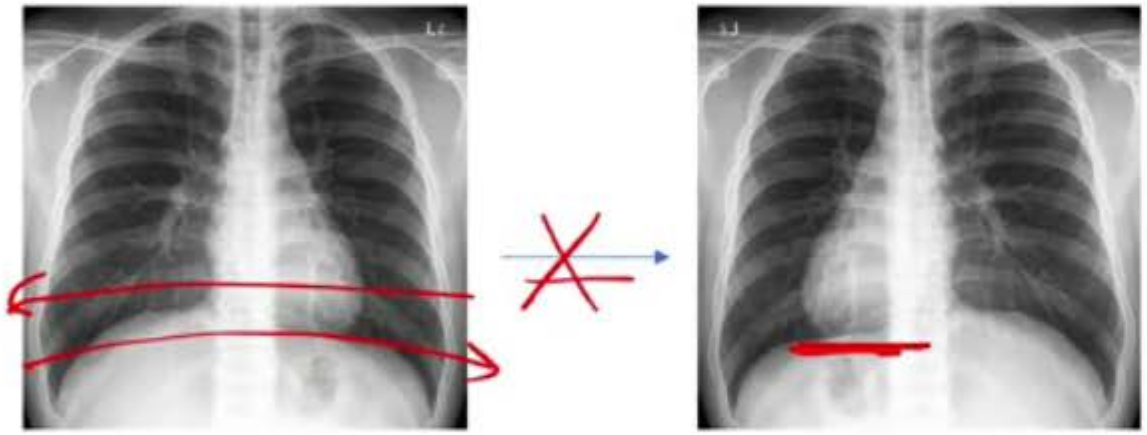
Data Augmentation

Do Augmentations Reflect Variations In Real World?

Mass

Mass

Do Augmentations Keep the Label the Same?

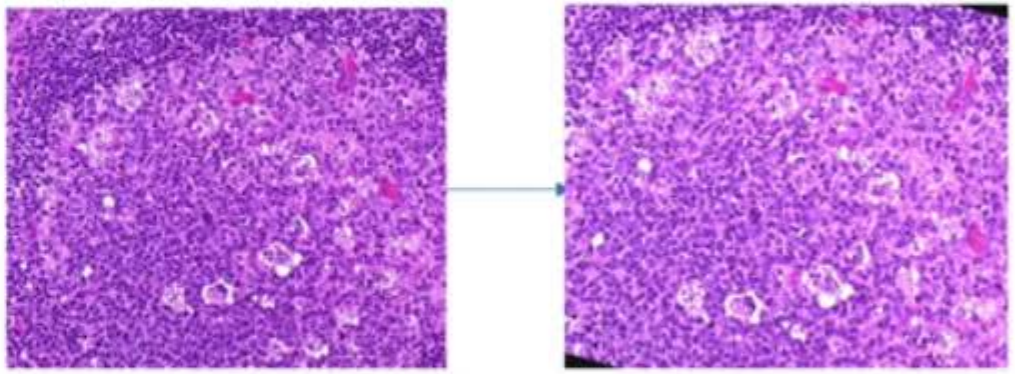


Normal

Normal
Or
Dextrocardia?

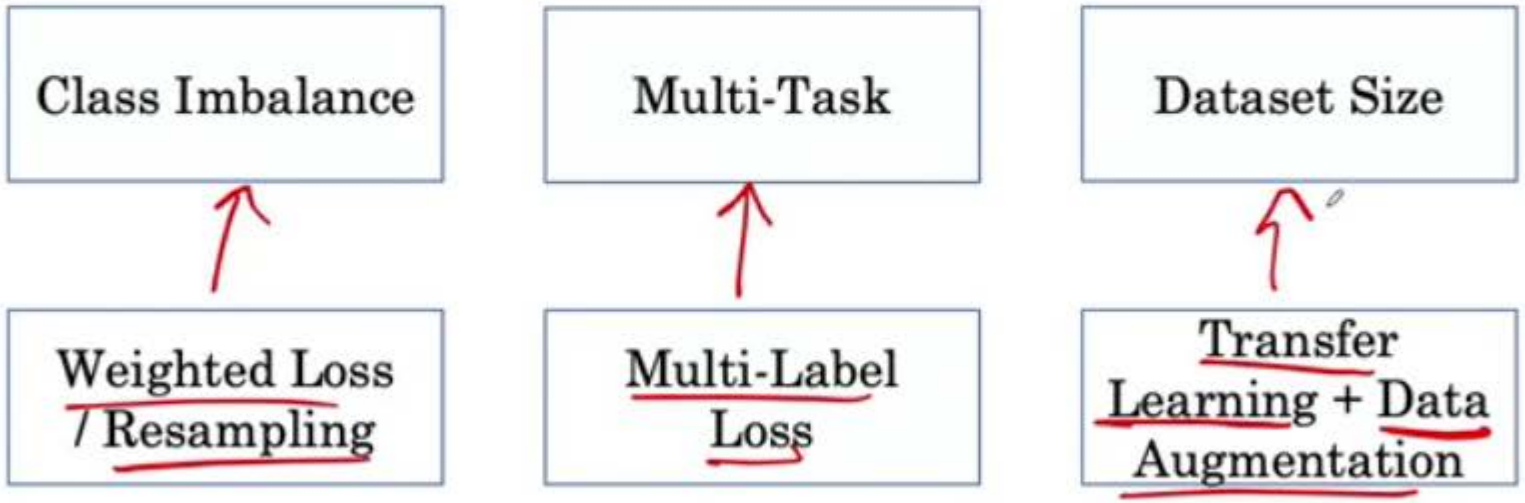
1.00

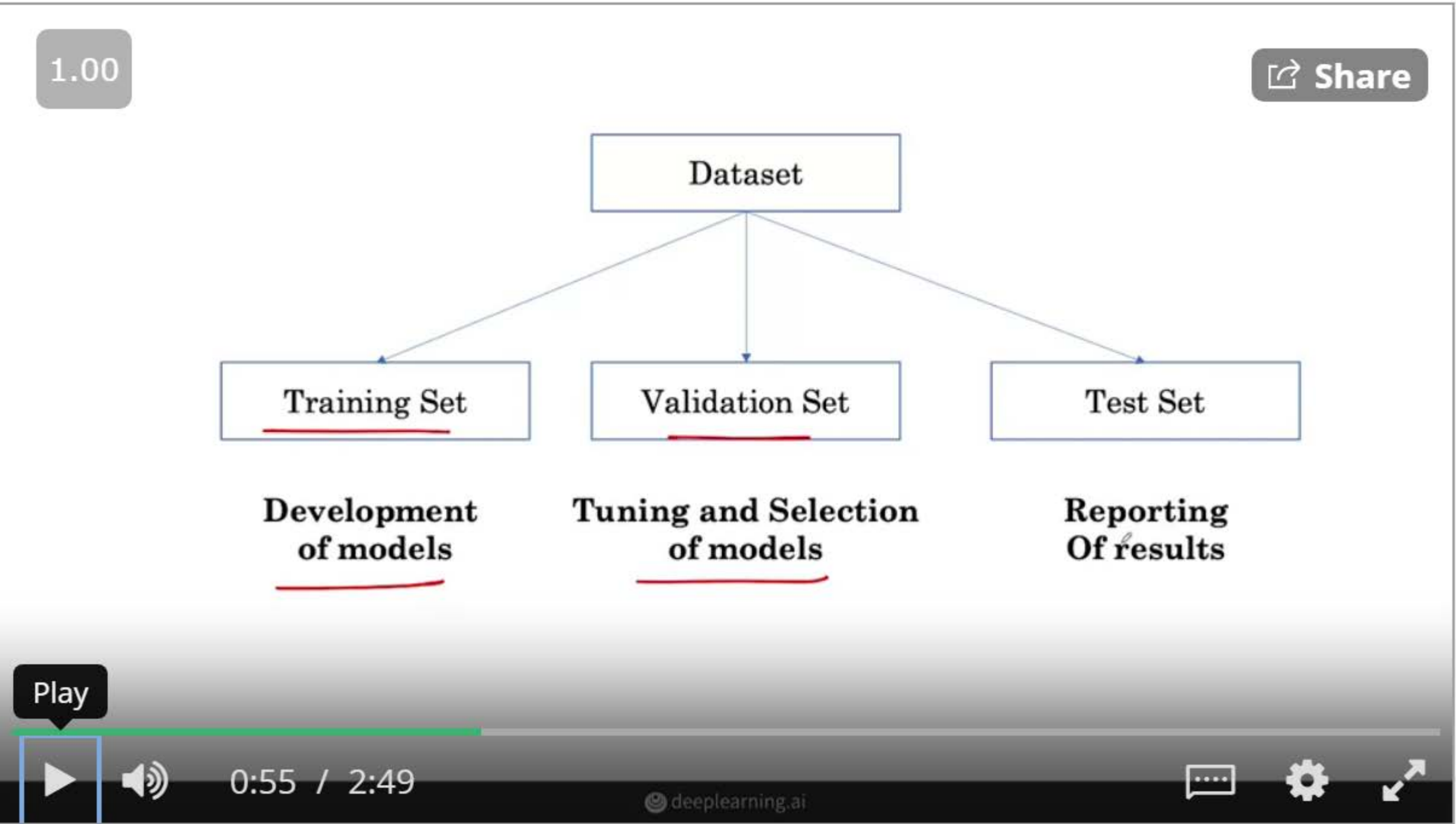
Rotate + Flip

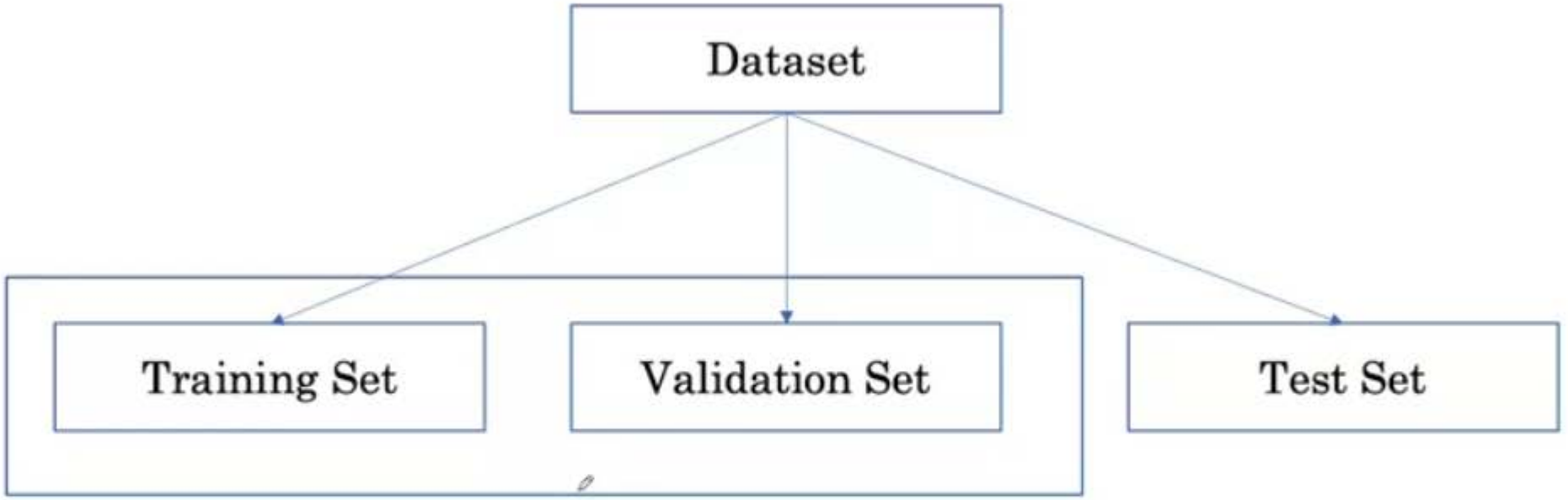


Rotate + Crop + Color Noise

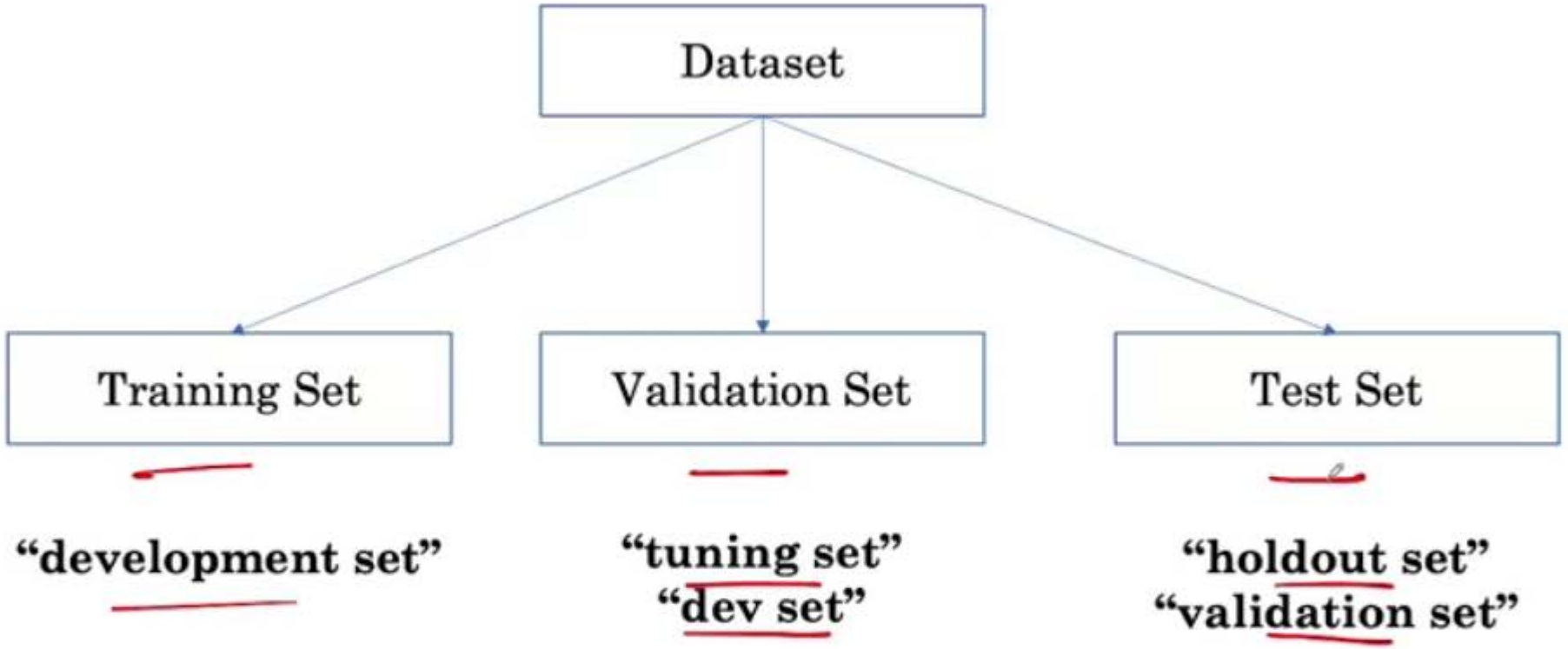
1.00

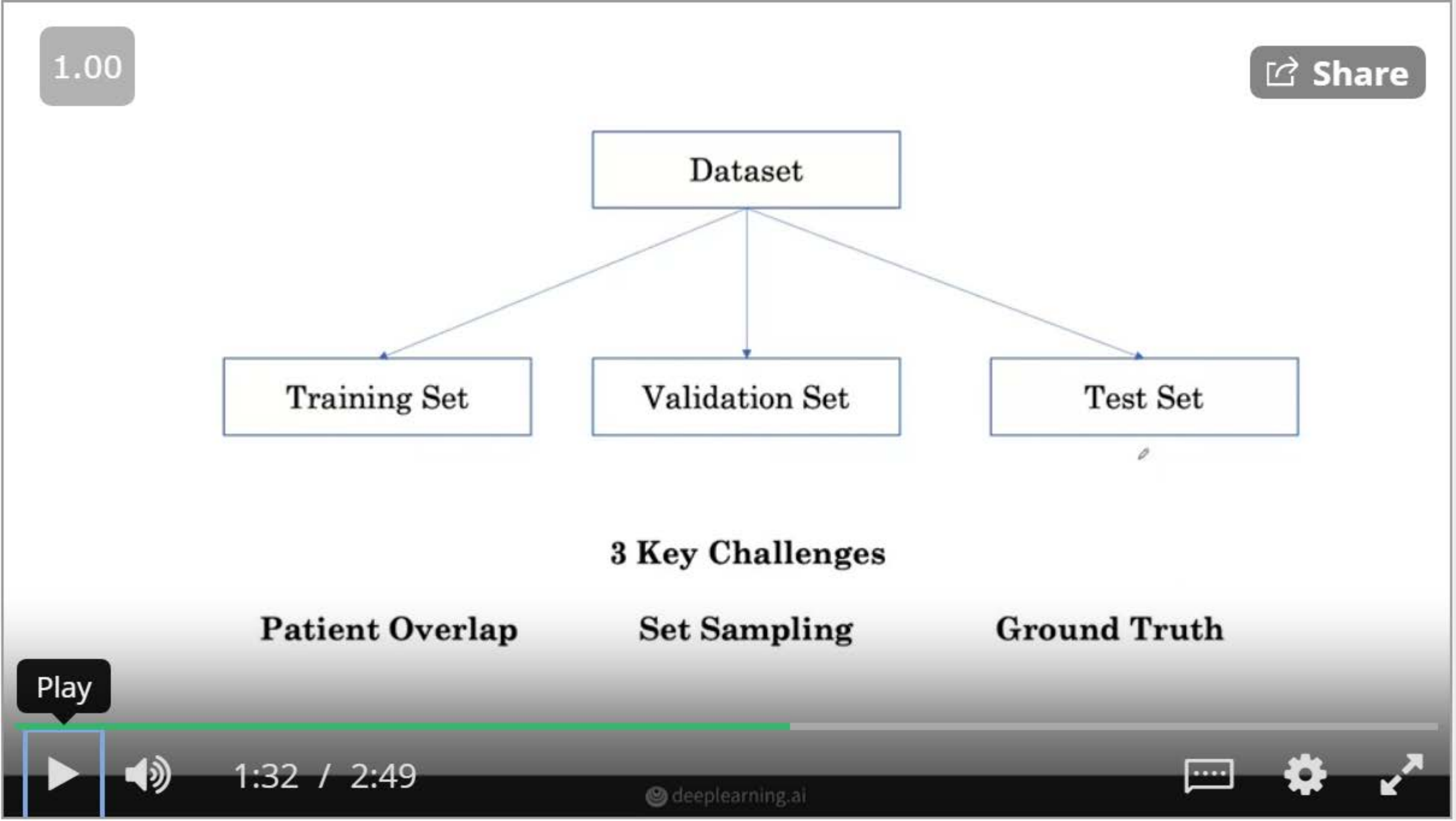

Class Imbalance
Multi-Task
Dataset Size
Weighted Loss / Resampling
Multi-Label Loss
Transfer Learning + Data Augmentation

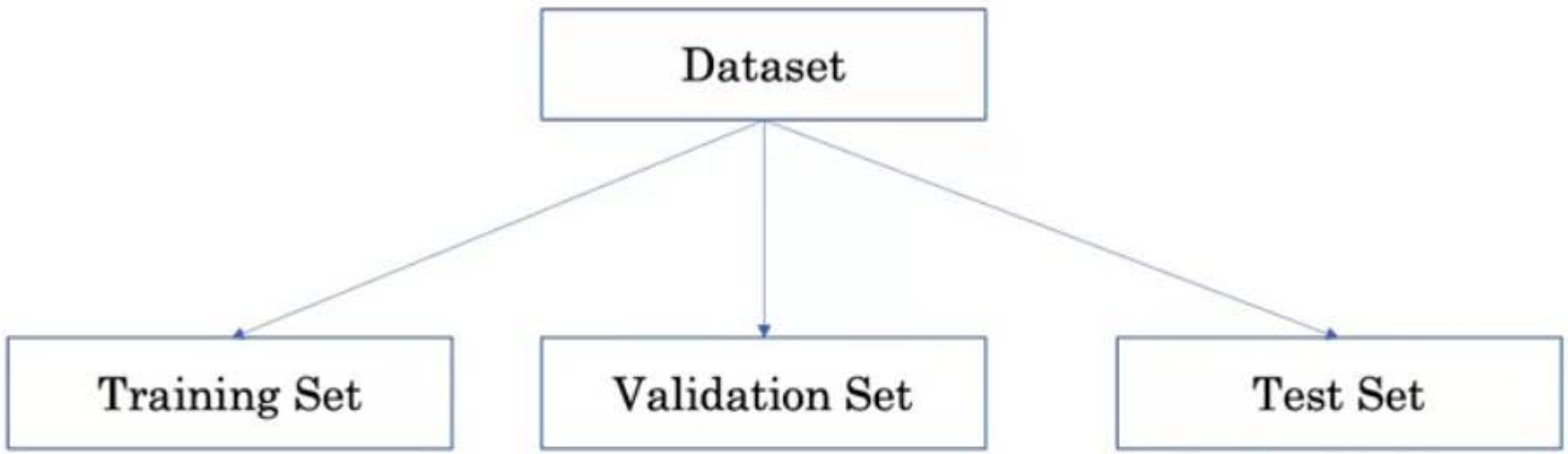

1.00
Share
Dataset
Training Set
Validation Set
Test Set
Development of models
Tuning and Selection of models
Reporting Of results
Play
0:55 / 2:49
deeplearning.ai



Cross-validation


Dataset
Training Set
Validation Set
Test Set
"development set"
"tuning set"
"dev set"
"holdout set"
"validation set"


1.00
Share
Dataset
Training Set
Validation Set
Test Set
3 Key Challenges
Patient Overlap
Set Sampling
Ground Truth
Play
1:32 / 2:49
deeplearning.ai



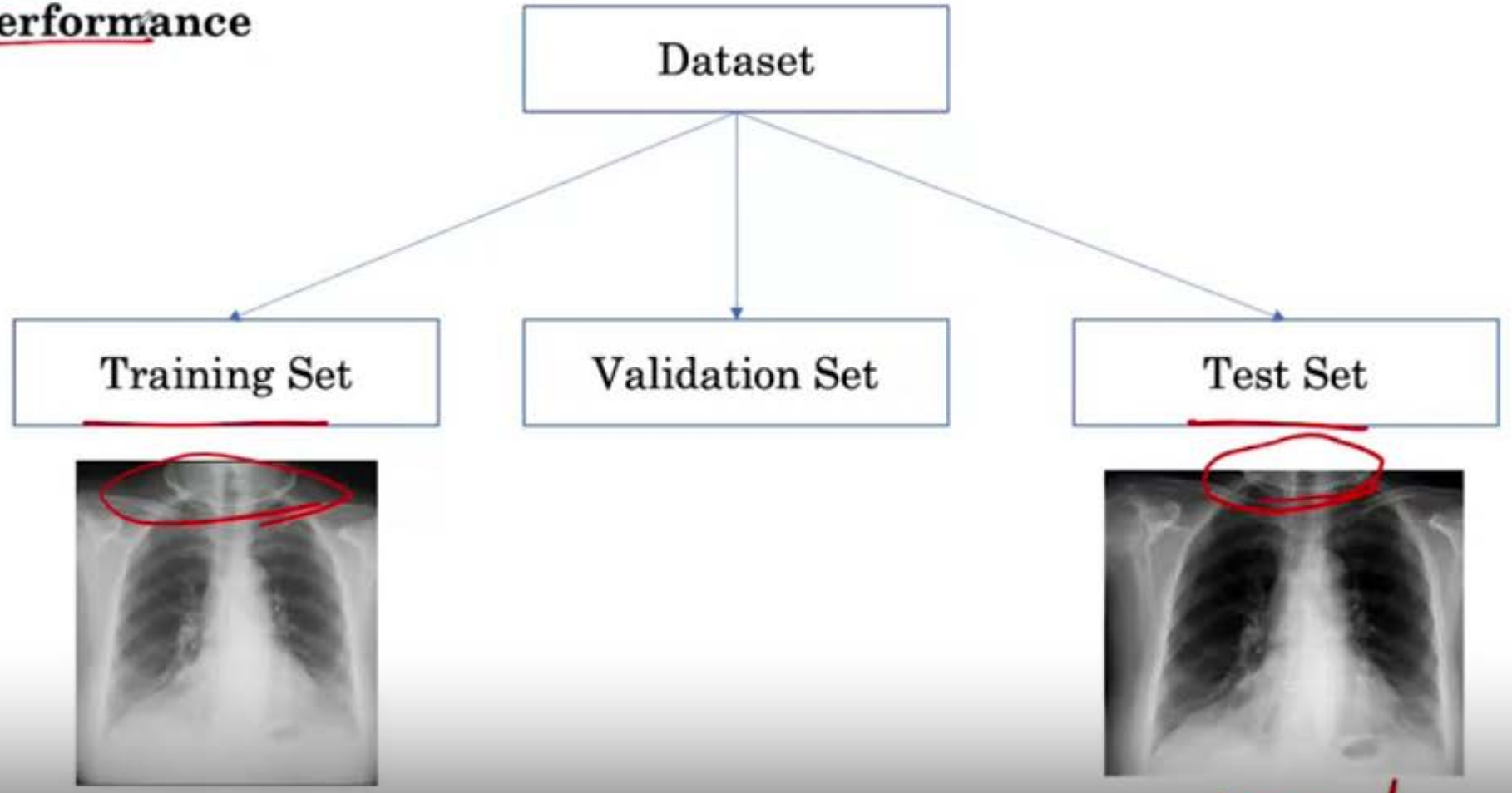
3 Key Challenges

Patient Overlap **Set Sampling** **Ground Truth**

1.00

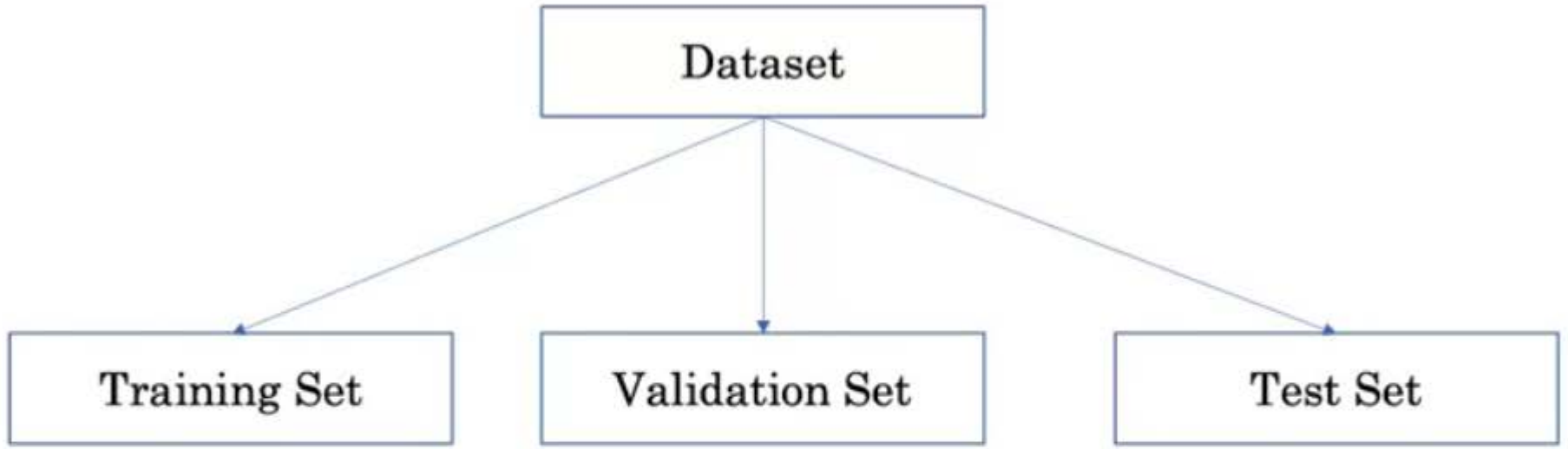
Share

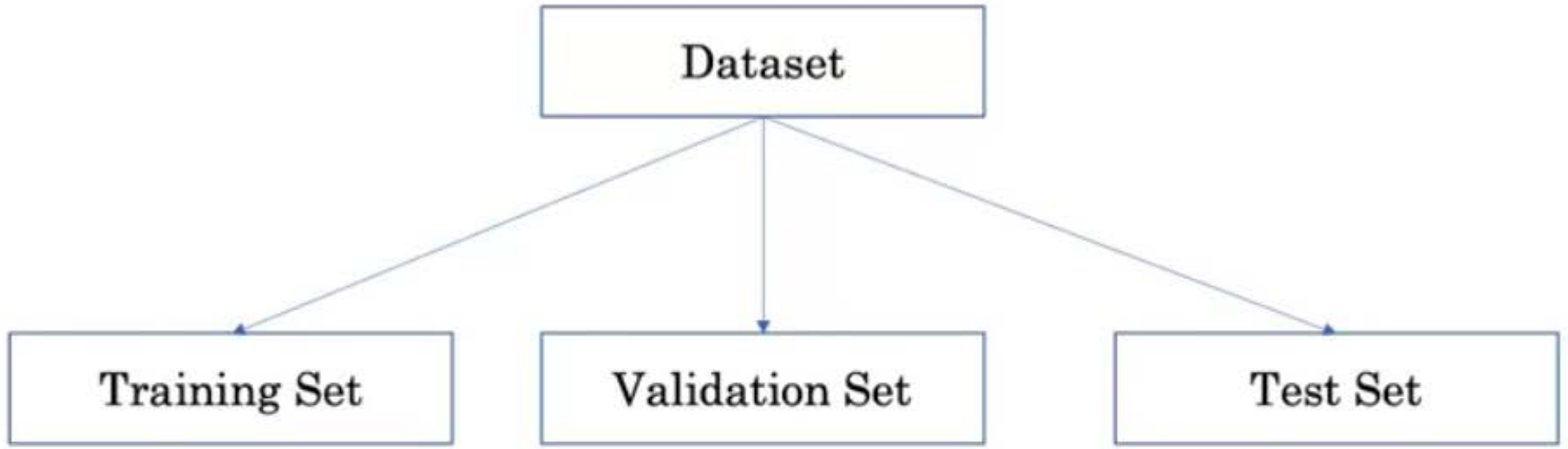
Over-optimistic Test set Performance



2:46 / 2:49

deeplearning.ai





Split By Image

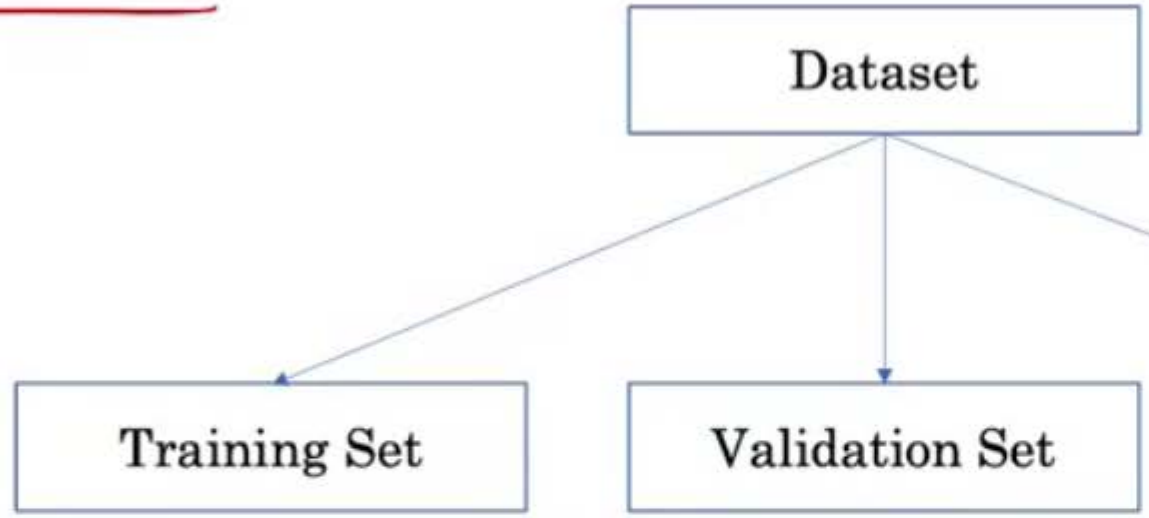


Image	Patient id	Label (Mass)	...
xray1.jpg	20	1	
xray4.jpg	17	0	
xray7.jpg	32	0	
...			

Image	Patient id	Label (Mass)	...
xray2.jpg	20	1	
xray5.jpg	11	0	
xray9.jpg	32	0	
...			

Image	Patient id	Label (Mass)	...
xray0.jpg	20	1	
xray3.jpg	38	0	
xray8.jpg	32	0	
...			

Patient Overlap

Split By Patient

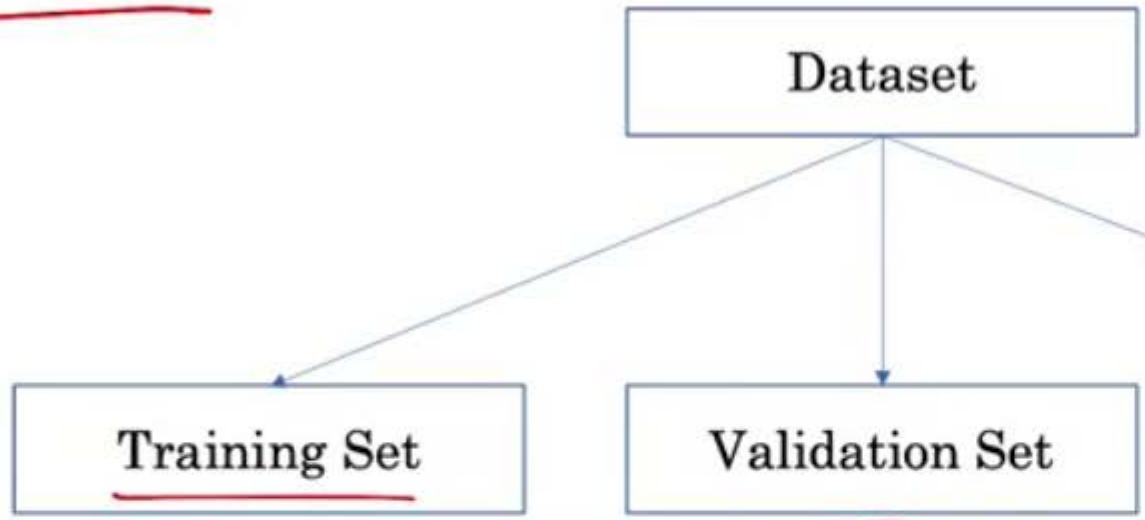


Image	Patient id	Label (Mass)	...
xray1.jpg	20	1	
xray2.jpg	20	1	
xray0.jpg	20	1	
...			

Image	Patient id	Label (Mass)	...
xray7.jpg	32	1	
xray8.jpg	32	0	
xray9.jpg	32	0	
...			

Image	Patient id	Label (Mass)	...
xray4.jpg	17	0	
xray3.jpg	38	0	
xray5.jpg	11	0	
...			

1.00

~10k or ~100k Patients with Labels

Image	Patient id	Label (Mass)	...
xray10.jpg	15	0	
xray23.jpg	24	0	
xray31.jpg	20	0	
xray41.jpg	56	1	
...			

Sizes in Studies
120 CT scans, 400-500 X-Rays, 130 Whole Slides

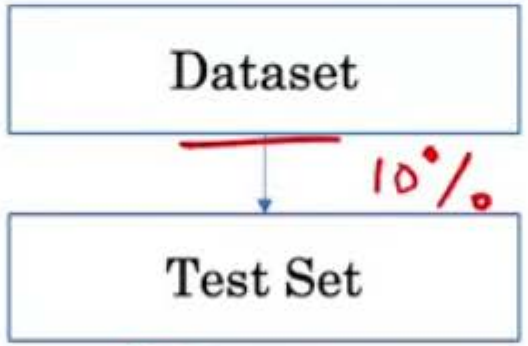


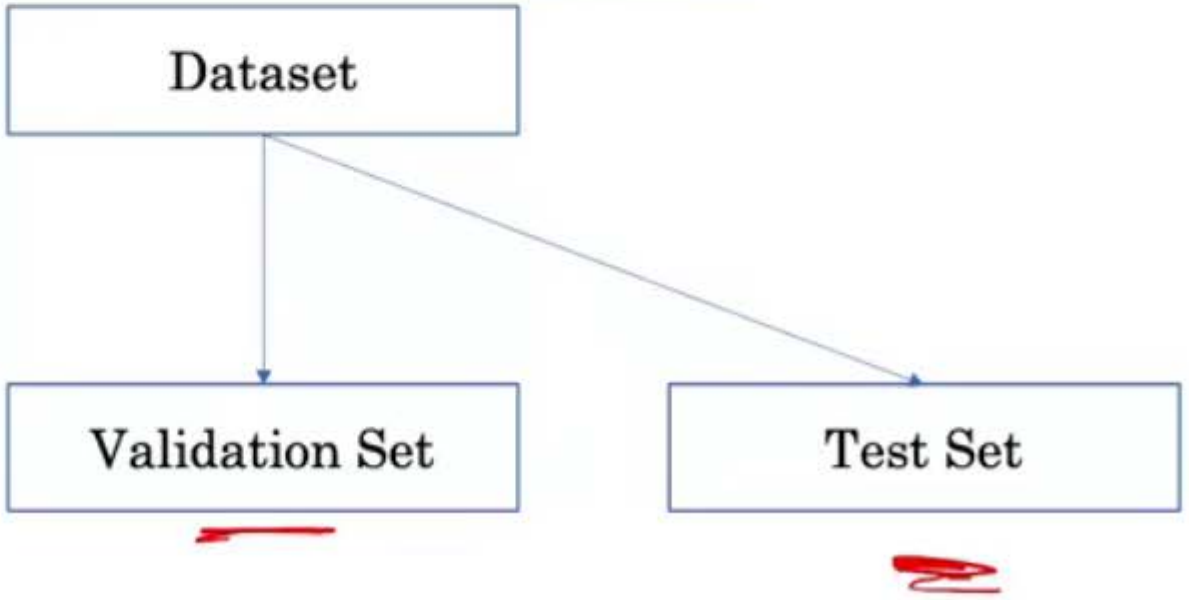
Image	Patient id	Label (Mass)	...
xray4.jpg	17	0	
xray3.jpg	38	0	
xray5.jpg	11	0	
...			

1.00

Image	Patient id	Label (Mass)	...
xray10.jpg	15	0	
xray23.jpg	24	0	
xray31.jpg	20	0	
xray41.jpg	56	1	
...			

Sample Test Set, then Validation, then Train

Sample to have same distribution of classes as the test set.

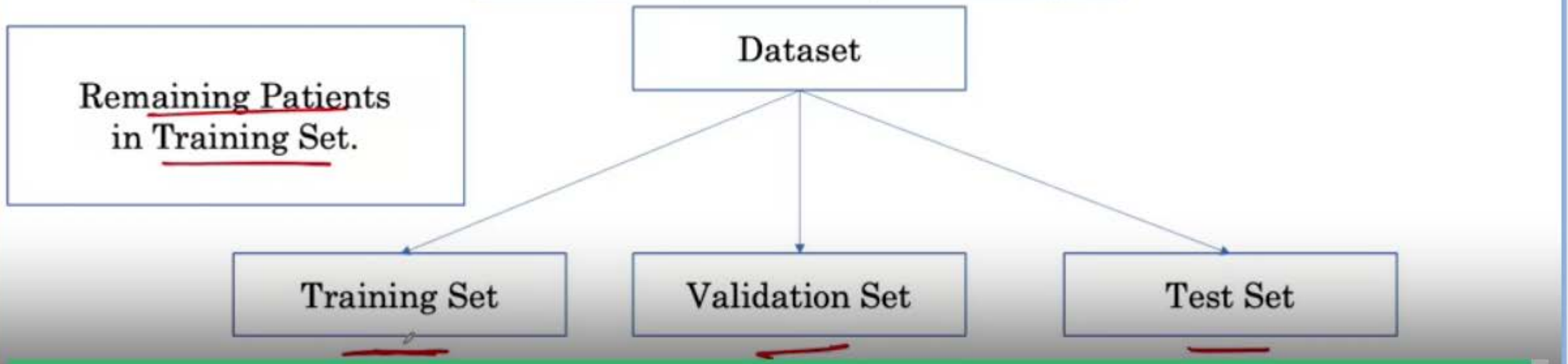


1.00

Share

Image	Patient id	Label (Mass)	...
xray10.jpg	15	0	
xray23.jpg	24	0	
xray31.jpg	20	0	
xray41.jpg	56	1	
...			

Sample Test Set, then Validation, then Train



2:47 / 2:49

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1.00
Share
Ground Truth /
Reference Standard
Play
0:12 / 1:31
deeplearning.ai

Pneumonia

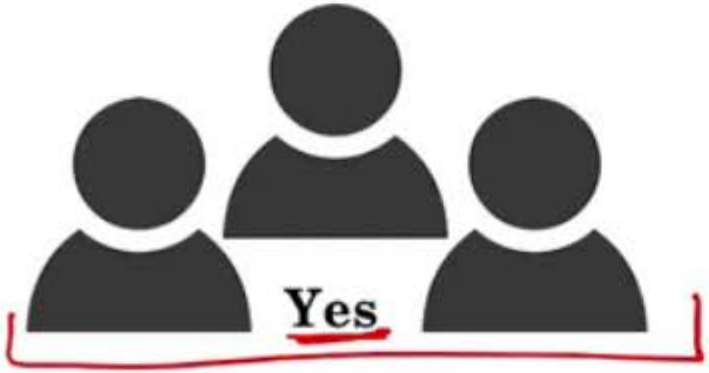
Other Disease

inter-observer disagreement

1.00

Is it pneumonia? Yes

Consensus Voting

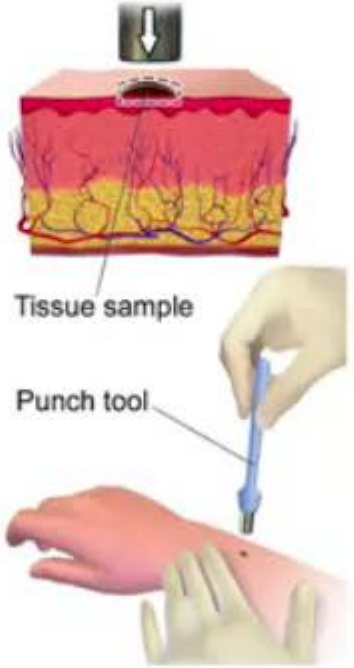


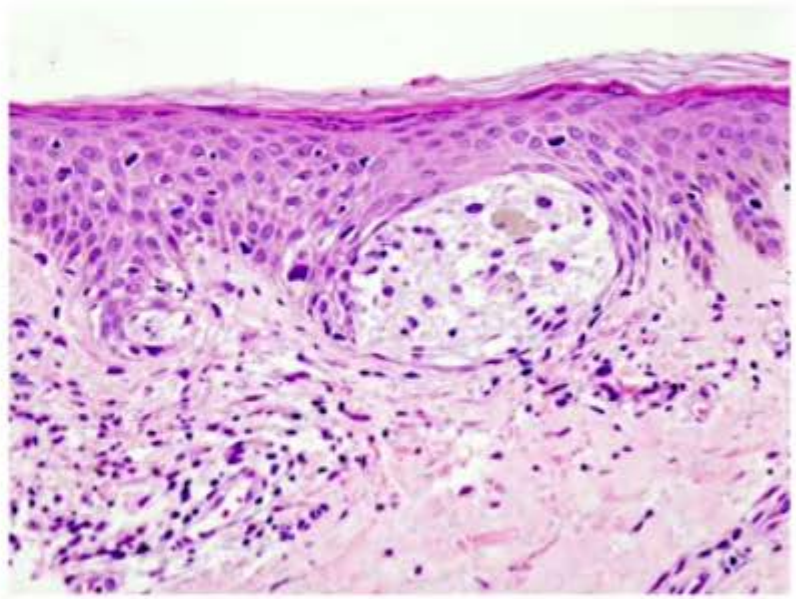
Is it pneumonia? Yes

CT Confirmation

Mass

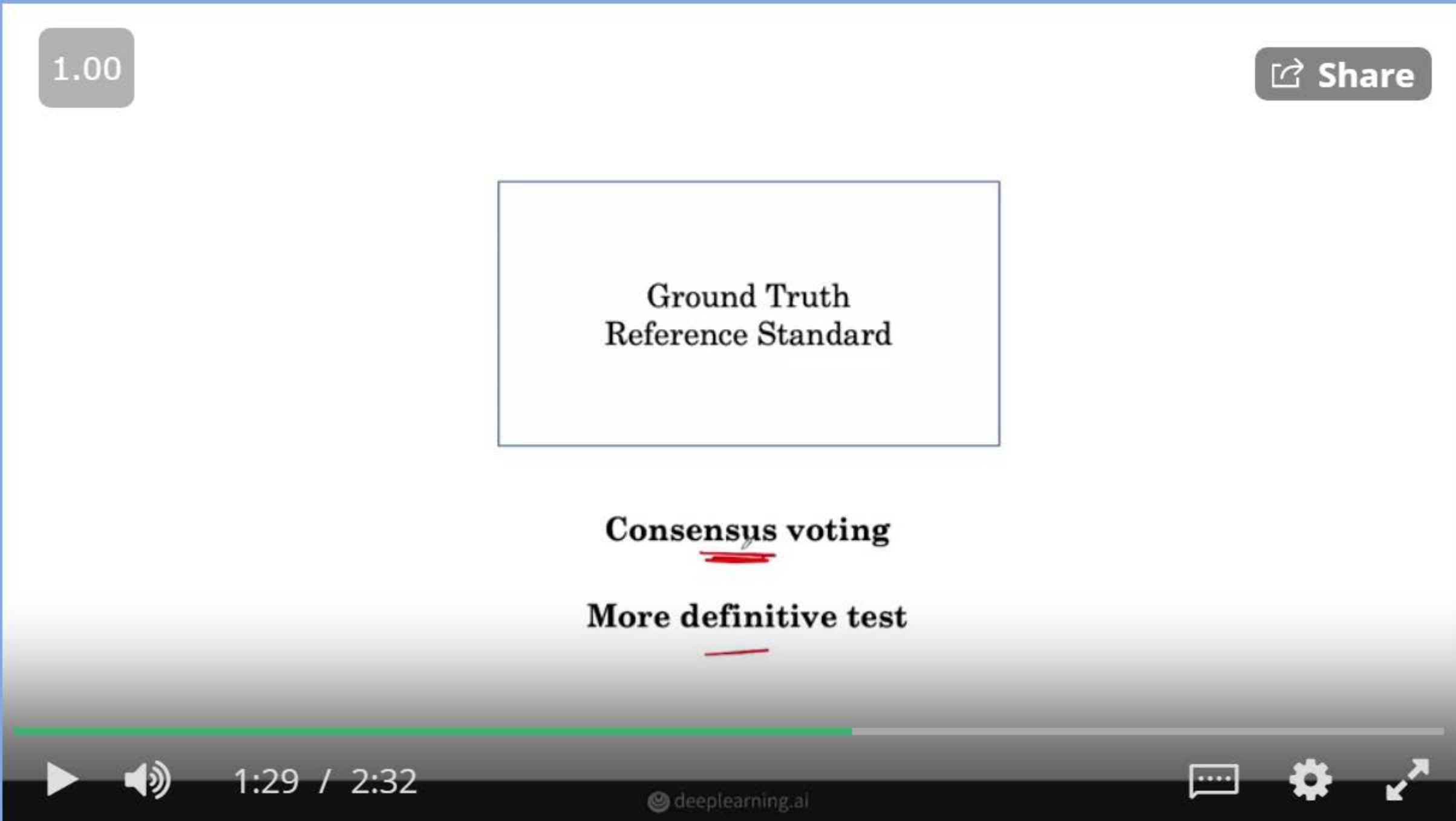
Skin Biopsy





Cancerous

Play


1.00
Share
Ground Truth
Reference Standard
Consensus voting
More definitive test
1:29 / 2:32
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1.00
Share
3 Key Challenges
Patient Overlap
Split by Patient
Set Sampling
Minority class Sampling
Ground Truth
Consensus voting / more definitive test
1:56 / 2:32
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