

# How to Evaluate a Model

## Confusion Matrix

		Predicted Label			
		Circle	Idle	Left-Right	Up-Down
Actual Label	Circle				
	Idle				
	Left-Right				
	Up-Down				

## Confusion Matrix

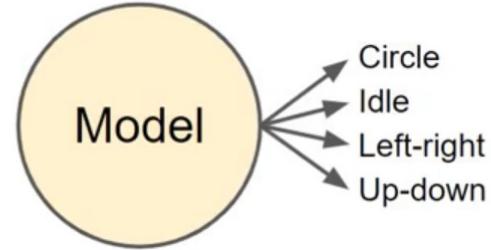
Actual Label

	Circle	Idle	Left-Right	Up-Down
Circle				
Idle				
Left-Right				
Up-Down				

## Validation Set

Validation Sample	Actual Label
1	Idle
2	Circle
3	Circle
4	Up-Down
5	Left-Right
6	Up-Down

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Predicted Label

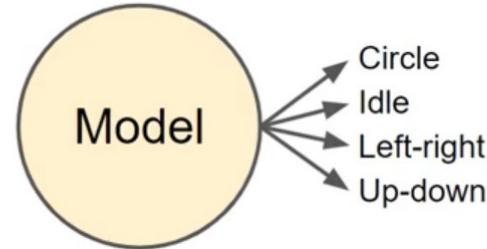
## Confusion Matrix

Actual Label	Circle	Idle	Left-Right	Up-Down
Circle	0	0	0	0
Idle	0	0	0	0
Left-Right	0	0	0	0
Up-Down	0	0	0	0

Validation Set

Validation Sample	Actual Label
1	Idle
2	Circle
3	Circle
4	Up-Down
5	Left-Right
6	Up-Down

:      :



Predicted Label

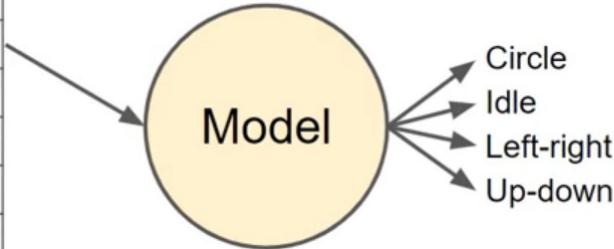
## Confusion Matrix

Actual Label

	Circle	Idle	Left-Right	Up-Down
Circle	0	0	0	0
Idle	0	0	0	0
Left-Right	0	0	0	0
Up-Down	0	0	0	0

## Validation Set

Validation Sample	Actual Label
1	Idle
2	Circle
3	Circle
4	Up-Down
5	Left-Right
6	Up-Down
:	:



Predicted Label

## Confusion Matrix

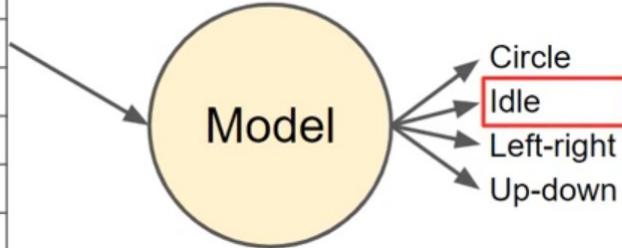
Actual Label

	Circle	Idle	Left-Right	Up-Down
Circle	0	0	0	0
Idle	0	0	0	0
Left-Right	0	0	0	0
Up-Down	0	0	0	0

## Validation Set

Validation Sample	Actual Label
1	Idle
2	Circle
3	Circle
4	Up-Down
5	Left-Right
6	Up-Down

: : :



Predicted Label

## Confusion Matrix

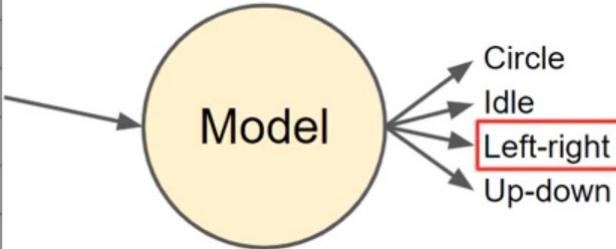
Actual Label

	Circle	Idle	Left-Right	Up-Down
Circle	0	0	0	0
Idle	0	1	0	0
Left-Right	0	0	0	0
Up-Down	0	0	0	0

## Validation Set

Validation Sample	Actual Label
1	Idle
2	Circle
3	Circle
4	Up-Down
5	Left-Right
6	Up-Down

: : :



Predicted Label

## Confusion Matrix

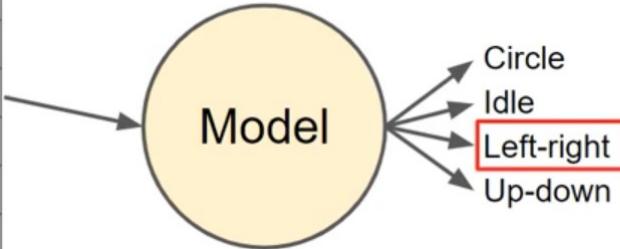
Actual Label

	Circle	Idle	Left-Right	Up-Down
Circle	0	0	1	0
Idle	0	1	0	0
Left-Right	0	0	0	0
Up-Down	0	0	0	0

## Validation Set

Validation Sample	Actual Label
1	Idle
2	Circle
3	Circle
4	Up-Down
5	Left-Right
6	Up-Down

: :



Predicted Label

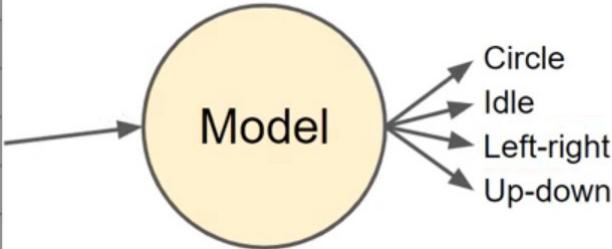
## Confusion Matrix

Actual Label

	Circle	Idle	Left-Right	Up-Down
Circle	0	0	1	0
Idle	0	1	0	0
Left-Right	0	0	0	0
Up-Down	0	0	0	0

## Validation Set

Validation Sample	Actual Label
1	Idle
2	Circle
3	Circle
4	Up-Down
5	Left-Right
6	Up-Down
:	:



Predicted Label

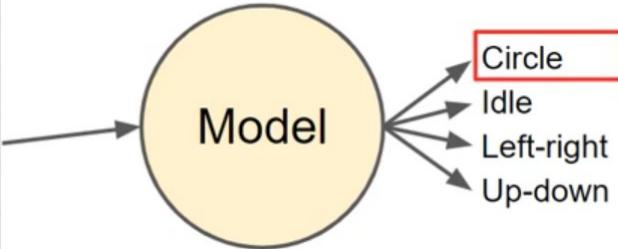
## Confusion Matrix

Actual Label

	Circle	Idle	Left-Right	Up-Down
Circle	0	0	1	0
Idle	0	1	0	0
Left-Right	0	0	0	0
Up-Down	0	0	0	0

## Validation Set

Validation Sample	Actual Label
1	Idle
2	Circle
3	Circle
4	Up-Down
5	Left-Right
6	Up-Down
:	:



Predicted Label

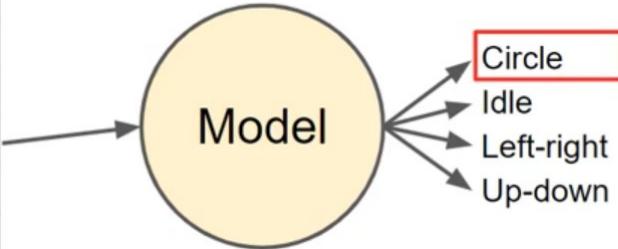
## Confusion Matrix

Actual Label

	Circle	Idle	Left-Right	Up-Down
Circle	1	0	1	0
Idle	0	1	0	0
Left-Right	0	0	0	0
Up-Down	0	0	0	0

## Validation Set

Validation Sample	Actual Label
1	Idle
2	Circle
3	Circle
4	Up-Down
5	Left-Right
6	Up-Down
:	:



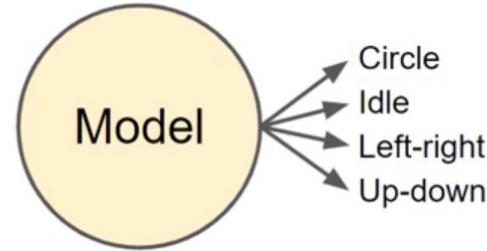
Predicted Label

## Confusion Matrix

Actual Label	Predicted Label			
	Circle	Idle	Left-Right	Up-Down
Circle	205	10	1	46
Idle	6	199	0	32
Left-Right	9	17	223	34
Up-Down	21	8	3	186

Validation Set

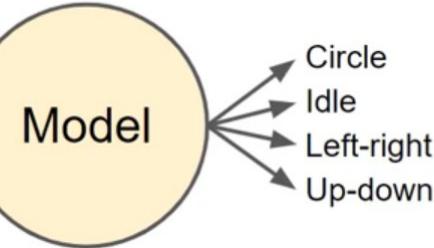
Validation Sample	Actual Label
1	Idle
2	Circle
3	Circle
4	Up-Down
5	Left-Right
6	Up-Down
:	:



## Confusion Matrix

Validation Set

Validation Sample	Actual Label
1	Idle
2	Circle
3	Circle
4	Up-Down
5	Left-Right
6	Up-Down
:	:



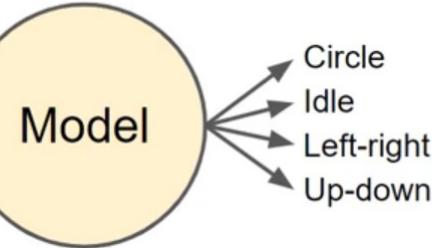
Predicted Label

	Circle	Idle	Left-Right	Up-Down
Circle	205	10	1	46
Idle	6	199	0	32
Left-Right	9	17	223	34
Up-Down	21	8	3	186

## Confusion Matrix

Validation Set

Validation Sample	Actual Label
1	Idle
2	Circle
3	Circle
4	Up-Down
5	Left-Right
6	Up-Down
:	:



Predicted Label

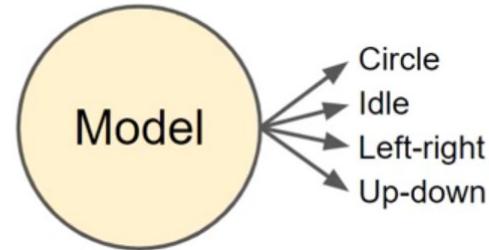
	Circle	Idle	Left-Right	Up-Down
Circle	205	10	1	46
Idle	6	199	0	32
Left-Right	9	17	223	34
Up-Down	21	8	3	186

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Actual Label	Predicted Label			
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Circle	205	10	1	46
Idle	6	199	0	32
Left-Right	9	17	223	34
Up-Down	21	8	3	186

Validation Sample	Actual Label
1	Idle
2	Circle
3	Circle
4	Up-Down
5	Left-Right
6	Up-Down

:      :



Predicted Label

Total accuracy:

$$\frac{\sum \text{correct}}{\sum \text{all}} = \frac{813}{1000} = 0.813$$

Confusion Matrix

		Predicted Label			
		Circle	Idle	Left-Right	Up-Down
Actual Label	Circle	205	10	1	46
	Idle	6	199	0	32
	Left-Right	9	17	223	34
	Up-Down	21	8	3	186

## Confusion Matrix

Total accuracy:

		Predicted Label			
		Circle	Idle	Left-Right	Up-Down
Actual Label	Circle	0	6	0	0
	Idle	0	973	0	0
	Left-Right	0	11	0	0
	Up-Down	0	10	0	0

## Confusion Matrix

		Predicted Label			
		Circle	Idle	Left-Right	Up-Down
Actual Label	Circle	0	6	0	0
	Idle	0	973	0	0
	Left-Right	0	11	0	0
	Up-Down	0	10	0	0

Total accuracy:

$$\frac{\sum \text{correct}}{\sum \text{all}} = \frac{973}{1000} = 0.973$$

## Confusion Matrix

		Predicted Label	
		Positive	Negative
Actual Label	Positive	38	17
	Negative	3	42

## Confusion Matrix

		Predicted Label
Actual Label	Positive	Negative
	Positive	17
Negative	3	42

True Positive (TP): Predicted positive matches actual positive

## Confusion Matrix

		Predicted Label
Actual Label	Positive	Negative
	Positive	17
Negative	3	42

True Positive (TP): Predicted positive matches actual positive

True Negative (TN): Predicted negative matches actual negative

## Confusion Matrix

		Predicted Label
Actual Label	Positive	Negative
	Positive	17
Negative	3	42

True Positive (TP): Predicted positive matches actual positive

True Negative (TN): Predicted negative matches actual negative

False Positive (FP) ("Type I Error"): Predicted positive does not match actual negative

**Confusion Matrix**

		Predicted Label	
		Positive	Negative
Actual Label	Positive	38	17
	Negative	3	42

True Positive (TP): Predicted positive matches actual positive

True Negative (TN): Predicted negative matches actual negative

False Positive (FP) (“Type I Error”): Predicted positive does not match actual negative

False Negative (FN) (“Type II Error”): Predicted negative does not match actual positive

## Confusion Matrix

		Predicted Label			
		Circle	Idle	Left-Right	Up-Down
Actual Label	Circle	205	10	1	46
	Idle	6	199	0	32
	Left-Right	9	17	223	34
	Up-Down	21	8	3	186

## Confusion Matrix

Predicted Label

	Circle	Idle	Left-Right	Up-Down
Circle	205	10	1	46
Idle	6	199	0	32
Left-Right	9	17	223	34
Up-Down	21	8	3	186

## Confusion Matrix

		Predicted Label			
		Circle	Idle	Left-Right	Up-Down
Actual Label	Circle	205	10	1	46
	Idle	6	199	0	32
	Left-Right	9	17	223	34
	Up-Down	21	8	3	186

True Positive (TP): Predicted positive matches actual positive

## Confusion Matrix

		Predicted Label			
		Circle	Idle	Left-Right	Up-Down
Actual Label	Circle	205	10	1	46
	Idle	6	199	0	32
	Left-Right	9	17	223	34
	Up-Down	21	8	3	186

True Positive (TP): Predicted positive matches actual positive

False Positive (FP) ("Type I Error"): Predicted positive does not match actual negative

## Confusion Matrix

		Predicted Label			
		Circle	Idle	Left-Right	Up-Down
Actual Label	Circle	205	10	1	46
	Idle	6	199	0	32
	Left-Right	9	17	223	34
	Up-Down	21	8	3	186

True Positive (TP): Predicted positive matches actual positive

False Positive (FP) ("Type I Error"): Predicted positive does not match actual negative

False Negative (FN) ("Type II Error"): Predicted negative does not match actual positive

**Confusion Matrix**

		Predicted Label			
		Circle	Idle	Left-Right	Up-Down
Actual Label	Circle	205	10	1	46
	Idle	6	199	0	32
	Left-Right	9	17	223	34
	Up-Down	21	8	3	186

True Positive (TP): Predicted positive matches actual positive

True Negative (TN): Predicted negative matches actual negative

False Positive (FP) (“Type I Error”): Predicted positive does not match actual negative

False Negative (FN) (“Type II Error”): Predicted negative does not match actual positive

**Confusion Matrix**

		Predicted Label			
		Circle	Idle	Left-Right	Up-Down
Actual Label	Circle	205	10	1	46
	Idle	6	199	0	32
	Left-Right	9	17	223	34
	Up-Down	21	8	3	186

Accuracy

$$ACC = \frac{TP + TN}{P + N} = \frac{TP + TN}{TP + TN + FP + FN} = \frac{\text{[Green Box]} + \text{[Blue Box]}}{\text{Total}}$$

**Confusion Matrix**

		Predicted Label			
		Circle	Idle	Left-Right	Up-Down
Actual Label	Circle	205	10	1	46
	Idle	6	199	0	32
	Left-Right	9	17	223	34
	Up-Down	21	8	3	186

Accuracy

$$\begin{aligned} ACC &= \frac{TP + TN}{P + N} = \frac{TP + TN}{TP + TN + FP + FN} = \frac{\text{[Green Box]} + \text{[Blue Box]}}{\text{Total}} \\ &= \frac{199 + 728}{1000} = 0.927 \end{aligned}$$

**Confusion Matrix**

		Predicted Label			
		Circle	Idle	Left-Right	Up-Down
Actual Label	Circle	205	10	1	46
	Idle	6	199	0	32
	Left-Right	9	17	223	34
	Up-Down	21	8	3	186

True Positive Rate (TPR), Sensitivity, Recall, Hit Rate

$$TPR = \frac{TP}{P} = \frac{TP}{TP + FN} = \frac{\text{[Green Box]}}{\text{[Green Box]} + \text{[Purple Box]}}$$
$$= \frac{199}{199 + 38} = 0.840$$

**Confusion Matrix**

		Predicted Label			
		Circle	Idle	Left-Right	Up-Down
Actual Label	Circle	205	10	1	46
	Idle	6	199	0	32
	Left-Right	9	17	223	34
	Up-Down	21	8	3	186

True Negative Rate (TNR), Specificity, Selectivity

$$TNR = \frac{TN}{N} = \frac{TN}{TN + FP} = \frac{\boxed{\text{Blue}}}{\boxed{\text{Blue}} + \boxed{\text{Orange}}}$$

**Confusion Matrix**

		Predicted Label			
		Circle	Idle	Left-Right	Up-Down
Actual Label	Circle	205	10	1	46
	Idle	6	199	0	32
	Left-Right	9	17	223	34
	Up-Down	21	8	3	186

True Negative Rate (TNR), Specificity, Selectivity

$$TNR = \frac{TN}{N} = \frac{TN}{TN + FP} = \frac{\boxed{\text{blue}}}{\boxed{\text{blue}} + \boxed{\text{orange}}}$$
$$= \frac{728}{728 + 35} = 0.954$$

### Confusion Matrix

		Predicted Label			
		Circle	Idle	Left-Right	Up-Down
Actual Label	Circle	205	10	1	46
	Idle	6	199	0	32
	Left-Right	9	17	223	34
	Up-Down	21	8	3	186

Positive Predictive Value (PPV), Precision

$$PPV = \frac{TP}{TP + FP} = \frac{\text{Green Box}}{\text{Green Box} + \text{Orange Box}}$$

### Confusion Matrix

		Predicted Label			
		Circle	Idle	Left-Right	Up-Down
Actual Label	Circle	205	10	1	46
	Idle	6	199	0	32
	Left-Right	9	17	223	34
	Up-Down	21	8	3	186

Positive Predictive Value (PPV), Precision

$$\begin{aligned} PPV &= \frac{TP}{TP + FP} = \frac{\text{[Green Box]}}{\text{[Green Box]} + \text{[Orange Box]}} \\ &= \frac{199}{199 + 35} = 0.850 \end{aligned}$$

**Confusion Matrix**

		Predicted Label			
		Circle	Idle	Left-Right	Up-Down
Actual Label	Circle	205	10	1	46
	Idle	6	199	0	32
	Left-Right	9	17	223	34
	Up-Down	21	8	3	186

F1 Score

$$F_1 = 2 \cdot \frac{PPV \cdot TPR}{PPV + TPR} = \frac{2TP}{2TP + FP + FN}$$

### Confusion Matrix

		Predicted Label			
		Circle	Idle	Left-Right	Up-Down
Actual Label	Circle	205	10	1	46
	Idle	6	199	0	32
	Left-Right	9	17	223	34
	Up-Down	21	8	3	186

F1 Score

$$\begin{aligned} F_1 &= 2 \cdot \frac{PPV \cdot TPR}{PPV + TPR} = \frac{2TP}{2TP + FP + FN} \\ &= 2 \cdot \frac{0.850 \cdot 0.840}{0.850 + 0.840} = 0.845 \end{aligned}$$

**Confusion Matrix**

		Predicted Label			
		Circle	Idle	Left-Right	Up-Down
Actual Label	Circle	205	10	1	46
	Idle	6	199	0	32
	Left-Right	9	17	223	34
	Up-Down	21	8	3	186

Per-class accuracy    0.907    0.927    0.936    0.856

F1 scores    0.815    0.845    0.875    0.721

Total accuracy:    0.813

F1 average:    0.818

### Confusion Matrix

		Predicted Label			
		Circle	Idle	Left-Right	Up-Down
Actual Label	Circle	0	6	0	0
	Idle	0	973	0	0
	Left-Right	0	11	0	0
	Up-Down	0	10	0	0

Per-class accuracy    0.994    0.973    0.989    0.99

F1 scores        0.0        0.986        0.0        0.0

Total accuracy:    0.973

### Confusion Matrix

		Predicted Label			
		Circle	Idle	Left-Right	Up-Down
Actual Label	Circle	0	6	0	0
	Idle	0	973	0	0
	Left-Right	0	11	0	0
	Up-Down	0	10	0	0

Per-class accuracy    0.994    0.973    0.989    0.99

F1 scores            0.0            0.986            0.0            0.0

Total accuracy:    0.973

F1 average:        0.247

# Conteúdo Adicional Recomendado

Embora seja opcional, recomendo que você dê uma olhada nos artigos e vídeos a seguir para saber mais sobre os tópicos abordados nesta lição:

- [Understanding Confusion Matrix](#)
- [Everything you Should Know about Confusion Matrix for Machine Learning](#)
- [Beyond Accuracy: Precision and Recall](#)
- [StackExchange: How to calculate precision and recall in a 3 x 3 confusion matrix](#)