Confusion Matrix

PR = Precision

RE = Recall

CA = Accuracy

F_1 - Score

$$PR = \frac{TP}{TP + FP}$$

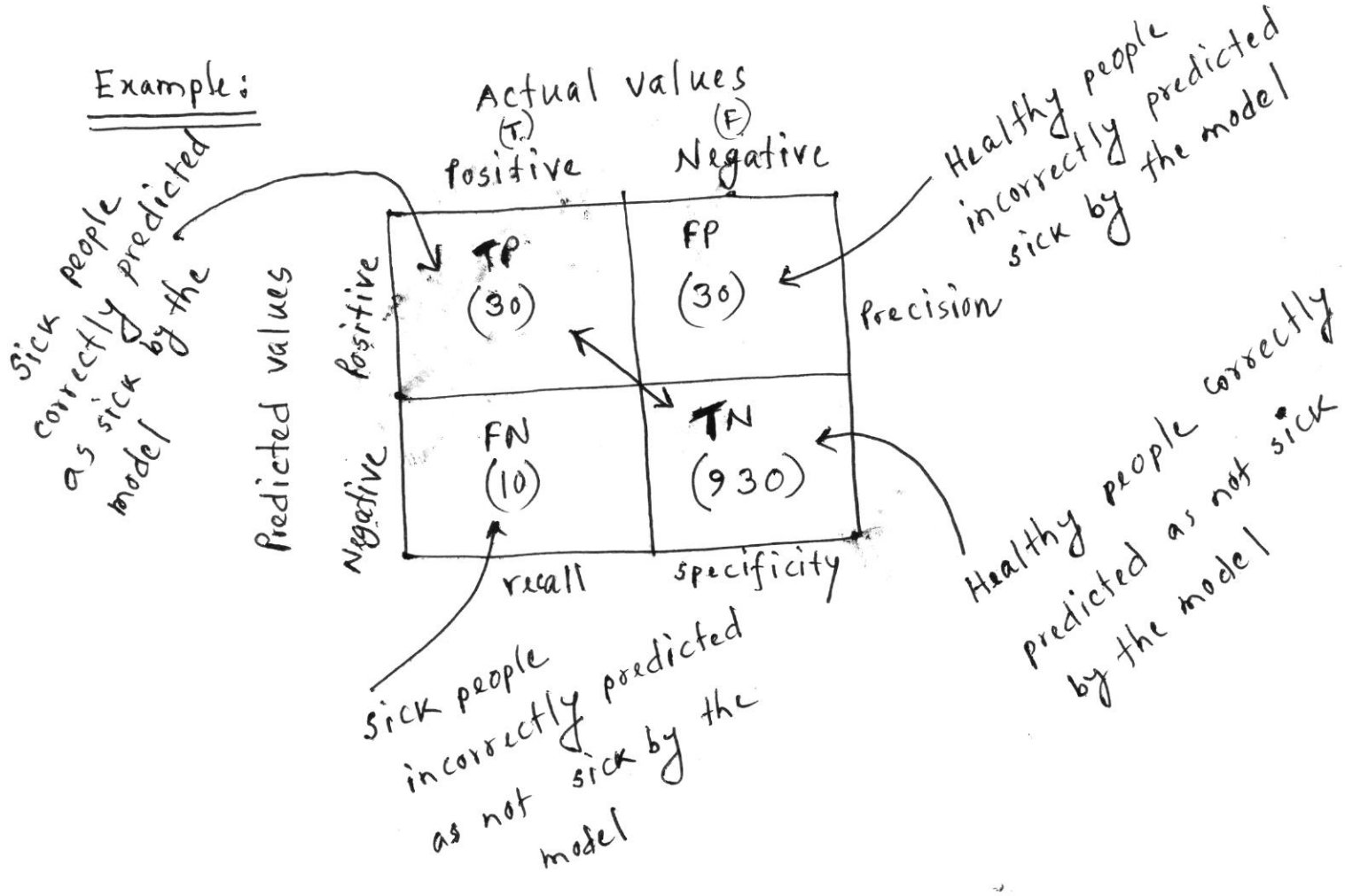
$$RE = \frac{TP}{TP + FN}$$

$$CA = \frac{TP + TN}{TP + TN + FP + FN}$$

$$F_1 = \frac{2TP}{2TP + FP + FN} = \frac{2 \times \text{Precision} \times \text{recall}}{\text{Precision} + \text{recall}}$$

$$\text{Specificity} = \frac{TN}{TN + FP}$$

Example:



TP = Actual positive predicted positive*
True Positive (TP)

FP = Actual Negative predicted positive*
False positive (FP)

FN = Actual positive Predicted Negative*
False Negative (FN)

TN = Actual Negative predicted Negative*
True Negative (TN)

$$\text{Precision, } PR = \frac{TP}{TP+FP} * 100\%$$

$$= \frac{30}{30+30} * 100\%$$

$$= 50\%$$

$$\text{Recall, } RE = \frac{TP}{TP+FN} * 100\%$$

$$= \frac{30}{30+10} * 100\%$$

$$= 75\%$$

$$\text{Accuracy, } CA = \frac{TP+TN}{TP+TN+FP+FN} * 100\%$$

$$= \frac{30+930}{30+930+30+10} * 100\%$$

$$= \frac{960}{1000} * 100\% = 96\%$$

$$\text{F-Measure} = \frac{2 \times PR \times RE}{PR+RE} * 100\% = \frac{2 \times 0.5 \times 0.75}{0.5+0.75} * 100\%$$

$$= 60\%$$

$$F_1 = \frac{2 \times TP}{2TP+FP+FN} * 100\% = \frac{2 \times 30}{2+30+30+10} * 100\% = 60\%$$

2-class confusion Matrix

Actual	Predicted
man	woman
man	man ←
woman	woman ←
man	man ←
woman	man
woman	woman ←
woman	woman ←
man	man ←
man	woman
woman	woman ←

Total instance = 10

Correctly classified = 7

$$\text{Accuracy} = \frac{7}{10} * 100\% = 70\%$$

man class correctly prediction = 3

Woman " " " = 4

man classified as woman = 2

Woman " as man = 1

confusion matrix:

Predicted \ Actual	man	woman
man	3	1
Woman	2	4

⇒

	P	N
P	TP (3)	FP (1)
N	FN (2)	TN (4)

Calculate precision, recall, F-Measure, Accuracy and specificity.

Ans:

$$\text{Precision, } PR = \frac{TP}{TP+FP} * 100\%$$

$$= \frac{3}{3+1} * 100\%$$

$$= \frac{3}{4} * 100\% = 75\%$$

$$\text{Recall, } RE = \frac{TP}{TP+FN} * 100\%$$

$$= \frac{3}{3+2} * 100\%$$

$$= 60\%$$

$$\text{Accuracy, } CA = \frac{TP+TN}{TP+TN+FP+FN} * 100\%$$

$$= \frac{3+4}{3+4+1+2} * 100\%$$

$$= 70\%$$

$$\text{F-Measure} = \frac{2 \times PR \times RE}{PR+RE} * 100\%$$

$$= \frac{2 * 0.75 * 0.60}{0.75 + 0.60} * 100\%$$

$$= \frac{0.9}{1.35} * 100\%$$

$$= 66.67\%$$

$$\text{Specificity} = \frac{TN}{TN+FP} * 100\% = \frac{4}{4+1} * 100\%$$

$$= 80\%$$

Significance

If Accuracy is high, model is best when $FP \cong FN$

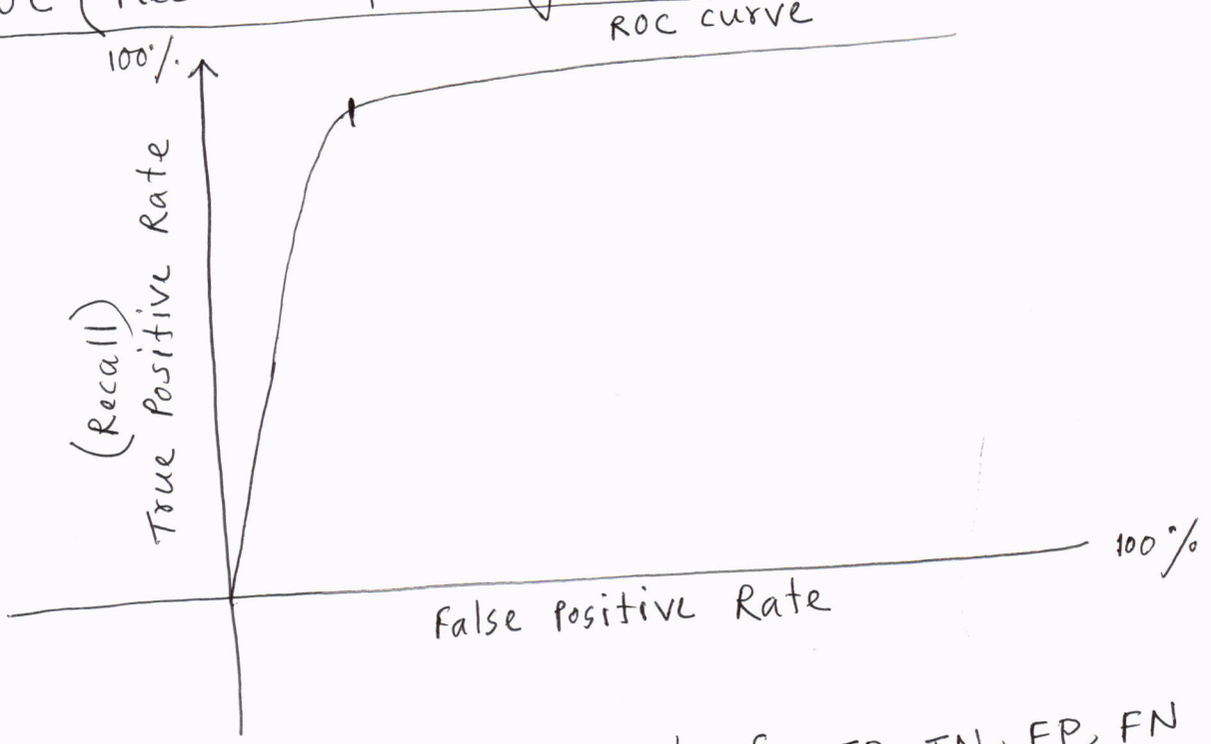
If precision is high, low false positive rate

If recall (sensitivity) is high, low false negative rate

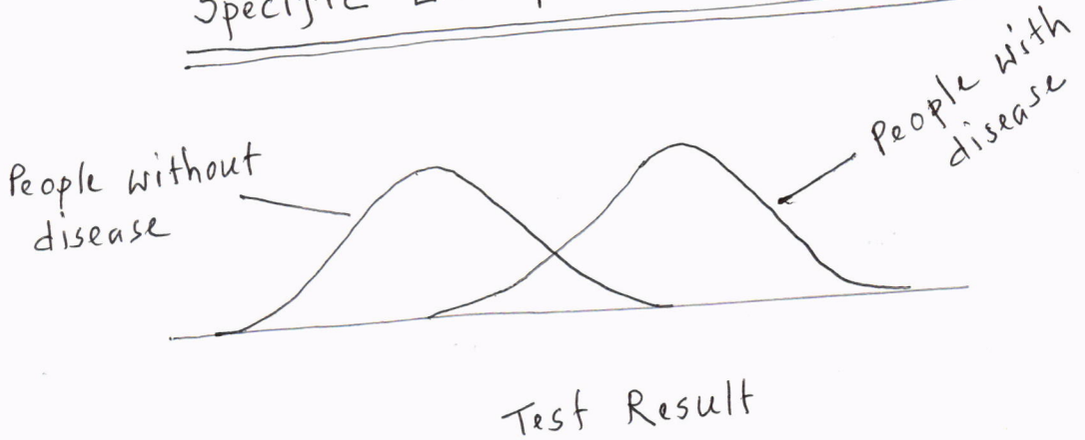
F1-score is useful than Accuracy if $FP \neq FN$

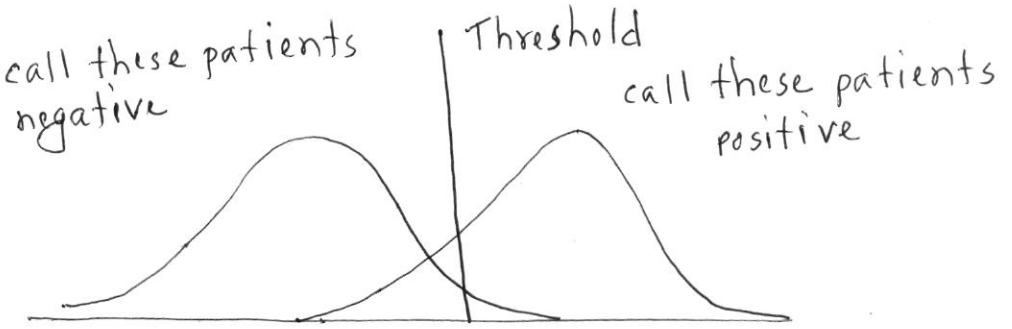
ML usually minimize FP+FN

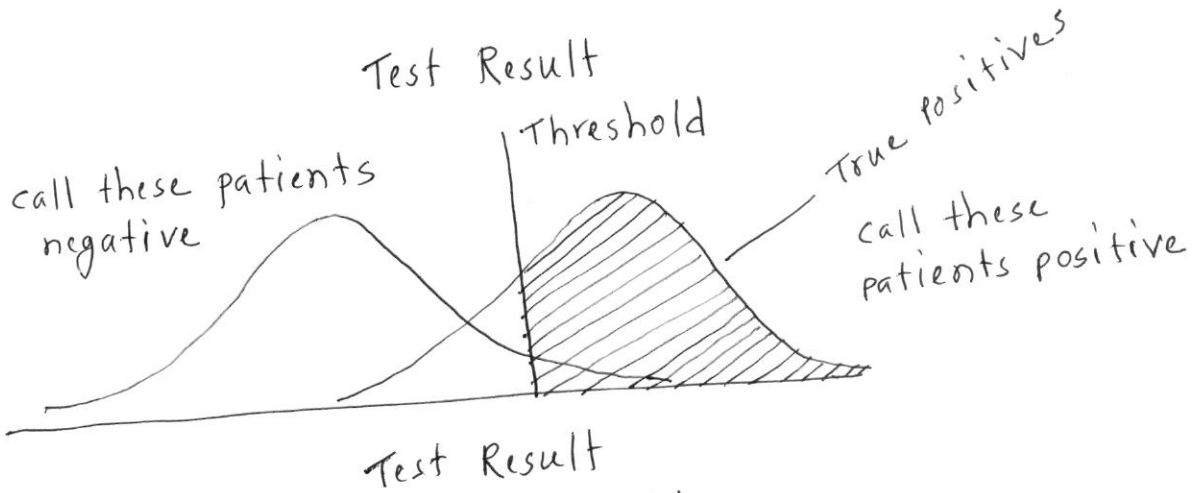
ROC (Receiver Operating characteristics)

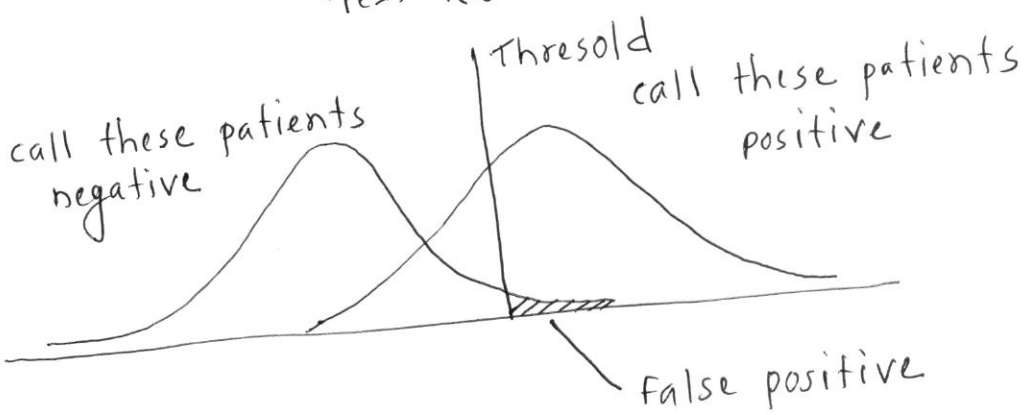


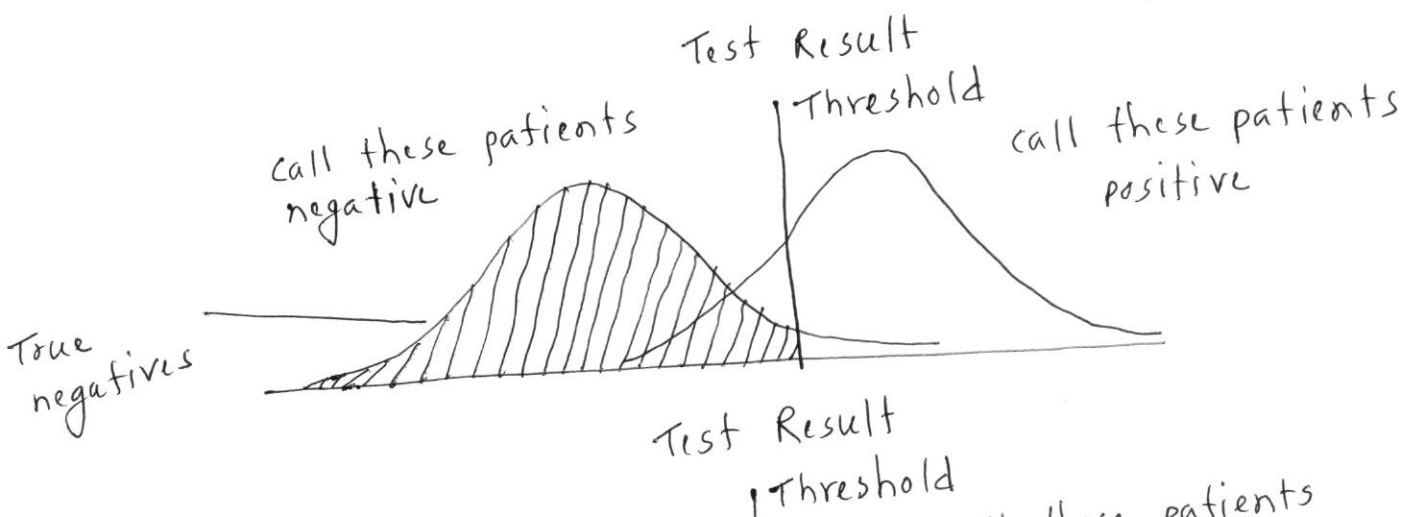
Specific Example for TP, TN, FP, FN

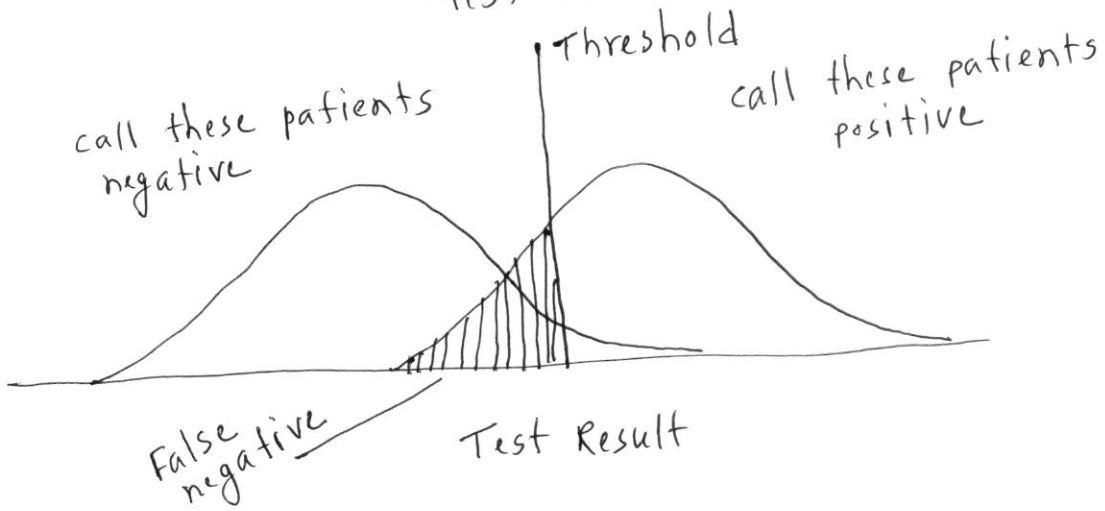



call these patients negative
Threshold
call these patients positive
Test Result


call these patients negative
Threshold
True positives
call these patients positive
Test Result


call these patients negative
Thresold
call these patients positive
False positive
Test Result


call these patients negative
Threshold
call these patients positive
True negatives
Test Result


call these patients negative
Threshold
call these patients positive
False negative
Test Result

Sensitivity, recall, hit rate or True positive rate (TPR)

$$TPR = \frac{TP}{TP + FN}$$

specificity, selectivity or True negative rate (TNR)

$$TNR = \frac{TN}{TN + FP}$$

Precision or positive predictive value (PPV)

$$PPV = \frac{TP}{TP + FP}$$

Negative predictive value (NPV)

$$NPV = \frac{TN}{TN + FN}$$

Miss rate or false negative rate (FNR)

$$FNR = \frac{FN}{FN + TP}$$

Fall out or false positive rate (FPR)

$$FPR = \frac{FP}{FP + TN}$$

False discovery rate (FDR)

$$FDR = \frac{FP}{FP + TP}$$

False omission rate (FOR)

$$FOR = \frac{FN}{FN + TN}$$

$$\text{Accuracy} = \frac{TP + TN}{TP + TN + FP + FN}$$

Balanced Accuracy (BA)

$$BA = \frac{TPR + TNR}{2}$$

$$\text{F1 score} = \frac{2 \cdot PPV \cdot TPR}{PPV + TPR} = \frac{2TP}{2TP + FP + FN}$$

$$= \frac{2 \cdot \text{Precision} \cdot \text{recall}}{\text{Precision} + \text{recall}}$$

Multiclass confusion Matrix:

True/Actual

Predicted	cat	Fish	Hen
cat	4	6	3
Fish	1	2	0
Hen	1	2	6

A sample confusion matrix that is produced after classing 25 photos (4+6+3 + 1+2+0 + 1+2+6)

i) Find Precision, Recall for each class. Also F1-score

ii) Find overall system Accuracy.

iii) Find Macro and Weighted avg of Precision, Recall and F1-score

Ans:

Predicted \ Actual	cat	Fish	Hen	Precision
cat	4	6	3	$\frac{4}{4+6+3} = 0.308$
Fish	1	2	0	$\frac{2}{1+2+0} = 0.667$
Hen	1	2	6	$\frac{6}{1+2+6} = 0.667$
Recall ⇒	$\frac{4}{4+1+1} = 0.667$	$\frac{2}{6+2+2} = 0.200$	$\frac{6}{3+0+6} = 0.667$	

Now,

	Precision	Recall	F1-score	Support
cat	0.308	0.667	0.421	4+1+1 = 6
Fish	0.667	0.200	0.308	6+2+2 = 10
Hen	0.667	0.667	0.667	3+0+6 = 9
				Total support = 25

$$\frac{2*0.308*0.667}{0.308+0.667} = \frac{2*Pre*Recall}{Pre+Recall}$$

$$\text{Accuracy} = \frac{4+2+6}{(4+6+3)+(1+2+0)+(1+2+6)}$$

$$= \frac{12}{25}$$

$$= 0.48$$

	Precision	Recall	F1-Score
Macro Avg	0.547	0.511	0.465
Weighted Avg	0.581	0.480	0.464

$$\frac{0.308 + 0.667 + 0.667}{3}$$

$$\frac{0.667 + 0.200 + 0.667}{3}$$

$$\frac{0.421 + 0.308 + 0.667}{3}$$

$$\frac{0.308 * 6 + 0.667 * 10 + 0.667 * 9}{6+10+9}$$

$$\frac{0.667 * 6 + 0.200 * 10 + 0.667 * 9}{6+10+9}$$

$$\frac{0.421 * 6 + 0.308 * 10 + 0.667 * 9}{6+10+9}$$