Machine Learning-
Theory & Practice

Module 1: An Overview of Machine Learning

Lecture 3:

Theme: Performance Issues

Lecture Outline

Topic 1: Performance Perspectives

Topic 2: Sources & Types of Errors

Topic 3: Confusion Matrix

Topic 1: Performance Perspectives

Performance perspectives of stakeholders

End User

Exporter of mangoes

Low quality mangoes should not be mis-classified as high quality mangoes

Stock Trader

The prediction should closely match the real variations in stock values

Librarian

Online research papers on ML should be segregated from research papers on COVID

Online recommendation system

Predictions should evolve as customers' tastes change over time

ML System Developer

- Classification: Maximize ratio of True Positives to False Positives
- Regression: Maximize match between the *Variances* in actual stocks data and predictions
- Clustering: Maximize cohesiveness of books clustered together & maximize distance between clusters
- Real Time system: Reinforcement learning - maximize short term rewards and long term rewards

System Architect’s perspective

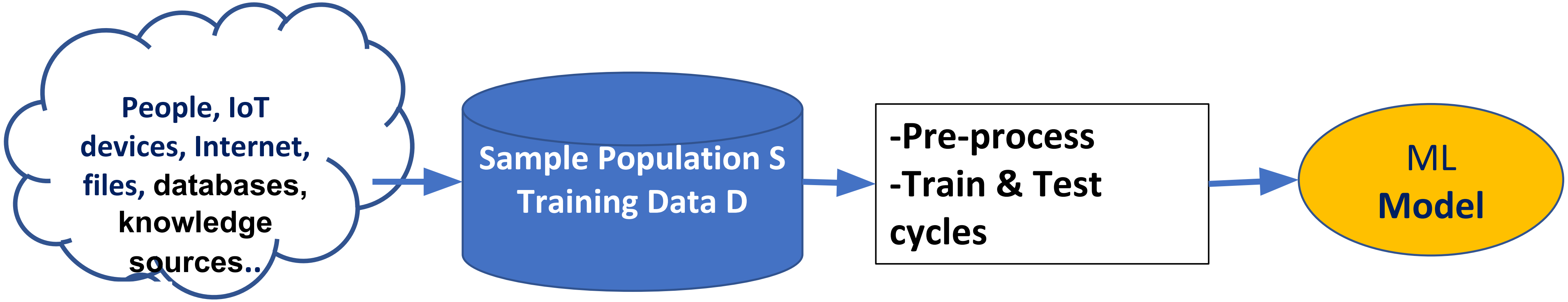
- Aim: Maximize overall system performance by reducing data acquisition time and training time
- Concern 1: How much data is required for acceptable performance?
- Concern 2: Will training time be excessive?

 COMPUTATIONAL LEARNING THEORY

- Decisions: What sources should data be collected from? Should the system be parallelized / distributed?

Topic 2: Sources & Types of Errors

Sources of Errors



1. NOISE
Environmental errors
Human Errors
Transmission Errors

DATA ERRORS
-Erroneous values
-Missing values
-Redundant Data
-Not desired form

2. TRAINING & TESTING ERRORS

Mean Squared Error

- Consider one random data point (X_i,y_i) in sample space S

  Prediction Error due to one piece of training data is

$$e_i = \hat{y}_i - y_i$$

  Mean Prediction Error over S:

$$\bar{e} = Exp_S[e] = \frac{1}{n}\sum_{i=1,n} e_i$$

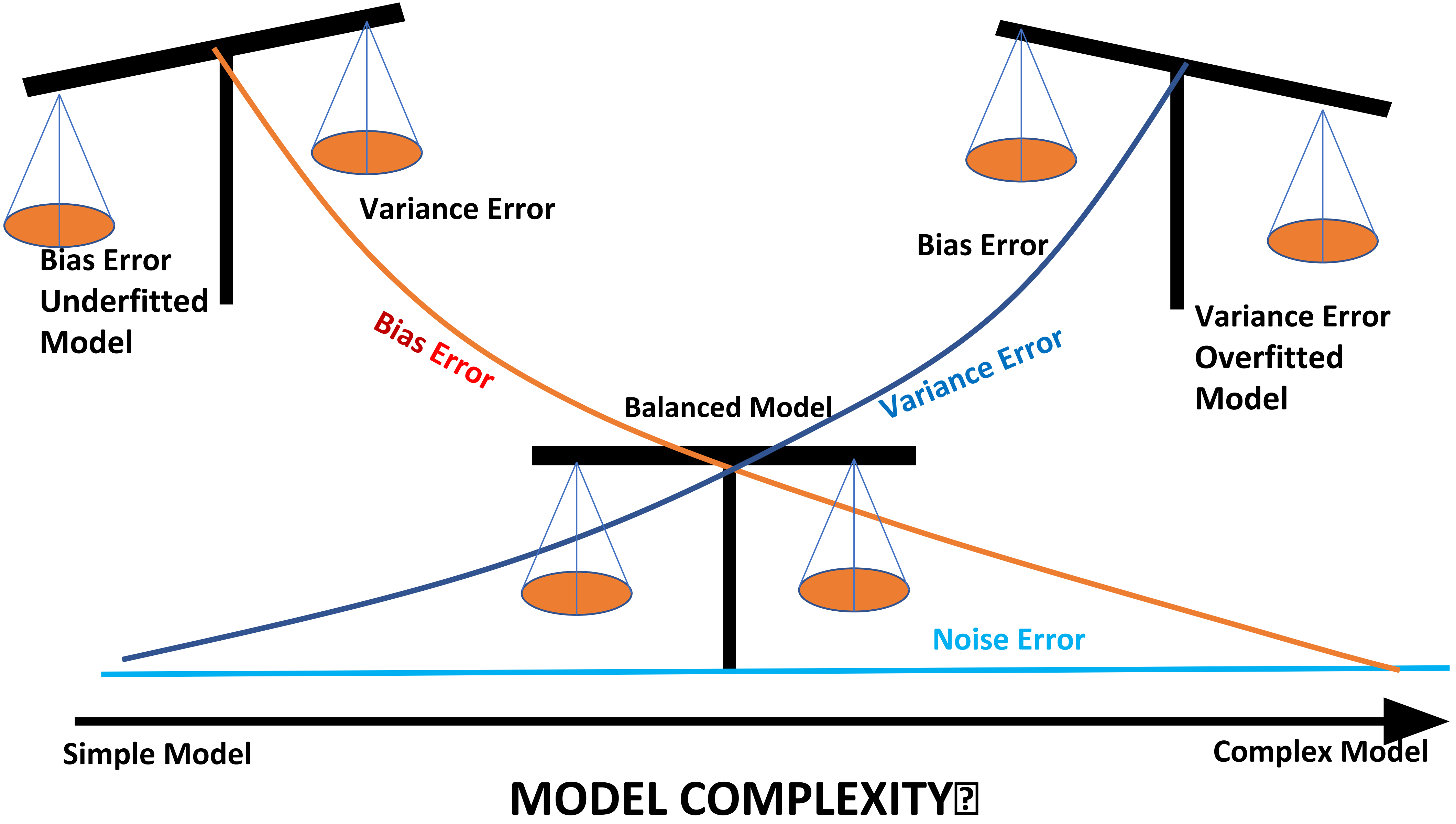
  Mean Squared Error is:

$$\overline{e^2} = Exp_S\left[e^2\right] = \frac{1}{n}\sum_{i=1,n} e_i^2$$

Components of MSE - Variance and Bias Errors

The Variance in Prediction Error is:

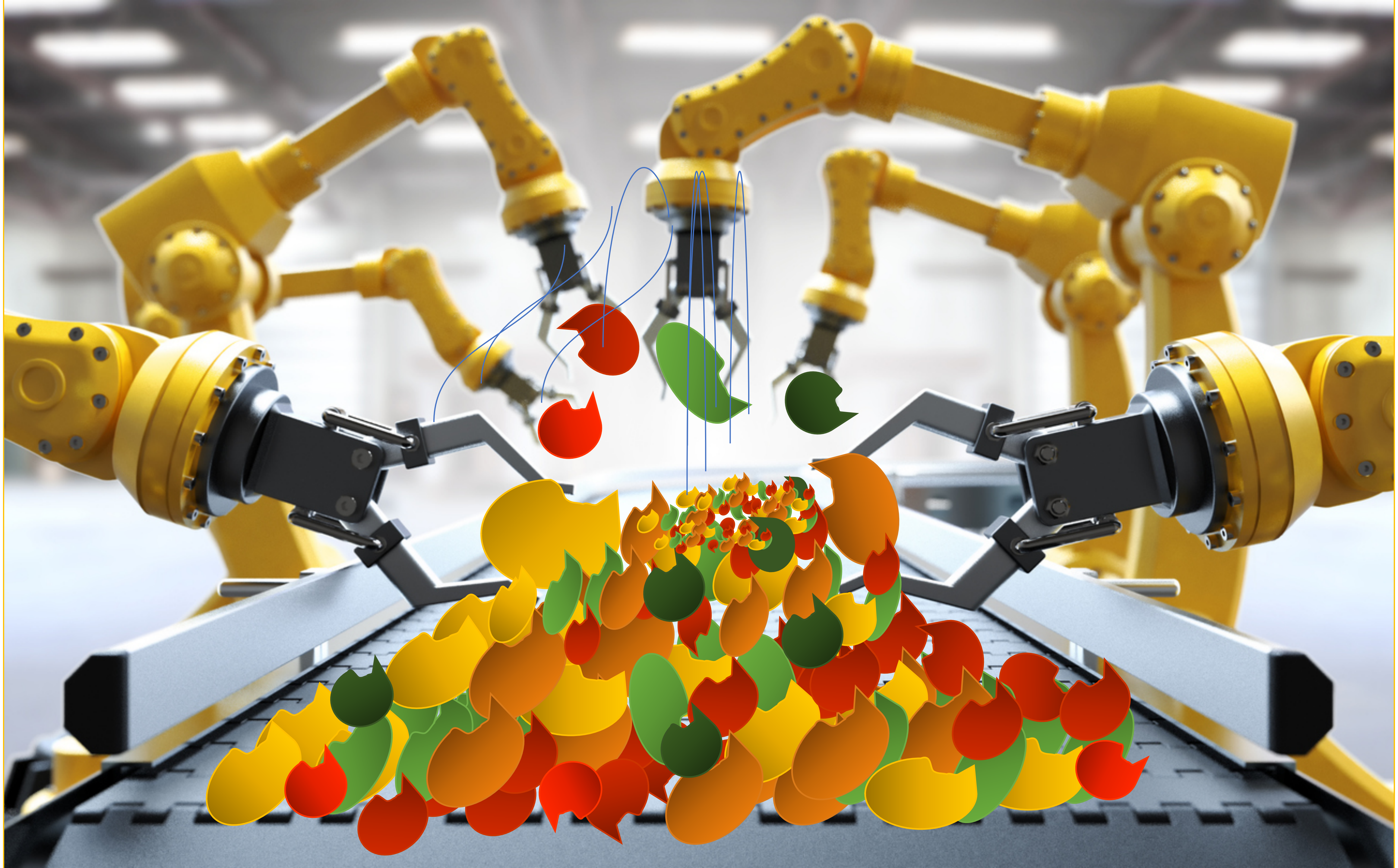
Mean Squared Error =
Variance in Error + Constant Bias Error + Noise



Variance Error
Bias Error
Underfitted
Model
Bias Error
Bias Error
Variance Error
Overfitted
Model
Balanced Model
Variance Error
Noise Error
Simple Model
Complex Model
MODEL COMPLEXITY

Topic 3: Confusion Matrix


House of
ENO



Confusion Matrix

Ground Truths↓ Predictions	Actual Alphanso	Actual Chausa	Actual Totapuri	Actual Dushehri
Predicted Alphanso	True Positive	False Positive	False Positive	False Positive
Predicted Chausa	False Negative	True Negative	True Negative	True Negative
Predicted Totapuri	False Negtiative	True Negative	True Negative	True Negative
Predicted Dusheri	False Negative	True Negative	True Negative	True Negative

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Confusion Matrix parameters

	Actual Class 1	Actual Class 2	
Predicted Class 1	True Positive TP 20	False Positive FP 56	76
Predicted Class 2	False Negative FN 44	True Negative TN 78	122
	64	134	

TPR = $\frac{TP}{TP+FN} = \frac{20}{64}$

TNR = $\frac{TN}{FP+TN} = \frac{78}{134}$

FNR = $\frac{FN}{TP+FN} = \frac{44}{64}$

FPR = $\frac{FP}{FP+TN} = \frac{56}{134}$

Performance Metric: Accuracy

	Actual True	Actual False
Predicted True	True Positive TP	False Positive FP
Predicted False	False Negative FN	True Negative TN

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

Indicates aggregate performance of the system

Recall

	Actual True	Actual False
Predicted True	True Positive TP	False Positive FP
Predicted False	False Negative FN	True Negative TN

$$\textit{Recall or Sensitivity or True Positive Rate or Hit Rate} = \frac{TP}{TP + FN}$$

-Profit Motive in Business: No Alphanso should be missed

-Medical treatment: All COVID affected people should be identified during screening

Precision

	Actual True	Actual False
Predicted True	True Positive TP	False Positive FP
Predicted False	False Negative FN	True Negative TN

$$\text{Precision} = \frac{TP}{TP+FP}$$

-Quality Objective in business: No Chousa should creep into a box of Alphansos to be exported.
-Medical: People not having cancer should not be falsely diagnosed.

Specificity

	Actual True	Actual False
Predicted True	True Positive TP	False Positive FP
Predicted False	False Negative FN	True Negative TN

$$\textit{Specificity or True Negative Rate} = \frac{TN}{TN+FP} = 1 - \frac{FP}{TN+FP} = 1 - FPR$$

-Secondary Decision: How many non-Alphansoes can be sold in local market?

-How many people do not test COVID +ve?

Recall and Precision Tradeoff

	Actual True	Actual False
Predicted True	True Positive TP	False Positive FP
Predicted False	False Negative FN	True Negative TN

F1 Measure

- **Harmonic Mean of Recall and Precision**
- **Gives a good overall balance between Recall and Precision**

$$\boldsymbol{F1 = \frac{1}{\frac{1}{2}(\frac{1}{Recall} + \frac{1}{Precision})} = 2 \times \frac{Recall \times Precision}{Recall + Precision}}$$

$$\boldsymbol{F1 = \frac{TP}{TP + \frac{1}{2}(FN + FP)}}$$

Multiclass Average Metrics

$$\boldsymbol{Microaveraged\ Recall} = \frac{\sum_i TP}{\sum_i TP + \sum_i FN}$$

$$\boldsymbol{Microaveraged\ Precision} = \frac{\sum_i TP}{\sum_i TP + \sum_i FP}$$

Macro-averaged Metrics

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$$Macroaveraged\ Recall\ MR = \frac{1}{N}\sum_{i}\frac{TP_i}{TP_i + FN_i}$$

$$Macroaveraged\ Precision\ MP = \frac{1}{N}\sum_{i}\frac{TP_i}{TP_i + FP_i}$$

$$Macroaveraged\ F1 = Harmonic\ Mean\ (MR, MP)$$

IMBALANCED CLASSES

Actual Classes

Predicted Classes	A	B	C	
A	5	90	8	103
B	1	30	10	41
C	2	20	25	47
	8	140	43	

Class	TP	FP	FN	Recall	Precision
A	5	98	3	0.625	0.048
B	30	11	110	0.214	0.731
C	25	22	18	0.581	0.532
Totals	60	131	131		

Macroaveraged Recall = 0.473

Microaveraged Recall = 60/(60+131)= 0.314

Macroaveraged Precision = 0.437

Macroaveraged F1 $=2*(0.437^{-1} + 0.473^{-1})^{-1} = 0.454$

Recap: Performance and errors

- Performance can be understood from the perspectives of user, software developer and system architect
- The components of Mean Squared Error are Variance error and Bias error that occur during training, and random noise
- Bias-Variance Tradeoff: A simple model underfits and gives bias error. A complex model overfits and gives variance error. A balanced model gives the least overall Mean Square Error

Recap: Confusion matrix

- **Accuracy: What proportion of all cases are correctly predicted**
- **Recall: What proportion of given class are predicted correctly (+ve)**
- **Precision: What proportion of +ve predictions of a given class actually belong to that class**
- **Specificity: What proportion of another class are predicted -ve**
- **There is a tradeoff between Recall and Precision. F1 measure is harmonic mean of Recall and Precision**

Recap: Microaveraged and Macroaveraged metrics

- **For any Micro measure, first add the TP, TN, FP and FN for all classes, and then calculate it. The contribution of any given class is in proportion to its relative population strength.**
- **Macroaveraged performance metrics are averaged over all classes, with equal priority to each class.**

IF YOU WANT TO CREATE ENDURING PRODUCTS,

BE PREPARED FOR TRADE-OFFS….