Error Metrics:

Error metrics **measure** how wrong **the predictions are.**

1. MAE (Mean Absolute Error)

Average of absolute differences between predicted and actual values.

Advantages:

- Easy to understand.
- Not affected by large outliers.
- Same unit as target variable.

Disadvantages:

- Treats all errors equally.
- Doesn’t emphasize big errors.

Use Cases:

- When all errors are equally important.
- Robust model performance without outlier sensitivity.

✅ **1. What is MAE (Mean Absolute Error)?**

📌 **Definition:**

MAE is the average of the **absolute** (positive) differences between actual and predicted values.

📐 **Step-by-step:**

Student	Actual	Predicted	Error (|A - P|)
1	90	85	5
2	80	82	2
3	70	65	5
4	60	70	10
5	50	45	5

$$\text{MAE} = \frac{5+2+5+10+5}{5} = \frac{27}{5} = 5.4$$

💡 **Conclusion**: On average, our prediction is **5.4 marks off**.

2. MSE (Mean Squared Error)

Average of squared differences between predicted and actual values.

Advantages:

- Penalizes large errors more.
- Good for mathematical optimization (smooth gradient).

Disadvantages:

- Sensitive to outliers.
- Output is in squared units (not same as target).

Use Cases:

- When large errors are unacceptable.
- Training regression models with focus on minimizing big errors.

✅ 2. What is MSE (Mean Squared Error)?

📌 **Definition:**

MSE is the average of **squared** differences between actual and predicted values.

📐 **Squared Errors:**

$$(90-85)^2 = 25,\ (80-82)^2 = 4,\ (70-65)^2 = 25,\ (60-70)^2 = 100,\ (50-45)^2 = 25$$

$$\text{MSE} = \frac{25+4+25+100+25}{5} = \frac{179}{5} = 35.8$$

💡 **Conclusion**: MSE penalizes the large error (like 10) more due to squaring (10^2 = 100).

3. RMSE (Root Mean Squared Error)

Square root of MSE. Shows average error in original unit.

Advantages:

- Same unit as target variable.
- Penalizes large errors more than MAE.
- More interpretable than MSE.

Disadvantages:

- Also sensitive to outliers.
- Slightly complex to calculate.

Use Cases:

- Performance metric in regression.
- Useful when large prediction errors matter.

✅ 3. What is RMSE (Root Mean Squared Error)?

📌 **Definition:**

RMSE is the square root of MSE. It tells error in original units (like marks).

$$\mathrm{RMSE} = \sqrt{35.8} \approx 5.98$$

💡 **Conclusion**: On average, our prediction error is around **6 marks** — same unit as actual data.

4. R Squared

R^2 Value	Meaning	
1.0	Perfect prediction – model explains all variation	
0.9	90% of the variation is explained by the model	
0.5	50% accuracy – model is average	
0	Model explains nothing (like predicting the mean every time)	
< 0	Model is **worse than a guess** – very poor fit	

R^2 is a metric that tells us **how well our model explains the variation in the data**

Smaller the error → Better the model

Helps us decide: Is this model good enough or do we need to improve it?

f you build 2 models, you can **compare** their errors:

- Model A: MAE = 5
- Model B: MAE = 3

→ **Model B is better** (less error)

⚠️ Important Notes:

- **High R^2 ≠ Best model** always. It might be overfitting.
- **Low R^2 ≠ Useless model** – sometimes data is noisy and hard to predict.
- Always check **other metrics** like MAE, RMSE, and visualize the results.