**Real-Time Example: Confusion Matrix in Disease Diagnosis (Healthcare Domain)**

**Scenario**

A hospital uses a machine learning model to detect **COVID-19** based on patient symptoms, test results, and medical history. The model classifies patients as **Positive (COVID-19 Present)** or **Negative (No COVID-19)**.

After testing **2,000 patients**, the results are summarized in a **confusion matrix**.

**Confusion Matrix for COVID-19 Detection**

| **Actual \ Predicted** | **COVID Positive (Positive)** | **COVID Negative (Negative)** |
| --- | --- | --- |
| **COVID Positive (Positive)** | **300** (True Positive, TP) | **50** (False Negative, FN) |
| **COVID Negative (Negative)** | **40** (False Positive, FP) | **1,610** (True Negative, TN) |

**Explanation of the Values**

* **True Positive (TP) = 300**  
  → Patients correctly diagnosed with COVID-19.
* **False Negative (FN) = 50**  
  → COVID-19 patients wrongly classified as healthy (missed cases).
* **False Positive (FP) = 40**  
  → Healthy patients wrongly diagnosed with COVID-19 (false alarm).
* **True Negative (TN) = 1,610**  
  → Healthy patients correctly classified as not having COVID-19.

**Key Performance Metrics**

Using the confusion matrix, we calculate key metrics:

**1. Accuracy = (TP + TN) / (Total Patients)**

(300 + 1,610) / 2,000 = 0.955 \text{ (95.5% accurate)}

**2. Precision (COVID-19 Detection Accuracy) = TP / (TP + FP)**

300 / (300 + 40) = 0.882 \text{ (88.2%)}

→ Out of all predicted COVID-19 cases, 88.2% were actually infected.

**3. Recall (Sensitivity or True Positive Rate) = TP / (TP + FN)**

300 / (300 + 50) = 0.857 \text{ (85.7%)}

→ The model correctly identified 85.7% of actual COVID-19 cases.

**4. F1-Score (Harmonic Mean of Precision & Recall)**

2 \times \frac{0.882 \times 0.857}{0.882 + 0.857} = 0.869 \text{ (86.9%)}

**Insights and Medical Impact**

* **High Accuracy (95.5%)** shows the model performs well overall.
* **High Precision (88.2%)** means fewer false alarms (healthy patients misdiagnosed as COVID-19).
* **High Recall (85.7%)** ensures most COVID-19 cases are detected, reducing the risk of undiagnosed infections.
* **False Negatives (50 missed COVID-19 cases)** could lead to severe health risks as infected patients remain untreated.
* **False Positives (40 healthy patients wrongly diagnosed)** might cause unnecessary isolation or treatment.

**Conclusion**

The confusion matrix helps the hospital evaluate the trade-off between detecting real COVID-19 cases and avoiding unnecessary quarantines. The model could be further refined by using **additional lab tests (e.g., CT scans, PCR tests)** to reduce false negatives.