1. Accuracy and Performance Metrics

- **Mushrooms Dataset**
    - Accuracy: **100%**
    - Precision, Recall, F1-Score (macro/weighted): **1.0**
    - Interpretation: Perfect classification → features are highly discriminative (e.g., odor, spore-print-color). No signs of class overlap.
- **Nursery Dataset**
    - Accuracy: **98.87%**
    - Precision/Recall (weighted): ~0.989
    - Precision/Recall (macro): ~0.958
    - Interpretation: Very high performance, but macro-average slightly lower → suggests some **minor class imbalance**, where smaller classes are not predicted as accurately.
- **Tic-Tac-Toe Dataset**
    - Accuracy: **88.36%**
    - Precision/Recall (weighted): ~0.883
    - Precision/Recall (macro): ~0.87
    - Interpretation: Still good, but clearly harder than mushrooms/nursery. Some decision patterns (winning conditions) overlap, leading to misclassifications.

2. Tree Complexity Metrics

- **Mushrooms**
    - Max Depth: 4
    - Total Nodes: 29 (24 leaf, 5 internal)
    - Interpretation: Very **shallow & compact tree**, yet perfect accuracy → strong indicators of highly separable classes.
- **Nursery**
    - Max Depth: 7
    - Total Nodes: 983 (703 leaf, 280 internal)
    - Interpretation: Tree is **huge**, reflecting the dataset's multi-valued categorical features. High complexity but generalizes well (~99% accuracy).
- **Tic-Tac-Toe**
    - Max Depth: 7
    - Total Nodes: 260 (165 leaf, 95 internal)
    - Interpretation: Medium complexity, but still less accurate → suggests the dataset has **noisy/ambiguous decision patterns** (different board states map to same outcomes).

3. Dataset-Specific Insights

- **Mushrooms**
    - Feature Importance: Odor, spore-print-color, gill-size (highly predictive).
    - Class Distribution: Balanced (edible vs poisonous).
    - Decision Patterns: Few strong rules can perfectly separate classes.
    - Overfitting: None → shallow tree, perfect accuracy.
- **Nursery**
    - Feature Importance: Parents, financial status, health, housing.
    - Class Distribution: Imbalanced (some class labels have very few samples).
    - Decision Patterns: Many branch paths due to multi-valued features.
    - Overfitting: Large tree, but accuracy still high → no severe overfitting.
- **Tic-Tac-Toe**
    - Feature Importance: Central cell, corners, and edges (critical for win/loss).
    - Class Distribution: Likely balanced (win vs lose/draw).
    - Decision Patterns: Board states with similar moves → harder to separate.
    - Overfitting: Tree depth 7, but not high accuracy → dataset complexity is the limiting factor.

4. Comparative Analysis

a) Algorithm Performance

- Highest accuracy: **Mushrooms dataset (100%)**, because features perfectly separate edible/poisonous mushrooms.
- Dataset size: Larger datasets (Nursery) → more complex trees, but still high accuracy due to more examples.
- Number of features: Multi-valued categorical features in Nursery led to deeper, much larger trees compared to binary features in Tic-Tac-Toe.

b) Data Characteristics Impact

- Class imbalance: Affected **Nursery** slightly (macro F1 < weighted F1).
- Feature type:
    - **Binary features** (Tic-Tac-Toe) → more ambiguity, lower accuracy.
    - **Multi-valued categorical features** (Nursery, Mushrooms) → stronger splits, better classification.

c) Practical Applications

- **Mushrooms Dataset**: Food safety / biological classification. Very interpretable and trustworthy because tree is small.
- **Nursery Dataset**: Decision support (e.g., admission systems, resource allocation). Large tree makes interpretation harder, but accuracy is strong.
- **Tic-Tac-Toe Dataset**: Game AI / strategy learning. Accuracy <90% shows decision trees might not capture optimal strategies perfectly.

d) Improvements

- **Mushrooms**: Already perfect → no improvement needed.

- **Nursery**: Use **pruning** to reduce complexity without losing much accuracy. Could also try ensemble methods (Random Forest).

- **Tic-Tac-Toe**: Try **feature engineering** (e.g., detecting win/lose lines directly). Ensemble methods may improve accuracy beyond 88%.