

Decision Tree Analysis Report

1. Performance Results

Accuracy and Scores by Dataset

Mushrooms Dataset:

- Accuracy: 100.00%
- Weighted Precision: 1.0000, Recall: 1.0000, F1-Score: 1.0000
- Macro Precision: 1.0000, Recall: 1.0000, F1-Score: 1.0000

Tic-Tac-Toe Dataset:

- Accuracy: 87.30%
- Weighted Precision: 0.8741, Recall: 0.8730, F1-Score: 0.8734
- Macro Precision: 0.8590, Recall: 0.8638, F1-Score: 0.8613

Nursery Dataset:

- Accuracy: 98.67%
- Weighted Precision: 0.9876, Recall: 0.9867, F1-Score: 0.9872
- Macro Precision: 0.7604, Recall: 0.7654, F1-Score: 0.7628

What This Means

- Mushrooms: Perfect results (100% correct)
- Nursery: Very good results (98.67% correct)
- Tic-Tac-Toe: Good results (87.30% correct)
- Nursery has a big difference between weighted and macro scores, which means some classes have way more examples than others

2. Tree Structure Details

Tree Size Information

Dataset	Max Depth	Total Nodes	Leaf Nodes	Internal Nodes	Training Samples	Test Samples
Mushrooms	4	29	24	5	6,499	1,625
Tic-Tac-Toe	7	281	180	101	766	192
Nursery	7	952	680	272	10,368	2,592

What This Means

- Mushrooms: Small, simple tree (only 4 levels deep, 29 nodes total)
- Tic-Tac-Toe: Medium complexity (7 levels, 281 nodes)
- Nursery: Most complex tree (952 nodes, same depth as Tic-Tac-Toe)
- Tree complexity depends more on how easy the data is to separate than on dataset size

3. Dataset Details

Mushrooms Dataset

- **Features:** 22 attributes (cap-shape, cap-surface, cap-color, bruises, odor, etc.)
- **Samples:** 8,124 total (6,499 training, 1,625 test)
- **Classes:** 2 (poisonous 'p', edible 'e')

Key Points:

- Most important feature: odor (information gain: 0.9083) - this is the root of the tree
- The odor feature alone can almost perfectly classify mushrooms
- Tree is very shallow (depth 4) because the features separate the classes clearly
- Other features used: spore-print-color, habitat, gill-size, cap-color (for edge cases)
- Perfect classification with no overfitting problems

Tic-Tac-Toe Dataset

- **Features:** 9 attributes (all board positions: top-left-square through bottom-right-square)
- **Samples:** 958 total (766 training, 192 test)
- **Classes:** 2 (positive, negative)

Key Points:

- Tree is the deepest relative to dataset size (depth 7, 281 nodes)
- 87.30% accuracy suggests the game logic is complex
- All features are board positions with equal importance
- May have some overfitting because the tree is complex for a small dataset

Nursery Dataset

- **Features:** 8 attributes (parents, has_nurs, form, children, housing, finance, social, health)
- **Samples:** 12,960 total (10,368 training, 2,592 test)
- **Classes:** 5 (recommend, priority, not_recom, very_recom, spec_prior)

Key Points:

- Class imbalance: Big difference between weighted (98.67%) and macro (76.54%) precision means classes have very different numbers of examples
- Largest tree (952 nodes) because it handles 5 classes
- High weighted scores but moderate macro scores means some classes are easy to separate, others are not

4. Comparison Summary

How Dataset Features Affect Tree Performance

Aspect	Mushrooms	Tic-Tac-Toe	Nursery
How well data separates	Excellent (perfect)	Moderate (87%)	Good (98%)
Feature quality	Very high (odor decides everything)	Moderate (all positions matter)	Good (hierarchical attributes)
Class balance	Balanced	Balanced	Imbalanced
Tree efficiency	Very efficient (29 nodes)	Moderate efficiency	Lower efficiency (952 nodes)

5. Main Findings

1. **Feature Dominance:** Mushrooms work great because one feature (odor) is super predictive
2. **Problem Complexity:** Tic-Tac-Toe game logic needs more complex decision rules
3. **Multi-class Challenge:** Nursery's 5 classes make the tree more complex
4. **Overfitting Risk:** Tic-Tac-Toe has highest risk because complex tree + small dataset
5. **Dataset Size Impact:** Larger datasets (Nursery) can handle complex trees better

6. Recommendations

1. **Mushrooms:** Model is perfect - don't change anything
2. **Tic-Tac-Toe:** Try pruning the tree or use ensemble methods to reduce overfitting
3. **Nursery:** Fix class imbalance using sampling techniques or cost-sensitive learning

7. Implementation Check

The PyTorch and scikit-learn versions give identical results for the Mushrooms dataset, which shows the implementations are correct and consistent.