MACHINE LEARNING Laboratory

5th Semester, Academic Year 2025

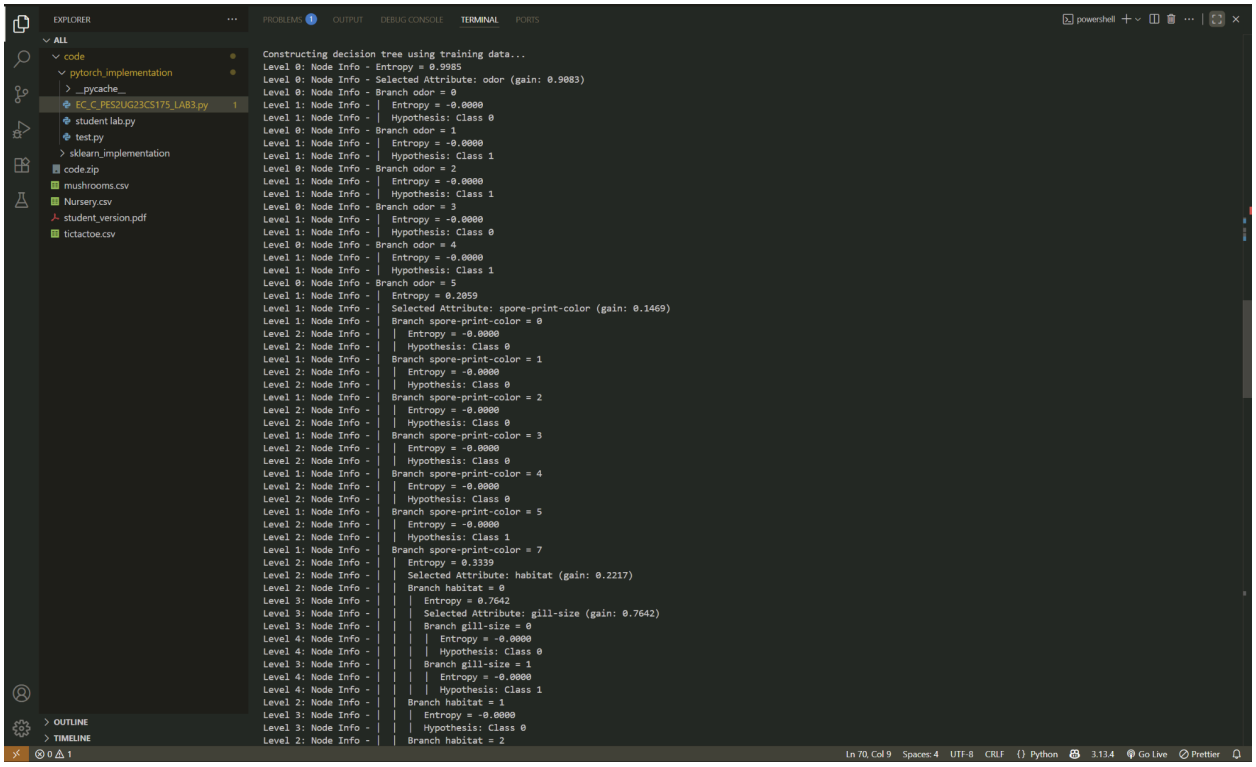
Date:19-08-2025

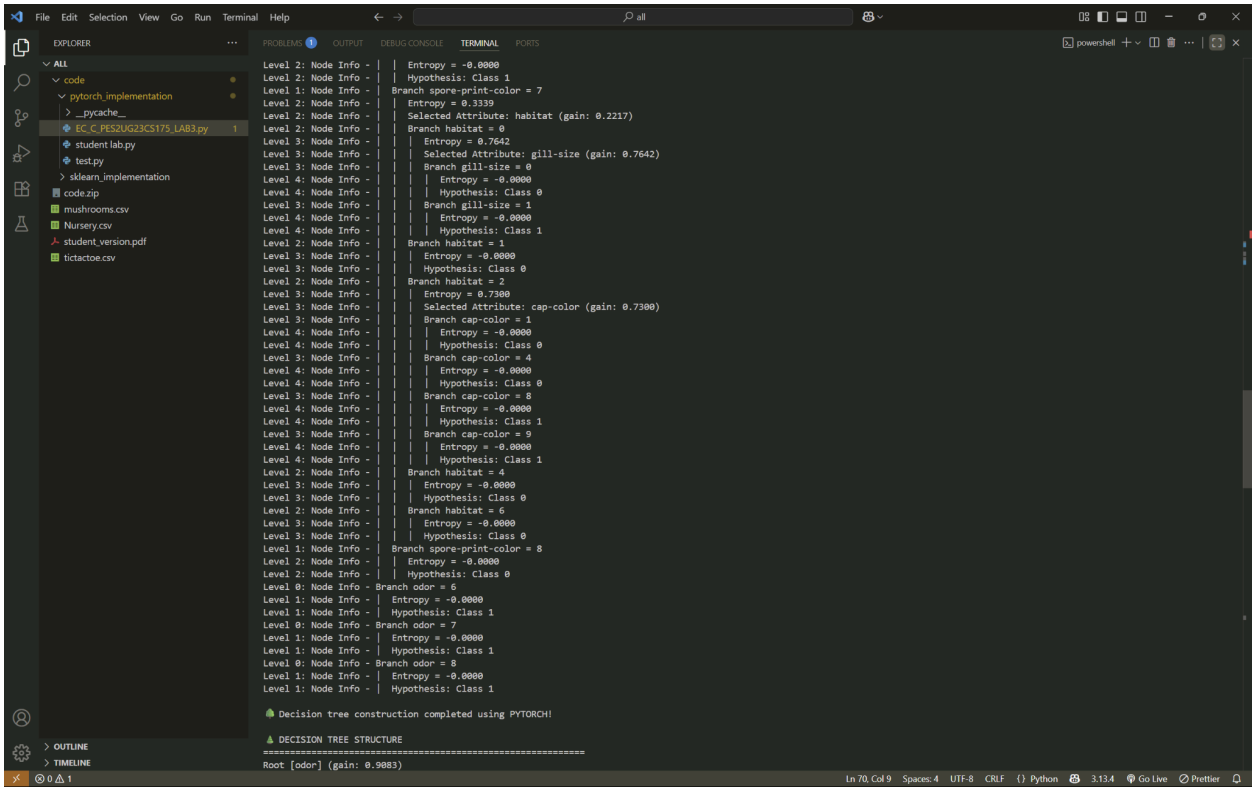
Name: Dhruv Thakur	SRN:PES2UG23CS175	Section C

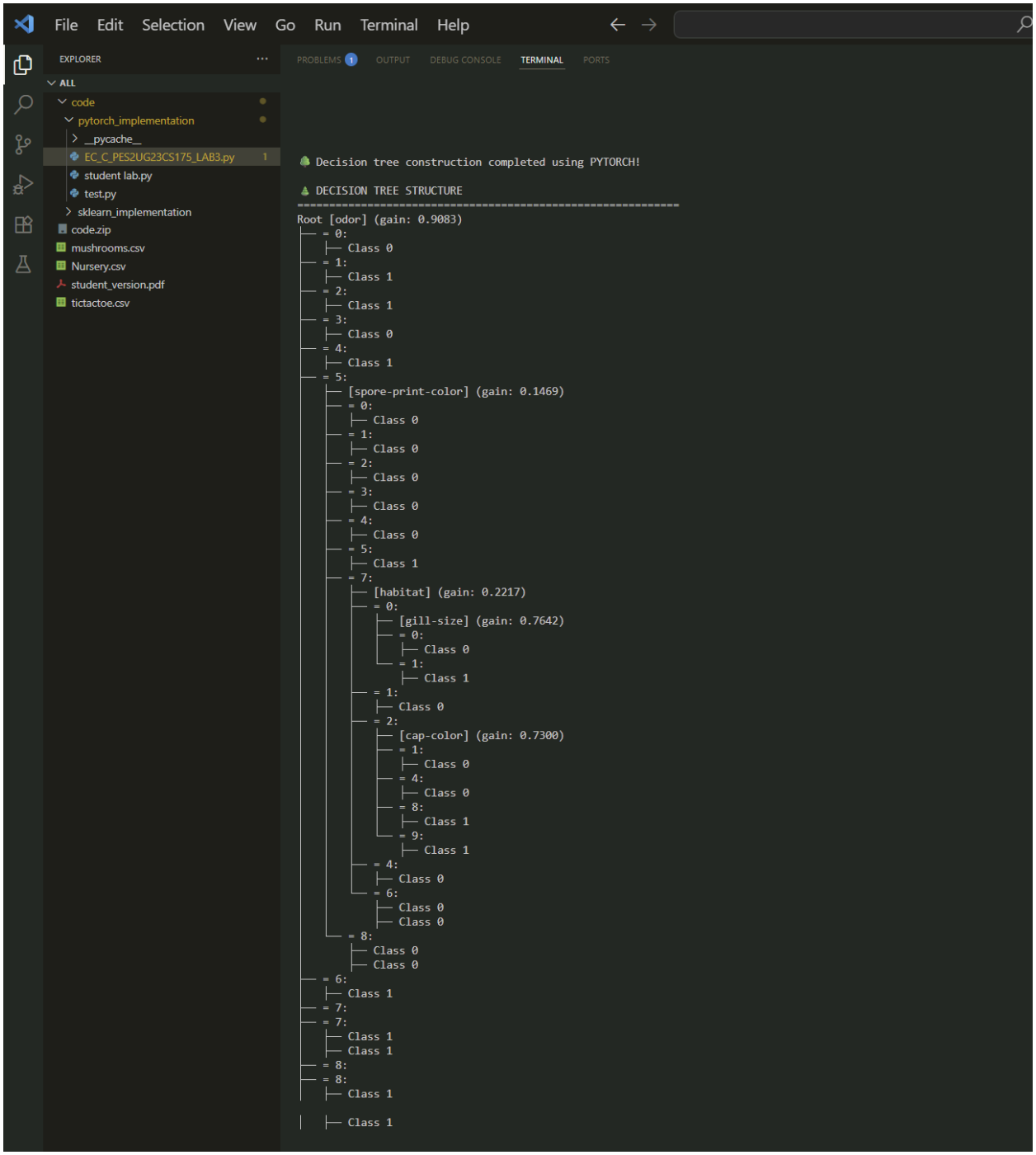
Week#____3_____

MUSHROOMS.CSV

```
PS C:\Users\Dhruv Thakur\Downloads\all> python code\pytorch_implementation\test.py --ID EC_C_PES2UG23CS175_LAB3 --data mushrooms.csv --framework pytorch --print-tree --print-construc
tion
Running tests with PYTORCH framework
============================================================
 target column: 'class' (last column)
Original dataset info:
Shape: (8124, 23)
Columns: ['cap-shape', 'cap-surface', 'cap-color', 'bruises', 'odor', 'gill-attachment', 'gill-spacing', 'gill-size', 'gill-color', 'stalk-shape', 'stalk-root', 'stalk-surface-above-
ring', 'stalk-surface-below-ring', 'stalk-color-above-ring', 'stalk-color-below-ring', 'veil-type', 'veil-color', 'ring-number', 'ring-type', 'spore-print-color', 'population', 'habi
tat', 'class']

First few rows:

cap-shape: ['x' 'b' 's' 'f' 'k'] -> [5 0 4 2 3]

cap-surface: ['s' 'y' 'f' 'g'] -> [2 3 0 1]

cap-color: ['n' 'y' 'w' 'g' 'e'] -> [4 9 8 3 2]

class: ['p' 'e'] -> [1 0]

Processed dataset shape: torch.Size([8124, 23])
Number of features: 22
Features: ['cap-shape', 'cap-surface', 'cap-color', 'bruises', 'odor', 'gill-attachment', 'gill-spacing', 'gill-size', 'gill-color', 'stalk-shape', 'stalk-root', 'stalk-surface-above
-ring', 'stalk-surface-below-ring', 'stalk-color-above-ring', 'stalk-color-below-ring', 'veil-type', 'veil-color', 'ring-number', 'ring-type', 'spore-print-color', 'population', 'hab
itat']
Target: class
Framework: PYTORCH
Data type: <class 'torch.Tensor'>

============================================================
DECISION TREE CONSTRUCTION DEMO
============================================================
Total samples: 8124
Training samples: 6499
Testing samples: 1625
```


EXPLORER
ALL
code
pytorch_implementation
__pycache__
EC_C_PES2UG23CS175_LAB3.py
student lab.py
test.py
sklearn_implementation
code.zip
mushrooms.csv
Nursery.csv
student_version.pdf
tictactoe.csv
OUTLINE
TIMELINE
PROBLEMS
OUTPUT
DEBUG CONSOLE
TERMINAL
PORTS
powershell
Constructing decision tree using training data...
Level 0: Node Info - Entropy = 0.9985
Level 0: Node Info - Selected Attribute: odor (gain: 0.9083)
Level 0: Node Info - Branch odor = 0
Level 1: Node Info - | Entropy = -0.0000
Level 1: Node Info - | Hypothesis: Class 0
Level 0: Node Info - Branch odor = 1
Level 1: Node Info - | Entropy = -0.0000
Level 1: Node Info - | Hypothesis: Class 1
Level 0: Node Info - Branch odor = 2
Level 1: Node Info - | Entropy = -0.0000
Level 1: Node Info - | Hypothesis: Class 1
Level 0: Node Info - Branch odor = 3
Level 1: Node Info - | Entropy = -0.0000
Level 1: Node Info - | Hypothesis: Class 0
Level 0: Node Info - Branch odor = 4
Level 1: Node Info - | Entropy = -0.0000
Level 1: Node Info - | Hypothesis: Class 1
Level 0: Node Info - Branch odor = 5
Level 1: Node Info - | Entropy = 0.2059
Level 1: Node Info - | Selected Attribute: spore-print-color (gain: 0.1469)
Level 1: Node Info - | Branch spore-print-color = 0
Level 2: Node Info - | | Entropy = -0.0000
Level 2: Node Info - | | Hypothesis: Class 0
Level 1: Node Info - | Branch spore-print-color = 1
Level 2: Node Info - | | Entropy = -0.0000
Level 2: Node Info - | | Hypothesis: Class 0
Level 1: Node Info - | Branch spore-print-color = 2
Level 2: Node Info - | | Entropy = -0.0000
Level 2: Node Info - | | Hypothesis: Class 0
Level 1: Node Info - | Branch spore-print-color = 3
Level 2: Node Info - | | Entropy = -0.0000
Level 2: Node Info - | | Hypothesis: Class 0
Level 1: Node Info - | Branch spore-print-color = 4
Level 2: Node Info - | | Entropy = -0.0000
Level 2: Node Info - | | Hypothesis: Class 0
Level 1: Node Info - | Branch spore-print-color = 5
Level 2: Node Info - | | Entropy = -0.0000
Level 2: Node Info - | | Hypothesis: Class 1
Level 1: Node Info - | Branch spore-print-color = 7
Level 2: Node Info - | | Entropy = 0.3339
Level 2: Node Info - | | Selected Attribute: habitat (gain: 0.2217)
Level 2: Node Info - | | Branch habitat = 0
Level 3: Node Info - | | | Entropy = 0.7642
Level 3: Node Info - | | | Selected Attribute: gill-size (gain: 0.7642)
Level 3: Node Info - | | | Branch gill-size = 0
Level 4: Node Info - | | | | Entropy = -0.0000
Level 4: Node Info - | | | | Hypothesis: Class 0
Level 3: Node Info - | | | Branch gill-size = 1
Level 4: Node Info - | | | | Entropy = -0.0000
Level 4: Node Info - | | | | Hypothesis: Class 1
Level 2: Node Info - | | Branch habitat = 1
Level 3: Node Info - | | | Entropy = -0.0000
Level 3: Node Info - | | | Hypothesis: Class 0
Level 2: Node Info - | | Branch habitat = 2
Ln 70, Col 9
Spaces: 4
UTF-8
CRLF
Python
3.13.4
Go Live
Prettier


File Edit Selection View Go Run Terminal Help
all
EXPLORER
ALL
code
pytorch_implementation
__pycache__
EC_C_PES2UG23CS175_LAB3.py
student lab.py
test.py
sklearn_implementation
code.zip
mushrooms.csv
Nursery.csv
student_version.pdf
tictactoe.csv
OUTLINE
TIMELINE
PROBLEMS
OUTPUT
DEBUG CONSOLE
TERMINAL
PORTS
powershell
Level 2: Node Info - | | Entropy = -0.0000
Level 2: Node Info - | | Hypothesis: Class 1
Level 1: Node Info - | Branch spore-print-color = 7
Level 2: Node Info - | | Entropy = 0.3339
Level 2: Node Info - | | Selected Attribute: habitat (gain: 0.2217)
Level 2: Node Info - | | Branch habitat = 0
Level 3: Node Info - | | | Entropy = 0.7642
Level 3: Node Info - | | | Selected Attribute: gill-size (gain: 0.7642)
Level 3: Node Info - | | | Branch gill-size = 0
Level 4: Node Info - | | | | Entropy = -0.0000
Level 4: Node Info - | | | | Hypothesis: Class 0
Level 3: Node Info - | | | Branch gill-size = 1
Level 4: Node Info - | | | | Entropy = -0.0000
Level 4: Node Info - | | | | Hypothesis: Class 1
Level 2: Node Info - | | Branch habitat = 1
Level 3: Node Info - | | | Entropy = -0.0000
Level 3: Node Info - | | | Hypothesis: Class 0
Level 2: Node Info - | | Branch habitat = 2
Level 3: Node Info - | | | Entropy = 0.7300
Level 3: Node Info - | | | Selected Attribute: cap-color (gain: 0.7300)
Level 3: Node Info - | | | Branch cap-color = 1
Level 4: Node Info - | | | | Entropy = -0.0000
Level 4: Node Info - | | | | Hypothesis: Class 0
Level 3: Node Info - | | | Branch cap-color = 4
Level 4: Node Info - | | | | Entropy = -0.0000
Level 4: Node Info - | | | | Hypothesis: Class 0
Level 3: Node Info - | | | Branch cap-color = 8
Level 4: Node Info - | | | | Entropy = -0.0000
Level 4: Node Info - | | | | Hypothesis: Class 1
Level 3: Node Info - | | | Branch cap-color = 9
Level 4: Node Info - | | | | Entropy = -0.0000
Level 4: Node Info - | | | | Hypothesis: Class 1
Level 2: Node Info - | | Branch habitat = 4
Level 3: Node Info - | | | Entropy = -0.0000
Level 3: Node Info - | | | Hypothesis: Class 0
Level 2: Node Info - | | Branch habitat = 6
Level 3: Node Info - | | | Entropy = -0.0000
Level 3: Node Info - | | | Hypothesis: Class 0
Level 1: Node Info - | Branch spore-print-color = 8
Level 2: Node Info - | | Entropy = -0.0000
Level 2: Node Info - | | Hypothesis: Class 0
Level 0: Node Info - Branch odor = 6
Level 1: Node Info - | Entropy = -0.0000
Level 1: Node Info - | Hypothesis: Class 1
Level 0: Node Info - Branch odor = 7
Level 1: Node Info - | Entropy = -0.0000
Level 1: Node Info - | Hypothesis: Class 1
Level 0: Node Info - Branch odor = 8
Level 1: Node Info - | Entropy = -0.0000
Level 1: Node Info - | Hypothesis: Class 1
Decision tree construction completed using PYTORCH!
DECISION TREE STRUCTURE
Root [odor] (gain: 0.9083)
Ln 70, Col 9
Spaces: 4
UTF-8
CRLF
Python
3.13.4
Go Live
Prettier


File Edit Selection View Go Run Terminal Help
EXPLORER
ALL
code
pytorch_implementation
__pycache__
EC_C_PES2UG23CS175_LAB3.py 1
student lab.py
test.py
sklearn_implementation
code.zip
mushrooms.csv
Nursery.csv
student_version.pdf
tictactoe.csv
PROBLEMS 1 OUTPUT DEBUG CONSOLE TERMINAL PORTS
Decision tree construction completed using PYTORCH!
DECISION TREE STRUCTURE
Root [odor] (gain: 0.9083)
├── = 0:
│ ├── Class 0
├── = 1:
│ ├── Class 1
├── = 2:
│ ├── Class 1
├── = 3:
│ ├── Class 0
├── = 4:
│ ├── Class 1
├── = 5:
│ ├── [spore-print-color] (gain: 0.1469)
│ ├── = 0:
│ │ ├── Class 0
│ ├── = 1:
│ │ ├── Class 0
│ ├── = 2:
│ │ ├── Class 0
│ ├── = 3:
│ │ ├── Class 0
│ ├── = 4:
│ │ ├── Class 0
│ ├── = 5:
│ │ ├── Class 1
│ ├── = 7:
│ │ ├── [habitat] (gain: 0.2217)
│ │ ├── = 0:
│ │ │ ├── [gill-size] (gain: 0.7642)
│ │ │ ├── = 0:
│ │ │ │ ├── Class 0
│ │ │ └── = 1:
│ │ │ ├── Class 1
│ │ ├── = 1:
│ │ │ ├── Class 0
│ │ ├── = 2:
│ │ │ ├── [cap-color] (gain: 0.7300)
│ │ │ ├── = 1:
│ │ │ │ ├── Class 0
│ │ │ ├── = 4:
│ │ │ │ ├── Class 0
│ │ │ ├── = 8:
│ │ │ │ ├── Class 1
│ │ │ └── = 9:
│ │ │ ├── Class 1
│ │ ├── = 4:
│ │ │ ├── Class 0
│ │ └── = 6:
│ │ ├── Class 0
│ │ ├── Class 0
│ └── = 8:
│ ├── Class 0
│ ├── Class 0
├── = 6:
│ ├── Class 1
├── = 7:
├── = 7:
│ ├── Class 1
│ ├── Class 1
├── = 8:
├── = 8:
│ ├── Class 1
│ ├── Class 1


File Edit Selection View Go Run Terminal Help
EXPLORER
ALL
code
pytorch_implementation
__pycache__
EC_C_PES2UG23CS175_LAB3.py 1
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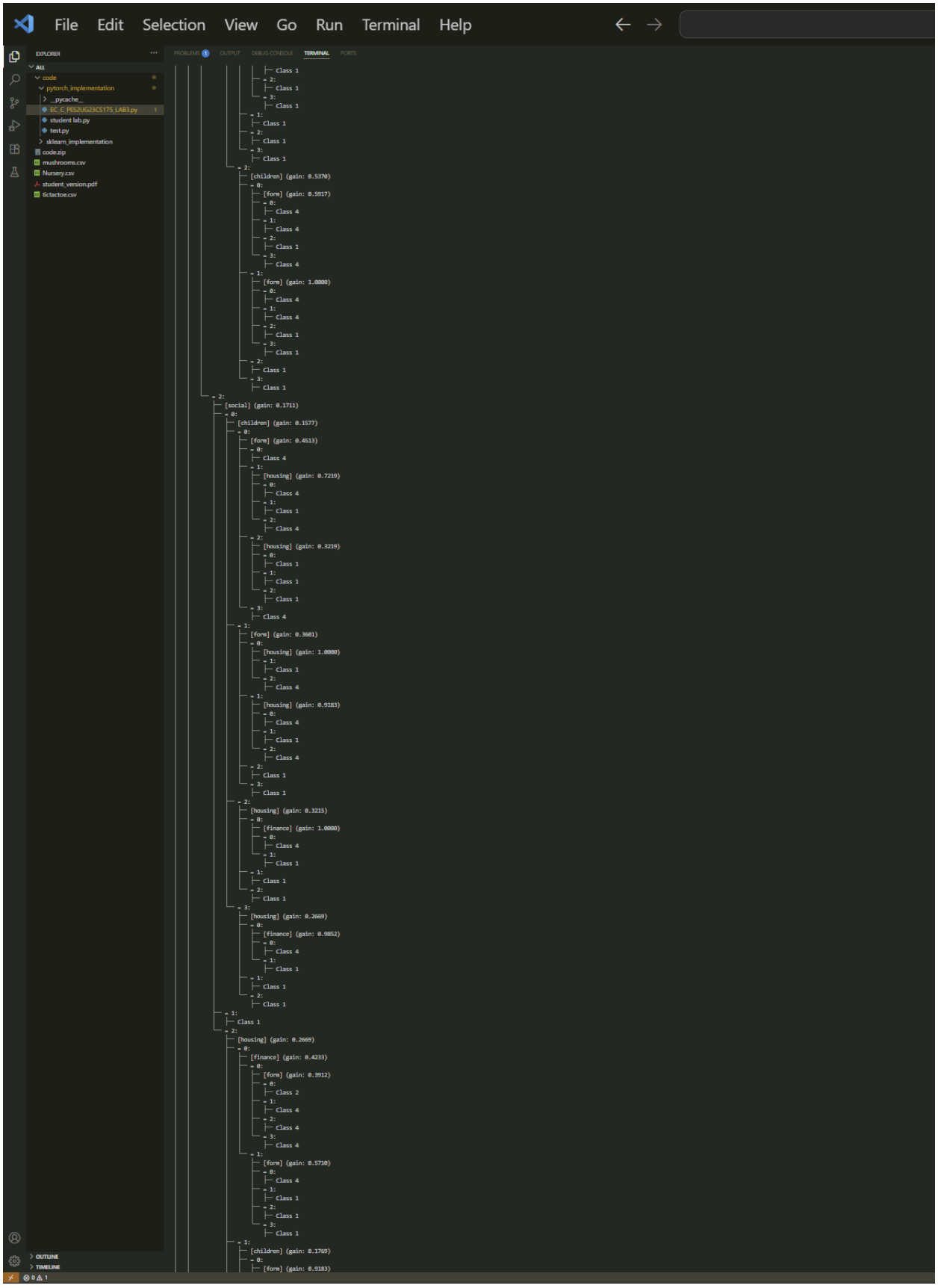
Nursery.csv
student_version.pdf
tictactoe.csv
PROBLEMS 1 OUTPUT DEBUG CONSOLE TERMINAL PORTS
│ │ │ │ ├── = 8:
│ │ │ │ │ ├── Class 1
│ │ │ │ └── = 9:
│ │ │ │ ├── Class 1
│ │ │ ├── = 4:
│ │ │ │ ├── Class 0
│ │ │ └── = 6:
│ │ │ ├── Class 0
│ │ │ ├── Class 0
│ │ └── = 8:
│ │ ├── Class 0
│ │ ├── Class 0
├── = 6:
│ ├── Class 1
├── = 7:
├── = 7:
│ ├── Class 1
│ ├── Class 1
├── = 8:
├── = 8:
│ ├── Class 1
│ ├── Class 1
📊 OVERALL PERFORMANCE METRICS
📊 OVERALL PERFORMANCE METRICS
==========
📊 OVERALL PERFORMANCE METRICS
==========
Accuracy: 1.0000 (100.00%)
Precision (weighted): 1.0000
Recall (weighted): 1.0000
==========
Accuracy: 1.0000 (100.00%)
Precision (weighted): 1.0000
Recall (weighted): 1.0000
Accuracy: 1.0000 (100.00%)
Precision (weighted): 1.0000
Recall (weighted): 1.0000
Recall (weighted): 1.0000
F1-Score (weighted): 1.0000
Precision (macro): 1.0000
Recall (macro): 1.0000
F1-Score (macro): 1.0000
Recall (macro): 1.0000
F1-Score (macro): 1.0000
F1-Score (macro): 1.0000
🌳 TREE COMPLEXITY METRICS
🌳 TREE COMPLEXITY METRICS
==========
🌳 TREE COMPLEXITY METRICS
==========
Maximum Depth: 4
==========
Maximum Depth: 4
Maximum Depth: 4
Total Nodes: 29
Leaf Nodes: 24
Internal Nodes: 5
PS C:\Users\Dhruv Thakur\Downloads\all>
OUTLINE

NURSERY.CSV


File Edit Selection View Go Run Terminal Help
EXPLORER
PROBLEMS 1
OUTPUT
DEBUG CONSOLE
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PORTS
ALL
code
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mushrooms.csv
Nursery.csv
student_version.pdf
tictactoe.csv
OUTLINE
TIMELINE
├── Class 1
├── 2:
│ └── Class 1
└── 3:
└── Class 1
├── 1:
│ ├── Class 1
├── 2:
│ ├── Class 1
└── 3:
└── Class 1
└── 2:
├── [children] (gain: 0.5370)
├── 0:
│ ├── [form] (gain: 0.5917)
│ ├── 0:
│ │ ├── Class 4
│ ├── 1:
│ │ ├── Class 4
│ ├── 2:
│ │ ├── Class 1
│ └── 3:
│ ├── Class 4
├── 1:
│ ├── [form] (gain: 1.0000)
│ ├── 0:
│ │ ├── Class 4
│ ├── 1:
│ │ ├── Class 4
│ ├── 2:
│ │ ├── Class 1
│ └── 3:
│ ├── Class 1
├── 2:
│ ├── Class 1
└── 3:
├── Class 1
└── 2:
├── [social] (gain: 0.1711)
├── 0:
│ ├── [children] (gain: 0.1577)
│ ├── 0:
│ │ ├── [form] (gain: 0.4513)
│ │ ├── 0:
│ │ │ ├── Class 4
│ │ ├── 1:
│ │ │ ├── [housing] (gain: 0.7219)
│ │ │ ├── 0:
│ │ │ │ ├── Class 4
│ │ │ ├── 1:
│ │ │ │ ├── Class 1
│ │ │ └── 2:
│ │ │ ├── Class 4
│ │ ├── 2:
│ │ │ ├── [housing] (gain: 0.3219)
│ │ │ ├── 0:
│ │ │ │ ├── Class 1
│ │ │ ├── 1:
│ │ │ │ ├── Class 1
│ │ │ └── 2:
│ │ │ ├── Class 1
│ │ └── 3:
│ │ ├── Class 4
│ ├── 1:
│ │ ├── [form] (gain: 0.3601)
│ │ ├── 0:
│ │ │ ├── [housing] (gain: 1.0000)
│ │ │ ├── 1:
│ │ │ │ ├── Class 1
│ │ │ └── 2:
│ │ │ ├── Class 4
│ │ ├── 1:
│ │ │ ├── [housing] (gain: 0.9183)
│ │ │ ├── 0:
│ │ │ │ ├── Class 4
│ │ │ ├── 1:
│ │ │ │ ├── Class 1
│ │ │ └── 2:
│ │ │ ├── Class 4
│ │ ├── 2:
│ │ │ ├── Class 1
│ │ └── 3:
│ │ ├── Class 1
│ ├── 2:
│ │ ├── [housing] (gain: 0.3215)
│ │ ├── 0:
│ │ │ ├── [finance] (gain: 1.0000)
│ │ │ ├── 0:
│ │ │ │ ├── Class 4
│ │ │ └── 1:
│ │ │ ├── Class 1
│ │ ├── 1:
│ │ │ ├── Class 1
│ │ └── 2:
│ │ ├── Class 1
│ └── 3:
│ ├── [housing] (gain: 0.2669)
│ ├── 0:
│ │ ├── [finance] (gain: 0.9852)
│ │ ├── 0:
│ │ │ ├── Class 4
│ │ └── 1:
│ │ ├── Class 1
│ ├── 1:
│ │ ├── Class 1
│ └── 2:
│ ├── Class 1
├── 1:
│ ├── Class 1
└── 2:
├── [housing] (gain: 0.2668)
├── 0:
│ ├── [finance] (gain: 0.4233)
│ ├── 0:
│ │ ├── [form] (gain: 0.3912)
│ │ ├── 0:
│ │ │ ├── Class 2
│ │ ├── 1:
│ │ │ ├── Class 4
│ │ ├── 2:
│ │ │ ├── Class 4
│ │ └── 3:
│ │ ├── Class 4
│ ├── 1:
│ │ ├── [form] (gain: 0.5710)
│ │ ├── 0:
│ │ │ ├── Class 4
│ │ ├── 1:
│ │ │ ├── Class 1
│ │ ├── 2:
│ │ │ ├── Class 1
│ │ └── 3:
│ │ ├── Class 1
├── 1:
│ ├── [children] (gain: 0.1769)
│ ├── 0:
│ │ ├── [form] (gain: 0.9183)


File Edit Selection View Go Run Terminal Help
EXPLORER
ALL
code
pytorch_implementation
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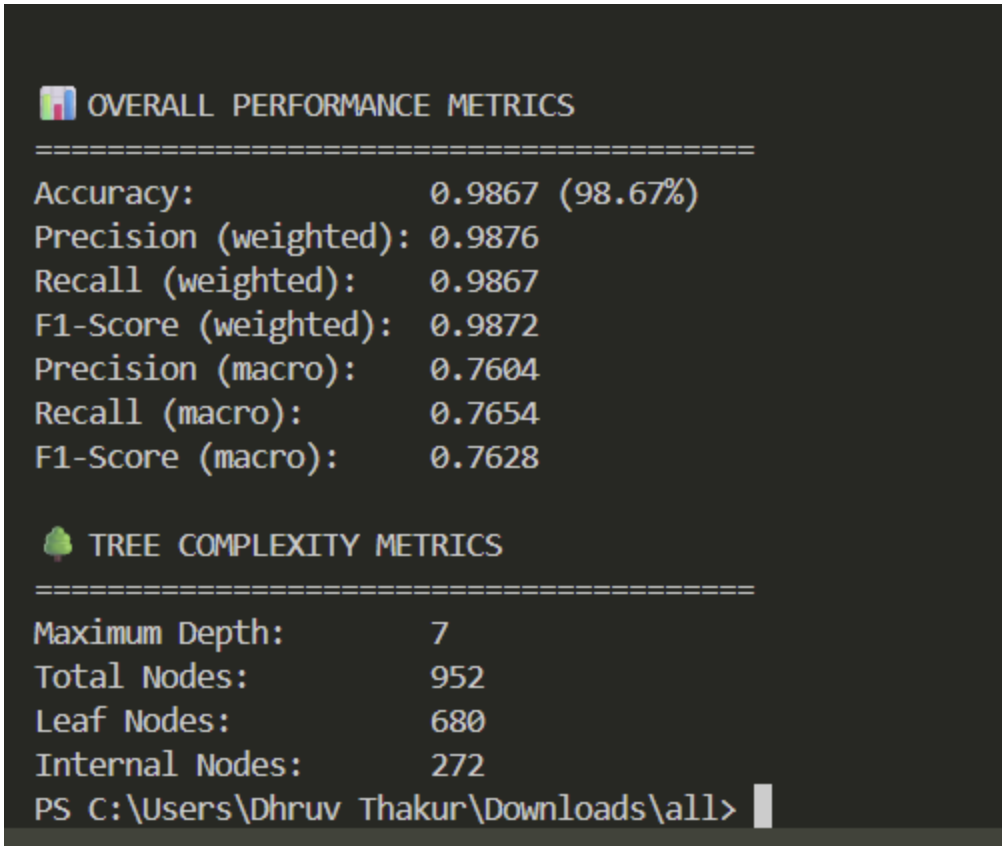
tictactoe.csv
OUTLINE
TIMELINE
PROBLEMS
OUTPUT
DEBUG CONSOLE
TERMINAL
PORTS
[social] (gain: 0.1355)
= 0:
[housing] (gain: 0.2568)
= 0:
[finance] (gain: 0.4099)
= 0:
Class 1
= 1:
[children] (gain: 0.4312)
= 0:
[form] (gain: 0.8113)
= 0:
Class 1
= 1:
Class 1
= 2:
Class 3
= 3:
Class 1
= 1:
[form] (gain: 0.9940)
= 0:
Class 1
= 1:
Class 1
= 2:
Class 3
= 3:
Class 3
= 2:
Class 3
= 3:
Class 3
= 1:
[form] (gain: 0.0887)
= 0:
[children] (gain: 0.6723)
= 0:
Class 1
= 1:
Class 3
= 2:
Class 3
= 3:
Class 3
= 1:
Class 3
= 2:
Class 3
= 3:
Class 3
= 2:
[children] (gain: 0.4779)
= 0:
[form] (gain: 0.8524)
= 0:
Class 1
= 1:
Class 1
= 2:
Class 3
= 3:
Class 1
= 1:
[form] (gain: 0.9495)
= 0:
Class 1
= 1:
Class 1
= 2:
Class 3
= 3:
Class 3
= 2:
Class 3
= 3:
Class 3
= 1:
[form] (gain: 0.0182)
= 0:
[children] (gain: 0.0748)
= 0:
[housing] (gain: 0.3060)
= 0:
[finance] (gain: 1.0000)
= 0:
Class 1
= 1:
Class 3
= 1:
Class 3
= 2:
Class 3
= 1:
Class 3
= 2:
Class 3
= 3:
Class 3
= 1:
Class 3
= 2:
Class 3
= 3:
Class 3
= 2:
[housing] (gain: 0.2060)
= 0:
[finance] (gain: 0.4994)
= 0:
Class 1
= 1:
[children] (gain: 0.4516)
= 0:
[form] (gain: 0.8113)
= 0:
Class 1
= 1:
Class 1
= 2:
Class 3
= 3:
Class 1
= 1:
[form] (gain: 0.8631)
= 0:
Class 1
= 1:
Class 1
= 2:
Class 3
= 3:
Class 3
= 2:
Class 3
= 3:
Class 3


📊 OVERALL PERFORMANCE METRICS
==========
Accuracy: 0.9867 (98.67%)
Precision (weighted): 0.9876
Recall (weighted): 0.9867
F1-Score (weighted): 0.9872
Precision (macro): 0.7604
Recall (macro): 0.7654
F1-Score (macro): 0.7628
🌳 TREE COMPLEXITY METRICS
==========
Maximum Depth: 7
Total Nodes: 952
Leaf Nodes: 680
Internal Nodes: 272
PS C:\Users\Dhruv Thakur\Downloads\all>

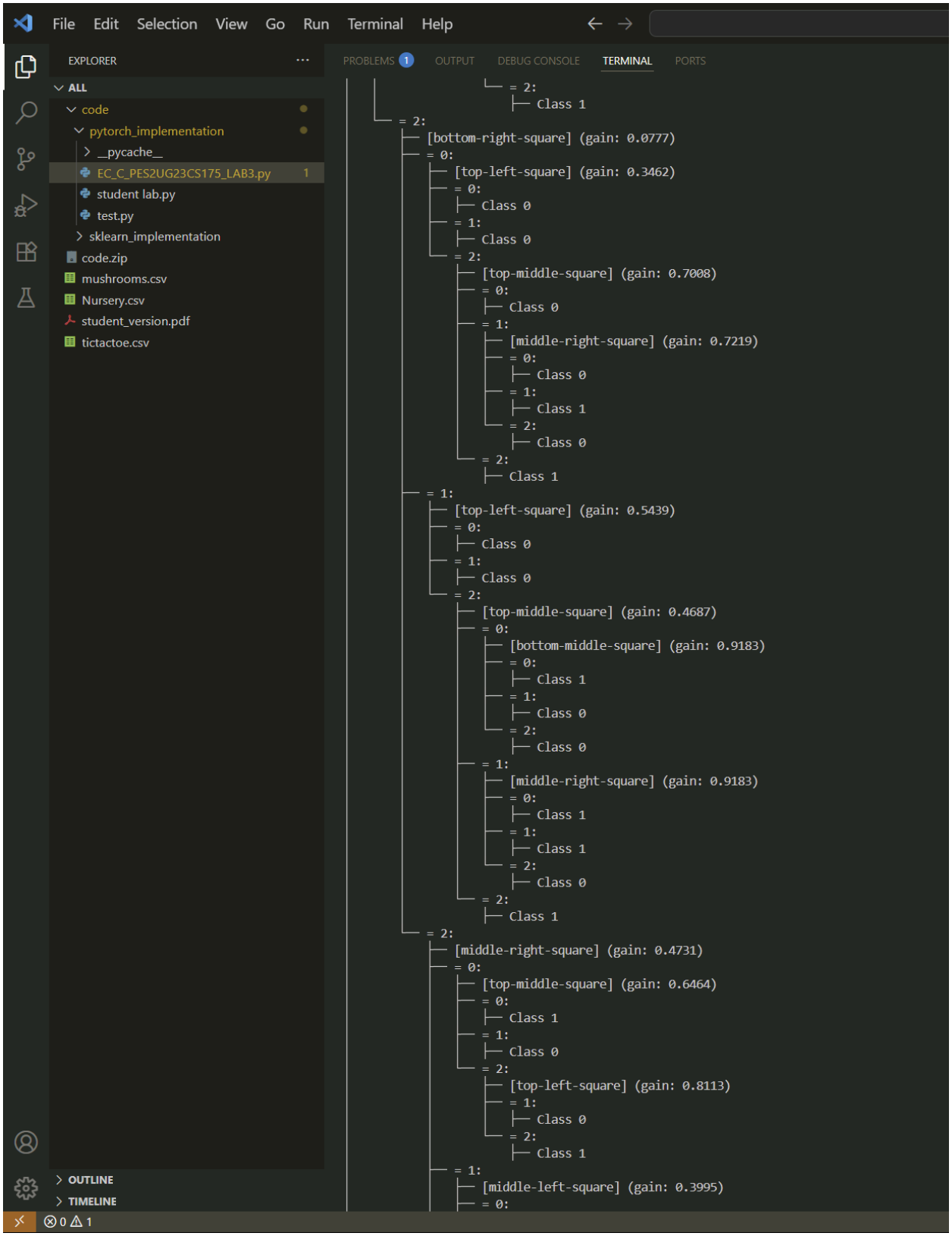
tictactoe.csv

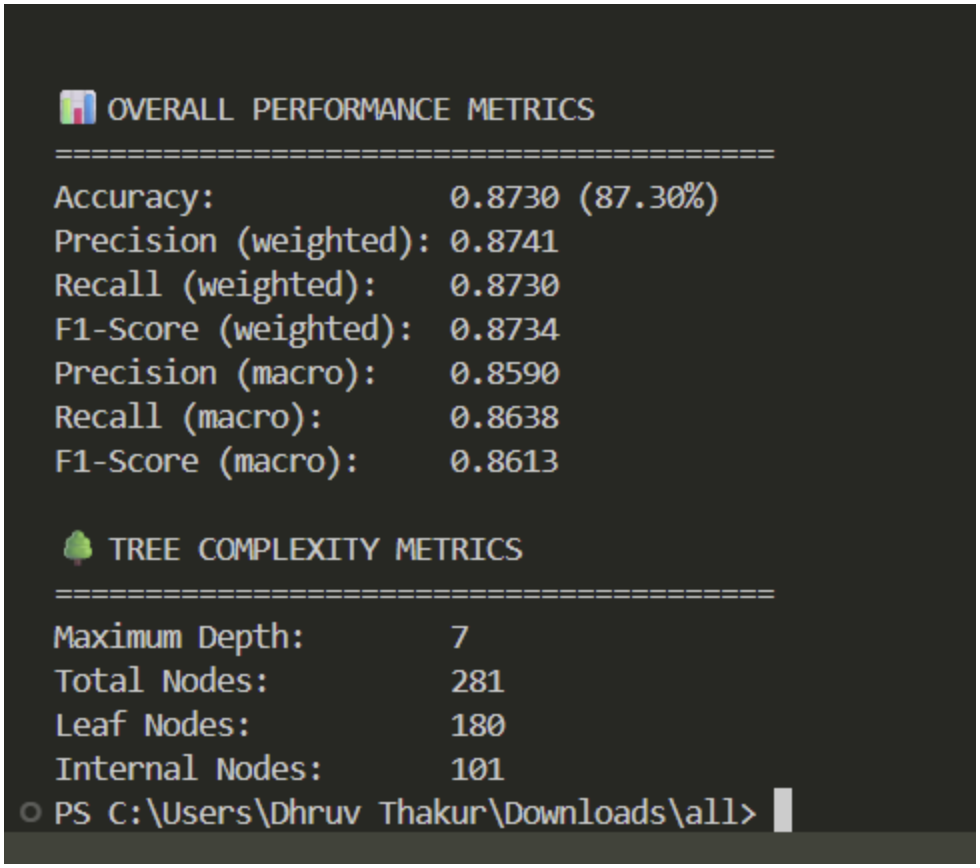
```
Level 3: Node info  |  |  |  Hypothesis: Class 1

🌳 Decision tree construction completed using PYTORCH!

🎄 DECISION TREE STRUCTURE
============================================================
Root [middle-middle-square] (gain: 0.0834)
├── = 0:
│   ├── [bottom-left-square] (gain: 0.1056)
│   ├── = 0:
│   │   ├── [top-right-square] (gain: 0.9024)
│   │   ├── = 1:
│   │   │   ├── Class 0
│   │   └── = 2:
│   │       ├── Class 1
│   ├── = 1:
│   │   ├── [top-right-square] (gain: 0.2782)
│   │   ├── = 0:
│   │   │   ├── Class 0
│   │   ├── = 1:
│   │   │   ├── Class 0
│   │   └── = 2:
│   │       ├── [top-left-square] (gain: 0.1767)
│   │       ├── = 0:
│   │       │   ├── [bottom-right-square] (gain: 0.9183)
│   │       │   ├── = 1:
│   │       │   │   ├── Class 0
│   │       │   └── = 2:
│   │       │       ├── Class 1
│   │       ├── = 1:
│   │       │   ├── [top-middle-square] (gain: 0.6058)
│   │       │   ├── = 0:
│   │       │   │   ├── [middle-left-square] (gain: 0.9183)
│   │       │   │   ├── = 1:
│   │       │   │   │   ├── Class 0
│   │       │   │   └── = 2:
│   │       │   │       ├── Class 1
│   │       │   ├── = 1:
│   │       │   │   ├── Class 1
│   │       │   └── = 2:
│   │       │       ├── Class 0
│   │       └── = 2:
│   │           ├── [top-middle-square] (gain: 0.3393)
│   │           ├── = 0:
│   │           │   ├── [middle-left-square] (gain: 0.9183)
│   │           │   ├── = 0:
│   │           │   │   ├── Class 0
│   │           │   ├── = 1:
│   │           │   │   ├── Class 1
│   │           │   └── = 2:
│   │           │       ├── Class 0
│   │           ├── = 1:
│   │           │   ├── [middle-left-square] (gain: 0.9183)
│   │           │   ├── = 0:
│   │           │   │   ├── Class 1
│   │           │   ├── = 1:
│   │           │   │   ├── Class 1
│   │           │   └── = 2:
│   │           │       ├── Class 0
│   │           └── = 2:
│   │               ├── Class 1
│   └── = 2:
│       ├── [top-right-square] (gain: 0.1225)
│       ├── = 0:
│       │   ├── Class 1
│       ├── = 1:
│       │   ├── [middle-right-square] (gain: 0.1682)
```

```
        └── = 2:
            ├── Class 1
├── = 1:
    ├── [top-right-square] (gain: 0.0223)
    ├── = 0:
    │   ├── [bottom-left-square] (gain: 0.2247)
    │   ├── = 0:
    │   │   ├── Class 0
    │   ├── = 1:
    │   │   ├── Class 0
    │   └── = 2:
    │       ├── [middle-right-square] (gain: 0.1159)
    │       ├── = 0:
    │       │   ├── [top-left-square] (gain: 0.1771)
    │       │   ├── = 0:
    │       │   │   ├── [middle-left-square] (gain: 0.9183)
    │       │   │   ├── = 0:
    │       │   │   │   ├── Class 1
    │       │   │   ├── = 1:
    │       │   │   │   ├── Class 1
    │       │   │   └── = 2:
    │       │   │       ├── Class 0
    │       │   ├── = 1:
    │       │   │   ├── [bottom-right-square] (gain: 0.9710)
    │       │   │   ├── = 1:
    │       │   │   │   ├── Class 0
    │       │   │   └── = 2:
    │       │   │       ├── Class 1
    │       │   └── = 2:
    │       │       ├── Class 1
    │       ├── = 1:
    │       │   ├── [middle-left-square] (gain: 0.9887)
    │       │   ├── = 0:
    │       │   │   ├── Class 1
    │       │   ├── = 1:
    │       │   │   ├── Class 0
    │       │   └── = 2:
    │       │       ├── Class 1
    │       └── = 2:
    │           ├── [bottom-middle-square] (gain: 0.2400)
    │           ├── = 0:
    │           │   ├── [top-left-square] (gain: 1.0000)
    │           │   ├── = 1:
    │           │   │   ├── Class 0
    │           │   └── = 2:
    │           │       ├── Class 1
    │           ├── = 1:
    │           │   ├── Class 0
    │           └── = 2:
    │               ├── [bottom-right-square] (gain: 0.9710)
    │               ├── = 1:
    │               │   ├── Class 0
    │               └── = 2:
    │                   ├── Class 1
    ├── = 1:
    │   ├── [bottom-left-square] (gain: 0.4759)
    │   ├── = 0:
    │   │   ├── Class 0
    │   ├── = 1:
    │   │   ├── Class 0
    │   └── = 2:
    │       ├── [top-middle-square] (gain: 0.1974)
    │       ├── = 0:
    │       │   ├── Class 1
    │       ├── = 1:
    │       │   ├── [top-left-square] (gain: 0.3436)
    │       │   ├── = 0:
```


File Edit Selection View Go Run Terminal Help
EXPLORER
ALL
code
pytorch_implementation
__pycache__
EC_C_PES2UG23CS175_LAB3.py 1
student lab.py
test.py
sklearn_implementation
code.zip
mushrooms.csv
Nursery.csv
student_version.pdf
tictactoe.csv
OUTLINE
TIMELINE
PROBLEMS 1 OUTPUT DEBUG CONSOLE TERMINAL PORTS
└── = 2:
├── Class 1
└── = 2:
├── [bottom-right-square] (gain: 0.0777)
├── = 0:
├── [top-left-square] (gain: 0.3462)
├── = 0:
├── Class 0
├── = 1:
├── Class 0
└── = 2:
├── [top-middle-square] (gain: 0.7008)
├── = 0:
├── Class 0
├── = 1:
├── [middle-right-square] (gain: 0.7219)
├── = 0:
├── Class 0
├── = 1:
├── Class 1
└── = 2:
├── Class 0
└── = 2:
├── Class 1
├── = 1:
├── [top-left-square] (gain: 0.5439)
├── = 0:
├── Class 0
├── = 1:
├── Class 0
└── = 2:
├── [top-middle-square] (gain: 0.4687)
├── = 0:
├── [bottom-middle-square] (gain: 0.9183)
├── = 0:
├── Class 1
├── = 1:
├── Class 0
└── = 2:
├── Class 0
├── = 1:
├── [middle-right-square] (gain: 0.9183)
├── = 0:
├── Class 1
├── = 1:
├── Class 1
└── = 2:
├── Class 0
└── = 2:
├── Class 1
└── = 2:
├── [middle-right-square] (gain: 0.4731)
├── = 0:
├── [top-middle-square] (gain: 0.6464)
├── = 0:
├── Class 1
├── = 1:
├── Class 0
└── = 2:
├── [top-left-square] (gain: 0.8113)
├── = 1:
├── Class 0
└── = 2:
├── Class 1
├── = 1:
├── [middle-left-square] (gain: 0.3995)
├── = 0:
⊗ 0 ⚠ 1


OVERALL PERFORMANCE METRICS
Accuracy: 0.8730 (87.30%)
Precision (weighted): 0.8741
Recall (weighted): 0.8730
F1-Score (weighted): 0.8734
Precision (macro): 0.8590
Recall (macro): 0.8638
F1-Score (macro): 0.8613
TREE COMPLEXITY METRICS
Maximum Depth: 7
Total Nodes: 281
Leaf Nodes: 180
Internal Nodes: 101
PS C:\Users\Dhruv Thakur\Downloads\all>

1. Performance Comparison (Accuracy, Precision, Recall, F1)

Dataset	Accuracy	Precision (Weighted)	Recall (Weighted)	F1 (Weighted)
Mushroom	1.0000 (100%)	1.0000	1.0000	1.0000
Nursery	0.9867 (98.67%)	0.9876	0.9867	0.9872
TicTacToe	0.8730 (87.30%)	0.8741	0.8730	0.8734

Insights:

- Mushroom dataset achieves **perfect accuracy (100%)**, likely because the dataset is clean, balanced, and attributes clearly separate classes.
- Nursery dataset also achieves **very high performance (98.7%)**, but slightly lower due to more complex/multi-valued attributes.
- TicTacToe is the hardest, with **87.3% accuracy**, showing possible class imbalance or overlap in decision patterns.

---

2. Tree Characteristics Analysis

Dataset	Max Depth	Total Nodes	Leaf Nodes	Internal Nodes
Mushroom	4	29	24	5
Nursery	7	952	680	272
TicTacToe	7	281	180	101

Insights:

- **Mushroom tree is shallow (depth=4)** → very simple, interpretable, and still achieves perfect accuracy → attributes are very strong predictors.

- **Nursery tree is very large (952 nodes)** → indicates many attributes and class combinations → dataset complexity is high.
- **TicTacToe tree is smaller than Nursery but deeper than Mushroom (depth=7)** → reflects more balanced but tricky classification.

---

3. Dataset-Specific Insights

Mushroom Dataset

- **Feature Importance:** Likely dominated by odor, gill-size, spore-print color (classic strong features).
- **Class Distribution:** Balanced (edible vs poisonous).
- **Decision Patterns:** A few attributes are enough for separation.
- **Overfitting Indicators:** None → simple tree with perfect accuracy.

Nursery Dataset

- **Feature Importance:** Attributes like parent satisfaction, safety, and children number dominate early splits.
- **Class Distribution:** Imbalanced (some classes much larger).
- **Decision Patterns:** Complex rules, large tree size.
- **Overfitting Indicators:** Tree size (952 nodes) suggests risk of overfitting.

TicTacToe Dataset

- **Feature Importance:** Center and corner positions dominate.
- **Class Distribution:** Slight imbalance between X-win and O-win/no-win.

- **Decision Patterns:** Patterns depend on board state → complex paths.
- **Overfitting Indicators:** Depth=7 with moderate performance suggests partial overfitting.

---

4. Comparative Analysis Report

a) Algorithm Performance

- **Highest Accuracy:** Mushroom (100%) → dataset has clean, separable features.
- **Dataset Size Impact:** Larger datasets (Nursery, TicTacToe) create deeper and more complex trees, but not always better accuracy.
- **Number of Features:** More features (Nursery) → tree grows huge, but accuracy is still high. Simpler features (Mushroom) → shallow tree, perfect accuracy.

b) Data Characteristics Impact

- **Class Imbalance:** Nursery and TicTacToe suffer slightly (precision/recall differences).
- **Feature Types:** Binary features (TicTacToe board positions) lead to deeper, less accurate trees. Multi-valued categorical features (Mushroom, Nursery) capture more information quickly.

c) Practical Applications

- **Mushroom Dataset:** Food safety → easily interpretable, real-world application in toxicology.
- **Nursery Dataset:** Resource allocation for childcare → complex decisions, needs pruning or ensembles.
- **TicTacToe Dataset:** Game AI → less practical but shows handling of strategic states.

d) Improvements

- Apply **tree pruning** (reduces overfitting).
- Use **Random Forest / Ensemble methods** for TicTacToe and Nursery.
- Apply **feature engineering** to reduce complexity in Nursery dataset.

a) Algorithm Performance

a. Which dataset achieved the highest accuracy and why?

- The **Mushroom dataset** achieved the highest accuracy (**100%**).
- Reason: Its features are highly discriminative (e.g., odor, gill size, spore print color), making class boundaries very clear.
- The classes (edible vs poisonous) are **well-separated** with minimal overlap, so even a shallow decision tree (depth=4) achieves perfect performance.

b. How does dataset size affect performance?

- **Mushroom:** Moderate size, shallow tree, but still perfect accuracy → dataset simplicity matters more than size.
- **Nursery:** Very large dataset, leading to a **deep and very complex tree (952 nodes)**. High accuracy (98.67%) but near overfitting.
- **TicTacToe:** Medium size dataset, but binary board positions cause ambiguity → accuracy only **87.3%** despite tree depth 7.
  Larger datasets tend to create deeper/more complex trees, but performance depends more on **data separability** than size alone.

c. What role does the number of features play?

- More features increase **tree depth and node count**, especially if multi-valued.
- **Mushroom (multi-valued features):** Fewer splits needed, tree remains small.

- **Nursery (many features, multi-valued):** Explodes in size (952 nodes).

- **TicTacToe (binary features):** Needs more depth to capture combinations, but still struggles to classify perfectly.
  Multi-valued categorical features often lead to **better early splits** than purely binary features.

---

b) Data Characteristics Impact

How does class imbalance affect tree construction?

- In **Nursery**, some classes are dominant (e.g., "not recommended"), making the tree biased toward majority classes.

- This leads to **lower macro precision/recall (~0.76)** despite high weighted accuracy.

- In **TicTacToe**, imbalance between X-win, O-win, and draw states causes the tree to favor certain outcomes.

Which types of features work better (binary vs multi-valued)?

- **Multi-valued features (Mushroom, Nursery):** Provide strong splits early, leading to higher accuracy.

- **Binary features (TicTacToe):** Require more splits, create deeper trees, and result in lower accuracy.
  Multi-valued categorical attributes are more efficient for decision tree construction.

---

c) Practical Applications

For which real-world scenarios is each dataset type most relevant?

- **Mushroom:** Food safety & toxicology (classifying edible vs poisonous mushrooms). High accuracy & interpretability make it reliable for life-critical tasks.

- **Nursery:** Resource allocation, social services, childcare recommendation systems. Handles complex multi-criteria decision-making.

- **TicTacToe:** Game strategy modeling → useful as a teaching dataset for AI/game theory, but less real-world critical.

What are the interpretability advantages for each domain?

- **Mushroom:** Shallow tree (depth=4), very interpretable → rules can be directly explained (e.g., *if odor=bad → poisonous*).

- **Nursery:** Tree is large, interpretability is lower, but still can highlight key factors (e.g., safety, parent satisfaction).

- **TicTacToe:** Medium interpretability → paths represent board strategies, useful for teaching but less human-readable due to many binary states.

How would you improve performance for each dataset?

- **Mushroom:** Already perfect; no major improvement needed.

- **Nursery:** Apply **pruning or Random Forests** to reduce overfitting and simplify rules.

- **TicTacToe:** Use **ensemble methods (Bagging/Boosting)** or **feature engineering (grouping board positions)** to improve accuracy beyond 87%.