ANALOG DEVICES
AHEAD OF WHAT'S POSSIBLE™

كلية الهندسة جامعة الزقازيق
Faculty of Engineering Zagazig University

Integration and testing the system

Zagazig gp team

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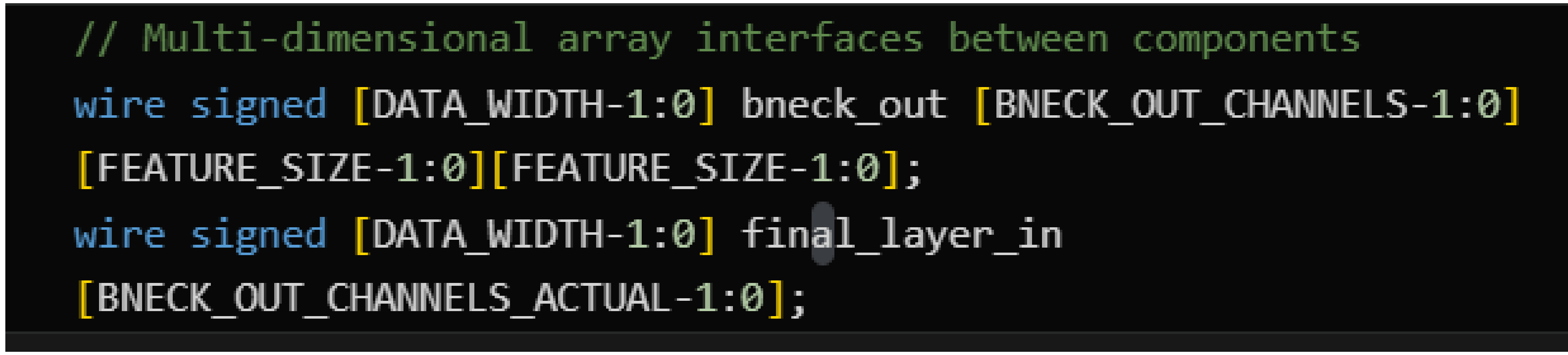
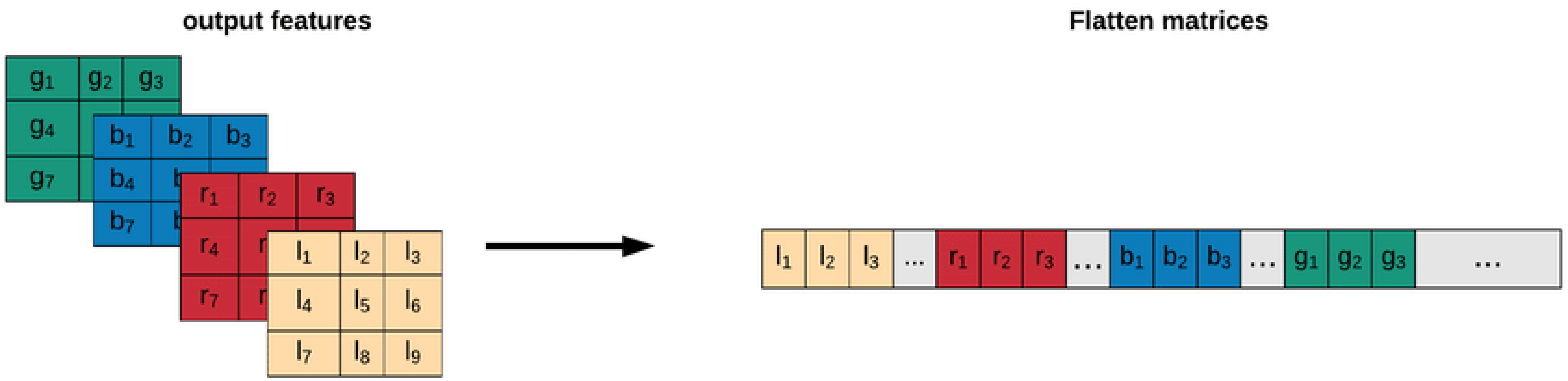
THE Main problem

Integrating multi-dimensional array interfaces between hardware components presented significant challenges in our MobileNetV3 implementation:



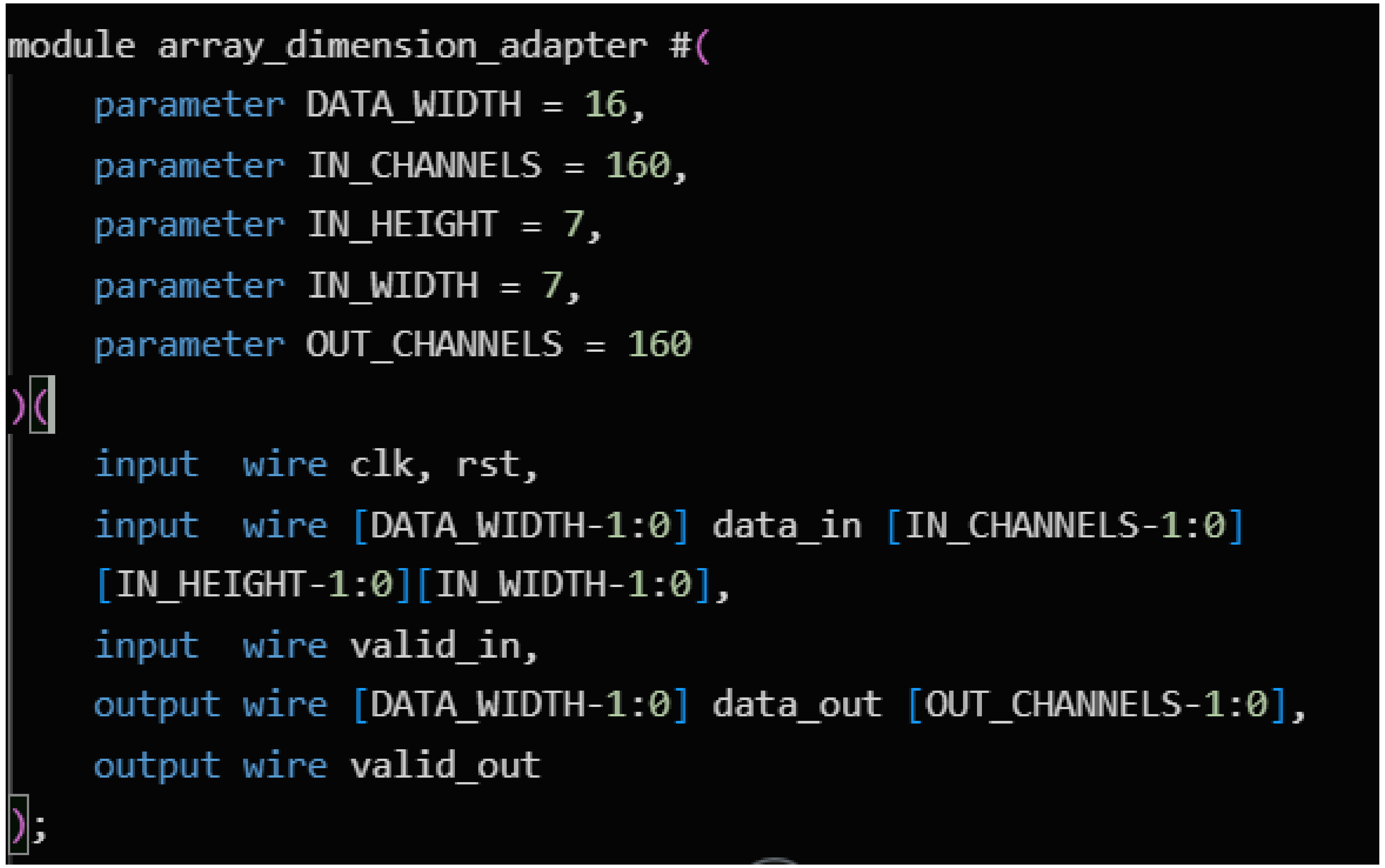
```
// Multi-dimensional array interfaces between components
wire signed [DATA_WIDTH-1:0] bneck_out [BNECK_OUT_CHANNELS-1:0]
[FEATURE_SIZE-1:0][FEATURE_SIZE-1:0];
wire signed [DATA_WIDTH-1:0] final_layer_in
[BNECK_OUT_CHANNELS_ACTUAL-1:0];
```

The solution



We implemented a comprehensive interface standardization approach:

module serves a critical role in neural network hardware implementation by transforming multi-dimensional feature maps into flattened representations



```
module array_dimension_adapter #(
    parameter DATA_WIDTH = 16,
    parameter IN_CHANNELS = 160,
    parameter IN_HEIGHT = 7,
    parameter IN_WIDTH = 7,
    parameter OUT_CHANNELS = 160
)(
    input  wire clk, rst,
    input  wire [DATA_WIDTH-1:0] data_in [IN_CHANNELS-1:0]
    [IN_HEIGHT-1:0][IN_WIDTH-1:0],
    input  wire valid_in,
    output wire [DATA_WIDTH-1:0] data_out [OUT_CHANNELS-1:0],
    output wire valid_out
);
```

2. Verification of Complex Neural Network Systems

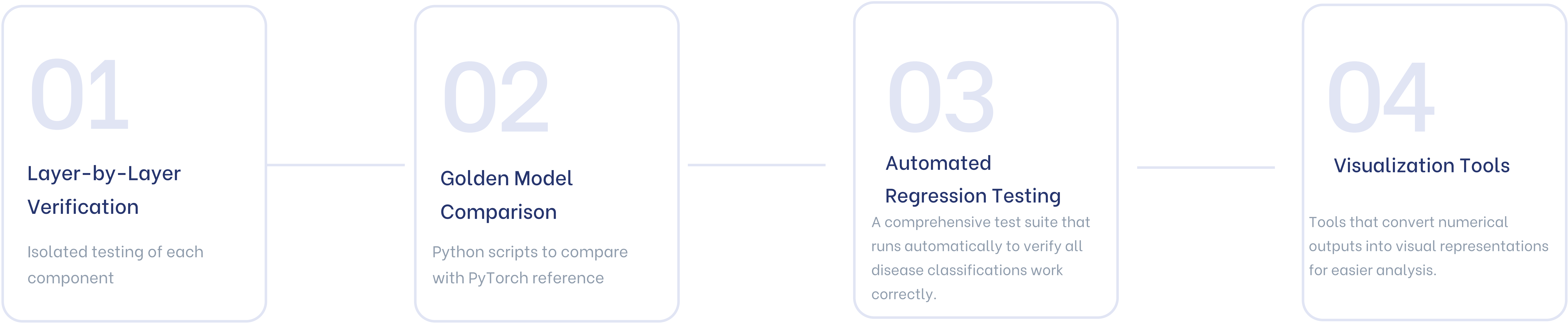
The Challenge

Verifying a complex neural network hardware implementation presented unique difficulties:

Key Problems:

1. **Reference Comparison**: Needed bit-exact comparison with software model
2. **Intermediate Activation Verification**: Difficult to extract and compare internal states
3. **Combinatorial Explosion**: 15 diseases × multiple layers × multiple parameters
4. **Long Simulation Times**: Full system verification taking hours

The Solution



01

Layer-by-Layer Verification

Isolated testing of each component

02

Golden Model Comparison

Python scripts to compare with PyTorch reference

03

Automated Regression Testing

A comprehensive test suite that runs automatically to verify all disease classifications work correctly.

04

Visualization Tools

Tools that convert numerical outputs into visual representations for easier analysis.

3. Quantization Challenges

Converting from floating-point to fixed-point representation introduced significant accuracy issues

- Dynamic Range Limitations: 16-bit Q8.8 format limiting representable values
- Error Accumulation: Small errors compounding through network layers
- Activation Function Approximation: Hardware-friendly approximations reducing accuracy
- Batch Normalization Parameters: Scaling issues in fixed-point representation

THE SOLUTION

1. Layer-specific Quantization

2. Quantization-Aware Training

3. Error Compensation:
Counteracted systematic
quantization errors

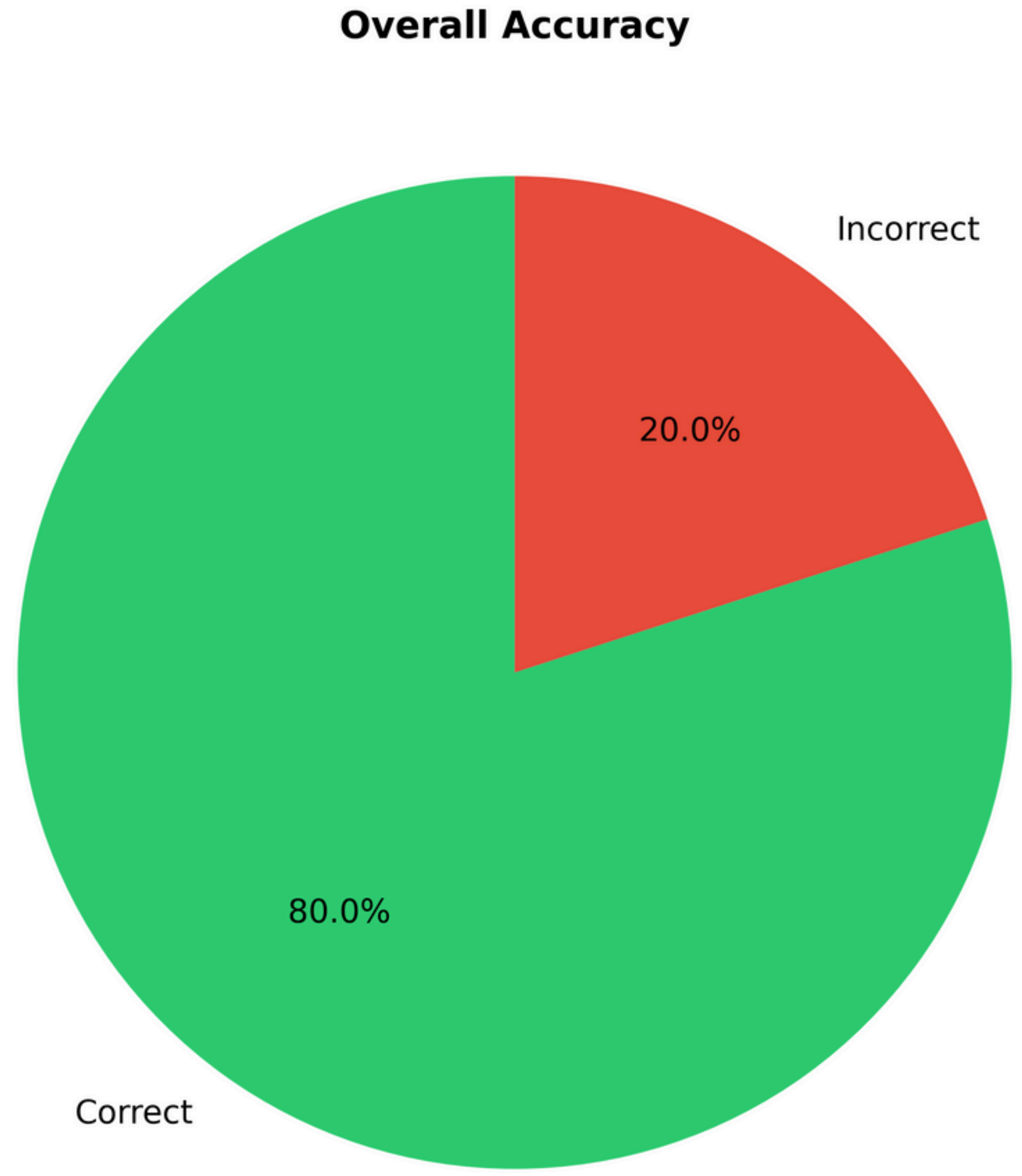
4. Complex Textual Pattern Analysis

Analyzing complex textual outputs from hardware simulations was extremely difficult

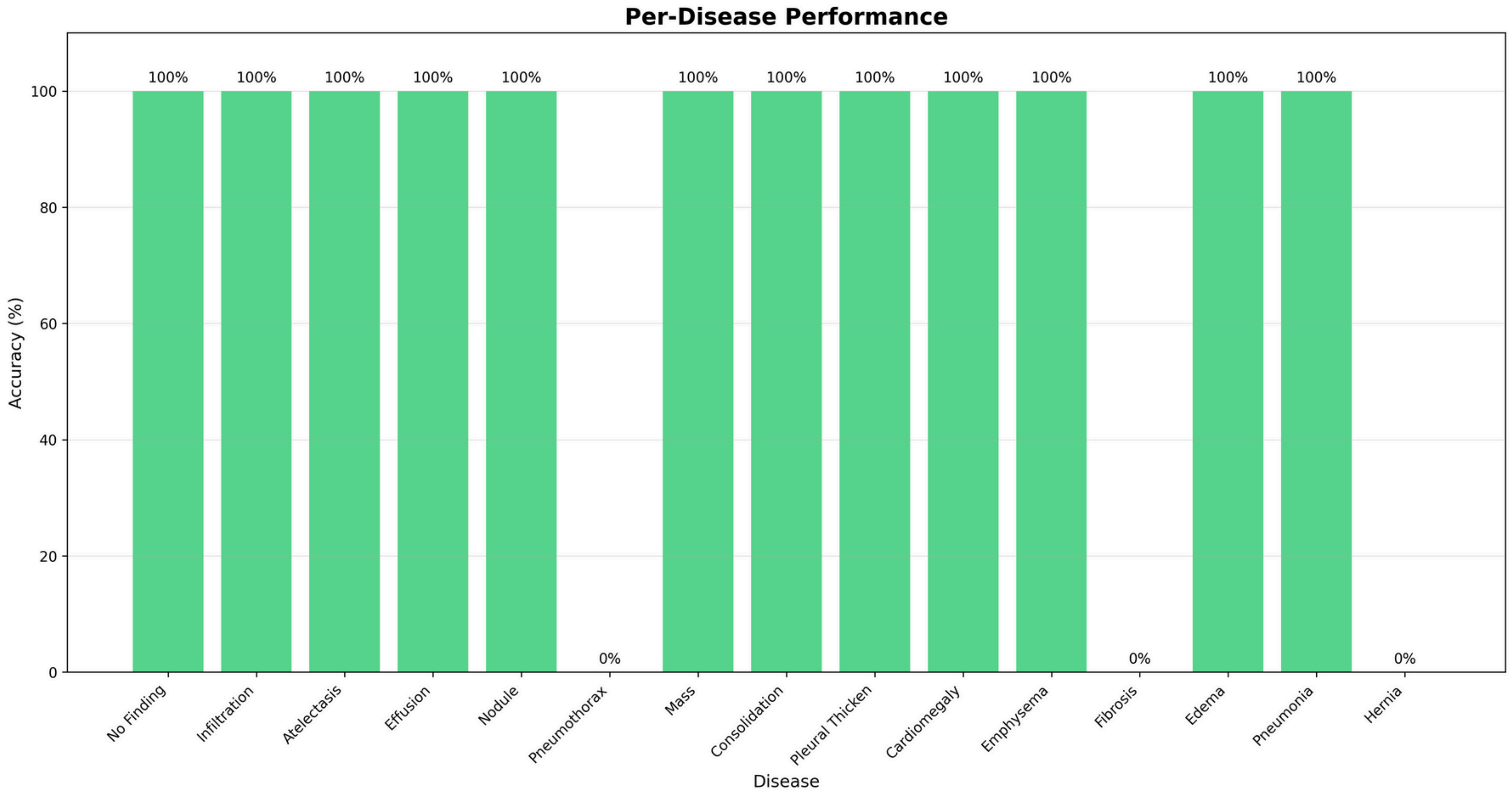
The solution

We developed specialized visualization and analysis tools

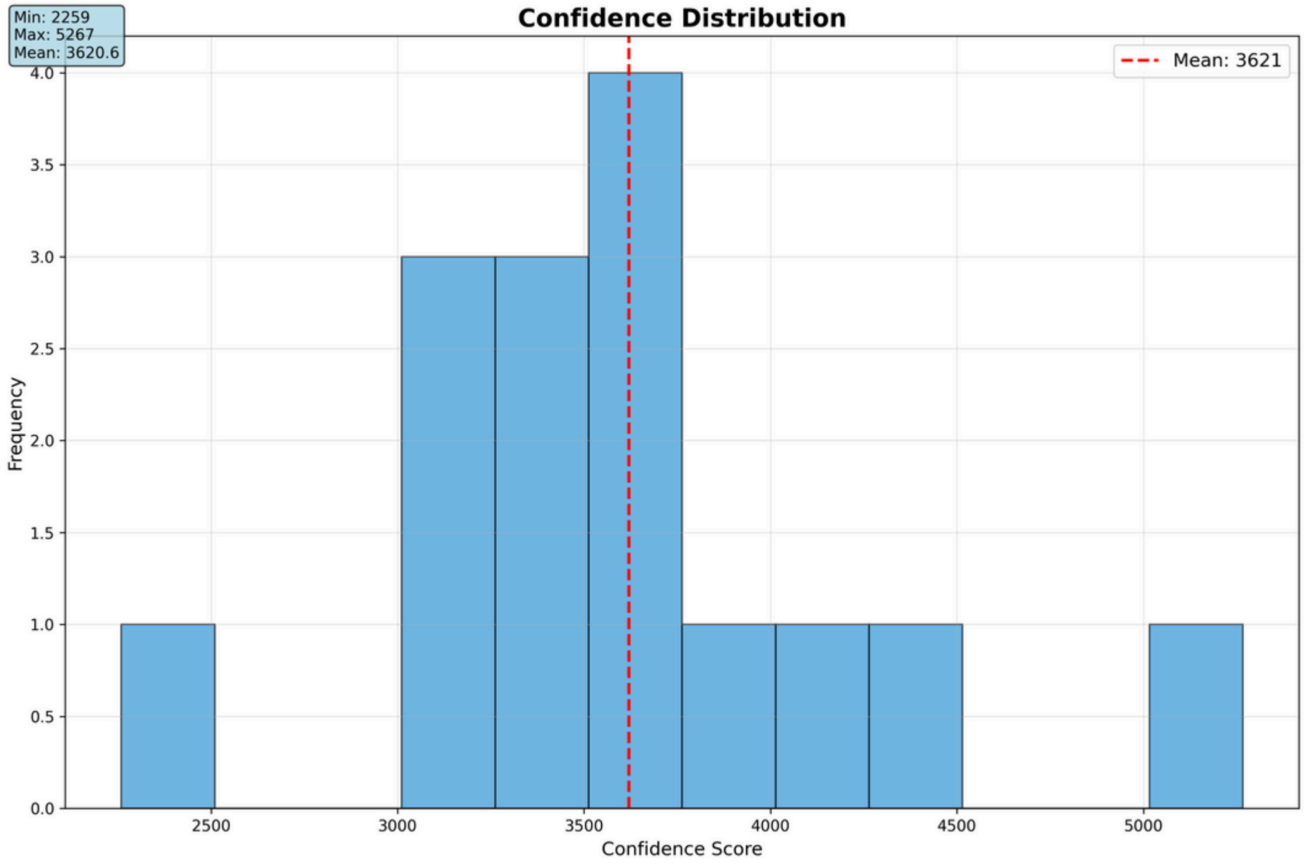
RESULTS

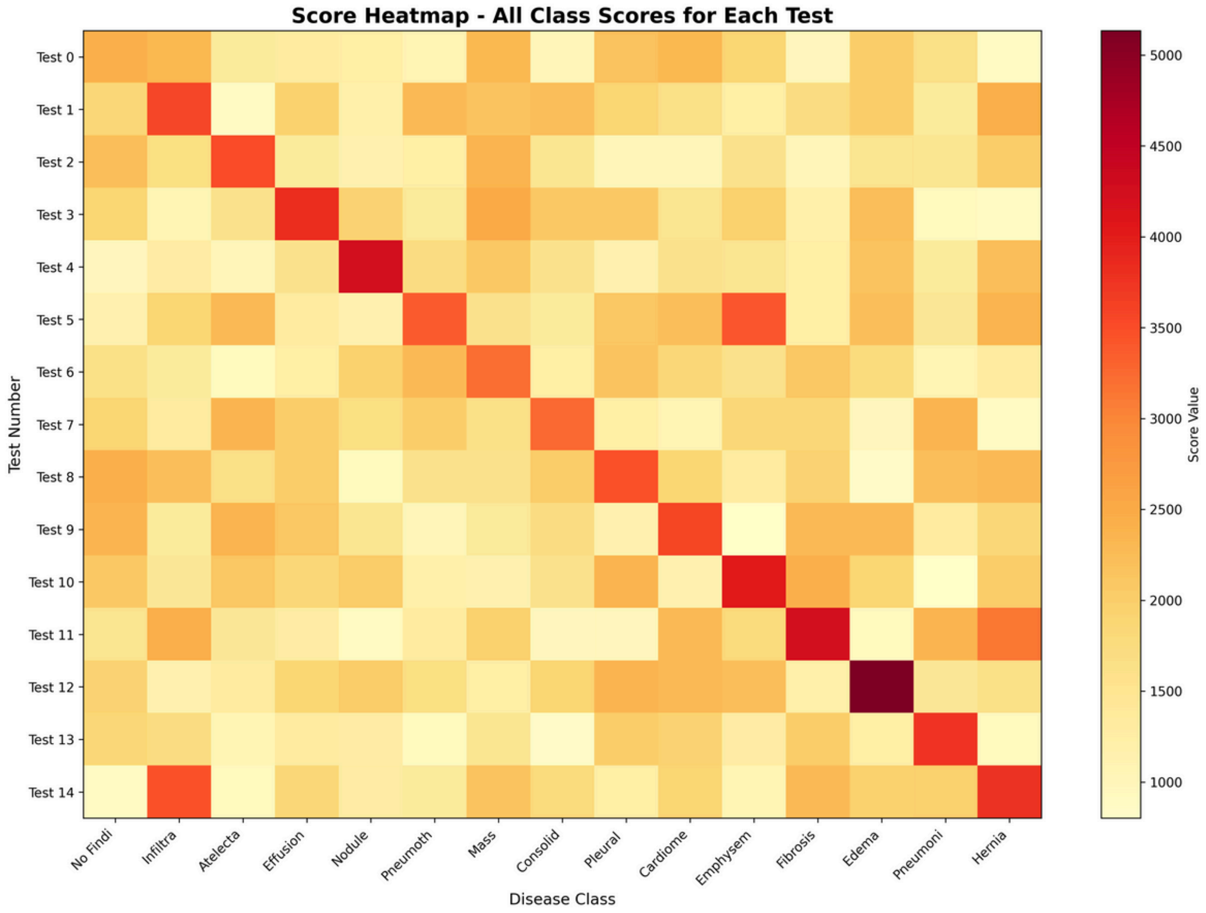


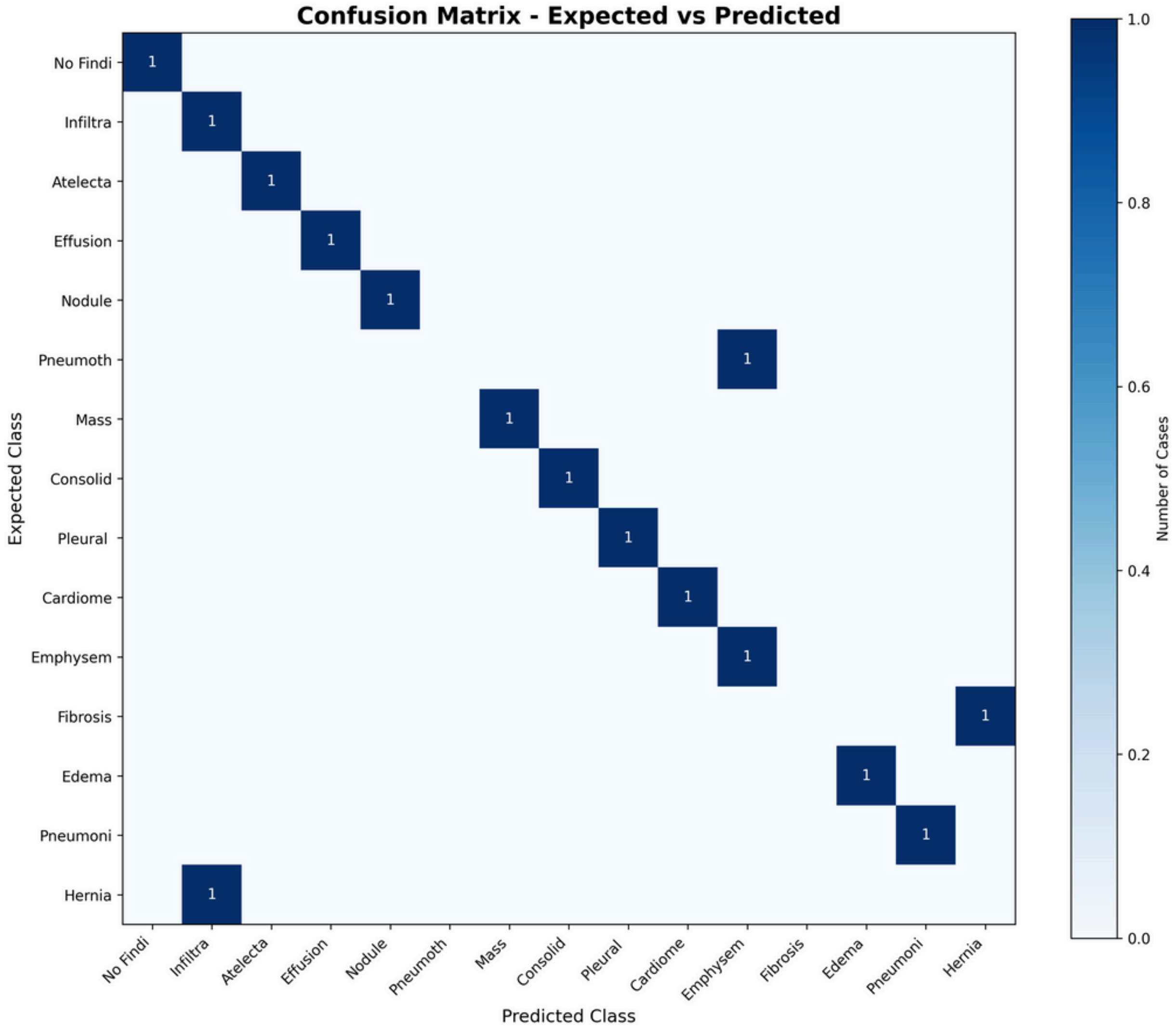
Accuracy: 80.0% (12/15)

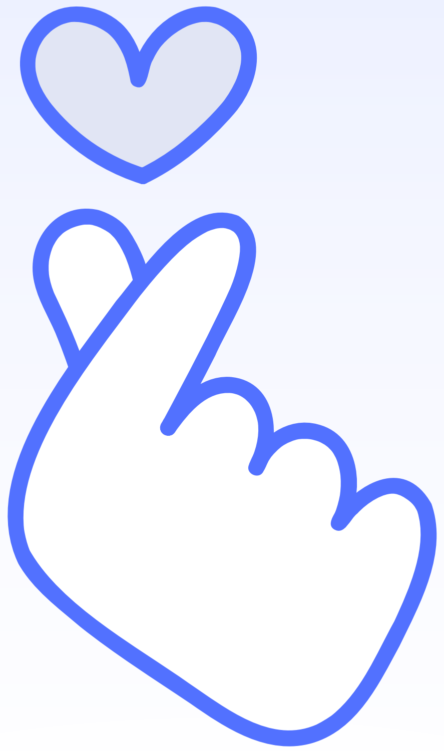


RESULTS


Confidence Distribution
Min: 2259
Max: 5267
Mean: 3620.6
Mean: 3621
Frequency
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
2500
3000
3500
4000
4500
5000
Confidence Score


Score Heatmap - All Class Scores for Each Test
Test Number
Test 0
Test 1
Test 2
Test 3
Test 4
Test 5
Test 6
Test 7
Test 8
Test 9
Test 10
Test 11
Test 12
Test 13
Test 14
No Findi
Infiltra
Atelecta
Effusion
Nodule
Pneumoth
Mass
Consolid
Pleural
Cardiome
Emphysem
Fibrosis
Edema
Pneumoni
Hernia
Disease Class
Score Value
5000
4500
4000
3500
3000
2500
2000
1500
1000


Confusion Matrix - Expected vs Predicted
Expected Class
No Findi
Infiltra
Atelecta
Effusion
Nodule
Pneumoth
Mass
Consolid
Pleural
Cardiome
Emphysem
Fibrosis
Edema
Pneumoni
Hernia
1
1
1
1
1
1
1
1
1
1
1
1
1
1
1
No Findi
Infiltra
Atelecta
Effusion
Nodule
Pneumoth
Mass
Consolid
Pleural
Cardiome
Emphysem
Fibrosis
Edema
Pneumoni
Hernia
Predicted Class
Number of Cases
1.0
0.8
0.6
0.4
0.2
0.0



Thank You