Course Project Assignment

IJCNN-Style Research Project:

Trustworthy Hybrid Neural Diagnosis with Hyperparameter Optimization and Neuro-Symbolic Interpretability

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1. Project Overview

This course project is designed to mirror the structure and expectations of a full research paper suitable for submission to the **International Joint Conference on Neural Networks (IJCNN)**.

Students will build a **trustworthy diagnostic system** on the **Breast Cancer Wisconsin Dataset**, combining:

- A fixed-architecture **MLP neural network**
- **Hyperparameter optimization** (Grid, Bayesian, Evolutionary)
- A **Neuro-Symbolic Interpretability Layer**:
  - Rule-based reasoning
  - Fuzzy inference
  - Bayesian probability update
- **Calibration and robustness analysis**

This project aligns with IJCNN themes: *trustworthy AI, hybrid neural systems, neuro-symbolic reasoning, and evolutionary optimization.*

2. Learning Objectives

- Implement a fixed-architecture MLP for medical diagnosis.
- Apply multiple hyperparameter optimization (HPO) approaches: Grid Search, Bayesian Optimization, and an Evolutionary Algorithm.
- Design and integrate symbolic interpretability modules.
- Perform calibration and robustness studies.
- Present results in a research format suitable for IJCNN.

3. Dataset

The project uses the **Breast Cancer Wisconsin Diagnostic Dataset** (`sklearn.datasets.load_brea`

4. Project Components

4.1 Baseline MLP (Required)

Implement a fixed neural network architecture, e.g.:

- Input: 30 features
- Hidden layers: [32, 16]
- Activation: ReLU
- Optimizer: Adam
- Output: Sigmoid (binary classification)

Compute baseline metrics:

Accuracy, F1-score, ROC-AUC, Brier score (calibration), Confusion matrix

4.2 Hyperparameter Optimization (Required)

You must evaluate at least **three** HPO techniques:

a) **Grid/Random Search** (baseline)

b) **Bayesian Optimization** (Optuna, Scikit-Optimize, or Hyperopt)

c) **Evolutionary Algorithm** (GA, DE, PSO) — **only for hyperparameters**

Hyperparameters to tune (examples):

- Learning rate
- Batch size
- L2 regularization coefficient
- Dropout rate
- Training epochs
- Adam parameters (β_1, β_2)

Record for each HPO method:

- Best metric found
- Number of model evaluations
- Time taken
- Hyperparameter configuration

4.3 Neuro-Symbolic Interpretability (Required)

Every team must implement:

Rule-Based Reasoning

Derive 3–7 interpretable rules, e.g.:

IF mean_radius ¿ 15 AND worst_concavity ¿ 0.3 THEN malignant

Rules may:

- override the neural net, OR
- revise predictions when MLP confidence is low.

Fuzzy Inference

Define fuzzy sets for two features (e.g., radius, concavity) and compute a fuzzy malignancy risk score.

Combine with the MLP output using:

$$P^* = \alpha P_{MLP} + (1 - \alpha) P_{fuzzy}$$

Bayesian Update

Compute:

$$P(M \mid x) = \frac{P(x \mid M) P(M)}{P(x)}$$

using dataset statistics.

Use this to generate interpretable probabilistic explanations.

4.4 Calibration and Robustness

Evaluate:

- Reliability diagram
- Brier score
- Sensitivity to noise in features
- Behavior on borderline cases (`mean_radius` in [13, 15])

4.5 Report (IJCNN Format)

Students must submit an IJCNN-style paper (8 pages max) following the template below.

5. Deliverables

1. **Code** (clean, modular, runnable)
2. **IJCNN-format paper** (PDF)
3. **Presentation slides (optional)**

6. Marking Scheme

Component	Weight
Baseline MLP	10%
Hyperparameter Optimization	30%
Neuro-Symbolic Interpretability	25%
Calibration & Robustness	15%
Paper Quality (IJCNN format)	20%