Intelligent Systems (SInt) - Assignment 2

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GitHub Repository

1 Hair Dryer Dataset Problem

1.1 Neural Network Model

Note: See the *Assignment 2 - Neural Networks.ipynb* file.

In the process of comparing different model configurations, the **Mean Squared Error (MSE)** was selected as the primary metric. MSE measures the average squared difference between predicted and actual values, heavily penalizing larger errors, which makes it particularly useful for regression tasks like the one at hand.

To find the best model configurations, a **range of hidden layers**, from 2 to 4, were evaluated, and the **number of nodes per layer** was varied between 5, 10, 15, 20, 25, 30, and 35.

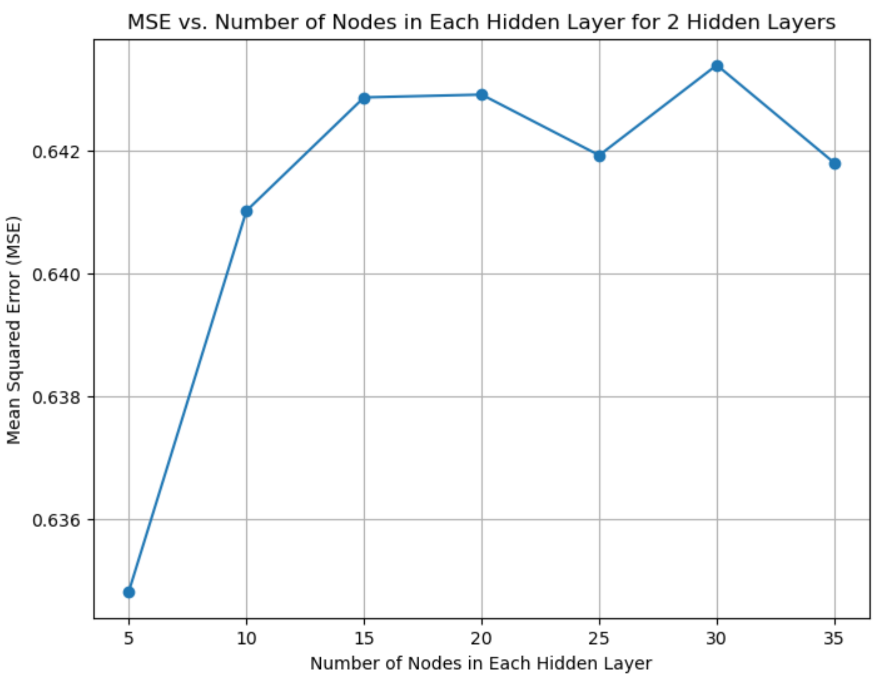

Figure 1: MSE vs. Number of Nodes in Each Hidden Layer for 2 Hidden Layers with `random_state = 42`.

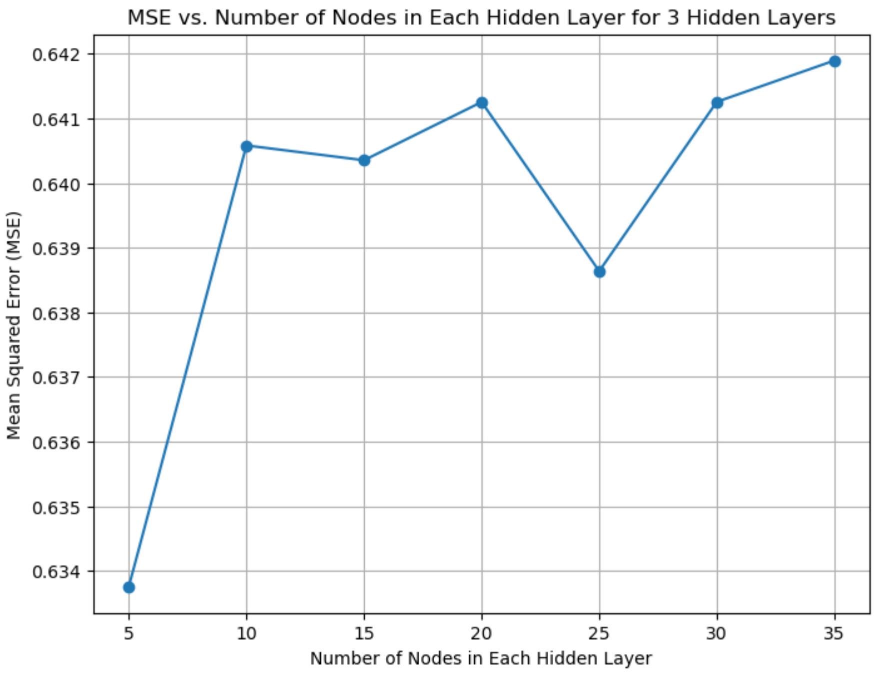

Figure 2: MSE vs. Number of Nodes in Each Hidden Layer for 4 Hidden Layers with `random_state = 42`.

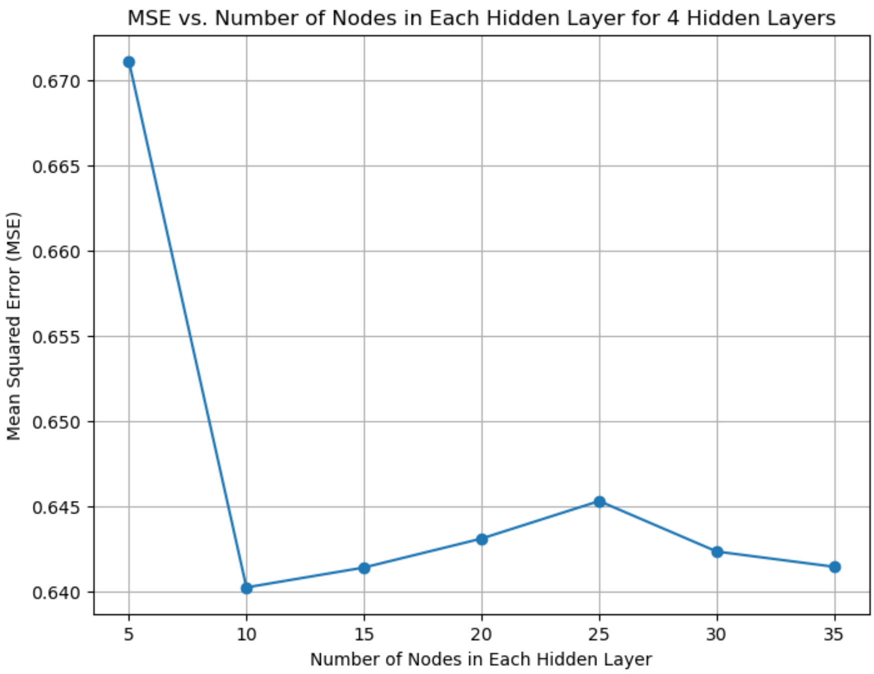

Figure 3: MSE vs. Number of Nodes in Each Hidden Layer for 4 Hidden Layers with `random_state = 42`.

For the configurations with 2 hidden layers (refer to Figure 1), the MSE values range approximately between 0.636 and 0.643 on the y-axis, indicating minimal variation in MSE across the different configurations. Similarly, for the configurations with 3 hidden layers (refer to Figure 2), the MSE values also exhibit a narrow range, approximately between 0.634 and 0.642.

These small variations suggest that increasing the number of nodes does not significantly improve or degrade the model's performance, implying that the model is no longer making substantial gains in learning from the data. It can be concluded that the model is likely in the **saturation plateau**, where increasing the number of nodes (complexity) no longer results in significant performance improvements, as indicated by the relatively stable MSE and minimal fluctuations. This suggests that overfitting is controlled and the model is not sensitive to additional complexity within the tested range.

For the configurations with 4 hidden layers (refer to Figure 3), a more stable behavior is observed. The MSE starts high but drops significantly around 10 nodes, reaching the saturation plateau at this point, where it stabilizes with only small fluctuations as the number of nodes increases.

For **2 hidden layers** and `random_state = 42`, the best configuration appears to be approximately 25 nodes in each hidden layer. Similarly, for **3 hidden layers** with `random_state = 42`, the best configuration also appears to be around 25 nodes in each hidden layer. The regression metrics for these configurations are given in the following tables:

Regression Metrics		
MSE	**MAPE**	**EVS**
0.642	15.4%	0.049

Table 1: Regression metrics for the model configuration with 2 hidden layers and 25 nodes in each layer.

Regression Metrics		
MSE	**MAPE**	**EVS**
0.639	15.3%	0.049

Table 2: Regression metrics for the model configuration with 3 hidden layers and 25 nodes in each layer.

While there are other configurations with smaller MSE values, these configurations provide a good balance between model complexity and performance.

For **4 hidden layers** and `random_state = 42`, the best configuration appears to be approximately 10 nodes in each hidden layer. The regression metrics for this configuration are given in the table below:

Regression Metrics		
MSE	**MAPE**	**EVS**
0.640	15.4%	0.049

Table 3: Regression metrics for the model configuration with 4 hidden layers and 10 nodes in each layer.

The MSE drops significantly around 10 nodes and stabilizes with minor fluctuations after that. Adding more nodes does not significantly improve performance, suggesting the model has reached the saturation plateau.

1.2 Neuro-Fuzzy Model

In this problem, a range of 2 to 15 clusters was tested, and the **Root Mean Square Error (RMSE)** remained consistent across all cluster sizes, with a RMSE of 0.781 for the ANFIS model. Given this uniformity in performance, the model with two clusters would be the most suitable choice, as it minimizes the number of clusters, thereby reducing computational costs without compromising performance (see the *hairdryer_neuro_fuzzy_fcm.m* file).

2 Wisconsin Breast Cancer Original Dataset Problem

2.1 Neural Network Model

Note: See the *Assignment 2 - Neural Networks.ipynb* file.

For this problem, the **F1-Score** was selected as the primary metric for comparing different model configurations. The F1-Score is the harmonic mean of precision and recall, providing a balanced measure of both metrics. It is particularly valuable in situations where both false positives and false negatives matter, making it well-suited for problems with class imbalance, such as medical diagnoses, like the one at hand.

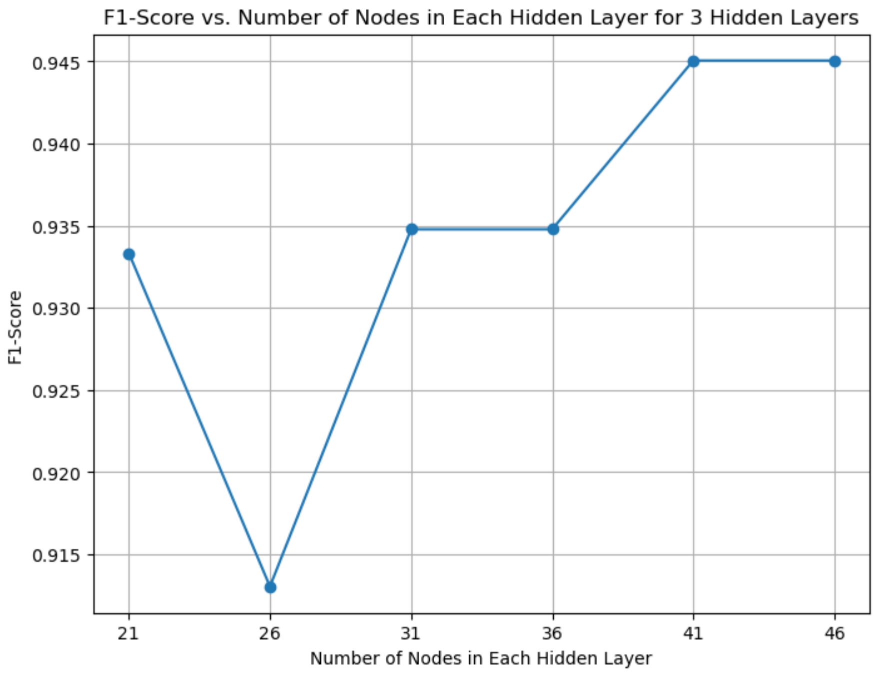

Figure 4: F1-Score vs. Number of Nodes in Each Hidden Layer for 3 Hidden Layers with `random_state = 42`.

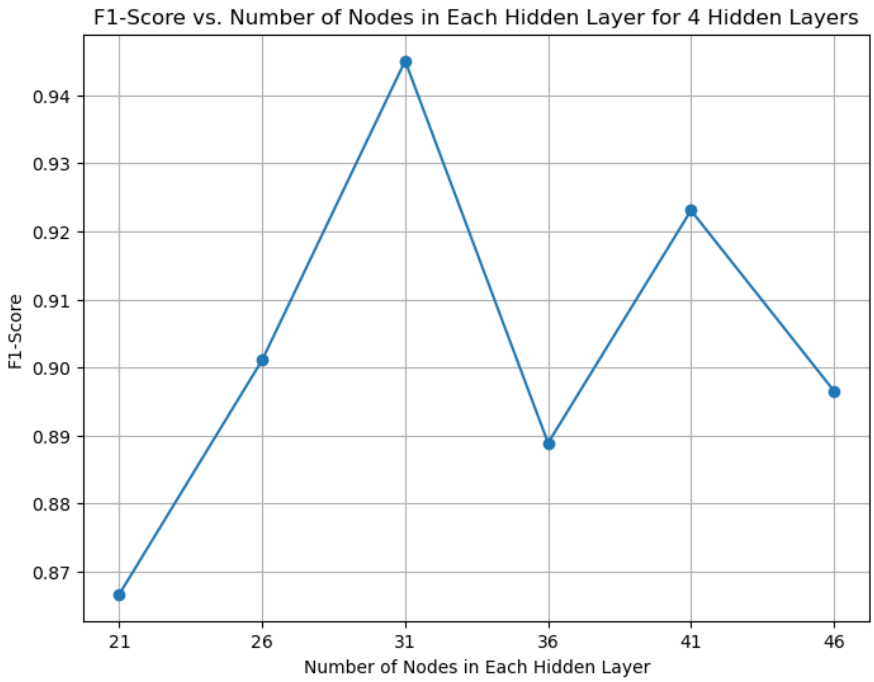

Figure 5: F1-Score vs. Number of Nodes in Each Hidden Layer for 4 Hidden Layers with `random_state = 42`.

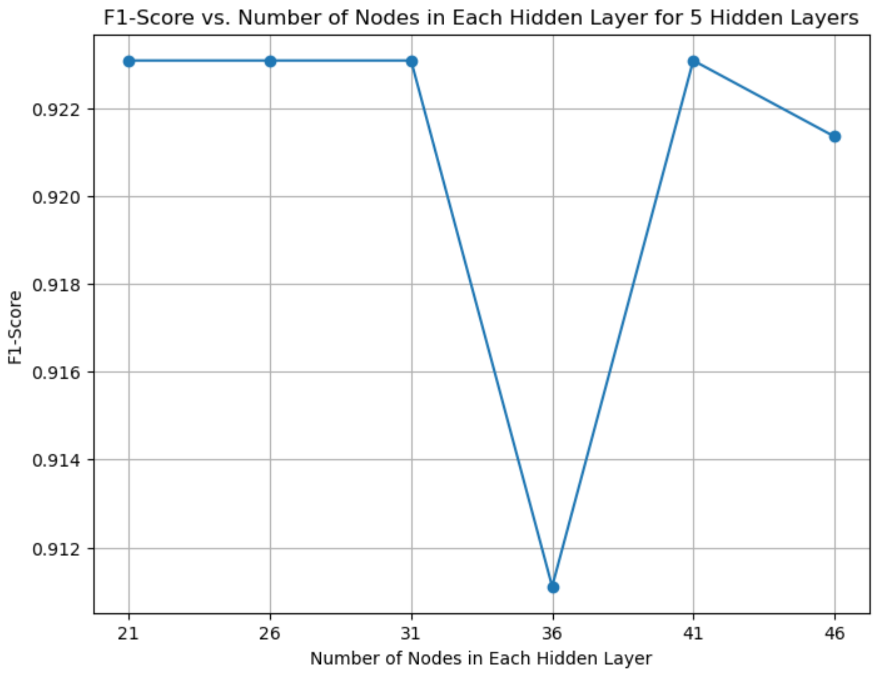

Figure 6: F1-Score vs. Number of Nodes in Each Hidden Layer for 5 Hidden Layers with `random_state = 42`.

For the configurations with 5 hidden layers (refer to Figure 6), the F1-Score values also exhibit a narrow range, approximately between 0.912 and 0.923.

These small variations observed indicate that increasing the number of nodes doesn't significantly improve or degrade the model's performance. This suggests that the model is no longer achieving substantial gains in learning from the data. Therefore, it can be concluded that the model has likely reached the saturation plateau.

For **3 hidden layers** and `random_state = 42`, the best configuration appears to be approximately 41 nodes in each hidden layer. The regression metrics for this configuration are given in the following table:

Classification Metrics				
Accuracy	**Recall**	**Precision Score**	**F1-Score**	**Kappa Score**
0.964	0.896	1.000	0.945	0.919

Table 4: Classification metrics for the model configuration with 3 hidden layers and 41 nodes in each layer.

For **4 hidden layers** and `random_state = 42`, the best configuration appears to be approximately 31 nodes in each hidden layer. The regression metrics for this configuration are given in the table below:

Classification Metrics				
Accuracy	**Recall**	**Precision Score**	**F1-Score**	**Kappa Score**
0.964	0.896	1.000	0.945	0.919

Table 5: Classification metrics for the model configuration with 4 hidden layers and 31 nodes in each layer.

For **5 hidden layers** and `random_state = 42`, the best configuration appears to be approximately 21 nodes in each hidden layer. The regression metrics for this configuration are given in the following table:

Classification Metrics				
Accuracy	**Recall**	**Precision Score**	**F1-Score**	**Kappa Score**
0.950	0.875	0.977	0.923	0.886

Table 6: Classification metrics for the model configuration with 5 hidden layers and 21 nodes in each layer.

2.2 Neuro-Fuzzy Model

In this problem, a range of 2 to 15 clusters was tested using the **Fuzzy C-Means (FCM)** clustering algorithm. For the models with 5 and 7 clusters, the ANFIS model achieved an **Accuracy** of 0.971, a **Sensitivity** of 0.966, and a **Specificity** of 0.979. These models provide a balanced performance, with a high level of sensitivity (minimizing missed diagnoses) and specificity (reducing unnecessary false positives), both of which are critical in healthcare applications. Given this consistency in performance, the model with 5 clusters is the most suitable choice, as it reduces the number of clusters, thus lowering computational costs without compromising performance (see the *wbco_neuro_fuzzy_fcm.m* file).