

Neural Network Assignment

Tirumal Report

Objective

The objective of this assignment is to design, train, and evaluate neural network models with different configurations on the IMDB sentiment classification dataset. Two types of neural network architectures were tested:

1. Single-layer Neural Network
2. Three-layer Neural Network

Each model was tested with various combinations of hidden units, activation functions, and loss functions. The goal is to compare the performance of these models in terms of both training and validation accuracy.

Dataset

The IMDB dataset was used, which consists of 50,000 movie reviews, labeled as either positive or negative. For this task:

- Training Set: 25,000 reviews
- Test Set: 25,000 reviews
- Only the top 10,000 most frequent words were kept from the dataset.
- Each review was padded or truncated to a maximum length of 500 words.

Model Architectures

1. Single-layer Model

The single-layer model consisted of an input embedding layer, followed by a fully connected dense layer, and an output layer for binary classification. The general structure of the model is:

- Embedding Layer: Embeds the input words into 128-dimensional vectors.
- Flatten Layer: Converts the 2D embeddings into a 1D vector.
- Dense Layer: A single dense layer with 'relu' or 'tanh' activation.
- Output Layer: A single neuron with a sigmoid activation for binary classification.

2. Three-layer Model

The three-layer model follows the same structure as the single-layer model but with three dense layers instead of one. This allows the model to capture more complex patterns in the data.

- Embedding Layer: Same as in the single-layer model.
- Flatten Layer: Same as in the single-layer model.
- Three Dense Layers: Three consecutive dense layers with 'relu' or 'tanh' activation.
- Output Layer: A single neuron with a sigmoid activation.

Experimental Setup

For both model types (single-layer and three-layer), the following configurations were tested:

- Hidden Units: 32, 64, and 128 neurons in each dense layer.
- Activation Functions: 'relu' and 'tanh'.
- Loss Functions: 'binary_crossentropy' and 'mean_squared_error'.
- Regularization: L2 regularization with a rate of 0.01 to avoid overfitting.
- Dropout: A dropout rate of 0.5 to further reduce overfitting.

Results

Single-layer Model Results

Model Type	Hidden Units	Activation	Loss Function	Train Accuracy	Val Accuracy
Single Layer	32	relu	binary_crossentropy	0.98005	0.8672
Single Layer	32	relu	mean_squared_error	0.9522	0.8664
Single Layer	32	tanh	binary_crossentropy	0.98445	0.8668
Single Layer	32	tanh	mean_squared_error	0.96965	0.8632
Single Layer	64	relu	binary_crossentropy	0.9787	0.8602
Single Layer	64	relu	mean_squared_error	0.9589	0.8666
Single Layer	64	tanh	binary_crossentropy	0.98555	0.86
Single Layer	64	tanh	mean_squared_error	0.964	0.8548
Single Layer	128	relu	binary_crossentropy	0.9765	0.8656
Single Layer	128	relu	mean_squared_error	0.95205	0.855
Single Layer	128	tanh	binary_crossentropy	0.9819	0.8532
Single Layer	128	tanh	mean_squared_error	0.9664	0.8626

Three-layer Model Results

Model Type	Hidden Units	Activation	Loss Function	Train Accuracy	Val Accuracy
Three Layer	32	relu	binary_crossentropy	0.50155	0.5062
Three Layer	32	relu	mean_squared_error	0.50135	0.5062
Three Layer	32	tanh	binary_crossentropy	0.9976	0.863
Three Layer	32	tanh	mean_squared_error	0.99145	0.8714
Three Layer	64	relu	binary_crossentropy	0.50405	0.5062
Three Layer	64	relu	mean_squared_error	0.50195	0.5062
Three Layer	64	tanh	binary_crossentropy	0.9966	0.8686
Three Layer	64	tanh	mean_squared_error	0.9885	0.8694
Three Layer	128	relu	binary_crossentropy	0.504	0.5062
Three Layer	128	relu	mean_squared_error	0.50255	0.4938
Three Layer	128	tanh	binary_crossentropy	0.99725	0.8648
Three Layer	128	tanh	mean_squared_error	0.50595	0.5062

Key Observations

1. Single-layer Models:

- The tanh activation performed slightly better than `relu` in terms of both training and validation accuracy across different configurations.
- Models with binary_crossentropy as the loss function consistently achieved higher accuracies than models with mean_squared_error.

2. Three-layer Models:

- Models with tanh activation and binary_crossentropy performed exceptionally well, achieving high training accuracy (close to 99%) and competitive validation accuracy.
- Relu-based models struggled in the three-layer architecture, often getting stuck with 50% accuracy, suggesting issues in model convergence for these configurations.
- The use of mean_squared_error as a loss function was less effective than binary_crossentropy for this binary classification problem, as evidenced by the generally lower accuracies.

3. Comparison between Single-layer and Three-layer Models:

- Three-layer models with `tanh` and `binary_crossentropy` outperformed most single-layer models in terms of training accuracy, though the validation accuracy was quite similar.
- Single-layer models provided more consistent validation performance across different configurations, while three-layer models exhibited more variability.

Conclusion

The results indicate that tanh activation and binary_crossentropy are generally more suitable for both single-layer and three-layer models in this binary sentiment classification task. While the three-layer models with `tanh` achieved very high training accuracies, they did not consistently outperform the single-layer models in validation accuracy, suggesting potential overfitting. On the other hand, single-layer models offered more stable performance across all configurations.

Loading Data

```
In [1]: import tensorflow as tf
from tensorflow.keras.datasets import imdb
from tensorflow.keras.preprocessing.sequence import pad_sequences

# Load the IMDB dataset
num_words = 10000
(x_train, y_train), (x_test, y_test) = imdb.load_data(num_words=num_words)

# Pad sequences to ensure uniform input size
maxlen = 500
x_train = pad_sequences(x_train, maxlen=maxlen)
x_test = pad_sequences(x_test, maxlen=maxlen)

print(f"Shape of x_train: {x_train.shape}")
print(f"Shape of y_train: {y_train.shape}")
```

Downloading data from <https://storage.googleapis.com/tensorflow/tf-keras-datasets/imdb.npz>
17464789/17464789 ————— 0s 0us/step
Shape of x_train: (25000, 500)
Shape of y_train: (25000,)

Model Definition

```
In [2]: import tensorflow as tf
from tensorflow.keras import layers, models, regularizers

def build_single_layer_model(hidden_units, activation='relu', loss_function='binary_crossentropy'):
    model = models.Sequential()
    model.add(layers.InputLayer(input_shape=(maxlen,)))
    model.add(layers.Embedding(input_dim=num_words, output_dim=128, input_length=maxlen))
    model.add(layers.Flatten()) # Flatten to convert 2D embeddings to 1D
    model.add(layers.Dense(hidden_units, activation=activation, kernel_regularizer=regularizers.l2(0.01)))
    model.add(layers.Dropout(dropout_rate))
    model.add(layers.Dense(1, activation='sigmoid')) # Output layer for binary classification

    model.compile(optimizer='adam', loss=loss_function, metrics=['accuracy'])
    return model

def build_three_layer_model(hidden_units, activation='relu', loss_function='binary_crossentropy'):
    model = models.Sequential()
    model.add(layers.InputLayer(input_shape=(maxlen,)))
    model.add(layers.Embedding(input_dim=num_words, output_dim=128, input_length=maxlen))
    model.add(layers.Flatten()) # Flatten to convert 2D embeddings to 1D
    model.add(layers.Dense(hidden_units, activation=activation, kernel_regularizer=regularizers.l2(0.01)))
    model.add(layers.Dense(hidden_units, activation=activation, kernel_regularizer=regularizers.l2(0.01)))
    model.add(layers.Dense(hidden_units, activation=activation, kernel_regularizer=regularizers.l2(0.01)))
    model.add(layers.Dropout(dropout_rate))
    model.add(layers.Dense(1, activation='sigmoid')) # Output layer for binary classification

    model.compile(optimizer='adam', loss=loss_function, metrics=['accuracy'])
    return model
```

Model Training

```
In [3]: import pandas as pd

def train_and_evaluate(models_config, model_type):
    results = []
    for config in models_config:
        model = config['model'](*config['args'], **config['kwargs'])
        model.summary()
        history = model.fit(x_train, y_train, epochs=10, batch_size=32, validation_split=0.1)

        # Collect results
        results.append({
            'model_type': model_type,
            'hidden_units': config['args'][0],
            'activation': config['kwargs'].get('activation'),
            'loss_function': config['kwargs'].get('loss_function'),
            'train_accuracy': max(history.history['accuracy']),
            'val_accuracy': max(history.history['val_accuracy']),
        })

    return pd.DataFrame(results)

# Define configurations
hidden_units_list = [32, 64, 128]
activation_functions = ['relu', 'tanh']
loss_functions = ['binary_crossentropy', 'mean_squared_error']
```

```

# Single-layer models
single_layer_configs = []
for units in hidden_units_list:
    for activation in activation_functions:
        for loss_function in loss_functions:
            single_layer_configs.append({
                'model': build_single_layer_model,
                'args': [units],
                'kwargs': {'activation': activation, 'loss_function': loss_function, '
            })

# Three-layer models
three_layer_configs = []
for units in hidden_units_list:
    for activation in activation_functions:
        for loss_function in loss_functions:
            three_layer_configs.append({
                'model': build_three_layer_model,
                'args': [units],
                'kwargs': {'activation': activation, 'loss_function': loss_function, '
            })

# Train and store results
single_layer_results = train_and_evaluate(single_layer_configs, 'single_layer')
three_layer_results = train_and_evaluate(three_layer_configs, 'three_layer')

```

```

/usr/local/lib/python3.10/dist-packages/keras/src/layers/core/input_layer.py:26: User
Warning: Argument `input_shape` is deprecated. Use `shape` instead.
  warnings.warn(
/usr/local/lib/python3.10/dist-packages/keras/src/layers/core/embedding.py:90: UserWa
rning: Argument `input_length` is deprecated. Just remove it.
  warnings.warn(

```











Model: "sequential"

Layer (type)	Output Shape	Pa
embedding (Embedding)	(None, 500, 128)	1,28
flatten (Flatten)	(None, 64000)	
dense (Dense)	(None, 32)	2,04
dropout (Dropout)	(None, 32)	
dense_1 (Dense)	(None, 1)	

Total params: 3,328,065 (12.70 MB)











Trainable params: 3,328,065 (12.70 MB)

Non-trainable params: 0 (0.00 B)

Epoch 1/10
625/625  6s 5ms/step - accuracy: 0.6240 - loss: 0.8473 - val_accuracy: 0.8330 - val_loss: 0.7101
Epoch 2/10
625/625  8s 4ms/step - accuracy: 0.8826 - loss: 0.6654 - val_accuracy: 0.8612 - val_loss: 0.7893
Epoch 3/10
625/625  2s 4ms/step - accuracy: 0.9169 - loss: 0.6558 - val_accuracy: 0.8672 - val_loss: 0.7849
Epoch 4/10
625/625  3s 5ms/step - accuracy: 0.9377 - loss: 0.6632 - val_accuracy: 0.8568 - val_loss: 0.9775
Epoch 5/10
625/625  3s 4ms/step - accuracy: 0.9577 - loss: 0.6236 - val_accuracy: 0.8610 - val_loss: 1.0044
Epoch 6/10
625/625  5s 4ms/step - accuracy: 0.9652 - loss: 0.6662 - val_accuracy: 0.8542 - val_loss: 1.0082
Epoch 7/10
625/625  2s 3ms/step - accuracy: 0.9759 - loss: 0.6164 - val_accuracy: 0.8482 - val_loss: 1.1438
Epoch 8/10
625/625  3s 4ms/step - accuracy: 0.9748 - loss: 0.6946 - val_accuracy: 0.8532 - val_loss: 1.2238
Epoch 9/10
625/625  3s 4ms/step - accuracy: 0.9809 - loss: 0.5900 - val_accuracy: 0.8556 - val_loss: 1.1823
Epoch 10/10
625/625  4s 3ms/step - accuracy: 0.9780 - loss: 0.7188 - val_accuracy: 0.8420 - val_loss: 1.1500
Model: "sequential_1"

Layer (type)	Output Shape	Params
embedding_1 (Embedding)	(None, 500, 128)	1,280,000
flatten_1 (Flatten)	(None, 64000)	0
dense_2 (Dense)	(None, 32)	2,048,000
dropout_1 (Dropout)	(None, 32)	0
dense_3 (Dense)	(None, 1)	32

Total params: 3,328,065 (12.70 MB)
Trainable params: 3,328,065 (12.70 MB)
Non-trainable params: 0 (0.00 B)

Epoch 1/10
625/625  4s 4ms/step - accuracy: 0.6251 - loss: 0.3255 - val_accuracy: 0.8460 - val_loss: 0.2689
Epoch 2/10
625/625  4s 4ms/step - accuracy: 0.8644 - loss: 0.2729 - val_accuracy: 0.8494 - val_loss: 0.2886
Epoch 3/10
625/625  2s 3ms/step - accuracy: 0.8934 - loss: 0.2739 - val_accuracy: 0.8664 - val_loss: 0.3331
Epoch 4/10
625/625  2s 3ms/step - accuracy: 0.9071 - loss: 0.2783 - val_accuracy: 0.8548 - val_loss: 0.4083
Epoch 5/10
625/625  2s 3ms/step - accuracy: 0.9165 - loss: 0.2920 - val_accuracy: 0.8334 - val_loss: 0.4002
Epoch 6/10
625/625  3s 3ms/step - accuracy: 0.9246 - loss: 0.2997 - val_accuracy: 0.8518 - val_loss: 0.3433
Epoch 7/10
625/625  3s 4ms/step - accuracy: 0.9283 - loss: 0.2980 - val_accuracy: 0.8474 - val_loss: 0.3926
Epoch 8/10
625/625  2s 3ms/step - accuracy: 0.9446 - loss: 0.2984 - val_accuracy: 0.8584 - val_loss: 0.3589
Epoch 9/10
625/625  2s 3ms/step - accuracy: 0.9491 - loss: 0.2967 - val_accuracy: 0.8342 - val_loss: 0.4144
Epoch 10/10
625/625  2s 3ms/step - accuracy: 0.9511 - loss: 0.3228 - val_accuracy: 0.8532 - val_loss: 0.4515

Model: "sequential_2"











Layer (type)	Output Shape	Params
embedding_2 (Embedding)	(None, 500, 128)	1,280
flatten_2 (Flatten)	(None, 64000)	
dense_4 (Dense)	(None, 32)	2,048
dropout_2 (Dropout)	(None, 32)	
dense_5 (Dense)	(None, 1)	

Total params: 3,328,065 (12.70 MB)
Trainable params: 3,328,065 (12.70 MB)
Non-trainable params: 0 (0.00 B)

Epoch 1/10
625/625 ————— 5s 5ms/step - accuracy: 0.7027 - loss: 0.8580 - val_accu
racy: 0.8540 - val_loss: 0.7562
Epoch 2/10
625/625 ————— 3s 3ms/step - accuracy: 0.8991 - loss: 0.6625 - val_accu
racy: 0.8668 - val_loss: 0.8263
Epoch 3/10
625/625 ————— 3s 3ms/step - accuracy: 0.9425 - loss: 0.5922 - val_accu
racy: 0.8528 - val_loss: 1.0909
Epoch 4/10
625/625 ————— 2s 3ms/step - accuracy: 0.9642 - loss: 0.5937 - val_accu
racy: 0.8592 - val_loss: 0.9061
Epoch 5/10
625/625 ————— 3s 3ms/step - accuracy: 0.9767 - loss: 0.5323 - val_accu
racy: 0.8178 - val_loss: 1.6674
Epoch 6/10
625/625 ————— 2s 3ms/step - accuracy: 0.9729 - loss: 0.7865 - val_accu
racy: 0.8368 - val_loss: 1.0676
Epoch 7/10
625/625 ————— 2s 3ms/step - accuracy: 0.9813 - loss: 0.6017 - val_accu
racy: 0.8552 - val_loss: 1.0314
Epoch 8/10
625/625 ————— 2s 3ms/step - accuracy: 0.9812 - loss: 0.6165 - val_accu
racy: 0.8506 - val_loss: 1.1627
Epoch 9/10
625/625 ————— 3s 3ms/step - accuracy: 0.9875 - loss: 0.5065 - val_accu
racy: 0.8400 - val_loss: 1.4517
Epoch 10/10
625/625 ————— 2s 3ms/step - accuracy: 0.9818 - loss: 0.7050 - val_accu
racy: 0.8376 - val_loss: 1.4200
Model: "sequential_3"

Layer (type)	Output Shape	Pa
embedding_3 (Embedding)	(None, 500, 128)	1,28
flatten_3 (Flatten)	(None, 64000)	
dense_6 (Dense)	(None, 32)	2,04
dropout_3 (Dropout)	(None, 32)	
dense_7 (Dense)	(None, 1)	











Total params: 3,328,065 (12.70 MB)
Trainable params: 3,328,065 (12.70 MB)
Non-trainable params: 0 (0.00 B)

Epoch 1/10
625/625  6s 5ms/step - accuracy: 0.6781 - loss: 0.3664 - val_accuracy: 0.8496 - val_loss: 0.2910
Epoch 2/10
625/625  3s 3ms/step - accuracy: 0.8779 - loss: 0.2750 - val_accuracy: 0.8632 - val_loss: 0.3190
Epoch 3/10
625/625  2s 3ms/step - accuracy: 0.9062 - loss: 0.2812 - val_accuracy: 0.8526 - val_loss: 0.3461
Epoch 4/10
625/625  2s 3ms/step - accuracy: 0.9280 - loss: 0.2855 - val_accuracy: 0.8516 - val_loss: 0.3219
Epoch 5/10
625/625  3s 4ms/step - accuracy: 0.9448 - loss: 0.2726 - val_accuracy: 0.8522 - val_loss: 0.3271
Epoch 6/10
625/625  2s 3ms/step - accuracy: 0.9502 - loss: 0.2888 - val_accuracy: 0.8622 - val_loss: 0.3296
Epoch 7/10
625/625  2s 3ms/step - accuracy: 0.9630 - loss: 0.2558 - val_accuracy: 0.8454 - val_loss: 0.4344
Epoch 8/10
625/625  2s 3ms/step - accuracy: 0.9601 - loss: 0.3043 - val_accuracy: 0.8350 - val_loss: 0.4299
Epoch 9/10
625/625  2s 3ms/step - accuracy: 0.9632 - loss: 0.2780 - val_accuracy: 0.8546 - val_loss: 0.4126
Epoch 10/10
625/625  2s 3ms/step - accuracy: 0.9721 - loss: 0.2734 - val_accuracy: 0.8486 - val_loss: 0.3924

Model: "sequential_4"











Layer (type)	Output Shape	Params
embedding_4 (Embedding)	(None , 500, 128)	1,280
flatten_4 (Flatten)	(None , 64000)	
dense_8 (Dense)	(None , 64)	4,096
dropout_4 (Dropout)	(None , 64)	
dense_9 (Dense)	(None , 1)	

Total params: 5,376,129 (20.51 MB)
Trainable params: 5,376,129 (20.51 MB)
Non-trainable params: 0 (0.00 B)

Epoch 1/10
625/625  6s 5ms/step - accuracy: 0.6457 - loss: 0.9368 - val_accuracy: 0.8486 - val_loss: 0.7823
Epoch 2/10
625/625  3s 4ms/step - accuracy: 0.8826 - loss: 0.7533 - val_accuracy: 0.8392 - val_loss: 0.8766
Epoch 3/10
625/625  3s 4ms/step - accuracy: 0.9110 - loss: 0.7590 - val_accuracy: 0.8576 - val_loss: 1.1006
Epoch 4/10
625/625  3s 5ms/step - accuracy: 0.9437 - loss: 0.7417 - val_accuracy: 0.8396 - val_loss: 1.1196
Epoch 5/10
625/625  4s 4ms/step - accuracy: 0.9555 - loss: 0.7542 - val_accuracy: 0.8602 - val_loss: 1.1512
Epoch 6/10
625/625  2s 4ms/step - accuracy: 0.9684 - loss: 0.7094 - val_accuracy: 0.8524 - val_loss: 1.2076
Epoch 7/10
625/625  3s 4ms/step - accuracy: 0.9768 - loss: 0.6916 - val_accuracy: 0.8496 - val_loss: 1.3549
Epoch 8/10
625/625  3s 4ms/step - accuracy: 0.9778 - loss: 0.7510 - val_accuracy: 0.8600 - val_loss: 1.0497
Epoch 9/10
625/625  5s 4ms/step - accuracy: 0.9781 - loss: 0.7228 - val_accuracy: 0.8546 - val_loss: 1.1966
Epoch 10/10
625/625  2s 4ms/step - accuracy: 0.9796 - loss: 0.7735 - val_accuracy: 0.8446 - val_loss: 1.1923
Model: "sequential_5"

Layer (type)	Output Shape	Params
embedding_5 (Embedding)	(None , 500, 128)	1,280
flatten_5 (Flatten)	(None , 64000)	0
dense_10 (Dense)	(None , 64)	4,096
dropout_5 (Dropout)	(None , 64)	0
dense_11 (Dense)	(None , 1)	64











Total params: 5,376,129 (20.51 MB)
Trainable params: 5,376,129 (20.51 MB)
Non-trainable params: 0 (0.00 B)

Epoch 1/10
625/625  5s 6ms/step - accuracy: 0.6691 - loss: 0.4116 - val_accuracy: 0.8490 - val_loss: 0.3415
Epoch 2/10
625/625  3s 4ms/step - accuracy: 0.8713 - loss: 0.3236 - val_accuracy: 0.8480 - val_loss: 0.3621
Epoch 3/10
625/625  2s 3ms/step - accuracy: 0.8951 - loss: 0.3390 - val_accuracy: 0.8646 - val_loss: 0.3441
Epoch 4/10
625/625  3s 3ms/step - accuracy: 0.9107 - loss: 0.3412 - val_accuracy: 0.8666 - val_loss: 0.4443
Epoch 5/10
625/625  2s 3ms/step - accuracy: 0.9252 - loss: 0.3462 - val_accuracy: 0.8612 - val_loss: 0.4714
Epoch 6/10
625/625  3s 4ms/step - accuracy: 0.9310 - loss: 0.3695 - val_accuracy: 0.8454 - val_loss: 0.4461
Epoch 7/10
625/625  2s 3ms/step - accuracy: 0.9413 - loss: 0.3705 - val_accuracy: 0.8500 - val_loss: 0.4440
Epoch 8/10
625/625  2s 4ms/step - accuracy: 0.9493 - loss: 0.3567 - val_accuracy: 0.8376 - val_loss: 0.4906
Epoch 9/10
625/625  2s 3ms/step - accuracy: 0.9480 - loss: 0.3975 - val_accuracy: 0.8440 - val_loss: 0.4828
Epoch 10/10
625/625  2s 4ms/step - accuracy: 0.9597 - loss: 0.3558 - val_accuracy: 0.8454 - val_loss: 0.5142

Model: "sequential_6"











Layer (type)	Output Shape	Params
embedding_6 (Embedding)	(None , 500, 128)	1,280
flatten_6 (Flatten)	(None , 64000)	
dense_12 (Dense)	(None , 64)	4,096
dropout_6 (Dropout)	(None , 64)	
dense_13 (Dense)	(None , 1)	

Total params: 5,376,129 (20.51 MB)
Trainable params: 5,376,129 (20.51 MB)
Non-trainable params: 0 (0.00 B)

Epoch 1/10
625/625  6s 5ms/step - accuracy: 0.7003 - loss: 1.0175 - val_accuracy: 0.8420 - val_loss: 0.9901
Epoch 2/10
625/625  2s 4ms/step - accuracy: 0.8905 - loss: 0.7987 - val_accuracy: 0.8426 - val_loss: 0.9662
Epoch 3/10
625/625  3s 4ms/step - accuracy: 0.9367 - loss: 0.7292 - val_accuracy: 0.8484 - val_loss: 1.1469
Epoch 4/10
625/625  2s 3ms/step - accuracy: 0.9569 - loss: 0.7360 - val_accuracy: 0.8474 - val_loss: 1.2975
Epoch 5/10
625/625  3s 5ms/step - accuracy: 0.9717 - loss: 0.7586 - val_accuracy: 0.8472 - val_loss: 1.2780
Epoch 6/10
625/625  2s 3ms/step - accuracy: 0.9763 - loss: 0.7420 - val_accuracy: 0.8534 - val_loss: 1.3253
Epoch 7/10
625/625  2s 4ms/step - accuracy: 0.9828 - loss: 0.6885 - val_accuracy: 0.8498 - val_loss: 1.3680
Epoch 8/10
625/625  2s 3ms/step - accuracy: 0.9782 - loss: 0.8148 - val_accuracy: 0.8462 - val_loss: 1.4601
Epoch 9/10
625/625  2s 4ms/step - accuracy: 0.9799 - loss: 0.7948 - val_accuracy: 0.8396 - val_loss: 1.4160
Epoch 10/10
625/625  2s 4ms/step - accuracy: 0.9907 - loss: 0.5907 - val_accuracy: 0.8600 - val_loss: 1.2505
Model: "sequential_7"











Layer (type)	Output Shape	Params
embedding_7 (Embedding)	(None , 500, 128)	1,280
flatten_7 (Flatten)	(None , 64000)	0
dense_14 (Dense)	(None , 64)	4,096
dropout_7 (Dropout)	(None , 64)	0
dense_15 (Dense)	(None , 1)	64

Total params: 5,376,129 (20.51 MB)
Trainable params: 5,376,129 (20.51 MB)
Non-trainable params: 0 (0.00 B)

Epoch 1/10
625/625  5s 5ms/step - accuracy: 0.6969 - loss: 0.4386 - val_accuracy: 0.8340 - val_loss: 0.3499
Epoch 2/10
625/625  2s 3ms/step - accuracy: 0.8763 - loss: 0.3311 - val_accuracy: 0.8548 - val_loss: 0.3973
Epoch 3/10
625/625  2s 3ms/step - accuracy: 0.9003 - loss: 0.3417 - val_accuracy: 0.8374 - val_loss: 0.4301
Epoch 4/10
625/625  2s 4ms/step - accuracy: 0.9192 - loss: 0.3342 - val_accuracy: 0.8232 - val_loss: 0.4581
Epoch 5/10
625/625  3s 4ms/step - accuracy: 0.9286 - loss: 0.3382 - val_accuracy: 0.8514 - val_loss: 0.4322
Epoch 6/10
625/625  2s 3ms/step - accuracy: 0.9422 - loss: 0.3435 - val_accuracy: 0.8460 - val_loss: 0.3951
Epoch 7/10
625/625  2s 4ms/step - accuracy: 0.9548 - loss: 0.3167 - val_accuracy: 0.8422 - val_loss: 0.4594
Epoch 8/10
625/625  3s 4ms/step - accuracy: 0.9571 - loss: 0.3353 - val_accuracy: 0.8492 - val_loss: 0.4530
Epoch 9/10
625/625  2s 3ms/step - accuracy: 0.9633 - loss: 0.3352 - val_accuracy: 0.8464 - val_loss: 0.4137
Epoch 10/10
625/625  3s 4ms/step - accuracy: 0.9631 - loss: 0.3476 - val_accuracy: 0.8394 - val_loss: 0.4700
Model: "sequential_8"











Layer (type)	Output Shape	Params
embedding_8 (Embedding)	(None , 500, 128)	1,280
flatten_8 (Flatten)	(None , 64000)	
dense_16 (Dense)	(None , 128)	8,192
dropout_8 (Dropout)	(None , 128)	
dense_17 (Dense)	(None , 1)	

Total params: 9,472,257 (36.13 MB)
Trainable params: 9,472,257 (36.13 MB)
Non-trainable params: 0 (0.00 B)

Epoch 1/10
625/625  6s 6ms/step - accuracy: 0.6597 - loss: 1.1435 - val_accuracy: 0.8432 - val_loss: 0.9450
Epoch 2/10
625/625  3s 5ms/step - accuracy: 0.8828 - loss: 0.9508 - val_accuracy: 0.8380 - val_loss: 1.1946
Epoch 3/10
625/625  5s 5ms/step - accuracy: 0.9114 - loss: 1.0006 - val_accuracy: 0.8476 - val_loss: 1.3515
Epoch 4/10
625/625  3s 5ms/step - accuracy: 0.9360 - loss: 0.9744 - val_accuracy: 0.8656 - val_loss: 1.3480
Epoch 5/10
625/625  6s 5ms/step - accuracy: 0.9530 - loss: 0.9774 - val_accuracy: 0.8530 - val_loss: 1.3104
Epoch 6/10
625/625  3s 5ms/step - accuracy: 0.9670 - loss: 0.8669 - val_accuracy: 0.8474 - val_loss: 1.6241
Epoch 7/10
625/625  3s 5ms/step - accuracy: 0.9700 - loss: 0.9505 - val_accuracy: 0.8528 - val_loss: 1.3827
Epoch 8/10
625/625  6s 6ms/step - accuracy: 0.9714 - loss: 0.9665 - val_accuracy: 0.8432 - val_loss: 1.2535
Epoch 9/10
625/625  5s 5ms/step - accuracy: 0.9766 - loss: 0.9399 - val_accuracy: 0.8418 - val_loss: 1.7564
Epoch 10/10
625/625  5s 5ms/step - accuracy: 0.9810 - loss: 0.9250 - val_accuracy: 0.8494 - val_loss: 1.7427
Model: "sequential_9"











Layer (type)	Output Shape	Params
embedding_9 (Embedding)	(None, 500, 128)	1,280
flatten_9 (Flatten)	(None, 64000)	
dense_18 (Dense)	(None, 128)	8,192
dropout_9 (Dropout)	(None, 128)	
dense_19 (Dense)	(None, 1)	

Total params: 9,472,257 (36.13 MB)
Trainable params: 9,472,257 (36.13 MB)
Non-trainable params: 0 (0.00 B)

Epoch 1/10
625/625  **6s** 6ms/step - accuracy: 0.6555 - loss: 0.5143 - val_accuracy: 0.8208 - val_loss: 0.4045
Epoch 2/10
625/625  **3s** 5ms/step - accuracy: 0.8623 - loss: 0.4190 - val_accuracy: 0.8492 - val_loss: 0.4736
Epoch 3/10
625/625  **4s** 6ms/step - accuracy: 0.8893 - loss: 0.4328 - val_accuracy: 0.8522 - val_loss: 0.5703
Epoch 4/10
625/625  **3s** 5ms/step - accuracy: 0.9052 - loss: 0.4446 - val_accuracy: 0.8414 - val_loss: 0.5068
Epoch 5/10
625/625  **3s** 5ms/step - accuracy: 0.9160 - loss: 0.4409 - val_accuracy: 0.8548 - val_loss: 0.5093
Epoch 6/10
625/625  **3s** 5ms/step - accuracy: 0.9210 - loss: 0.4676 - val_accuracy: 0.8464 - val_loss: 0.5504
Epoch 7/10
625/625  **3s** 5ms/step - accuracy: 0.9362 - loss: 0.4188 - val_accuracy: 0.8532 - val_loss: 0.4659
Epoch 8/10
625/625  **5s** 5ms/step - accuracy: 0.9413 - loss: 0.4502 - val_accuracy: 0.8488 - val_loss: 0.4714
Epoch 9/10
625/625  **3s** 5ms/step - accuracy: 0.9475 - loss: 0.4310 - val_accuracy: 0.8550 - val_loss: 0.5993
Epoch 10/10
625/625  **3s** 5ms/step - accuracy: 0.9582 - loss: 0.4308 - val_accuracy: 0.8474 - val_loss: 0.5044
Model: "sequential_10"

Layer (type)	Output Shape	Params
embedding_10 (Embedding)	(None , 500 , 128)	1,280
flatten_10 (Flatten)	(None , 64000)	
dense_20 (Dense)	(None , 128)	8,192
dropout_10 (Dropout)	(None , 128)	
dense_21 (Dense)	(None , 1)	

Total params: [9,472,257](#) (36.13 MB)
Trainable params: [9,472,257](#) (36.13 MB)
Non-trainable params: [0](#) (0.00 B)

Epoch 1/10
625/625  6s 6ms/step - accuracy: 0.6968 - loss: 1.2297 - val_accuracy: 0.8470 - val_loss: 0.9787
Epoch 2/10
625/625  3s 5ms/step - accuracy: 0.8863 - loss: 0.9661 - val_accuracy: 0.8512 - val_loss: 1.0514
Epoch 3/10
625/625  5s 5ms/step - accuracy: 0.9245 - loss: 0.8595 - val_accuracy: 0.8440 - val_loss: 1.2587
Epoch 4/10
625/625  5s 5ms/step - accuracy: 0.9533 - loss: 0.8345 - val_accuracy: 0.8522 - val_loss: 1.3252
Epoch 5/10
625/625  3s 5ms/step - accuracy: 0.9700 - loss: 0.7698 - val_accuracy: 0.8428 - val_loss: 1.3927
Epoch 6/10
625/625  5s 5ms/step - accuracy: 0.9697 - loss: 0.8921 - val_accuracy: 0.8532 - val_loss: 1.5130
Epoch 7/10
625/625  3s 5ms/step - accuracy: 0.9778 - loss: 0.8096 - val_accuracy: 0.8366 - val_loss: 1.9993
Epoch 8/10
625/625  3s 5ms/step - accuracy: 0.9771 - loss: 1.0100 - val_accuracy: 0.8406 - val_loss: 1.6456
Epoch 9/10
625/625  3s 5ms/step - accuracy: 0.9802 - loss: 0.8408 - val_accuracy: 0.8450 - val_loss: 1.1170
Epoch 10/10
625/625  3s 5ms/step - accuracy: 0.9871 - loss: 0.6953 - val_accuracy: 0.8442 - val_loss: 1.5956
Model: "sequential_11"











Layer (type)	Output Shape	Params
embedding_11 (Embedding)	(None, 500, 128)	1,280,000
flatten_11 (Flatten)	(None, 64000)	0
dense_22 (Dense)	(None, 128)	8,192
dropout_11 (Dropout)	(None, 128)	0
dense_23 (Dense)	(None, 1)	128

Total params: 9,472,257 (36.13 MB)
Trainable params: 9,472,257 (36.13 MB)
Non-trainable params: 0 (0.00 B)

Epoch 1/10
625/625 ————— 6s 6ms/step - accuracy: 0.6823 - loss: 0.5578 - val_accuracy: 0.8368 - val_loss: 0.3989
Epoch 2/10
625/625 ————— 4s 5ms/step - accuracy: 0.8632 - loss: 0.4180 - val_accuracy: 0.8288 - val_loss: 0.4599
Epoch 3/10
625/625 ————— 5s 5ms/step - accuracy: 0.8915 - loss: 0.4283 - val_accuracy: 0.8430 - val_loss: 0.5295
Epoch 4/10
625/625 ————— 5s 5ms/step - accuracy: 0.9135 - loss: 0.3942 - val_accuracy: 0.8526 - val_loss: 0.4700
Epoch 5/10
625/625 ————— 5s 5ms/step - accuracy: 0.9305 - loss: 0.3807 - val_accuracy: 0.8336 - val_loss: 0.4697
Epoch 6/10
625/625 ————— 5s 5ms/step - accuracy: 0.9305 - loss: 0.3989 - val_accuracy: 0.8416 - val_loss: 0.4749
Epoch 7/10
625/625 ————— 5s 5ms/step - accuracy: 0.9537 - loss: 0.3711 - val_accuracy: 0.8626 - val_loss: 0.5254
Epoch 8/10
625/625 ————— 5s 5ms/step - accuracy: 0.9603 - loss: 0.3522 - val_accuracy: 0.8500 - val_loss: 0.4827
Epoch 9/10
625/625 ————— 6s 5ms/step - accuracy: 0.9648 - loss: 0.3485 - val_accuracy: 0.8456 - val_loss: 0.5260
Epoch 10/10
625/625 ————— 5s 5ms/step - accuracy: 0.9684 - loss: 0.3533 - val_accuracy: 0.8572 - val_loss: 0.4454
Model: "sequential_12"

Layer (type)	Output Shape	Params
embedding_12 (Embedding)	(None, 500, 128)	1,280,000
flatten_12 (Flatten)	(None, 64000)	0
dense_24 (Dense)	(None, 32)	2,048
dense_25 (Dense)	(None, 32)	1,024
dense_26 (Dense)	(None, 32)	1,024
dropout_12 (Dropout)	(None, 32)	0
dense_27 (Dense)	(None, 1)	32

Total params: 3,330,177 (12.70 MB)
Trainable params: 3,330,177 (12.70 MB)
Non-trainable params: 0 (0.00 B)

Epoch 1/10
625/625  **6s** 6ms/step - accuracy: 0.5038 - loss: 1.0221 - val_accuracy: 0.4938 - val_loss: 0.6946
Epoch 2/10
625/625  **7s** 3ms/step - accuracy: 0.4982 - loss: 0.6938 - val_accuracy: 0.5062 - val_loss: 0.6931
Epoch 3/10
625/625  **3s** 4ms/step - accuracy: 0.5006 - loss: 0.6931 - val_accuracy: 0.5062 - val_loss: 0.6931
Epoch 4/10
625/625  **2s** 4ms/step - accuracy: 0.4943 - loss: 0.6933 - val_accuracy: 0.4938 - val_loss: 0.6932
Epoch 5/10
625/625  **2s** 3ms/step - accuracy: 0.5077 - loss: 0.6931 - val_accuracy: 0.4938 - val_loss: 0.6932
Epoch 6/10
625/625  **2s** 3ms/step - accuracy: 0.4924 - loss: 0.6932 - val_accuracy: 0.4938 - val_loss: 0.6932
Epoch 7/10
625/625  **2s** 3ms/step - accuracy: 0.5050 - loss: 0.6931 - val_accuracy: 0.4938 - val_loss: 0.6931
Epoch 8/10
625/625  **2s** 3ms/step - accuracy: 0.4975 - loss: 0.6932 - val_accuracy: 0.4938 - val_loss: 0.6932
Epoch 9/10
625/625  **2s** 4ms/step - accuracy: 0.5007 - loss: 0.6932 - val_accuracy: 0.4938 - val_loss: 0.6932
Epoch 10/10
625/625  **2s** 4ms/step - accuracy: 0.4954 - loss: 0.6932 - val_accuracy: 0.4938 - val_loss: 0.6933
Model: "sequential_13"

Layer (type)	Output Shape	Params
embedding_13 (Embedding)	(None , 500 , 128)	1,280
flatten_13 (Flatten)	(None , 64000)	
dense_28 (Dense)	(None , 32)	2,048
dense_29 (Dense)	(None , 32)	
dense_30 (Dense)	(None , 32)	
dropout_13 (Dropout)	(None , 32)	
dense_31 (Dense)	(None , 1)	

Total params: [3,330,177](#) (12.70 MB)
Trainable params: [3,330,177](#) (12.70 MB)
Non-trainable params: [0](#) (0.00 B)

Epoch 1/10
625/625 ————— 6s 5ms/step - accuracy: 0.4982 - loss: 0.5365 - val_accuracy: 0.4938 - val_loss: 0.2502
Epoch 2/10
625/625 ————— 2s 3ms/step - accuracy: 0.4959 - loss: 0.2501 - val_accuracy: 0.4938 - val_loss: 0.2500
Epoch 3/10
625/625 ————— 2s 4ms/step - accuracy: 0.5020 - loss: 0.2500 - val_accuracy: 0.5062 - val_loss: 0.2500
Epoch 4/10
625/625 ————— 2s 4ms/step - accuracy: 0.5024 - loss: 0.2500 - val_accuracy: 0.4938 - val_loss: 0.2500
Epoch 5/10
625/625 ————— 2s 3ms/step - accuracy: 0.5023 - loss: 0.2500 - val_accuracy: 0.4938 - val_loss: 0.2500
Epoch 6/10
625/625 ————— 3s 3ms/step - accuracy: 0.4974 - loss: 0.2500 - val_accuracy: 0.4938 - val_loss: 0.2501
Epoch 7/10
625/625 ————— 2s 3ms/step - accuracy: 0.5041 - loss: 0.2500 - val_accuracy: 0.4938 - val_loss: 0.2500
Epoch 8/10
625/625 ————— 3s 3ms/step - accuracy: 0.5023 - loss: 0.2500 - val_accuracy: 0.4938 - val_loss: 0.2500
Epoch 9/10
625/625 ————— 3s 4ms/step - accuracy: 0.4959 - loss: 0.2500 - val_accuracy: 0.4938 - val_loss: 0.2500
Epoch 10/10
625/625 ————— 2s 3ms/step - accuracy: 0.4981 - loss: 0.2500 - val_accuracy: 0.4938 - val_loss: 0.2500
Model: "sequential_14"

Layer (type)	Output Shape	Params
embedding_14 (Embedding)	(None, 500, 128)	1,280,000
flatten_14 (Flatten)	(None, 64000)	0
dense_32 (Dense)	(None, 32)	2,048
dense_33 (Dense)	(None, 32)	10,240
dense_34 (Dense)	(None, 32)	10,240
dropout_14 (Dropout)	(None, 32)	0
dense_35 (Dense)	(None, 1)	32

Total params: 3,330,177 (12.70 MB)
Trainable params: 3,330,177 (12.70 MB)
Non-trainable params: 0 (0.00 B)

Epoch 1/10
625/625 ————— 6s 5ms/step - accuracy: 0.6800 - loss: 1.2108 - val_accuracy: 0.8562 - val_loss: 0.5731
Epoch 2/10
625/625 ————— 3s 4ms/step - accuracy: 0.9099 - loss: 0.4804 - val_accuracy: 0.8630 - val_loss: 0.5547
Epoch 3/10
625/625 ————— 2s 4ms/step - accuracy: 0.9624 - loss: 0.3318 - val_accuracy: 0.8562 - val_loss: 0.6196
Epoch 4/10
625/625 ————— 2s 3ms/step - accuracy: 0.9907 - loss: 0.2266 - val_accuracy: 0.8548 - val_loss: 0.6099
Epoch 5/10
625/625 ————— 2s 3ms/step - accuracy: 0.9923 - loss: 0.2066 - val_accuracy: 0.8566 - val_loss: 0.8022
Epoch 6/10
625/625 ————— 2s 3ms/step - accuracy: 0.9952 - loss: 0.2139 - val_accuracy: 0.8528 - val_loss: 0.5644
Epoch 7/10
625/625 ————— 3s 3ms/step - accuracy: 0.9973 - loss: 0.1367 - val_accuracy: 0.8508 - val_loss: 0.6516
Epoch 8/10
625/625 ————— 2s 4ms/step - accuracy: 0.9973 - loss: 0.1504 - val_accuracy: 0.8540 - val_loss: 0.5947
Epoch 9/10
625/625 ————— 2s 4ms/step - accuracy: 0.9947 - loss: 0.2404 - val_accuracy: 0.8440 - val_loss: 0.6759
Epoch 10/10
625/625 ————— 2s 3ms/step - accuracy: 0.9983 - loss: 0.1292 - val_accuracy: 0.8420 - val_loss: 1.0361
Model: "sequential_15"

Layer (type)	Output Shape	Params
embedding_15 (Embedding)	(None, 500, 128)	1,280,000
flatten_15 (Flatten)	(None, 64000)	0
dense_36 (Dense)	(None, 32)	2,048,000
dense_37 (Dense)	(None, 32)	102,400
dense_38 (Dense)	(None, 32)	102,400
dropout_15 (Dropout)	(None, 32)	0
dense_39 (Dense)	(None, 1)	32

Total params: 3,330,177 (12.70 MB)
Trainable params: 3,330,177 (12.70 MB)
Non-trainable params: 0 (0.00 B)

Epoch 1/10
625/625 ————— 5s 5ms/step - accuracy: 0.6241 - loss: 0.6264 - val_accuracy: 0.8502 - val_loss: 0.2057
Epoch 2/10
625/625 ————— 4s 4ms/step - accuracy: 0.8859 - loss: 0.1877 - val_accuracy: 0.8610 - val_loss: 0.1916
Epoch 3/10
625/625 ————— 5s 3ms/step - accuracy: 0.9202 - loss: 0.1583 - val_accuracy: 0.8714 - val_loss: 0.1897
Epoch 4/10
625/625 ————— 2s 3ms/step - accuracy: 0.9480 - loss: 0.1311 - val_accuracy: 0.8642 - val_loss: 0.1663
Epoch 5/10
625/625 ————— 3s 3ms/step - accuracy: 0.9692 - loss: 0.1025 - val_accuracy: 0.8602 - val_loss: 0.1672
Epoch 6/10
625/625 ————— 2s 4ms/step - accuracy: 0.9838 - loss: 0.0797 - val_accuracy: 0.8626 - val_loss: 0.1833
Epoch 7/10
625/625 ————— 2s 4ms/step - accuracy: 0.9893 - loss: 0.0767 - val_accuracy: 0.8586 - val_loss: 0.1539
Epoch 8/10
625/625 ————— 2s 3ms/step - accuracy: 0.9937 - loss: 0.0677 - val_accuracy: 0.8574 - val_loss: 0.1627
Epoch 9/10
625/625 ————— 3s 3ms/step - accuracy: 0.9896 - loss: 0.0753 - val_accuracy: 0.8596 - val_loss: 0.1694
Epoch 10/10
625/625 ————— 3s 3ms/step - accuracy: 0.9939 - loss: 0.0736 - val_accuracy: 0.8582 - val_loss: 0.1820
Model: "sequential_16"

Layer (type)	Output Shape	Params
embedding_16 (Embedding)	(None, 500, 128)	1,280,000
flatten_16 (Flatten)	(None, 64000)	0
dense_40 (Dense)	(None, 64)	4,096,000
dense_41 (Dense)	(None, 64)	40,960
dense_42 (Dense)	(None, 64)	40,960
dropout_16 (Dropout)	(None, 64)	0
dense_43 (Dense)	(None, 1)	64

Total params: 5,384,449 (20.54 MB)
Trainable params: 5,384,449 (20.54 MB)
Non-trainable params: 0 (0.00 B)

Epoch 1/10
625/625 ————— 7s 5ms/step - accuracy: 0.5084 - loss: 1.2521 - val_accuracy: 0.4938 - val_loss: 0.6938
Epoch 2/10
625/625 ————— 2s 4ms/step - accuracy: 0.4977 - loss: 0.6935 - val_accuracy: 0.5062 - val_loss: 0.6931
Epoch 3/10
625/625 ————— 3s 4ms/step - accuracy: 0.5039 - loss: 0.6932 - val_accuracy: 0.5062 - val_loss: 0.6931
Epoch 4/10
625/625 ————— 2s 4ms/step - accuracy: 0.4999 - loss: 0.6932 - val_accuracy: 0.5062 - val_loss: 0.6931
Epoch 5/10
625/625 ————— 3s 5ms/step - accuracy: 0.4980 - loss: 0.6932 - val_accuracy: 0.4938 - val_loss: 0.6932
Epoch 6/10
625/625 ————— 2s 4ms/step - accuracy: 0.5059 - loss: 0.6931 - val_accuracy: 0.5062 - val_loss: 0.6931
Epoch 7/10
625/625 ————— 2s 4ms/step - accuracy: 0.4923 - loss: 0.6932 - val_accuracy: 0.4938 - val_loss: 0.6932
Epoch 8/10
625/625 ————— 2s 4ms/step - accuracy: 0.5007 - loss: 0.6931 - val_accuracy: 0.4938 - val_loss: 0.6932
Epoch 9/10
625/625 ————— 2s 4ms/step - accuracy: 0.5037 - loss: 0.6932 - val_accuracy: 0.4938 - val_loss: 0.6932
Epoch 10/10
625/625 ————— 3s 5ms/step - accuracy: 0.4991 - loss: 0.6932 - val_accuracy: 0.4938 - val_loss: 0.6932
Model: "sequential_17"











Layer (type)	Output Shape	Params
embedding_17 (Embedding)	(None, 500, 128)	1,280
flatten_17 (Flatten)	(None, 64000)	
dense_44 (Dense)	(None, 64)	4,096
dense_45 (Dense)	(None, 64)	
dense_46 (Dense)	(None, 64)	
dropout_17 (Dropout)	(None, 64)	
dense_47 (Dense)	(None, 1)	

Total params: 5,384,449 (20.54 MB)
Trainable params: 5,384,449 (20.54 MB)
Non-trainable params: 0 (0.00 B)

Epoch 1/10
625/625 ————— 6s 6ms/step - accuracy: 0.4970 - loss: 0.6938 - val_accuracy: 0.4938 - val_loss: 0.2502
Epoch 2/10
625/625 ————— 3s 5ms/step - accuracy: 0.5014 - loss: 0.2501 - val_accuracy: 0.5062 - val_loss: 0.2500
Epoch 3/10
625/625 ————— 5s 4ms/step - accuracy: 0.4948 - loss: 0.2500 - val_accuracy: 0.5062 - val_loss: 0.2500
Epoch 4/10
625/625 ————— 3s 4ms/step - accuracy: 0.4984 - loss: 0.2500 - val_accuracy: 0.4938 - val_loss: 0.2500
Epoch 5/10
625/625 ————— 2s 4ms/step - accuracy: 0.4988 - loss: 0.2500 - val_accuracy: 0.4938 - val_loss: 0.2500
Epoch 6/10
625/625 ————— 3s 4ms/step - accuracy: 0.4952 - loss: 0.2500 - val_accuracy: 0.4938 - val_loss: 0.2500
Epoch 7/10
625/625 ————— 3s 4ms/step - accuracy: 0.5027 - loss: 0.2500 - val_accuracy: 0.4938 - val_loss: 0.2500
Epoch 8/10
625/625 ————— 2s 4ms/step - accuracy: 0.4992 - loss: 0.2500 - val_accuracy: 0.4938 - val_loss: 0.2500
Epoch 9/10
625/625 ————— 2s 4ms/step - accuracy: 0.5008 - loss: 0.2500 - val_accuracy: 0.4938 - val_loss: 0.2500
Epoch 10/10
625/625 ————— 2s 4ms/step - accuracy: 0.4939 - loss: 0.2500 - val_accuracy: 0.4938 - val_loss: 0.2500
Model: "sequential_18"











Layer (type)	Output Shape	Param #
embedding_18 (Embedding)	(None, 500, 128)	1,280
flatten_18 (Flatten)	(None, 64000)	
dense_48 (Dense)	(None, 64)	4,096
dense_49 (Dense)	(None, 64)	
dense_50 (Dense)	(None, 64)	
dropout_18 (Dropout)	(None, 64)	
dense_51 (Dense)	(None, 1)	

Total params: 5,384,449 (20.54 MB)
Trainable params: 5,384,449 (20.54 MB)
Non-trainable params: 0 (0.00 B)

Epoch 1/10
625/625  **7s** 5ms/step - accuracy: 0.6546 - loss: 1.6058 - val_accuracy: 0.8654 - val_loss: 0.5585
Epoch 2/10
625/625  **7s** 4ms/step - accuracy: 0.9035 - loss: 0.4820 - val_accuracy: 0.8660 - val_loss: 0.5435
Epoch 3/10
625/625  **5s** 4ms/step - accuracy: 0.9617 - loss: 0.3341 - val_accuracy: 0.8588 - val_loss: 0.6695
Epoch 4/10
625/625  **3s** 4ms/step - accuracy: 0.9832 - loss: 0.2922 - val_accuracy: 0.8630 - val_loss: 0.7020
Epoch 5/10
625/625  **3s** 4ms/step - accuracy: 0.9936 - loss: 0.2174 - val_accuracy: 0.8386 - val_loss: 0.8818
Epoch 6/10
625/625  **3s** 5ms/step - accuracy: 0.9942 - loss: 0.2178 - val_accuracy: 0.8686 - val_loss: 0.5181
Epoch 7/10
625/625  **4s** 4ms/step - accuracy: 0.9965 - loss: 0.1752 - val_accuracy: 0.8578 - val_loss: 0.6569
Epoch 8/10
625/625  **2s** 4ms/step - accuracy: 0.9972 - loss: 0.1678 - val_accuracy: 0.8496 - val_loss: 0.6682
Epoch 9/10
625/625  **3s** 4ms/step - accuracy: 0.9968 - loss: 0.1562 - val_accuracy: 0.8546 - val_loss: 0.6275
Epoch 10/10
625/625  **3s** 5ms/step - accuracy: 0.9959 - loss: 0.1602 - val_accuracy: 0.8488 - val_loss: 0.6658
Model: "sequential_19"

Layer (type)	Output Shape	Params
embedding_19 (Embedding)	(None , 500 , 128)	1,280
flatten_19 (Flatten)	(None , 64000)	
dense_52 (Dense)	(None , 64)	4,096
dense_53 (Dense)	(None , 64)	
dense_54 (Dense)	(None , 64)	
dropout_19 (Dropout)	(None , 64)	
dense_55 (Dense)	(None , 1)	

Total params: [5,384,449](#) (20.54 MB)
Trainable params: [5,384,449](#) (20.54 MB)
Non-trainable params: [0](#) (0.00 B)

Epoch 1/10
625/625  **6s** 5ms/step - accuracy: 0.6252 - loss: 0.8460 - val_accuracy: 0.8438 - val_loss: 0.2057
Epoch 2/10
625/625  **3s** 5ms/step - accuracy: 0.8782 - loss: 0.1921 - val_accuracy: 0.8544 - val_loss: 0.1997
Epoch 3/10
625/625  **3s** 4ms/step - accuracy: 0.9153 - loss: 0.1586 - val_accuracy: 0.8570 - val_loss: 0.1903
Epoch 4/10
625/625  **2s** 4ms/step - accuracy: 0.9377 - loss: 0.1457 - val_accuracy: 0.8652 - val_loss: 0.2010
Epoch 5/10
625/625  **2s** 4ms/step - accuracy: 0.9624 - loss: 0.1388 - val_accuracy: 0.8664 - val_loss: 0.2540
Epoch 6/10
625/625  **2s** 4ms/step - accuracy: 0.9731 - loss: 0.1229 - val_accuracy: 0.8694 - val_loss: 0.1732
Epoch 7/10
625/625  **3s** 4ms/step - accuracy: 0.9846 - loss: 0.0927 - val_accuracy: 0.8674 - val_loss: 0.2131
Epoch 8/10
625/625  **3s** 4ms/step - accuracy: 0.9823 - loss: 0.1146 - val_accuracy: 0.8638 - val_loss: 0.1715
Epoch 9/10
625/625  **5s** 4ms/step - accuracy: 0.9882 - loss: 0.0958 - val_accuracy: 0.8600 - val_loss: 0.1679
Epoch 10/10
625/625  **2s** 4ms/step - accuracy: 0.9918 - loss: 0.0739 - val_accuracy: 0.8606 - val_loss: 0.1992
Model: "sequential_20"

Layer (type)	Output Shape	Params
embedding_20 (Embedding)	(None , 500 , 128)	1,280
flatten_20 (Flatten)	(None , 64000)	
dense_56 (Dense)	(None , 128)	8,192
dense_57 (Dense)	(None , 128)	16,384
dense_58 (Dense)	(None , 128)	16,384
dropout_20 (Dropout)	(None , 128)	
dense_59 (Dense)	(None , 1)	128

Total params: [9,505,281](#) (36.26 MB)
Trainable params: [9,505,281](#) (36.26 MB)
Non-trainable params: [0](#) (0.00 B)

Epoch 1/10
625/625 ————— 7s 7ms/step - accuracy: 0.5007 - loss: 1.5311 - val_accuracy: 0.4938 - val_loss: 0.6933
Epoch 2/10
625/625 ————— 3s 5ms/step - accuracy: 0.4945 - loss: 0.6933 - val_accuracy: 0.4938 - val_loss: 0.6933
Epoch 3/10
625/625 ————— 3s 5ms/step - accuracy: 0.4976 - loss: 0.6933 - val_accuracy: 0.4938 - val_loss: 0.6932
Epoch 4/10
625/625 ————— 5s 5ms/step - accuracy: 0.5057 - loss: 0.6932 - val_accuracy: 0.5062 - val_loss: 0.6931
Epoch 5/10
625/625 ————— 5s 5ms/step - accuracy: 0.5035 - loss: 0.6931 - val_accuracy: 0.4938 - val_loss: 0.6932
Epoch 6/10
625/625 ————— 3s 5ms/step - accuracy: 0.5027 - loss: 0.6932 - val_accuracy: 0.4938 - val_loss: 0.6932
Epoch 7/10
625/625 ————— 3s 5ms/step - accuracy: 0.4974 - loss: 0.6932 - val_accuracy: 0.5062 - val_loss: 0.6931
Epoch 8/10
625/625 ————— 3s 5ms/step - accuracy: 0.4951 - loss: 0.6932 - val_accuracy: 0.5062 - val_loss: 0.6931
Epoch 9/10
625/625 ————— 3s 5ms/step - accuracy: 0.4899 - loss: 0.6932 - val_accuracy: 0.4938 - val_loss: 0.6932
Epoch 10/10
625/625 ————— 3s 5ms/step - accuracy: 0.4956 - loss: 0.6932 - val_accuracy: 0.4938 - val_loss: 0.6932
Model: "sequential_21"

Layer (type)	Output Shape	Params
embedding_21 (Embedding)	(None, 500, 128)	1,280,000
flatten_21 (Flatten)	(None, 64000)	0
dense_60 (Dense)	(None, 128)	8,192,000
dense_61 (Dense)	(None, 128)	16,384
dense_62 (Dense)	(None, 128)	16,384
dropout_21 (Dropout)	(None, 128)	0
dense_63 (Dense)	(None, 1)	128











Total params: 9,505,281 (36.26 MB)
Trainable params: 9,505,281 (36.26 MB)
Non-trainable params: 0 (0.00 B)

Epoch 1/10
625/625 ————— 7s 6ms/step - accuracy: 0.5010 - loss: 0.9715 - val_accuracy: 0.4938 - val_loss: 0.2500
Epoch 2/10
625/625 ————— 3s 5ms/step - accuracy: 0.4985 - loss: 0.2500 - val_accuracy: 0.4938 - val_loss: 0.2500
Epoch 3/10
625/625 ————— 3s 5ms/step - accuracy: 0.4959 - loss: 0.2500 - val_accuracy: 0.4938 - val_loss: 0.2500
Epoch 4/10
625/625 ————— 3s 5ms/step - accuracy: 0.4980 - loss: 0.2500 - val_accuracy: 0.4938 - val_loss: 0.2500
Epoch 5/10
625/625 ————— 5s 5ms/step - accuracy: 0.4945 - loss: 0.2500 - val_accuracy: 0.4938 - val_loss: 0.2500
Epoch 6/10
625/625 ————— 3s 5ms/step - accuracy: 0.5002 - loss: 0.2500 - val_accuracy: 0.4938 - val_loss: 0.2500
Epoch 7/10
625/625 ————— 4s 6ms/step - accuracy: 0.4903 - loss: 0.2500 - val_accuracy: 0.4938 - val_loss: 0.2500
Epoch 8/10
625/625 ————— 3s 5ms/step - accuracy: 0.4981 - loss: 0.2500 - val_accuracy: 0.4938 - val_loss: 0.2500
Epoch 9/10
625/625 ————— 3s 5ms/step - accuracy: 0.5033 - loss: 0.2500 - val_accuracy: 0.4938 - val_loss: 0.2500
Epoch 10/10
625/625 ————— 3s 5ms/step - accuracy: 0.5016 - loss: 0.2500 - val_accuracy: 0.4938 - val_loss: 0.2500

Model: "sequential_22"











Layer (type)	Output Shape	Param #
embedding_22 (Embedding)	(None, 500, 128)	1,280
flatten_22 (Flatten)	(None, 64000)	0
dense_64 (Dense)	(None, 128)	8,192
dense_65 (Dense)	(None, 128)	16,384
dense_66 (Dense)	(None, 128)	16,384
dropout_22 (Dropout)	(None, 128)	0
dense_67 (Dense)	(None, 1)	128

Total params: 9,505,281 (36.26 MB)
Trainable params: 9,505,281 (36.26 MB)
Non-trainable params: 0 (0.00 B)

Epoch 1/10
625/625  8s 6ms/step - accuracy: 0.6417 - loss: 2.1878 - val_accuracy: 0.8306 - val_loss: 0.6339
Epoch 2/10
625/625  8s 6ms/step - accuracy: 0.8987 - loss: 0.5138 - val_accuracy: 0.8624 - val_loss: 0.6116
Epoch 3/10
625/625  3s 5ms/step - accuracy: 0.9553 - loss: 0.3910 - val_accuracy: 0.8444 - val_loss: 0.9131
Epoch 4/10
625/625  5s 5ms/step - accuracy: 0.9863 - loss: 0.3096 - val_accuracy: 0.8562 - val_loss: 0.7448
Epoch 5/10
625/625  3s 5ms/step - accuracy: 0.9935 - loss: 0.2395 - val_accuracy: 0.8648 - val_loss: 0.7216
Epoch 6/10
625/625  3s 5ms/step - accuracy: 0.9962 - loss: 0.2314 - val_accuracy: 0.8614 - val_loss: 0.5756
Epoch 7/10
625/625  5s 5ms/step - accuracy: 0.9983 - loss: 0.1309 - val_accuracy: 0.8592 - val_loss: 0.7297
Epoch 8/10
625/625  6s 6ms/step - accuracy: 0.9918 - loss: 0.4637 - val_accuracy: 0.8518 - val_loss: 0.7945
Epoch 9/10
625/625  3s 5ms/step - accuracy: 0.9970 - loss: 0.2028 - val_accuracy: 0.8388 - val_loss: 0.9690
Epoch 10/10
625/625  5s 5ms/step - accuracy: 0.9961 - loss: 0.2207 - val_accuracy: 0.8484 - val_loss: 1.2143
Model: "sequential_23"

Layer (type)	Output Shape	Params
embedding_23 (Embedding)	(None, 500, 128)	1,280,000
flatten_23 (Flatten)	(None, 64000)	0
dense_68 (Dense)	(None, 128)	8,192
dense_69 (Dense)	(None, 128)	16,384
dense_70 (Dense)	(None, 128)	16,384
dropout_23 (Dropout)	(None, 128)	0
dense_71 (Dense)	(None, 1)	128

Total params: 9,505,281 (36.26 MB)
Trainable params: 9,505,281 (36.26 MB)
Non-trainable params: 0 (0.00 B)

Epoch 1/10
625/625  7s 6ms/step - accuracy: 0.5105 - loss: 1.1586 - val_accuracy: 0.4938 - val_loss: 0.2501
Epoch 2/10
625/625  3s 5ms/step - accuracy: 0.4993 - loss: 0.2502 - val_accuracy: 0.4938 - val_loss: 0.2500
Epoch 3/10
625/625  5s 5ms/step - accuracy: 0.4952 - loss: 0.2502 - val_accuracy: 0.5062 - val_loss: 0.2500
Epoch 4/10
625/625  5s 5ms/step - accuracy: 0.4993 - loss: 0.2502 - val_accuracy: 0.5062 - val_loss: 0.2500
Epoch 5/10
625/625  3s 5ms/step - accuracy: 0.4937 - loss: 0.2502 - val_accuracy: 0.4938 - val_loss: 0.2501
Epoch 6/10
625/625  6s 6ms/step - accuracy: 0.5008 - loss: 0.2501 - val_accuracy: 0.4938 - val_loss: 0.2503
Epoch 7/10
625/625  3s 5ms/step - accuracy: 0.4998 - loss: 0.2501 - val_accuracy: 0.4938 - val_loss: 0.2500
Epoch 8/10
625/625  3s 5ms/step - accuracy: 0.5082 - loss: 0.2500 - val_accuracy: 0.5062 - val_loss: 0.2500
Epoch 9/10
625/625  5s 5ms/step - accuracy: 0.4957 - loss: 0.2503 - val_accuracy: 0.4938 - val_loss: 0.2502
Epoch 10/10
625/625  3s 5ms/step - accuracy: 0.5015 - loss: 0.2502 - val_accuracy: 0.5015 - val_loss: 0.2502

```
In [4]: print("Single Layer Results")
single_layer_results
```

Single Layer Results

```
Out[4]:
```

	model_type	hidden_units	activation	loss_function	train_accuracy	val_accuracy
0	single_layer	32	relu	binary_crossentropy	0.98005	0.8672
1	single_layer	32	relu	mean_squared_error	0.95220	0.8664
2	single_layer	32	tanh	binary_crossentropy	0.98445	0.8668
3	single_layer	32	tanh	mean_squared_error	0.96965	0.8632
4	single_layer	64	relu	binary_crossentropy	0.97870	0.8602
5	single_layer	64	relu	mean_squared_error	0.95890	0.8666
6	single_layer	64	tanh	binary_crossentropy	0.98555	0.8600
7	single_layer	64	tanh	mean_squared_error	0.96400	0.8548
8	single_layer	128	relu	binary_crossentropy	0.97650	0.8656
9	single_layer	128	relu	mean_squared_error	0.95205	0.8550
10	single_layer	128	tanh	binary_crossentropy	0.98190	0.8532
11	single_layer	128	tanh	mean_squared_error	0.96640	0.8626

```
In [17]: print("Three Layer Results")
three_layer_results
```

Three Layer Results

```
Out[17]:
```

	model_type	hidden_units	activation	loss_function	train_accuracy	val_accuracy
0	three_layer	32	relu	binary_crossentropy	0.50155	0.5062
1	three_layer	32	relu	mean_squared_error	0.50135	0.5062
2	three_layer	32	tanh	binary_crossentropy	0.99760	0.8630
3	three_layer	32	tanh	mean_squared_error	0.99145	0.8714
4	three_layer	64	relu	binary_crossentropy	0.50405	0.5062
5	three_layer	64	relu	mean_squared_error	0.50195	0.5062
6	three_layer	64	tanh	binary_crossentropy	0.99660	0.8686
7	three_layer	64	tanh	mean_squared_error	0.98850	0.8694
8	three_layer	128	relu	binary_crossentropy	0.50400	0.5062
9	three_layer	128	relu	mean_squared_error	0.50255	0.4938
10	three_layer	128	tanh	binary_crossentropy	0.99725	0.8648
11	three_layer	128	tanh	mean_squared_error	0.50595	0.5062

Results Visualization

```
In [9]: import seaborn as sns

df = single_layer_results

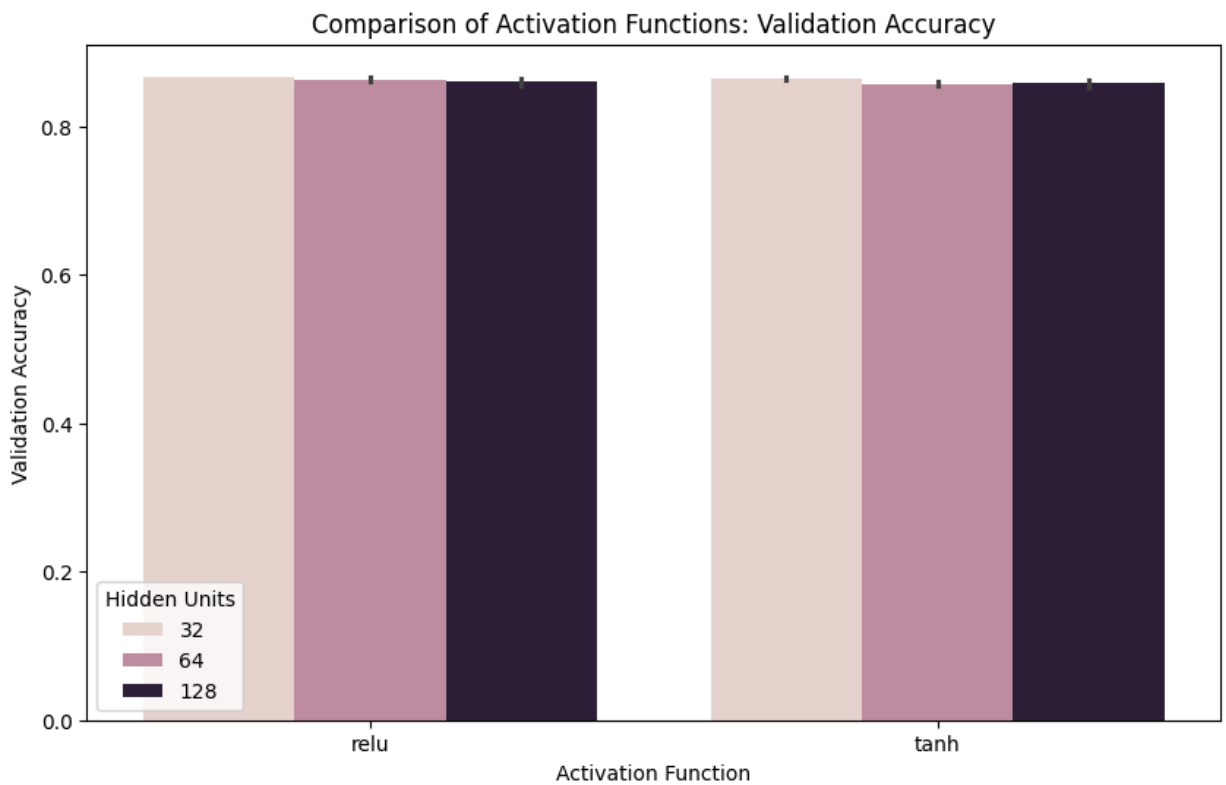
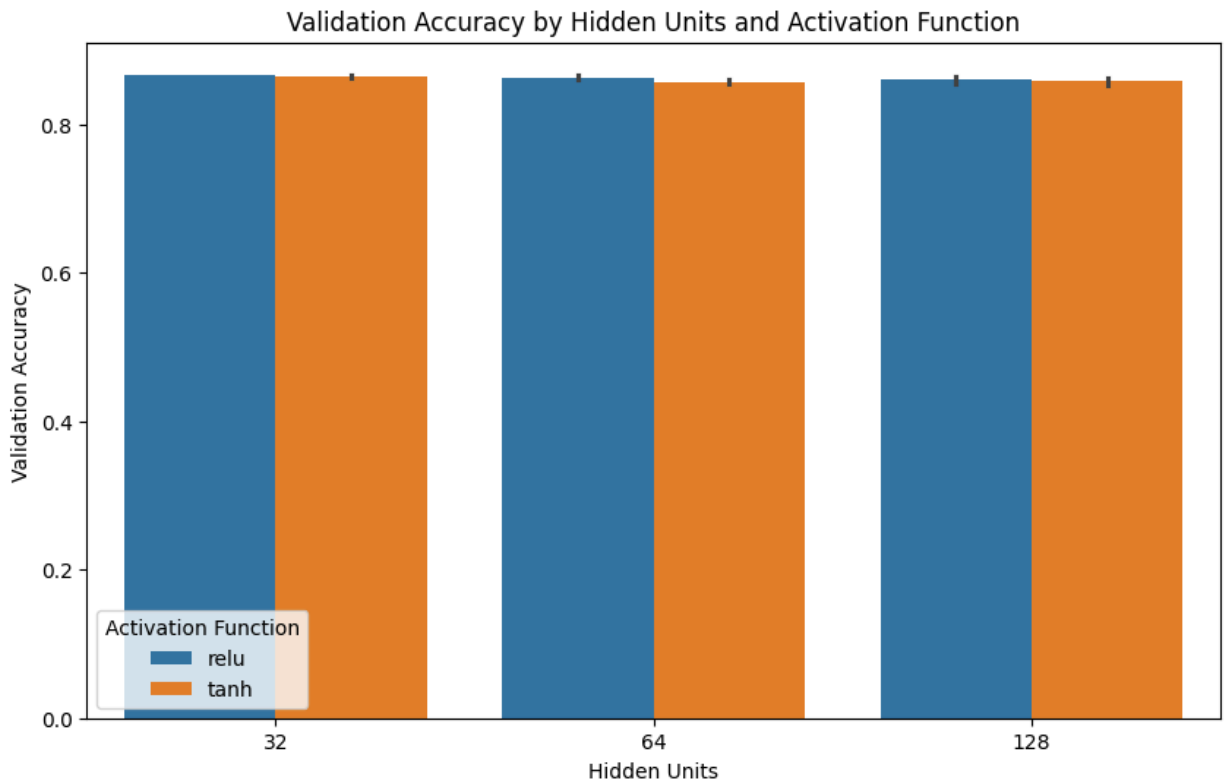
# 1. Bar Plot: Validation Accuracy by Hidden Units
plt.figure(figsize=(10, 6))
sns.barplot(x='hidden_units', y='val_accuracy', hue='activation', data=df)
plt.title('Validation Accuracy by Hidden Units and Activation Function')
plt.xlabel('Hidden Units')
plt.ylabel('Validation Accuracy')
plt.legend(title='Activation Function')
plt.show()

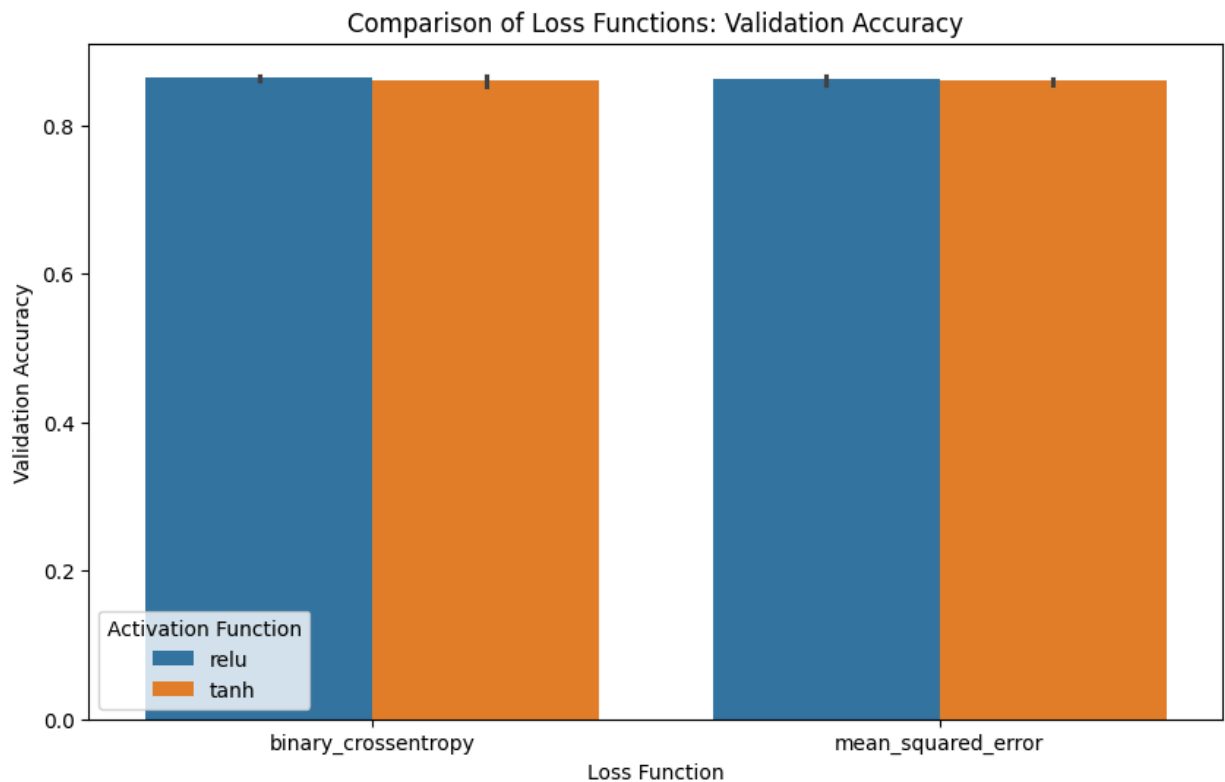
# 2. Bar Plot: Comparison of Activation Functions
plt.figure(figsize=(10, 6))
sns.barplot(x='activation', y='val_accuracy', hue='hidden_units', data=df)
plt.title('Comparison of Activation Functions: Validation Accuracy')
plt.xlabel('Activation Function')
plt.ylabel('Validation Accuracy')
plt.legend(title='Hidden Units')
plt.show()

# 3. Bar Plot: Comparison of Loss Functions
plt.figure(figsize=(10, 6))
sns.barplot(x='loss_function', y='val_accuracy', hue='activation', data=df)
plt.title('Comparison of Loss Functions: Validation Accuracy')
plt.xlabel('Loss Function')
```



```
plt.ylabel('Validation Accuracy')
plt.legend(title='Activation Function')
plt.show()
```



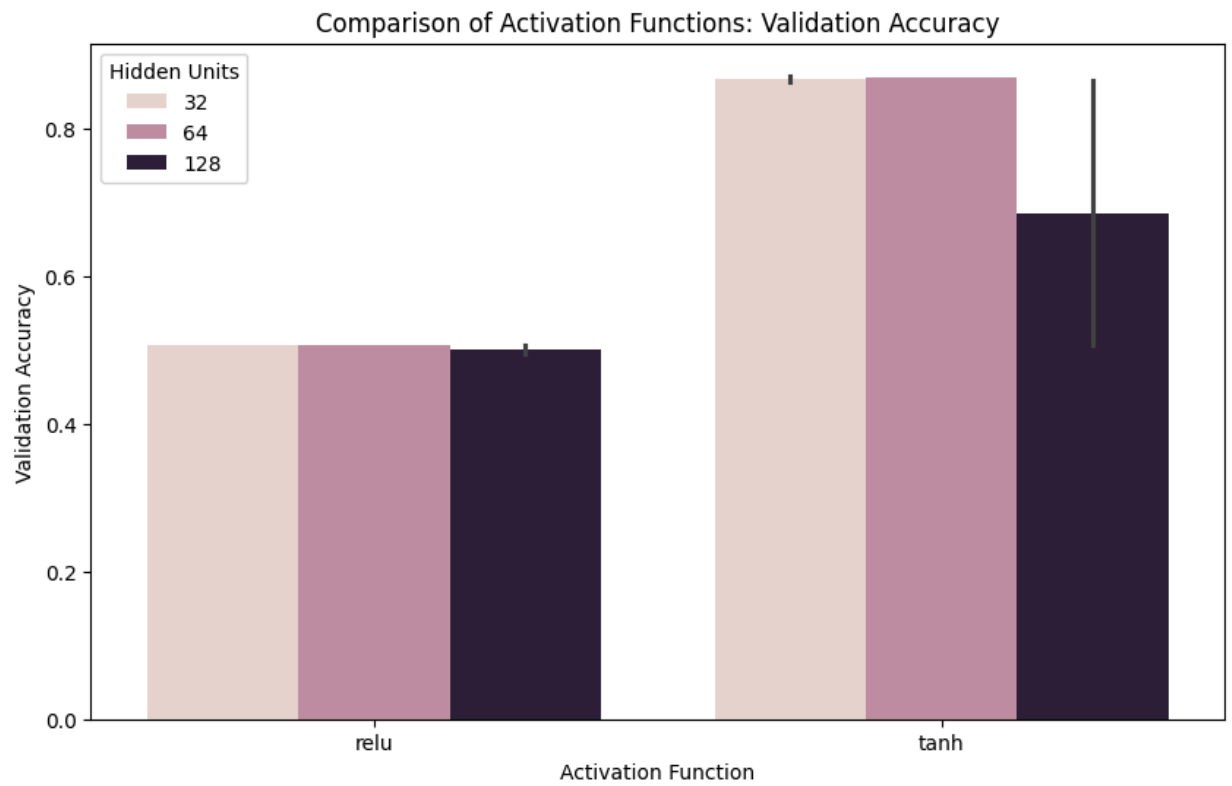
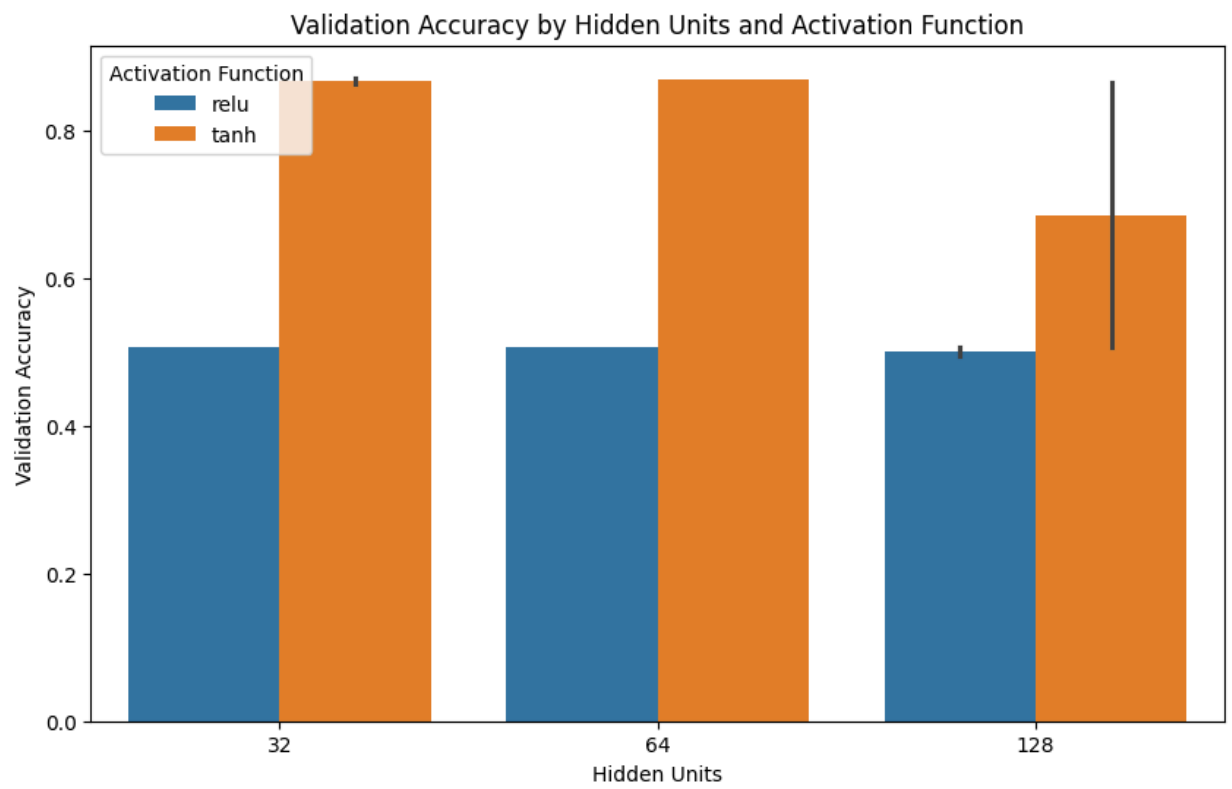


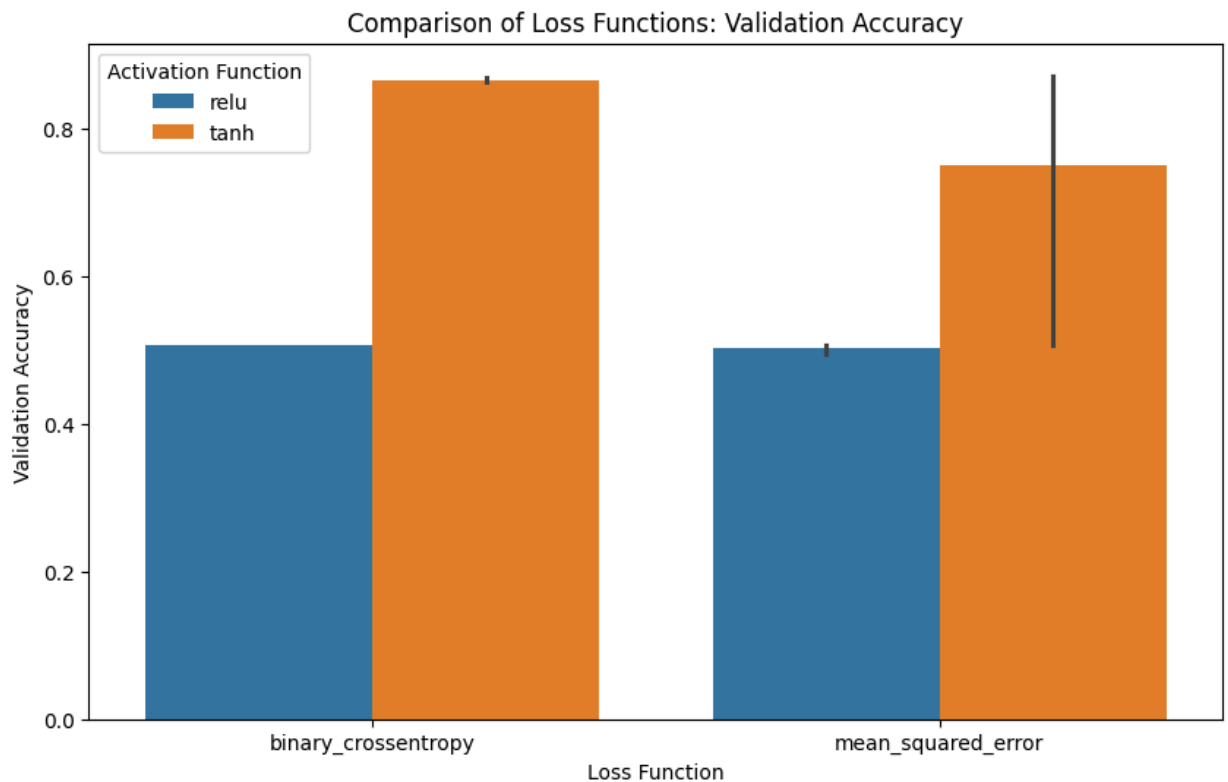
```
In [10]: df = three_layer_results

# 1. Bar Plot: Validation Accuracy by Hidden Units
plt.figure(figsize=(10, 6))
sns.barplot(x='hidden_units', y='val_accuracy', hue='activation', data=df)
plt.title('Validation Accuracy by Hidden Units and Activation Function')
plt.xlabel('Hidden Units')
plt.ylabel('Validation Accuracy')
plt.legend(title='Activation Function')
plt.show()

# 2. Bar Plot: Comparison of Activation Functions
plt.figure(figsize=(10, 6))
sns.barplot(x='activation', y='val_accuracy', hue='hidden_units', data=df)
plt.title('Comparison of Activation Functions: Validation Accuracy')
plt.xlabel('Activation Function')
plt.ylabel('Validation Accuracy')
plt.legend(title='Hidden Units')
plt.show()

# 3. Bar Plot: Comparison of Loss Functions
plt.figure(figsize=(10, 6))
sns.barplot(x='loss_function', y='val_accuracy', hue='activation', data=df)
plt.title('Comparison of Loss Functions: Validation Accuracy')
plt.xlabel('Loss Function')
plt.ylabel('Validation Accuracy')
plt.legend(title='Activation Function')
plt.show()
```





```
In [16]: # Combine both results into a single DataFrame
combined_results = pd.concat([single_layer_results, three_layer_results])

# Comparison of loss functions within each model type
plt.figure(figsize=(14, 8))

# Grouped barplot for validation accuracy by loss function
sns.barplot(x='hidden_units', y='val_accuracy', hue='loss_function', data=combined_results)

# Annotate each bar with the value
for p in plt.gca().patches:
    plt.gca().annotate(f'{p.get_height():.3f}',
                       (p.get_x() + p.get_width() / 2., p.get_height()),
                       ha='center', va='baseline', fontsize=12, color='black', rotation=0,
                       textcoords='offset points')

# Adding titles and labels
plt.title('Validation Accuracy by Loss Function: Single Layer vs Three Layer Models',
plt.xlabel('Hidden Units', fontsize=14)
plt.ylabel('Validation Accuracy', fontsize=14)
plt.legend(title='Loss Function', fontsize=12)

# Show the plot
plt.show()

plt.figure(figsize=(14, 8))

# Grouped barplot for validation accuracy by activation function
sns.barplot(x='hidden_units', y='val_accuracy', hue='activation', data=combined_results)

# Annotate each bar with the value
for p in plt.gca().patches:
    plt.gca().annotate(f'{p.get_height():.3f}',
                       (p.get_x() + p.get_width() / 2., p.get_height()),
```

```
ha='center', va='baseline', fontsize=12, color='black', rotatio
textcoords='offset points')
```

```
# Adding titles and Labels
```

```
plt.title('Validation Accuracy by Activation Function: Single Layer vs Three Layer Mod
```

```
plt.xlabel('Hidden Units', fontsize=14)
```

```
plt.ylabel('Validation Accuracy', fontsize=14)
```

```
plt.legend(title='Activation Function', fontsize=12)
```

```
# Show the plot
```

```
plt.show()
```

