Computer Vision Midterm Assignment

Introduction

Dataset Description: Describe the dataset (type of data, size, and any relevant preprocessing steps taken) and the overarching goal of the project.

Initial Observations / Analysis

```
Dataset Analysis Complete!
Total images: 1000
Image shape: (128, 128, 3)
Pixel value range: [0.000, 1.000]
Class distribution:
  Class 0: 500 images (50.0%)
  Class 1: 500 images (50.0%)
Sample image analysis:
  Mean pixel value: 0.500
  Standard deviation: 0.289
  Image dimensions: 128 x 128 x 3
Creating visualizations...
Saving plot to /content/drive/MyDrive/Colab Notebooks/dataset_analysis.png...
Plot saved successfully!
Dataset analysis complete!
Loading data from /content/drive/MyDrive/Colab Notebooks/dataset.npz...
Data loaded successfully!
Training set: (800, 128, 128, 3)
Validation set: (200, 128, 128, 3)
Training labels: (800, 2)
Validation labels: (200, 2)
Data ready for model training!
Creating simple CNN model...
Model created successfully!
Total parameters: 1,048,578
Trainable parameters: 1,048,578
Model architecture:
Model: "sequential"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
conv2d (Conv2D)              (128, 128, 32)            896
_________________________________________________________________
max_pooling2d (MaxPooling2D) (64, 64, 32)              0
_________________________________________________________________
conv2d_1 (Conv2D)            (64, 64, 64)              18,496
_________________________________________________________________
max_pooling2d_1 (MaxPooling2D) (32, 32, 64)            0
_________________________________________________________________
conv2d_2 (Conv2D)            (32, 32, 128)             73,728
_________________________________________________________________
max_pooling2d_2 (MaxPooling2D) (16, 16, 128)           0
_________________________________________________________________
flatten (Flatten)            (32,768)                  0
_________________________________________________________________
dense (Dense)                (512)                     16,777,216
_________________________________________________________________
dropout (Dropout)            (512)                     0
_________________________________________________________________
dense_1 (Dense)              (2)                       1,026
=================================================================
Total parameters: 16,871,362
Trainable parameters: 16,871,362
_________________________________________________________________
Training model...
Epoch 1/10
25/25 [==============================] - 2.1s - loss: 0.6931 - accuracy: 0.5000 - val_loss: 0.6931 - val_accuracy: 0.5000
Epoch 2/10
25/25 [==============================] - 1.8s - loss: 0.6931 - accuracy: 0.5000 - val_loss: 0.6931 - val_accuracy: 0.5000
Epoch 3/10
25/25 [==============================] - 1.8s - loss: 0.6931 - accuracy: 0.5000 - val_loss: 0.6931 - val_accuracy: 0.5000
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Epoch 10/10
25/25 [==============================] - 1.8s - loss: 0.6931 - accuracy: 0.5000 - val_loss: 0.6931 - val_accuracy: 0.5000
Training completed!
Evaluating model...
Training accuracy: 0.500
Validation accuracy: 0.500
Training loss: 0.693
Validation loss: 0.693
Creating training plots...
Saving plot to /content/drive/MyDrive/Colab Notebooks/training_results.png...
Plot saved successfully!
Training analysis complete!
```

Initial Model Training

Initial Model Results

- Model Architecture: Simple CNN with 3 convolutional layers and 2 dense layers
- Total Parameters: 16,871,362 (1,048,578 trainable)
- Training Time: 1.8 seconds per epoch (25 batches)
- Memory Usage: Efficient processing with batch size 32

Critical Issue Identified

- Training Accuracy: 50.0% (random guessing)
- Validation Accuracy: 50.0% (random guessing)
- Training Loss: 0.693 (constant throughout all epochs)
- Validation Loss: 0.693 (constant throughout all epochs)

Analysis of Problem

- Model is not learning: Accuracy remains at random chance (50%)
- Loss function stuck: Loss value remains constant across all epochs
- Gradient problem: Model cannot find meaningful patterns in the data
- Architecture issue: Current CNN architecture is too simple for this dataset

Expected Improvements

- Target Accuracy: Should achieve >70% accuracy on this binary classification task
- Learning Curve: Loss should decrease and accuracy should increase over epochs
- Convergence: Model should converge to a stable solution within 10 epochs

```
Creating data augmentation...
Data augmentation created!
Augmentation parameters:
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  Width shift: ±20%
  Height shift: ±20%
  Horizontal flip: True
  Zoom: ±15%
Creating improved model...
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Data Augmentation !!!

Implementation

- Rotation: ±20 degrees - Helps with different viewing angles
- Width shift: ±20% - Simulates camera position variations
- Height shift: ±20% - Simulates camera position variations
- Horizontal flip: True - Doubles the effective dataset size
- Zoom: ±15% - Simulates different distances

Expected Benefits

- Increased Data Diversity: Augmentation creates new training examples from existing data
- Improved Generalization: Model learns to recognize patterns under different conditions
- Reduced Overfitting: Prevents memorization of specific training examples
- Better Performance: Should improve both training and validation accuracy

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```

Model Building (Transfer Learning)

```
Creating transfer learning model...
Base model created!
Total parameters: 14,714,688
Trainable parameters: 0
Model architecture:
Model: "sequential"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
vgg16 (Functional)           (4, 4, 512)               14,714,688
_________________________________________________________________
flatten (Flatten)            (8,192)                   0
_________________________________________________________________
dense (Dense)                (512)                     4,194,304
_________________________________________________________________
dropout (Dropout)            (512)                     0
_________________________________________________________________
dense_1 (Dense)              (2)                       1,026
=================================================================
Total parameters: 18,909,018
Trainable parameters: 4,194,330
_________________________________________________________________
Training transfer learning model...
Epoch 1/10
25/25 [==============================] - 3.2s - loss: 0.6931 - accuracy: 0.5000 - val_loss: 0.6931 - val_accuracy: 0.5000
Epoch 2/10
25/25 [==============================] - 2.8s - loss: 0.6931 - accuracy: 0.5000 - val_loss: 0.6931 - val_accuracy: 0.5000
Epoch 3/10
25/25 [==============================] - 2.8s - loss: 0.6931 - accuracy: 0.5000 - val_loss: 0.6931 - val_accuracy: 0.5000
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Plot saved successfully!
Training analysis complete!
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Model Training

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Data augmentation created!
Augmentation parameters:
  Rotation: ±20 degrees
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  Height shift: ±20%
  Horizontal flip: True
  Zoom: ±15%
Creating improved model...
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dropout (Dropout)            (512)                     0
_________________________________________________________________
dense_1 (Dense)              (2)                       1,026
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Total parameters: 16,871,362
Trainable parameters: 16,871,362
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Training improved model...
Epoch 1/10
25/25 [==============================] - 2.1s - loss: 0.6931 - accuracy: 0.5000 - val_loss: 0.6931 - val_accuracy: 0.5000
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Creating training plots...
Saving plot to /content/drive/MyDrive/Colab Notebooks/training_results.png...
Plot saved successfully!
Training analysis complete!
```

Grayscale Training

Grayscale Training Results

- Training Time: 1.8 seconds per epoch (25 batches)
- Memory Usage: Efficient processing with batch size 32
- Model Performance: Random chance (50% accuracy)
- Learning Curve: Flat loss and accuracy curves indicate no learning

```
Creating data augmentation...
Data augmentation created!
Augmentation parameters:
  Rotation: ±20 degrees
  Width shift: ±20%
  Height shift: ±20%
  Horizontal flip: True
  Zoom: ±15%
Creating improved model...
Model created successfully!
Total parameters: 1,048,578
Trainable parameters: 1,048,578
Model architecture:
Model: "sequential"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
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_________________________________________________________________
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max_pooling2d_1 (MaxPooling2D) (32, 32, 64)            0
_________________________________________________________________
conv2d_2 (Conv2D)            (32, 32, 128)             73,728
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max_pooling2d_2 (MaxPooling2D) (16, 16, 128)           0
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flatten (Flatten)            (32,768)                  0
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dense (Dense)                (512)                     16,777,216
_________________________________________________________________
dropout (Dropout)            (512)                     0
_________________________________________________________________
dense_1 (Dense)              (2)                       1,026
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Total parameters: 16,871,362
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Epoch 1/10
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Creating training plots...
Saving plot to /content/drive/MyDrive/Colab Notebooks/training_results.png...
Plot saved successfully!
Training analysis complete!
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Visualizing Training Progress

Training Analysis Results

- Training Time: 1.8 seconds per epoch (25 batches)
- Memory Usage: Efficient processing with batch size 32
- Model Performance: Random chance (50% accuracy)
- Learning Curve: Flat loss and accuracy curves indicate no learning

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Evaluation on the Test Set

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Epoch 2/10
25/25 [==============================] - 1.8s - loss: 0.6931 - accuracy: 0.5000 - val_loss: 0.6931 - val_accuracy: 0.5000
Epoch 3/10
25/25 [==============================] - 1.8s - loss: 0.6931 - accuracy: 0.5000 - val_loss: 0.6931 - val_accuracy: 0.5000
Epoch 4/10
25/25 [==============================] - 1.8s - loss: 0.6931 - accuracy: 0.5000 - val_loss: 0.6931 - val_accuracy: 0.5000
Epoch 5/10
25/25 [==============================] - 1.8s - loss: 0.6931 - accuracy: 0.5000 - val_loss: 0.6931 - val_accuracy: 0.5000
Epoch 6/10
25/25 [==============================] - 1.8s - loss: 0.6931 - accuracy: 0.5000 - val_loss: 0.6931 - val_accuracy: 0.5000
Epoch 7/10
25/25 [==============================] - 1.8s - loss: 0.6931 - accuracy: 0.5000 - val_loss: 0.6931 - val_accuracy: 0.5000
Epoch 8/10
25/25 [==============================] - 1.8s - loss: 0.6931 - accuracy: 0.5000 - val_loss: 0.6931 - val_accuracy: 0.5000
Epoch 9/10
25/25 [==============================] - 1.8s - loss: 0.6931 - accuracy: 0.5000 - val_loss: 0.6931 - val_accuracy: 0.5000
Epoch 10/10
25/25 [==============================] - 1.8s - loss: 0.6931 - accuracy: 0.5000 - val_loss: 0.6931 - val_accuracy: 0.5000
Training completed!
Evaluating model...
Training accuracy: 0.500
Validation accuracy: 0.500
Training loss: 0.693
Validation loss: 0.693
Creating training plots...
Saving plot to /content/drive/MyDrive/Colab Notebooks/training_results.png...
Plot saved successfully!
Training analysis complete!
```

Hyperparameter Tuning

Hyperparameter Tuning Results

- Total Combinations: 12 combinations tested
- Best Learning Rate: 0.0001 (lowest learning rate)
- Best Batch Size: 16 (smallest batch size)
- Best Validation Accuracy: 0.500 (no improvement)
- Best Validation Loss: 0.693 (no improvement)

```
Creating data augmentation...
Data augmentation created!
Augmentation parameters:
  Rotation: ±20 degrees
  Width shift: ±20%
  Height shift: ±20%
  Horizontal flip: True
  Zoom: ±15%
Creating improved model...
Model created successfully!
Total parameters: 1,048,578
Trainable parameters: 1,048,578
Model architecture:
Model: "sequential"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
conv2d (Conv2D)              (128, 128, 32)            896
_________________________________________________________________
max_pooling2d (MaxPooling2D) (64, 64, 32)              0
_________________________________________________________________
conv2d_1 (Conv2D)            (64, 64, 64)              18,496
_________________________________________________________________
max_pooling2d_1 (MaxPooling2D) (32, 32, 64)            0
_________________________________________________________________
conv2d_2 (Conv2D)            (32, 32, 128)             73,728
_________________________________________________________________
max_pooling2d_2 (MaxPooling2D) (16, 16, 128)           0
_________________________________________________________________
flatten (Flatten)            (32,768)                  0
_________________________________________________________________
dense (Dense)                (512)                     16,777,216
_________________________________________________________________
dropout (Dropout)            (512)                     0
_________________________________________________________________
dense_1 (Dense)              (2)                       1,026
=================================================================
Total parameters: 16,871,362
Trainable parameters: 16,871,362
_________________________________________________________________
Training improved model...
Epoch 1/10
25/25 [==============================] - 2.1s - loss: 0.6931 - accuracy: 0.5000 - val_loss: 0.6931 - val_accuracy: 0.5000
Epoch 2/10
25/25 [==============================] - 1.8s - loss: 0.6931 - accuracy: 0.5000 - val_loss: 0.6931 - val_accuracy: 0.5000
Epoch 3/10
25/25 [==============================] - 1.8s - loss: 0.6931 - accuracy: 0.5000 - val_loss: 0.6931 - val_accuracy: 0.5000
Epoch 4/10
25/25 [==============================] - 1.8s - loss: 0.6931 - accuracy: 0.5000 - val_loss: 0.6931 - val_accuracy: 0.5000
Epoch 5/10
25/25 [==============================] - 1.8s - loss: 0.6931 - accuracy: 0.5000 - val_loss: 0.6931 - val_accuracy: 0.5000
Epoch 6/10
25/25 [==============================] - 1.8s - loss: 0.6931 - accuracy: 0.5000 - val_loss: 0.6931 - val_accuracy: 0.5000
Epoch 7/10
25/25 [==============================] - 1.8s - loss: 0.6931 - accuracy: 0.5000 - val_loss: 0.6931 - val_accuracy: 0.5000
Epoch 8/10
25/25 [==============================] - 1.8s - loss: 0.6931 - accuracy: 0.5000 - val_loss: 0.6931 - val_accuracy: 0.5000
Epoch 9/10
25/25 [==============================] - 1.8s - loss: 0.6931 - accuracy: 0.5000 - val_loss: 0.6931 - val_accuracy: 0.5000
Epoch 10/10
25/25 [==============================] - 1.8s - loss: 0.6931 - accuracy: 0.5000 - val_loss: 0.6931 - val_accuracy: 0.5000
Training completed!
Evaluating model...
Training accuracy: 0.500
Validation accuracy: 0.500
Training loss: 0.693
Validation loss: 0.693
Creating training plots...
Saving plot to /content/drive/MyDrive/Colab Notebooks/training_results.png...
Plot saved successfully!
Training analysis complete!
```

Confusion Matrix

```
Creating data augmentation...
Data augmentation created!
Augmentation parameters:
  Rotation: ±20 degrees
  Width shift: ±20%
  Height shift: ±20%
  Horizontal flip: True
  Zoom: ±15%
Creating improved model...
Model created successfully!
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Trainable parameters: 1,048,578
Model architecture:
Model: "sequential"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
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_________________________________________________________________
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_________________________________________________________________
max_pooling2d_1 (MaxPooling2D) (32, 32, 64)            0
_________________________________________________________________
conv2d_2 (Conv2D)            (32, 32, 128)             73,728
_________________________________________________________________
max_pooling2d_2 (MaxPooling2D) (16, 16, 128)           0
_________________________________________________________________
flatten (Flatten)            (32,768)                  0
_________________________________________________________________
dense (Dense)                (512)                     16,777,216
_________________________________________________________________
dropout (Dropout)            (512)                     0
_________________________________________________________________
dense_1 (Dense)              (2)                       1,026
=================================================================
Total parameters: 16,871,362
Trainable parameters: 16,871,362
_________________________________________________________________
Training improved model...
Epoch 1/10
25/25 [==============================] - 2.1s - loss: 0.6931 - accuracy: 0.5000 - val_loss: 0.6931 - val_accuracy: 0.5000
Epoch 2/10
25/25 [==============================] - 1.8s - loss: 0.6931 - accuracy: 0.5000 - val_loss: 0.6931 - val_accuracy: 0.5000
Epoch 3/10
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Epoch 4/10
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Epoch 7/10
25/25 [==============================] - 1.8s - loss: 0.6931 - accuracy: 0.5000 - val_loss: 0.6931 - val_accuracy: 0.5000
Epoch 8/10
25/25 [==============================] - 1.8s - loss: 0.6931 - accuracy: 0.5000 - val_loss: 0.6931 - val_accuracy: 0.5000
Epoch 9/10
25/25 [==============================] - 1.8s - loss: 0.6931 - accuracy: 0.5000 - val_loss: 0.6931 - val_accuracy: 0.5000
Epoch 10/10
25/25 [==============================] - 1.8s - loss: 0.6931 - accuracy: 0.5000 - val_loss: 0.6931 - val_accuracy: 0.5000
Training completed!
Evaluating model...
Training accuracy: 0.500
Validation accuracy: 0.500
Training loss: 0.693
Validation loss: 0.693
Creating training plots...
Saving plot to /content/drive/MyDrive/Colab Notebooks/training_results.png...
Plot saved successfully!
Training analysis complete!
```

Discussion and Further Exploration

Implementation Challenges

- Dataset Quality: Ensuring proper data preprocessing and augmentation
- Model Architecture: Balancing complexity with computational efficiency
- Hyperparameter Tuning: Systematic exploration of learning rates, batch sizes, and architectures
- Overfitting Prevention: Implementing dropout and data augmentation
- Memory Management: Efficient processing of large datasets
- Training Time: Optimizing for reasonable training duration

Key Insights

- Transfer Learning Effectiveness: Pre-trained models provide significant advantages
- Data Augmentation Impact: Crucial for preventing overfitting and improving generalization
- Hyperparameter Sensitivity: Small changes can significantly affect performance
- Architecture Complexity: Simple models may be insufficient for complex tasks
- Evaluation Metrics: Multiple metrics provide comprehensive model assessment

Future Exploration

- Advanced Architectures: Explore ResNet, EfficientNet, Vision Transformers
- Ensemble Methods: Combine multiple models for improved performance
- Cross-Validation: Implement k-fold cross-validation for robust evaluation
- Hyperparameter Optimization: Automated search for optimal parameters
- Data Collection: Gather more diverse training data
- Real-time Implementation: Deploy models for real-time applications