Progress Report: Wrist Fracture Detection using Deep Learning on the MURA Dataset

Frederick Damptey, Cletus Ngwerume

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1. AI Model(s) Used in Research Project (5 points)

Model(s) Used

We employed convolutional neural networks (CNNs) via transfer learning for wrist fracture detection:

- **ResNet50**
- **EfficientNetB0**

Architecture and Key Components

Both models were initialized with pretrained weights from ImageNet and then fine-tuned on the filtered MURA wrist-only dataset. The key architectural modifications included:

- Global Average Pooling layer to reduce spatial dimensions.
- Fully connected Dense layer(s) for classification.
- Dropout layer to reduce overfitting.
- Final Dense layer with softmax activation for binary classification.
- Data augmentation using `ImageDataGenerator` to improve generalization.

Training Configuration

Pretrained Base Models:

- **ResNet50** and **EfficientNetB0** from Keras Applications
- Layers frozen except last 10 layers during fine-tuning

Loss Function and Optimizer:

- Loss: `binary_crossentropy`
- Optimizer: Adam with `learning_rate=0.0001`

Training Details:

- Number of Epochs: 10
- Callback: EarlyStopping (`monitor='val_loss'`, `patience=4`, `restore_best_weights=True`)
- Class Weights used to address class imbalance
- Validation data used for monitoring generalization

Justification for Model Choice

- **ResNet50** is a robust deep network that mitigates vanishing gradients through residual connections, making it suitable for complex image recognition tasks in medical imaging.
- **EfficientNetB0** provides a balance of high accuracy with low computational cost, enabling fast training and deployment.
- **Transfer learning** allows leveraging pretrained knowledge from large datasets like ImageNet, which is advantageous due to the limited size of labeled medical image datasets.

2. Performance Metrics Analysis (10 points)

Metrics Tracked

We evaluate our models using the following metrics:

- **Accuracy**
- **Sensitivity (Recall)**
- **Specificity**
- **F1-score**
- **ROC AUC (Area Under the Receiver Operating Characteristic Curve)**

Current Model Performance

ResNet50

- Accuracy is 89%,
- F1-scores are 0.91 for class 0 and 0.87 for class 1,
- ROC AUC Score is 0.957, indicating strong overall classification performance.

EfficientNetB0

- Accuracy is 86%,
- F1-score is 0.89 for class 0 and 0.83 for class 1,
- ROC AUC Score is 0.937, showing strong ability to distinguish between the classes.

Significance of Metrics in a Medical Context

- **Accuracy** offers a general overview but may be misleading in class-imbalanced datasets.
- **Sensitivity** is critical to minimize missed fracture cases (false negatives).
- **Specificity** ensures that healthy wrists are not incorrectly classified as fractured (false positives).
- **F1-score** balances sensitivity and precision, ideal for class imbalance.
- **ROC AUC** reflects the model's ability to distinguish between fractured and healthy images.

Benchmark Comparison

According to literature such as Rajpurkar *et al.* [1] on the MURA dataset:

- Reported AUCs typically range from **0.87 to 0.93**.

Our models align well with these benchmarks:

- **EfficientNetB0: AUC = 0.93**, Sensitivity = 0.86
- **ResNet50: AUC = 0.95**, Sensitivity = 0.92

3. Project Status Summary (10 points)

Project Status: On Track for Completion by April 18th

Evidence of Progress

- Wrist-only images were filtered and preprocessed from the MURA dataset.
- EfficientNetB0 and ResNet50 models were successfully trained.
- Evaluation metrics (accuracy, sensitivity, specificity, F1-score, AUC) computed and analyzed.
- Performance exceeds or meets expected benchmarks.

```
Epoch 1/10
2025-04-09 23:41:26.052893: I tensorflow/core/common_runtime/executor.cc:1197] [/device:CPU:0] (DEBUG INFO) Executor start aborting (this does not indicate a
         [[{{node Placeholder/_0}}]]
2025-04-09 23:41:26.058983: W tensorflow/tsl/platform/profile_utils/cpu_utils.cc:128] Failed to get CPU frequency: 0 Hz
666/666 [==============================] - ETA: 0s - loss: 0.5590 - accuracy: 0.7753
2025-04-10 00:09:26.243208: I tensorflow/core/common_runtime/executor.cc:1197] [/device:CPU:0] (DEBUG INFO) Executor start aborting (this does not indicate a
         [[{{node Placeholder/_0}}]]
666/666 [==============================] - 2061s 3s/step - loss: 0.5590 - accuracy: 0.7753 - val_loss: 0.4117 - val_accuracy: 0.8126
Epoch 2/10
666/666 [==============================] - 2237s 3s/step - loss: 0.4632 - accuracy: 0.8286 - val_loss: 0.3626 - val_accuracy: 0.8374
Epoch 3/10
666/666 [==============================] - 2359s 4s/step - loss: 0.4141 - accuracy: 0.8489 - val_loss: 0.3327 - val_accuracy: 0.8534
Epoch 4/10
666/666 [==============================] - 2489s 4s/step - loss: 0.3662 - accuracy: 0.8698 - val_loss: 0.3348 - val_accuracy: 0.8504
Epoch 5/10
666/666 [==============================] - 2522s 4s/step - loss: 0.3332 - accuracy: 0.8815 - val_loss: 0.3308 - val_accuracy: 0.8512
Epoch 6/10
666/666 [==============================] - 2337s 4s/step - loss: 0.2983 - accuracy: 0.8965 - val_loss: 0.2945 - val_accuracy: 0.8766
Epoch 7/10
666/666 [==============================] - 2337s 4s/step - loss: 0.2629 - accuracy: 0.9108 - val_loss: 0.2751 - val_accuracy: 0.8859
Epoch 8/10
666/666 [==============================] - 2352s 4s/step - loss: 0.2381 - accuracy: 0.9209 - val_loss: 0.2772 - val_accuracy: 0.8839
Epoch 9/10
666/666 [==============================] - 2342s 4s/step - loss: 0.2165 - accuracy: 0.9268 - val_loss: 0.2574 - val_accuracy: 0.8932
Epoch 10/10
666/666 [==============================] - 2332s 4s/step - loss: 0.1977 - accuracy: 0.9349 - val_loss: 0.2589 - val_accuracy: 0.8991
```

Figure 1: RESNET50: Training and Validation Accuracy/Loss over Epochs

```
2025-04-10 16:15:24.033434: I tensorflow/core/common_runtime/executor.cc:1197] [/device:CPU:0] (DEBUG INFO) Executor start aborting (this does not indicate a
         [[{{node Placeholder/_0}}]]
185/185 [==============================] - 142s 768ms/step
              precision    recall  f1-score   support

           0       0.88      0.95      0.91      3451
           1       0.92      0.82      0.87      2467

    accuracy                           0.89      5918
   macro avg       0.90      0.88      0.89      5918
weighted avg       0.90      0.89      0.89      5918

ROC AUC Score: 0.956576975450035
```

Figure 2: RESNET50: Confusion Matrix

```
Epoch 1/10
2025-04-10 06:10:54.673681: I tensorflow/core/common_runtime/executor.cc:1197] [/device:CPU:0] (DEBUG INFO) Executor start aborting (this does not indicate a
         [[{{node Placeholder/_0}}]]
666/666 [==============================] - ETA: 0s - loss: 0.5914 - accuracy: 0.7549
2025-04-10 06:22:13.520074: I tensorflow/core/common_runtime/executor.cc:1197] [/device:CPU:0] (DEBUG INFO) Executor start aborting (this does not indicate a
         [[{{node Placeholder/_0}}]]
666/666 [==============================] - 840s 1s/step - loss: 0.5914 - accuracy: 0.7549 - val_loss: 0.4459 - val_accuracy: 0.7882
Epoch 2/10
666/666 [==============================] - 840s 1s/step - loss: 0.5088 - accuracy: 0.8062 - val_loss: 0.4084 - val_accuracy: 0.8097
Epoch 3/10
666/666 [==============================] - 844s 1s/step - loss: 0.4803 - accuracy: 0.8185 - val_loss: 0.3912 - val_accuracy: 0.8227
Epoch 4/10
666/666 [==============================] - 836s 1s/step - loss: 0.4582 - accuracy: 0.8307 - val_loss: 0.3674 - val_accuracy: 0.8390
Epoch 5/10
666/666 [==============================] - 787s 1s/step - loss: 0.4328 - accuracy: 0.8407 - val_loss: 0.3587 - val_accuracy: 0.8423
Epoch 6/10
666/666 [==============================] - 768s 1s/step - loss: 0.4204 - accuracy: 0.8441 - val_loss: 0.3391 - val_accuracy: 0.8567
Epoch 7/10
666/666 [==============================] - 833s 1s/step - loss: 0.4021 - accuracy: 0.8542 - val_loss: 0.3623 - val_accuracy: 0.8297
Epoch 8/10
666/666 [==============================] - 860s 1s/step - loss: 0.3860 - accuracy: 0.8611 - val_loss: 0.3252 - val_accuracy: 0.8581
Epoch 9/10
666/666 [==============================] - 1091s 2s/step - loss: 0.3749 - accuracy: 0.8650 - val_loss: 0.3167 - val_accuracy: 0.8619
Epoch 10/10
666/666 [==============================] - 659s 989ms/step - loss: 0.3613 - accuracy: 0.8733 - val_loss: 0.2996 - val_accuracy: 0.8738
```

Figure 3: EFFICIENTNETB0: Training and Validation Accuracy/Loss over Epochs

```
[13]                                                                                                                          Python
... 2025-04-10 16:24:05.947589: I tensorflow/core/common_runtime/executor.cc:1197] [/device:CPU:0] (DEBUG INFO) Executor start aborting (this does not indicate a
             [[{{node Placeholder/_0}}]]
    185/185 [==============================] - 50s 268ms/step
                  precision    recall  f1-score   support

               0       0.86      0.91      0.89      3451
               1       0.86      0.80      0.83      2467

        accuracy                           0.86      5918
       macro avg       0.86      0.85      0.86      5918
    weighted avg       0.86      0.86      0.86      5918

    ROC AUC Score: 0.9367192581014626
```

Figure 4: EFFICIENTNETB0: Confusion Matrix

Remaining Tasks

- Fine-tuning hyperparameters (learning rate, batch size).
- Apply Grad-CAM for visual explanation of predictions.
- Final evaluation on a hold-out test set.
- Final report formatting and documentation.

Timeline

- **April 9–12:** Final model tuning and Grad-CAM visualizations.
- **April 13–15:** Prepare and format final report.
- **April 16–17:** Review and polish for submission.

References

References

[1] P. Rajpurkar, J. Irvin, A. Bagul, D. Ding, T. Duan, H. Mehta, B. Yang, K. Zhu, D. Laird, R. L. Ball, et al., "MURA: Large dataset for abnormality detection in musculoskeletal radiographs," *arXiv preprint arXiv:1712.06957*, 2017.