Pebbles vs Shells Image Classification

I. Training Phase

In this phase, the script train_max78000.sh executes the main train.py in which this is configured in order to perform the Quantization-Aware Training. The table below shows the correct folder structure for the dataset for pebbles and shells.

	Dataset	**Data Loader**	**Model**	**Train Script**
Folder	data	datasets	models	scripts
File	pebbles_vs_shells	pebbles_vs_shells.py	ai85net-cd.py	Train_max78000.sh

Table. *Folder Structure*

- The process begins with the load datasets where it first calls the pebbles_vs_shells.py loader to fins the dataset in the directory *data/pebbles_vs_shells*. This directory splits into train and test folders where all of the images are resized to 128x128 pixels and the training images are passed through an albumentations pipeline for the data augmentation.

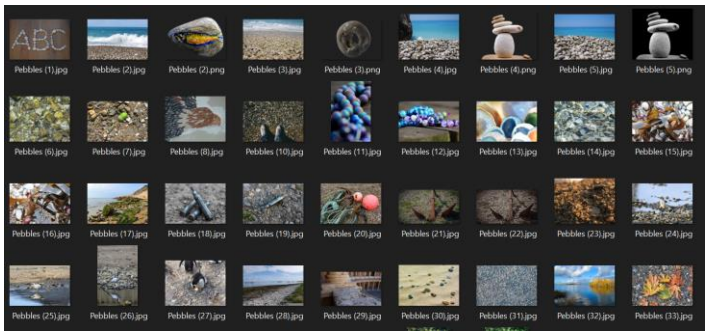
```
# Training Script for Pebbles and Shells
python train.py --epochs 100 --optimizer Adam --lr 0.001 --wd 0 --deterministic \
--compress policies/schedule-pebblesshells.yaml --model ai85cdnet --dataset pebbles_vs_shells \
--confusion --param-hist --embedding --device MAX78000 --workers 0 --enable-tensorboard
```

Code Snippet for train_max78000.sh

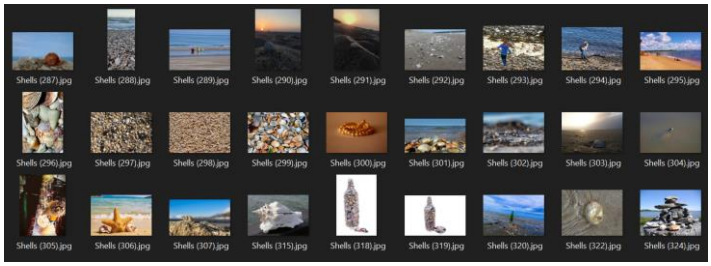
- This trains a machine learning model to classify images of pebbles and shells using the "ai85cdnet" architecture and the "pebbles_vs_shells" dataset. It runs for 100 epochs with the Adam optimizer and includes tools and for evaluating the system performance.

```
Epoch: [99][   12/   12]    Overall Loss 0.461397    Objective Loss 0.461397    Top1 75.456389    LR 0.000216    Time 5.309154
--- validate (epoch=99)-----------
339 samples (256 per mini-batch)
Epoch: [99][    2/    2]    Loss 0.537802    Top1 75.516224
==> Top1: 75.516    Loss: 0.538

==> Confusion:
[[193  33]
 [ 50  63]]

==> Best [Top1: 77.286   Sparsity:0.00   Params: 57776 on epoch: 65]
Saving checkpoint to: logs\2025.11.07-230746\qat_checkpoint.pth.tar
```

Display Output Result of Training Phase



Pebbles Dataset Images

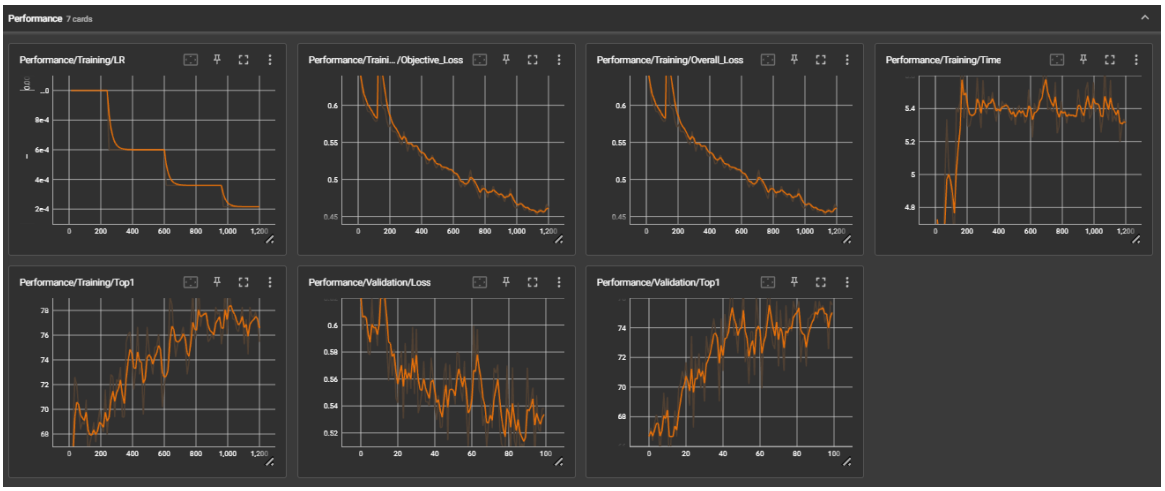


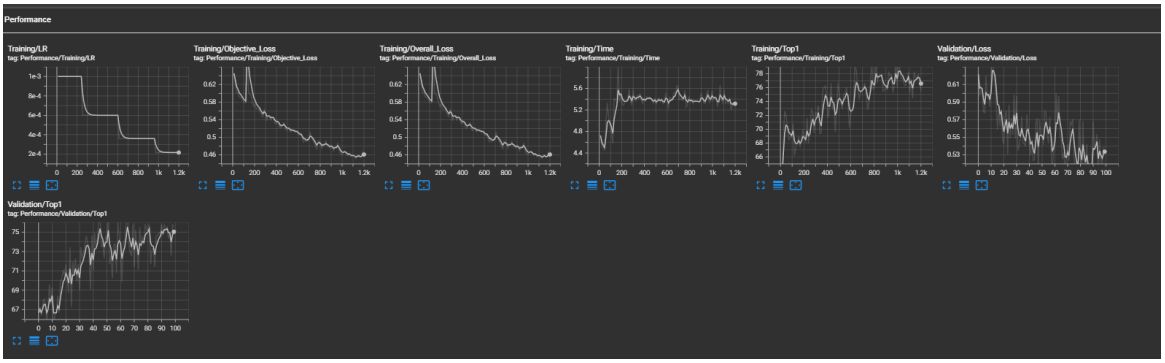
Shells Dataset Images

II. Log Display on TensorBoard

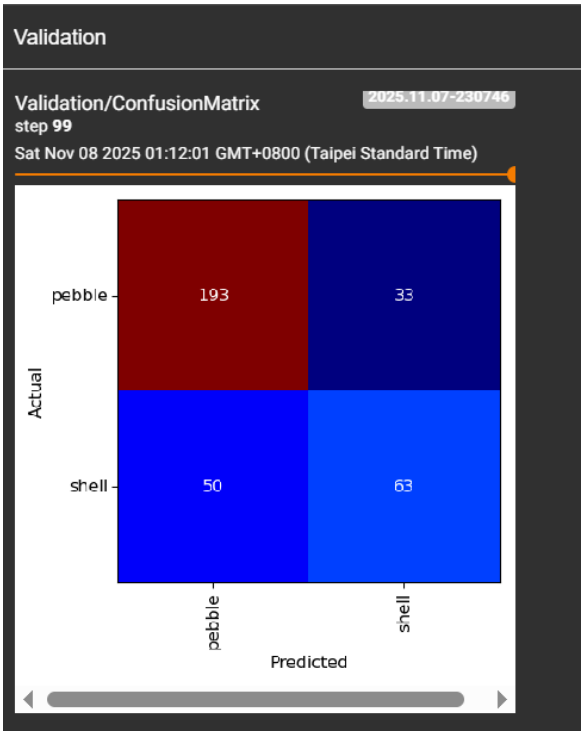
After the training phase, the performance data is saved to the *./logs* directory, where this data can be visualized using the TensorBoard allowing the user view the training progress.

- *Performance Training*





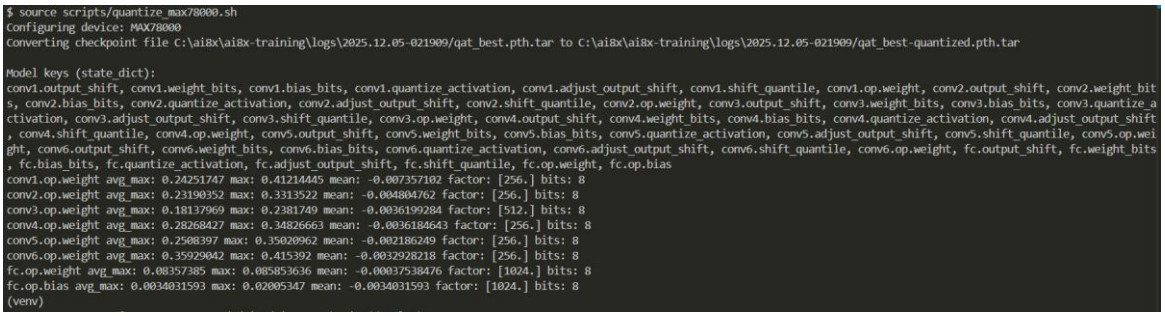
- *Confusion Matrix*



- This is the confusion matrix of the pebbles vs shells showing the correct and incorrect guesses. The top-left shows the high percentage for correctly guessed as Pebbles. The top-right us the incorrect prediction of the model which the model saw a pebble but predicted as shell. For the bottom-left, the model saw a shell but incorrectly predicted it was a pebble. And for the bottom-right, is the correct prediction of the model which is a shell.

III. Quantization

The best performing model checkpoint was copied to the logs folder to the synthesis folder and renamed to qat_best-quantized.pth.tar.



- This quantize_pebblesvsshells.sh script was executed to synthesize the model. Which this phase it loads the 8-bit quantized checkpoint, converts the model weights and biased into specific format, and the verbose output that confirms the layers that successfully analyzed.

IV. Evaluation

The script evaluate_max78000.sh was run to get the final performance score for the model.

```
$ source scripts/evaluate_max78000.sh
Configuring device: MAX78000, simulate=True.
Log file for this run: C:\ai8x\ai8x-training\logs\2025.11.08-023632\2025.11.08-023632.log
{'start_epoch': 10, 'weight_bits': 8}
=> loading checkpoint ../ai8x-synthesis/trained/ai85-pebblesshells-qat8-q.pth.tar
=> Checkpoint contents:
+----------------------+------------+-----------+
| Key                  | Type       | Value     |
|----------------------+------------+-----------|
| arch                 | str        | ai85cdnet |
| compression_sched    | dict       |           |
| epoch                | int        | 99        |
| extras               | dict       |           |
| optimizer_state_dict | dict       |           |
| optimizer_type       | type       | Adam      |
| state_dict           | OrderedDict |           |
+----------------------+------------+-----------+

=> Checkpoint['extras'] contents:
+-----------------+--------+-------------------+
| Key             | Type   | Value             |
|-----------------+--------+-------------------|
| best_epoch      | int    | 65                |
| best_mAP        | int    | 0                 |
| best_top1       | float  | 77.28613569321534 |
| clipping_method | str    | MAX_BIT_SHIFT     |
| current_mAP     | int    | 0                 |
| current_top1    | float  | 75.51622418879056 |
+-----------------+--------+-------------------+
```

```
$  source scripts/evaluate_max78000.sh
Configuring device: MAX78000, simulate=True.
Log file for this run: C:\ai8x\ai8x-training\logs\2025.12.05-061855\2025.12.05-061855.log
{'start_epoch': 10, 'weight_bits': 8}
=> loading checkpoint C:\ai8x\ai8x-training\logs\2025.12.05-021909\qat_best-quantized.pth.tar
=> Checkpoint contents:
+----------------------+------------+-----------+
| Key                  | Type       | Value     |
|----------------------+------------+-----------|
| arch                 | str        | ai85cdnet |
| compression_sched    | dict       |           |
| epoch                | int        | 65        |
| extras               | dict       |           |
| optimizer_state_dict | dict       |           |
| optimizer_type       | type       | Adam      |
| state_dict           | OrderedDict |           |
+----------------------+------------+-----------+

=> Checkpoint['extras'] contents:
+-----------------+--------+-------------------+
| Key             | Type   | Value             |
|-----------------+--------+-------------------|
| best_epoch      | int    | 65                |
| best_mAP        | int    | 0                 |
| best_top1       | float  | 77.28613569321534 |
| clipping_method | str    | MAX_BIT_SHIFT     |
| current_mAP     | int    | 0                 |
| current_top1    | float  | 77.28613569321534 |
+-----------------+--------+-------------------+
```

```
Loaded compression schedule from checkpoint (epoch 65)
=> loaded 'state_dict' from checkpoint 'C:\ai8x\ai8x-training\logs\2025.12.05-021909\qat_best-quantized.pth.tar'
Optimizer Type: <class 'torch.optim.sgd.SGD'>
Optimizer Args: {'lr': 0.1, 'momentum': 0.9, 'dampening': 0, 'weight_decay': 0.0001, 'nesterov': False}
Dataset sizes:
        training=3053
        validation=339
        test=849
--- test ---------------------
849 samples (256 per mini-batch)
==> Saving sample at index 1 to sample_pebbles_vs_shells.npy
Test: [    4/    4]    Loss 0.557227    Top1 73.144876
==> Top1: 73.145    Loss: 0.557

==> Confusion:
[[461  79]
 [149 160]]


Log file for this run: C:\ai8x\ai8x-training\logs\2025.12.05-061855\2025.12.05-061855.log
(venv)
```

```
Loaded compression schedule from checkpoint (epoch 99)
=> loaded 'state_dict' from checkpoint '../ai8x-synthesis/trained/ai85-pebblesshells-qat8-q.pth.tar'
Optimizer Type: <class 'torch.optim.sgd.SGD'>
Optimizer Args: {'lr': 0.1, 'momentum': 0.9, 'dampening': 0, 'weight_decay': 0.0001, 'nesterov': False}
Dataset sizes:
        training=3053
        validation=339
        test=849
--- test ---------------------
849 samples (256 per mini-batch)
==> Saving sample at index 1 to sample_pebbles_vs_shells.npy
Test: [    4/    4]    Loss 0.527790    Top1 73.969376
==> Top1: 73.969    Loss: 0.528

==> Confusion:
[[492  48]
 [173 136]]
```

- This loads the fully quantized model and runs the model against the entire dataset. The result shows that the Top-1 Accuracy of 73.969376. This is a slight drop from the 77.2861% training peak is an expected and normal trade-off for converting a 32-bit model into 8-bit model.

V. Why it didn't reach 80% accuracy?

- I think the cause of this is the dataset is kind of hard for it to classify as the pebbles and shells are somewhat similar to shape and size which the training accuracy percentage is quite not that high. The model used also is too simple to learn the complex pattern in the dataset, as this model is fast. I also did try to make the dataset image size to 224x224 with models that can increase the accuracy, however, it did not complete and failed with assertion error. In conclusion, this training with 100 epoch was successful but this only reaches the accuracy of 77.2861%, which I think that is the maximum possible accuracy for this model using the pebbles and shells dataset.

VI. Uploading to max78000

- **Source gen-workshop-max78000.sh**

```
Ian James B. Cruza@IJBC-13 MINGW64 /c/ai8x/ai8x-synthesis (develop)
$ source gen-workshop-max78000.sh
Configuring device: MAX78000
Reading networks/cats-dogs-hwc.yaml to configure network...
WARNING: Cannot run "yamllint" linter to check networks/cats-dogs-hwc.yaml
Reading C:/ai8x/ai8x-training/logs/2025.12.05-021909/qat_best-quantized.pth.tar to configure network weights...
Checkpoint for epoch 65, model ai85cdnet - weight and bias data:
 InCh OutCh  Weights        Quant Shift  Min  Max    Size Key                                 Bias       Quant  Min  Max Size Key
    3    16  (48, 3, 3)         8    -1  -83  106     432 conv1.op.weight                     N/A            0    0    0    0 N/A
   16    32  (512, 3, 3)        8    -1  -84   85    4608 conv2.op.weight                     N/A            0    0    0    0 N/A
   32    64  (2048, 3, 3)       8    -2 -120  122   18432 conv3.op.weight                     N/A            0    0    0    0 N/A
   64    32  (2048, 3, 3)       8    -1  -89   81   18432 conv4.op.weight                     N/A            0    0    0    0 N/A
   32    32  (1024, 3, 3)       8    -1  -90   85    9216 conv5.op.weight                     N/A            0    0    0    0 N/A
   32    16  (512, 3, 3)        8    -1 -106  104    4608 conv6.op.weight                     N/A            0    0    0    0 N/A
 1024     2  (1, 2, 1024)       8    -3  -88   86    2048 fc.op.weight                        (2,)           8  -21   14    2 fc.op.bias
TOTAL: 7 parameter layers, 57,778 parameters, 57,778 bytes
Configuring data set: pebbles_vs_shells.
pebblesshells...
Arranging weights... ━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 100%
Storing weights...   ━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 100%
Creating network...  ━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 100%
NOTICE: --scale-output set, but all output scales are zero. Unload operation will be realized without scaling.
(venv)
```

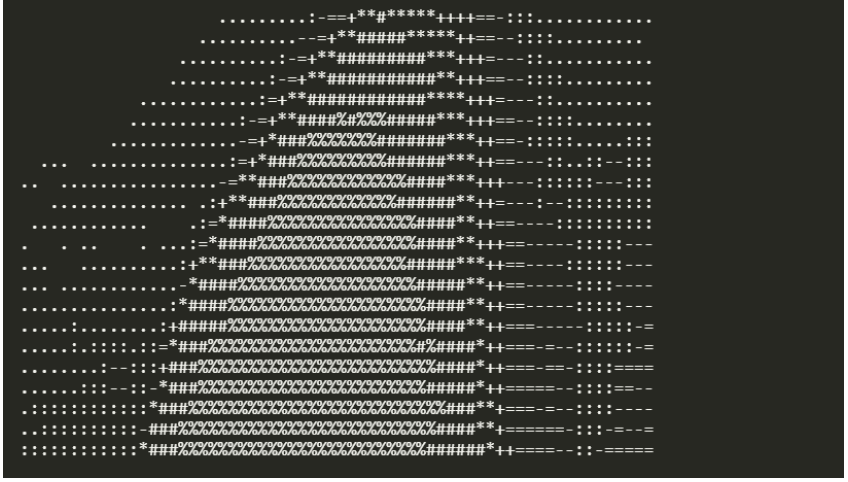
```
C:\Users\Ian James B. Cruza>cd C:\MaximSDK\Examples\MAX78000\CNN\pebbleShell-gen

C:\MaximSDK\Examples\MAX78000\CNN\pebbleShell-gen>make -r clean
Loaded project.mk
********************************************************************************
* Analog Devices MSDK
* - User Guide: https://analogdevicesinc.github.io/msdk/USERGUIDE/
* - Get Support: https://www.analog.com/support/technical-support.html
* - Report Issues: https://github.com/analogdevicesinc/msdk/issues
* - Contributing: https://analogdevicesinc.github.io/msdk/CONTRIBUTING/
********************************************************************************
- RMDIR /c/MaximSDK/Examples/MAX78000/CNN/pebbleShell-gen/build
```

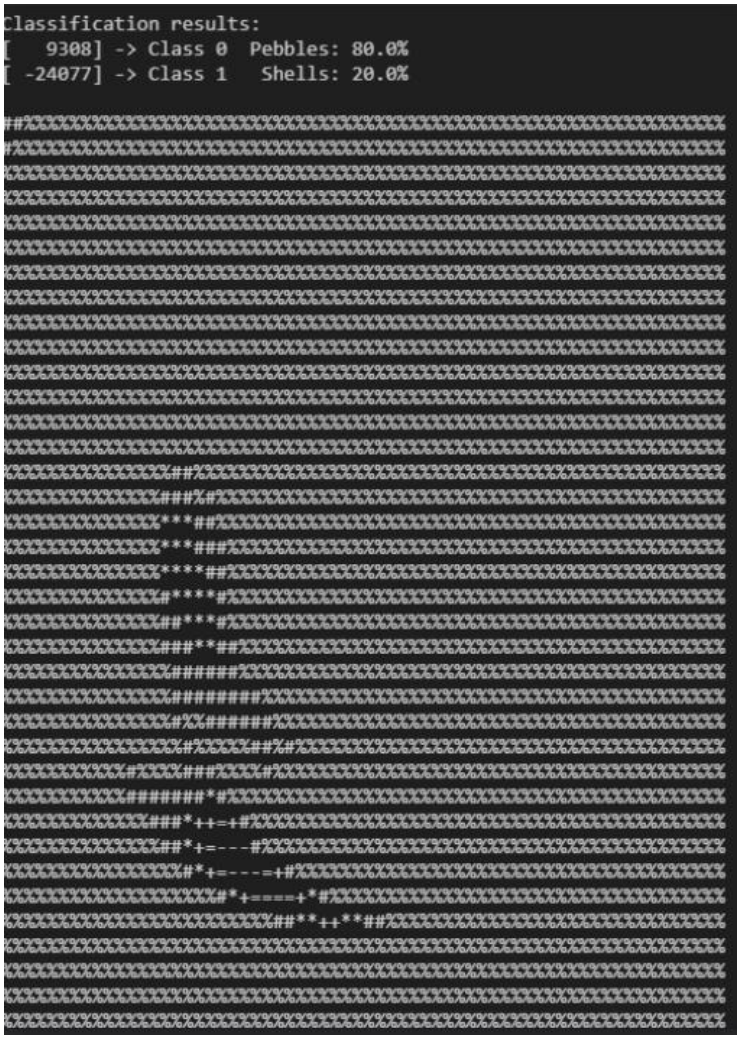
```
C:\MaximSDK\Examples\MAX78000\CNN\pebbleShell-gen>make -r
Loaded project.mk
********************************************************************************
* Analog Devices MSDK
* - User Guide: https://analogdevicesinc.github.io/msdk/USERGUIDE/
* - Get Support: https://www.analog.com/support/technical-support.html
* - Report Issues: https://github.com/analogdevicesinc/msdk/issues
* - Contributing: https://analogdevicesinc.github.io/msdk/CONTRIBUTING/
********************************************************************************
- MKDIR /c/MaximSDK/Examples/MAX78000/CNN/pebbleShell-gen/build
- CC cnn.c
- CC main.c
- CC softmax.c
- CC C:/MaximSDK/Libraries/Boards/MAX78000/FTHR_RevA/Source/board.c
- CC C:/MaximSDK/Libraries/MiscDrivers/stdio.c
- CC C:/MaximSDK/Libraries/MiscDrivers/LED/led.c
- CC C:/MaximSDK/Libraries/MiscDrivers/PushButton/pb.c
- CC C:/MaximSDK/Libraries/MiscDrivers/Display/tft_ili9341.c
- CC C:/MaximSDK/Libraries/MiscDrivers/Camera/camera.c
- CC C:/MaximSDK/Libraries/MiscDrivers/Camera/ov7692.c
- CC C:/MaximSDK/Libraries/MiscDrivers/Camera/sccb.c
- CC C:/MaximSDK/Libraries/MiscDrivers/PMIC/max20303.c
- CC C:/MaximSDK/Libraries/MiscDrivers/CODEC/max9867.c
- CC C:/MaximSDK/Libraries/MiscDrivers/SRAM/N01S830HA.c
- CC C:/MaximSDK/Libraries/MiscDrivers/SRAM/fastspi.c
- AS C:/MaximSDK/Libraries/CMSIS/Device/Maxim/MAX78000/Source/GCC/startup_max78000.S
- CC C:/MaximSDK/Libraries/CMSIS/Device/Maxim/MAX78000/Source/heap.c
- CC C:/MaximSDK/Libraries/CMSIS/Device/Maxim/MAX78000/Source/system_max78000.c
- LD /c/MaximSDK/Examples/MAX78000/CNN/pebbleShell-gen/build/max78000.elf
Memory region         Used Size  Region Size  %age Used
            ROM:           0 GB        64 KB      0.00%
          FLASH:         119 KB       512 KB     23.24%
           SRAM:       71188 B       128 KB     54.31%
arm-none-eabi-size --format=berkeley /c/MaximSDK/Examples/MAX78000/CNN/pebbleShell-gen/build/max78000.elf
   text    data     bss     dec     hex filename
 118740    2616   68612  189968   2e610 C:/MaximSDK/Examples/MAX78000/CNN/pebbleShell-gen/build/max78000.elf
```

```
C:\MaximSDK\Examples\MAX78000\CNN\pebbleShell-gen>openocd -s C:/MaximSDK/Tools/OpenOCD/scripts -f interface/cmsis-dap.cfg -f target/max78000.cfg -c "program build/max78000.elf reset exit"
Open On-Chip Debugger (Analog Devices 0.12.0-1.0.0-7)  OpenOCD 0.12.0 (2023-09-27-07:53)
Licensed under GNU GPL v2
Report bugs to <processor.tools.support@analog.com>
Info : CMSIS-DAP: SWD supported
Info : CMSIS-DAP: Atomic commands supported
Info : CMSIS-DAP: Test domain timer supported
Info : CMSIS-DAP: FW Version = 2.0.0
Info : CMSIS-DAP: Serial# = 042317025279ca6a000000000000000000000000097969906
Info : CMSIS-DAP: Interface Initialised (SWD)
Info : SWCLK/TCK = 1 SWDIO/TMS = 1 TDI = 0 TDO = 0 nTRST = 0 nRESET = 1
Info : CMSIS-DAP: Interface ready
Info : clock speed 2000 kHz
Info : SWD DPIDR 0x2ba01477
Info : [max32xxx.cpu] Cortex-M4 r0p1 processor detected
Info : [max32xxx.cpu] target has 6 breakpoints, 4 watchpoints
Info : starting gdb server for max32xxx.cpu on 3333
Info : Listening on port 3333 for gdb connections
[max32xxx.cpu] halted due to debug-request, current mode: Thread
xPSR: 0x21000000 pc: 0x10002a8c msp: 0x2001ffe0
Info : SWD DPIDR 0x2ba01477
[max32xxx.cpu] halted due to debug-request, current mode: Thread
xPSR: 0x81000000 pc: 0x00002124 msp: 0x20003ff0
** Programming Started **
** Programming Finished **
** Resetting Target **
Info : SWD DPIDR 0x2ba01477
shutdown command invoked
```

- **Testing and Results**

```
Pebbles and Shell Classification
Init Camera.
********** Press PB1(SW1) to capture an image **********
W:128 H:128 L:65536
Time for CNN: 12056 us

Classification results:
[ -16908] -> Class 0  Pebbles: 20.0%
[  16284] -> Class 1   Shells: 80.0%
```





VII. GitHUB Link

https://github.com/ianjamescruza/COE187/tree/main/Pebbles_vs_Shells