Machine Learning on Mobile with OpenCL

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Overview

• Machine Learning on Mobile is a rapidly growing area.
  ◦ Increase in number of use cases.
  ◦ Increase in research references.

• GPUs remain a popular option for ML on mobile
  ◦ A large number of ML frameworks and compilers use OpenCL
    • TFLite, SNPE, MNN, Mace, Paddle-Lite and TVM

• Currently most ML use cases are focused on inference.
  ◦ We see training at the edge as an emerging area.

• Important Considerations for ML on mobile
  ◦ Low Power consumption, low latency dispatch and synchronization
  ◦ Zero Copy Data Import/Export (Android Hardware Buffer, DMA-BUF)
  ◦ Reduced memory footprint (reuse memory across layers when possible)
cl_qcom_ml_ops

- Extension for Accelerating Machine Learning on Adreno GPUs at the Op (Metacommand) Level.
  - Shipping from Snapdragon 888 onwards with inference support.
  - Training support added on Snapdragon 8 Gen 1
  - Integrated with TVM BYOC (See our poster at IWOCL 2022)

- Uses existing OpenCL constructs such as command queues, events and buffers
  - Adds new constructs such as ops and tensors.

- Fully interoperable with other OpenCL kernels
  - Inline execution, synchronization and data sharing.
  - Vendor provided Ops can deliver a significant performance advantage.

- Samples and documentation available from
Training with cl_qcom_ml_ops

• Use cases for edge training include Transfer Learning, Personalization and Federated Learning

• Memory footprint is a major consideration for training on mobile devices
  ◦ The memory needed for all of the weights, gradients and activations for Mobilenet can be around 2 GB.

• cl_qcom_ml_ops leverages the Tensor Batch 1 approach for significantly reduced memory footprint.
  ◦ Activations and gradients have a tensor batch size of 1. Gradients are accumulated, then applied at the end of the batch.
  ◦ If Batch Normalization layers are present, the statistics are frozen.
  ◦ This approach works well for Transfer Learning/Personalization use cases.
  ◦ Additional training approaches will be supported going forward.
Qualcomm Extensions for ML

• **cl_qcom_dot_product8**
  ◦ OpenCL C builtins for 8 bit dot product with saturating accumulate
  ◦ Useful for accelerating 8 bit quantized DNNs.

• **cl_qcom_recordable_queues**
  ◦ Record a sequence of EnqueueNDRangeKernel commands
  ◦ Replay recording with optional updates to kernel arguments
  ◦ Significant improvements in dispatch latency and CPU power consumption for enqueue of Machine Learning models.
  ◦ Especially useful for streaming mode ML use cases.

• Extensions related to zero copy (DMA-BUF/AHB import), subgroup operations, subgroup size control.
Upcoming ML related Extensions from Khronos

• cl_khr_integer_dot_product

• Command Buffer Recording and Replay (provisional)
  ◦ cl_khr_command_buffer
  ◦ cl_khr.mutable_dispatch

• cl_ext_float_atomics (roadmap)

• Generalized Image from buffer
  ◦ cl_ext_image_from_buffer

• Extended Vectors (roadmap)

• Semaphores (provisional)
  ◦ cl_khr_semaphore, cl_khr_external_semaphore, cl_khr_external_semaphore_sync_fd
Summary

• Machine Learning on mobile is an important and growing technology area
• Qualcomm will continue to invest in extensions that accelerate Machine Learning with OpenCL.
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