Machine Learning in Khronos | Vulkan

Pierre Boudier
NVIDIA
January 2021

Objectives of Vulkan Machine Learning (ML)

- **Enable native Vulkan application to use ML with low latency and overhead**
  - Avoid interop, or to embed very large third-party frameworks (python)

- **There are many common blocks in Neural Nets:**
  - Matrix multiplication
  - Convolution
  - Tanh/Sigmoid/ReLU
  - …

- **But the eco system is actually diverse and new mathematical approaches are introduced every week:**
  - Locality sensitive hashing, binary weights, sparse matrices, …

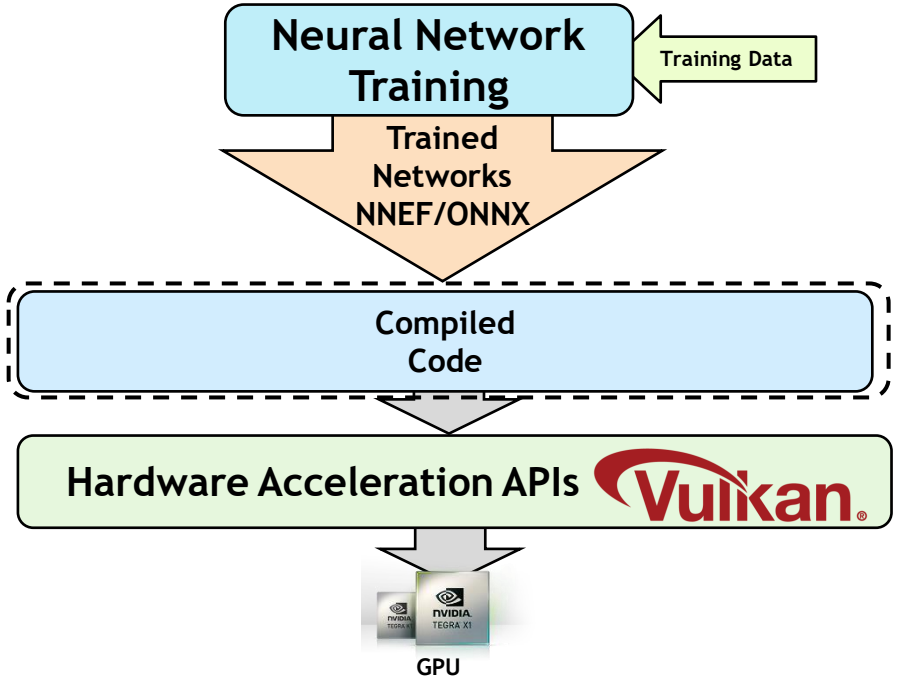
- **Vulkan should not limit itself to current architectures**
  - Luckily, Vulkan already has a compute shader abstraction !

Inferencing Acceleration

Networks trained on high-end desktop and cloud systems

Applications link to compiled inferencing code or dynamically generate it

Accélération Hardware (GPUs)



Data type extensions

- **By default, the 32 bit floating precision is used for both training and inferencing, which are basically just running a computational graph:**
  - Training runs a forward pass, and often times a backward pass to propagate back the gradient
  - Inferencing is just about doing the forward pass

- **But both can be done in lower precision types for faster compute time and reduced data storage**
  - The following extensions are available in vulkan 1.2:
    - VK_KHR_shader_float16_int8
    - VK_KHR_8bit_storage / VK_KHR_16bit_storage
  - 8 bit integers data types are used for quantized Neural Nets
  - FP16 data types can be used for faster math with gradient rescaling in training

  - Upcoming: SPV_KHR_integer_dot_product
    - Take advantage of fast integer math without implicit compiler peephole optimization for quantized neural networks

Improved Compute Shader

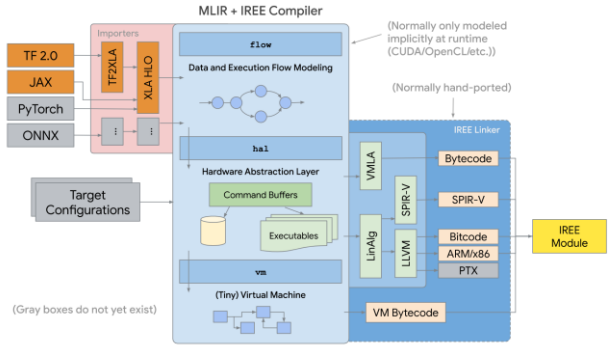
- **New extensions are devised to improve efficiency**
  - Upcoming:
    - VK_KHR_workgroup_memory_explicit_layout
    - Allow more efficient data loading into shared memory for further use with efficient matrix multiplication operations.

    - VK_EXT_ML_primitives
    - Exposes basic primitives used in the main stream Neural Nets as optimized building blocks

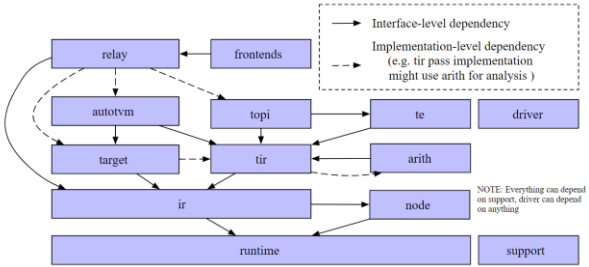
  - Available:
    - VK_NV_cooperative_matrix (NVIDIA)
    - Exposes high throughput matrix/vector multiplication hardware units
    - Typically used be convolution / matmul layer in fp16 formats

Primary Machine Learning Compilers

	tvm.ai	XLA OctoML Google
Import Formats	Caffe, Keras, MXNet, ONNX	TensorFlow Graph, PyTorch, ONNX
Front-end / IR	NNVM / Relay IR	XLA HLO MLIR
Output	SPIR-V	SPIR-V / vulkan API

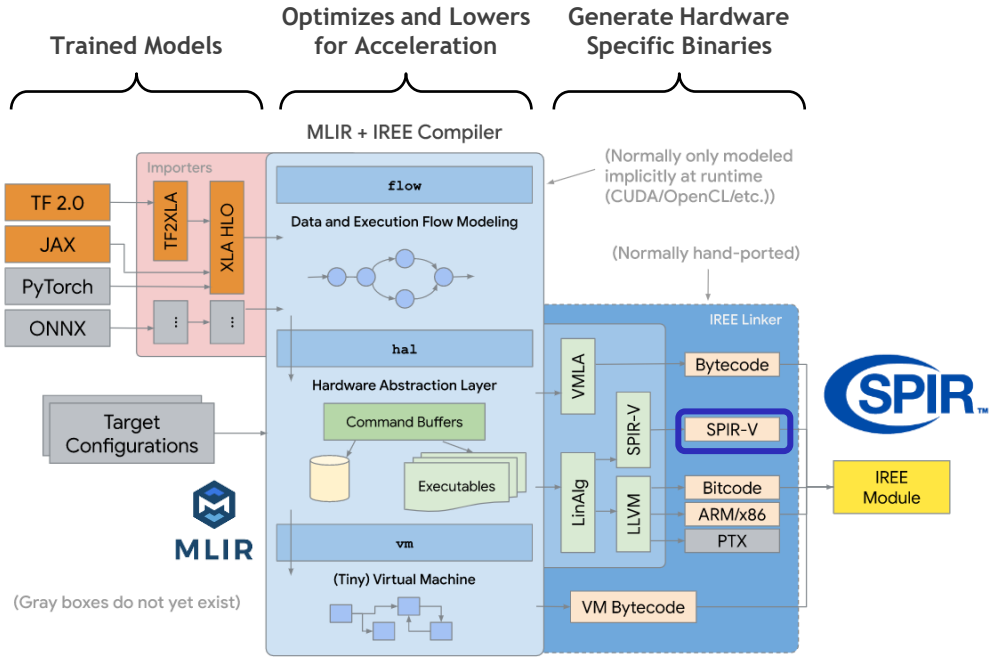


Logical Architecture Components



TVM Architecture Diagram

Google MLIR and IREE Compilers



IREE is a research project today. Google is working with Khronos working groups to explore how SPIR-V code can provide effective inferencing acceleration on APIs such as Vulkan

MLIR

Multi-level Intermediate Representation

Format and library of compiler utilities that sits between the trained model representation and low-level compilers/executors that generate hardware-specific code

IREE

Intermediate Representation Execution Environment

Lowers and optimizes ML models for real-time accelerated inferencing on mobile/edge heterogeneous hardware

Contains ***scheduling*** logic to communicate data dependencies to low-level parallel pipelined hardware/APIs like Vulkan, and ***execution*** logic to encode dense computation in the form of hardware/API-specific binaries like SPIR-V

Third Party frameworks

Alibaba MNN	Tencent 	Ax inc. ax
MNN	NCNN	Ailia
https://github.com/alibaba/MNN	https://github.com/Tencent/ncnn	https://axinc.jp/en/
Lightweight frameworks for inferencing and training for mobile platforms	Cross platform optimized inferencing framework	SDK for optimized running of many popular neural networks on multiple platform

Non Neural Net Machine Learning

Jülich 	Ethical ML 	UNITY 
VkFFT	**Kompute**	**ML agents**
https://github.com/DTolm/VkFFT	https://github.com/EthicalML/vulkan-kompute	https://github.com/Unity-Technologies/ml-agents
Accelerated fast fourrier transform library, which can be used for image resampling, image registration, signal processing …	General purpose GPU compute framework cross graphics card	Open source project that enables simulation for training intelligent agents via the Unity engine

Call To Action

- **The Vulkan Machine Learning Subgroup is welcoming feedback:**
  - What functionality would you like to see in Vulkan to accelerate your ML needs ?
    - Neural Nets
    - Other algorithms:
      - random forest
      - logistic regression
      - K-nearest neighbor
      - T-SNE
      - …
  - Do you have existing product using Vulkan for ML:
    - Do you want to get in touch with hardware vendors ?
    - Do you have suggestion on how to improve your pain points?

- **Contact us at: pboudier@nvidia.com**
- **Help us and join the Vulkan Advisory Panel, or become a Khronos member**