The OpenVX Computer Vision and Neural Network Inference

Standard for Portable, Efficient Code

KHRONOS GROUP

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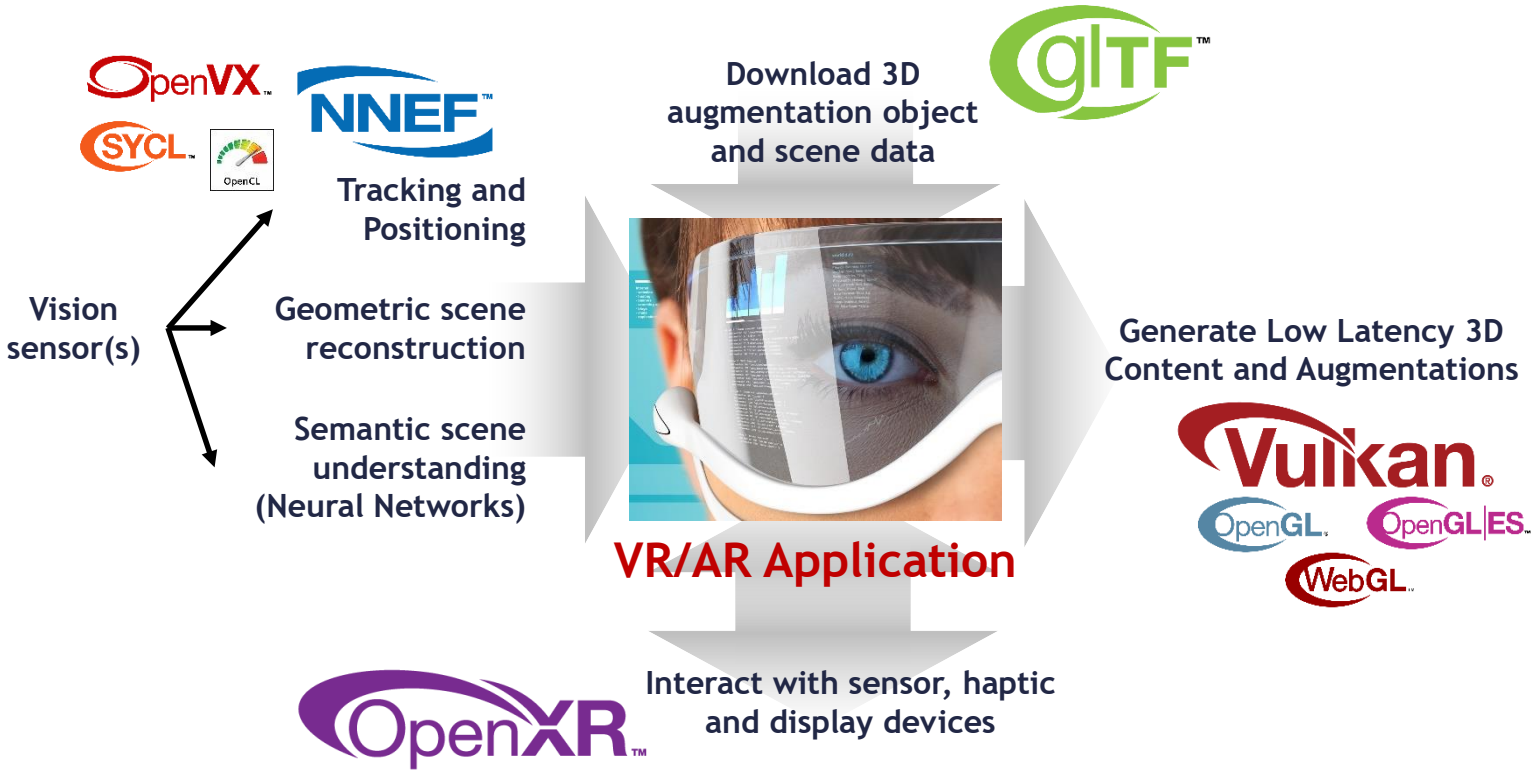
Khronos Open Standards

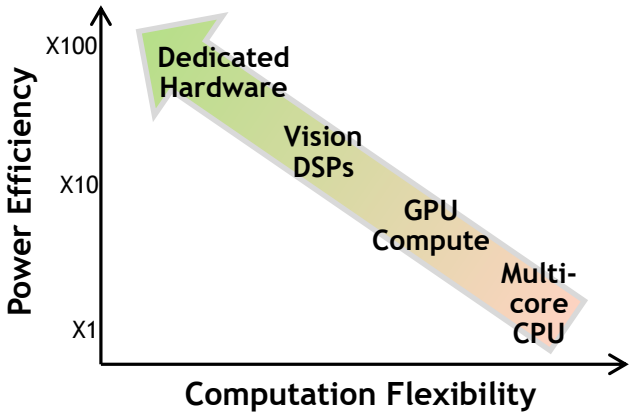


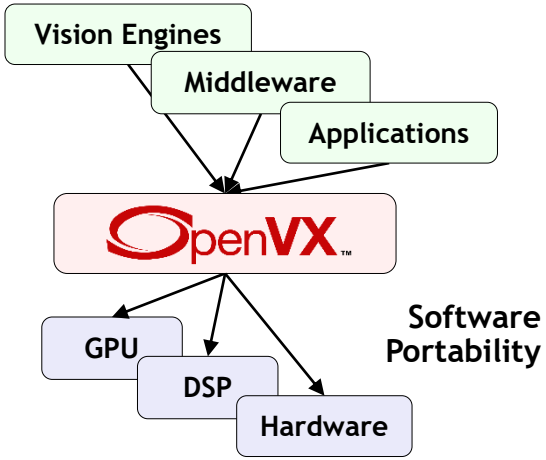
The OpenVX Standard

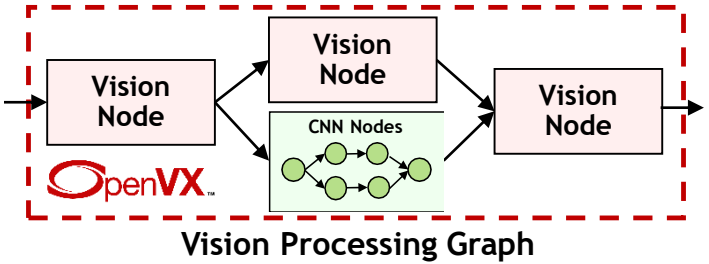
Wide range of vision and neural network hardware architectures

OpenVX enables high-level Graph-level optimizations!
Can be implemented on almost any hardware or processor!

Portable, Efficient Vision Processing!







OpenVX Evolution

Conformant Implementations

AMD
CEVA
Imagination
NVIDIA
Texas Instruments
VeriSilicon
cadence
eSilicon Neolek
intel
SYNOPSYS
socionext

AMD OpenVX Tools

Open source, highly optimized for x86 CPU and OpenCL for GPU
"Graph Optimizer" & Tools.
Modules: 360º video stitching, Neural Network Inference
http://bit.ly/openvx-amd

Current Progress

OpenVX 1.2

Spec released May 2017
Adopters Program November 2017

Functionality

Conditional node execution
Feature detection
Classification operators

Extensions

Neural Network Acceleration
Pipeline, stream, batch processing
OpenCL interop
Import vendor kernel, …

Safety Critical

OpenVX 1.1 SC for safety-certifiable systems

OpenVX 1.3 or 2.0?

Roadmap under Discussion

Enhance NN support

Profiles/subsets
NN-only profile

Merge safety-critical

More feature detectors
Stereo vision support
SLAM support

More flow control

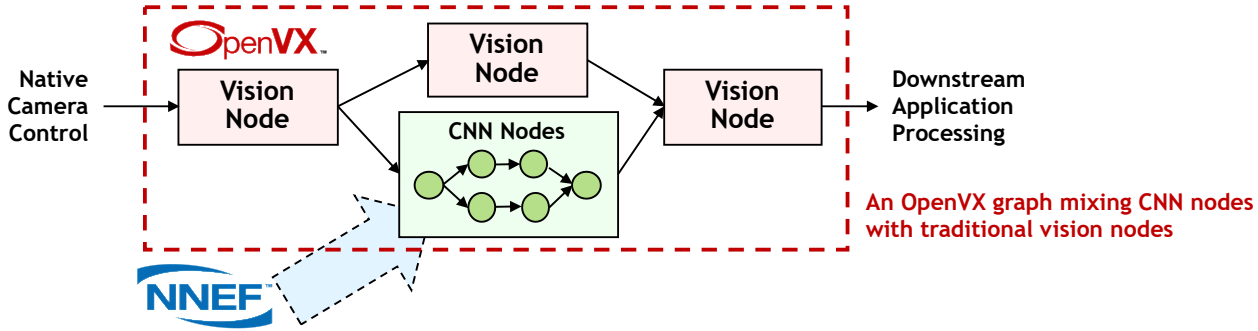
OpenVX Key Features

- **Faster development of efficient and portable vision and neural network applications**
  - Graph-level abstraction using C APIs
  - Opaque memory model
  - Developers are protected from hardware complexities
  - No platform-specific performance optimizations needed

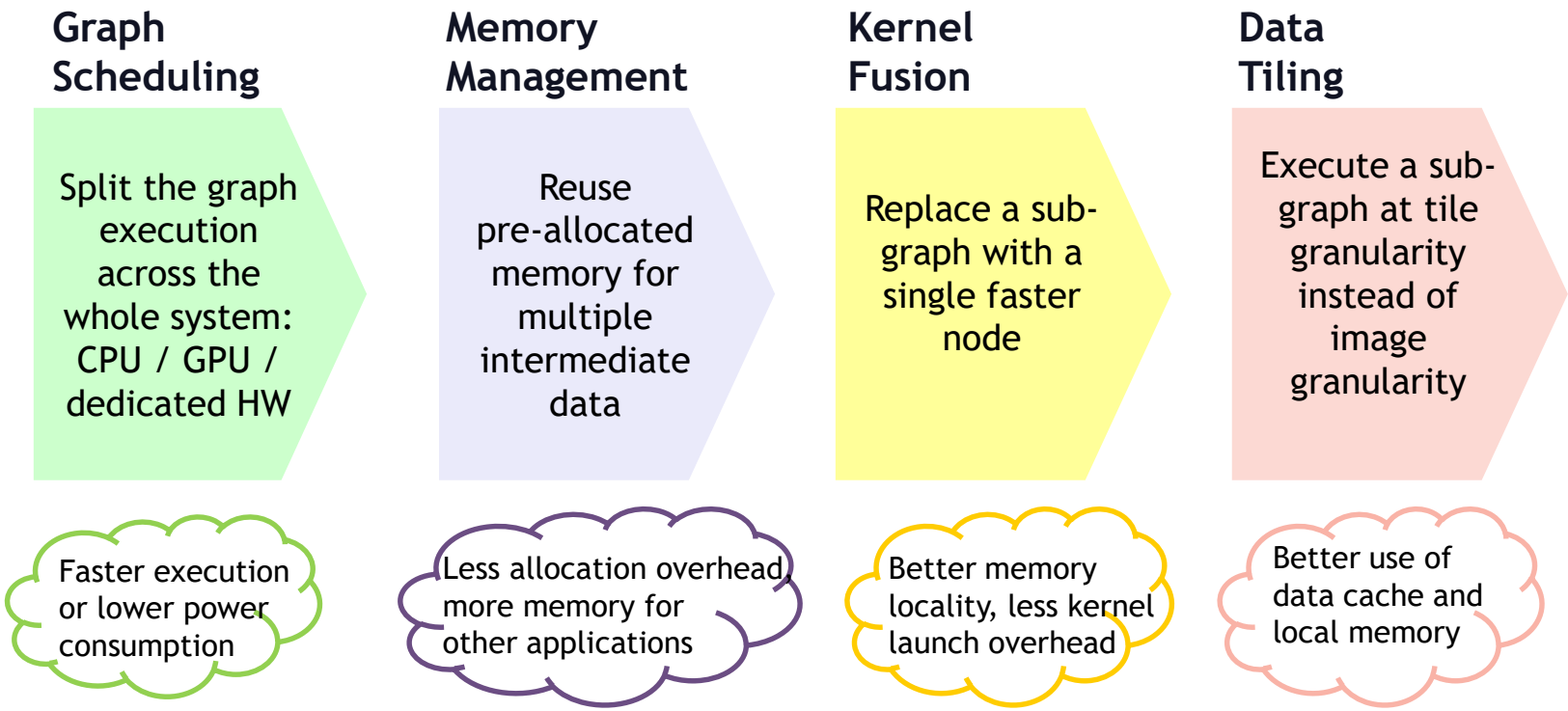
- **Performance portability to diverse hardware**
  - Hardware agility for different use case requirements
  - Application software investment is protected as hardware evolves

OpenVX Graph Level Abstraction

- **OpenVX developers express a graph of image or tensor operations ('Nodes')**
  - Using a C API
- **Nodes can be executed on any hardware or processor coded in any language**
  - Implementers can optimize under the high-level graph abstraction
- **Graphs are the key to run-time power and performance optimizations**
  - e.g. Node fusion, pipelining, tiled graph processing for cache efficiency etc.
- **CNN nodes can be mixed with traditional vision nodes**



OpenVX Efficiency through Graphs



Simple Edge Detector in OpenVX

```
vx_image input = vxCreateImage(1280, 720, U8);
vx_image output = vxCreateImage(1280, 720, U8);

vx_graph g = vxCreateGraph();
vx_image horiz = vxCreateVirtualImage(g);
vx_image vert = vxCreateVirtualImage(g);
vx_image mag = vxCreateVirtualImage(g);

vxSobel3x3Node(g, input, horiz, vert);
vxMagnitudeNode(g, horiz, vert, mag);
vxThresholdNode(g, mag, THRESH, output);

status = vxVerifyGraph(g);

status = vxProcessGraph(g);
```

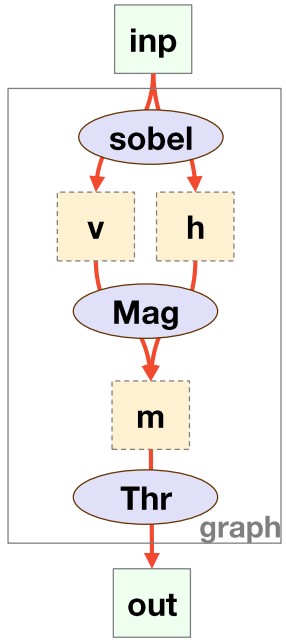
Declare Input and Output Images

Declare Intermediate Images

Construct the Graph topology

Compile the Graph

Execute the Graph



OpenVX Functions

[Computer Vision: 63 functions]

- Image Color Conversion
- Pixel-wise Image Operations
- Image Scaling & Filters
- Pyramids: Gaussian, Laplacian
- Histogram & Statistical
- Tensor Operations
- Classification, Feature Detection, and Tracking
- Control Flow Operations

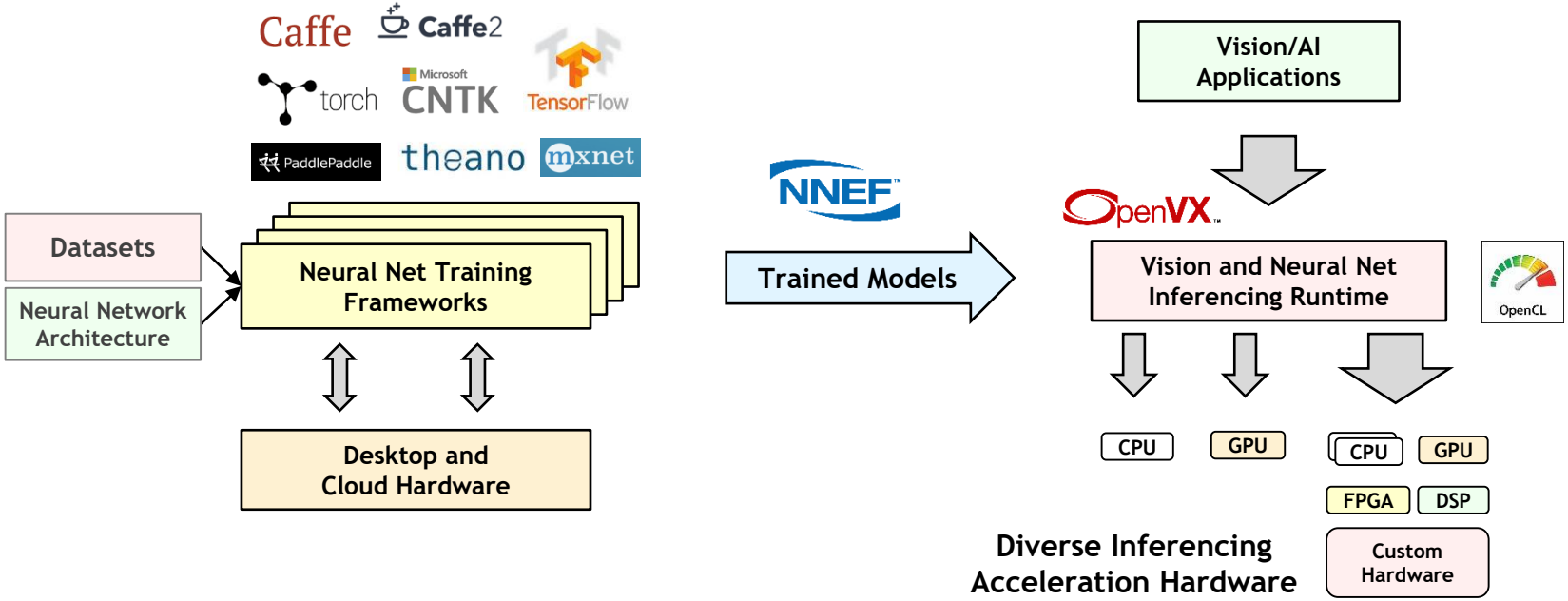
[Neural Network Extension: 8 functions]

- Convolution
- Deconvolution
- Fully Connected
- Max Pooling & Average Pooling
- Activations
- LRN
- Softmax
- ROI Pooling

OpenVX Extensions

- **Neural Network: run inference as part of a graph**
  - Layers are represented as OpenVX nodes
- **Classification: detect and recognize objects in an image based on a set of features**
  - Import a classifier model trained offline
  - Classify objects based on a set of input features
- **Pipelining: increase hardware utilization and throughput**
  - Provide a way of pipelining, streaming, and batch processing
  - Multiple initiations of a graph with different inputs and outputs
- **OpenCL Interop: interop between OpenVX and OpenCL application & user-kernels**
- **Import/Export: provide a way of exporting and importing pre-verified graphs & objects**
- **Import Kernel: import pre-compiler vendor binary (e.g., pre-compiled NN as a kernel)**

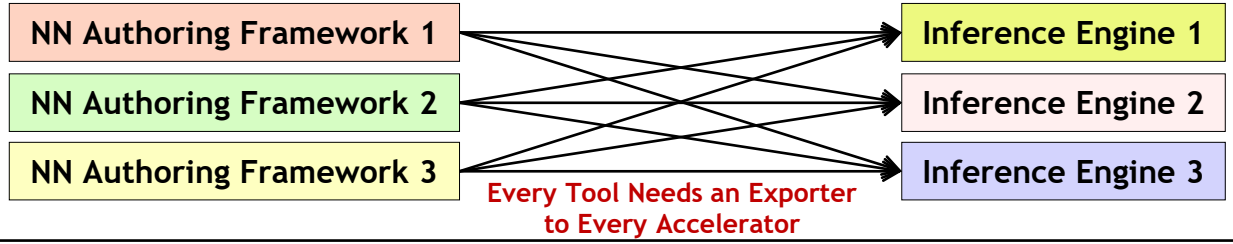
Neural Network Workflow



OpenVX - Solving Fragmentation

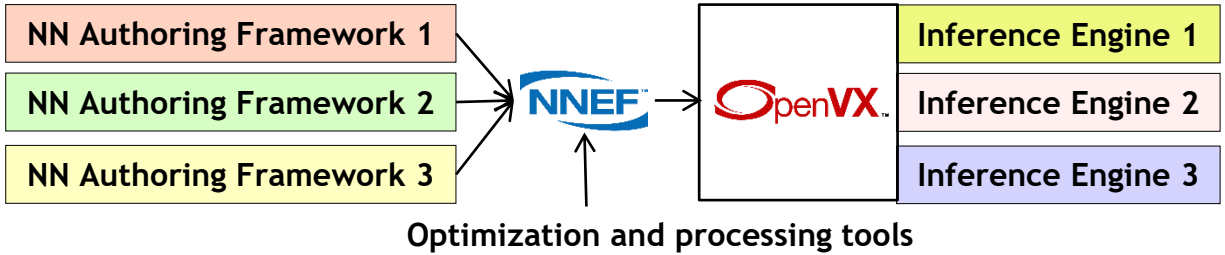
Before OpenVX & NNEF - NN Training and Inferencing Fragmentation

mxnet, Caffe2, Caffe, TensorFlow, torch, Microsoft CNTK, theano, PaddlePaddle



With OpenVX & NNEF- NN Training and Inferencing Interoperability

mxnet, Caffe2, Caffe, TensorFlow, torch, Microsoft CNTK, theano, PaddlePaddle



NNEF 1.0 Provisional

- **Released as Provisional to get industry feedback before finalization**
  - Welcoming comments and feedback on Khronos GitHub
- **Initial focus on passing trained frameworks to embedded inference engines**
  - Authoring interchange, importing NNEF *into* tools, is also an emerging use case
- **Support deployable range of network topologies**
  - Rapid evolution to encompass new network types as they emerge from research

NNEF Working Group Participants

OpenVX Benefits

- **Faster development of efficient and portable vision and NN applications**
  - Developers are protected from hardware complexities
  - No platform-specific performance optimizations needed
  - OpenVX with NNEF solves fragmentation problem
- **Graph description enables significant automatic optimizations**
  - Kernel fusion, pipelining, and tiling
- **Performance portability to diverse hardware**
  - Hardware agility for different use case requirements
  - Application software investment is protected as hardware evolves
- **Roadmap driven by community participation**
  - Join us and bring your ideas

OpenVX Resources

- **OpenVX Resources**
  - OpenVX Overview
    - https://www.khronos.org/openvx
  - OpenVX Specifications: current, previous, and extensions
    - https://www.khronos.org/registry/OpenVX
  - OpenVX Resources: implementations, tutorials, reference guides, etc.
    - https://www.khronos.org/openvx/resources
- **NNEF Resources**
  - NNEF Specification
    - https://www.khronos.org/registry/NNEF
- **Embedded Vision Summit Workshop**
  - "Khronos Standards for Neural Networks and Embedded Vision"
  - Thursday, May 24, 2018 from 8:00am-5:30pm
    - https://www.khronos.org/events/2018-embedded-vision-summit