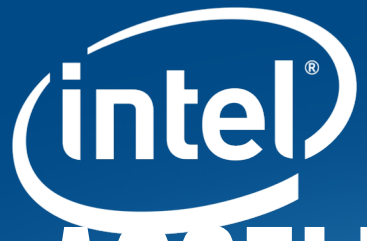

ACCELERATE DEEP LEARNING INFERENCE USING INTEL TECHNOLOGIES

OBJECT DETECTION USING INTEL® DISTRIBUTION OF OPENVINO™ TOOLKIT

November 2018

Core and Visual Computing Group

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Smart Video Workshop Overview

Introduction

1. Introduction to Intel technologies for deep learning inference
2. Hardware acceleration techniques

Each module contains a hands-on lab exercise that introduces various Intel technologies to accelerate computer vision application with hardware heterogeneity.

Intel® Distribution of OpenVINO™ 101

2. Basic End-to-End Object Detection Example

Hardware Acceleration

3./4./5. Hardware Acceleration with CPU, Integrated GPU, Intel® Movidius™ NCS, FPGA

Optimization

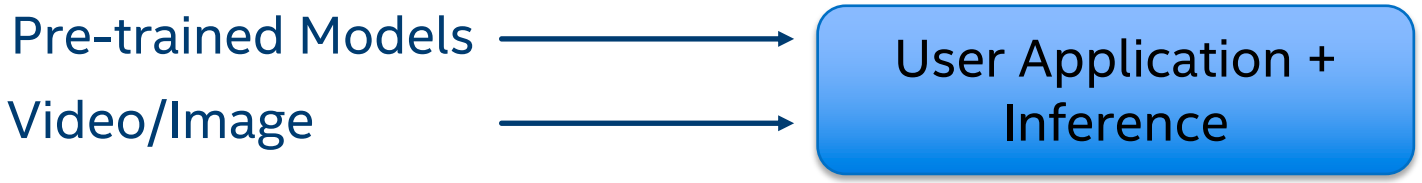
6. Optimization Tools and Techniques

Application

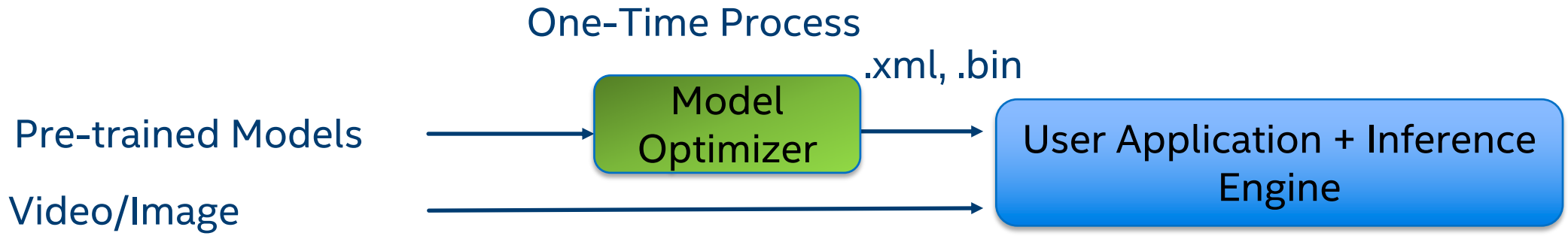
7. Advanced Video Analytics

Deep Learning Application Deployment

Traditional



With Intel® Distribution of OpenVINO™ Toolkit



Intel® Deep Learning Deployment Toolkit

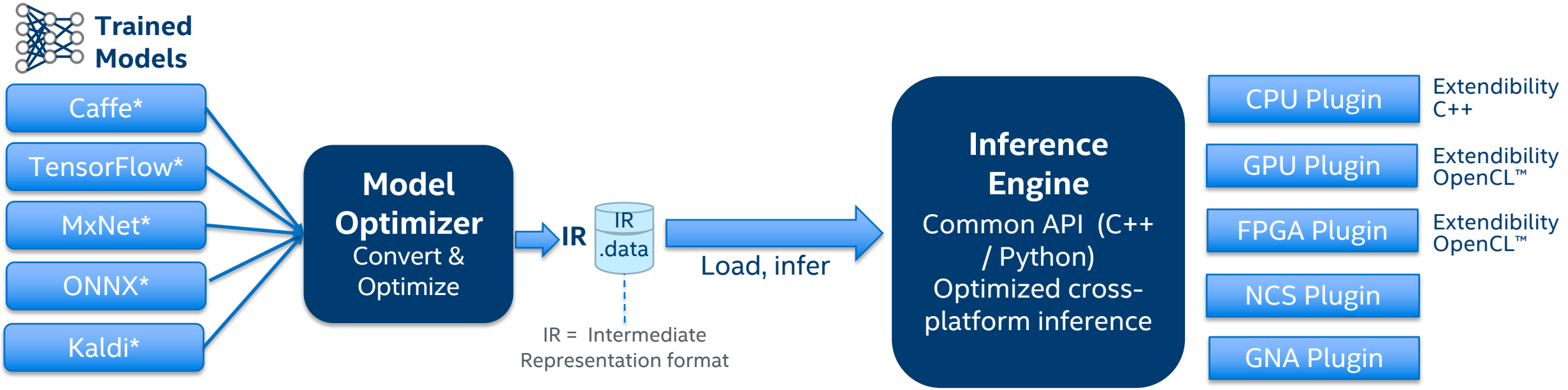
For Deep Learning Inference

Model Optimizer

- **What it is**: A python based tool to import trained models and convert them to Intermediate representation.
- **Why important**: Optimizes for performance/space with conservative topology transformations; biggest boost is from conversion to data types matching hardware.

Inference Engine

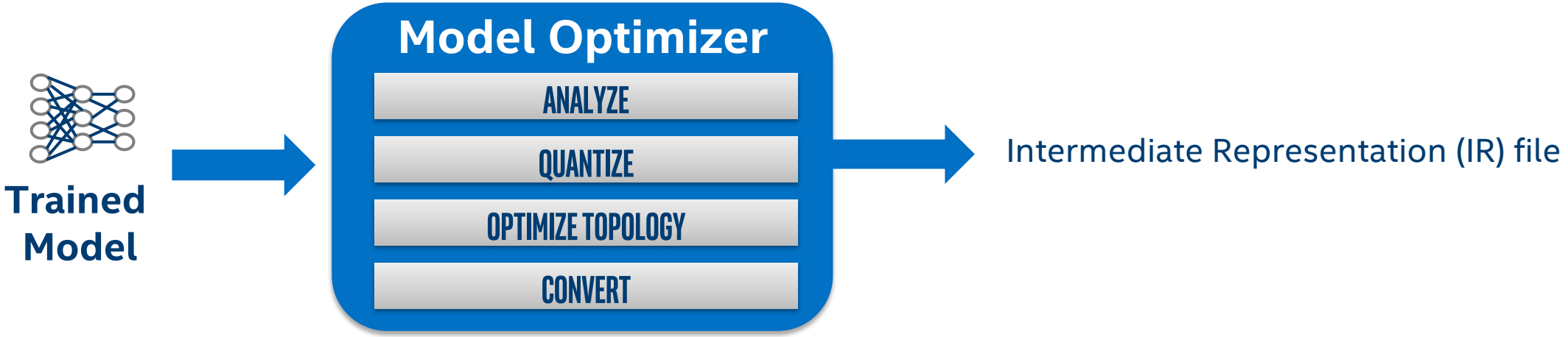
- **What it is**: High-level inference API
- **Why important**: Interface is implemented as dynamically loaded plugins for each hardware type. Delivers best performance for each type without requiring users to implement and maintain multiple code pathways.



GPU = Intel CPU with integrated graphics processing unit/Intel® Processor Graphics

Model Optimizer

Improve Performance with Model Optimizer



- Easy to use, Python*-based workflow does not require rebuilding frameworks.
- Import Models from various supported frameworks - Caffe*, TensorFlow*, MXNet*, ONNX*, Kaldi*.
- 100+ models for Caffe, MXNet and TensorFlow validated. All public models on ONNX* model zoo supported.
- With Kaldi support, the model optimizer extends inferencing for non-vision networks.
- IR files for models using standard layers or user-provided custom layers do not require Caffe.
- Fallback to original framework is possible in cases of unsupported layers, but requires original framework.

Model Optimizer

Model optimizer performs generic optimization:

- Node merging
- Horizontal fusion
- Batch normalization to scale shift
- Fold scale shift with convolution
- Drop unused layers (dropout)
- FP16/FP32 quantization
- Model optimizer can add normalization and mean operations, so some preprocessing is ‘added’ to the deep learning model

  --mean_values (104.006, 116.66, 122.67)

  --scale_values (0.07, 0.075, 0.084)

	FP32	FP16
CPU	yes	no
GPU	yes	recommended
MYRIAD	no	yes
FPGA/DLA	no	yes

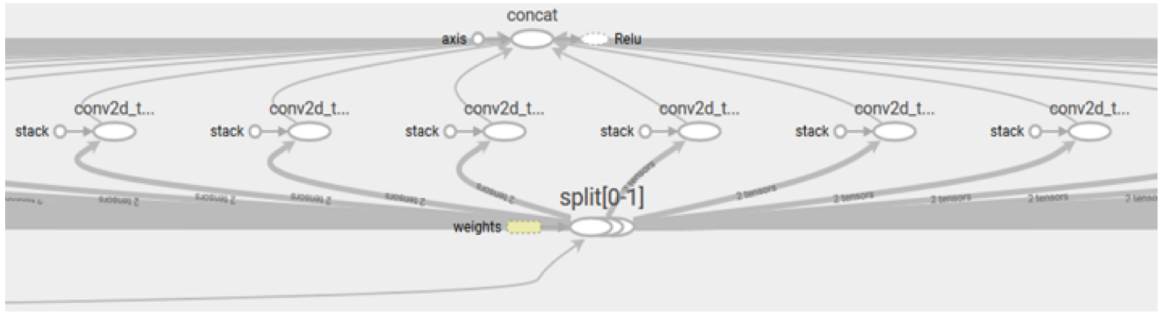
Intel® DL Deployment Toolkit Functionality
Model Optimizer/Optimization Tech

Linear Operation Fusing

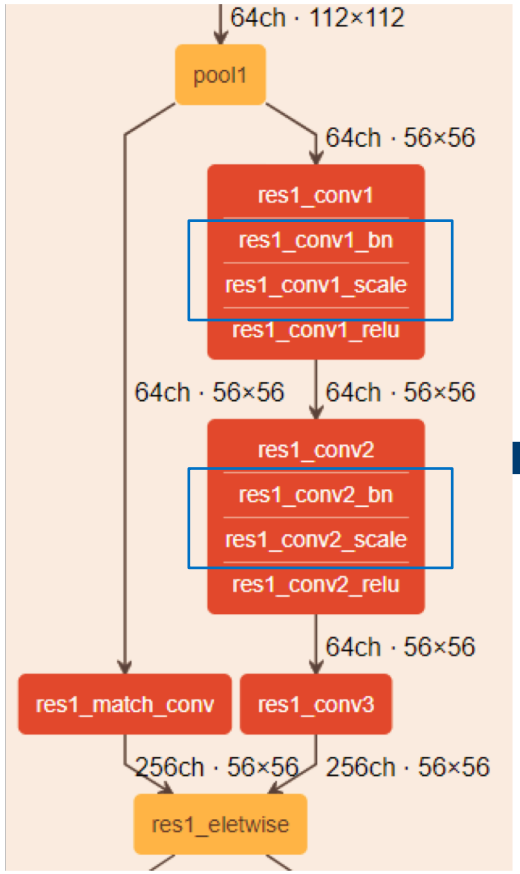
- **BatchNorm and ScaleShift decomposition:** *BN* layers decomposes to *Mul->Add->Mul->Add* sequence; ScaleShift layers decomposes to *Mul->Add* sequence.
- **Linear operations merge:** Merges sequences of Mul and Add operations to the **single** Mul->Add instance.
- **Linear operations fusion:** Fuses Mul and Add operations to Convolution or FullybConnected layers.

Grouped Convolutions Fusing

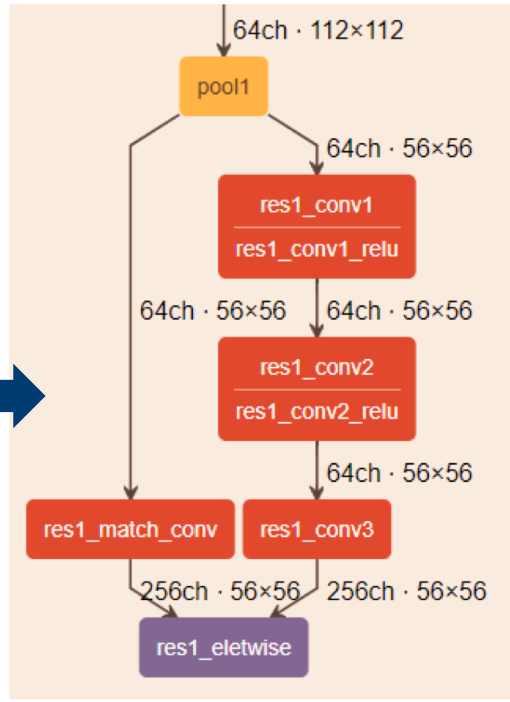
Specific optimization that applies for TensorFlow* topologies. (Xception*)



Split->Convolutions->Concat block from TensorBoard*



Caffe Resnet269 block (from Netscope)

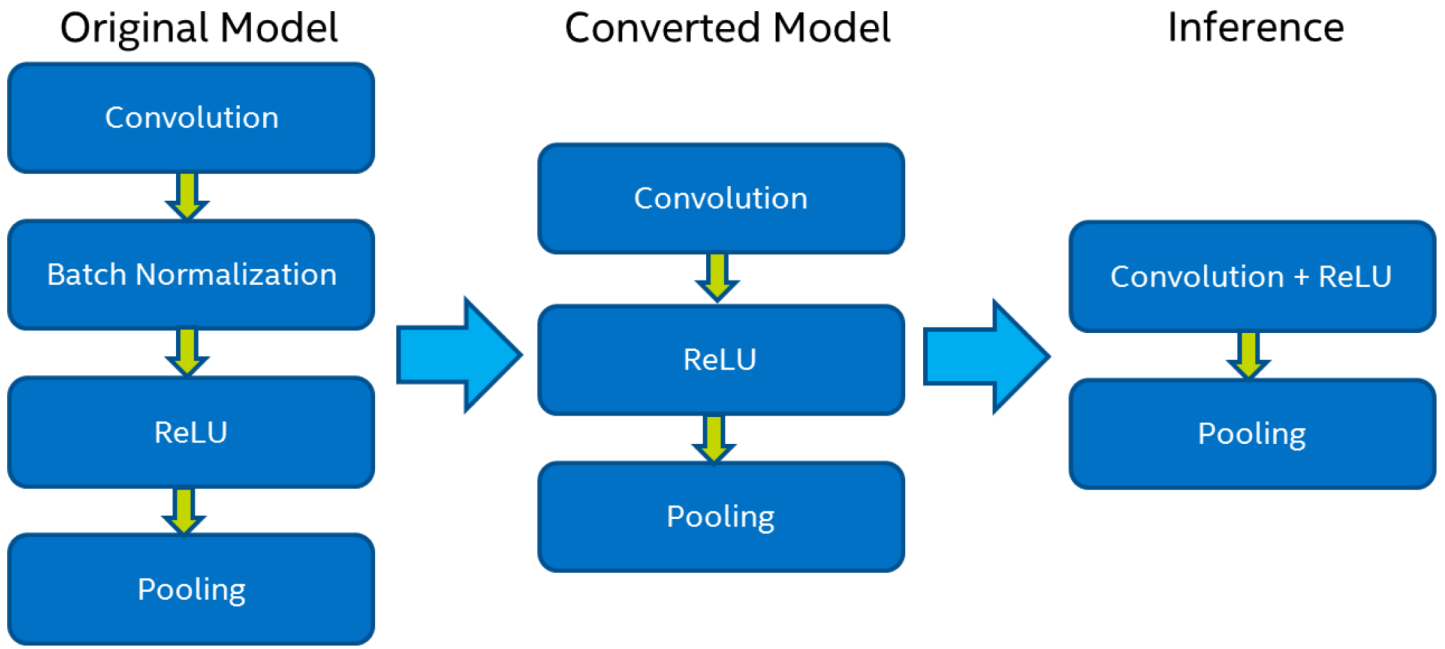


Fused Caffe* Resnet269 block (from Netscope*)

Model Optimizer (1 of 2)

Example

1. Remove Batch normalization stage.
2. Recalculate the weights to ‘include’ the operation.
3. Merge Convolution and ReLU into one optimized kernel.



Model Optimizer (2 of 2)

Model optimizer can change the topology:

- Model optimizer can add normalization and mean operations, so some pre-processing is ‘added’ to the deep learning model.

  --mean_values (104.006, 116.66, 122.67)

  --scale_values (0.07, 0.075, 0.084)

Model optimizer can cut out a portion of the network:

- Model has pre/post-processing parts that cannot be mapped to existing layers.
- Model has a training part that is not used during inference.
- Model is too complex and cannot be converted in one shot.
- Use the --input and --output options.

Intermediate Representation (IR)

Squeezenet1.1.caffemodel → Squeezenet1.1.bin

Squeezenet1.1.prototxt → Squeezenet1.1.xml

```
layer {
  name: "data"
  type: "Input"
  top: "data"
  input_param { shape: { dim: 1 dim: 3 dim: 227 dim: 227 } }
}
layer {
  name: "conv1"
  type: "Convolution"
  bottom: "data"
  top: "conv1"
  convolution_param {
    num_output: 64
    kernel_size: 3
    stride: 2
  }
}
```

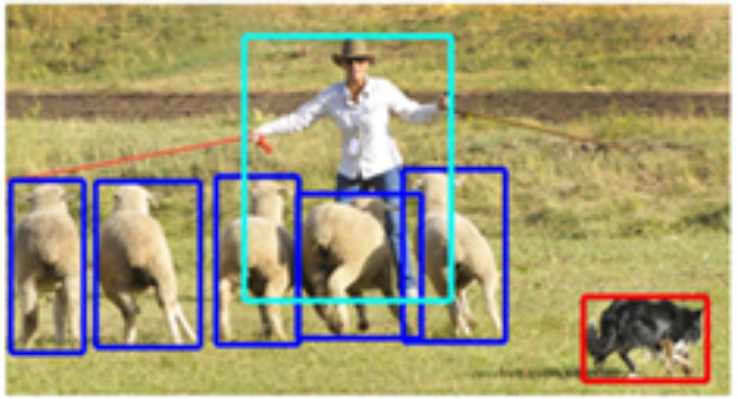
```
<net batch="1" name="model" version="2">
  <layers>
    <layer id="100" name="data" precision="FP32" type="Input">
      <output>
        <port id="0">
          <dim>1</dim>
          <dim>3</dim>
          <dim>227</dim>
          <dim>227</dim>
        </port>
      </output>
    </layer>
    <layer id="129" name="conv1" precision="FP32" type="Convolution">
      <data dilation-x="1" dilation-y="1" group="1" kernel-x="3" kernel-y="3" output="64" pa
      <input>
        <port id="0">
          <dim>1</dim>
          <dim>3</dim>
          <dim>227</dim>
          <dim>227</dim>
        </port>
      </input>
      <output>
        <port id="3">
          <dim>1</dim>
          <dim>64</dim>
          <dim>113</dim>
          <dim>113</dim>
        </port>
      </output>
      <blobs>
        <weights offset="2275104" size="6912"/>
        <biases offset="4805920" size="256"/>
      </blobs>
```

Inference Engine

Inference on an Intel® Edge Systems

Many deep learning networks are available—choose the one you need.

(a) classification



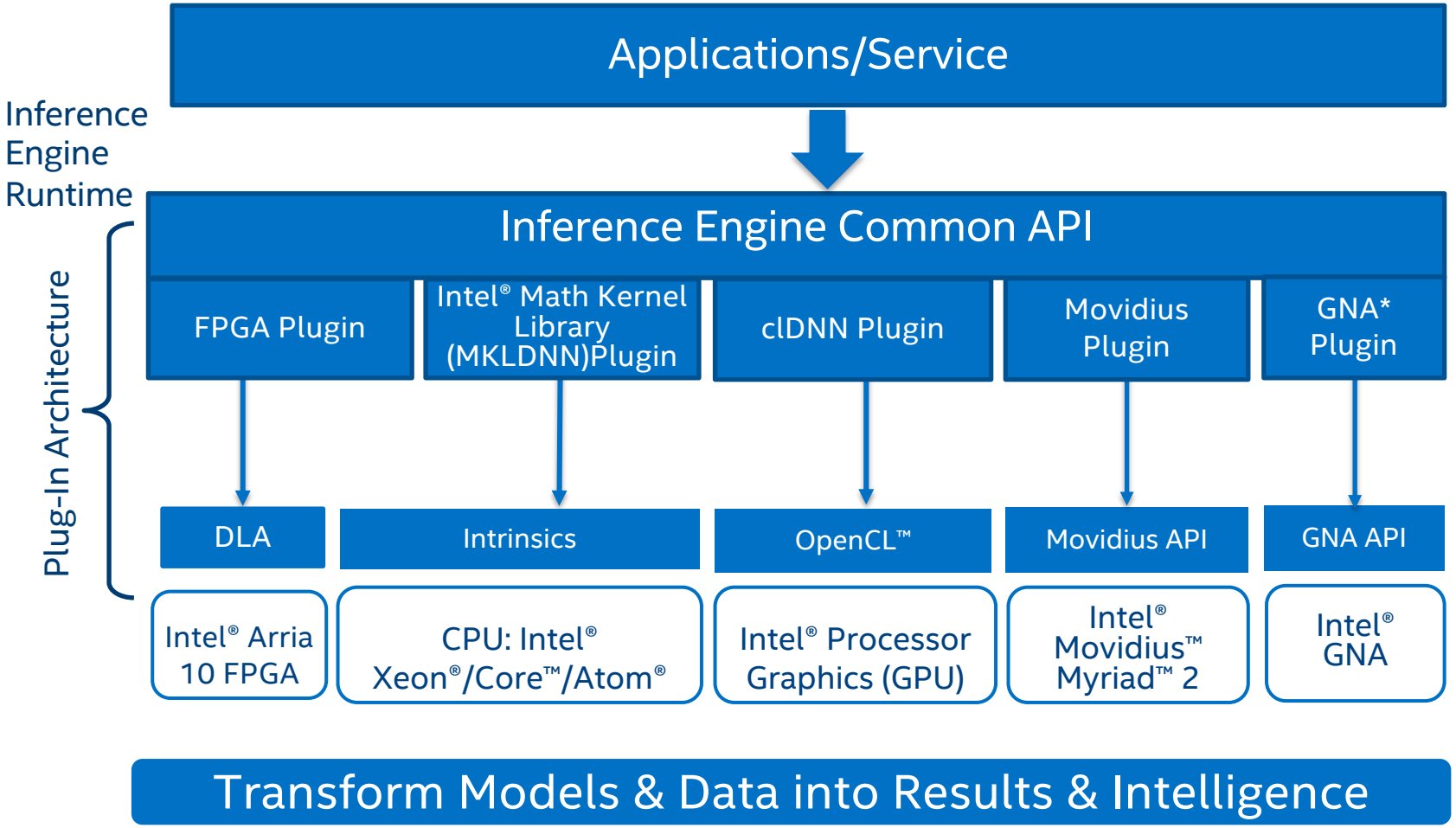
(b) detection

(c) segmentation

The complexity of the problem (data set) dictates the network structure. The more complex the problem, the more ‘features’ required, the deeper the network.

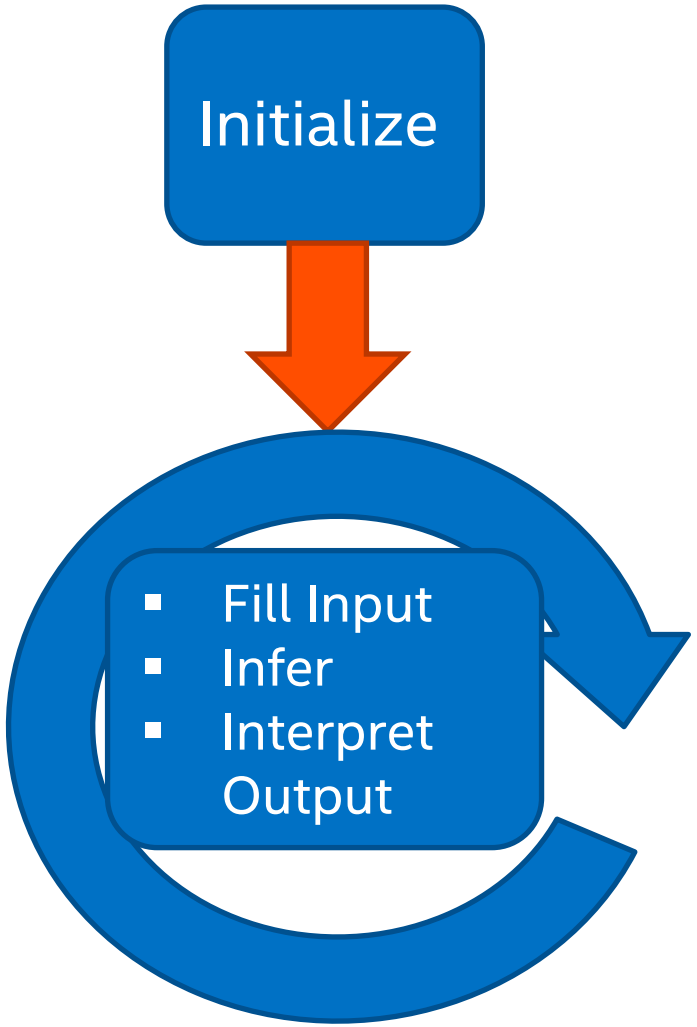
Optimal Model Performance Using the Inference Engine

- Simple & Unified API for Inference across all Intel® architecture
- Optimized inference on large IA hardware targets (CPU/GEN/FPGA)
- Heterogeneity support allows execution of layers across hardware types
- Asynchronous execution improves performance
- Futureproof/scale your development for future Intel® processors



GPU = Intel CPU with integrated graphics/Intel® Processor Graphics/GEN
GNA = Gaussian mixture model and Neural Network Accelerator

Workflow



Initialization

- Load model and weights
- Set batch size (if needed)
- Load inference plugin (CPU, GPU, FPGA)
- Load network to plugin
- Allocate input, output buffers

Main Loop

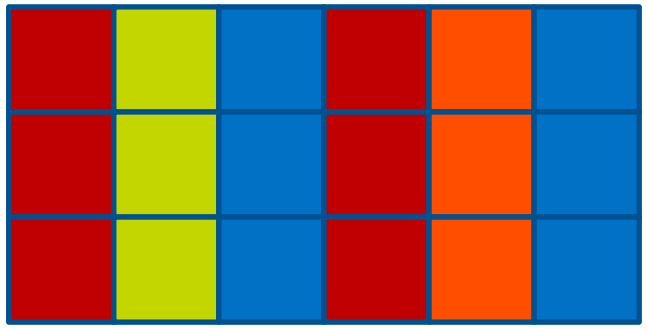
- Fill input buffer with data
- Run inference
- Interpret output results

Pre-processing

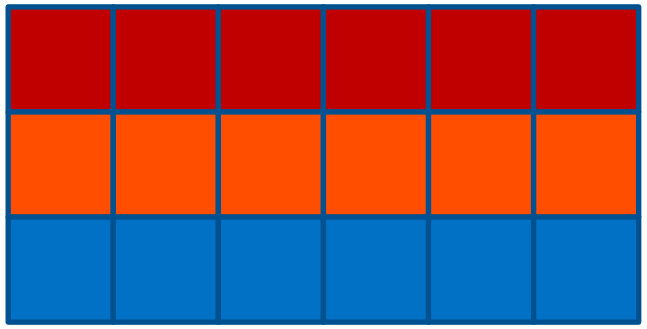
Most of the image formats are interleaved formats (RGB, BGR, BGRA, and so forth). Inference engine expects input to be in RGB planar format, such as:

R-plain, G-plain, B-plain

Interleaved



Planar



Post-processing

Developers are responsible for parsing inference output.

Many output formats are available. Some examples include:

- **Simple Classification (alexnet*):** an array of float confidence scores, # of elements=# of classes in the model
- **SSD:** Many “boxes” with a confidence score, label #, xmin,ymin, xmax,ymax

Unless a model is well documented, the output pattern may not be immediately obvious.

CPU/GPU/FPGA/Intel® Movidius™ Neural Compute Stick

Hardware Heterogenity

Heterogeneous Dichotomies

Data vs. Task Parallelism

- Data parallelism between devices is usually explicit and extremely error-prone (like in OpenCL™).
- Inference engine heterogeneity support is inherently **task-oriented** (node-level).

Dynamic vs. Static

- **User-defined work split** vs. adaptive schemes (like load-balancing).
- For both, there is a question on the granularity (communications costs, next).

***Heterogeneity* is basically *Fallback*.**

Apply Device Affinities to Layers Automatically Using Fallback Policy (1 of 2)

```
$ object_detection_sample_ssd -d HETERO:CPU,GPU -l
lib/libicv_extension.so -m ssd.xml -i snake.bmp
```

All IE samples support loading CPU and GPU extensions as usual ("-l" and "-c"). The "priorities" defines a greedy behavior:

- Keeps all layers that can be executed on the device (FPGA)
- Carefully respects topological and other limitations
- Follows priorities when searching (for example, CPU)

Apply Device Affinities to Layers Automatically Using Fallback Policy (2 of 2)

```
HeteroPluginPtr plugin(make_plugin_name("HeteroPlugin"));

CNNNetReader reader;

reader.ReadNetwork(“Model.xml”);

reader.ReadWeights(“Model.bin”);

CNNNetwork network = reader.getNetwork();

plugin->SetConfig({ { "TARGET_FALLBACK", “FPGA,CPU"} }, &response);

plugin->LoadNetwork(exeNetwork, network,{}, &response);
```

Intel® Movidius™ Neural Compute Stick

Core and Visual Computing Group

Intel® Movidius™ Neural Compute Stick

Redefining the AI Developer Kit

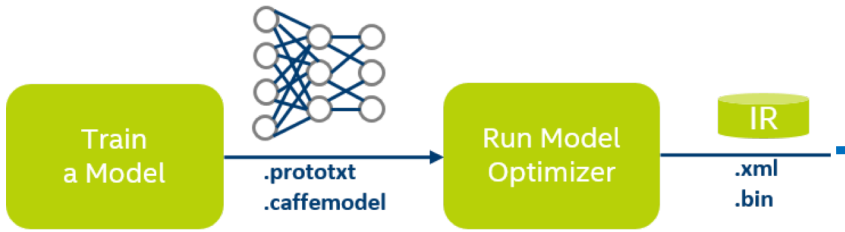
- Neural network accelerator in USB stick form factor
- Tensorflow* and Caffe* and many popular frames are supported
- Prototype, tune, validate, and deploy deep neural networks at the edge
- Features the same Intel® Movidius™ Vision Processing Unit (VPU) used in drones, surveillance cameras, virtual reality headsets, and other low-power intelligent and autonomous products

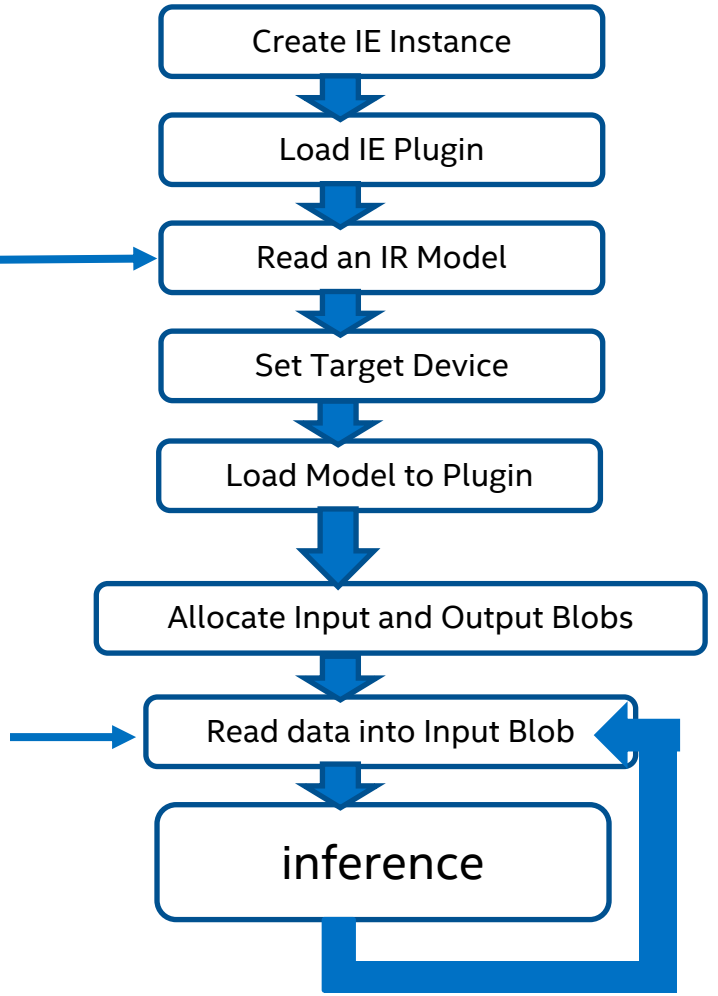
Car Detection

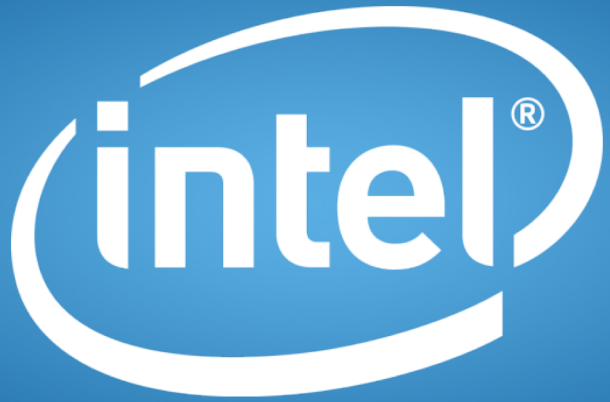
Hands-On Example

Offline, One-Time Run of the Model Optimizer

- Integrate inference engine (IE) API into the application.
- Intel® MKL-DNN plugin for CPU, Cl-DNN for GPU.
- Target device could be CPU/GPU/Intel® Movidius™ NCS/FPGA.






intel

Workshop hands-on exercise

https://github.com/intel-iot-devkit/smart-video-workshop

OR

Copy from the flash drive handed over in the workshop room